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Wyse, David E

From: Clarke, Tracey
Sent: Tuesday, January 24, 2017 1:00 PM
To: Wyse, David E; Kozarski, Vladan; Sekerka, Anne Marie; Clairoux, Zoe
Subject: Re: MSPV face to face agenda item requests? G. Peddle

Vladan will be there and he's the best person to discuss stabilizers.

Tracey

Sent from my BlackBerry 10 smartphone on the Rogers network.

From: Wyse, David E
Sent: Tuesday, January 24, 2017 12:58 PM
To: Clarke, Tracey; Kozarski, Vladan; Sekerka, Anne Marie; Clairoux, Zoe
Subject: Fw: MSPV face to face agenda item requests? G. Peddle

Can someone come to discuss stabilizer on MSPVs?

Sent from my BlackBerry 10 smartphone on the Rogers network.

From: G Peddle, Commanding Officer <GPeddleCO@ped.ccgs-ngcc.gc.ca>
Sent: Tuesday, January 24, 2017 12:00 PM
To: Wyse, David E
Subject: RE: MSPV face to face agenda item requests? G. Peddle

Hello Dave,

Looks like Garth, Harold and myself are coming from the Atlantic fleet so far.

I would like to see a talk on an anti-roll system for these boats.
I think you had looked into this with Damen for active stabilizing fins.
Other options are the hinged fins that many Fishing vessels have or active trim tabs.

All I know is something needs to be done. They want us to patrol through the nights whenever possible.
The crews are getting fatigued trying to achieve this in North Atlantic conditions in the winter.
Most 45 foot fishing boat we work around are wider than the MSPV's.

The other is the command center modification and gangway replacement. Sound like you have the first one on the agenda already.
The insulation around the transceivers sound like a good plan. I was on the Kaeble last summer and really like their layout.

Fred Emeneau
Commanding Officer | Commandant
CCGS G. Peddle S.C.| NGCC G. Peddle S.C.
Canadian Coast Guard | Garde côtière canadienne
Atlantic Region | Région de l'Atlantique
Telephone | Téléphone: 902-478-9806
Email | courriel: gpeddleCO@ped.ccgs-ngcc.gc.ca

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From: Wyse, David E [mailto:David.Wyse@dfo-mpo.gc.ca]
Sent: Monday, January 23, 2017 10:30 PM
To: Chaikin, Gabriel; Bosley, Laurie; Couillard-Desjardins, Isabelle; Mercier, Jeffrey; (corporalmclarenCO@mcl.ccgs-ngcc.gc.ca); A leblanc CO (aleblancCO@ccgs-ngcc.gc.ca); Carriere; CCGS-NGCC, Corporal Teather Commanding Officer (CorporalTeatherCO@ccgs-ngcc.gc.ca); G Peddle, Commanding Officer; goddard-captain@god.ccgs-ngcc.gc.ca; Kaeble; M Charles; Private Robertson; aleblancCE@ccgs-ngcc.gc.ca; ConstableCarriereCE@ccgs-ngcc.gc.ca; CorporalMcLarenMMVCE. CCGS@dfo-mpo. gc. ca (CorporalMcLarenCE@MCL.ccgs-ngcc.gc.ca); CorporalTeatherCE@ccgs-ngcc.gc.ca; G Peddle, Chief Engineer; Goddard-ChiefEngineer@GOD.ccgs-ngcc.gc.ca; KaebleCE@ccgs-ngcc.gc.ca; mcharlesce@cha.ccgs-ngcc.gc.ca; PrivateRobertsonCE@ccgs-ngcc.gc.ca
Subject: MSPV face to face agenda item requests?

Good evening all,

Is there any agenda item requests for the upcoming face to face meeting?

Y a-t-il des demandes pour l'ordre du jour pour la rencontre à venir?

Merci
Dave

David Wyse
Project Engineer | Mécanicien de Projet
Marine Engineering | Ingénierie Navale
Integrated Technical Services | Services Techniques Intégrés
Canadian Coast Guard | Garde Côtière Canadienne
200 Kent Street, Office 7W076, Mail Drop 7W064
Ottawa, ON, K1A 0E6
David.Wyse@dfo-mpo.gc.ca
Telephone | Téléphone 613-993-2710

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Wyse, David E

From: Clarke, Tracey
Sent: Wednesday, March 8, 2017 2:15 PM
To: Wyse, David E; Kozarski, Vladan
Subject: Re: MSPV stabilizer study question

Your timeline sounds reasonable - obviously we would try to accelerate anything we could.

Tracey

s.21(1)(b)

Sent from my BlackBerry 10 smartphone on the Rogers network.

From: Wyse, David E
Sent: Wednesday, March 8, 2017 2:14 PM
To: Clarke, Tracey; Kozarski, Vladan
Subject: RE: MSPV stabilizer study question

No just looking at timelines if all works out for the end result of them getting stabilizers

1. Feasibility study – 5 months – to September 2017 –
2. Agreement on feasibility moving forward – 3 months – to December 2017
3. Engineering for Stabilizers – 5 months to May 2018
4. Agreement for Engineering – 3 months to September 2018
5. Spec and Drawings – 1 month to October 2018
6. Contracts and implementation - ????

Dave

From: Clarke, Tracey
Sent: March-08-17 2:04 PM
To: Wyse, David E; Kozarski, Vladan
Subject: Re: MSPV stabilizer study question

Are you talking about promising that stabilizers are coming in 2 years? We're going to do the feasibility study and I think it looks promising but there will be trade offs that Fleet will have to agree to (carry less fuel, vessels that go slower because of the appendages) so I don't know that you'd be in a position to promise stabilizers. Even if ITS recommended them, it will likely come to a fleet decision because of what we may have to compromise on operationally.

Tracey

Sent from my BlackBerry 10 smartphone on the Rogers network.

From: Wyse, David E
Sent: Wednesday, March 8, 2017 1:42 PM
To: Clarke, Tracey; Kozarski, Vladan

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Subject: RE: MSPV stabilizer study question

I will have to answer the RCMP and C&P tomorrow about the status of getting stabilizers. Do I stick with my 2 years from now if everything works out to get to the installation phase?

Thanks
Dave

From: Clarke, Tracey
Sent: March-07-17 3:47 PM
To: Wyse, David E; Kozarski, Vladan
Subject: RE: MSPV stabilizer study question

Vladan presented the plan for the feasibility study. He presented the options to be studied in the feasibility study.

We've got to get a contract in place with Damen to get analysis done. So I don't have a date yet...

Tracey

From: Wyse, David E
Sent: Tuesday, March 7, 2017 3:45 PM
To: Clarke, Tracey <Tracey.Clarke@dfo-mpo.gc.ca>; Kozarski, Vladan <Vladan.Kozarski@dfo-mpo.gc.ca>
Subject: RE: MSPV stabilizer study question

I thought Vladan did the feasibility and presented at the face to face and we were moving to engineering and options study. So the feasibility is still on going? Can you give me a report date so I can get back to the group?

Thanks
Dave

From: Clarke, Tracey
Sent: March-07-17 3:42 PM
To: Wyse, David E; Kozarski, Vladan
Subject: RE: MSPV stabilizer study question

This is a feasibility study not engineering so I think it's premature for a CCR...

Tracey

From: Wyse, David E
Sent: Tuesday, March 7, 2017 3:39 PM
To: Kozarski, Vladan <Vladan.Kozarski@dfo-mpo.gc.ca>; Clarke, Tracey <Tracey.Clarke@dfo-mpo.gc.ca>
Subject: FW: MSPV stabilizer study question

Are we making this into a CCR yet?

From: CCGS Captain Goddard M.S.M. Commanding Officer [mailto:Goddard-Captain@GOD.ccgs-ngcc.gc.ca]
Sent: March-07-17 3:23 PM
To: Wyse, David E
Cc: CCGS-NGCC, Aleblanc Commandant; CCGS-NGCC, Constable Carriere Commanding Officer; CCGS-NGCC, Corporal Teather Commanding Officer; CCGS, G Peddle Captain; CCGS-NGCC, Caporal Kaeble Commandant; Capstick, Charles;

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CCGS-NGCC, Private Robertson Commanding Officer
Subject: RE: MSPV stabilizer study question

Dave,

With the Captain Goddard's area of operation being the north coast of British Columbia we experience a wide range of different weather and swell conditions.

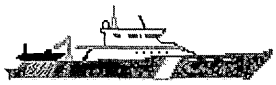
We are 100% in favor of any form of stabilisation. (I know our clients would be much happier)

As the engine room is quite cramped there is probably no chance of installing "Active stabilisers" but even bilge keels would be a great addition to the stability of the vessel.

Best Regards,

Dustin Flahr - Commanding Officer
CCGS Captain Goddard M.S.M.
Canadian Coast Guard, Western Region
Goddard-Captain@GOD.ccgs-ngcc.gc.ca
Cell [redacted]

s.16(2)



From: CCGS-NGCC, Caporal Kaeble Commandant [mailto:kaebleCO@ccgs-ngcc.gc.ca]
Sent: March-07-17 3:31 AM
To: Wyse David
Cc: CCGS-NGCC, Aleblanc Commandant; CCGS-NGCC, Constable Carriere Commanding Officer; CCGS-NGCC, Corporal Teather Commanding Officer; CCGS G Peddle Captain; CCGS Captain Goddard M.S.M. Commanding Officer; CCGS-NGCC, Caporal Kaeble Commandant; Capstick Charles; CCGS-NGCC, Private Robertson Commanding Officer
Subject: RE: MSPV stabilizer study question

Hi Dave!

Our main concern for waves are located in Gulf St-Laurence.
From my experience those waves are shorts and steeply.
Close the ones we find on Great lakes.

Thanks.

Cmdt. Yves Gervais
Commanding officer | Commandant
CCGS Caporal Kaeble VC | NGCC Caporal Kaeble VC
Canadian Coast Guard | Garde côtière canadienne
Québec Region | Région de Québec
Government of Canada | Gouvernement du Canada
Cell: [redacted]
Email: kaebleco@ccgs-ngcc.gc.ca

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De : Wyse, David E [mailto:David.Wyse@dfo-mpo.gc.ca]
Envoyé : 6 février 2017 11:37
À : (corporalmclarenCO@mcl.ccgs-ngcc.gc.ca); CCGS-NGCC, Aleblanc Commandant; CCGS-NGCC, Constable Carriere Commanding Officer; CCGS-NGCC, Corporal Teather Commanding Officer; G Peddle Captain; goddard-captain@god.ccgs-ngcc.gc.ca; CCGS-NGCC, Caporal Kaeble Commandant; M Charles; CCGS-NGCC, Private Robertson Commanding Officer
Cc : Sanchez-Carol Lisa
Objet : MSPV stabilizer study question

Hi Captains,

HQ is starting to run studies into stabilizers for the MSPV's (info will be presented at the MSPV face to face). I have received concerns from Atlantic region with rolling, etc. Does the Great Lakes or Pacific have the same concerns? If there is no concern with Pacific or Great lakes then we can narrow the study down to waveforms in Atlantic only. Waveforms are different in each area.

Thank you
Dave

David Wyse
Project Engineer | Mécanicien de Projet
Marine Engineering | Ingénierie Navale
Integrated Technical Services | Services Techniques Intégrés
Canadian Coast Guard | Garde Côtière Canadienne
200 Kent Street, Office 7W076, Mail Drop 7W064
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Telephone | Téléphone 613-993-2710

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Wyse, David E

From: Chaikin, Gabriel
Sent: Tuesday, April 11, 2017 2:49 PM
To: Wyse, David E
Subject: FW: Damen 4207 Stabalizers
Attachments: Quantum RFI - Stabilizer Sizing Data 160919.pdf; Quantum Specification Sheet - Control SMC4000 131022.pdf; Quantum Specification Sheet - Danfoss VLT MCD 500 150309.pdf; Quantum Specification Sheet - Fin S-Series QC1200 131022.pdf; Quantum Specification Sheet - HPU QP20E 160311.pdf; Quantum Specification Sheet - Stabilizer QC1200 140604.pdf; Quantum Specification Sheet - HPU MPU20 130722.pdf; A-Guideline for Reducing Cavitation at the Fin Stabilizers 150914.pdf; FIN Location-Pg. 9 Ch 2 - QC-3600 - Fin R1 091105.pdf; Pipe and Tube Bulkhead Mounting Guide to Reduce Noise J&A (Bulkhead N&V Control) 090622.pdf

Hi Dave,

Simon is working on a new CCR. **s.20(1)(c)** **s.21(1)(b)**

Regards,

Gabriel Chaikin
Marine Engineering | Ingénierie navale
(250) 363-0228

From: CCGS Captain Goddard M.S.M. Chief Engineer [mailto:Goddard-ChiefEngineer@GOD.ccgs-ngcc.gc.ca]
Sent: 2017–April-10 6:39 PM
To: Chaikin, Gabriel
Subject: FW: Damen 4207 Stabalizers

FYI

Talked to the rep today at Quantum, the QC1200 is the unit put on the rest of the Damen 4207's. Ballpark cost from him was [redacted] plus installation, [redacted]

I wonder if we could run the fins off our current Central Hydraulics? We need to shave a couple thousand pounds off to get this installed, less fuel is about the only option. Diesel outboards and remove the gas tanks.

Once I get some more information from Quantum I will finish the CCR and submit it to you Gabe.

How did the meeting go today? I know you were busy today but did you manage to get down to the boat shop to see if they had a spare ignition switch for our RHIB?

Talk to you tomorrow.

Simon Williamson
Chief Engineer
CCGS Captain Goddard MSM
Canadian Coast Guard Western Region

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goddard-chiefengineer@god.ccgs-ngcc.gc.ca
Cell:
Iridium Sat:

From:
Sent: April-10-17 3:54 PM
To: CCGS Captain Goddard M.S.M. Chief Engineer
Subject: RE: Damen 4207 Stabalizers

s.16(2)
s.19(1)

Hi Simon:

Good speaking with you, please see the attached RFI.

I have also included the spec sheets as discussed but keep in mind I still need to run the numbers on the power and size of the HPU.

Also I have attached a couple of data sheets for general info for N&V and potential for cavitation and how to reduce the chance of it.

If you have any questions, please let me know.

Sincerely,

Quantum Marine
Cell: Tel.
Skype:
www.quantumhydraulic.com

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From: CCGS Captain Goddard M.S.M. Chief Engineer [mailto:Goddard-ChiefEngineer@GOD.ccgs-ngcc.gc.ca]
Sent: Monday, April 10, 2017 5:15 PM
To:
Subject: RE: Damen 4207 Stabalizers

Yes

Simon Williamson
Chief Engineer
CCGS Captain Goddard MSM
Canadian Coast Guard Western Region

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goddard-chiefengineer@god.ccgs-ngcc.gc.ca
Cell: [redacted]
Iridium Sat: [redacted]

From: [redacted]
Sent: April-10-17 3:12 PM
To: CCGS Captain Goddard M.S.M. Chief Engineer
Subject: RE: Damen 4207 Stabalizers

s.16(2)
s.19(1)

Hi Simon:

Are you available for a telephone call?

Sincerely,

[redacted]
Quantum Marine
Cell: [redacted] Tel. [redacted]
Skype: [redacted]
www.quantumhydraulic.com

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From: CCGS Captain Goddard M.S.M. Chief Engineer [mailto:Goddard-ChiefEngineer@GOD.ccgs-ngcc.gc.ca]
Sent: Monday, April 10, 2017 5:05 PM
To: [redacted]
Subject: RE: Damen 4207 Stabalizers

Excellent. Thank you [redacted] we are just in the process of getting an engineering/feasibility study started and wanted to know what model was installed on other 4207's to put in our preliminary proposal. Would you mind sending me the product specification for the QC1200 if possible?

Thanks,

Simon Williamson
Chief Engineer
CCGS Captain Goddard MSM
Canadian Coast Guard Western Region
goddard-chiefengineer@god.ccgs-ngcc.gc.ca
Cell: [redacted]

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Iridium Sat: [redacted]

From: [redacted]
Sent: April-10-17 2:36 PM
To: CCGS Captain Goddard M.S.M. Chief Engineer
Subject: Re: Damen 4207 Stabalizers

s.16(2)
s.19(1)

Hi Simon:

I left a message for you to discuss since there are certain variables but basically the hull units are QC1200

Sincerely

[redacted]

On Apr 10, 2017, at 4:34 PM, CCGS Captain Goddard M.S.M. Chief Engineer <Goddard-ChiefEngineer@GOD.ccgs-ngcc.gc.ca> wrote:

> HI [redacted]
>
> Wondering if you could confirm what model stabilizer your company has been installing on the Damen 4207 Class vessel. We have 9 in our fleet and are looking to retrofit fins on in the future.
>
> Thanks,

Simon Williamson
Chief Engineer
CCGS Captain Goddard MSM
Canadian Coast Guard Western Region
goddard-chiefengineer@god.ccgs-ngcc.gc.ca
Cell: [redacted]
Iridium Sat: [redacted]

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REQUEST FOR INFORMATION (RFI)

Please provide the below information, which Quantum will use for stabilizer selection purposes. For assistance in completing the form, please contact a Quantum sales representative.

Quantum

Date:		Sales Enquiry Number: *(Quantum Use Only)*	
Ship Type:		Application:	

Single Ship

Original Shipyard:	
Hull Number:	
Ship Name:	
IMO Number:	

Group of Ships

Series/Class Name:	
Quantity of Ships in Series/Class:	
Quantity of Ships needing Stabilizers:	
End User:	

Prepared by:		Email:	
Company:		Mobile Number:	

Ship Characteristics

Length (Overall, m):		Speed (Cruise, kts):	
Length (Waterline, m):		Speed (Service, kts): †	
Beam (Overall, m):		Speed (Max Ahead, kts):	
Beam (Waterline, m):		Speed (Max Astern, kts):	
Beam (at Rub-rail, m):		Survey Authority:	Ice Class:
Hull Material:		Power Supply:	
Hull Type:		Hull Lines Plan Available?	
Chine Type:		Stability Booklet Available?	

Ship Load Conditions

Load Condition	*Displacement (tonnes)*	*GM (m)*	*KG (m) or KM (m)*		*Draft (m)*	*Roll Period (sec)*
Full Load						
Half Load†						
Lightship†						

Stabilizer System Requests

Technology: ☐ Fixed Fin ☐ XT™ Fin ☐ Maglift™		Ambient Temperature (°C): †	
Number of Units:		Cooling Water Temperature (°C): †	
Operation Modes:		Active stabilizer model tests?	

Notes:

† *This information is optional. If not provided, Quantum will provide estimate based on company norms.*

For military applications, please also complete the next page.

The information provided in this document is the basis for the system sizing and will be held in confidence. Any inaccuracies or changes to this information are to be reported to Quantum as they may affect the system specifications and projected performance.

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3685 SW 30th Avenue · Fort Lauderdale, Florida 33312 · USA Phone: +1 954-587-4205 Fax: +1 954-587-4259 www.quantumhydraulic.com
Industriestraat 5 · 6361 HD Nuth · The Netherlands Phone: +31 045-577-8430 Fax: +31 (0)45 577-8431 www.quantumcontrols.nl

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REQUEST FOR INFORMATION (RFI)

Please provide the below information, which Quantum will use for stabilizer selection purposes. For assistance in completing the form, please contact a Quantum sales representative.

Mission Requirements

Maximum Time at Sea/Year (Days):		Time between Dockings (Years):	

Stabilizer Loading Requirements◆ †

Sea State:		Speed (kts):		Time (%):	
Sea State:		Speed (kts):		Time (%):	
Sea State:		Speed (kts):		Time (%):	

Stabilizer Performance Requirements †

Max Sea State for Ship Operations:		Requested Roll Reduction (%)*:	
Max Sea State for Stabilizer Operations:		Requested Roll Reduction (%)*:	
Sea State of Primary Concern:		Requested Roll Reduction (%)*:	
Required Wave Slope Capacity (°):		Requested Roll Reduction at Zero Speed (%)*:	
At Speed (kts):			

Notes:

ITAR Information

Per the US International Traffic in Arms Regulations, Quantum seeks an export license prior to providing defense articles or defense services to non-US persons or companies. The following information is required to obtain an export license.

Name of the company making stabilizer inquiry:	
Country in which the company is based:	
Company's role in the project:	
Company address:	
Name of the end user of the ship:	
Country the end user is based in:	
If model tests are planned, what facility will be used?	
If this project is affiliated with a US Foreign Military Sales case, provide case number:	

Please provide a summary of the current phase in development of the project:

Please list below any other person or company who Quantum will need to correspond with in the project:

◆ *To estimate the sustained load on the stabilizers, the time the vessel will operate in a sea state and at a specific speed is requested. Please provide the time as a percentage per 12-month period.*

* *Roll reduction is typically analyzed for the 1m beam sea condition at resonant frequency.*

† *This information is optional. If not provided, Quantum will provide estimate based on company norms.*

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Industriestraat 5 · 6361 HD Nuth · The Netherlands Phone: +31 045-577-8430 Fax: +31 (0)45-577-8431 www.quantumcontrols.nl

TECHNICAL SPECIFICATION DOCUMENT

DANFOSS VLT MCD 500

ADVANCED DIGITAL ONE SPEED DRIVE SOLUTION

DESCRIPTION:

The DANFOSS MCD 500 provides the most advanced digital soft start solution for the complete range of Quantum hydraulic power units. The MCD 500 incorporates full motor protection features and has been designed for reliable performance in the most demanding installations.

FEATURES:

- **SIMPLE INSTALLATION:** The Quantum/DANFOSS MCD 500 units arrive mounted in IP55 enclosures. One enclosure size can house one or two soft starters, depending on installation type. No line reactor requirement further simplifies installation and also lowers installation cost.
- **INTEGRAL BYPASS CONTACTOR:** No harmonic distortion on the ship's buss.
- **FULLY PROGRAMMABLE:** Includes output signal simulation.
- **DISPLAY:** User friendly liquid crystal display.
- **APPEARANCE:** Delivered in the enclosure complete with cable glands and painted to customer specifications.
- **CERTIFICATIONS:** C√; UL/C-UL; CE; CCC; Marine-Lloyds No.1; RoHS

Equipment is covered by Quantum's 1 year comprehensive warranty.
Service and technical support are available worldwide.

Capacity	15 - 50 HP [11 - 37KW]
IP Rating	IP 55 [in enclosure]
Outputs	3x relay programmable Analog programmable
Voltage	200-525VAC 50-60Hz
Liquid Crystal Display	Loggings, real time graphs, SCR conduction bar graph
Protection	Wiring/Connection/Supply Current, Thermal, External, Starter
Dimensions* **	490 x 410 x 210 [H x W x D]
Weight**	17.8kg/22.8kg
Heat Rejection**	41watt/82watt

**Provided for reference only. Consult a Quantum representative for system sizing.*
*** Refers to one or two pump version.*
**** Dimensions are of the equipment, and do not include service allowances.*

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QP20E

HYDRAULIC POWER UNIT

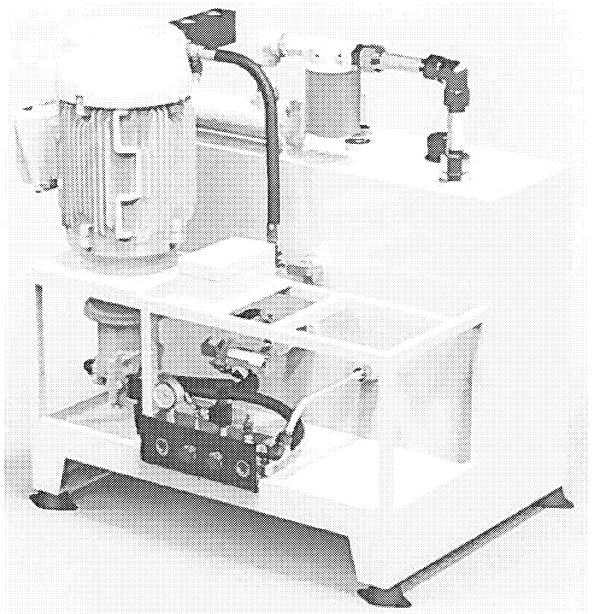
DESCRIPTION:

The QP20E hydraulic power unit provides the fluid power necessary to articulate the stabilizer fins. Quantum power units can be paired with a variety of stabilizer hull unit sizes and quantities based on vessel requirements providing for a multitude of arrangement options.

Designed to consolidate maximum machinery output into a small footprint, this compact and economical unit can be easily positioned into tight machinery spaces. The QP20E power unit consolidates on a single skid the hydraulic drive train on an a steel frame with drip tray, an oil reservoir with associated gauging and sensors, as well as return filtration and oil cooler. The QP20E is a proven heavy duty built machine which can be depended upon to supply hydraulic power for the most demanding stabilizer systems.

FEATURES:

- **SIMPLE INSTALLATION:** The QP20E is designed to incorporate maximum hydraulic function within a single "plug and play" assembly. Thus, straight-forward connections for mechanical installation, as well as hydraulic and cooling pipe work are at the heart of the QP20E design.
- **EFFICIENT:** The power unit only draws the minimum power necessary to operate the hydraulic components on demand, thus reducing the load on the vessel's electrical power and cooling systems.
- **MINIMAL NOISE:** Quantum's power units utilize a single isolation system to bring vibration levels down.
- **FUNCTIONALITY:** The durable paint finish, polished stainless steel tubing and military grade black anodized manifolds make this unit a practical marine-grade solution. Easy access to all components also translates into timesaving maintenance.



Operating Capacity*	15kW (20hp)
Operating Pressure	172bar (2500psi)
Tank Capacity	201L (53Gal)
Length *(overall)***	1206mm (47.5")
Height *(overall)***	1150mm (45.3")
Depth *(overall)***	873mm (35.4")
Weight *(dry)*	454kg (1000lbs)

**Provided for reference only. Consult a Quantum representative for system sizing.*
*** Dimensions are of the equipment, and do not include service allowances.*

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INNOVATION

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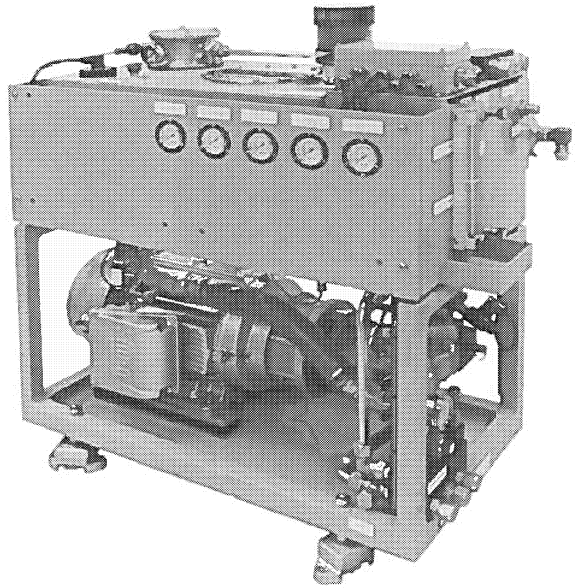
MPU20

MILITARY HYDRAULIC POWER UNIT



DESCRIPTION:

The military hydraulic power unit provides the fluid power necessary to articulate the stabilizer fins. Quantum power units can be paired with a variety of stabilizer hull unit sizes and quantities based on vessel requirements providing a multitude of arrangement options.

Designed to consolidate maximum machinery output into a small footprint, this compact unit can be easily positioned into tight machinery spaces. The MPU20 power unit consolidates on a single skid the hydraulic drive train on an aluminum frame with drip tray, stainless steel oil reservoir with associated gauging and sensors, as well as return filtration and oil cooler. The MPU20 is a proven heavy duty built machine which can be depended upon to supply hydraulic power for the most demanding stabilizer systems.

FEATURES:

- **SIMPLE INSTALLATION:** The MPU20 is designed to incorporate maximum hydraulic function within a single "plug and play" assembly. Thus, straight-forward connections for mechanical installation, as well as hydraulic and cooling pipe work are at the heart of the MPU20 design.
- **EFFICIENT:** The power unit only draws the minimum power necessary to operate the hydraulic components on demand, thus reducing the load on the vessel's electrical power and cooling systems.
- **MINIMAL NOISE:** Quantum's power units utilize a three-point isolation system to bring both noise and vibration levels down. Hydraulic noise suppressors are attached directly at pump discharge to minimize hydraulic noise in the pipes.
- **FUNCTIONALITY:** The durable paint finish, polished stainless steel tubing and black anodized manifolds make this unit a work of art as well as a practical marine-grade solution. A desiccant breather and thermo-couplings ensure the system operates optimally in any condition to stabilize your mission .

Operating Capacity*	15kW (20hp)
Operating Pressure	136bar (2000psi)
Tank Capacity	125L (33Gal)
Length *(overall)***	1172mm (46")
Height *(overall)***	1036mm (41")
Depth *(overall)***	648mm (25")
Weight *(dry)*	374kg (824 lbs)

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2.1.2 Longitudinal Location

The stabilizers are to be placed within the middle third of the vessel length, taken from the forward start of the design waterline (DWL) to the propeller(s).

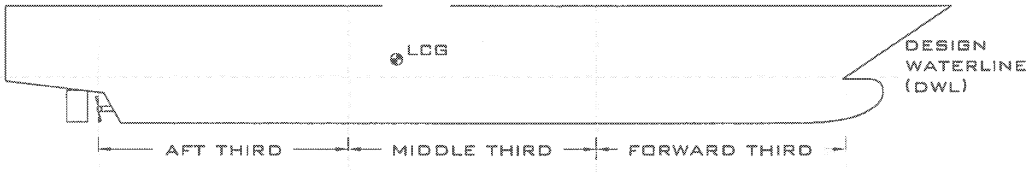


Figure 7: Longitudinal Fin Location

Stabilizers placed within the forward third are prone to slamming loads, which may cause damage to the stabilizer equipment. In addition, stabilizers in the forward third may be located in the vicinity of the bow wave, which will significantly alter incoming flow to the fin and may significantly reduce the effective depth of the fin in the water.

Stabilizers placed within the aft third are prone to cause a yawing effect, which may influence vessel steering, especially in seas aft of the beam. In addition, stabilizers positioned in the aft third are very likely to influence the flow of water into the propeller, which may affect propeller efficiency and ultimately vessel speed.

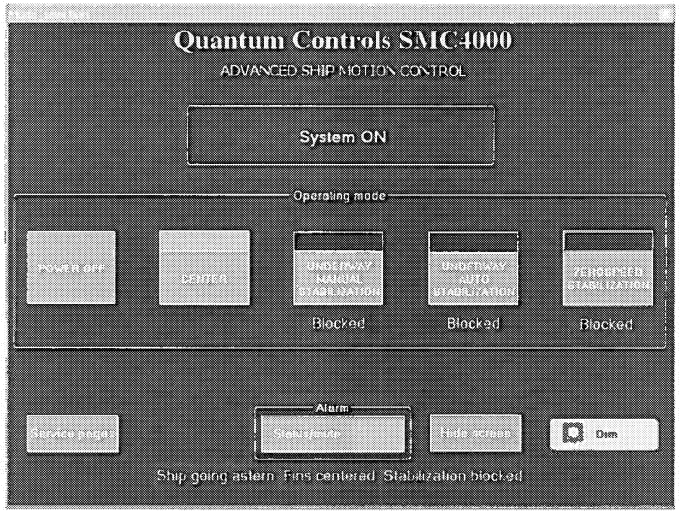
Stabilizer fins that are to be active during underway operations are to be located at or forward of the Longitudinal Center of Gravity (LCG).

Figure 8: Longitudinal Center of Gravity

Stabilizer influences on the steering of the vessel are apparent when the fins are aft of the LCG and are amplified with distance aft of the LCG. Please note: For some four-fin stabilizer systems, it may be necessary only to run the forward stabilizer pair underway. In these cases, the aft pair may be located aft of the LCG, but may not be run underway unless the possible steering effects are understood and can be tolerated.

SMC4000

ADAPTIVE STABILIZER CONTROL



DESCRIPTION:

The stabilizer control is the brain behind the stabilizer system. Collecting vessel roll motion data and instantaneous performance feedback, the stabilizer control system combines the necessary parameters to quickly comprehend vessel roll motions and to then instigate an immediate response. The control logic is capable of accounting for and compensating to various operating conditions. The control is capable of collecting ship's speed data via a NMEA 0183 interface to control maximum fin angle for high speed use. Adaptive logic tailors the ride making the SMC4000 perfect for underway and Zero Speed™ stabilization.

FEATURES:

- **DUAL-MODE OPERATION:** The SMC4000 features an Automatic Mode, which accounts for vessel motions and adjusts the system response, without the need for continual manual adjustments. The control also offers full manual control for those situations in which manual input can result in improved performance.
- **EASY-TO-UNDERSTAND OPERATION:** The SMC4000 control head, which is to be mounted on the bridge for easy access, features an LED display of stabilizer activity, easy to use controls, and a dimmable display for nighttime navigation. System alarms can be displayed on the SMC4000 control head, or can be integrated with the ship's central alarm monitoring system.
- **SIMPLE INSTALLATION:** The control system is comprised of a minimal quantity of components, which are quickly and easily bolted into place.
- **SAFETY PRECAUTIONS:** To avoid damage to the stabilizer system, the SMC4000 ensures that the stabilizer fin is automatically brought to the center position when Neutral or Astern operations are employed. The "Center" function can also be employed by the captain with the push of a button.

Required Power Supply	24V DC
Length (control head)*	188mm (7.4")
Width (control head)*	257mm (10.1")
Depth (control head, excluding cables)*	50mm (2.0")

** Dimensions are of the equipment, and do not include service allowances.*

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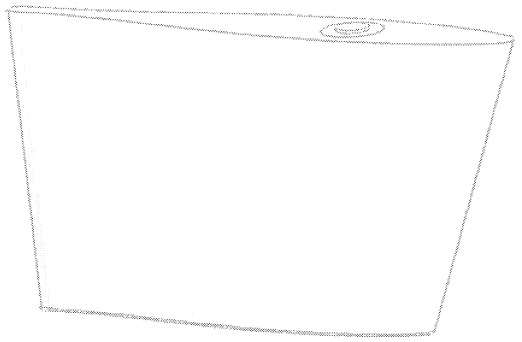
QC1200

UNDERWAY (S-SERIES) STABILIZER FIN



DESCRIPTION:

A stabilizer fin is the device which develops the hydrodynamic forces needed to counter the roll motions of the vessel. The fin is installed on the stabilizer hull unit shaft, which serves as the axis about which the fin is deflected. Much like an airplane wing, as the fin is deflected, pressure differences result in a hydrodynamic force on the fin. This resultant force is used to counter-act the roll of the vessel.

Designed based on extensive experience and model testing, the QC1200 S-series stabilizer fin is capable of significantly reducing vessel roll during underway operations.

FEATURES:

- **SIMPLE INSTALLATION:** The fin is installed on the stabilizer hull unit shaft via a hydraulic coupling method. This attachment technique provides a durable and reliable connection, easily achieved with the use of supplied tools and instructions.
- **MINIMAL NOISE:** Quantum's stabilizer fins are designed with innovative features such as minimal hull-to-fin clearances and trailing edge vortex generators. These elements help to reduce hydrodynamic noise and vibrations.
- **ROBUST CONSTRUCTION:** The fins are fabricated of steel or stainless steel combined with strategic internal reinforcement. This interior bolstering enables the fin to withstand the cyclic loads encountered during operation.
- **MINIMAL MAINTENANCE:** The fin requires no maintenance during normal operation. The units are designed for maintenance intervals corresponding to vessel haul-outs every other year.

Typical Vessel Length*	30-45m (100-150ft)
Fin Size Range**	1.4-2.7m² (15.0-29.0ft²)
Typical Aspect Ratios	0.53-0.64
Typical Balance	25%
Dimensions	See a Quantum Representative for Drawings

**Provided for reference only. Consult a Quantum representative for system sizing.*
*** Size may be limited for higher speed vessels; see a Quantum representative for more information.*

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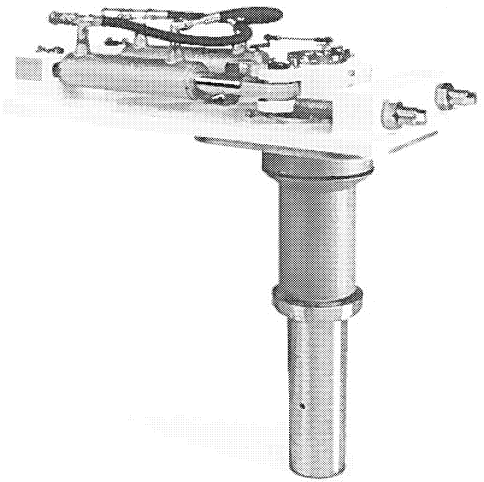
TECHNICAL SPECIFICATION DOCUMENT

QC1200

STABILIZER HULL UNIT



DESCRIPTION:

A stabilizer hull unit is the energy transfer device in Quantum's fin stabilizer systems. The hull unit is installed in the turn of the bilge with its main shaft penetrating through the vessel's hull to connect to the stabilizer fin. It uses hydraulic cylinders to rotate the main shaft, which in turn, deflects the fin to reduce roll.

Designed using the latest technology and high-quality materials, the QC1200 is a rugged machine that is capable of significantly reducing vessel roll during both underway and Zero Speed™ operations. The QC1200 can be made available with built-in porting and electronics to allow this unit to be used with Quantum's innovative extendable (XT™) fin system, or as a Heavy Duty (HD) unit with larger load bearing components.

FEATURES:

- **SIMPLE INSTALLATION:** The hull unit is delivered fully assembled for easy installation into the vessel's structure, via the supplied welding bushing.
- **PRECISE FITS AND CLEARANCES:** The main shaft features a tapered cut for true stabilizer fin connection, and a rotating-spline connection to the tiller and hydraulic cylinders. These precise fits promote a smooth transfer of energy from the hydraulic cylinders to the stabilizer fin.
- **SAFETY PRECAUTIONS:** Heavy-duty bolts are used to manually return the fin to its center position in the event of an emergency.
- **LOAD HANDLING:** A series of sleeve bearings and a spherical roller bearing distribute the motions and loads imposed on the hull unit.
- **MINIMAL MAINTENANCE:** The hull unit is simple to maintain during normal operation, with stainless steel components used extensively to minimize corrosion. Easily accessible grease nipples are built-in with internal porting for regular greasing of the bearings. The unit is designed for replacement of o-rings, seals, and bearings during vessel haul-outs every other year.

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Typical Vessel Length*	30-45m (100-150ft)
Fin Size Range**	1.4-2.5m² (15-27ft²)
XT™ Fin Size(s) Available**	1.2x1.6m² (13x17ft²)
Length *(including centering bolts)****	1145mm (45")
Width***	440mm (17")
Height *(overall)****	970mm (38")
Height *(inside vessel after installation)****	630mm (25")
Weight *(dry)****	290kg (640 lbs)

**Provided for reference only. Consult a Quantum representative for system sizing.*
*** Size may be limited for higher speed vessels; see a Quantum representative for more information.*
**** Dimensions are approximate dimensions of the equipment, and do not include service allowances.*

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Guideline for Reducing Cavitation at the Fin Stabilizers

Purpose

This document is intended to relay detailed information to the designer and builder on proven methods to minimize cavitation noise due to the gap between the top of the stabilizer fin and the hull plating.

The Art of Cavitation Reduction

The presence of cavitation on fin stabilizers is a reality and cannot be avoided for all applications or in all operational states. It is however desirable and possible to reduce this cavitation to a level at which it does not cause irritation. There are many ship design aspects that influence stabilizer fin cavitation. These include but are not limited to:

- the longitudinal location of the fin on the hull
- the gap between the hull plating and the fin
- the boundary layer
- fin immersion depth
- fin aspect ratio
- vessel speed (VERY CRITICAL for higher speed applications*)
- installation techniques
- other hull appendages

These variables make every application entirely unique. It is possible to perform both mathematical and scale model testing to anticipate the onset of cavitation, but these methods are costly and are not always reliable. This guideline is offered to help abate cavitation related issues based upon Quantum's accumulated experience.

*The likelihood of cavitation increases with vessel speed. For vessels operating in excess of 20 knots, it is Quantum's recommendation that the fin-to-hull gap meets the minimum tolerance provided in the "Allowable Fin-to-Hull Gap" table. (*See Mitigation Steps: After Vessel Construction* for more information)

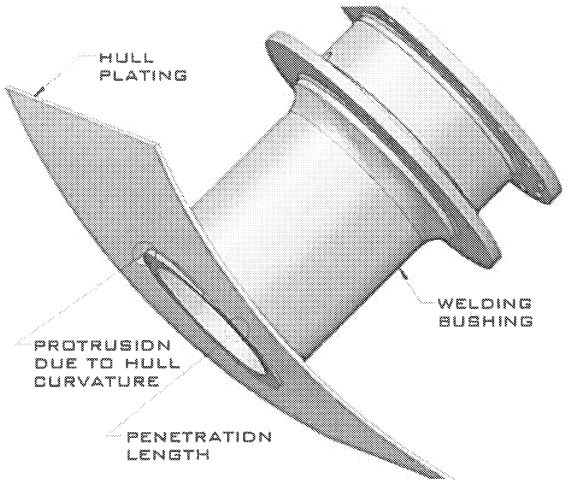
Mitigation Steps: During Vessel Design

During the vessel's design phase the fin size and location on the hull are determined. The designer and builder must check the location of the fins in relation to other underwater hull appendages such as hull penetrations, sea-chest scoops, and bilge keels. The designer should ensure that the installation details of the welding bushing include steps that will minimize the chance of cavitation at the fin. These details are described below.

Mitigation Steps: During Hull Construction

The distance that the welding bushing protrudes through the hull plating and its angle to the hull has a direct relationship on the fin-to-hull gap. Although this initial installation requires careful precision, it is one of the easiest implementable steps towards cavitation reduction.

Flush mounting the bottom surface of the welding bushing to the hull bottom with a back bevel weld is highly recommended over an exterior fillet weld. This allows the welding bushing to be drawn into the hull resulting in a surface that is as flush as possible. Purely for the purposes of structural integrity the welding bushing may protrude slightly, however the protrusion should not exceed 10mm. It should be noted that a



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protrusion of the welding bushing through the shell plate increases the fin to hull gap and therefore increases potential for cavitation.

The welding bushing must be installed normal to the local hull surface in all directions. A slight error in the angular orientation could result in either the aft end of the fin colliding with the hull, or resulting in a very large gap between the fin and the hull. It may be helpful to make and use an alignment tool or jig for this installation.

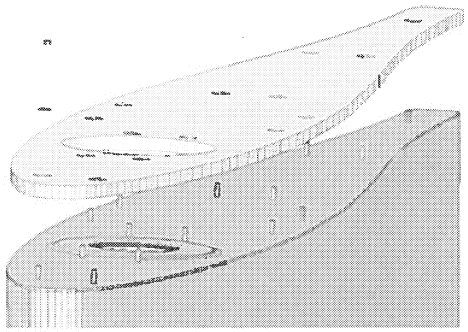
Mitigation Steps: After Vessel Construction

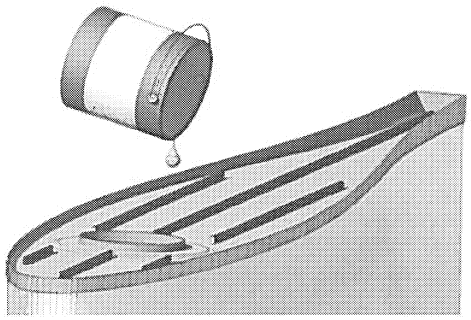
It is possible to reduce the gap after the installation is complete by adding material to the top of the fin. It is prudent to perform this task as a preventative measure to avoid cavitation. There are two notable techniques to accomplish this task. Be mindful when choosing materials as some may swell under water which would close up the gap further and may cause chafing or prevent the fin from moving completely. Keep in mind that some gap is required to accommodate increasing paint thickness over the years, marine life growth and most importantly shaft deflection due to hydrodynamic forces. The allowable gap shown in the table at right is to be maintained along the entire chord length of the fin in its center position.

Allowable Fin-to-Hull Gap		
Hull Unit	Min. [mm]	Max. [mm]
QC1000	8	18
QC1200		
QC1500		23
QC1800	10	
QC2200 QC2400 QC2600	12	25
QC3600	14	35

Quantum permits any of these modifications to the fin listed below as long as they do not compromise the integrity of the fin. However, Quantum cannot be held liable for damages to the equipment or hull caused by any modifications or consequences resulting from the modifications.

1. A full length shim can be shaped and attached to the top of the fin. To precisely attain the optimal shim thickness, it is best to first install the fin and physically measure the gap. It is recommended to use a bonding adhesive under the shim. Quantum can, upon request, supply a fin with threaded inserts to facilitate mounting a shim. If not supplied by Quantum, shipyard can weld threaded studs to the fin and counterbore the shim holes to keep the nuts from protruding.





2. An epoxy filler can be poured onto the top of the fin. One method is to install the fin and tack weld strips of metal to the side of the fin to create a temporary fence to hold the epoxy until it hardens. This method is easier to create a varying thickness of build up for a more uniform gap thickness. The green represents the removable border, while the blue represents permanent welded strips to increase fin bonding surface area for the epoxy.

Unless agreed upon in the terms and conditions for sale, Quantum is not responsible for the reduction of the fin-to-hull gap.

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fax (978) 741-4447

NOISE AND VIBRATION REDUCTION FOR HYDRAULIC PIPES AT BULKHEAD AND DECK PENETRATIONS

Insufficient vibration isolation of hydraulic pipes at bulkhead and deck penetrations can cause significant structure-borne noise and vibration. Pressure pulsations in the hydraulic fluid traveling through pipes - due to piston motion and valving, as well as mechanical vibrations originating in hydraulic pumps - can create structureborne vibration in bulkheads and decks, resulting in radiation of airborne noise from these large panel structures. To ensure that the vessel safety requirements are met without compromising noise and vibration control performance, special attention must be paid to bulkhead and deck penetrations.

The best solution to reduce the transfer of vibration from hydraulic pipes to bulkheads and decks consists of two components:

1. A soft attachment (or no attachment) to the bulkhead or deck, at
2. A relatively rigid point in the bulkhead or deck, achieved by
   - Existing stiffeners or additional stiffeners,
   - Proximity to intersections of structural members,
   - Increased plate thickness at the penetration location.

There are many types of commercially available soft attachments for bulkhead and deck penetrations, for different applications. The basic options are described below (all systems should be installed according to manufacturer instructions):

I. Fire-Rated and Watertight Rated

a) Softest

The softest hydraulic pipe penetration system, in J&A's experience, is the RISE system, from CSD Sealing Systems. The RISE system, shown right in Figure 1, consists of fire-resisting rubber sleeves that wrap the hydraulic pipes. Gaps in the deck or bulkhead penetration are then filled with additional rubber sleeves and the penetration is closed with a highly-elastic watertight sealant. In case of a fire, the rubber sleeves will expand up to five times their original volume and provide a tight seal against smoke and fire.

During installation, care should be taken that the additional sleeves are not packed too tightly as this could reduce the effectiveness of the vibration isolation they provide. Good alignment should be maintained such that the pipes are centered in the penetration.

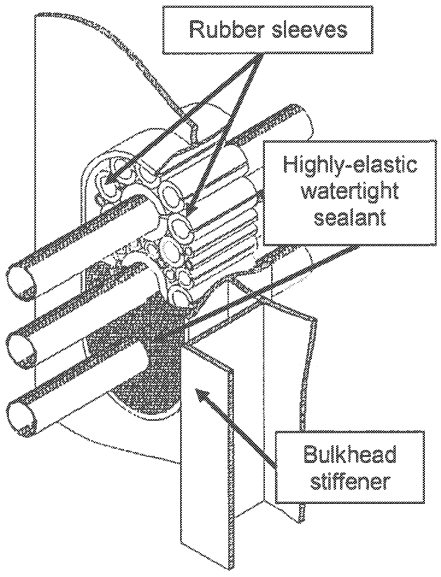

Figure 1: RISE System for Fire-Rated and Watertight Penetrations

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Noise and Vibration Engineering
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b) Semi-soft

Transit systems such as the Nelson Transit System, the Hawke Transit System, and the Roxtec sealing system, all provide fire and watertight rated, semi-soft attachment for pipes. These systems consist of a frame in which several pipes can be isolated in individual modules, as shown in Figure 2. The kit is then tightened and the modules compressed so that all gaps around pipes are eliminated.

c) Hard

Hard rubber plug systems, such as CSD Slipseal plugs, are available that meet fire and watertight ratings. These systems typically provide less vibration isolation than the soft and semi-soft systems described above.

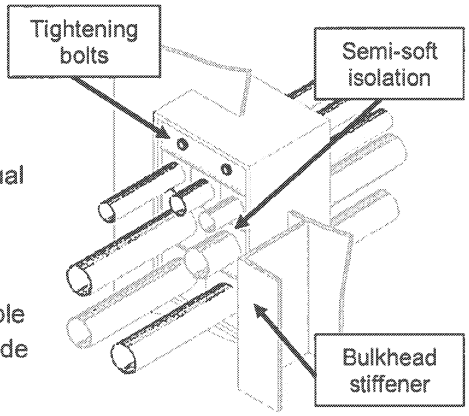

Figure 2: Transit System for Fire-Rated and Watertight Penetrations

II. Water-Resistant Penetrations

Several good options exist for vibration isolation of hydraulic pipes in water-resistant bulkheads and decks. One method is a vibration isolator around the pipe, such as soft rubber or Sylomer foam, in combination with a highly flexible watertight sealant. If Sylomer is used, 12mm (1/2") of Sylomer R (blue) is recommended. Compression of the Sylomer R-12 strip should not exceed 2.5mm. It is also important that the pipe is centered in the penetration before inserting Sylomer. This concept is shown in Figure 3.

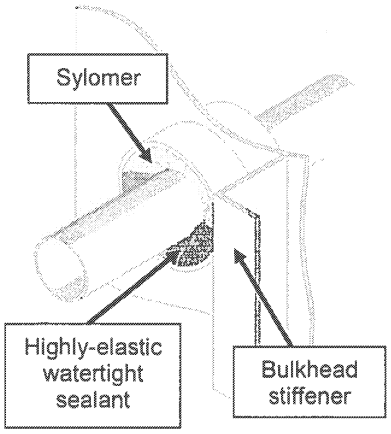

Figure 3: Sylomer Foam and Sealant for Water-Resistant Penetrations

Another option for pipe vibration isolation in water-resistant bulkheads and decks is a system such as the Flexicraft PipeSeal; see Figure 4. This system consists of rubber sections that are tightened to expand and fill gaps around the pipe. RISE and Roxtec (previously mentioned) also provide water-resistant bulkhead isolation systems.

All systems should be installed according to manufacturer instructions.

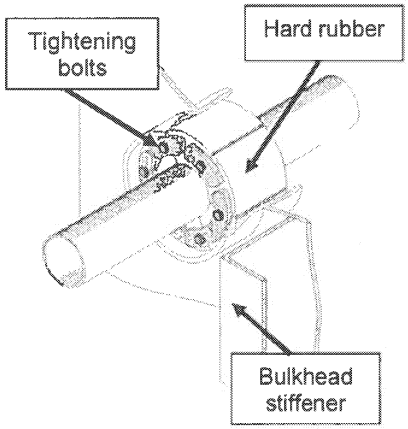

Figure 4: Flexicraft PipeSeal System

III. Non-Fire-Rated, Non-Watertight Penetrations

The best method for isolating hydraulic pipe vibration from non-fire-rated, non-watertight penetrations is to pass the pipes through the penetration without contact. Pipes can be supported on isolated pipe clamps on separate points of rigid vessel structure on either side of the penetration. See the J&A paper "Noise and Vibration Reduction of Hydraulic Pipes and Accessories" for guidelines on the isolation mounting of pipes.

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Wyse, David E

From: Wyse, David E
Sent: Tuesday, April 11, 2017 3:08 PM
To: Kozarski, Vladan; Kozarski, Natasa
Subject: RE: MSPV stabilizer study question

Hey Vladan,

Are we still on track to have the feasibility study done by September for stabilizers?

Region is starting a CCR to implement the Quantum stabilizers. That will put more pressure on this project.

Dave

From: Wyse, David E
Sent: March-08-17 2:14 PM
To: Clarke, Tracey; Kozarski, Vladan
Subject: RE: MSPV stabilizer study question

s.21(1)(b)

No just looking at timelines if all works out for the end result of them getting stabilizers [redacted]

1. Feasibility study – 5 months – to September 2017 –
2. Agreement on feasibility moving forward – 3 months – to December 2017
3. Engineering for Stabilizers – 5 months to May 2018
4. Agreement for Engineering – 3 months to September 2018
5. Spec and Drawings – 1 month to October 2018
6. Contracts and implementation - ????

[redacted]

Dave

From: Clarke, Tracey
Sent: March-08-17 2:04 PM
To: Wyse, David E; Kozarski, Vladan
Subject: Re: MSPV stabilizer study question

Are you talking about promising that stabilizers are coming in 2 years? We're going to do the feasibility study and I think it looks promising but there will be trade offs that Fleet will have to agree to (carry less fuel, vessels that go slower because of the appendages) so I don't know that you'd be in a position to promise stabilizers. Even if ITS recommended them, it will likely come to a fleet decision because of what we may have to compromise on operationally.

Tracey

Sent from my BlackBerry 10 smartphone on the Rogers network.

From: Wyse, David E

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Sent: Wednesday, March 8, 2017 1:42 PM
To: Clarke, Tracey; Kozarski, Vladan
Subject: RE: MSPV stabilizer study question

I will have to answer the RCMP and C&P tomorrow about the status of getting stabilizers. Do I stick with my 2 years from now if everything works out to get to the installation phase?

Thanks
Dave

From: Clarke, Tracey
Sent: March-07-17 3:47 PM
To: Wyse, David E; Kozarski, Vladan
Subject: RE: MSPV stabilizer study question

Vladan presented the plan for the feasibility study. He presented the options to be studied in the feasibility study.

We've got to get a contract in place with Damen to get analysis done. So I don't have a date yet...

Tracey

From: Wyse, David E
Sent: Tuesday, March 7, 2017 3:45 PM
To: Clarke, Tracey <Tracey.Clarke@dfo-mpo.gc.ca>; Kozarski, Vladan <Vladan.Kozarski@dfo-mpo.gc.ca>
Subject: RE: MSPV stabilizer study question

I thought Vladan did the feasibility and presented at the face to face and we were moving to engineering and options study. So the feasibility is still on going? Can you give me a report date so I can get back to the group?

Thanks
Dave

From: Clarke, Tracey
Sent: March-07-17 3:42 PM
To: Wyse, David E; Kozarski, Vladan
Subject: RE: MSPV stabilizer study question

This is a feasibility study not engineering so I think it's premature for a CCR...

Tracey

From: Wyse, David E
Sent: Tuesday, March 7, 2017 3:39 PM
To: Kozarski, Vladan <Vladan.Kozarski@dfo-mpo.gc.ca>; Clarke, Tracey <Tracey.Clarke@dfo-mpo.gc.ca>
Subject: FW: MSPV stabilizer study question

Are we making this into a CCR yet?

From: CCGS Captain Goddard M.S.M. Commanding Officer [mailto:Goddard-Captain@GOD.ccgs-ngcc.gc.ca]
Sent: March-07-17 3:23 PM
To: Wyse, David E
Cc: CCGS-NGCC, Aleblanc Commandant; CCGS-NGCC, Constable Carriere Commanding Officer; CCGS-NGCC, Corporal

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Teather Commanding Officer; CCGS, G Peddle Captain; CCGS-NGCC, Caporal Kaeble Commandant; Capstick, Charles; CCGS-NGCC, Private Robertson Commanding Officer
Subject: RE: MSPV stabilizer study question

Dave,

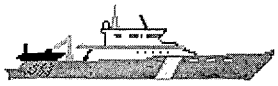
With the Captain Goddard's area of operation being the north coast of British Columbia we experience a wide range of different weather and swell conditions.

We are 100% in favor of any form of stabilisation. (I know our clients would be much happier)

As the engine room is quite cramped there is probably no chance of installing "Active stabilisers" but even bilge keels would be a great addition to the stability of the vessel.

Best Regards,

Dustin Flahr - Commanding Officer **s.16(2)**
CCGS Captain Goddard M.S.M.
Canadian Coast Guard, Western Region
Goddard-Captain@GOD.ccgs-ngcc.gc.ca
Cell [redacted]



From: CCGS-NGCC, Caporal Kaeble Commandant [mailto:kaebleCO@ccgs-ngcc.gc.ca]
Sent: March-07-17 3:31 AM
To: Wyse David
Cc: CCGS-NGCC, Aleblanc Commandant; CCGS-NGCC, Constable Carriere Commanding Officer; CCGS-NGCC, Corporal Teather Commanding Officer; CCGS G Peddle Captain; CCGS Captain Goddard M.S.M. Commanding Officer; CCGS-NGCC, Caporal Kaeble Commandant; Capstick Charles; CCGS-NGCC, Private Robertson Commanding Officer
Subject: RE: MSPV stabilizer study question

Hi Dave!

Our main concern for waves are located in Gulf St-Laurence.
From my experience those waves are shorts and steeply.
Close the ones we find on Great lakes.

Thanks.

Cmdt. Yves Gervais
Commanding officer | Commandant
CCGS Caporal Kaeble VC | NGCC Caporal Kaeble VC
Canadian Coast Guard | Garde côtière canadienne
Québec Region | Région de Québec
Government of Canada | Gouvernement du Canada
Cell: [redacted]
Email: kaebleco@ccgs-ngcc.gc.ca

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De : Wyse, David E [mailto:David.Wyse@dfo-mpo.gc.ca]
Envoyé : 6 février 2017 11:37
À : (corporalmclarenCO@mcl.ccgs-ngcc.gc.ca); CCGS-NGCC, Aleblanc Commandant; CCGS-NGCC, Constable Carriere Commanding Officer; CCGS-NGCC, Corporal Teather Commanding Officer; G Peddle Captain; goddard-captain@god.ccgs-ngcc.gc.ca; CCGS-NGCC, Caporal Kaeble Commandant; M Charles; CCGS-NGCC, Private Robertson Commanding Officer
Cc : Sanchez-Carol Lisa
Objet : MSPV stabilizer study question

Hi Captains,

HQ is starting to run studies into stabilizers for the MSPV's (info will be presented at the MSPV face to face). I have received concerns from Atlantic region with rolling, etc. Does the Great Lakes or Pacific have the same concerns? If there is no concern with Pacific or Great lakes then we can narrow the study down to waveforms in Atlantic only. Waveforms are different in each area.

Thank you
Dave

David Wyse
Project Engineer | Mécanicien de Projet
Marine Engineering | Ingénierie Navale
Integrated Technical Services | Services Techniques Intégrés
Canadian Coast Guard | Garde Côtière Canadienne
200 Kent Street, Office 7W076, Mail Drop 7W064
Ottawa, ON, K1A 0E6
David.Wyse@dfo-mpo.gc.ca
Telephone | Téléphone 613-993-2710

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Granger, Louise Anne

From: Granger, Louise Anne
Sent: August 15, 2017 8:56 AM
To: Chaikin, Gabriel
Subject: FW: 20173103 Vessel National Hero Class Stabilizers ACK / Validated Major Normal

Tracking:	**Recipient**	**Delivery**	**Read**
	Chaikin, Gabriel	Delivered: 2017-08-15 8:57 AM	Read: 2017-08-15 1:16 PM

FYI, the official CCR on the topic.

LouiseAnne (LA) Granger
Marine Engineering | Ingénierie navale
(250) 363-6058

From: Nat CCR Coord / Coord Nat DCC (DFO/MPO)
Sent: 2017–July-31 8:44 AM
To: McBride, Blaine; Mariciuc, Liviu; Wyse, David E
Cc: Tettamanti, Ryan; Pike, Rod; Wyse, David E; Guyon, Benoit; ATL.CCR / DCC.ATL (DFO/MPO); Blight, David; Rossiter, Krista; Seitz, Jeffrey; Akerman, Darrin; Perron, Donat J; Chafe, Kathleen; XCA, Coordonnateur régional DCC Navires-Secteur ST-Laurent; Brown, Annette; Wilhelm, Ralph; Pleau, Sylvain; CCGWesternCCR / CCROuestGCC (DFO/MPO); Lawson, Keith; Granger, Louise Anne; Ross, Malcolm; Sanchez-Caro, Lisa
Subject: 20173103 E&I Vessel National Hero Class Stabilizers ACK / Validated Major Normal

Hello,

This message is to acknowledge the information submitted for this Configuration Change Request (CCR) and to inform Regional stakeholders about potential future configuration changes.

You can review the status of any CCRs at this address: http://intra.coast-guard.ca/ITS/tools/results.

CCR #	Scope	Priority	Title	Work Description	Drawings	ABS Num
3103	Major National	Normal	Hero Class stabilizers	The parent Hero Class design vessels are delivered with stabilizers. The Hero Class vessels do not have stabilizers installed. All vessel operators agree the vessels require stabilizers in all areas of operation. Program and operations can suffer do the fact that the vessels have extreme roll in high sea state conditions. Engineering and implementation plans are required		15E

It requires a CCR if it affects: Form, Fit, or Function. If not, it only requires a work order.

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Form: The shape, size, dimensions, mass and/or other visual parameters which uniquely characterize an item.

Fit: The ability of an item to physically interface or interconnect with or become an integral part of another

Function: The action[s] that an item is designed to perform. Note: performance and options may increase with n

Producing the CCR PDF Form (Points to look at)

- **2- Category:** Consider whether said changes should receive a wider application (such as class-wide, regionally and/or nationally) where additional benefits might be realized, before receiving RCCB approval. In such cases the scope for the CCR should be Major, rather than minor.
- **3- Work Description:** Break the work description into the following sub titles: Existing Condition, Solution, Benefits, maintenance cost, (Give more details of work using: Word, Excel, pictures, etc., attached documents to your email.)

Once you have completed **sections 1 to 5** of the most recent version of the pdf CCR Form, scan the form and sen ensure that the form is profiled into EKME. The RCCRC is then required to circulate the form secretarially or to ad Regional CCRC email addresses below.

Once the CCR has been signed by the Regional Authorities (section 6), the RCCRC is responsible to ensure that th inform the originator via email, with the NCCRC cc'd, of the request status. The NCCRC will then update the CCR

If you have any questions or suggestions regarding the CCR Form or Process, don't hesitate to email me at : NationalCCRCoordinator@DFO-MPO.GC.CA

Regards/ Cordialement,

Carol Gilliland

National CCR Coordinator /Coordonnateur national de DCC
Desk Officer, Configuration Management /Agent de bureau, Gestion de la configuration
Integrated Technical Services /Services techniques intégrés
Canadian Coast Guard /Garde côtière canadienne
200 Rue Kent Street, Ottawa, 7W120A

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Granger, Louise Anne

From: Chaikin, Gabriel
Sent: September 11, 2017 8:29 AM
To: Jack, David; Granger, Louise Anne
Subject: Fw: Stabilizers on Hero Class vessels
Attachments: What stabilizer looks like on inside of the Damen 4207 vessel.pdf

Sent from my BlackBerry 10 smartphone on the Rogers network.

From: Wyse, David E <David.Wyse@dfo-mpo.gc.ca>
Sent: Monday, September 11, 2017 6:02 AM
To: Chaikin, Gabriel; Mkrtychan, Sergey; Couillard-Desjardins, Isabelle; Mercier, Jeffrey; Hart, Sarah; (corporalmclarenCO@mcl.ccgs-ngcc.gc.ca); A leblanc CO (aleblancCO@ccgs-ngcc.gc.ca); Carriere; carriere chief officer; CCGS-NGCC, Corporal Teather Commanding Officer (CorporalTeatherCO@ccgs-ngcc.gc.ca); G Peddle Captain; goddard-captain@god.ccgs-ngcc.gc.ca; Kaeble; M Charles; Private Robertson; private robertson chief officer; Teather chief officer; aleblancCE@ccgs-ngcc.gc.ca; Carriere 1st engineer; ConstableCarriereCE@ccgs-ngcc.gc.ca; CorporalMcLarenMMVCE. CCGS@dfo-mpo. gc. ca (CorporalMcLarenCE@MCL.ccgs-ngcc.gc.ca); CorporalTeatherCE@ccgs-ngcc.gc.ca; G Peddle Chief Engineer; Goddard-ChiefEngineer@GOD.ccgs-ngcc.gc.ca; KaebleCE@ccgs-ngcc.gc.ca; mcharlesce@cha.ccgs-ngcc.gc.ca; PrivateRobertsonCE@ccgs-ngcc.gc.ca; Robertson 1st eng; Teather 1st eng
Subject: Stabilizers on Hero Class vessels

Good Morning all,

I just wanted to give an update on the stabilizer request for Hero Class. CCR 3103 is up for approval by the director board shortly. I have made another request to the RCMP and C&P head office points of contact for information on any lost program time due to lack of stabilizers and vessel rolling. If you have any of this information then send it along as I know this will help the case to install stabilizers. I have had a response from Great Lakes only stating that no program time has been lost due to lack of stabilizers and vessel rolling. Nothing from QC, Atlantic or Western.

Team Nav Arc has hired Damen to do a study to see if the stabilizers can be implemented on our vessels. I expect this study to be done at the end of this month. Engineering will have to be done after this and approved by the board of directors.

I have attached what the stabilizer unit installed on the Dutch Coast Guard vessel that I visited in June looks like from the inside.

Dave

David Wyse
Project Engineer | Mécanicien de Projet
Marine Engineering | Ingénierie Navale
Integrated Technical Services | Services Techniques Intégrés
Canadian Coast Guard | Garde Côtière Canadienne
200 Kent Street, Office 7W076, Mail Drop 7W064
Ottawa, ON, K1A 0E6
David.Wyse@dfo-mpo.gc.ca
Telephone | Téléphone 613-993-2710

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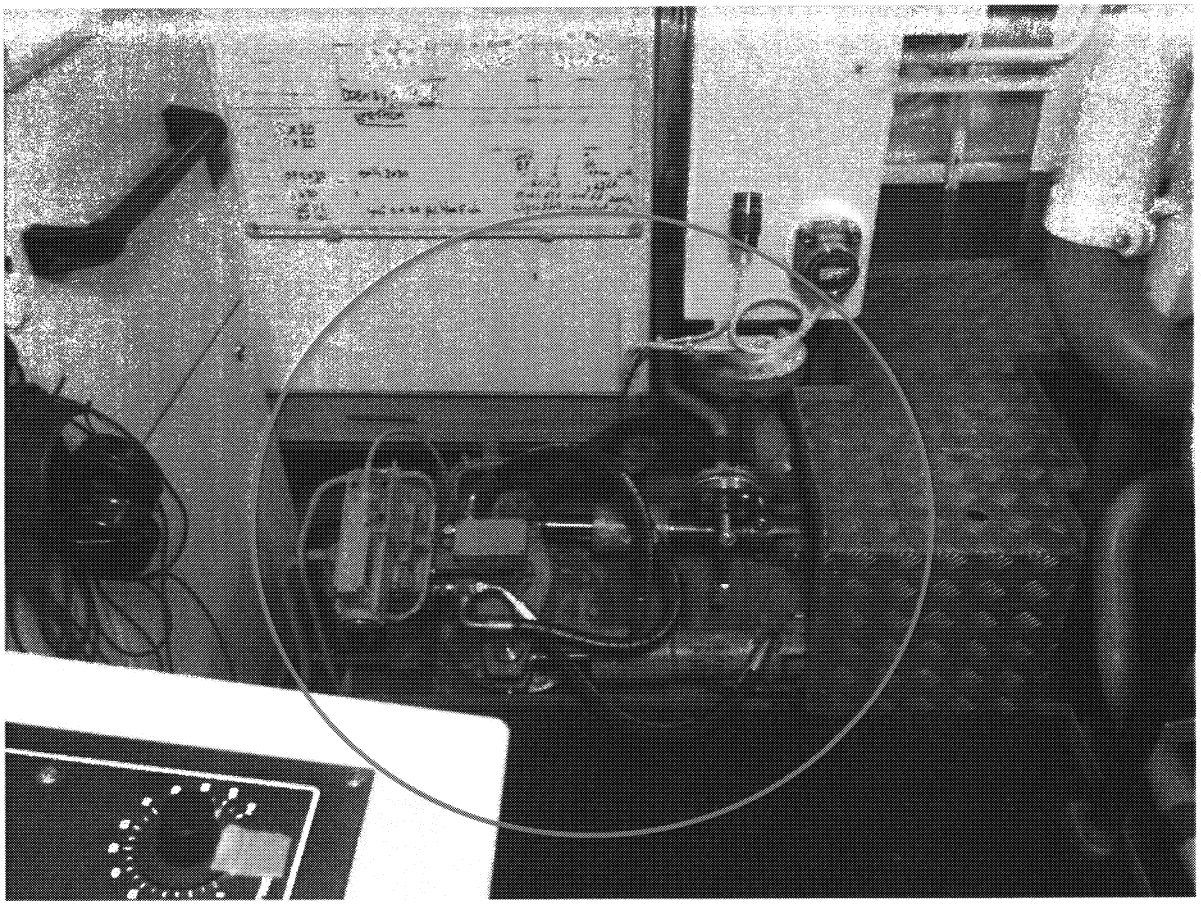
What stabilizer looks like on inside of the Damen 4207 vessel (Dutch Coast Guard vessel)



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Dutch Coast Guard vessel – Zeearend

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Wyse, David E

From: Wyse, David E
Sent: Monday, September 11, 2017 12:27 PM
To: CCGS M Charles - Captain
Subject: RE: Stabilizers on Hero Class vessels

Great thanks Dustin.

I will add that information in the CCR.

Dave

From: CCGS M Charles - Captain [mailto:MCharles-Captain@cha.ccgs-ngcc.gc.ca]
Sent: September-11-17 12:01 PM
To: Wyse, David E
Subject: RE: Stabilizers on Hero Class vessels

s.16(2)

Dave, good morning from the west coast.

I have asked our client for any information regarding lost time etc as per your request.
I have copied an email thread below.

There are no hard facts to days lost or hours lost but as you scroll down you eventually come back to one of your emails.

Dustin Flahr
Commanding Officer
CCGS M. Charles M.B.
Canadian Coast Guard, Western Region
MCharles-Captain@cha.ccgs-ngcc.gc.ca
Ship Cell [redacted]
Iridium [redacted]
Portable Cell [redacted]

Dustin

From: Crottey, Michael
Sent: Thursday, August 24, 2017 12:55
To: Kaatz, Robert
Subject: RE: Hero Class vessel stabilizers

Hi Robert can you give this a read over and see if it makes sence? I added your comments and Myas.

Hi Linda

I have canvassed the C&P crew on the Martin Charles and they have provided the following feedback on vessel stabilizers.

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It goes without saying that the crew is in favour of having stabilizers installed on the ship. Having less pitch and roll is always a good thing when at sea. Walking around the ship, climbing stairs, launching and retrieving the RHIB, storing gear, having meals and even sleeping is safer, less tiring and physically more comfortable, especially for those that succumb to motion sickness.

Seasickness is felt by both C&P and Coast Guard personnel and has an impact on vessel operation, as those employees are not operational while seasickness persists. Many officers/ crew who are not typically effected by motion sickness when they are moving about and doing physical day to day work when at sea, but when having to focus on a computer screen or other "paper work" the effects of the motion will cause some people to get sick. C&P officers tend to do their admin work during the periods when the vessel is transiting. So the more we can reduce officer down time due to the effects of motion, the more productive the officers will be getting the admin done during these periods of transiting, therefore increasing their time on the water when arriving at the next port of call.

The crew are in favor of having vessel stabilizers that function while at anchor as well as when underway. The ship at times anchors in areas at sea subject to ocean swell, I have experienced this myself and can state first hand that it makes for a sleepless night and makes it harder to do your admin work during the day.

As well while transiting at night from Sound to Sound in the exposed waters of the West Coast of Vancouver Island can make for a very uncomfortable night . On the trip I did in July we transited up the coast overnight and had to put rolled up jackets under the outer edge of my bunk to keep me rolled to the wall so I would not come out of my bunk in the night give the amount of roll in the ship . Although the stabilizers would not completely eliminate this issue it would certainly lessen the effect.

When officers get motion sickness , most use a medication either prophylactically or in response to the symptoms. The main ingredient in motion sickness oral medication is Dimenhydrinate, which is an antihistamine used to prevent and treat nausea, vomiting, and dizziness caused by motion sickness. Drowsiness and blurred vision, are common side effects of taking these medications adding to the problems associated with the constant motion of the vessel. Officers manage this and ensure they do not put themselves in danger , but if we could mitigate the need for taking medication we mitigate the probability of risk associated to the side effects of the medication .

Currently when the M Charles transits in exposed waters the skipper will set a weather course to keep the ship from really rocking around. This course is based on the swell and wind direction and is used to alleviate excessive ship motion and not based on the shortest distance to the destination. This prolongs the ships exposure to the swell albeit in a mitigative fashion, therefore exposing the ships crew to motion and therefore motion sickness. As well the ship tends to travel further distances on the weather course therefore burning more fuel and putting more engine hours on the vessel and increasing operation costs.

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Mike Crottey
Fishery Officer -A/Detachment Supervisor-MPP-South
Conservation and Protection| Conservation et Protection
Fisheries and Oceans Canada| Pêches et Océans Canada
304-60 Front Street | 304-60 rue Front
Nanaimo BC, V9R 5H7 | Nanaimo (C-B) V9R 5H7
Telephone | Téléphone: 250-754-0202
Cell |Cellulaire : [redacted]
Email :Michael.Crottey@dfo-mpo.gc.ca

s.16(2)

From: Wyse, David E [mailto:David.Wyse@dfo-mpo.gc.ca]
Sent: September-11-17 6:03 AM
To: Chaikin, Gabriel; Mkrtychan, Sergey; Couillard-Desjardins, Isabelle; Mercier, Jeffrey; Hart, Sarah; (corporalmclarenCO@mcl.ccgs-ngcc.gc.ca); A leblanc CO (aleblancCO@ccgs-ngcc.gc.ca); Carriere; carriere chief officer; CCGS-NGCC, Corporal Teather Commanding Officer (CorporalTeatherCO@ccgs-ngcc.gc.ca); G Peddle Captain; goddard-captain@god.ccgs-ngcc.gc.ca; Kaeble; CCGS M Charles - Captain; Private Robertson; private robertson chief officer; Teather chief officer; aleblancCE@ccgs-ngcc.gc.ca; Carriere 1st engineer; ConstableCarriereCE@ccgs-ngcc.gc.ca; CorporalMcLarenMMVCE. CCGS@dfo-mpo. gc. ca (CorporalMcLarenCE@MCL.ccgs-ngcc.gc.ca); CorporalTeatherCE@ccgs-ngcc.gc.ca; G Peddle Chief Engineer; Goddard-ChiefEngineer@GOD.ccgs-ngcc.gc.ca; KaebleCE@ccgs-ngcc.gc.ca; CCGS M Charles - Chief Engineer; PrivateRobertsonCE@ccgs-ngcc.gc.ca; Robertson 1st eng; Teather 1st eng
Subject: Stabilizers on Hero Class vessels

Good Morning all,

I just wanted to give an update on the stabilizer request for Hero Class. CCR 3103 is up for approval by the director board shortly. I have made another request to the RCMP and C&P head office points of contact for information on any lost program time due to lack of stabilizers and vessel rolling. If you have any of this information then send it along as I know this will help the case to install stabilizers. I have had a response from Great Lakes only stating that no program time has been lost due to lack of stabilizers and vessel rolling. Nothing from QC, Atlantic or Western.

Team Nav Arc has hired Damen to do a study to see if the stabilizers can be implemented on our vessels. I expect this study to be done at the end of this month. Engineering will have to be done after this and approved by the board of directors.

I have attached what the stabilizer unit installed on the Dutch Coast Guard vessel that I visited in June looks like from the inside.

Dave

David Wyse
Project Engineer | Mécanicien de Projet
Marine Engineering | Ingénierie Navale
Integrated Technical Services | Services Techniques Intégrés
Canadian Coast Guard | Garde Côtière Canadienne
200 Kent Street, Office 7W076, Mail Drop 7W064
Ottawa, ON, K1A 0E6
David.Wyse@dfo-mpo.gc.ca
Telephone | Téléphone 613-993-2710

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Wyse, David E

From: CCGS-NGCC, Caporal Kaeble Chef Mecanicien <kaebleCE@ccgs-ngcc.gc.ca>
Sent: Monday, September 11, 2017 1:15 PM
To: Wyse, David E
Subject: TR: Transférer : Faire suivre : Rép. : Fw: Hero Class vessel stabilizers **s.16(2)**

Dave,

Since you have had no response from Quebec, I did a partial survey on my ship. (I had no idea this was asked). These were the responses:

Replacement Captain: No real opinion [redacted]

Second nav officer: There have been two days this year where wind conditions have prevented the ship from moving (A team) read: non-operational.

And below is what the team leader for the RCMP sent his boss which I think is being sent to you.

Regards,

Sheldon

De : Pierre RICHER [mailto:Pierre.RICHER@rcmp-grc.gc.ca]
Envoyé : 11 septembre 2017 12:48
À : CCGS-NGCC, Caporal Kaeble Chef Mecanicien
Objet : Transférer : Faire suivre : Rép. : Fw: Hero Class vessel stabilizers

>>> Pierre RICHER 2017/09/11 10:50 >>>
Salut Hector,

J'ai regardé dans les fichiers de patrouilles des dernières années et j'ai noté approximativement 5 fois par saison où nous demeurons à quai à cause du mauvais temps. Ceci exclut aussi les jours de navigation que nous avons manqués pour profiter d'une fenêtre météo pour se rendre à destination. Je pense qu'il faut aussi prendre en considération que souvent nous prenons le large avec le KAEBLE en sachant que le trajet ne sera pas agréable. [redacted] Un autre point à considérer est celui de la mise à l'eau des Zodiacs lorsque la mer est agitée. Avec plus de stabilité du navire, celle-ci nous permettrait de larguer et de récupérer les Zodiacs beaucoup plus sécuritairement. [redacted] Une plus grande stabilité du navire serait appréciée par tout l'équipage et éviterait le mal de mer à répétition.

Pierre

>>> Hector Chiasson <Hector.Chiasson@rcmp-grc.gc.ca> 2017/09/11 08:40 >>>

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Bon matin Pierre, pour votre suivi à toi et JAB. Je sais que nous on est rester à quai une journée au mois d'août à cause du mauvais temps. Juste me fournir les infos svp. Merci.

Sent from my BlackBerry 10 smartphone on the Rogers network.

From: Wyse, David E <David.Wyse@dfo-mpo.gc.ca>
Sent: Monday, September 11, 2017 8:16 AM
To: Hector Chiasson; Stephen Thorne; Brent Napier; Emilie Plows; Jay Fulks; Judy Dwyer
Cc: G Peddle Chief Engineer
Subject: RE: Hero Class vessel stabilizers

Good morning all,
I just wanted to touch base to see if there has been any updates on the following request? I have heard from the Great Lakes so far that there is no documented program time lost due to lack of stabilization. I understand the G. Peddle has just experienced some rough seas while they were on program. The CCR will be going in front of the board approvers shortly.
Any information on program time lost due to sea sickness, inability to launch the RHIB or inability to board vessels due to the vessel rolling in rough seas would be helpful.
Thanks
Dave

From: Wyse, David E **s.21(1)(b)**
Sent: August-03-17 8:10 AM
To: Dwyer, Judy; Napier, Brent; Kent.Langley@rcmp-grc.gc.ca; Fulks, Jay; Hector.Chiasson@rcmp-grc.gc.ca; steve.thorne@rcmp-grc.gc.ca; Plows, Emilie
Subject: Hero Class vessel stabilizers
Good Morning all,
I have created a configuration change request (CCR 3103) to request engineering and implementation of stabilizers on the Hero Class vessels. This is a high priority for the CCG MSPV working group and vessels. But unfortunately since it is a big investment (I estimate around [redacted] CCG management will be looking for a good business case.
As discussed at the Partners User group workshop in Montreal, can the C&P and RCMP partners give me any documentation on program impact by not having stabilizers which would keep the vessel from rolling? Keep in mind there are different stabilizers, some stabilize the vessel only while underway and others might be able to stabilize while the vessel is idle and underway.
Any information on program time lost due to sea sickness, inability to launch the RHIB or inability to board vessels due to the vessel rolling in rough seas would be helpful.
Thank you
Dave

From: Mes, Marc
Sent: May-16-17 10:15 AM
To: Dwyer, Judy; Napier, Brent; Melanson, Simon; Donovan, Patrick; Kent.Langley@rcmp-grc.gc.ca; Fulks, Jay; Hector.Chiasson@rcmp-grc.gc.ca; steve.thorne@rcmp-grc.gc.ca; Wyse, David E
Subject: MSPV User Group Workshop Action Items
Good morning,
Attached is the list of action items developed following the national CCG/RCMP/C&P MSPV user-group workshop held on March 9, 2017 in Montreal.
Please let me know if you have any questions or concerns,
Marc

Bonjour,
La liste des mesures de suivi ci-jointe a été élaboré suite à l'atelier national du groupe d'utilisateurs des PSH du 9 mars 2017 à Montréal.
S.V.P. laissez-moi savoir si vous avez des questions ou des préoccupations,
Marc
Marc Mes

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Senior Director, Operational Support / Directeur principal, Soutien des operations
Canadian Coast Guard / Garde côtière canadienne
200 Kent Street, 6N144 / rue 200 Kent, 6N144
Ottawa, Ontario K1A 0E6
Tel:/Tél. : 613-990-0341
Cell. : s.16(2)
Fax./Téléc. : 613-995-4700
marc.mes@dfo-mpo.gc.ca

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Wyse, David E

From: Gregory Naugle <Gregory.Naugle@ccgs-ngcc.gc.ca>
Sent: Tuesday, September 12, 2017 7:25 PM
To: Wyse, David E
Subject: Re: Stabilizers on Hero Class vessels

Sounds Good Dave.

I'll see what we can round up. I know it's hard to get funding or progress without data to support the request.

Greg

Greg Naugle

s.16(2)
s.19(1)

On Tue, Sep 12, 2017 at 8:07 PM -0300, "Wyse, David E" <David.Wyse@dfo-mpo.gc.ca> wrote:

Hey [redacted]

If you don't mind. I heard back from most of the ships so far, but nothing from Atlantic region yet. I know you guys are getting the worst.

Thanks
Dave

Sent from my BlackBerry 10 smartphone on the Rogers network.

From: Gregory Naugle
Sent: Tuesday, September 12, 2017 4:42 PM
To: Wyse, David E
Subject: Re: Stabilizers on Hero Class vessels

Hi Dave,

I'm not sure if you have made regional contact with C&P in Dartmouth.

I know they keep a record of all their ship time, i.e. Time on patrol, boardings, anchor, weather bound in port, anchor, transit.

If you haven't heard from them I can try and contact Michael Grace here to see if we can get that data.

[redacted]

I [redacted] can email and phone to assist with this if necessary.

Regards,
Greg
[redacted]

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Greg Naugle

From: Wyse, David E [mailto:David.Wyse@dfo-mpo.gc.ca]
Sent: September 11, 2017 10:03 AM
To: Chaikin Gabriel; Mkrtychan, Sergey; Couillard-Desjardins Isabelle; Mercier Jeffrey; Hart Sarah; CCGS-NGCC, Corporal McLaren Captain; A leblanc CO (aleblancCO@ccgs-ngcc.gc.ca); Carriere; carriere chief officer; CCGS-NGCC, Corporal Teather Commanding Officer (CorporalTeatherCO@ccgs-ngcc.gc.ca); G Peddle Captain;goddard-captain@god.ccgs-ngcc.gc.ca; Kaeble; M Charles; Private Robertson; private robertson chief officer; Teather chief officer;aleblancCE@ccgs-ngcc.gc.ca; Carriere 1st engineer;ConstableCarriereCE@ccgs-ngcc.gc.ca; CCGS-NGCC, Corporal McLaren Chief Engineer;CorporalTeatherCE@ccgs-ngcc.gc.ca; G Peddle Chief Engineer;Goddard-ChiefEngineer@GOD.ccgs-ngcc.gc.ca;KaebleCE@ccgs-ngcc.gc.ca; mcharlesce@cha.ccgs-ngcc.gc.ca; PrivateRobertsonCE@ccgs-ngcc.gc.ca; Robertson 1st eng; Teather 1st eng
Subject: Stabilizers on Hero Class vessels

Good Morning all,

I just wanted to give an update on the stabilizer request for Hero Class. CCR 3103 is up for approval by the director board shortly. I have made another request to the RCMP and C&P head office points of contact for information on any lost program time due to lack of stabilizers and vessel rolling. If you have any of this information then send it along as I know this will help the case to install stabilizers. I have had a response from Great Lakes only stating that no program time has been lost due to lack of stabilizers and vessel rolling. Nothing from QC, Atlantic or Western.

Team Nav Arc has hired Damen to do a study to see if the stabilizers can be implemented on our vessels. I expect this study to be done at the end of this month. Engineering will have to be done after this and approved by the board of directors.

I have attached what the stabilizer unit installed on the Dutch Coast Guard vessel that I visited in June looks like from the inside.

Dave

David Wyse

Project Engineer | Mécanicien de Projet

Marine Engineering | Ingénierie Navale

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Integrated Technical Services | Services Techniques Intégrés

Canadian Coast Guard | Garde Côtière Canadienne

200 Kent Street, Office 7W076, Mail Drop 7W064

Ottawa, ON, K1A 0E6

David.Wyse@dfo-mpo.gc.ca

Telephone | Téléphone 613-993-2710

<What stabilizer looks like on inside of the Damen 4207 vessel.pdf>

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Wyse, David E

From: Wyse, David E
Sent: Wednesday, September 13, 2017 3:38 PM
To: Plows, Emilie
Subject: RE: Hero Class vessel stabilizers

Hey Emilie,

I received feedback from everyone except the Atlantic region – C&P and vessels and the Quebec – A. Leblanc C&P. I have a response from the Kaeble and the others already. Hoping to get the info by end of week?

Thanks
Dave

From: Plows, Emilie
Sent: September-13-17 9:02 AM
To: Wyse, David E
Subject: RE: Hero Class vessel stabilizers

Hi Dave,

Have you heard anything else on this issue? When is the deadline for a response?

Emilie Plows
A/Maritime Security Operations Analyst
Canadian Coast Guard / Government of Canada
emilie.plows@dfo-mpo.gc.ca / Tel: 613-998-8514

Analyste des opérations de la sûreté maritime p/i
Garde côtière canadienne / Gouvernement du Canada
emilie.plows@dfo-mpo.gc.ca / Tél : 613-998-8514

From: Wyse, David E
Sent: September-11-17 8:17 AM
To: Dwyer, Judy; Napier, Brent; Fulks, Jay; Hector.Chiasson@rcmp-grc.gc.ca; steve.thorne@rcmp-grc.gc.ca; Plows, Emilie
Cc: G Peddle Chief Engineer
Subject: RE: Hero Class vessel stabilizers

Good morning all,

I just wanted to touch base to see if there has been any updates on the following request? I have heard from the Great Lakes so far that there is no documented program time lost due to lack of stabilization. I understand the G. Peddle has just experienced some rough seas while they were on program. The CCR will be going in front of the board approvers shortly.

Any information on program time lost due to sea sickness, inability to launch the RHIB or inability to board vessels due to the vessel rolling in rough seas would be helpful.

Thanks

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Dave

From: Wyse, David E
Sent: August-03-17 8:10 AM
To: Dwyer, Judy; Napier, Brent; Kent.Langley@rcmp-grc.gc.ca; Fulks, Jay; Hector.Chiasson@rcmp-grc.gc.ca; steve.thorne@rcmp-grc.gc.ca; Plows, Emilie
Subject: Hero Class vessel stabilizers

s.21(1)(b)

Good Morning all,

I have created a configuration change request (CCR 3103) to request engineering and implementation of stabilizers on the Hero Class vessels. This is a high priority for the CCG MSPV working group and vessels. But unfortunately since it is a big investment (I estimate around [redacted] CCG management will be looking for a good business case.

As discussed at the Partners User group workshop in Montreal, can the C&P and RCMP partners give me any documentation on program impact by not having stabilizers which would keep the vessel from rolling? Keep in mind there are different stabilizers, some stabilize the vessel only while underway and others might be able to stabilize while the vessel is idle and underway.

Any information on program time lost due to sea sickness, inability to launch the RHIB or inability to board vessels due to the vessel rolling in rough seas would be helpful.

Thank you
Dave

From: Mes, Marc
Sent: May-16-17 10:15 AM
To: Dwyer, Judy; Napier, Brent; Melanson, Simon; Donovan, Patrick; Kent.Langley@rcmp-grc.gc.ca; Fulks, Jay; Hector.Chiasson@rcmp-grc.gc.ca; steve.thorne@rcmp-grc.gc.ca; Wyse, David E
Subject: MSPV User Group Workshop Action Items

Good morning,

Attached is the list of action items developed following the national CCG/RCMP/C&P MSPV user-group workshop held on March 9, 2017 in Montreal.

Please let me know if you have any questions or concerns,

Marc

Bonjour,

La liste des mesures de suivi ci-jointe a été élaboré suite à l'atelier national du groupe d'utilisateurs des PSH du 9 mars 2017 à Montréal.

S.V.P. laissez-moi savoir si vous avez des questions ou des préoccupations,

Marc

Marc Mes
Senior Director, Operational Support / Directeur principal, Soutien des operations

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Canadian Coast Guard / Garde côtière canadienne
200 Kent Street, 6N144 / rue 200 Kent, 6N144
Ottawa, Ontario K1A 0E6
Tel:/Tél. : 613-990-0341
Cell. : [redacted]
Fax./Téléc. : 613-995-4700
marc.mes@dfo-mpo.gc.ca

s.16(2)

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Wyse, David E

From: Hector Chiasson <Hector.Chiasson@rcmp-grc.gc.ca>
Sent: Thursday, September 14, 2017 11:23 AM
To: Wyse, David E
Subject: RE: Rép. : Hero Class vessel stabilizers **s.16(2)**

Thanks David, all the best leading this project. Talk soon.

HC

>>> "Wyse, David E" <David.Wyse@dfo-mpo.gc.ca> 2017/09/14 11:21 >>>
Great, thanks a lot Hector,

I will add this to responses for the CCR file. We will be going for approval tomorrow even though some engineering has already started. I will keep everyone posted.

Dave

From: Hector Chiasson [mailto:Hector.Chiasson@rcmp-grc.gc.ca]
Sent: September-14-17 10:49 AM
To: Wyse, David E
Cc: Jean-Alexandre Bouchard; Pierre RICHER; Stephen Thorne
Subject: Rép. : Hero Class vessel stabilizers

Good morning David, first I want to apologies for the delay in responding to your e-mail request. It is very good news to see that measures are being taken to improve the stability of those MSET Vessel. I have had the opportunity to patrol in the gulf of St. Lawrence and the rolling effect is very problematic.

With regard to your request regarding program lost. I have discussed with our officers that spend all their times on the ship and here is some of the comments that I received. Looking at the patrol files for the past few years, it shows that approximately 5 times per season where we are docked because of bad weather. This does not include navigation days that we had to stand down due to weather in order to get a window to travel to our next port. Because of the stability issues and rolling effects of the ship, often the crew knows in advance that the voyage they will undertake won't be pleasant, this create undue stress on everyone. Another point to consider is the launching of the Zodiacs when the sea is agitated. With more stability of the ship, it would allow us to launch and retrieve the Zodiacs much more safely. Greater stability of the ship would be appreciated by the entire crew and would avoid repeated seasickness.

Submitted for your information and follow up.

Yours truly,

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Serg. Hector Chiasson
G.R.C. / R.C.M.P.
S.O.R. Équipe Enquête Sûreté Maritime / NCO i/c Marine Security Enforcement Team
Coordonnateur / Coordinator
Programme de Surveillance Côtière et Aéroportuaire / Coastal & Airport Watch Program
(514) 420-5701 **s.16(2)**
Cell: [redacted] **s.21(1)(b)**
hector.chiasson@rcmp-grc.gc.ca
Devez-vous vraiment imprimer ce courriel? Pensons à l'environnement...
>>> "Wyse, David E" <David.Wyse@dfo-mpo.gc.ca> 2017/08/03 08:09 >>>
Good Morning all,
I have created a configuration change request (CCR 3103) to request engineering and implementation of stabilizers on the Hero Class vessels. This is a high priority for the CCG MSPV working group and vessels. But unfortunately since it is a big investment (I estimate around [redacted] CCG management will be looking for a good business case.
As discussed at the Partners User group workshop in Montreal, can the C&P and RCMP partners give me any documentation on program impact by not having stabilizers which would keep the vessel from rolling? Keep in mind there are different stabilizers, some stabilize the vessel only while underway and others might be able to stabilize while the vessel is idle and underway.
Any information on program time lost due to sea sickness, inability to launch the RHIB or inability to board vessels due to the vessel rolling in rough seas would be helpful.
Thank you
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From: Mes, Marc
Sent: May-16-17 10:15 AM
To: Dwyer, Judy; Napier, Brent; Melanson, Simon; Donovan, Patrick; Kent.Langley@rcmp-grc.gc.ca; Fulks, Jay; Hector.Chiasson@rcmp-grc.gc.ca; steve.thorne@rcmp-grc.gc.ca; Wyse, David E
Subject: MSPV User Group Workshop Action Items
Good morning,
Attached is the list of action items developed following the national CCG/RCMP/C&P MSPV user-group workshop held on March 9, 2017 in Montreal.
Please let me know if you have any questions or concerns,
Marc

Bonjour,
La liste des mesures de suivi ci-jointe a été élaboré suite à l'atelier national du groupe d'utilisateurs des PSH du 9 mars 2017 à Montréal.
S.V.P. laissez-moi savoir si vous avez des questions ou des préoccupations,
Marc

Marc Mes
Senior Director, Operational Support / Directeur principal, Soutien des operations
Canadian Coast Guard / Garde côtière canadienne
200 Kent Street, 6N144 / rue 200 Kent, 6N144
Ottawa, Ontario K1A 0E6
Tel:/Tél. : 613-990-0341
Cell. : [redacted]
Fax./Téléc. : 613-995-4700
marc.mes@dfo-mpo.gc.ca

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Wyse, David E

From: Gregory Naugle <Gregory.Naugle@ccgs-ngcc.gc.ca>
Sent: Friday, September 15, 2017 11:02 AM
To: Wyse, David E
Subject: Re: Stabilizers on Hero Class vessels

No problem.

Greg Naugle

On Fri, Sep 15, 2017 at 11:59 AM -0300, "Wyse, David E" <David.Wyse@dfo-mpo.gc.ca> wrote:

> This is great.
>
> Thanks a lot Greg.
>
> Dave

From: Gregory Naugle [mailto:Gregory.Naugle@ccgs-ngcc.gc.ca]
Sent: September-15-17 10:54 AM
To: Wyse, David E
Subject: FW: Stabilizers on Hero Class vessels

Good Morning Dave,

I'm not sure if all this helps or if its just too much information.
To sum it all up we lost 44.5% 112 of 252 days of allotted ship time in 2016/17 to weather.
In 2016/2017 87 days of those weather days were in seas less than 3m, which is inside the TSOR operational envelope.
In the previous year they lost 133 days to weather of which 107 days of that was under 3m seas.

You can see the report below I was given by Michael Grace who is in charge of the OSO branch in Dartmouth which is just one of our DFO clients, but this is the branch that we have the most weather related problems with due to the area of operations being the East Coast and not in the Gulf of St. Lawrence or other sheltered waters like the Labrador Coast.

Also I will reiterate Mr. Grace in that the 2016/17 report is still draft as it has not been approved by Ottawa.

I hope this helps. If I can get anything else for you please do not hesitate to ask.

Regards,

Greg

From: Grace, Michael [Michael.Grace@dfo-mpo.gc.ca]
Sent: Friday, September 15, 2017 8:58 AM
To: Gregory Naugle
Cc: Lalonde Christena; Parsons Derreck
Subject: RE: Stabilizers on Hero Class vessels

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Greg extracts from C&P reports on Program delivery in relation to SLA. The 2015-16 report has been shared with CCG. The 2016-17 report still requires my Director's approval and CCG needs to be consulted prior to finalization. As well, it is understood that sea state and wind do not always have a direct relationship – table 1 is meant to document typical conditions. Weather conditions we either direct observations as recorded in ships log and/or marine Forecasts recorded by FO's where a PV was in port. I hope this information is helpful and please do not hesitate to contact me if I can be of further assistance.

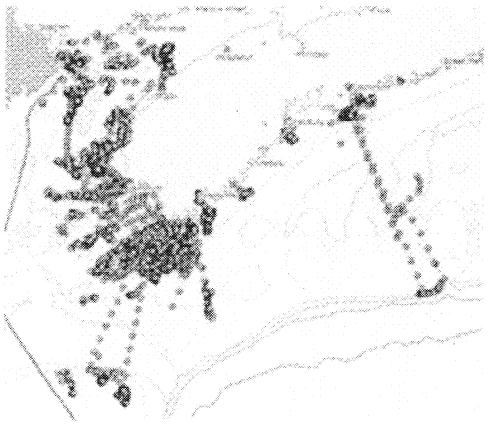
FYI – I have cc'ed Christena Lalonde as she is the staff officer at NHQ for large platforms and is C&P;s CCG contact in respect of large platforms.

2015-16 report – sharhed with CCG

Table 1: Anchored/ In Port Days and reported wind speeds /Sea state conditions (total 133.7 Days)

	≤ 20 knots		20 to 30 knots		30 to 35 knots		> 35 knots	
	Days	%	Days	%	Days	%	Days	%
	60.3	45	47.16	35.3	11.9	9	14.3	10.7
Sea State	.5 to 2 m		2 to 3 meters		3 meters		3+ meters	

Graphic 1: VMS depicting December 2, 2015 fishing activity



Several examples exist where the MSPV was "all fast" in port (e.g. Shelburne) as per Captain's direction due to weather while significant on water activity is taking place offshore. The graphic to the left, taken from Vessel Monitoring System Data (VMS) depicts fishing vessel activity from 0600 to 2359 on December 2, 2015 – 0600.

The Marine Weather forecast was: Winds Southerly 15 kts increasing to Southeast 20-25 kts in morning, veering to Southwest 20-25 kts. in afternoon, diminishing to Southwest 15 kts in evening, increasing to Southwest 25 kts overnight with 1 -2 meters seas. Unfortunately the MSPV was limited in ability to operate during the resulting conditions at sea.

s.16(2)

Graphic 2: Highlight of Fishing Activity versus Patrol Coverage
(DFO Science Data for Fishing Activity, VMS Overlay MSPV Activity)

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s.16(2)

- Red solid borders define Maritimes region area of responsibility.
- Yellow dotted line identifies the proposed 120 mile operational range of MSPV's, the blue dots are where the MSPV's conducted patrols.
- Red box is the East/West SAR restricted area.
- Green and the small red coloured areas display highest concentrations of fishing activity for the last 10 years. Progression is green being concentrated and red, highly concentrated.

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Graphic 3, VMS Data:

April, 2015 – September, 2015

Graphic 4, VMS Data:

October, 2015 - March, 2016

[redacted]

Graphics 3 &4 depict the areas where the MSPV patrolled from April 1 to Sept. 30, 2015 and October 1, 2015 to March 31, 2016. Orange identifies fishing activity and the black lines are the MSPV's tracks / patrol positions as reported by VMS. The red line represents the 200 nm limit. [redacted]

s.16(2)

[redacted]

Table 1: Anchored/ In Port Days and reported wind speeds /Sea state conditions (total 112.17 Days)

≤ 20 knots		20 to 30 knots		30 to 35 knots		> 35 knots	
Days	%	Days	%	Days	%	Days	%
31.14	27.76	56.7	50.54	13.8	12.32	10.53	9.38

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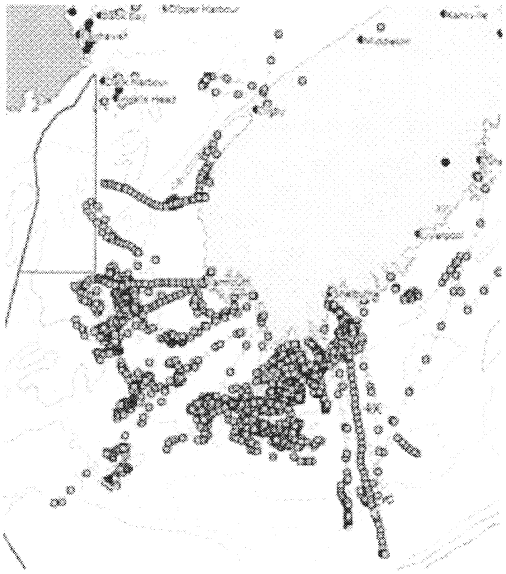
Sea State	.5 to 2 m	2 to 3 meters	3 meters	3+ meters

Graphic 1: VMS depicting November 30, 2016 fishing activity



Several examples exist where the MSPV was "all fast" in port (e.g. Shelburne) as per Captain's direction due to weather while significant on water activity is taking place offshore. The graphic to the left, taken from Vessel Monitoring System Data (VMS) depicts fishing vessel activity from 0001 to 2359 on November 30, 2016.

The Marine Weather forecast was: Winds Northeast 15 -25 kts. Unfortunately the MSPV was limited in ability to operate during the resulting conditions at sea. [redacted] Orange identifies fishing activity, the yellow line is the 50 nm boundary and the red line represents "The Hague" line.

s.16(2)

Graphic 2: Highlight of patrol Coverage versus 50 & 120 nm Boundaries

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s.16(2)

The VMS charting application (VUE) was utilized to calculate the area of responsibility and the MSPV operational area based on an operational range of 120 nautical miles (blue boundary). Fishing activity and the areas where MSPV's operated in the Maritimes for fiscal year 2016-17 were plotted. The square kilometers patrolled and the range of patrol activities were calculated based on VUE plots (VMS charting application). The red & green tracks represent MSPV activity, the yellow line is the 50 nm boundary, the blue line the 120 nm boundary and the outlaying red line represents "The Hague Line " / 200 mile boundary.

Graphic 3: Highlight of 10 Year Historical Fishing Activity versus Patrol Coverage
(DFO Oceans Data for Fishing Activity, VMS Overlay MSPV Activity)

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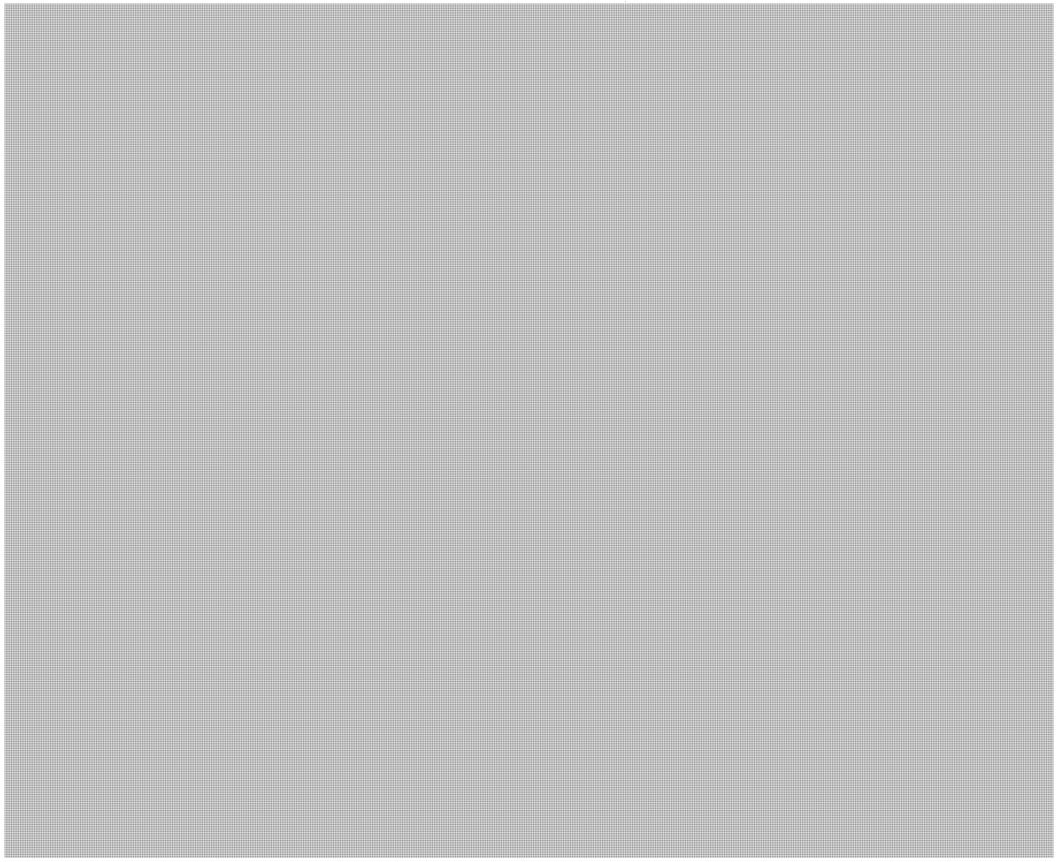

s.16(2)

- Red solid borders define Maritimes region area of responsibility and international boundaries.
- Yellow dotted line identifies the 120 mile operational range of MSPV's, the blue dots are where the MSPV's conducted patrols.
- Red box is the East/West SAR restricted area.
- Green and the small red coloured areas display highest concentrations of fishing activity for the last 10 years. Progression is green, yellow with red being highly concentrated.
- Activity within the SAR restricted area has historically declined

Graphic 4, VMS Data:

April 1, 2016 – June 30, 2016

Graphic 5, VMS Data:

July 1, 2016 – Sept. 30, 2016

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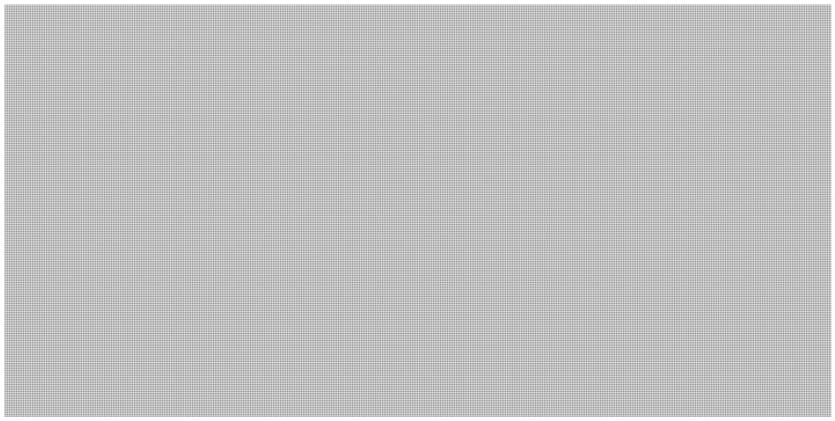

Graphics 4 & 5 depict the areas where the MSPV patrolled from April 1 to June 30, 2016 and July 1, 2016 to Sept. 30, 2016. Orange identifies fishing activity and the black/red/ lines are the MSPV's tracks / patrol positions as reported by VMS. The red line represents the 200 nm limit, the blue line a 120 nm boundary and the yellow line a 50 nm mile boundary.

s.16(2)

Graphic 6, VMS Data:
Oct. 1, 2016 – Dec. 31, 2016

Graphic 7, VMS Data:
Jan. 1, 2017 – March. 31, 2017

Graphics 6 & 7 depict the areas where the MSPV patrolled from Oct. 1, 2016 to Dec. 31, 2016 and Jan. 1 to March 31, 2107. These graphics depict activities in the same manner as in Graphics 4& 5.

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Where a platform was program operational, patrol took place [redacted] of the days from April 1 to September 30 and [redacted] of the days from October 1, 2016 to March 31, 2017. Respectively, patrol did not take place due to weather [redacted] and [redacted] of the days. There was a significant increase in loss of patrol time [redacted] due to weather from January 1 to March 31, 2017. (Appendix H) It is noteworthy that significant portions of the patrol effort achieved from October 1, 2016 to March 31, 2017 [redacted] (Graphics 6 & 7)

[redacted]

Appendix H – Program Delivery by Quarter

Period	Program Operational	Patrolled	Weather	C&P Port	CCG Turnaround
April 1 - June 30, 2016	78.85	[redacted]	29.89 (37.9%)	2.82	4.27
July 1 - Sept. 30, 2016	44.27		10.73 (24.2%)	1.79	2.08
Oct. 1 - Dec. 31, 2016	71.37		35.24 (49.3%)	3.17	6.48
Jan. 1 - March 31, 2017	57.41		36.31 (63.2%)	0.78	5.13
Total	**251.9**		**112.17 (44.5%)**	**8.56**	**17.96**

s.16(2)

From: Gregory Naugle [mailto:Gregory.Naugle@ccgs-ngcc.gc.ca]
Sent: September-13-17 10:29 AM
To: Grace, Michael
Subject: Fwd: Stabilizers on Hero Class vessels

Good Morning Mike,

I am wondering if you would be able to assist me with some data for the proposal to install stabilization systems on the MSPV's.

I was contacted by Dave Wyse our national project manager for the vessels and he was unable to get any information from Atlantic region.

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I know that the Fishery Officer's normally record all their program time, whether they are working or delayed. I do not know if that break down is kept on file and if you have a total amount of ship time booked versus received and how much of that ship time was actually used for work and how much we lost to weather or other issues.

If you keep this data on file would it be possible to have access to it, or be provided with some statistics that we can provide Ottawa. The more important one would be the amount of program time compared to the number of ships days you received.

As we do not really record this on the vessels as weather delays do not make a big difference on our end, any data you or your Fishery Officers could supply would be greatly appreciated. It will go towards helping the case to get a stabilization system installed on the vessels to hopefully decrease lost program time and make the vessels more useful to your department, our client.

I [redacted] can be reached via email or my cell at [redacted]

s.19(1)

Thank you,
Greg

Greg Naugle
Commanding Officer
CCGS Corporal McLaren M.M.V.

On Sep 11, 2017, at 4:15 PM, CCGS-NGCC, Corporal McLaren Captain <CorporalMcLarenCO@mcl.ccgs-ngcc.gc.ca> wrote:

> FYI
>
> ---
>
> **From:** Wyse, David E [mailto:David.Wyse@dfo-mpo.gc.ca]
> **Sent:** September 11, 2017 10:03 AM
> **To:** Chaikin Gabriel; Mkrtychan, Sergey; Couillard-Desjardins Isabelle; Mercier Jeffrey; Hart Sarah; CCGS-NGCC, Corporal McLaren Captain; A leblanc CO (aleblancCO@ccgs-ngcc.gc.ca); Carriere; carriere chief officer; CCGS-NGCC, Corporal Teather Commanding Officer (CorporalTeatherCO@ccgs-ngcc.gc.ca); G Peddle Captain;goddard-captain@god.ccgs-ngcc.gc.ca; Kaeble; M Charles; Private Robertson; private robertson chief officer; Teather chief officer;aleblancCE@ccgs-ngcc.gc.ca; Carriere 1st engineer;ConstableCarriereCE@ccgs-ngcc.gc.ca; CCGS-NGCC, Corporal McLaren Chief Engineer;CorporalTeatherCE@ccgs-ngcc.gc.ca; G Peddle Chief Engineer;Goddard-ChiefEngineer@GOD.ccgs-ngcc.gc.ca;KaebleCE@ccgs-ngcc.gc.ca; mcharlesce@cha.ccgs-ngcc.gc.ca; PrivateRobertsonCE@ccgs-ngcc.gc.ca; Robertson 1st eng; Teather 1st eng
> **Subject:** Stabilizers on Hero Class vessels
>
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>
> I just wanted to give an update on the stabilizer request for Hero Class. CCR 3103 is up for approval by the director board shortly. I have made another request to the RCMP and C&P head office points of contact for information on any lost program time due to lack of stabilizers and vessel rolling. If you have any of this information then send it along as I know this will help the case to install stabilizers. I have had a response from Great Lakes only stating that no program time has been lost due to lack of stabilizers and vessel rolling. Nothing from QC, Atlantic or Western.

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Team Nav Arc has hired Damen to do a study to see if the stabilizers can be implemented on our vessels. I expect this study to be done at the end of this month. Engineering will have to be done after this and approved by the board of directors.

I have attached what the stabilizer unit installed on the Dutch Coast Guard vessel that I visited in June looks like from the inside.

Dave

David Wyse
Project Engineer | Mécanicien de Projet
Marine Engineering | Ingénierie Navale
Integrated Technical Services | Services Techniques Intégrés
Canadian Coast Guard | Garde Côtière Canadienne
200 Kent Street, Office 7W076, Mail Drop 7W064
Ottawa, ON, K1A 0E6
David.Wyse@dfo-mpo.gc.ca
Telephone | Téléphone 613-993-2710

<What stabilizer looks like on inside of the Damen 4207 vessel.pdf>

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Wyse, David E

From: CCGS-NGCC, Caporal Kaeble Commandant <kaebleCO@ccgs-ngcc.gc.ca>
Sent: Friday, September 22, 2017 3:41 PM
To: Wyse, David E
Cc: CCGS-NGCC, Caporal Kaeble Chef Mecanicien
Subject: RE: Stabilizers on Hero Class vessels

Bonjour Dave,

C'est très difficile d'estimer le nombre de jours d'opérations perdus à cause des conditions de mer. Nous étudions les prévisions à court et moyen terme et adaptons notre programme et nos transits en conséquence. Depuis deux étés que je suis à bord, je suis peut-être resté « caché » 5 jours, mais probablement que nous ne serions pas sortis même avec des stabilisateurs !
Cela dit, je suis tout de même très en faveur de la pose de stabilisateurs. J'ai navigué un été sur le Frederick G Creed et ses stabilisateurs sont extrêmement efficaces (bien que ce soit un type de navire complètement différent). Ce serait une grande amélioration pour la sécurité du personnel, sans compter la qualité de vie.

Merci et bonne fin de semaine !

François Lanouette s.16(2)
Commandant, Équipe B | Commanding officer, B Crew
NGCC Caporal Kaeble V.C. | CCGS Caporal Kaeble V.C.
Garde côtière canadienne | Canadian Coast Guard
Navire | Ship: [redacted]
Cell: [redacted]
Email: kaebleco@ccgs-ngcc.gc.ca

De : Wyse, David E [mailto:David.Wyse@dfo-mpo.gc.ca]
Envoyé : 11 septembre 2017 09:03
À : Chaikin Gabriel; Mkrtychan Sergey; Couillard-Desjardins Isabelle; Mercier Jeffrey; Hart Sarah; (corporalmclarenCO@mcl.ccgs-ngcc.gc.ca); CCGS-NGCC, Aleblanc Commandant; CCGS-NGCC, Constable Carriere Commanding Officer; CCGS-NGCC, Constable Carriere Chief Officer; CCGS-NGCC, Corporal Teather Commanding Officer; G Peddle Captain; goddard-captain@god.ccgs-ngcc.gc.ca; CCGS-NGCC, Caporal Kaeble Commandant; M Charles; CCGS-NGCC, Private Robertson Commanding Officer; CCGS-NGCC, Private Robertson Chief Officer; CCGS-NGCC, Corporal Teather Chief Officer; CCGS-NGCC, ALeblanc Chef Mecanicien; CCGS-NGCC, Constable Carriere Engine Room; CCGS-NGCC, Constable Carriere Chief Engineer; CorporalMcLarenMMVCE. CCGS@dfo-mpo. gc. ca (CorporalMcLarenCE@MCL.ccgs-ngcc.gc.ca); CCGS-NGCC, Corporal Teather Chief Engineer; G Peddle Chief Engineer; Goddard-ChiefEngineer@GOD.ccgs-ngcc.gc.ca; CCGS-NGCC, Caporal Kaeble Chef Mecanicien; mcharlesce@cha.ccgs-ngcc.gc.ca; CCGS-NGCC, Private Robertson Chief Engineer; CCGS-NGCC, Private Roberston Engine Room; CCGS-NGCC, Corporal Teather Engine Room
Objet : Stabilizers on Hero Class vessels

Good Morning all,

I just wanted to give an update on the stabilizer request for Hero Class. CCR 3103 is up for approval by the director board shortly. I have made another request to the RCMP and C&P head office points of contact for information on any lost program time due to lack of stabilizers and vessel rolling. If you have any of this information then send it along as I know this will help the case to install stabilizers. I have had a response from Great Lakes only stating that no program time has been lost due to lack of stabilizers and vessel rolling. Nothing from QC, Atlantic or Western.

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Team Nav Arc has hired Damen to do a study to see if the stabilizers can be implemented on our vessels. I expect this study to be done at the end of this month. Engineering will have to be done after this and approved by the board of directors.

I have attached what the stabilizer unit installed on the Dutch Coast Guard vessel that I visited in June looks like from the inside.

Dave

David Wyse
Project Engineer | Mécanicien de Projet
Marine Engineering | Ingénierie Navale
Integrated Technical Services | Services Techniques Intégrés
Canadian Coast Guard | Garde Côtière Canadienne
200 Kent Street, Office 7W076, Mail Drop 7W064
Ottawa, ON, K1A 0E6
David.Wyse@dfo-mpo.gc.ca
Telephone | Téléphone 613-993-2710

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Wyse, David E

From: Ivany, Gary
Sent: Tuesday, October 3, 2017 7:08 PM
To: Clarke, Tracey
Cc: Harvey, Clifford; Sekerka, Anne Marie; Garcia-Villaveces, Lina Sofia; Wyse, David E
Subject: Re: MSPV Stabilizers

Thanks Tracey. Much appreciated

Gary

Sent from my BlackBerry 10 smartphone on the Rogers network.

From: Clarke, Tracey
Sent: Tuesday, October 3, 2017 1:52 PM
To: Ivany, Gary
Cc: Harvey, Clifford; Sekerka, Anne Marie; Garcia-Villaveces, Lina Sofia; Wyse, David E
Subject: RE: MSPV Stabilizers

Gary,

Concerning stabilizers, the status of the work we are doing is the follows:

We have a contract in place with Damen to do a seakeeping analysis of the MSPV with various types of stabilizer systems. Damen did the original seakeeping analysis that was delivered with the vessels and we want to make sure we have the same baseline for comparison purposes. Entry into this contract was delayed due to issues working through the system with DFO Contracting and then, once we had the contract in place, the OPI went on vacation. But they are actively working on it now. I have asked Damen for an update as to when we can expect to see a report.

The next step, we plan a contract to have a company physically look at the vessel for the feasibility of installing a system, particularly an active stabilization system. And active system will require internal space to accommodate the hydraulic and mechanical systems.

One system that's been put forward to us as a preferred option by the operators is a Zero Speed system that is reported to work while the vessel is stopped – we note that this system appears likely to add about 1.2 tonnes to the vessel. Any active system is likely to have a similar weight impact.

Aside from the internal space required for the associated equipment, and the envelopes needed for maintenance and possible encroachment on other systems / spaces and any potential impacts that may be determined, there is the issue of the additional weight. These vessels have a load line restriction that limits future weight growth, and 1+ tonnes for a single engineering change will have a major impact on that.

Marine Engineering did an assessment to determine if there was the potential to relax the load line restriction and it was found that damage stability compliance was the limiting criteria. Marine Engineering proposed to Operations that the through life growth margin could be changed from 4 tonnes to 10.5 tonnes – but this would mean that the vessel would not comply with the Passenger Vessel standard for Damage Stability. In the worst condition, the margin line would be submerged at the transom – although water would not be on the deck. It was shown that the vessel would still comply with other international standards for damage stability – but not the Passenger Vessel standard.

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Although it was tabled that there is no regulatory requirement for the MSPV to comply with any damage stability standard, this was an Owner's requirement for this project.

The results of the discussions with Operations last year were that they (Ops) were not willing to relax the requirement to meet the Damage Stability standard for Passenger Vessels and no change to the load line was authorized.

It appears that an approval for an active stabilization system for the MSPVs will require something to give.

With the analysis that we're doing, we aim to provide all of the benefits that the various types of stabilizers will bring to this class of vessels (including better seakeeping for operations and overall safety) so that they can be considered along with the costs (not just monetary, but space, weight, reduction of damage stability capacity).

Hopefully this gives a sufficient overview of the work we are doing.

Tracey

From: Clarke, Tracey
Sent: Tuesday, October 3, 2017 11:09 AM
To: Ivany, Gary (Gary.Ivany@dfo-mpo.gc.ca) <Gary.Ivany@dfo-mpo.gc.ca>
Cc: Harvey, Clifford <Clifford.Harvey@dfo-mpo.gc.ca>; Sekerka, Anne Marie <Anne-Marie.Sekerka@dfo-mpo.gc.ca>
Subject: MSPV Stabilizers

Gary,

Do you have time to discuss this today before you go to the MSPV meeting?

Tracey

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Wyse, David E

From: Molokopoy, Vitaliy
Sent: Friday, October 6, 2017 10:08 AM
To: Richardson, John; Wyse, David E; Falconer, William; Garcia-Villaveces, Lina Sofia; Kozarski, Vladan
Subject: RE: MSPV Question FW: Stabilizers Contract

My comments below

Vitaliy

From: Richardson, John
Sent: October-06-17 9:34 AM
To: Wyse, David E; Molokopoy, Vitaliy; Falconer, William; Garcia-Villaveces, Lina Sofia; Kozarski, Vladan
Subject: MSPV Question FW: Stabilizers Contract

All,

I am providing some information on the MSPVs to Vladan with regard to the stabilizers. Please advise if I have misspoken.

Could you please also let me know what power supply there is on board (frequency and voltage).

There is 600V, 230V, and 115V power distribution @ 60Hz
Correct. Most probably, the stabilizers should be wired to 600V, 3ph, 60Hz

Also a question from them if zero-speed stabilising can be done using the main engines for power (as opposed to using the generator).

Not quite clear on the question. The main engines are not fitted with alternators so they would not be able to provide electrical power. They do provide hydraulic power via PTO driven hydraulic pumps.
Agree, the question is not clear. Might be also somehow related to automatic retraction at zero-speed. From what I know, these stabilizers should automatically retract back in ship's hull when ship's speed drops to a certain value. Assumption is made that ship is approaching a dock and this is a precaution to prevent the damage to stabilizing fins in case of human error (operator can forget to retract them).

From: Kozarski, Vladan
Sent: 2017–October-06 8:40 AM
To: Richardson, John
Subject: FW: Stabilizers Contract

John,

Below is the e-mail from Damen. Questions are highlighted.

Thanks.

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Vladan.

From: [redacted]
Sent: Friday, October 06, 2017 4:30 AM
To: Kozarski, Vladan
Cc: Clarke, Tracey
Subject: RE: Stabilizers Contract

s.19(1)

Hi Vladan,

[redacted] I will finish the input next week. Here an update :

I want to mention the following points:
I took the quantum normal Stabilizers equal to those that are already installed on other 4207's.
Quantum gave preliminary numbers for the Pseries and is working on a more detailed fin. However they called me yesterday and said they need to make sure the vessels do not qualify as military. Can you confirm that your 4207s are not, based on the second page of the pdf I included (ITAR section).
Could you please also let me know what power supply there is on board (frequency and voltage).
Also a question from them if zero-speed stabilising can be done using the main engines for power (as opposed to using the generator). This is more stuff [redacted] will look into, but it may have a small influence on the capability of the fin. The answer shouldn't influence the fin much for this calculation.

Regarding the deck wetness, I advise to use the top of the bulwark instead of deck level, despite the holes in the bulwark. These holes will allow the deck to get wet, but the deck will be wet anyway due to spray in those conditions. The far more undesirable green water events will take place when the bulwark is submerged in a wave.

There are no other 4207s with bilge keels as far as I know, so I designed a bilge keel according to our standard practices.

[redacted]

Best regards, [redacted]

[redacted]
-------- Original message --------
From: "Kozarski, Vladan" <Vladan.Kozarski@dfo-mpo.gc.ca>
Date: 10/3/17 20:37 (GMT+01:00)
To: [redacted]
Cc: "Clarke, Tracey" <Tracey.Clarke@dfo-mpo.gc.ca>
Subject: RE: Stabilizers Contract

Hi [redacted]

[redacted]

Please let me know when you have something ready. [redacted]

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Regards.

Vladan.

From: [redacted]
Sent: Friday, September 29, 2017 3:18 PM
To: Kozarski, Vladan
Subject: RE: Stabilizers Contract

s.19(1)

Hi Vladan,

[redacted]

I spent a day at MARIN this week to create the model for the zero speed Stabilizers. I finished that, so it is now ready to run.

I also spent an hour there working on the wave spreading tool, but we still did not get it to work. I also don't quite agree with the method they propose, but time was limited so we will continue next week.

Hopefully I will have all the parameters next week, which I then want to discuss with you prior to running the analyses to check if you agree with the designs.

Enjoy the weekend.

Best regards, [redacted]

[redacted]
-------- Original message --------
From: "Kozarski, Vladan" <Vladan.Kozarski@dfo-mpo.gc.ca>
Date: 9/28/17 17:42 (GMT+01:00)
To: [redacted]
Subject: RE: Stabilizers Contract

[redacted]

[redacted] How is the stabilizers story progressing?

Regards.

Vladan.

From: [redacted]
Sent: Friday, September 01, 2017 8:32 AM
To: Kozarski, Vladan
Subject: Automatisch antwoord: Stabilizers Contract

Dear Reader,

Thank you for your e-mail.

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I will be out of office

For structures related matters, please contact

For other matters, please contact

Best regards,

s.19(1)

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Wyse, David E

From: Kozarski, Vladan
Sent: Friday, October 6, 2017 10:32 AM
To: Wyse, David E
Cc: Clarke, Tracey; [redacted]
Subject: FW: Stabilizers Contract

Dave,

We got two questions from Damen related to electric power supply and main engine power supply on MSPV's. They are highlighted in the e-mail below. You got this already from John. We got answer on the first one, and would appreciate if you can get more info on the second one.

You can respond to Tracey, or directly to [redacted] Damen.

s.19(1)

Thanks.

Vladan.

From: [redacted]
Sent: Friday, October 06, 2017 4:30 AM
To: Kozarski, Vladan
Cc: Clarke, Tracey
Subject: RE: Stabilizers Contract

Hi Vladan,

[redacted] I will finish the input next week. Here an update :

I want to mention the following points:
I took the quantum normal Stabilizers equal to those that are already installed on other 4207's.
Quantum gave preliminary numbers for the Pseries and is working on a more detailed fin. However they called me yesterday and said they need to make sure the vessels do not qualify as military. Can you confirm that your 4207s are not, based on the second page of the pdf I included (ITAR section).
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There are no other 4207s with bilge keels as far as I know, so I designed a bilge keel according to our standard practices.

[redacted]

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Best regards,

s.19(1)

-------- Original message --------
From: "Kozarski, Vladan" <Vladan.Kozarski@dfo-mpo.gc.ca>
Date: 10/3/17 20:37 (GMT+01:00)
To:
Cc: "Clarke, Tracey" <Tracey.Clarke@dfo-mpo.gc.ca>
Subject: RE: Stabilizers Contract

Hi

Please let me know when you have something ready.

Regards.

Vladan.

From:
Sent: Friday, September 29, 2017 3:18 PM
To: Kozarski, Vladan
Subject: RE: Stabilizers Contract

Hi Vladan,

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I also spent an hour there working on the wave spreading tool, but we still did not get it to work. I also don't quite agree with the method they propose, but time was limited so we will continue next week.

Hopefully I will have all the parameters next week, which I then want to discuss with you prior to running the analyses to check if you agree with the designs.

Enjoy the weekend.

Best regards,

-------- Original message --------
From: "Kozarski, Vladan" <Vladan.Kozarski@dfo-mpo.gc.ca>

Document Released Under the Access to Information Act / Document divulgué en vertu de la Loi sur l'accès à l'information.

Date: 9/28/17 17:42 (GMT+01:00)
To: [redacted]
Subject: RE: Stabilizers Contract

s.19(1)

[redacted]

[redacted] How is the stabilizers story progressing?

Regards.

Vladan.

From: [redacted]
Sent: Friday, September 01, 2017 8:32 AM
To: Kozarski, Vladan
Subject: Automatisch antwoord: Stabilizers Contract

Dear Reader,

Thank you for your e-mail.

I will be out of office [redacted]

For structures related matters, please contact [redacted]

For other matters, please contact [redacted]

Best regards,

[redacted]

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Configuration Change Request (CCR)

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1. Identification

CCR Number	2017-3103	Originator	David Wyse	☎	9932710	Date	2017-07-27
		Contact		☎		Region	NCR
		Contact		☎			

CCR Title	Hero Class stabilizers	AMS W.O.#:	
Equipment		ABS #:	15E
System	Auxiliary Systems	Asset Title:	
Drawings and/or specification affected			

Type of work	☑ HME	☐ E & I	☐ MCI	☐ S / ER

2. Category

Priority		Description
Normal	☑	The proposed configuration change is justified, but not urgent or high priority.
High	☐	A solution to an operational or technical problem must be determined and implemented within three months.
Urgent	☐	Affects safety or the ability to conduct operations and must be implemented immediately.

Scope:	☐ Minor	☐ Major	☑ Major National	Description: Form, Fit Function

3. Proposed Configuration Change (Add attachment as required to explain the situation in detail)

EXISTING CONDITIONS: Item affected. Identify contracts, systems, subsystems and when possible, contract and items or components affected by change.

The parent Hero Class design vessels are delivered with stabilizers. The Hero Class vessels do not have stabilizers installed. All vessel operators agree the Hero Class vessels require stabilizers in all areas of operation. Program and operations can suffer do the fact that the vessels have extreme roll in high sea state conditions.

RECOMMENDED SOLUTION: Describe hardware or software modification, and / or recommended study to correct the problem or to capitalize on an improvement opportunity. Rough sketches or diagrams may be attached to amplify this description. Enter rough cost estimate for the project.

Phase 1 - Engineering and feasibility study

Phase 2 - implementation after approval of phase 1

ANTICIPATED BENEFITS : How change will improve systems, e.g. reliability, reduced weight, decreased cost, substantially improved performance.

Vessels will be more stable for program and operations in high sea state conditions.

IMPACT ON MAINTENANCE BUDGET :	Yes ☐	No ☐	IMPACT ON OPERATIONAL BUDGET:	Yes ☐	No ☐

Impact of not implementing change e.g. safety hazard, mission failure, high maintenance costs, schedule slippage. Explain relative desirability of each alternative way to meet need for change.

Without stabilizers there is an increased hazard of crew injuries and program failures.

PRELIMINARY Estimated Cost by Fiscal Year			Total Estimated Cost
FY:	FY + 1	FY + 2	(attach sheet with details)

Total Cost includes : Purchase, fabrication, installation, training, updated drawings and publications, etc.

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Configuration Change Request (CCR)

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4. CCR Impact Assessment Checklist

Step 1		If impact applies, select (☑) for each item selected, attach file containing supporting details or AMS W.O. number related.
Step 2		To close CCR , (See Section 10) Verify that the action required to address impact was completed and attach the file containing supporting details or AMS W.O. # related.
#	1	Will Change have an impact on: (Give a brief description in an attached file.)
1	☒	Safety, health, habitability and human factors.
2	☒	Operational capacity, performance, and/or reliability.
3	☐	Compliance with laws/regulations and security requirements.
4	☒	Ship Stability, changes requirements - weight added and removed (Refer to standard operating procedure). TBD
5	☐	Other similar systems or interfaces with other systems.
6	☐	Real property.
7	☐	Environment.
8	☐	Other configuration changes that have been proposed or approved.
9	☒	Electrical power requirement; Electromagnetic compatibility; Equipment removal routes; HVAC and cooling.
10	☐	Existing inspections, tests and/or trials.
11	☐	IT Security: Seek Regional or National IT Security Coordinator advice where change could potentially compromise IT security. Arrange for action required (e.g. Risk Assessment, supporting documentation, etc) to maintain IT system security.
12	☒	Operations and Maintenance costs.
13	☐	Software.
14	☒	Procurement : Procure as necessary: Modification kits; Spares, repair parts and consumables; Special tools; Test equipment; and Diagnostic software.
15	☐	Existing inventory : Locate and modify all affected spares held in inventory.
16	☐	Disposal : Locate and purge all equipment and parts that are no longer required.
17	☒	Technical Data : Revise the affected drawing indices, drawings and parts lists. Affected Drawing(s) #:
18	☒	Amend the operating manuals and maintenance manuals affected by the modification.
19	☒	Update the maintenance requirements to be consistent with the revised configuration.
20	☒	Training : Update the training of personnel to reflect the modified equipment, including the revision of training
21	☐	Facilities : Modify / renovate facilities as necessary, including installation requirements such as space, power, air conditioning, lighting, etc.
22	☐	AMS: Update the asset structure in the Asset Management System, identifying new maintenance items.
23	☐	CM File: Place all documents pertaining to modification approval in the modification documentation file and retain for reference.
24	☐	

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Configuration Change Request (CCR)

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5.0 Unit / Originator Signatures

Once CCR is completed section 1 to 4, Originator signed here. In case of double crew vessels, space is available for concurrence by both Commanding Officers and Chief Engineers. Then transmit to Regional Office for evaluation.

1A	David Wyse	Wyse, David Digitally signed by Wyse, David DN: c=CA, o=GC, ou=DFO-MPO, cn=Wyse, David Date: 2017.07.27 11:07:47 -04'00'	LCM, Hero Class	2017-07-27
	Name	Signature	Title	Date
1B				
	Name	Signature	Title	Date
2A				
	Name	Signature	Title	Date
2B				
	Name	Signature	Title	Date

5.1 Final Verification (For ships only)

CCR is well completed all the information has been verified, Vessel Maintenance Manager (VMM) Recommend this CCR.

Name	Signature	Title	Date

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Configuration Change Request (CCR)

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6. Regional Evaluation

Yes	No	Responsibility of Committee members to evaluate documentation before Regional approval.
☐	☐	Change is properly documented section 3, including detailed description, photos, sketches and/or drawings.
☐	☐	Change is justified: given operational role, age and life expectancy of asset (justification is attached).
☐	☐	All items on impacts assessment are either not applicable or have been assessed as acceptable or modification plan is attached.

If the file is incomplete, return to originator and comments:

Date:

For a Minor CCR, all three signatures are required in Part 6, a copy of the form and package is to be forwarded to the National Configuration Change Request Coordinator (NCCRC) for information as soon as it is approved by the region.
For a Major CCR, the signature of the Operational and Technical Authorities are required to confirm support by the Region. A copy of the form and package is to be forwarded to the NCCRC for action at HQ. NationalCCRCoordinator@DFO-MPO.GC.CA

Yes	No	Operational Authority			
☐	☐				
		Name	Signature	Title	Date
		Technical Authority			
☐	☐				
		Name	Signature	Title	Date
		Financial Authority (For Minor CCR only)			
☐	☐				
		Name	Signature	Title	Date

Regional Committee Decision			
	☐ Reject	☐ Defer	
	☐ Minor CCR: Approval	☐ Develop / Engineering	
	☐ Major CCR: Recommend	☐ Implementation	

Comments:

Minor Funding Source	Project #	AMS Work Order #	WBS #

7. National Headquarters Evaluation

Yes	No	Operational Authority			
☑	☐	Blaine McBride	McBride, Blaine Digitally signed by McBride, Blaine DN: c=CA, o=GC, ou=DFO-MPO, cn=McBride, Blaine Date: 2017.08.29 08:16:01 -04'00'	Ops Requirements Analyst	2017-08-29
		Name	Signature	Title	Date
		Technical Authority			
☑	☐	David Wyse	Wyse, David Digitally signed by Wyse, David DN: c=CA, o=GC, ou=DFO-MPO, cn=Wyse, David Date: 2017.07.27 11:08:53 -04'00'	LCM, Hero Class	2017-07-27
		Name	Signature	Title	Date
		Asset Class Manager			
☑	☐	Liviu Mariciuc	Mariciuc, Liviu Digitally signed by Mariciuc, Liviu DN: c=CA, o=GC, ou=DFO-MPO, cn=Mariciuc, Liviu Date: 2017.08.29 08:22:26 -04'00'	ACM Group /CDO	2017-08-29
		Name	Signature	Title	Date

National Committee Decision			
	☐ Defer	☐ Reject	
	☐ Minor CCR: Approval	☐ Develop / Engineering	
	☐ Major CCR: Recommend	☐ Implementation	

Comments:

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Configuration Change Request (CCR)

Email DATA | Email PDF | Print

8. Assigned Responsibility and Updated Estimate

Engineering OPI:	David Wyse	LCM, Hero Class
	Name	Title
Installation OPI:	Regional VMM	Vessel Maintenance Manager
	Name	Title
Preliminary Engineering Study (if required, cost and source):		
Recommended Timing (Start date; duration):		
Recommended Source (Service Delivery)		

Estimated Cost by Fiscal Year			Total Estimated Cost
FY:	FY + 1	FY + 2	(attach sheet with details)
			$0.00

9. Configuration Control Board (CCB) Decisions

Yes	No	Responsibility of Committee members to evaluate documentation before Regional approval.
☐	☐	Change is properly documented section 3, including detailed description, sketch and/or drawings.
☐	☐	Change is justified: given operational role, age and life expectancy of asset (justification is attached).
☐	☐	All items on impacts assessment are either not applicable or have been assessed as acceptable or modification plan is attached.

If the file is incomplete, return to originator and comments:

Date

*Note: The mandate of the HQ Configuration Control Board (CCB) is to provide **"Approval in Principle"**, approval for **"Development / Engineering or Prototype"** regarding the proposed solution within the Configuration Change Request (CCR).*
The CCB does not approve the assignment of financial resources, which is the mandate of the respective National Management Committee (NMC).

Preliminary Approval	☑ Develop / Engineering Study	☐ Prototype	
Chairperson:	Crista-Lynn Ferguson	Ferguson, CristaLynn Digitally signed by Ferguson, CristaLynn Date: 2017.11.16 10:35:52 -05'00'	2017-11-16
	Name	Signature	Date
CCB Approval	☐ Approve In Principle	☐ Reject	☐ Defer
Chairperson:			
	Name	Signature	Date

CCB Instructions:

Asset Class Manager:	AMS Work Order #	Project #:	WBS #

Expenditures by Fiscal Year			Total Estimated Cost
FY:	FY + 1	FY + 2	(attach sheet with details)
			$0.00

10. Final Approval for Close out (Same persons or replacement who signed at section 5.0)

A- Unit / Originator - Confirming that work is complete.

1	Signature	Date	3	Signature	Date
Print Name/Title :			Print Name/Title :		
2			4		
Print Name/Title :			Print Name/Title :		

B- Engineering OPI Signature (Engineering OPI who closes the CCR must ensure that work identified in sections 4 Step 2, are implemented.)

Implementation, inspection, test and/or trial results:

*Note to OPI: A copy of the completed form and supporting details to be forwarded to the NCCRC. See SOP Para 3.6.1

Total Cost at Completion:		Date:		Signature OPI.	

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Transport Canada / Transports Canada

Document no. – N° du document: 2017-45248-040

INSPECTION CERTIFICATE

FOR A VESSEL EXCEEDING 150 TONS GROSS TONNAGE PLYING AS A NON-PASSENGER VESSEL ON VOYAGES TO WHICH THE SOLAS CONVENTION DOES NOT APPLY (SOLAS CHAPTER I, REGULATION 1 OR 3)

This Certificate is supplemented by a Record of Safety Equipment and a Safe Manning Document.

CERTIFICAT D'INSPECTION

CONCERNANT UN BÂTIMENT D'UNE JAUGE BRUTE DE PLUS DE 150 TONNEAUX UTILISÉ COMME BÂTIMENT NON À PASSAGERS NE RESSORTISSANT PAS À LA CONVENTION « SOLAS » : (SOLAS CHAPITRE I, RÈGLE I OU 3)

Le présent certificat est complété par une Fiche d'équipement de sécurité et un Document de l'effectifs de sécurité.

Name of vessel – Nom du bâtiment	Official number Numéro matricule	Port of registry – Port d'immatriculation	Gross tonnage Jauge brute	Date on which keel laid Date de pose de la quille (dd-mm-yyyy / jj-mm-aaaa)
CORPORAL McLAREN MMV	837734	OTTAWA	253.00	27-10-2012

Total number of persons for which life-saving appliances are provided – Nombre total de personnes pour lesquelles des engins de sauvetage sont prévus: 14

Vessel type – Type de bâtiment: Special - Patrol

That a Life Raft Register – Qu'un registre de radeaux

☐ has been issued – a été délivré ☑ has not been issued – n'a pas été délivré

THIS IS TO CERTIFY that the above-mentioned vessel has been duly inspected in accordance with the provisions of the ***Canada Shipping Act, 2001***, that the provisions of that Act respecting the inspection of vessels that are applicable to that vessel, have been complied with and that the vessel is, subject to such limitations as may be specified herein, fit to ply on voyages not beyond

LA PRÉSENTE FAIT FOI que le bâtiment précité a été dûment inspecté conformément à la ***Loi de 2001 sur la marine marchande du Canada,*** que les dispositions de ladite Loi relatives à l'inspection des bâtiments à vapeur applicables à ce bâtiment ont été observées et que celui-ci est, sous réserve des limitations pouvant être mentionnées au présent certificat, apte à effectuer des voyages dans les limites

Near Coastal Voyage, Class 1

LIM HT2

Limitation(s) on use of certificate – Limitations du présent certificat

- Voyages between places in Canada, the United States (except Hawaii) or Saint Pierre and Miquelon.
- Voyages on the Atlantic coast where the vessel does not go south of the port of New York.
- Voyages on the Pacific coast where the vessel does not go south of Portland, Oregon.
- Vessel to remain within 120 nautical miles from shore.
- Vessel to remain within 200 nautical miles from a place of refuge.

Terms and conditions - Conditions

None

Active Board Decisions granted to the vessel – Décisions du bureau actives accordées au bâtiment

MTRB 12011 - To exempt vessel from inclining experiment. MTRB 10809 - To exempt the vessel ventilator at aft end of Emergency Generator. MTRB 10814 - To exempt the vessel to use FM200.

This certificate is issued under the authority of the Government of Canada and is valid until:

Le présent certificat est délivré avec l'autorisation du gouvernement du Canada et est valide jusqu'au :

20-12-2018

Date (dd-mm-yyyy / jj-mm-aaaa)

Issued at – Délivré à: Dartmouth, NS (Place – Endroit) on – le: 21-12-2017 Date (dd-mm-yyyy / jj-mm-aaaa)

The undersigned is duly authorized by the Government of Canada to issue this certificate.

Le soussigné est dûment autorisé par le gouvernement du Canada à délivrer le présent certificat.

CERTIFIED COPY

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From: Nat CCR Coord / Coord Nat DCC (DFO/MPO)
To: Wyse, David E
Subject: RE: CCR 2018-3103 Hero Class stabilizers
Date: Wednesday, February 14, 2018 9:58:39 AM

OK
Will remove from the list.

s.16(2)

From: Wyse, David E
Sent: February-14-18 9:02 AM
To: Nat CCR Coord / Coord Nat DCC (DFO/MPO)
Subject: Re: CCR 2018-3103 Hero Class stabilizers

Thanks Marius,

Nope still working on Engineering

Dave

Sent from my BlackBerry 10 smartphone.

From: Nat CCR Coord / Coord Nat DCC (DFO/MPO)
Sent: Wednesday, February 14, 2018 8:59 AM
To: Wyse, David E
Subject: CCR 2018-3103 Hero Class stabilizers

Dave,
This CCR was approved for engineering by CCB in November.
Do you have document to present to CCB to get final approval?
I can add to CCB list : TODAY.
Marius

3103	Major National	Normal	Hero Class stabilizers	The parent Hero Class design vessels are delivered with stabilizers. The Hero Class vessels do not have stabilizers installed. All vessel operators agree the vessels require stabilizers in all areas of operation. Program and operations can suffer do the fact that the vessels have extreme roll in high sea state conditions. Engineering and implementation plans are required	MSPV	All Assets	Auxiliary Systems	N/A	David Wyse		Atlantic Region	27/07/2017	Approved for Engineering/Prototype	2017-07-31 Acknowledged/ Validated to NCCRRC. Ops pursuing information from region prior to deciding. 2017-08-18: National Evalution signed and is on this Fridays CCB agenda. 2017-10-23: deferred to next CCB. 2017-11-01 CCR Supported by CCR Committee. Routed to CCB for Rev./Approval Engineering Trial. 2017-11-15 CCB Approved for Engineering. OPI: David Wyse; to present Report to CCB to get final Approval before proceeding with installation.	3844082

Marius Parent
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SEAKEEPING ANALYSIS REPORT

Ship name:	**Hero Class**
Ship type:	**SPa 4207**
Project number:	**253739**

DAMEN SHIPYARDS GORINCHEM
Research Department

Document reference:	3266093
Date:	15 February 2018
Revision:	C

Author: Checked by:

s.19(1)

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Revision History

s.19(1)

Revision	Date	By	Remarks	Checked by
C	14-02-2018	[redacted]	Typos	[redacted]
B	15-01-2018		Extra rudder type and small updates	
A	03-11-2017		Initially created	

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1 Introduction

The Canadian Coast Guard has nine vessels in the Hero Class, which are the Damen SPa 4207 type, patrolling the Great Lakes and coasts of Canada. Although these vessels were not built by Damen – they were built by Irving Shipbuilding in Canada – Damen did make the design and the speed and seakeeping analyses (1). These vessels have no special roll stabilizers installed and the vessels consequently show high roll response. The department of Fisheries and Oceans Canada has requested Damen, as designer of the SPa 4207, to analyse five specific roll stabilization methods in seven configurations (2). These methods include both roll stabilizers that act at speed and stabalizers that also act at zero speed.

The goal of the analysis is to compare these seven configurations to each other and the ships as they are now. Additionally, the effect on top speed and range is investigated.

For this analysis the 2D strip theory program Qship (v.2.0.1) was used, developed by MARIN. Qship is a pre- and post-processor that combines several other tools. The 2D strip tool is Shipmo, the operability tool WASCO and the used post-processor tools are RAOviewer (v.2.14.4) and OperabilityViewer (v.1.11.1).

The report starts with a summary of general particulars in chapter two, followed by a chapter describing the environmental conditions. The fourth chapter describes the seven roll damping configurations and their design parameters. In the fifth chapter the influence of these methods on speed and range is calculated. The sixth chapter gives more details on the seakeeping modelling and parameters. All the result plots are given in the seventh chapter. The eighth and final chapter contains a general discussion and conclusions.

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2 Ship particulars

2.1 General particulars

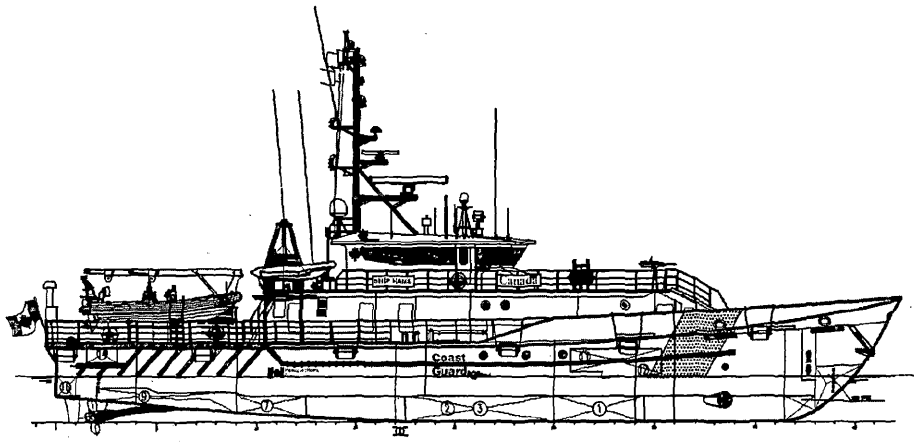
Project number	:	253739
Ship type	:	SPa 4207

2.2 Principal dimensions and loading conditions

Overall length	:	42.8	[m]
Length w.l.	:	40.0	[m]
Breadth waterline	:	7.0	[m]
Draught aft / fwd	:	2.27 / 2.15	[m]
Displacement	:	264.0	[t]
GM	:	1.00	[m]
LCG	:	16.70	[m]
VCG	:	2.91	[m]
TCG	:	0.00	[m]
k_{xx}	:	2.69	[m]
K_{yy}	:	10.20	[m]
K_{zz}	:	10.20	[m]

N.B. Values as used in calculation in Qship. Values may differ slightly from stability booklet, due to small inaccuracies in the lines plan which was used in Qship.

2.3 *Outline*



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2.4 Axis definitions

The axes of the coordinate system are:

X-axis: Longitudinal axis. Positive towards bow. Zero at aft perpendicular.

Y-axis: Transverse axis. Positive towards port side. Zero at centre line.

Z-axis: Vertical axis. Positive upwards. Zero at baseline.

2.5 Locations

The seakeeping analysis is performed for the following locations:

#	Description	X [m]	Y [m]	Z [m]
1	Bridge	20.92	0.93	7.20
2	RHIB launching station	5.00	3.50	3.90
3	Deck at 0.9L	38.50	1.75	5.72
4	Forefoot	38.50	0.00	0.00
5	Centre of gravity	16.70	0.00	2.91

Note that location number 3, the deck at 0.9 L, is used for green water occurrence estimation. Therefore the height is set to the top of the bulwark, rather than deck level.

2.6 Operational speeds

The vessel's cruising speed is 14 knots.

The maximum speed is 25 knots.

The seakeeping analysis is performed for 0 to 25 knots in 5 knot steps.

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3 Environmental conditions

The Hero Class patrols both the Great Lakes and the North Atlantic and North Pacific. The Great Lakes have a limited fetch and the seas are not fully developed. They are therefore best described by a JONSWAP spectrum. The North Atlantic and North Pacific are oceans where fully developed seas are more common. These oceans are both modelled as 2-parameter Pierson-Moskowitz (also called Bretschneider) wave spectra.

For both locations (Great Lakes and North Atlantic/Pacific) sea states 5 and 6 are analysed. In Table 2 the definitions of sea states are listed, as found in (3). The mean significant wave height and most probable peak period are selected. To combine the North Atlantic and North Pacific, the average of the peak periods is chosen. For the Great Lakes the most probable peak periods are assumed to be equal to those of the North Sea (4), by lack of data. Note that the North Sea / Great Lakes have much shorter waves (lower peak periods) than the more developed North Atlantic/Pacific. A summary of the analysed sea states is presented in Table 1.

Table 1. Sea states used in the analysis.

	Great Lakes		**North Atlantic/Pacific**	
	JONSWAP		Pierson-Moskowitz	
	Hs [m]	Tp [s]	Hs [m]	Tp [s]
Sea state 5	3.25	7.0	3.25	9.7
Sea state 6	5.0	9.0	5.0	13.1

In all the calculations the following definitions and assumptions have been used:

- The definition of heading with respect to waves is consistent with the direction in which the waves travel with respect to the vessel; 0° waves are stern waves, 90° is beam waves from starboard and 180° wave heading is sailing in head waves.
- Deep water has been assumed.
- The wave spectra are unidirectional or long-crested, i.e. no wave spreading was applied.

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Table 2. Sea state definitions. Source: (3).

Open Ocean Annual Sea State Occurrences from Bales (1983) for the North Atlantic and the North Pacific							
Sea State Number (–)	Significant Wave Height $H_{1/3}$ (m)		Sustained Wind Speed 1) (kn)		Probability of Sea State (%)	Modal Wave Period T_p (s)	
	Range	Mean	Range	Mean		Range 2)	Most 3) Probable
North Atlantic							
0 - 1	0.0 - 0.1	0.05	0 - 6	3	0	-	-
2	0.1 - 0.5	0.3	7 - 10	8.5	7.2	3.3 - 12.8	7.5
3	0.50 - 1.25	0.88	11 - 16	13.5	22.4	5.0 - 14.8	7.5
4	1.25 - 2.50	1.88	17 - 21	19	28.7	6.1 - 15.2	8.8
5	2.5 - 4.0	3.25	22 - 27	24.5	15.5	8.3 - 15.5	9.7
6	4 - 6	5.0	28 - 47	37.5	18.7	9.8 - 16.2	12.4
7	6 - 9	7.5	48 - 55	51.5	6.1	11.8 - 18.5	15.0
8	9 - 14	11.5	56 - 63	59.5	1.2	14.2 - 18.6	16.4
>8	>14	>14	>63	>63	<0.05	18.0 - 23.7	20.0
North Pacific							
0 - 1	0.0 - 0.1	0.05	0 - 6	3	0	-	-
2	0.1 - 0.5	0.3	7 - 10	8.5	4.1	3.0 - 15.0	7.5
3	0.50 - 1.25	0.88	11 - 16	13.5	16.9	5.2 - 15.5	7.5
4	1.25 - 2.50	1.88	17 - 21	19	27.8	5.9 - 15.5	8.8
5	2.5 - 4.0	3.25	22 - 27	24.5	23.5	7.2 - 16.5	9.7
6	4 - 6	5.0	28 - 47	37.5	16.3	9.3 - 16.5	13.8
7	6 - 9	7.5	48 - 55	51.5	9.1	10.0 - 17.2	15.8
8	9 - 14	11.5	56 - 63	59.5	2.2	13.0 - 18.4	18.0
>8	>14	>14	>63	>63	0.1	20.0	20.0

Note:
1) Ambient wind sustained at 19.5 m above surface to generate fully-developed seas. To convert to another altitude h_2, apply $V_2 = V_1 \cdot (h_2/19.5)^{1/7}$.
2) Minimum is 5 percentile and maximum is 95 percentile for periods given wave height range.
3) Based on periods associated with central frequencies included in Hindcast Climatology.

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4 Roll stabilization methods

This chapter describes the selected roll stabilizing methods and their main parameters.

4.1 None – current situation

The Hero Class in its current form has no roll stabilizers. The only roll damping appendages that are taken into account are the skegs and rudders. The skeg parameters are listed below, according to Figure A and Table 3. The rudders are defined according to Table 4. Two skegs and two rudders are fitted, around either propeller.

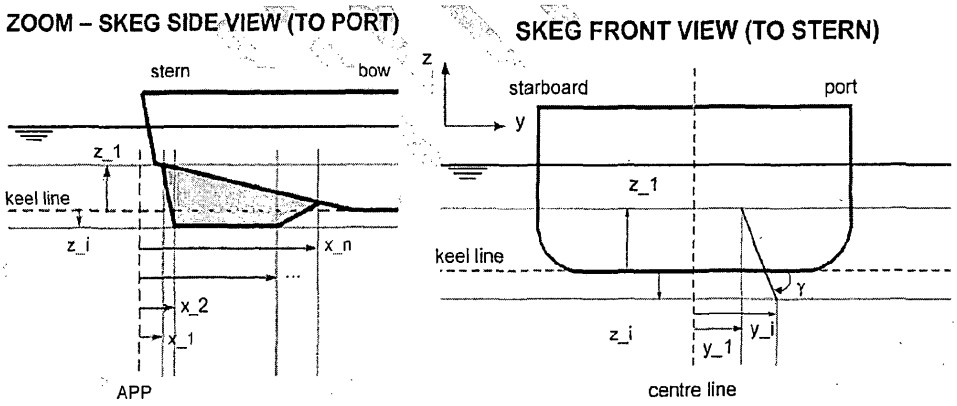

Figure A. Skeg parameter definitions.

Table 3. Skeg parameters

Parameter	Value	Unit
X_n	3.00 2.64 6.26	[m]
Y_n	±1.50 ±1.50 ±1.50	[m]
Z_n	1.20 0.60 1.00	[m]
Depression angle	90	[deg]

Table 4. Rudder parameters.

Parameter	Value	Unit
Root X	1.00	[m]
Root Y	±1.50	[m]
Root Z	1.30	[m]
Span	1.30	[m]
Chord	0.65	[m]
Depression angle	90	[deg]

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4.2 Active stabilizer fin

The first roll stabilizer method is to use active stabilizer fins. These are wing profiles attached to the sides of the vessel and actively rotated to control the angle of attack. The Quantum Underway S-series active stabilizer, model QC-1200, was selected as appropriate fin. It is fitted on several other SPa 4207s. Two fins are fitted, one on either side of the vessel. The main parameters are listed in Table 5.

Table 5. S-QC1200 parameters.

Parameter	Value	Unit
Root X	18.00	[m]
Root Y	±2.50	[m]
Root Z	1.14	[m]
Span	0.86	[m]
Chord	1.45	[m]
Area	1.25	[m^2]
Depression angle	64	[deg]

4.3 Active zero-speed stabilizer fin

The second roll stabilizer method is to use active zero-speed stabilizer fins. These are wing profiles attached to the sides of the vessel and actively rotated to control the angle of attack. The difference with regular active stabilizer fins is that these are also effective at zero speed, when there is no flow velocity along the fin. The stabilization at zero speed is obtained by a combination of drag and inertial forces that occur when rotating the fin around its axis. To achieve maximum effect, the fin has a long chord and a shaft placed close to one edge. The fin also works like a regular stabilizer fin, though it needs a larger fin area due to the less favourable aspect ratio.

The Quantum ZeroSpeed & Underway P-series active stabilizer, model QC-1500, was selected as appropriate fin. Two fins are fitted, one on either side of the vessel. The main parameters are listed in Table 5. For reference, an example of a different, slightly larger, P-series fin is shown in Figure B.

Table 6. P-QC1500 parameters.

Parameter	Value	Unit
Root X	18.00	[m]
Root Y	±2.50	[m]
Root Z	1.14	[m]
Span	1.04	[m]
Chord	2.89	[m]
Area	3.00	[m^2]
Depression angle	64	[deg]

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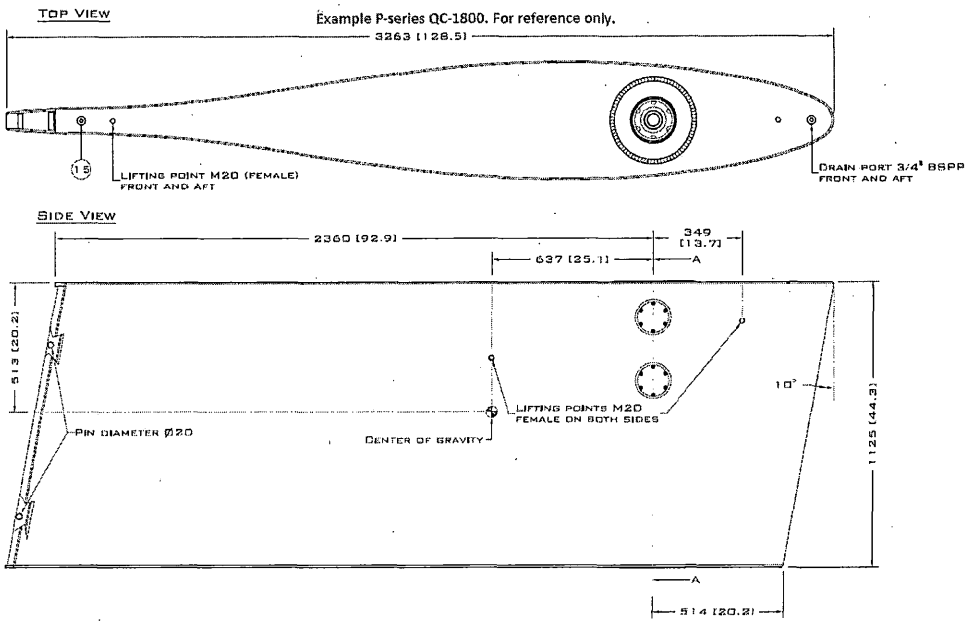

Figure B. Example of Quantum P-series fin, model QC1800 (not used in this analysis).

4.4 Bilge keels

The third roll stabilizer method is the application of bilge keels to the vessel. Bilge keels are long flat plates that run along a certain part of the length of the vessel, preferably at maximum distance from the roll axis (longitudinal through the centre of gravity) and as perpendicular to the flow in roll as possible.

Several design considerations are to be taken into account:

- The bilge keel should not interfere with the wake field. Starting the bilge keel at 1/3 L from the stern is usually a safe distance.
- The bilge keel should not extend forward too much, to avoid coupling with pitch. It also loses its effectiveness when it is placed closer to the roll axis, as happens closer to the bow. Generally the bilge keels are stopped at 2/3 L from the stern.
- The bilge keel should not extend below the bottom and out of the sides, to avoid them being vulnerable to collision of grounding damage.
- The height of the bilge keel is important for its effectiveness. However, at some point adding more height will only marginally increase effectiveness in roll damping, while still increasing resistance in forward direction. A common practice is to choose a large HP-profile.
- The bilge keel should be placed along the streamlines of the vessel, to

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minimize forward resistance.

The parameters of the chosen bilge keel design is listed in Table 7, the definitions in Figure C.

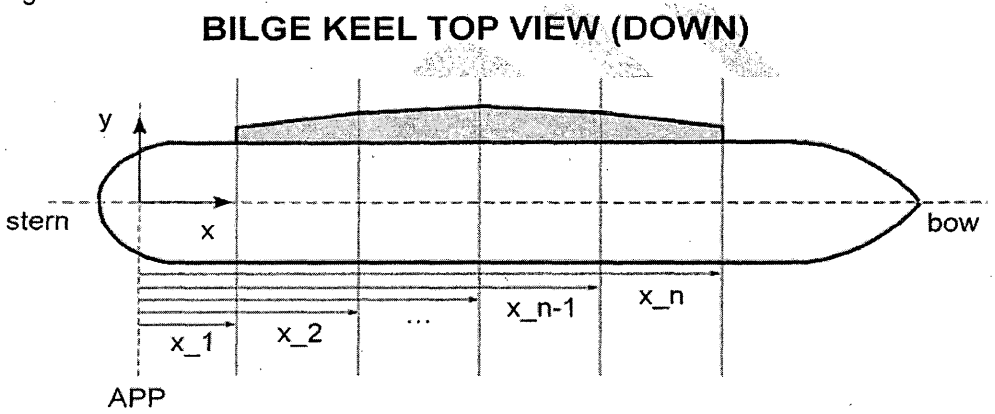

Figure C. Bilge keel parameter definitions.

Table 7. Bilge keel parameters.

Parameter	Value	Unit
X_n	13.9 18.7 23.0 28.0	[m]
Y_n	±2.75 ±2.67 ±2.58 ±2.12	[m]
Z_n	1.29 1.26 1.34 1.6	[m]
Depression angle	64	[deg]

4.5 Active rudder (existing rudder controls)

The fourth roll stabilizing method is active rudder roll damping. This uses the existing rudder and steering pumps installation but controls it to use the roll moment induced by rudder action to act as damping on roll motions. The inertia of the vessel in yaw (change of heading) is much larger than that in roll, making it possible to dampen roll without inducing large yawing motions. Since this method uses the existing rudders, the parameters are equal to those listed in Table 4. The appeal of this method is the absence of extra weight and hardware. N.B. The existing steering pumps may not be suitable for the intense use this method requires!

4.6 Active rudder (existing rudder controls) & bilge keels

The fifth method is a combination of the existing active rudders and bilge keels.

4.7 Active rudder (new rudder controls)

The sixth method is active rudder roll damping, using new rudder controls and steering pumps for a better performance.

4.8 Active rudder (existing rudder controls) & bilge keels

The seventh method is a combination of the new active rudders and bilge keels.

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5 Effect on speed and range

This chapter describes the effect of the presence of each of the roll damping methods described in the previous chapter on both maximum speed and range of vessel. For the calculations the assumption is that the active roll stabilizers (both fin types and rudders) are passive. Active systems will consume both hydraulic power and cause an increase in resistance due to changing angles of attack and drag coefficients, but these are highly dependent on the sea states, roll motions and speed of the vessel.
For all calculations a displacement of 250 tons is assumed, the displacement corresponding to 50% consumables. Some of the rudder stabilization method will add to the total weight of the vessel, thereby increasing the resistance and decreasing the maximum speed further. This is not taken into account in the following calculations, but rather a speed reduction in knots per ton gain in displacement is given at the end.

The reduction of the maximum speed is presented in knots, where the maximum speed itself is calculated at 24.9 knots for this displacement. An effect on maximum speed of e.g. -0.3 knots will therefore reduce the maximum speed to 24.6 knots.

For all range calculations the vessel is assumed to sail at cruising speed, i.e. 14 knots. The total fuel oil capacity is 31.3 m^3, or 31300 litre, leading to a range without any extra appendages of 2300 nautical miles.

5.1 Active stabilizer fin S-QC1200

The stabilizer fins are taken into account by adding the appendage drag to the vessel resistance. The appendage drag consists of two components:

- Friction. This depends on Reynolds number, velocity and wetted area.
- Pressure drag. This depends on frontal area, velocity and drag coefficient.

Effect on	Value	Unit
Maximum speed	-0.3	[kn]
Range at cruising speed	-68	[nm]

5.2 Active zero-speed stabilizer fin P-QC1500

The zero-speed stabilizer fins are taken into account by adding the appendage drag to the vessel resistance. The appendage drag consists of two components:

- Friction. This depends on Reynolds number, velocity and wetted area.
- Pressure drag. This depends on frontal area, velocity and drag coefficient.

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Effect on	Value	Unit
Maximum speed	-0.6	[kn]
Range at cruising speed	-114	[nm]

5.3 Bilge keels

The bilge keels are taken into account by adding the appendage drag to the vessel resistance. The appendage drag consists of one component:

- Friction. This depends on Reynolds number, velocity and wetted area. The length of the bilge keel is increased by a factor of 1.25 to account for the fact that it will never be perfectly aligned with the flow. This is a very rough correction.

Effect on	Value	Unit
Maximum speed	-0.5	[kn]
Range at cruising speed	-113	[nm]

5.4 Active rudder (existing and new rudder controls)

The active rudder uses the normal rudder and when in passive roll damping mode does not add anything to the resistance.

5.5 Active rudder (existing and new rudder controls) & bilge keels

The combination of active rudders and bilge keels is equal to the results of applying only bilge keels, since the rudders are already installed and assumed passive in roll damping.

Effect on	Value	Unit
Maximum speed	-0.5	[kn]
Range at cruising speed	-113	[nm]

5.6 Effect of 1 ton increased displacement

An indication of the effect on both maximum speed and range of added displacement is given below for an increase of 1 ton, i.e. a displacement of 265 ton.

Effect on	Value	Unit
Maximum speed	-0.07	[kn]
Range at cruising speed	-5.6	[nm]

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6 Seakeeping simulation parameters

Some of the more specialized seakeeping settings and parameters are described in this chapter.

6.1 Linearizing roll

Of all six motions a ship undergoes in seas, roll is almost always the largest. The roll stiffness of a regular hull is low compared to pitch and heave and the roll damping can be particularly low. Since the vessels natural roll period is often close to or even at the peak period of the wave spectrum it sails in, the roll motion is almost in resonance and damping dominates the roll amplitude. Since the roll damping is low, roll motions are often large.

The problem with modelling roll damping in linear theory, is that roll damping is very non-linear. That means that roll damping increases nonlinearly with roll angle (or rather, with roll velocity). This makes traditional approaches such as Response Amplitude Operators (RAOs) difficult, as an RAO is defined as a linear response per meter regular wave height. When the regular wave height increases from 1 meter to 2 meters, an RAO will predict an exact doubling of the roll angle. In reality, the roll angle will be less than double for the 2 meter wave.

To solve this issue, it is common to linearize the roll damping at several roll angles and then iterate to find the proper response. For every roll linearization angle a separate roll RAO is made.

It is therefore not meaningful to look only at 1 RAO and better to look at several. Best is to look at RMS values of the roll response in irregular seas.

That is why in this report, the values are often presented in terms of RMS. The RMS is defined as

$$RMS = \sqrt{M_0}$$

M_0 is the zero order spectral moment of the response or the variance. The spectral moment is defined as

$$M_n = \int_0^\infty S(\omega) \cdot \omega_e^n \cdot d\omega$$

In which $S(\omega)$ is the spectral density function of an arbitrary motion.

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6.2 Bare hull roll damping

The roll damping for the bare hull is modelled by so called PQ values. These describe the roll damping over a range of roll amplitudes and speeds and are obtained from model tests of the Spa 4207. The PQ values used are:

V [kn]	0	5	10	15	20	25
P	0.25	0.40	0.60	0.80	0.91	1.01
Q	0.030	0.029	0.027	0.026	0.024	0.023

6.3 Appendage damping gain parameters

The damping capacity of the active fins and rudders is influenced by the damping gain of the control system, which determines the active angle of attack on the fin as function of roll angular velocity and thereby the lift force on the fin. The choice of this gain is partly dependent on the roll angles of the vessels, but must be entered as 1 value for all sea states. These gains are determined in an iterative process, which ensures the fins' angles will stay between realistic limits. It was chosen to determine the damping gains for in between sea states 5 and 6 in the Great Lakes area, which yield the highest roll response. By setting these gains for these conditions, the roll damping will be somewhat overestimated in the other sea states in North Atlantic/Pacific.

When choosing these roll damping gains, the important boundary parameters are the maximum fin angle and maximum fin angular velocity.

The damping gain for both S-series and P-series was set at:

$$8\frac{deg}{deg/s}$$

The active rudder works in the same way. Although the maximum rudder angles are actually the same as the maximum fin angles, i.e. 35 deg, the maximum rudder angular velocity is much lower. From sea trial data of the Hero Class, the maximum rudder velocity with both existing steering pumps is estimated around 5 deg/s. The damping gain parameter is therefore also much lower than that of the fins. The damping gain for the active rudders with existing controls was set at:

$$0.8\frac{deg}{deg/s}$$

The damping gain of the active rudders, using new steering pumps capable of a recommended 15 deg/s rudder rates (5), was set at:

$$2.0\frac{deg}{deg/s}$$

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Although the damping gains of the active rudders are a lot lower than those for stabilizer fins, the much higher aspect ratio of the rudders results in a higher lift coefficient which ensures a decent roll damping performance.

6.4 Zero speed fin

The Quantum zero-speed stabilizers at zero speed are modelled by adding a damping, which is different for every linearized roll angle.

The zero speed fin is modelled by first principles of drag and inertial forces when rolling while the fin kicks from one extreme fin angle to the other extreme. The amount of work that is done by one cycle of the fin is then translated into an equivalent damping that acts during the entire roll motion of the vessel. Since the total work done in roll by the fin remains constant for every roll angle, the damping is calculated for specific roll angles and then used to interpolate between these.

6.5 Bilge keels

The bilge keels are modelled with IKEDA roll damping methods.

6.6 MSI

The Motion Sickness Index (MSI) according McCauley and O'Hanlon has been calculated for several locations. This index is an indication of the amount of people that get seasick in a population that is not accustomed to ship motions. Since the Hero Class crew are all highly accustomed sailors, the absolute numbers of the MSI results are not significant, but relative comparison is still valid.

6.7 Slamming

The slamming probability is calculated on the basis of the relative motion and relative velocity response at the specified location. The slamming probability is defined as the probability of emergence times the probability of exceedance of a specified relative velocity, as these parameters are assumed to be uncorrelated. The relative velocity is defined by Ochi's criterion (Ochi, 1964: Prediction of occurrence and severity of ship slamming at sea). Probability of exceedance is based on the local draught.

6.8 Deck wetness

The deck wetness is modelled in a similar way as slamming, where the relative motion threshold is equal to the local freeboard and there is no relative velocity threshold.

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7 Results

All seakeeping results are presented in this chapter. These include RAO plots of roll and polar plots of roll and other variables.

7.1 RAOs

The roll RAO plots are given for a range of speeds and headings (no head or stern waves as these cause no roll), for all 5 roll damping methods and current vessel at once. The vertical axis gives the roll response in degrees. The horizontal axis the regular wave frequency in rad/s.

The response is given for two different regular wave heights: 0.5 and 1.0 m. This is to illustrate the dependence of roll response to wave height. This means the plots are not strictly speaking RAOs, not even the plots that give roll response per 1.0 m wave, but RAOs for roll are not quite as meaningful as those for other motions, as explained in 6.1.

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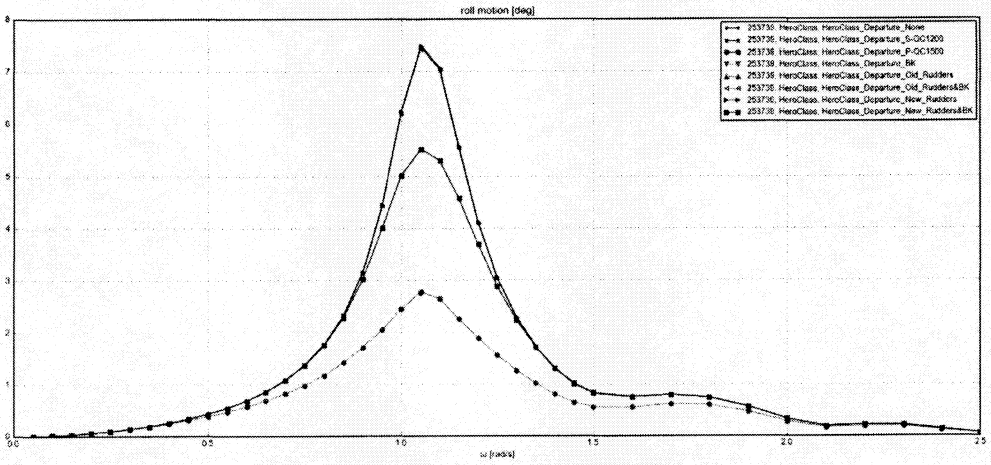
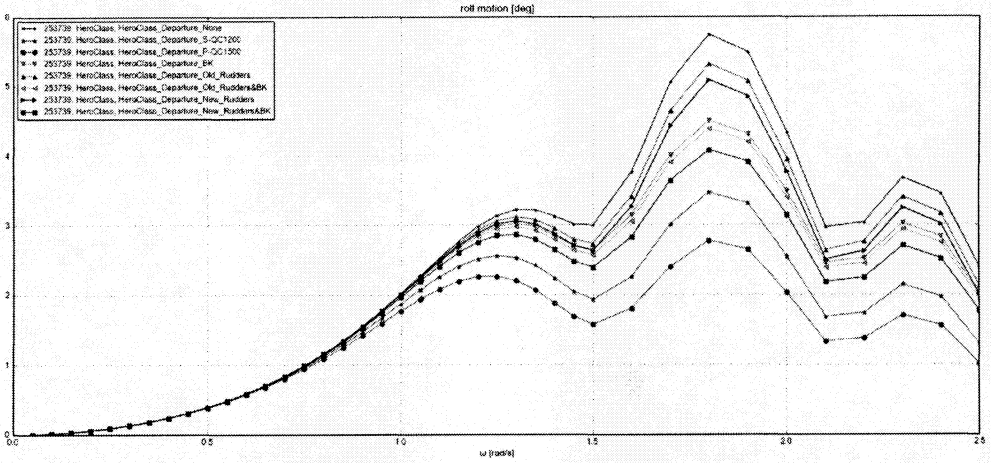
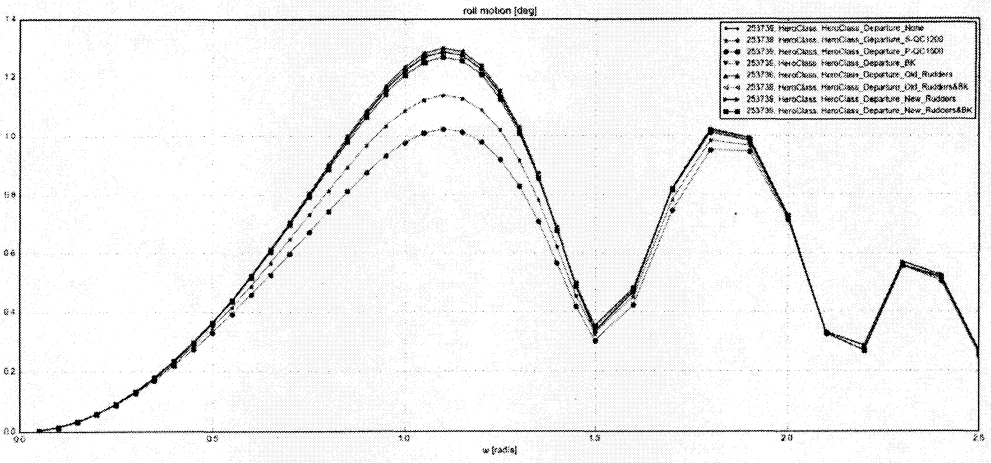
7.1.1 Roll RAO H = 0.5 [m] μ = 30 [deg]

Top to bottom: V = 0 [kn] V = 5 [kn] V = 10 [kn]







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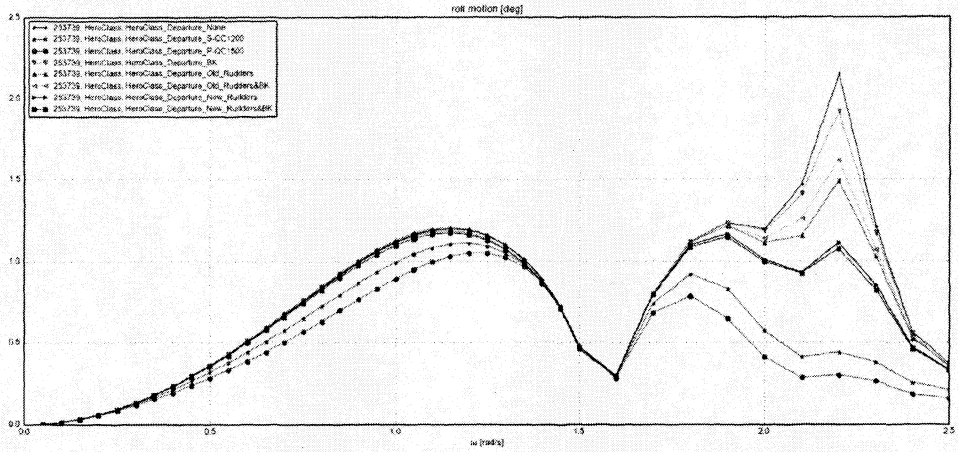
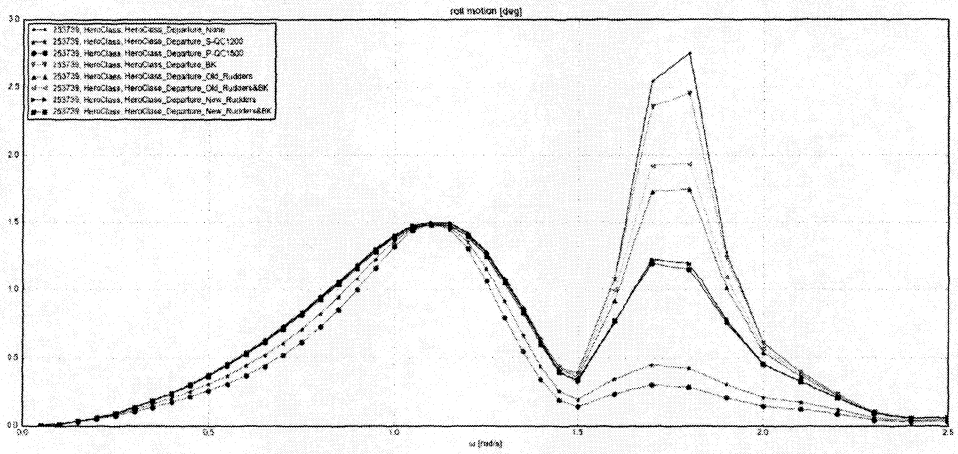
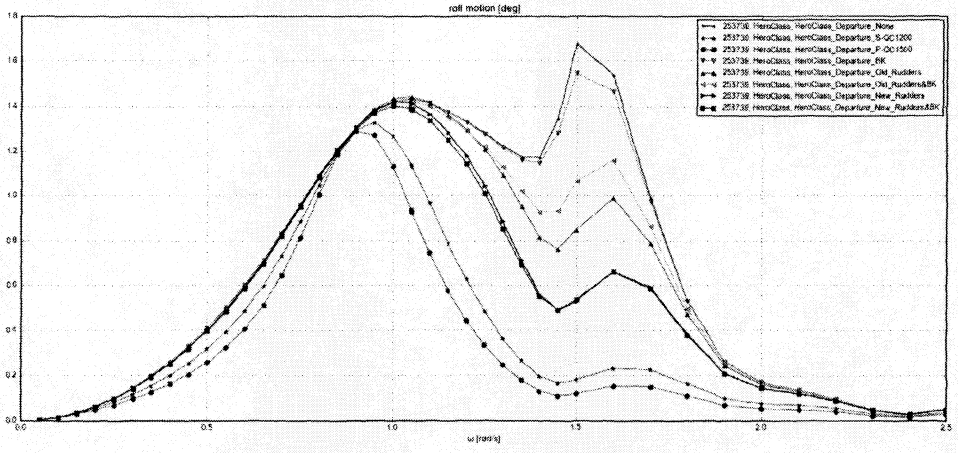
Roll RAO H = 0.5 [m] μ = 30 [deg]

Top to bottom: V = 15 [kn] V = 20 [kn] V = 25 [kn]







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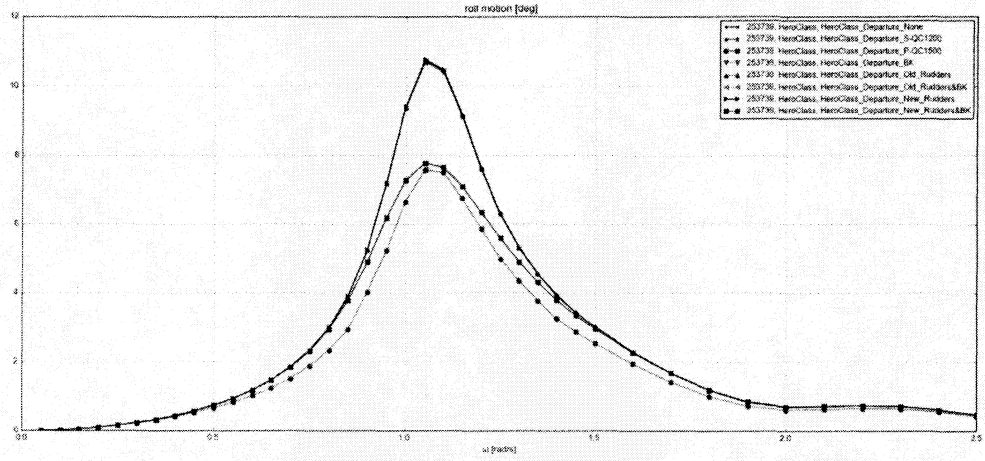
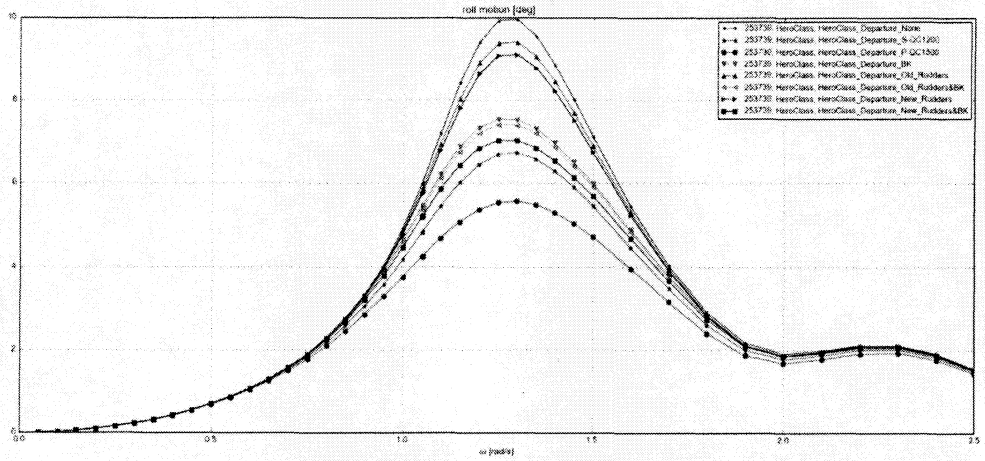
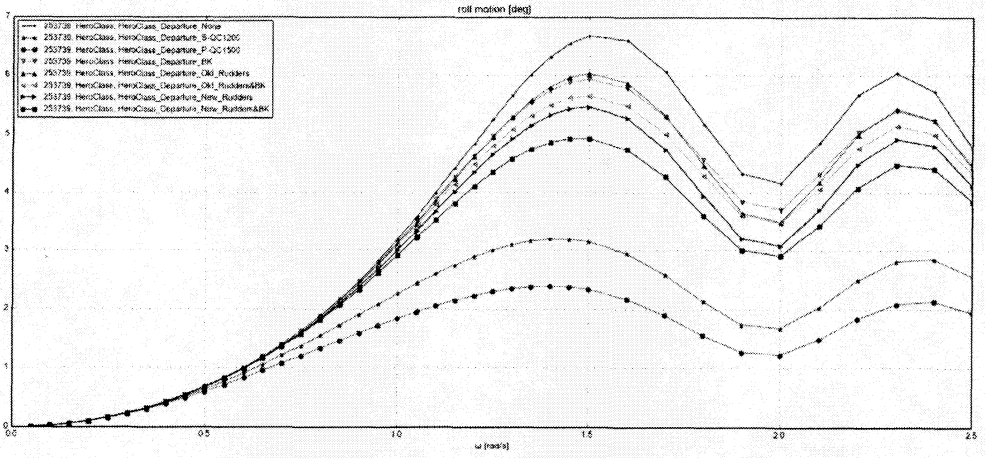
7.1.2 Roll RAO H = 0.5 [m] μ = 60 [deg]

Top to bottom: V = 0 [kn] V = 5 [kn] V = 10 [kn]







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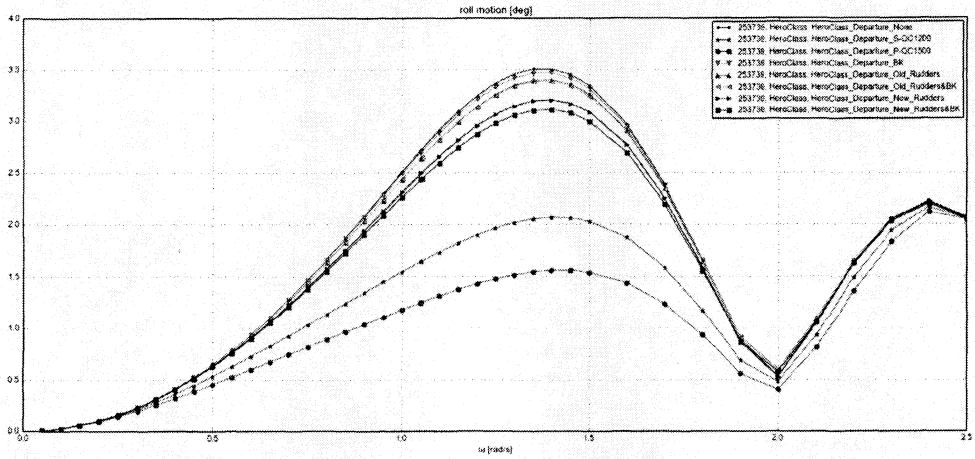
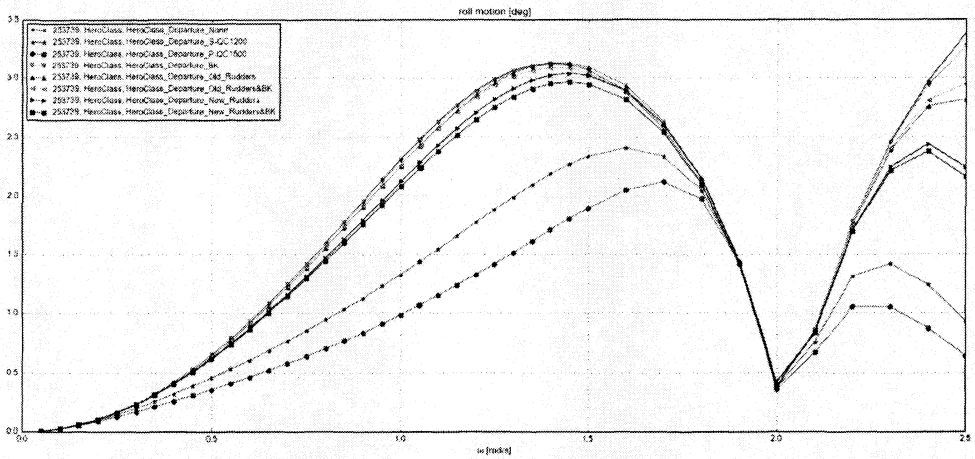
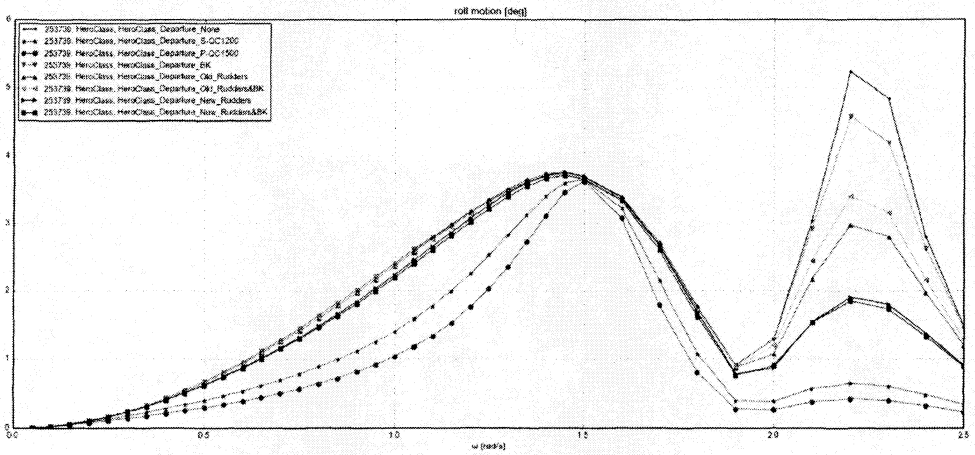
Roll RAO H = 0.5 [m] μ = 60 [deg]

Top to bottom: V = 15 [kn] V = 20 [kn] V = 25 [kn]







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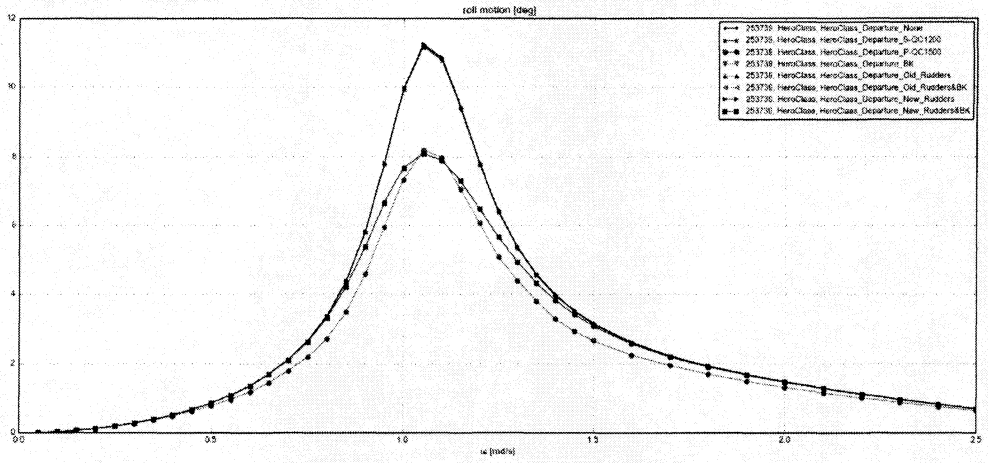
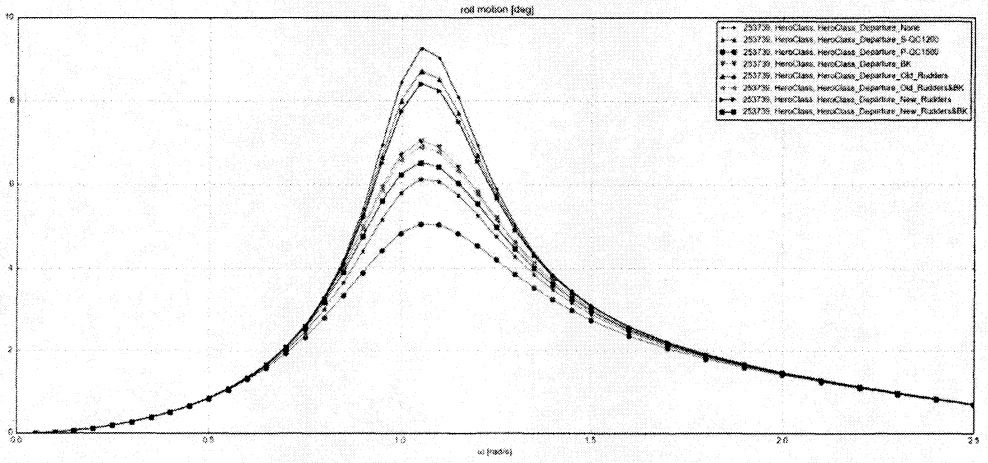
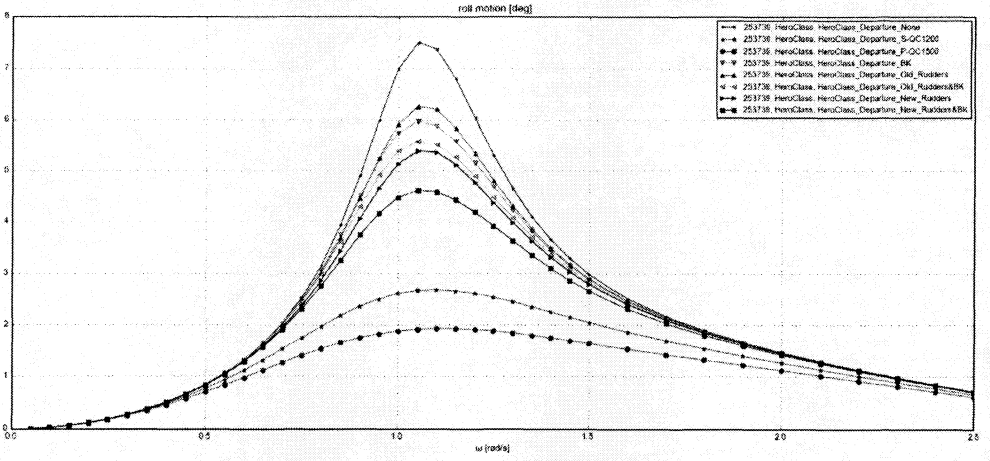
7.1.3 Roll RAO H = 0.5 [m] μ = 90 [deg]

Top to bottom: V = 0 [kn] V = 5 [kn] V = 10 [kn]







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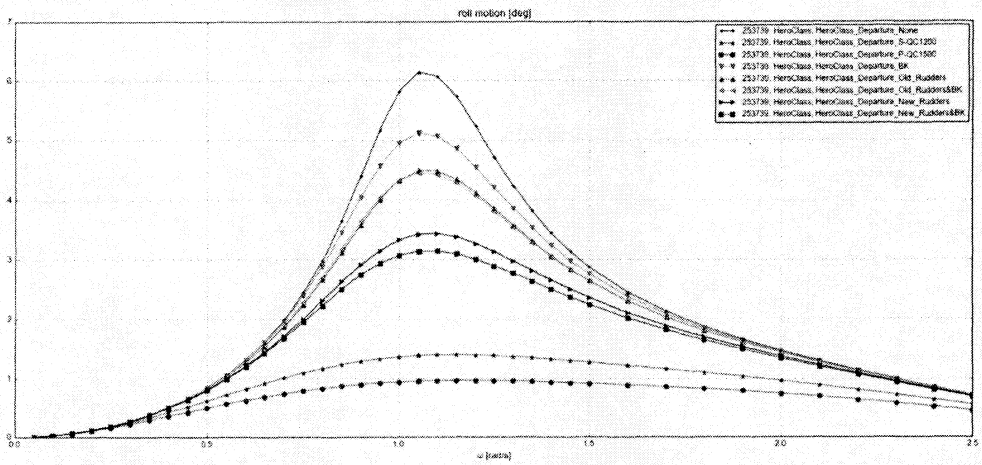
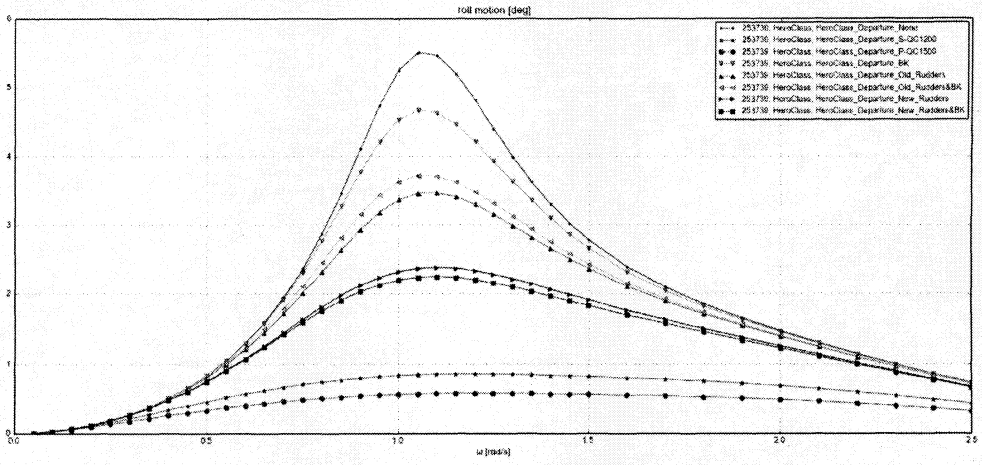
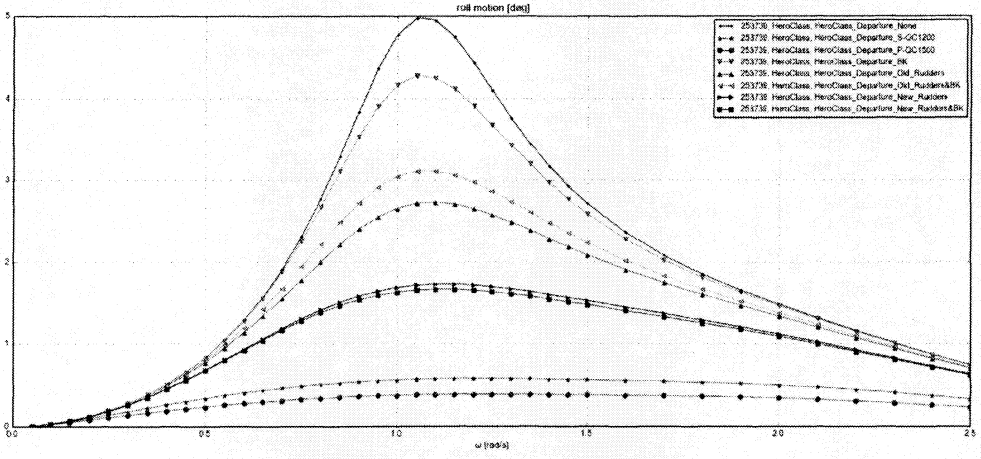
Roll RAO H = 0.5 [m] μ = 90 [deg]

Top to bottom: V = 15 [kn] V = 20 [kn] V = 25 [kn]







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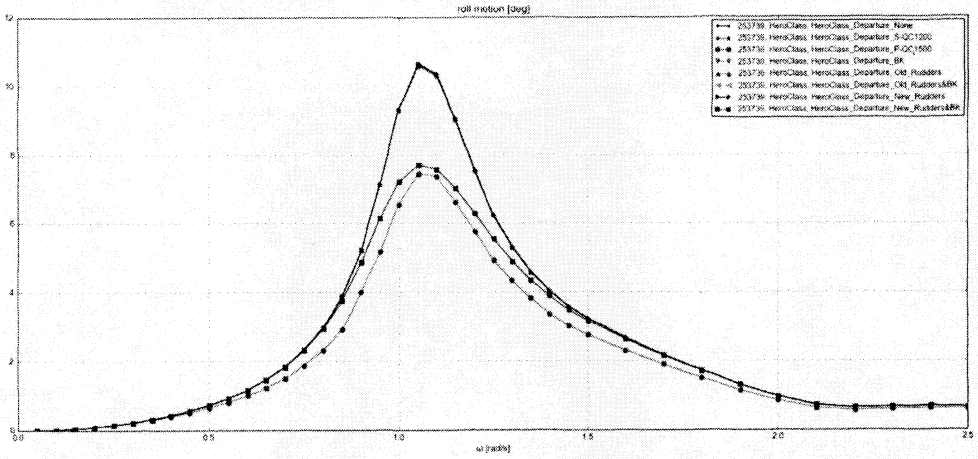
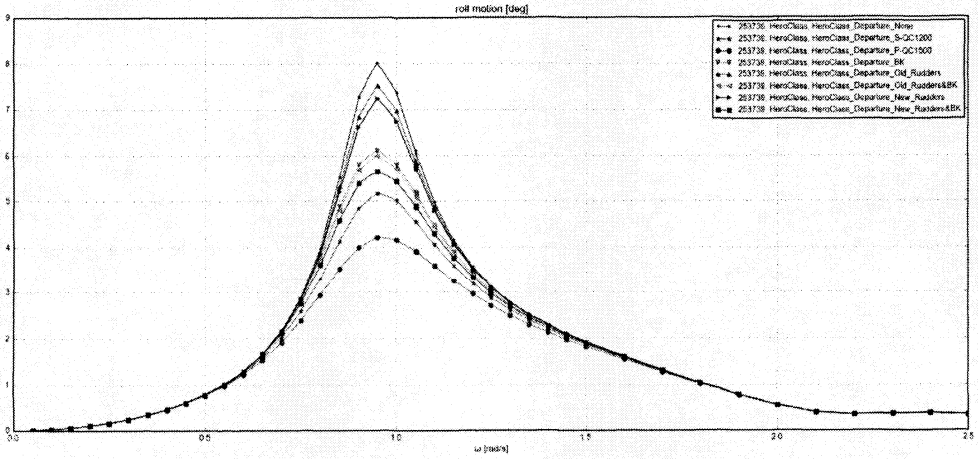
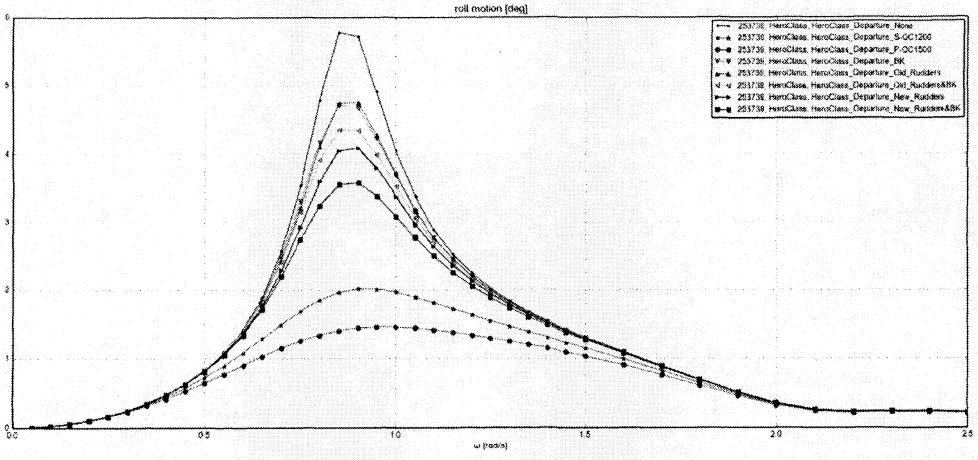
7.1.4 Roll RAO H = 0.5 [m] μ = 120 [deg]

Top to bottom: V = 0 [kn] V = 5 [kn] V = 10 [kn]







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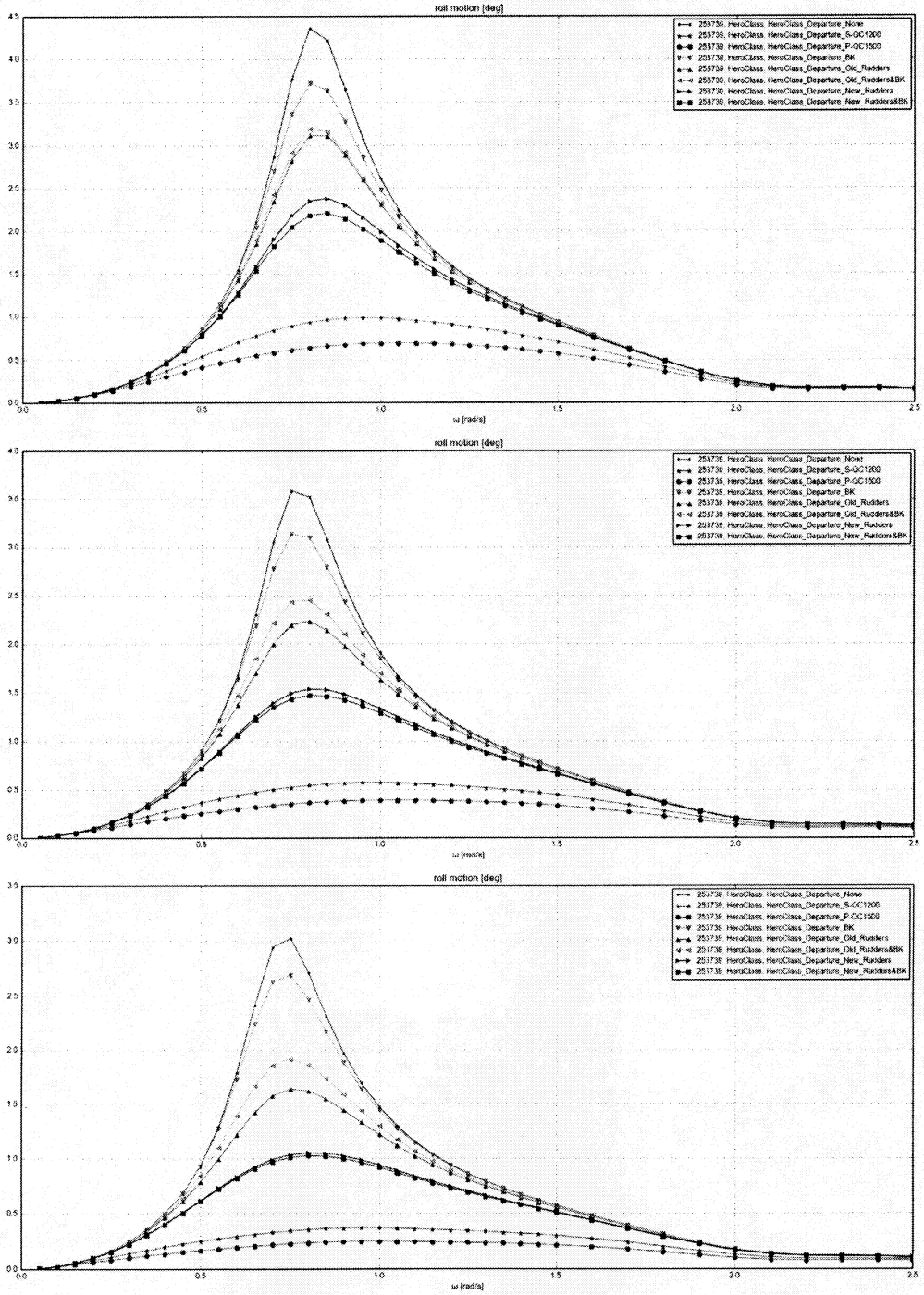
Roll RAO H = 0.5 [m] μ = 120 [deg]

Top to bottom: V = 15 [kn] V = 20 [kn] V = 25 [kn]



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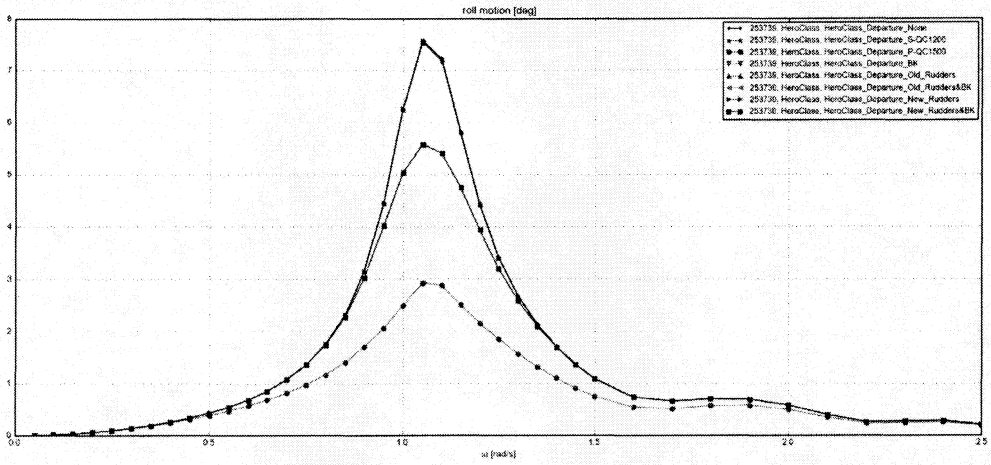
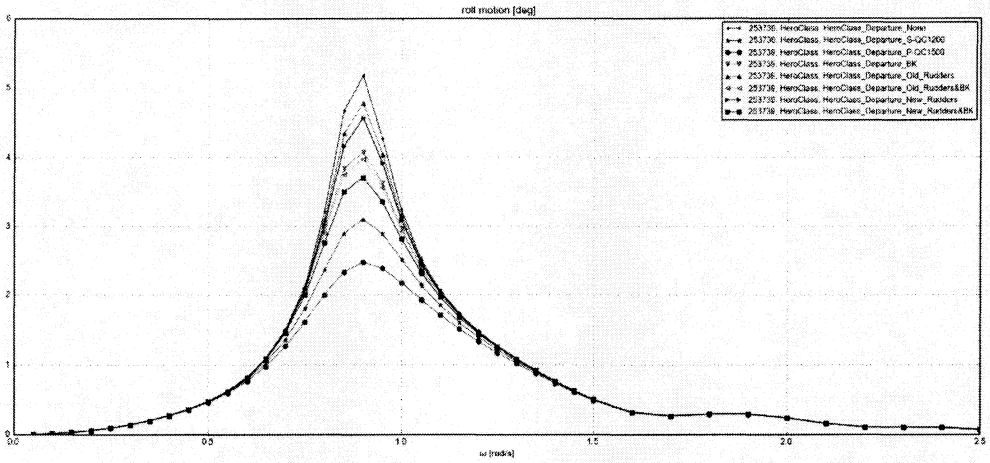
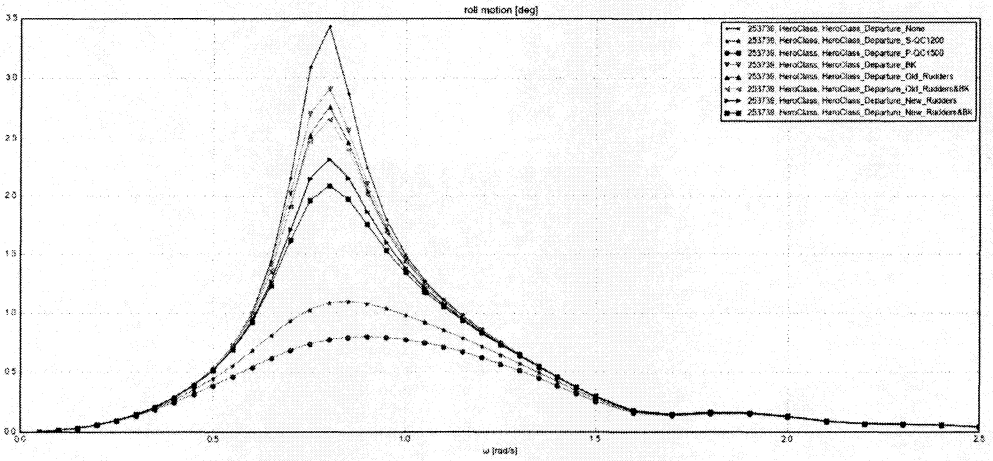
7.1.5 Roll RAO H = 0.5 [m] μ = 150 [deg]

Top to bottom: V = 0 [kn] V = 5 [kn] V = 10 [kn]







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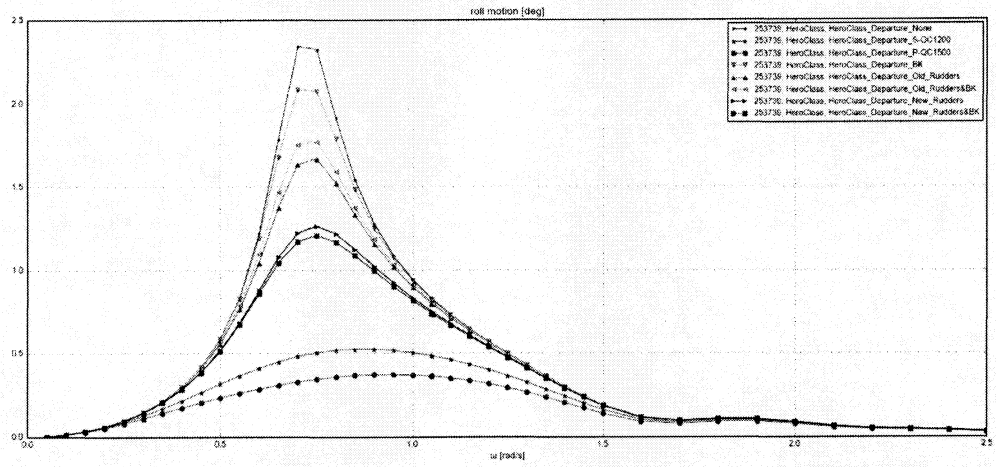
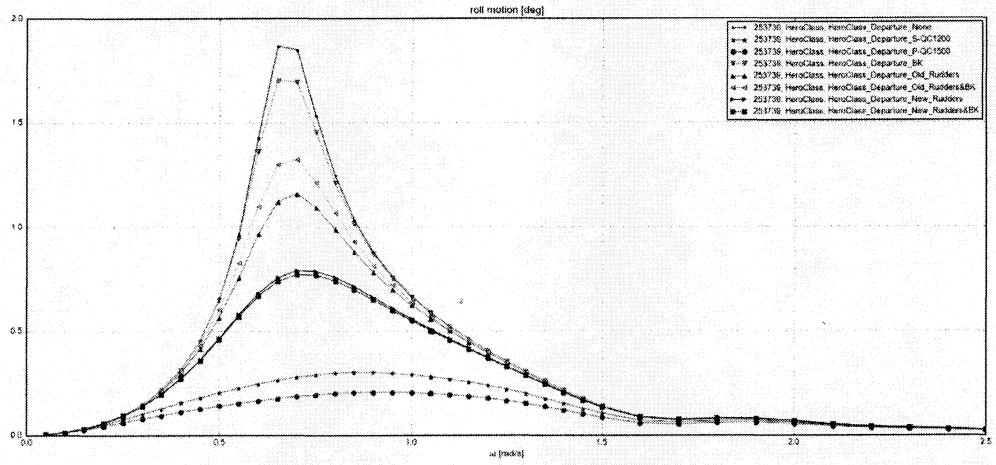
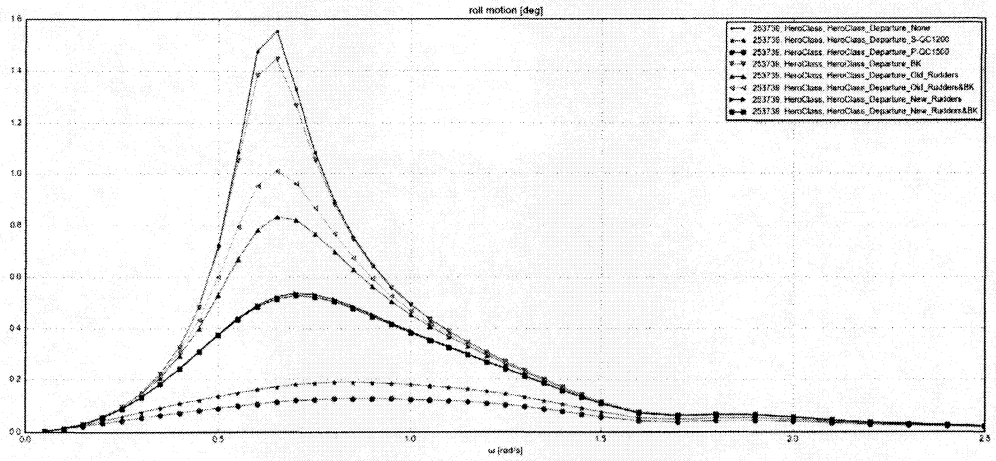
Roll RAO H = 0.5 [m] μ = 150 [deg]

Top to bottom: V = 15 [kn] V = 20 [kn] V = 25 [kn]







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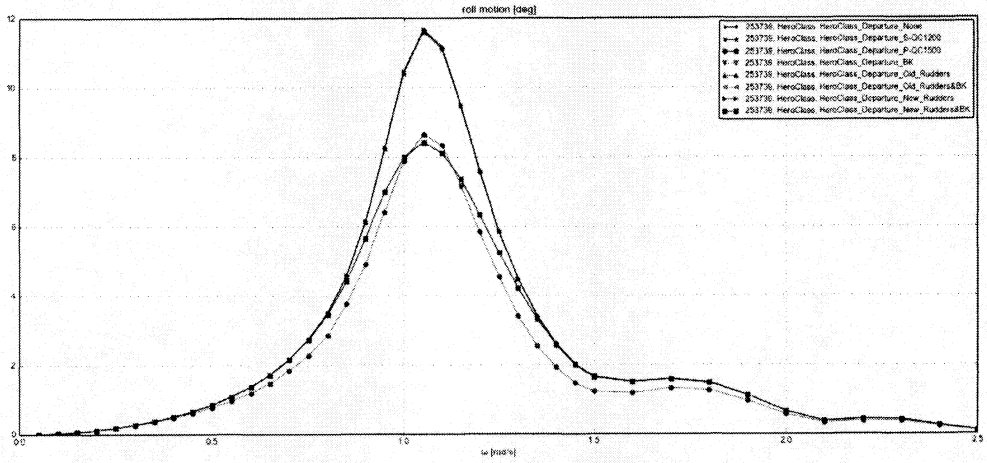
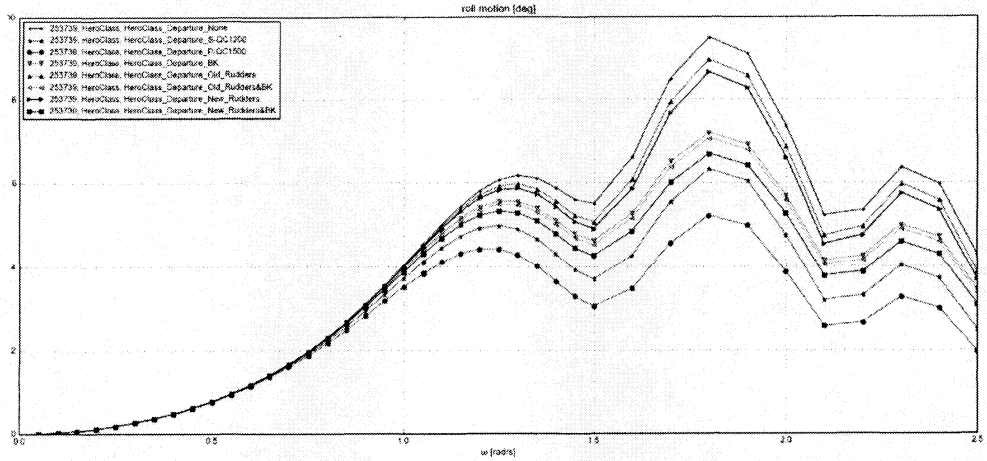
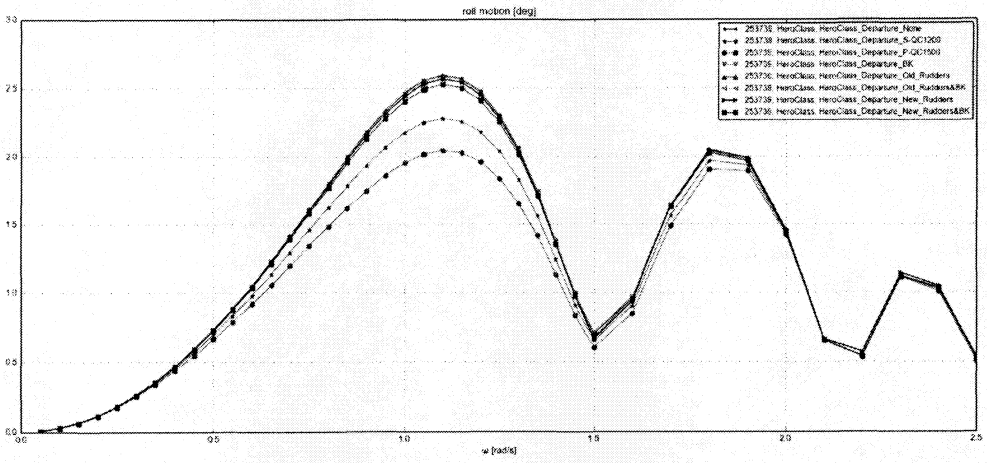
7.1.6 Roll RAO H = 1.0 [m] μ = 30 [deg]

Top to bottom: V = 0 [kn] V = 5 [kn] V = 10 [kn]







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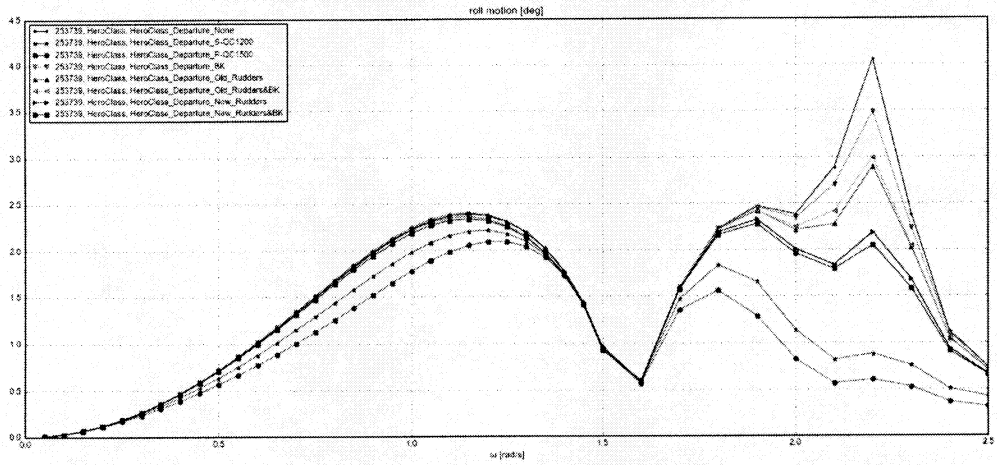
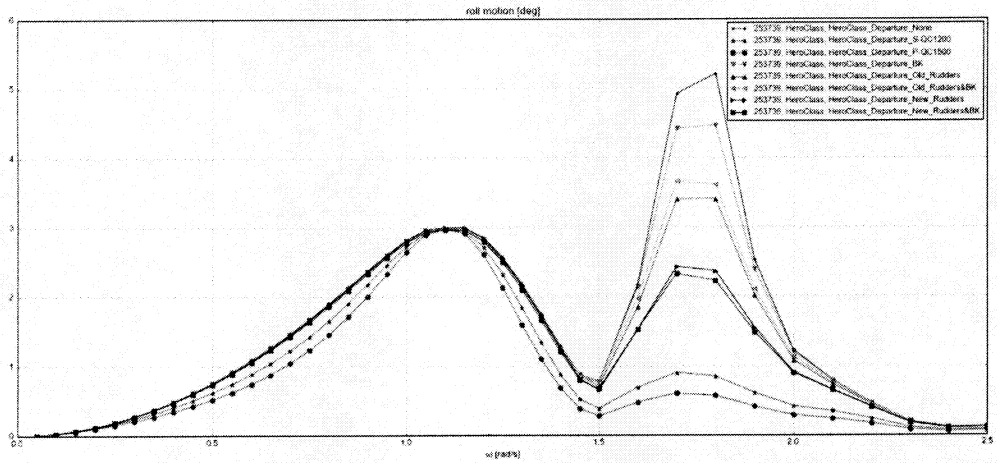
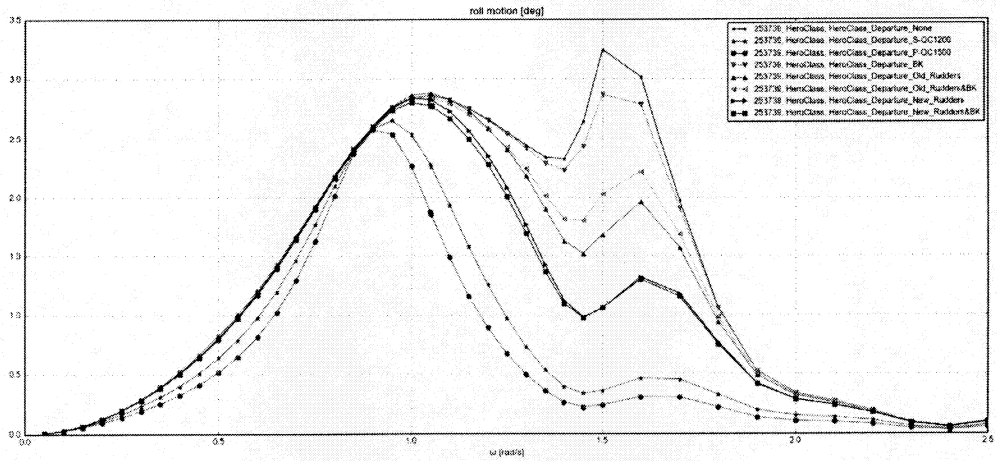
Roll RAO H = 1.0 [m] μ = 30 [deg]

Top to bottom: V = 15 [kn] V = 20 [kn] V = 25 [kn]







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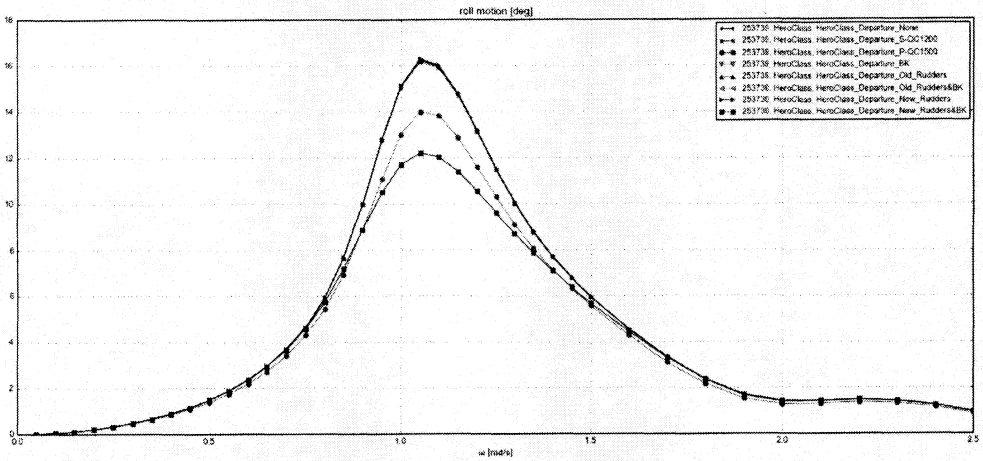
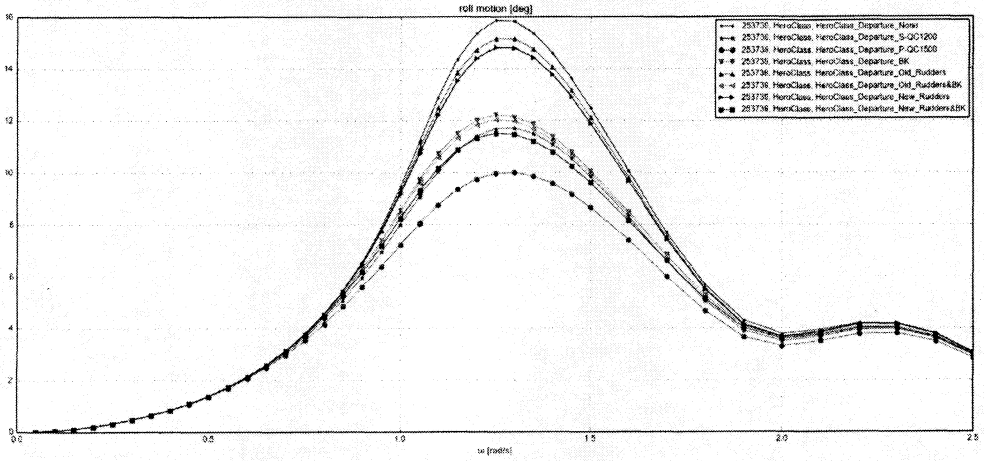
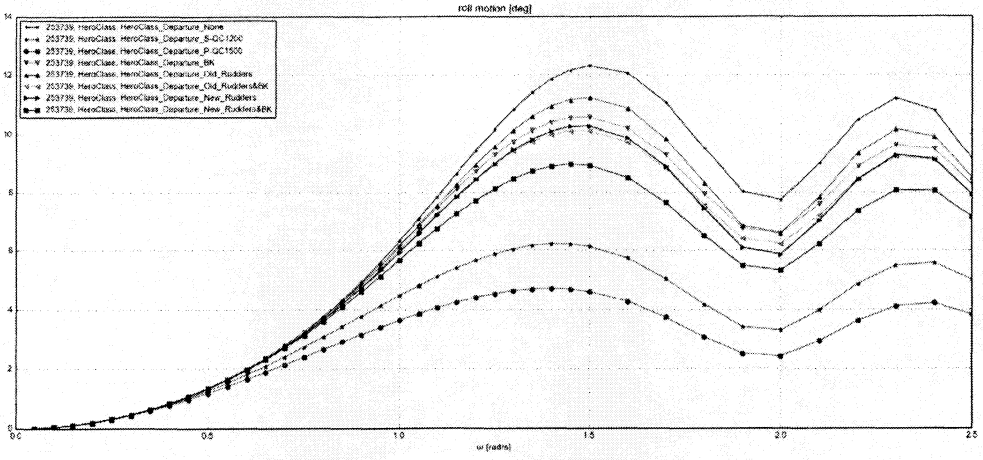
7.1.7 Roll RAO H = 1.0 [m] μ = 60 [deg]

Top to bottom: V = 0 [kn] V = 5 [kn] V = 10 [kn]







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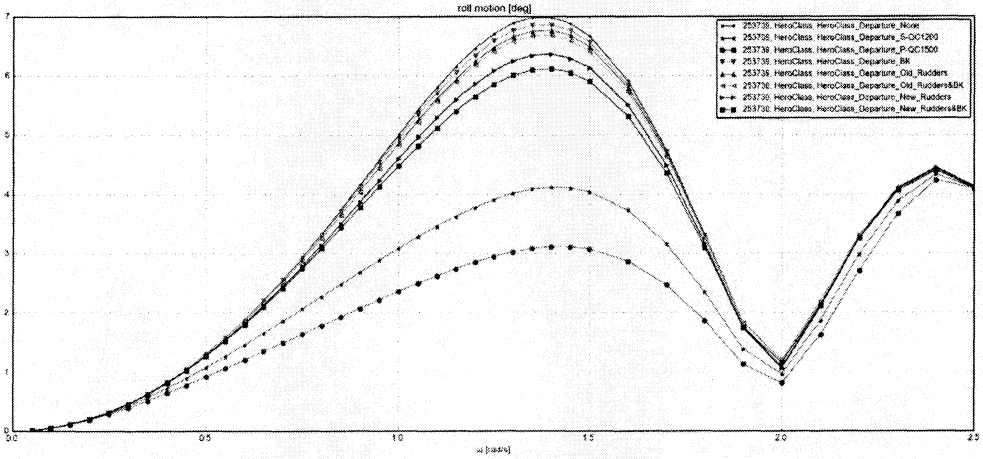
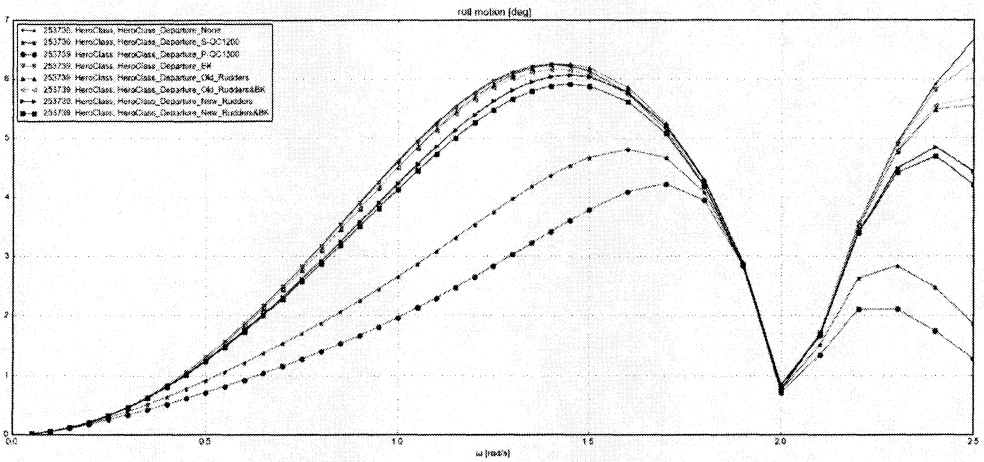
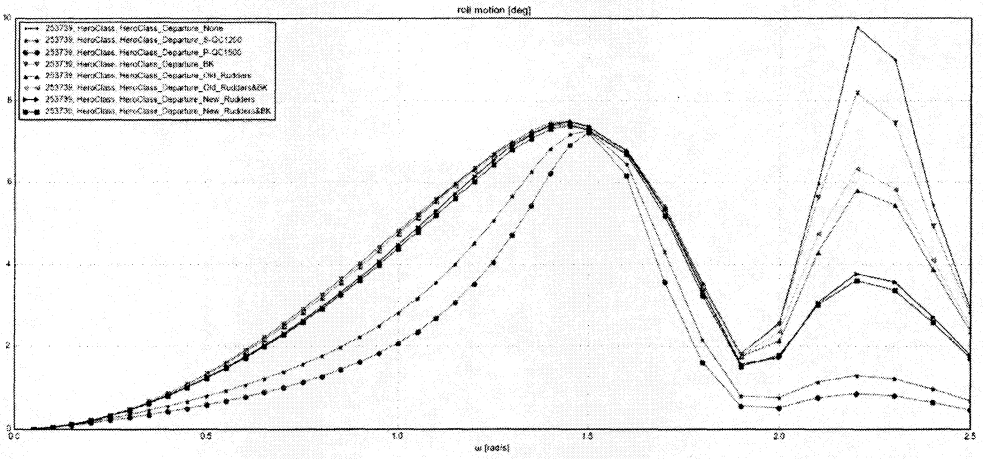
Roll RAO H = 1.0 [m] μ = 60 [deg]

Top to bottom: V = 15 [kn] V = 20 [kn] V = 25 [kn]







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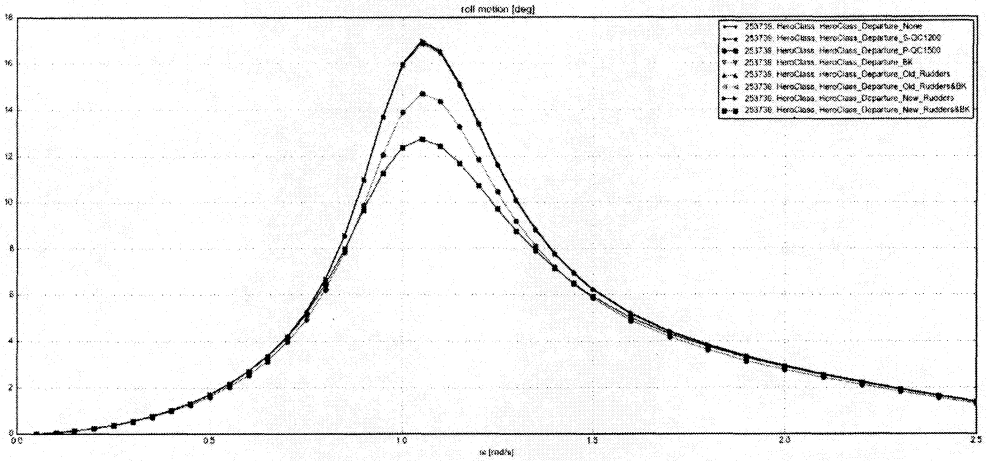
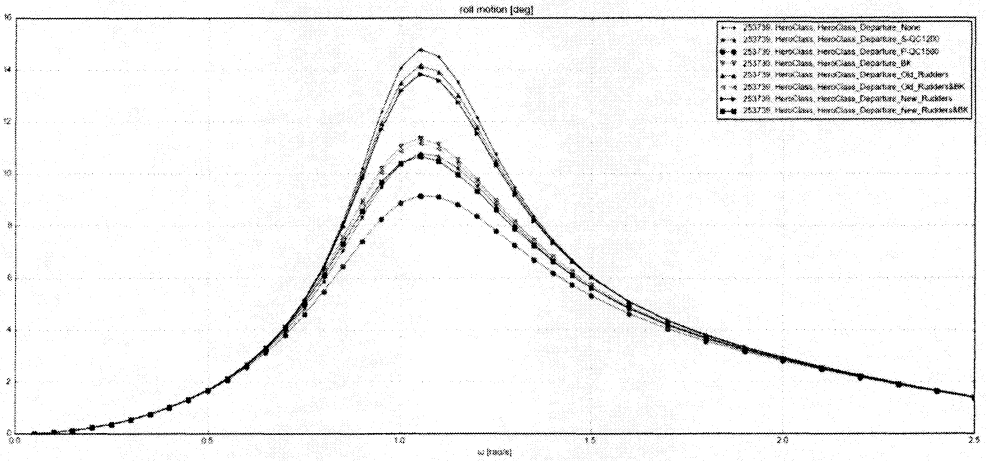
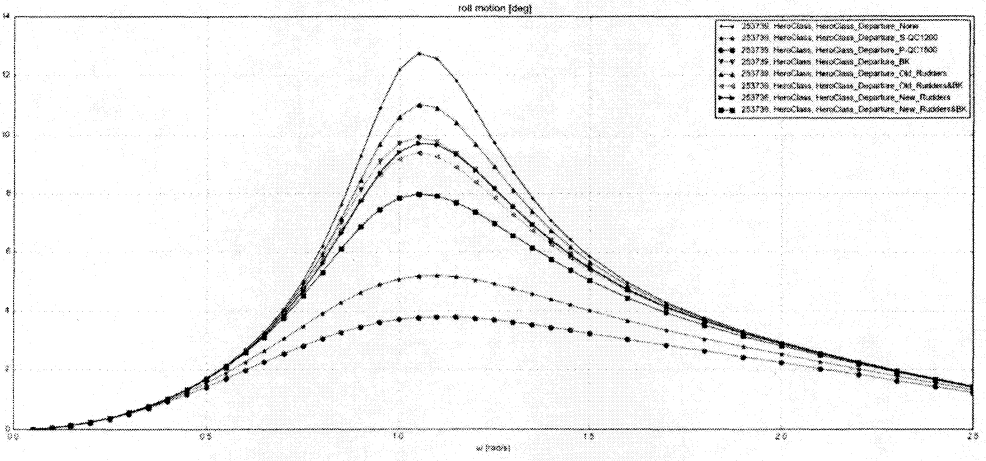
7.1.8 Roll RAO H = 1.0 [m] μ = 90 [deg]

Top to bottom: V = 0 [kn] V = 5 [kn] V = 10 [kn]







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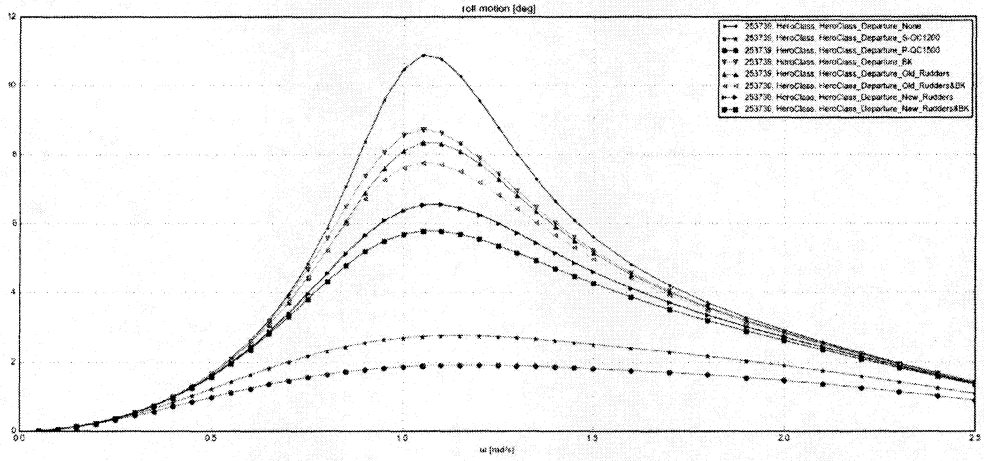
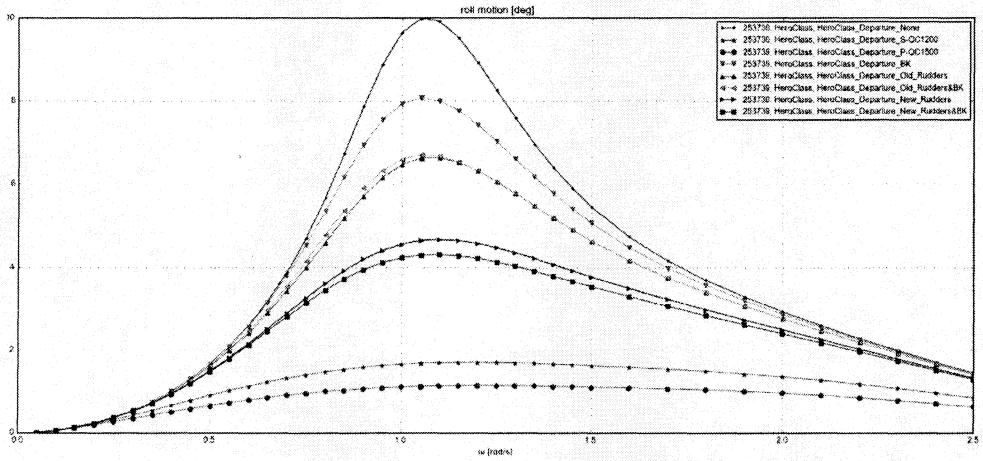
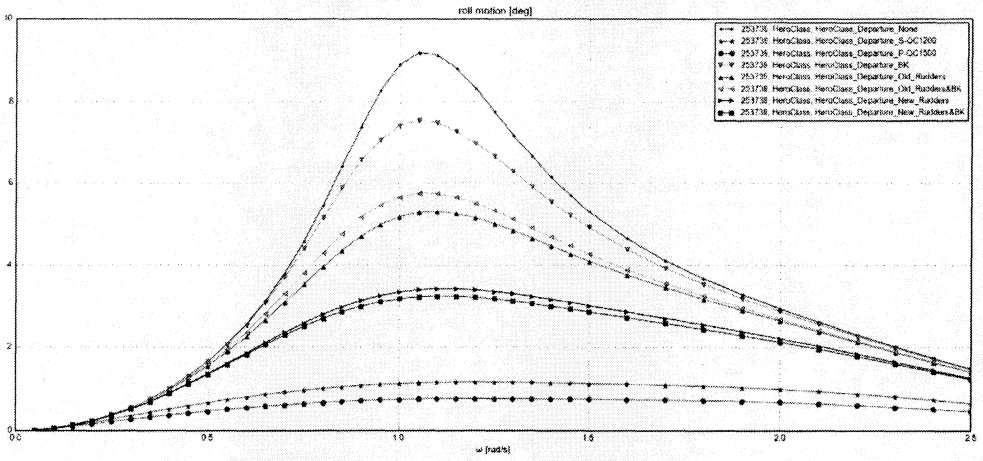
Roll RAO H = 1.0 [m] μ = 90 [deg]

Top to bottom: V = 15 [kn] V = 20 [kn] V = 25 [kn]







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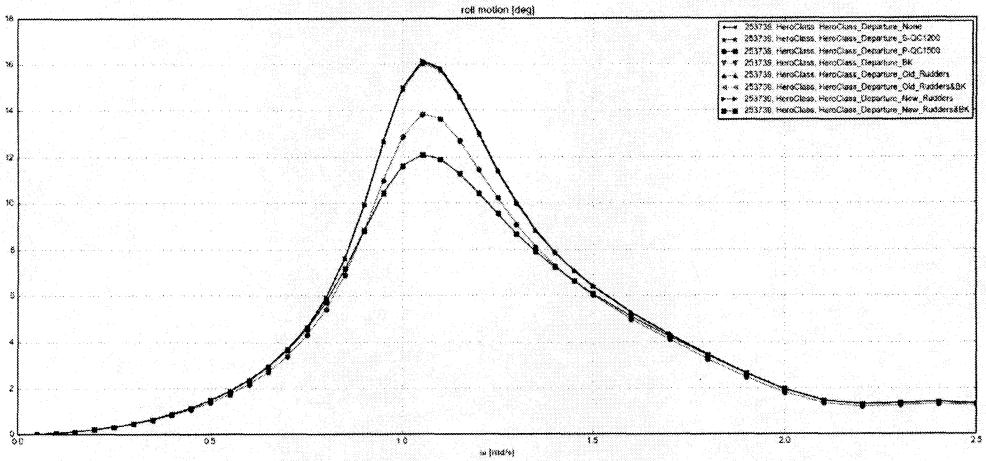
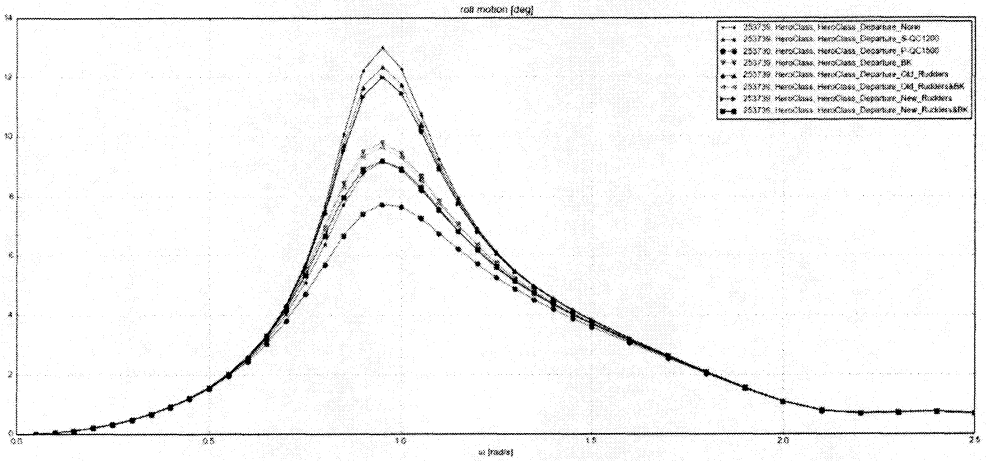
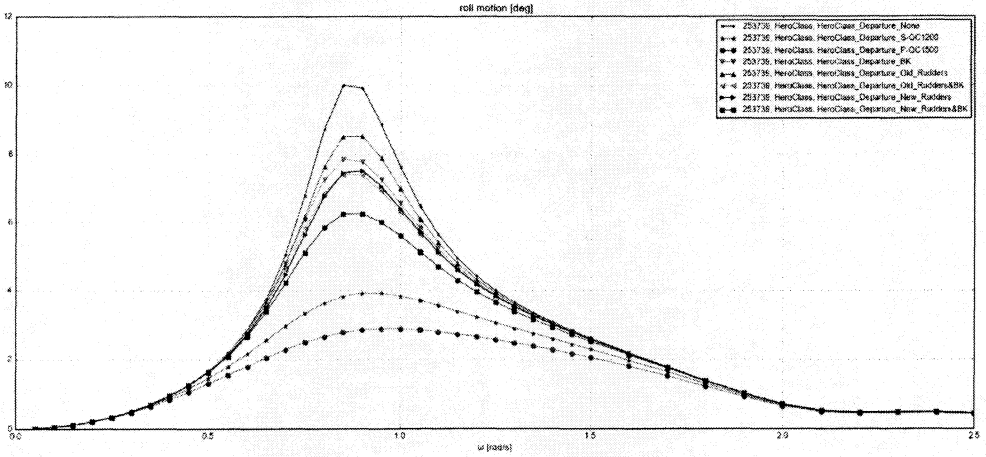
7.1.9 Roll RAO H = 1.0 [m] μ = 120 [deg]

Top to bottom: V = 0 [kn] V = 5 [kn] V = 10 [kn]







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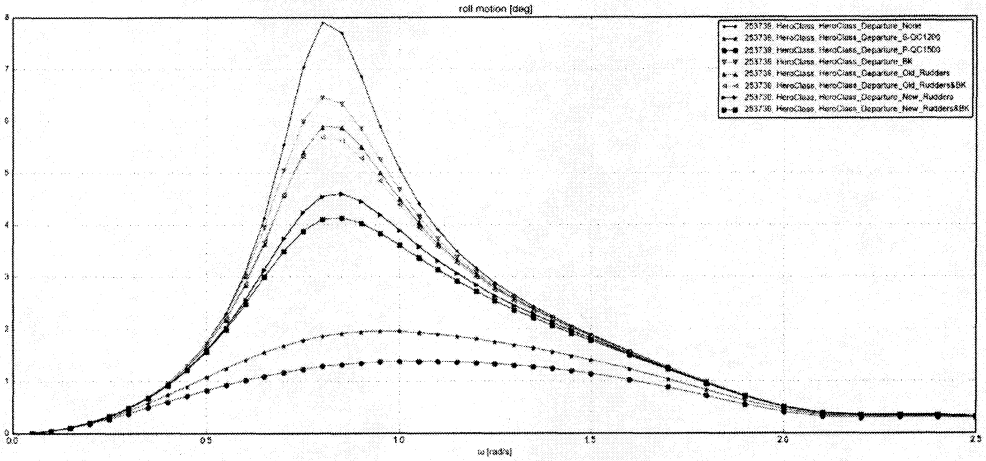
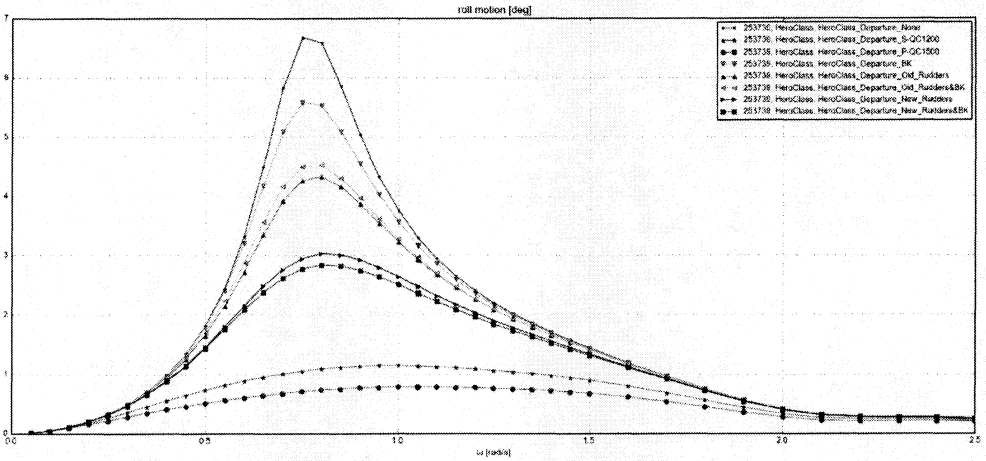
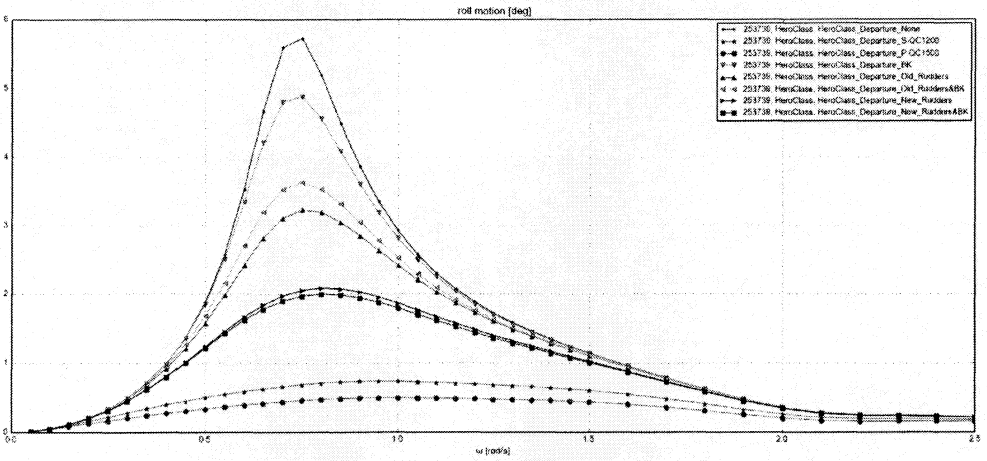
Roll RAO H = 1.0 [m] μ = 120 [deg]

Top to bottom: V = 15 [kn] V = 20 [kn] V = 25 [kn]







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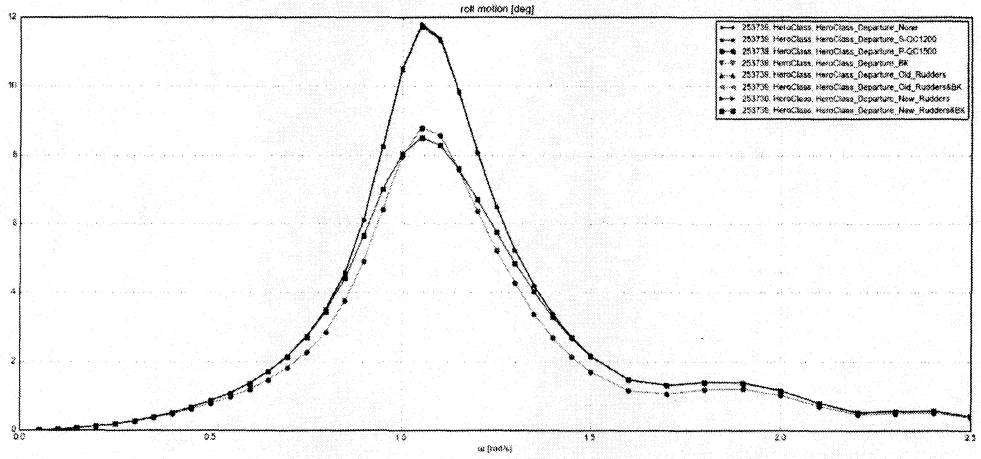
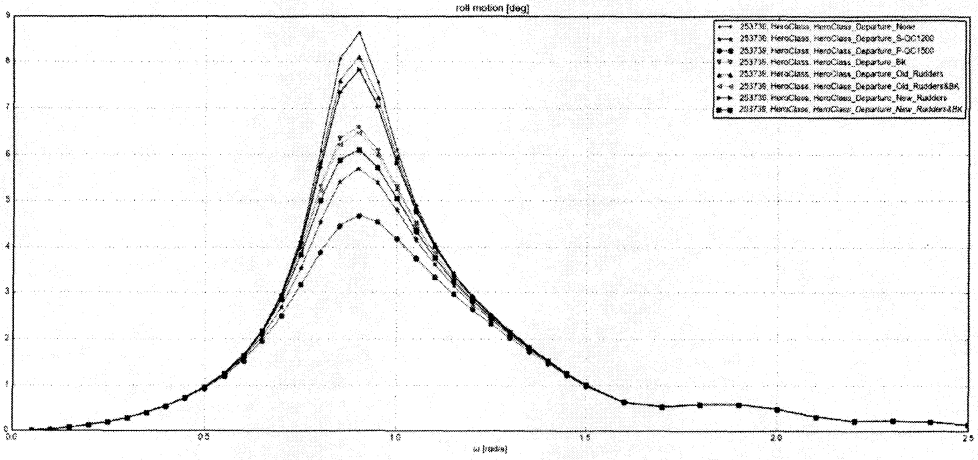
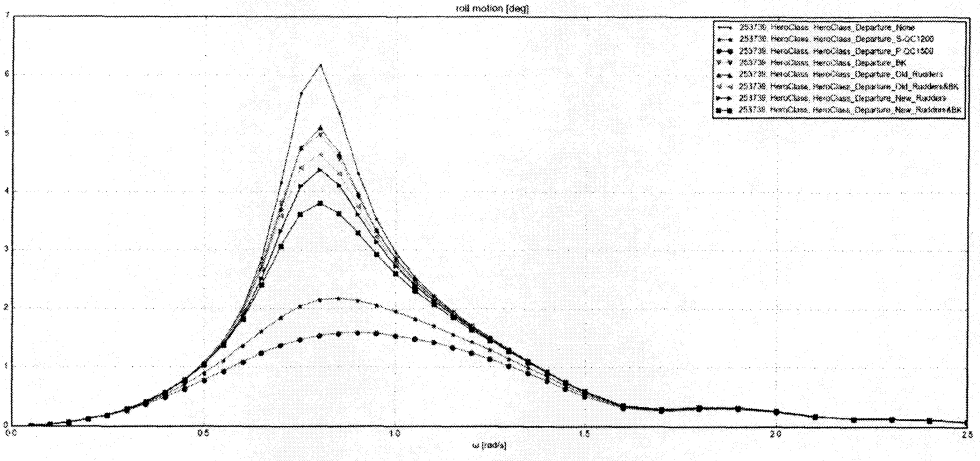
7.1.10 Roll RAO H = 1.0 [m] μ = 150 [deg]

Top to bottom: V = 0 [kn] V = 5 [kn] V = 10 [kn]







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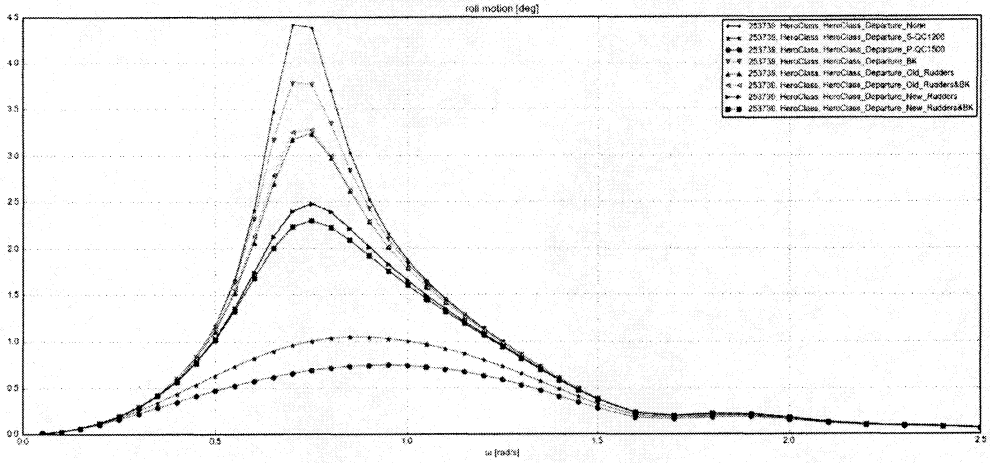
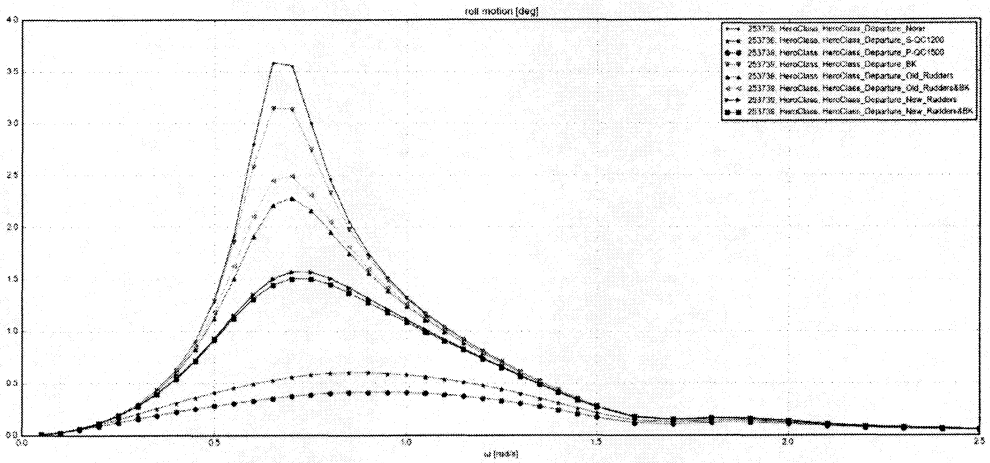
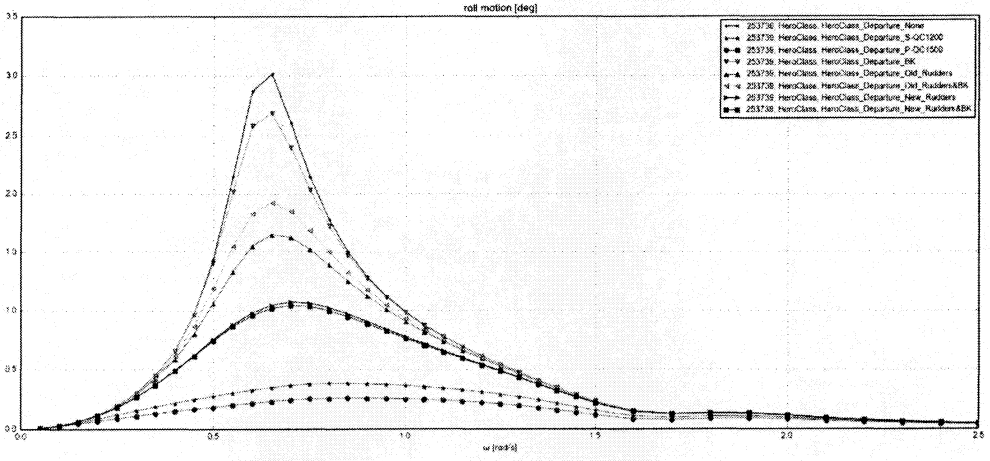
Roll RAO H = 1.0 [m] μ = 150 [deg]

Top to bottom: V = 15 [kn] V = 20 [kn] V = 25 [kn]







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7.2 Polar plots

The polar plots for roll and other variables are presented on the following pages.

Polar plots include heading variations in circumferential direction and speed variations in radial direction. The colours indicate the levels of response, mostly in RMS.

For each sea state and area combination the following plots are presented.

Variable	Response	Unit	# of plots
Roll	RMS	[deg]	6
Bridge lateral accelerations	RMS	[m/s^2]	6
RHIB station MSI	Probability	[%]	6
Pitch	RMS	[deg]	1
Bridge vertical accelerations	RMS	[m/s^2]	1
Sway accelerations	RMS	[m/s^2]	1
Heave accelerations	RMS	[m/s^2]	1
Green water events	Probability	[1/hr]	1
Bridge MSI	Probability	[%]	1

The first three variables are dependent on the roll stabilization method, which is why each method has its own polar plot. The remaining six variables were found to be roll independent or show negligible roll dependency. To avoid cluttering the results with too many plots, those variables are presented only once per sea state.

Since there are two different post processing tools used, there are small differences between MSI and green water plots on the one hand, and the RMS plots on the other. These difference include the omission of sea state information in the RMS plot headers. Also, in RMS plots the Bridge location is referred to as "ref_1" and Deck wetness as FEX_Deck.

The asymmetrical results in polar plots occur because some locations are defined away from centre line and therefore dependent on which side the waves are coming from.

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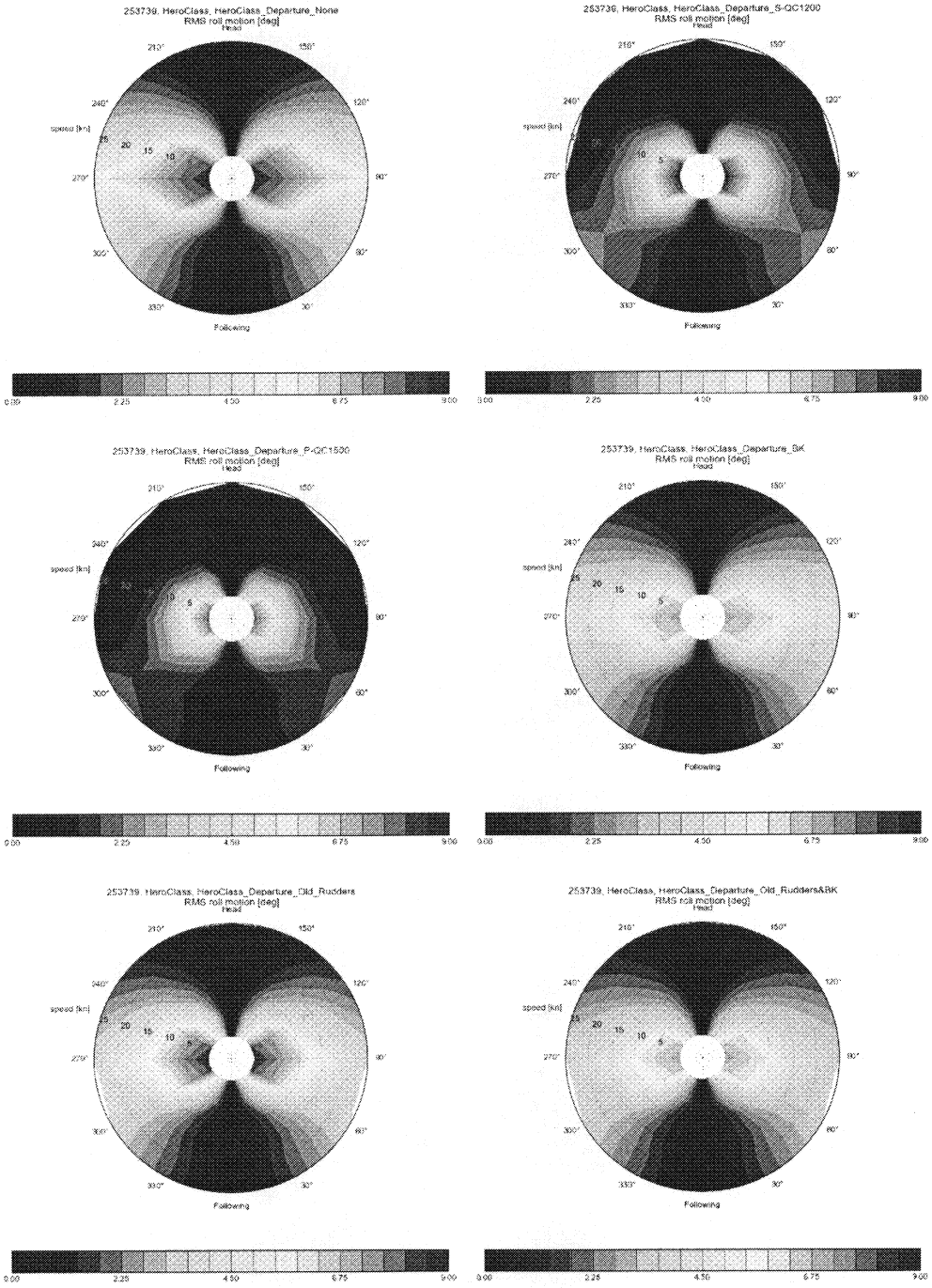
7.2.1 Great Lakes SS5 - Roll



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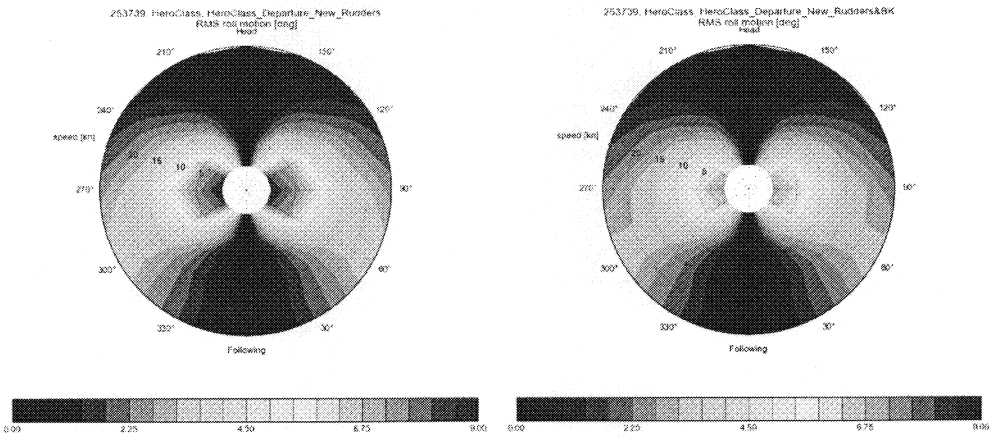
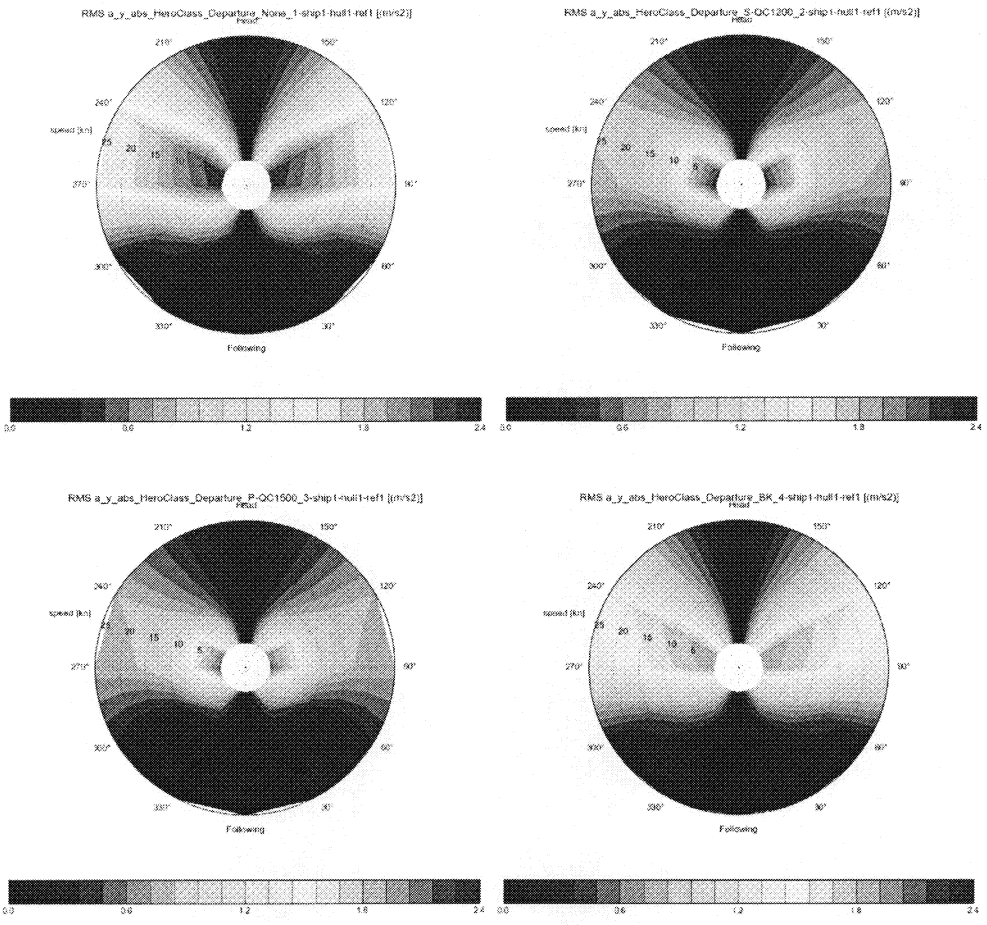


Great Lakes SS5 – Bridge transverse accelerations



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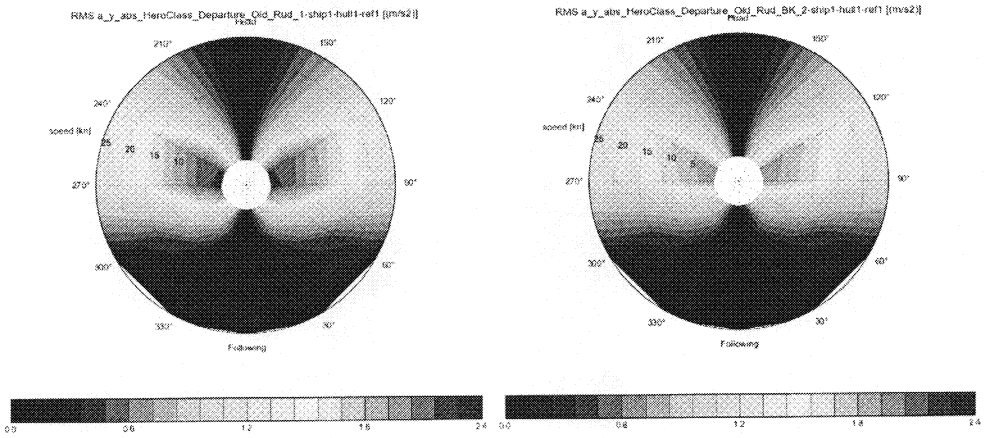
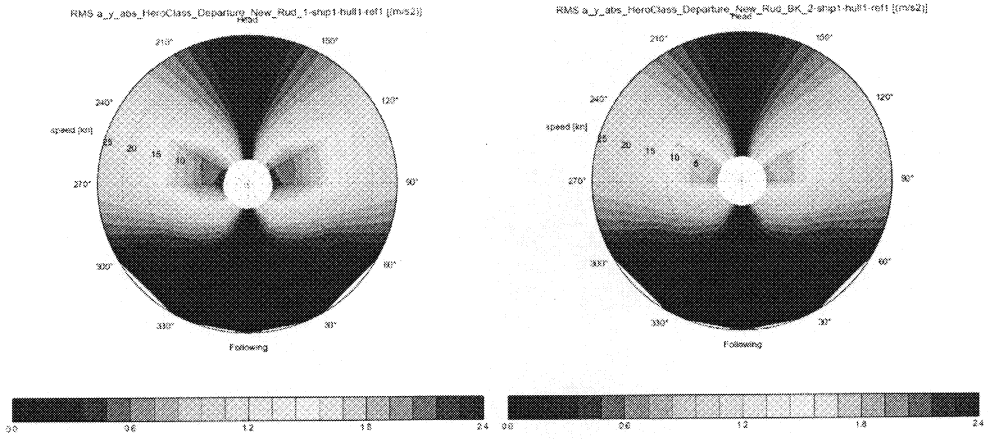
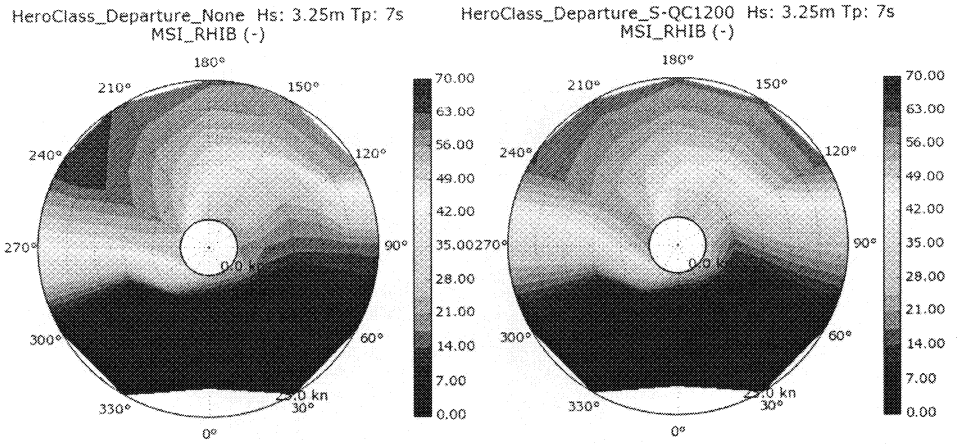




Great Lakes SS5 – RHIB station MSI



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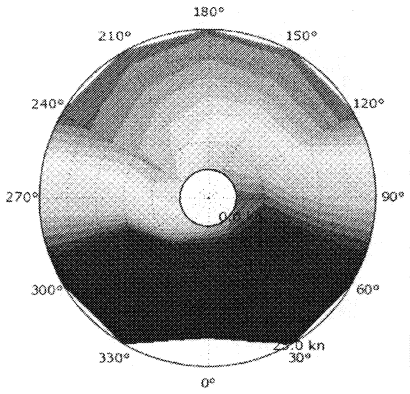
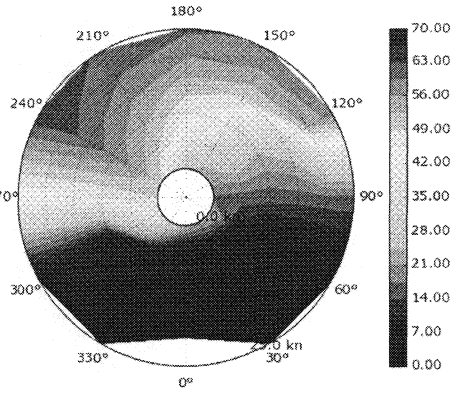
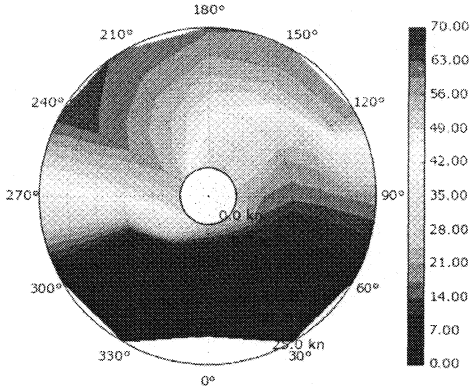
HeroClass_Departure_P-QC1500 Hs: 3.25m Tp: 7s MSI_RHIB (-)



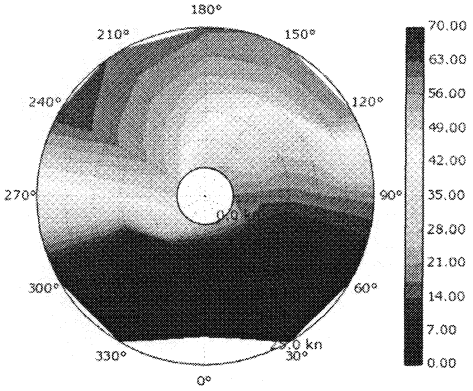
HeroClass_Departure_BK Hs: 3.25m Tp: 7s MSI_RHIB (-)



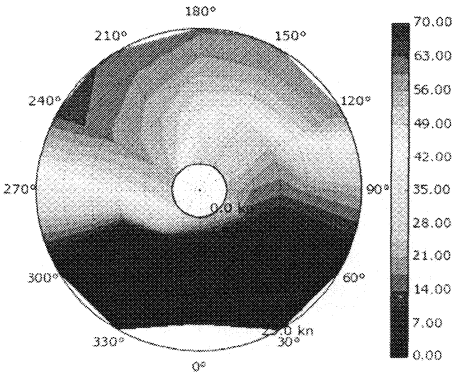
HeroClass_Departure_Old_Rudders Hs: 3.25m Tp: 7s MSI_RHIB (-)



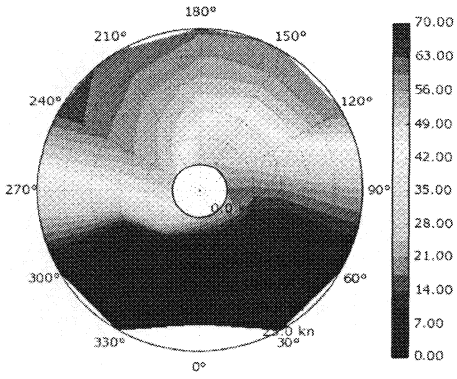
HeroClass_Departure_Old_Rudders&BK Hs: 3.25m Tp: 7s MSI_RHIB (-)



HeroClass_Departure_New_Rudders Hs: 3.25m Tp: 7s MSI_RHIB (-)



HeroClass_Departure_New_Rudders&BK Hs: 3.25m Tp: 7s MSI_RHIB (-)



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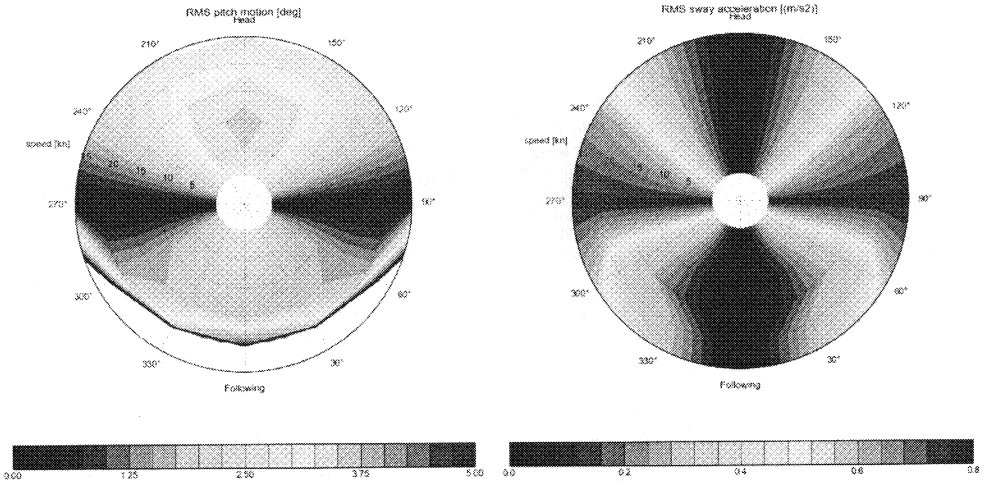
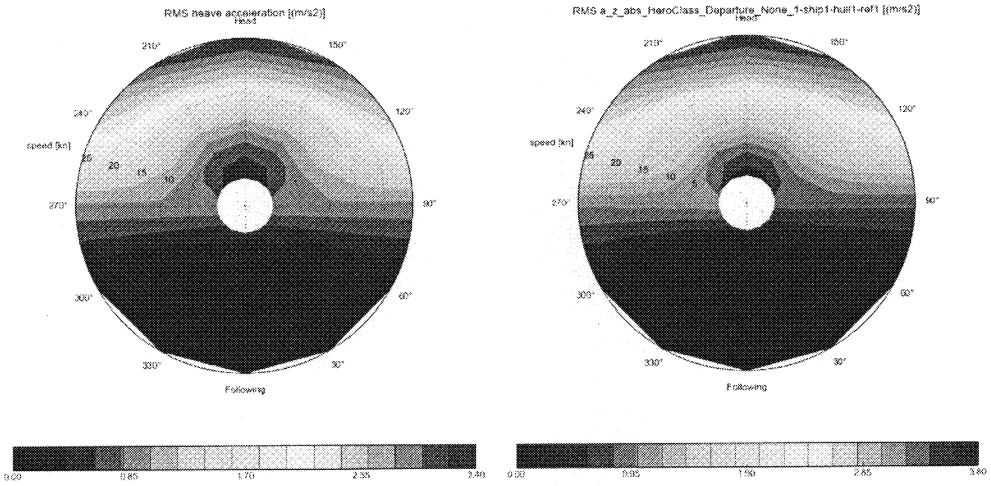
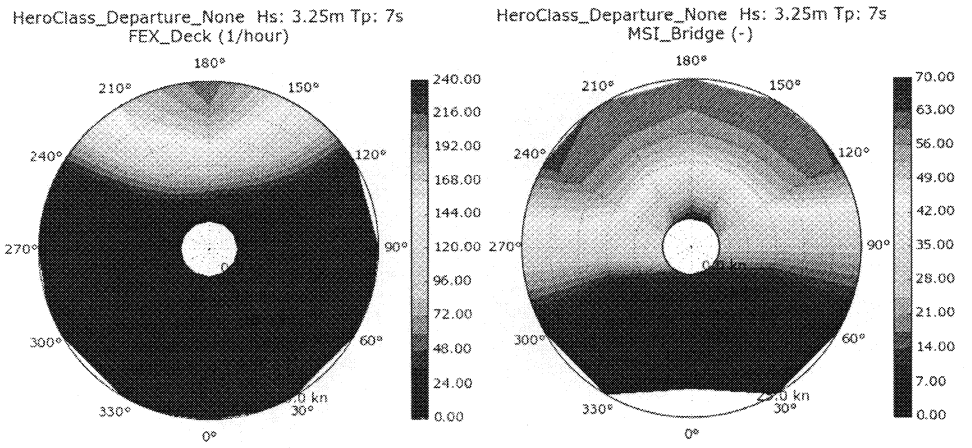
Great Lakes SS5 – Various parameters







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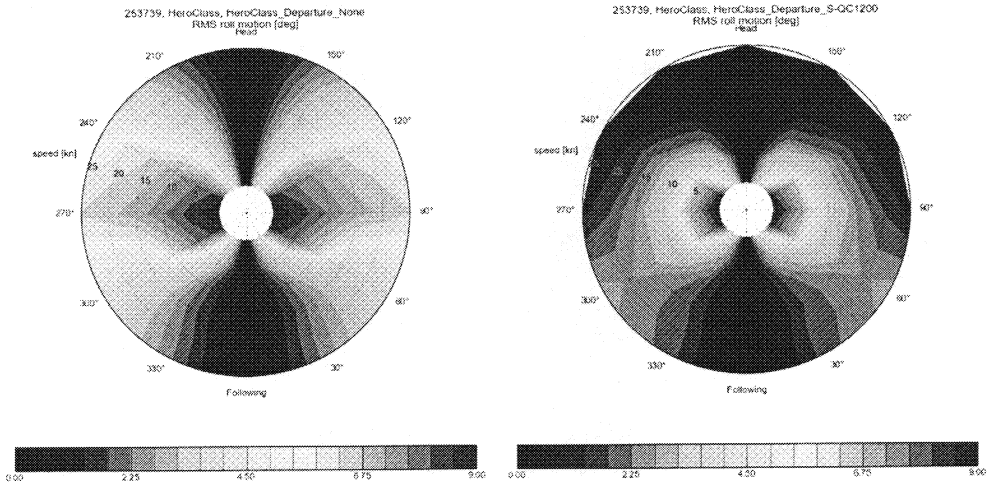
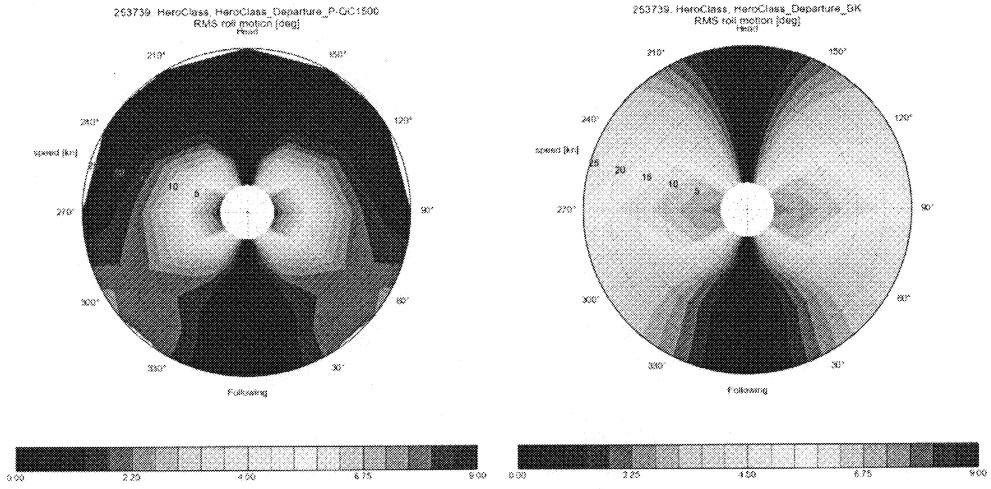
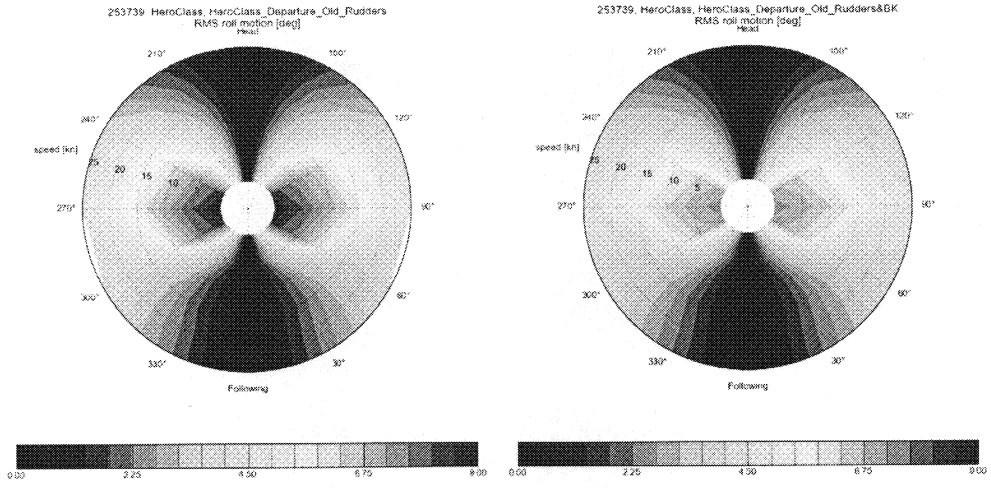
7.2.2 Great Lakes SS6 – Roll







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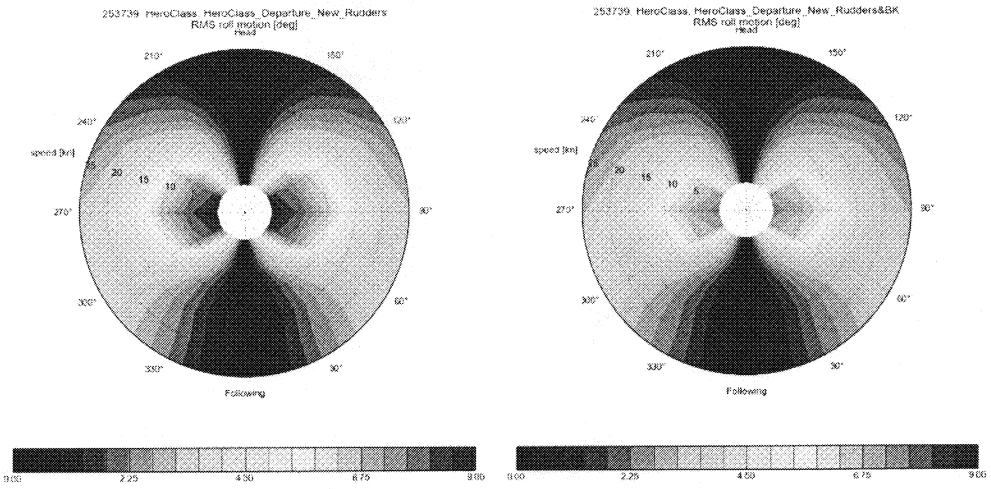
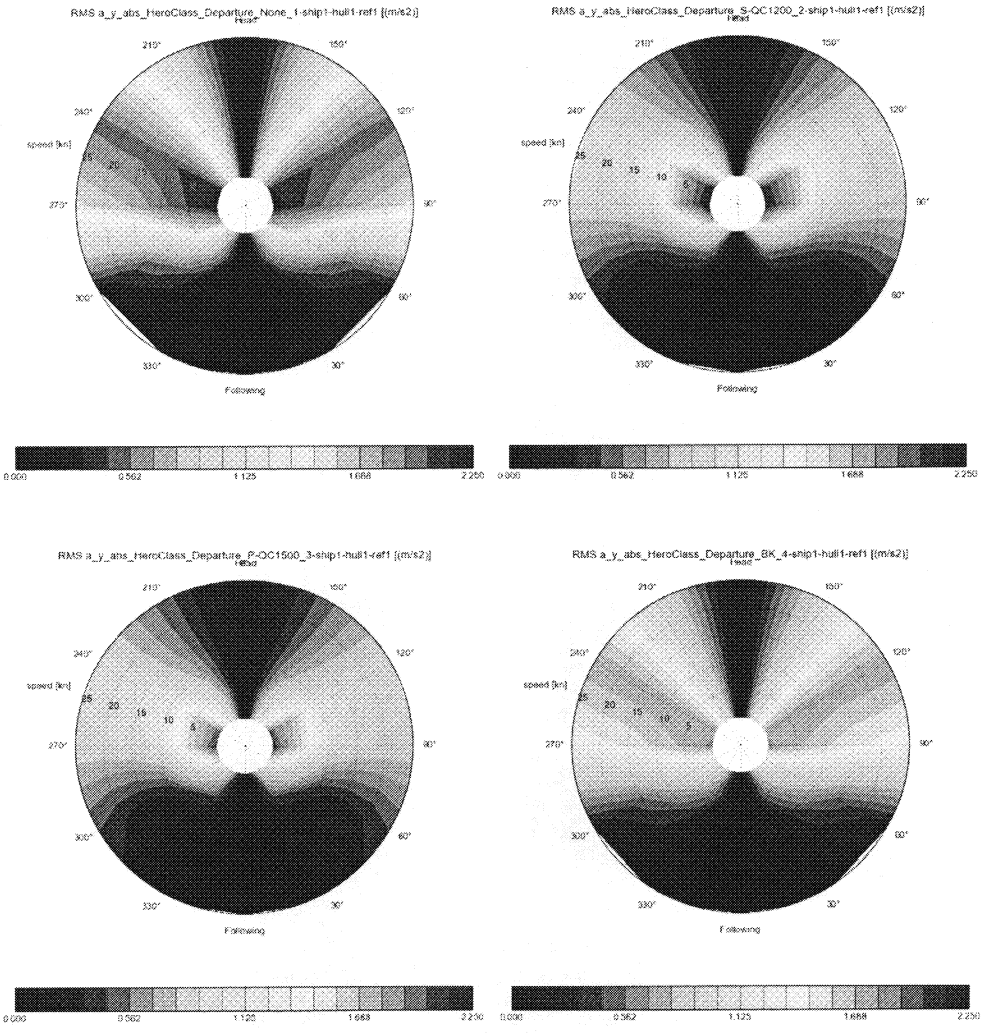


Great Lakes SS6 – Bridge transverse accelerations



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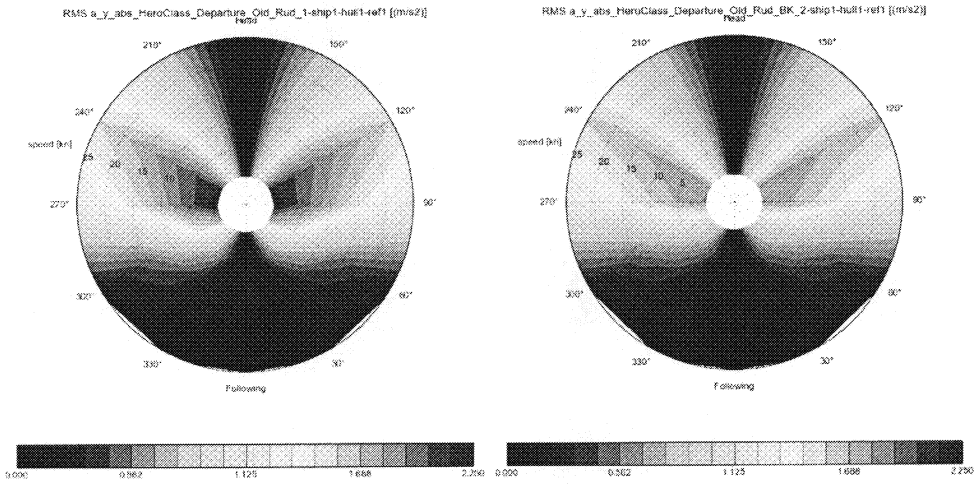
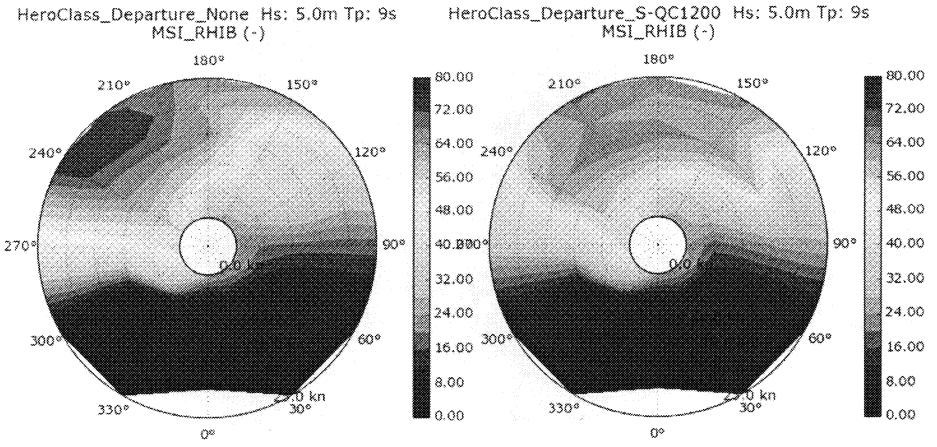


Great Lakes SS6 – RHIB station MSI



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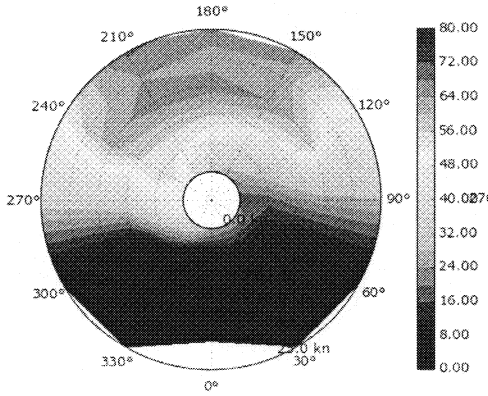
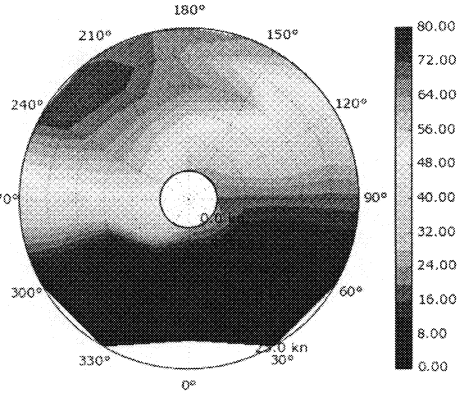
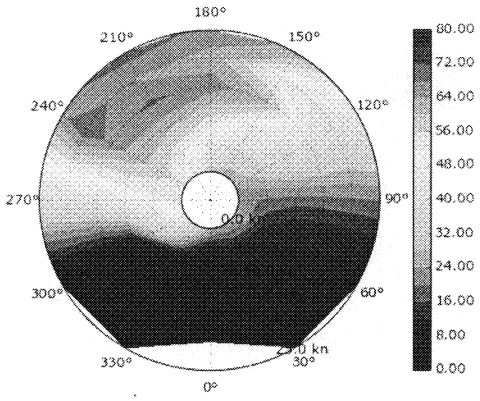
HeroClass_Departure_P-QC1500 Hs: 5.0m Tp: 9s
MSI_RHIB (-)



HeroClass_Departure_BK Hs: 5.0m Tp: 9s
MSI_RHIB (-)



HeroClass_Departure_Old_Rudders Hs: 5.0m Tp: 9s
MSI_RHIB (-)



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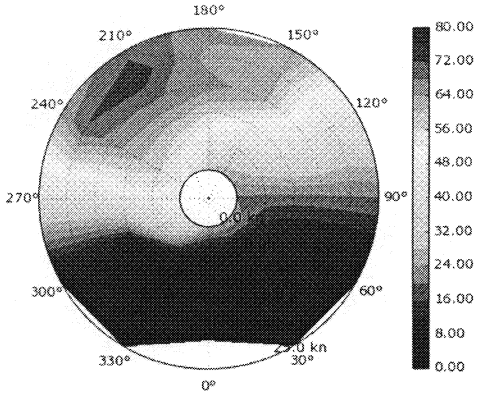

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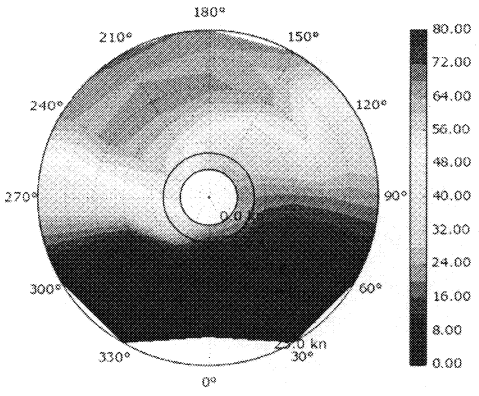

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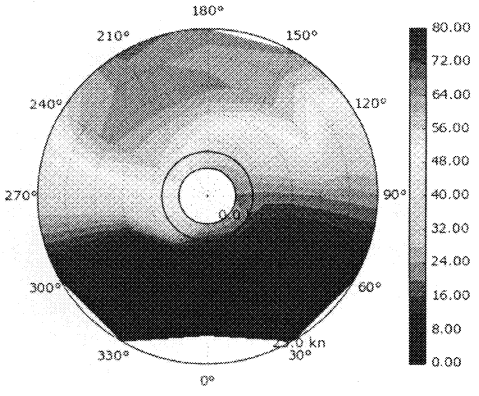

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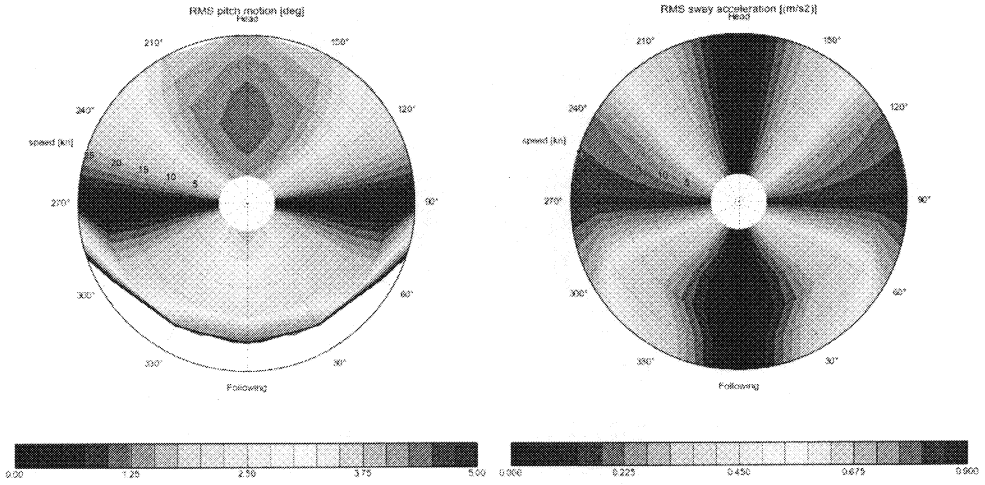
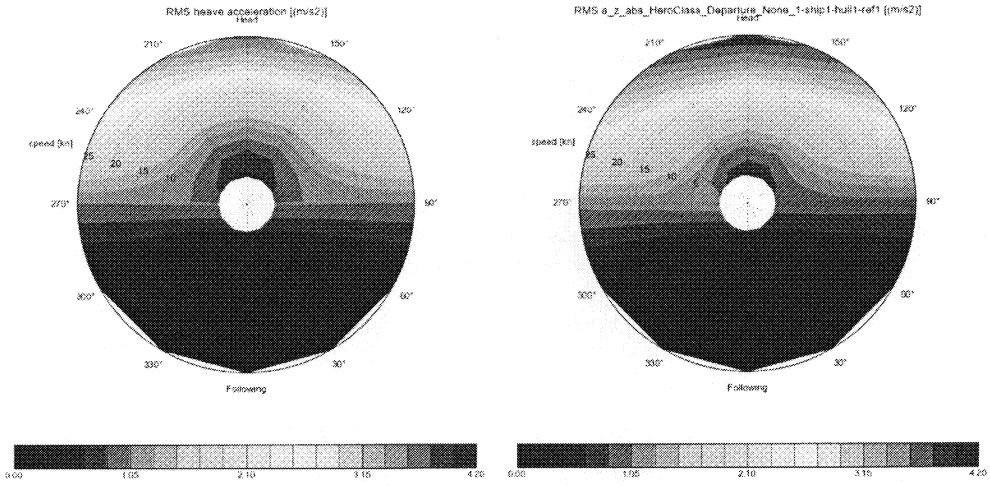
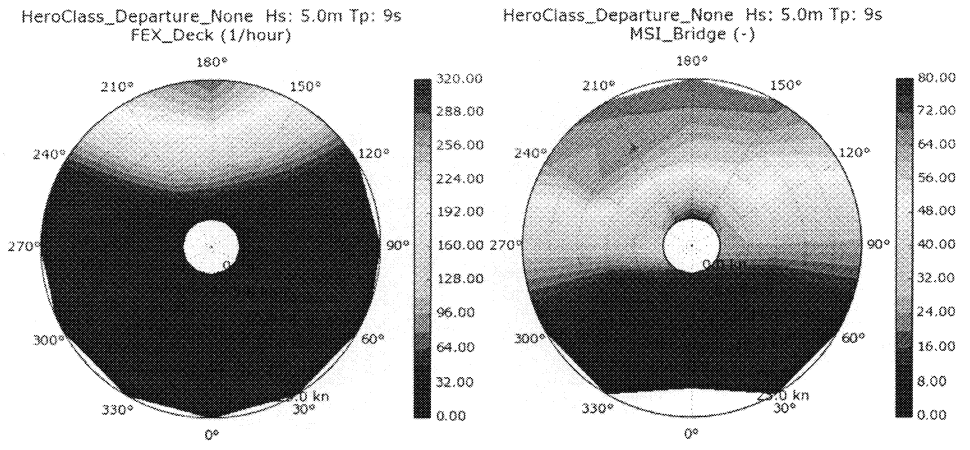
Great Lakes SS6 – Various parameters







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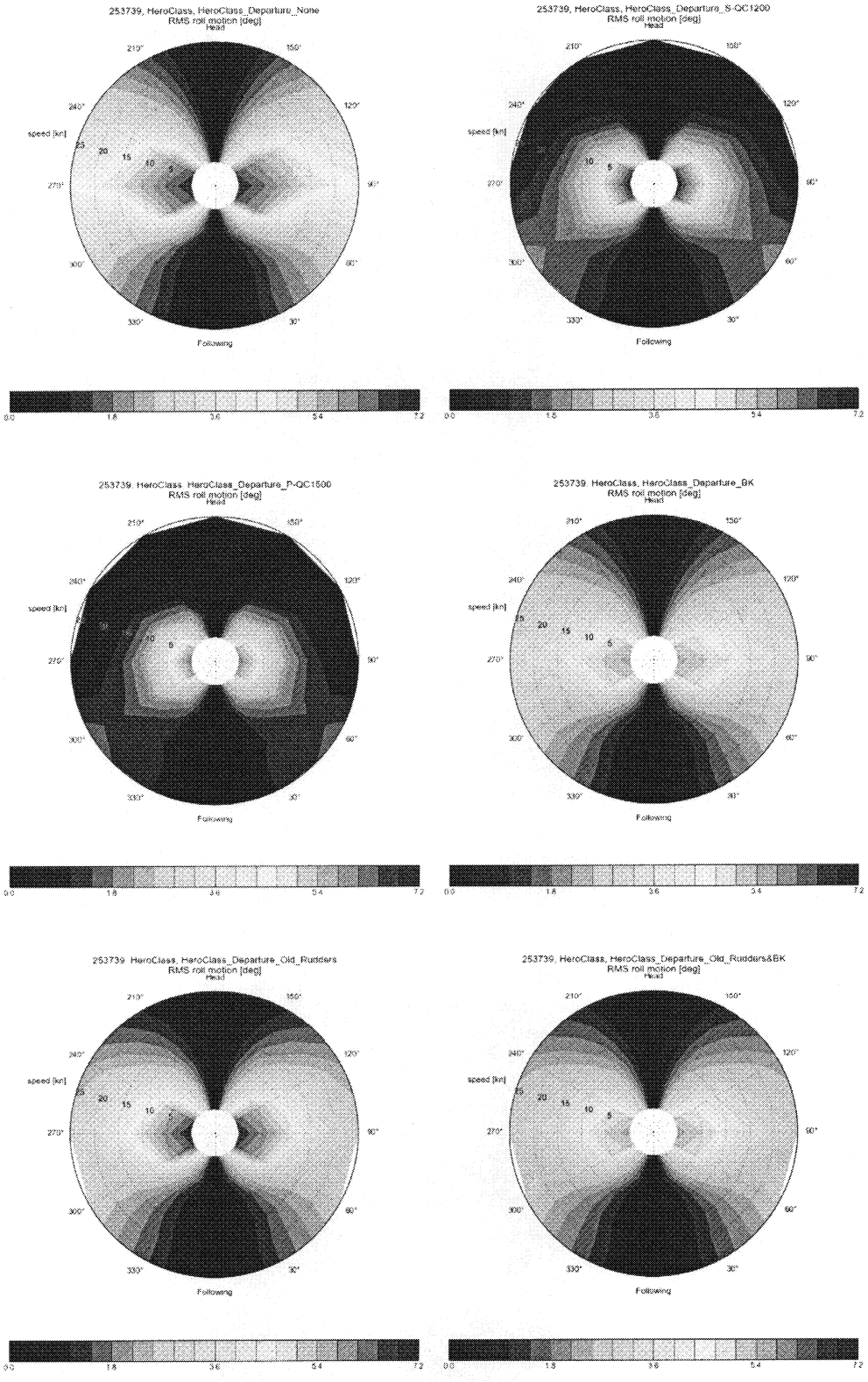
7.2.3 North Atlantic / Pacific SS5 – Roll



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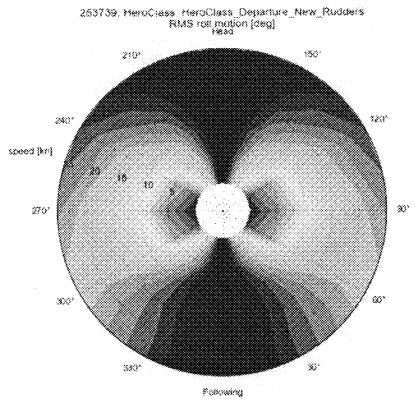
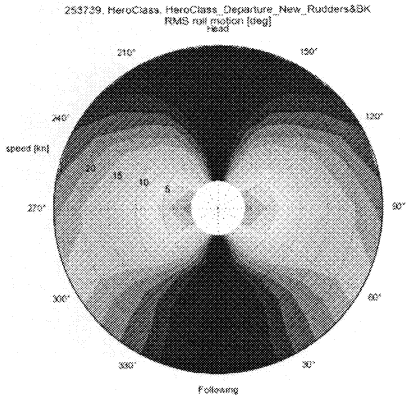
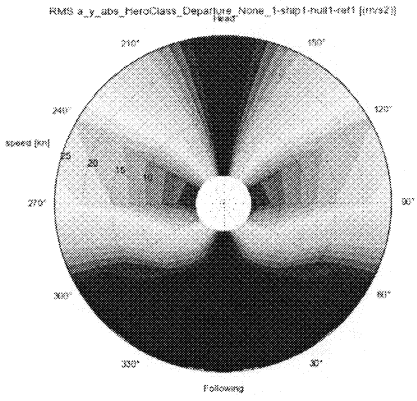
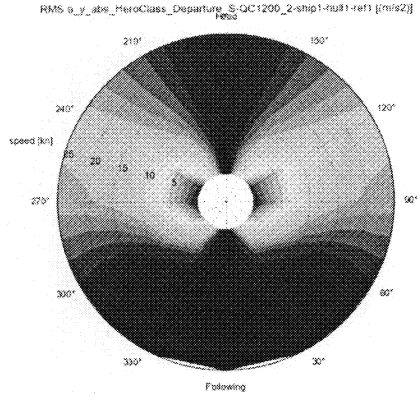
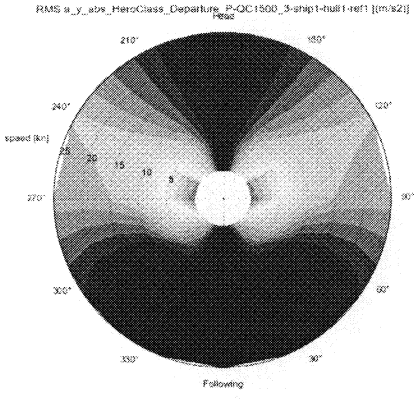


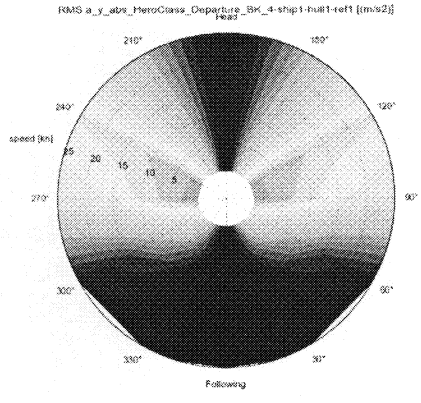


North Atlantic / Pacific SS5 – Bridge transverse accelerations









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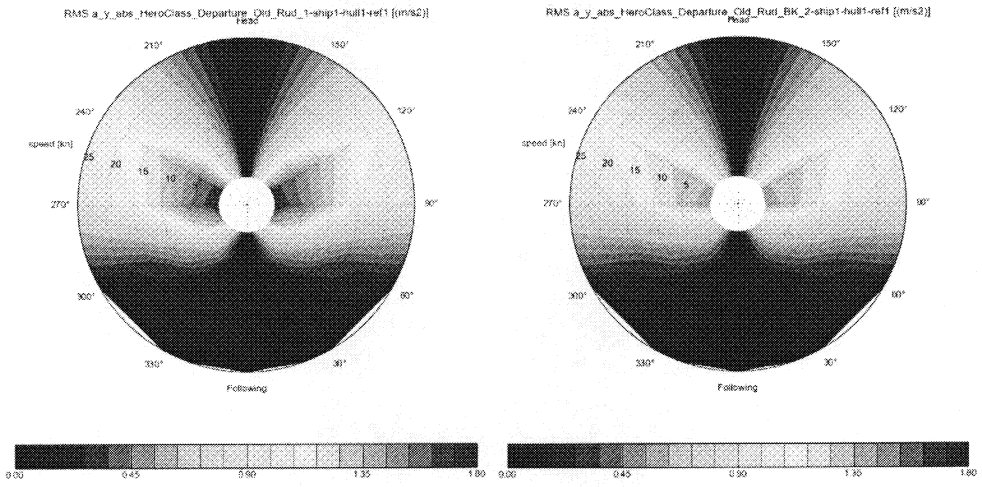
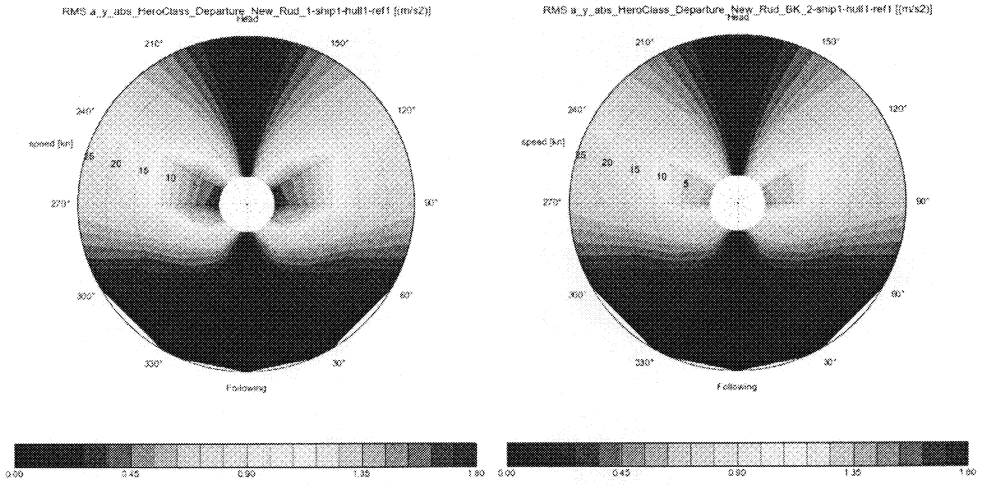
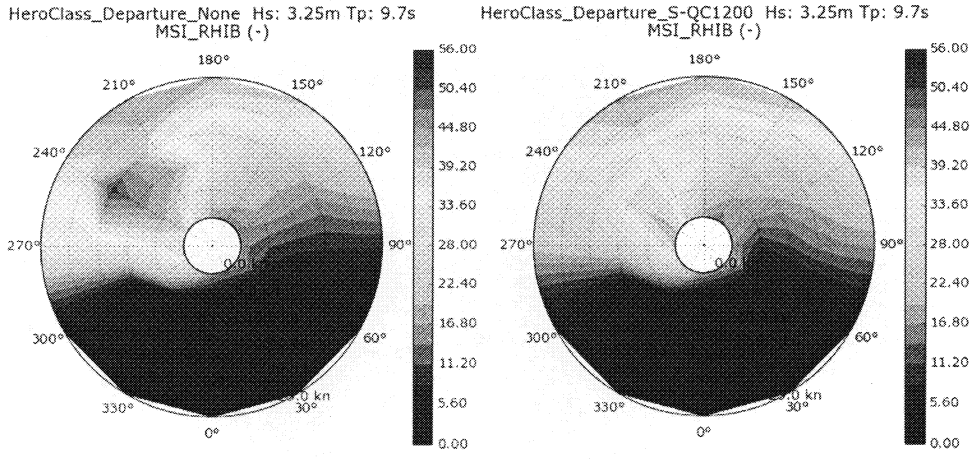




North Atlantic / Pacific SS5 – RHIB station MSI



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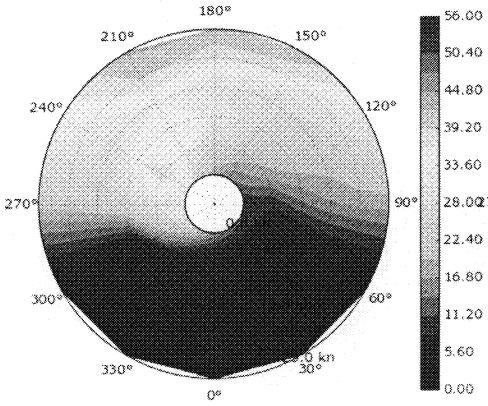
HeroClass_Departure_P-QC1500 Hs: 3.25m Tp: 9.7s
MSI_RHIB (-)



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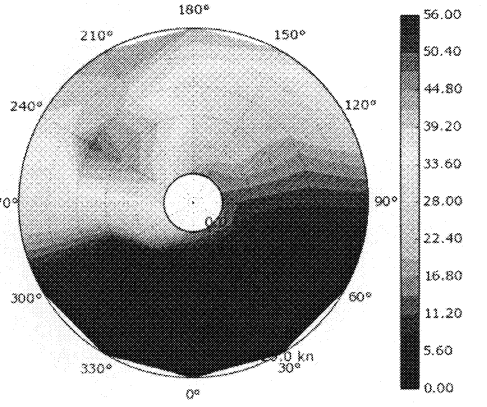
MSI_RHIB (-)



HeroClass_Departure_Old_Rudders Hs: 3.25m Tp: 9.7s
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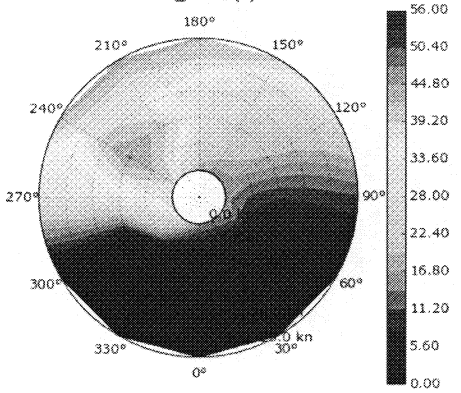
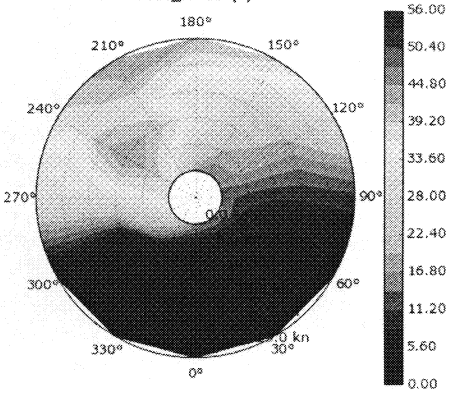


HeroClass_Departure_Old_Rudders&BK Hs: 3.25m Tp: 9.7s
MSI_RHIB (-)



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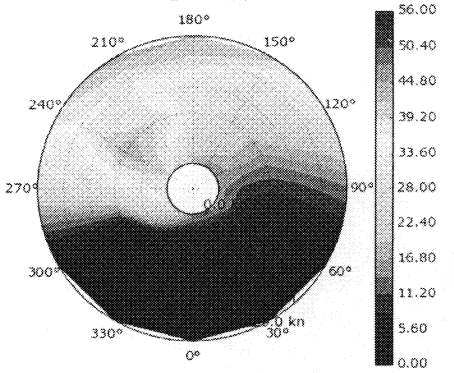

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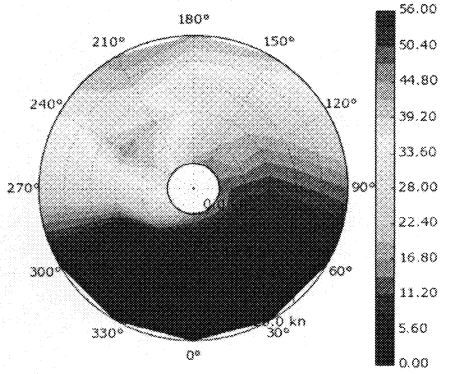

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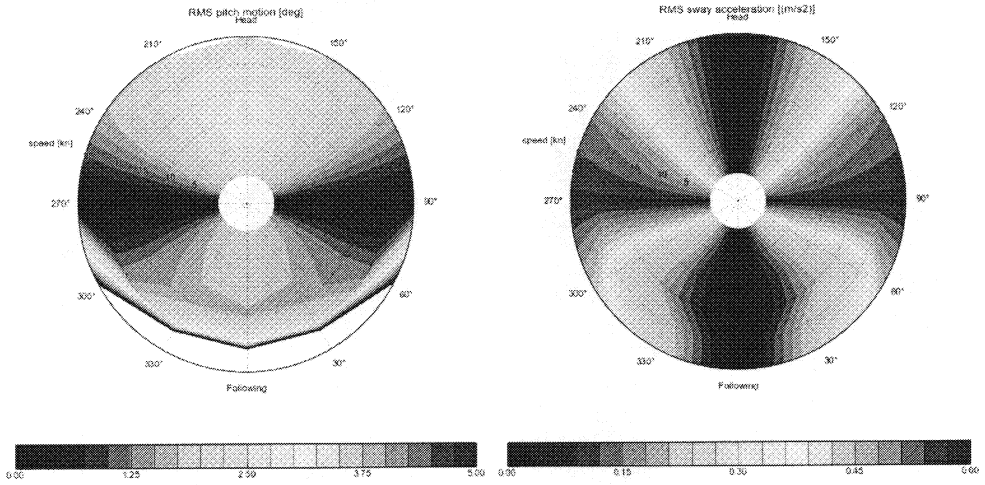
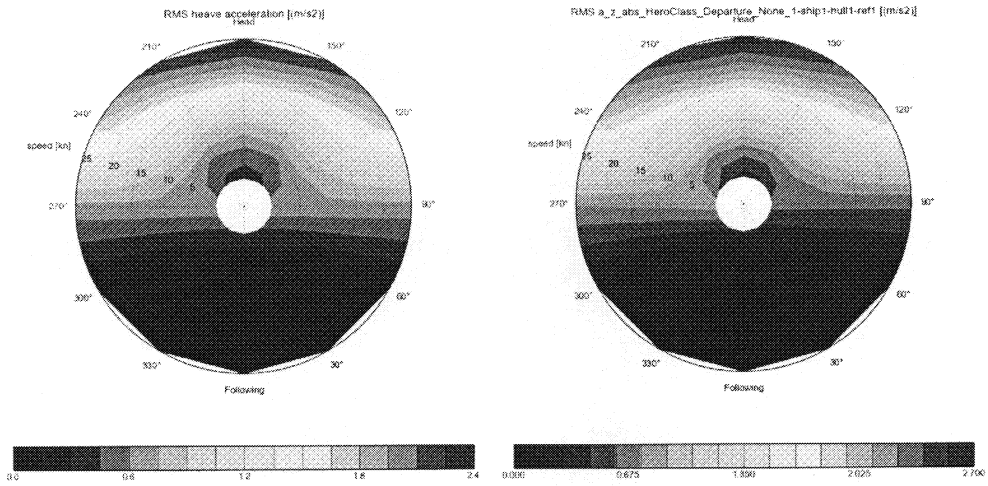
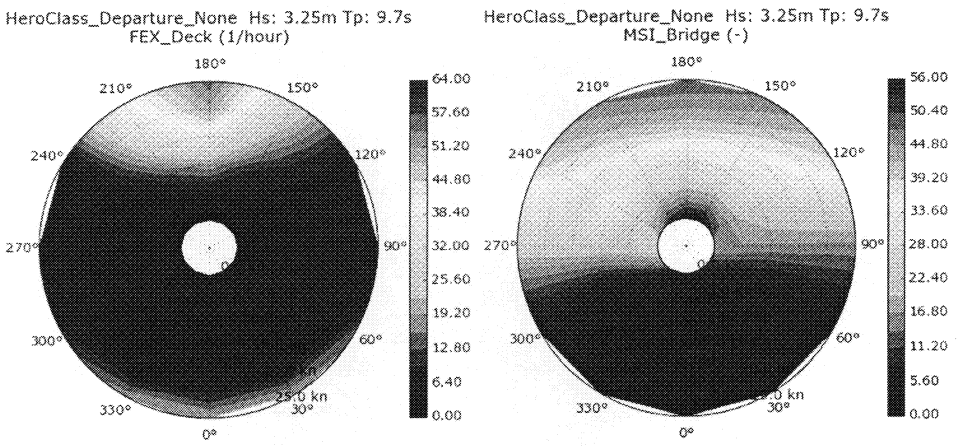
North Atlantic / Pacific SS5 – Various parameters







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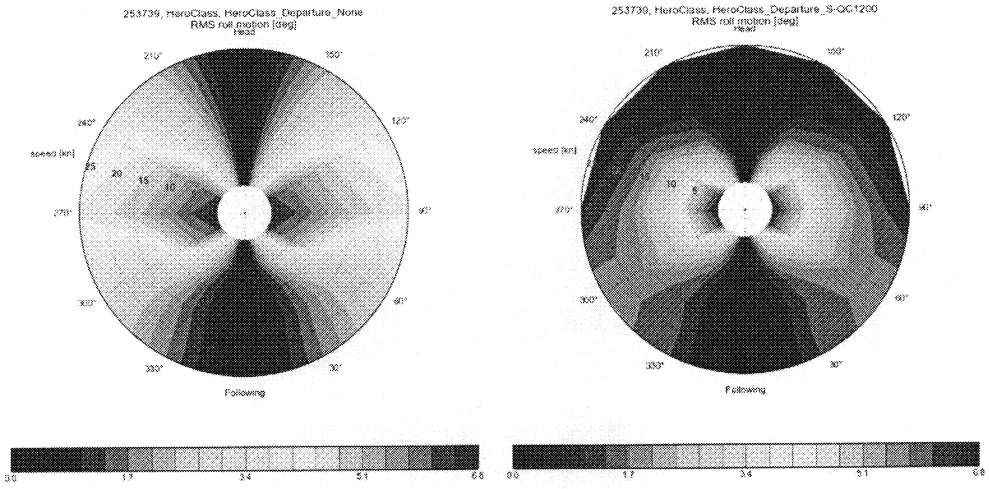
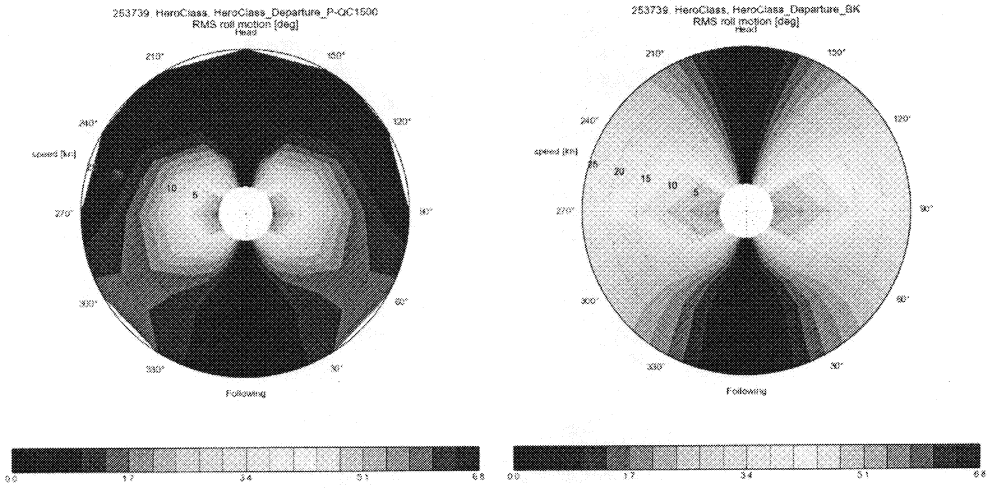
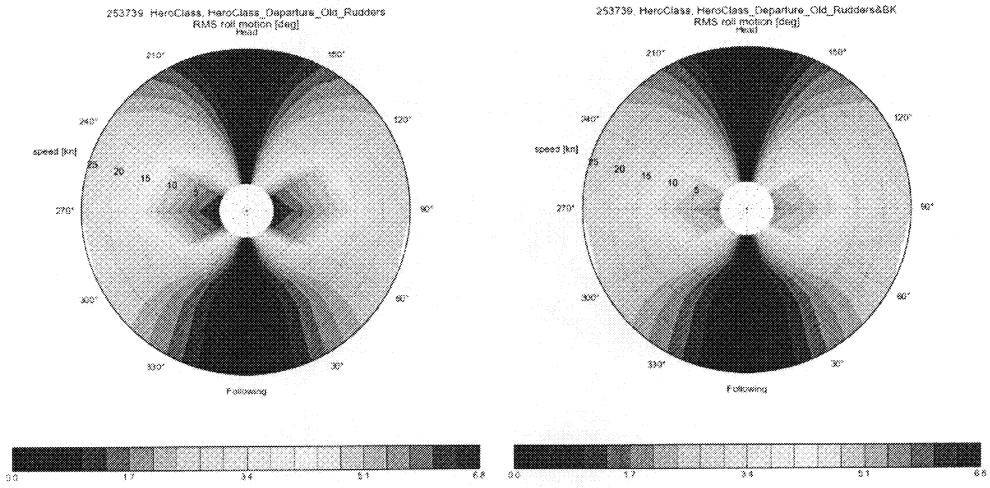
7.2.4 North Atlantic / Pacific SS6 – Roll







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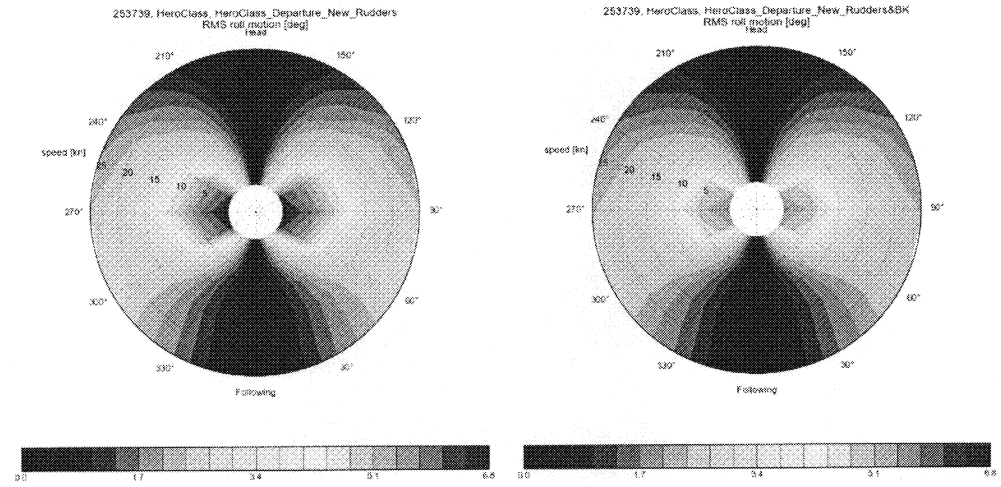
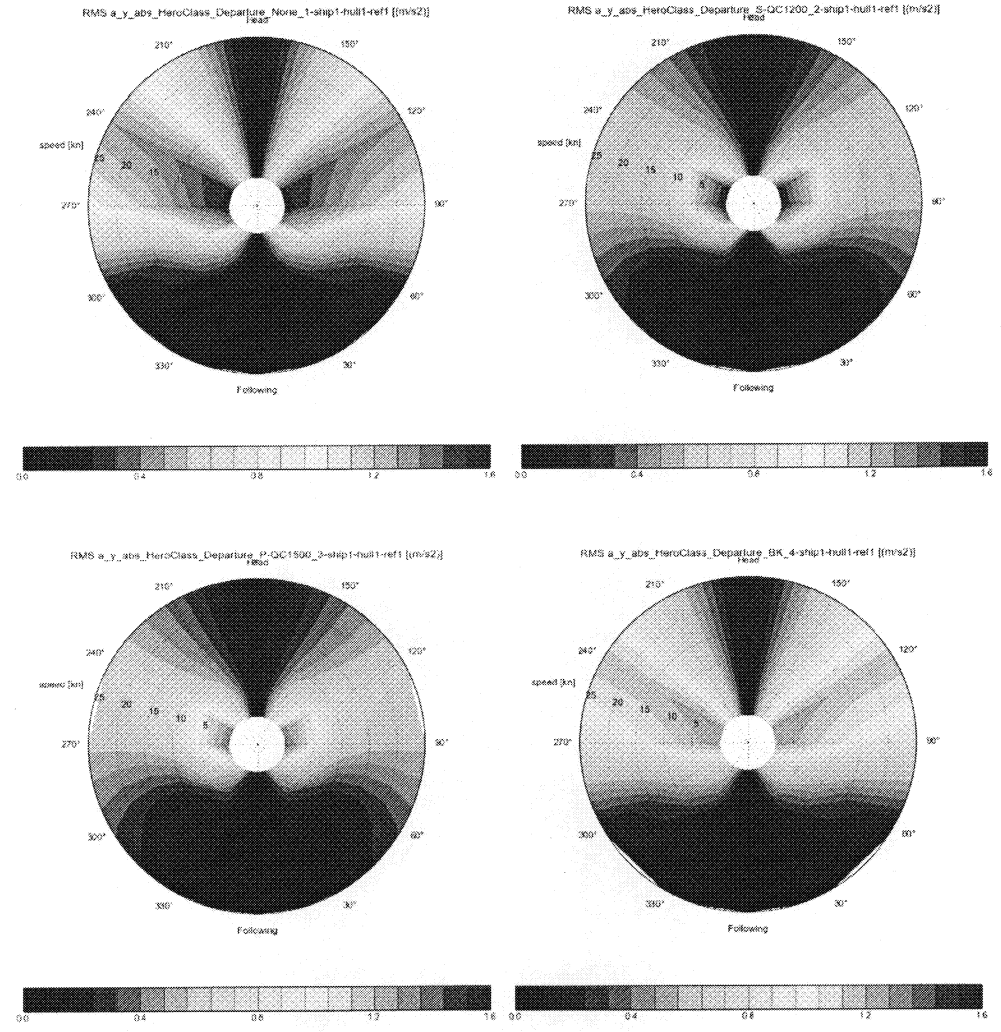


North Atlantic / Pacific SS6 – Bridge transverse accelerations



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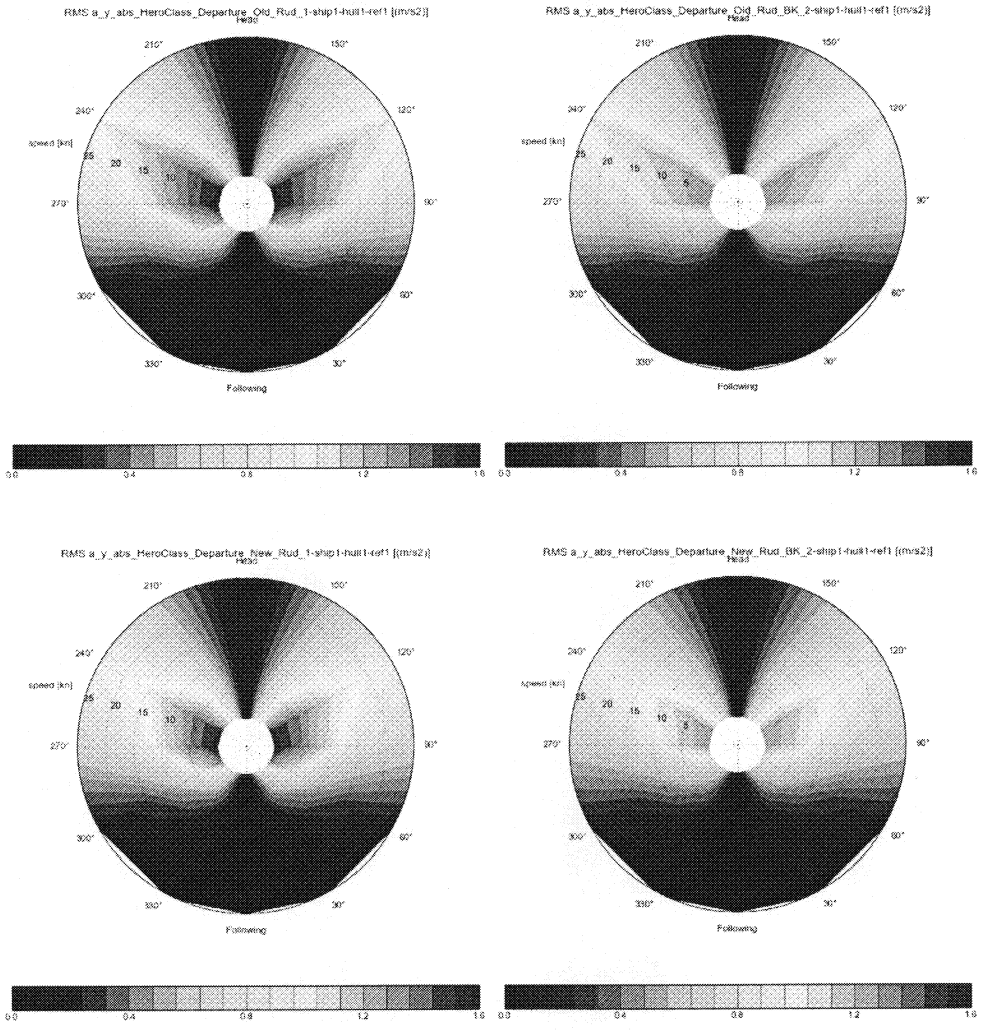
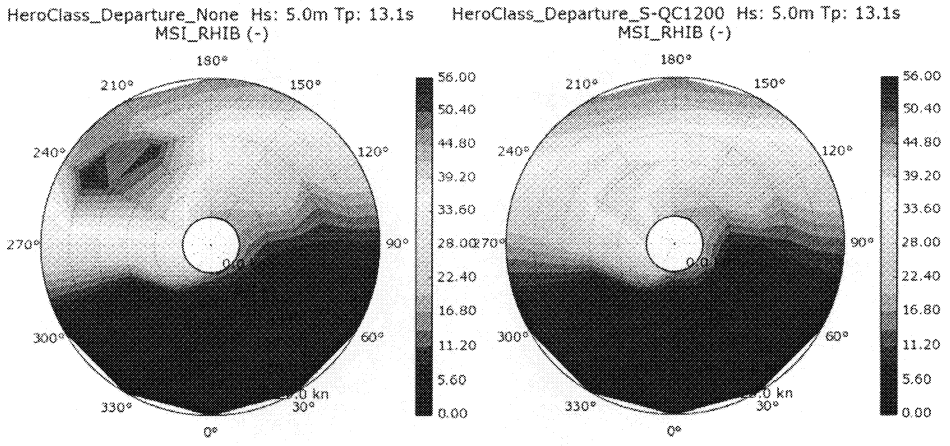


North Atlantic / Pacific SS6 – RHIB station MSI



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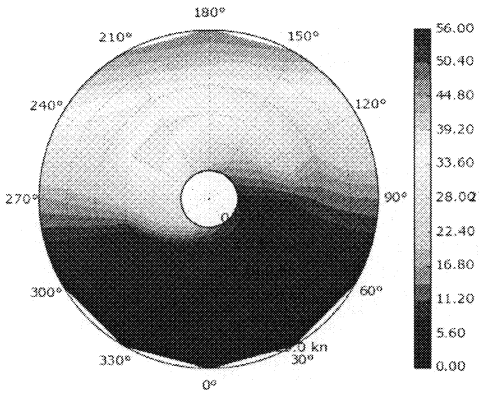
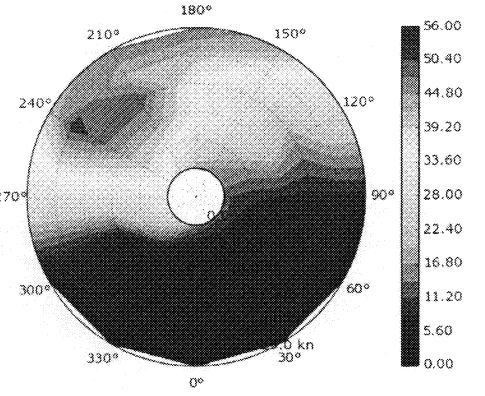
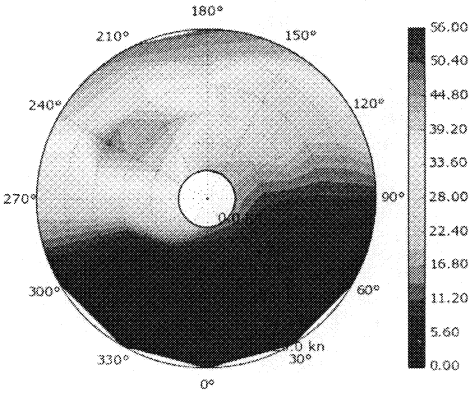
HeroClass_Departure_P-QC1500 Hs: 5.0m Tp: 13.1s
MSI_RHIB (-)



HeroClass_Departure_BK Hs: 5.0m Tp: 13.1s
MSI_RHIB (-)



HeroClass_Departure_Old_Rudders Hs: 5.0m Tp: 13.1s
MSI_RHIB (-)



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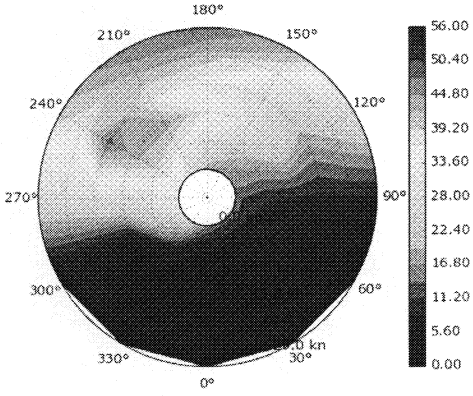

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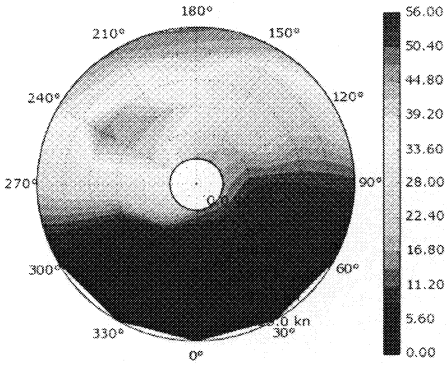

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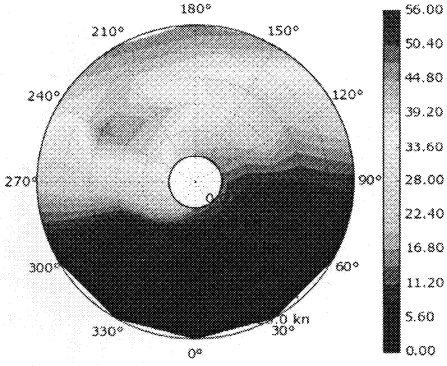

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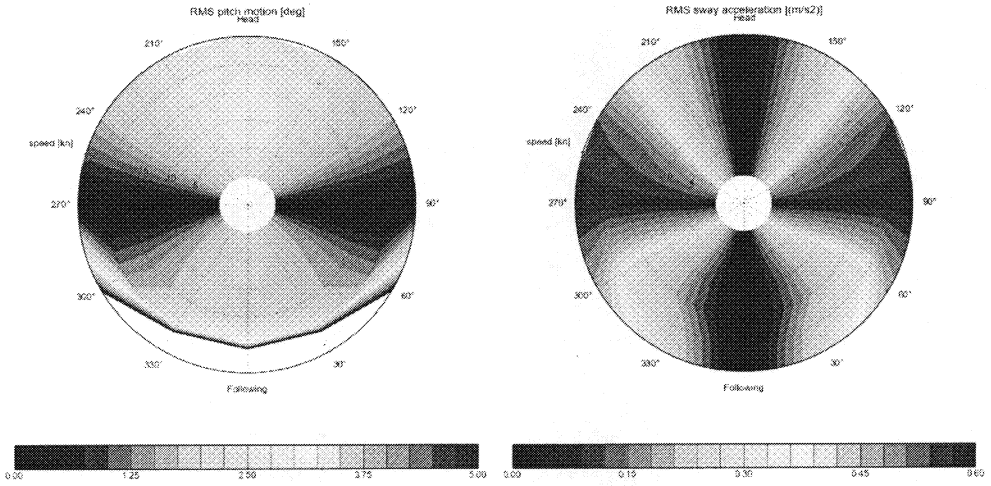
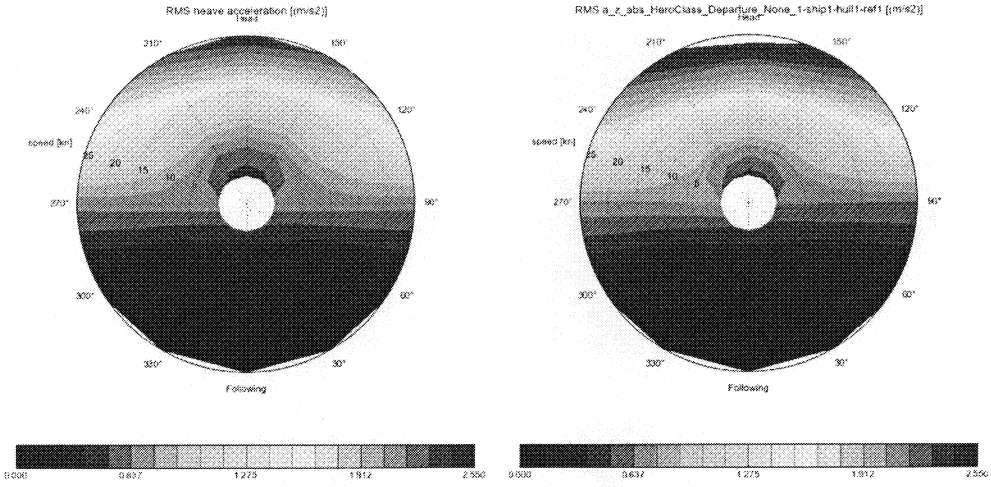
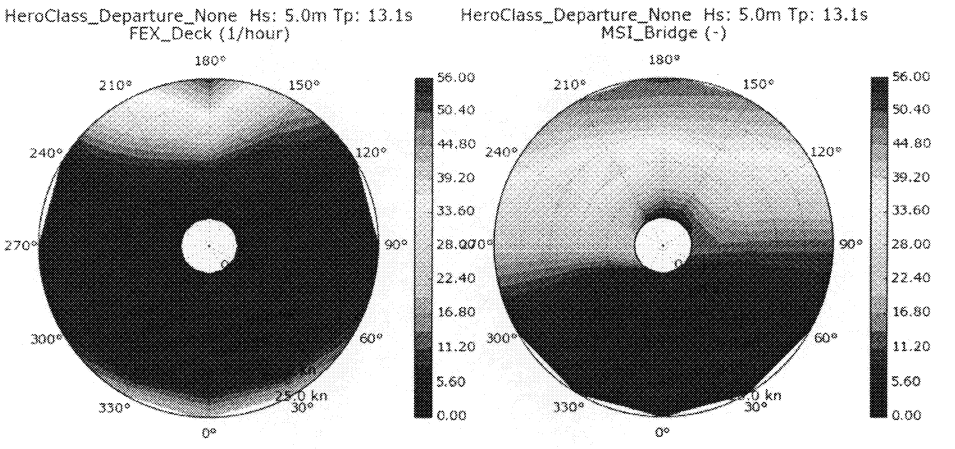
North Atlantic / Pacific SS6 – Various parameters







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8 Discussion and Conclusion

The discussion section below contains some general comments on the accuracy and right way of interpreting the results. The conclusion section contains several statements that can be made based on the results.

8.1 Discussion

The design of the appendages, i.e. dimensions and location and parameters, are first estimates, based on calculations or experience, and not to be taken as final values. The bilge keel design is by no means optimally positioned with respect to flow lines. If a more accurate design and resistance is required in the future, CFD analysis is recommended.

The software that is used is linear 2D strip theory. This means that the waterline plane of the ship does not change with waves or motions. This assumption is valid for small waves and motions, but becomes questionable for waves heights that exceed the draught. These limitations should be kept in mind when interpreting any of the results.

The roll damping linearization means that RAOs are not very meaningful to look at. This can clearly be seen when looking at the peak response of the unstabilised vessel in beam seas for 0.5 m and 1.0 m waves. The peak roll responses are around 11 and 17 degrees respectively, indicating it is by no means linear. It is therefore much more meaningful to look at RMS response in sea states.

The roll RAO plots show a dominant peak at the natural frequency, and sometimes other peaks at maximum wave excitation or roll-sway coupling frequencies. Generally speaking: the higher the velocity, the higher the roll damping.

There are some zero-encounter issues in the results, mainly visible for pitch. This occurs for stern (quartering) waves that travel with the ship, a dangerous situation that is avoided by captains. The mathematic of the tool failed to cope with this and pitch results where therefore cut and should be ignored for these headings.

MSI results are based on unaccustomed sailors and should therefore not be taken as absolute numbers. The MSI calculations are based on vertical motions, which is why there is no effect of roll on MSI in the COG for example. However, relative comparison is still valid between sea states and roll damping methods.

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8.2 Conclusions

The most relevant results are the RMS roll polar plots. The following conclusions can be drawn based on these:

- Shorter and higher sea states are worse for roll, particularly when peak periods are close to the natural roll period. JONSWAP is worse than Pierson Moskowitz. These two factors make the Great Lakes the worse region of the two.
- Active stabilizer fins are far superior to the other methods at high speed. The difference between the two fins (S- and P-series) is small at nonzero speed.
- Bilge keels and P-series are the only roll damping methods that act at zero speed. In general there is a turning point for which of the two methods is most effective. For low Hs the P-series is better. The lowest Hs at which bilge keels become better is at Hs = 1.3 m, at Tp = 6 seconds for JONSWAP spectra. Other peak periods and Pierson-Moskowitz spectrum will shift the turning points to higher Hs. See Appendix A for extra plots illustrating this effect.
- The active rudders using existing rudder controls are quite effective, but only at speed. They are better than bilge keels at max speed, but about the same at cruising speed. At zero speed they give no damping. Note that the existing rudder controls could be unsuited for the intense use required for active damping!
- The active rudders using new rudders controls are more effective than the existing ones, and perform somewhere in between existing active rudders and the stabilizer fins.

Based on the other plots the following conclusions can be drawn:

- Bridge transverse accelerations follow the same pattern as roll motion RMS.
- Motion sickness at the RHIB Launching station is influenced somewhat by roll stabilizers, mainly at speed. The effect is not very large, as roll is only one of three contributors, heave and pitch being the other two.
- The other variables are basically unaffected by roll. The coupling between them and roll is too small to be visible in the plots.

Based on the speed and range calculations, the following conclusions can be drawn:

- Active rudders are best for top speed and range, as these remain unchanged.
- Bilge keels and the zero-speed stabilizers are similar and worst for both top speed and range.
- The regular stabilizer fin performs somewhere in the middle.

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3. **Journée, J.M.J. & Massie, W.W.** ***Offshore Hydromechanics.*** **s.l. : Delft University of Technology, January 2001.**

4. ***Global Wave Statistics.*** **s.l. : British Maritime Technology Limited.**

5. ***Selection and Evaluation of Ship Roll Stabilization Systems.*** **Sellars, Frank H. & Martin, John P. 2, s.l. : Marine Technology, 1992, Vol. 29.**

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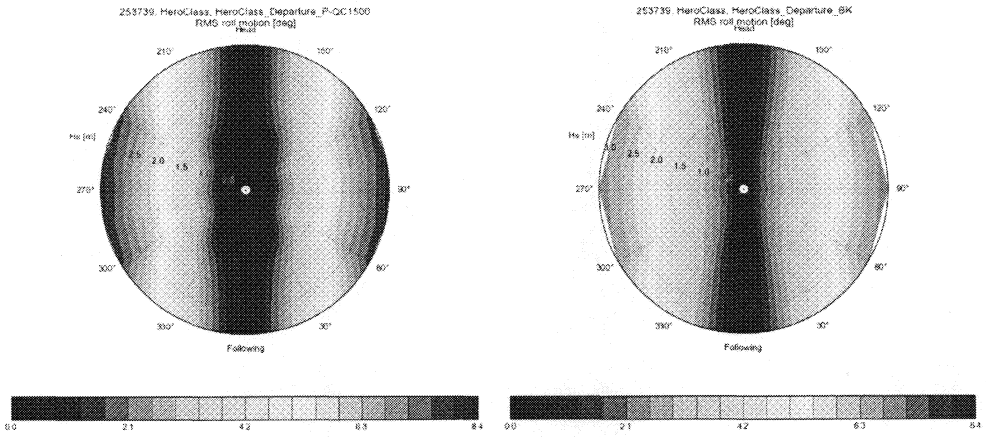
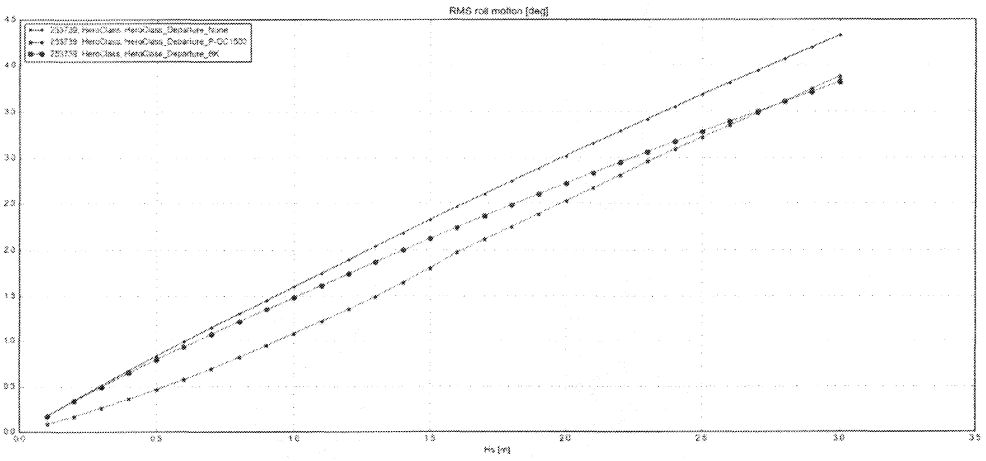
Appendix A Bilge keels versus P-series

Both bilge keels and the P-series fin give roll stabilization at zero speed. For low wave heights the P-series fin is better, but above a certain wave height (depending on wave period) bilge keels becomes better. Below are some results to show the performance of the two systems, both in polar plot for every heading and in graph form for beam seas only.



A 1. RMS roll for varying wave heights (radial direction) and headings. Tp = 6 seconds and spectrum type is JONSWAP.



A 2. RMS roll in beam seas at zero speed. Tp = 4 seconds.

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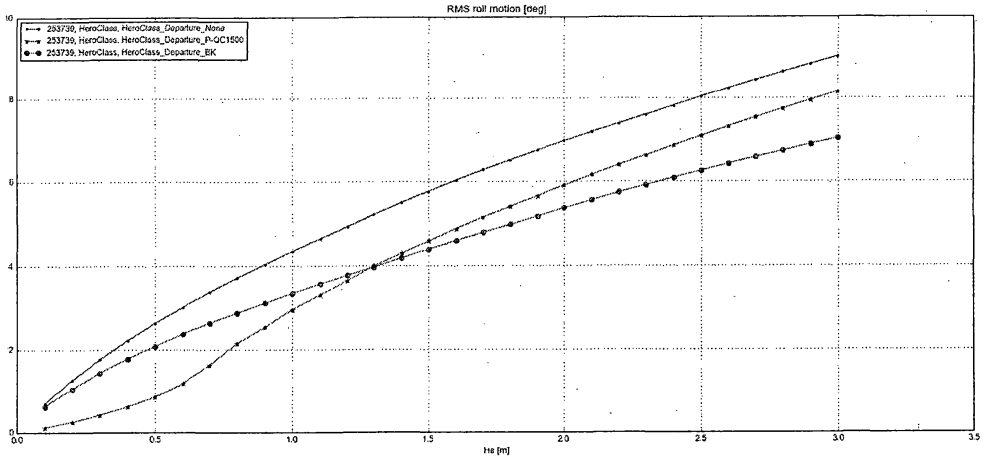
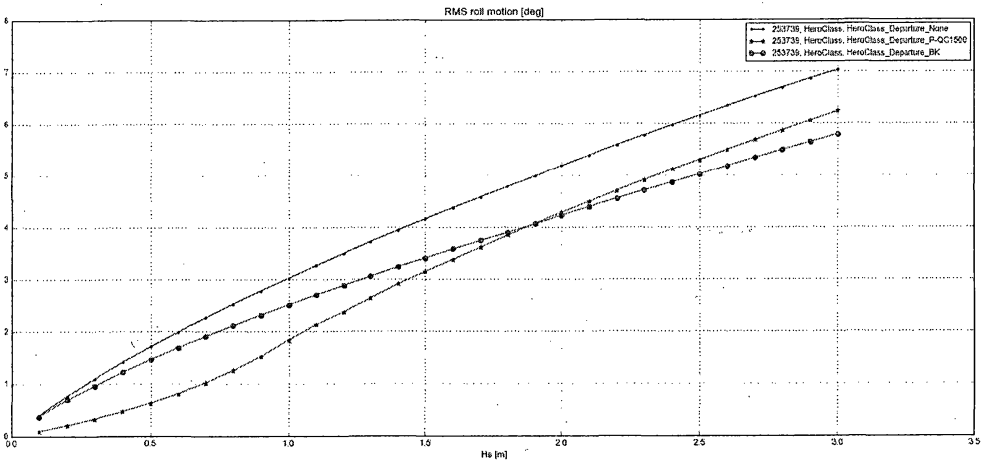
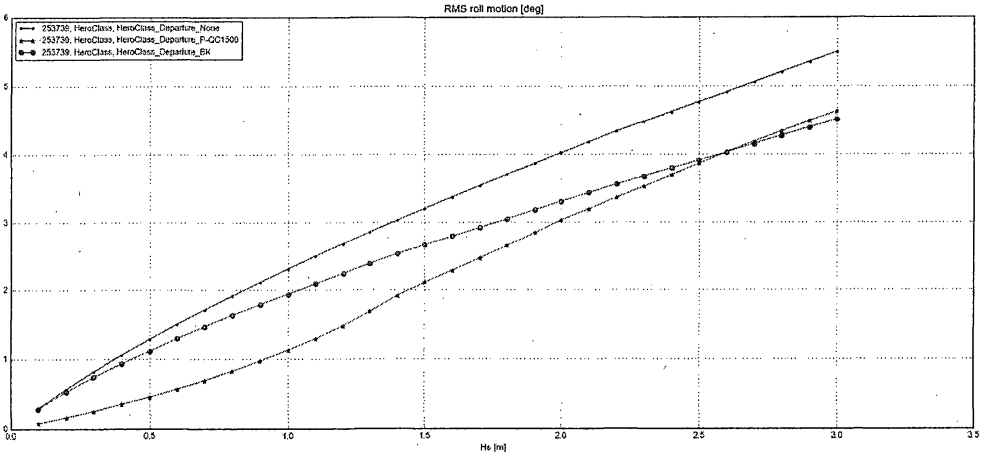


A 3. RMS roll in beam seas at zero speed. Tp = 6 seconds.



A 4. RMS roll in beam seas at zero speed. Tp = 8 seconds.



A 5. RMS roll in beam seas at zero speed. Tp = 10 seconds.

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Certificate of Class

This certificate is issued to the	**G. PEDDLE S.C.**
LR Number	**9586071**
Date of Build	**24/07/2013**
Port of Registry	**OTTAWA**
Gross tons	**253**
Geographical Limits	**NEAR COASTAL VOYAGE, CLASS 1, LIMITED HOME TRADE 2, (NC1, LIMITED HT2)**

to confirm that having been surveyed by Lloyd's Register Canada Ltd and having been found in compliance with the Rules and Regulations for the Classification of Special Service Craft, the aforesaid craft has been assigned the class

✠**100A1SSC** **Patrol, Mono, HSC, EP, G4**

MCH, UMS, CCS, ICC

Descriptive Note:

Green Passport, PSMR

Date Special Survey Assigned	**24 March 2018**
This Certificate is valid until*	**23 March 2023**

* Unless extended after completion of a Special Survey (see page 3) or in accordance with Part 1, Chapter 2, Section 4.5.11 of the Rules and Regulations (see page 3) and is subject to surveys as prescribed (see page 2) being satisfactorily completed. (See notes 1 to 4, page 3)

Issued at **Halifax, NS**

on **07 March 2018**

Lloyd's Register

Hakan Erkal

Marine and Offshore
Halifax, NS Office
Senior Surveyor

Hakan Erkal
Surveyor to Lloyd's Register Canada Limited

Lloyd's Register Canada Limited
~~A subsidiary of Lloyd's Register Group Limited~~

LR337.2016.09

Note:
1. To establish the classification status of this ship, the Class Direct web site and the Interim Certificates issued on completion of classification surveys should be consulted in addition to this certificate. Access to Class Direct is available via http://www.cdlive.lr.org.
2. Where an operational envelope is assigned, it will be attached as an appendix to this certificate.

Lloyd's Register Group Limited, its affiliates and subsidiaries and their respective officers, employees or agents are, individually and collectively, referred to in this clause as 'Lloyd's Register'. Lloyd's Register assumes no responsibility and shall not be liable to any person for any loss, damage or expense caused by reliance on the information or advice in this document or howsoever provided, unless that person has signed a contract with the relevant Lloyd's Register entity for the provision of this information or advice and in that case any responsibility or liability is exclusively on the terms and conditions set out in that contract.

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Transport Canada / Transports Canada

Document no. – N° du document: 2018-45045-040

INSPECTION CERTIFICATE

FOR A VESSEL EXCEEDING 150 TONS GROSS TONNAGE PLYING AS A NON-PASSENGER VESSEL ON VOYAGES TO WHICH THE SOLAS CONVENTION DOES NOT APPLY (SOLAS CHAPTER I, REGULATION 1 OR 3)

CERTIFICAT D'INSPECTION

CONCERNANT UN BÂTIMENT D'UNE JAUGE BRUTE DE PLUS DE 150 TONNEAUX UTILISÉ COMME BÂTIMENT NON À PASSAGERS NE RESSORTISSANT PAS À LA CONVENTION « SOLAS » : (SOLAS CHAPITRE I, RÈGLE I OU 3)

This Certificate is supplemented by a Record of Safety Equipment and a Safe Manning Document.

Le présent certificat est complété par une Fiche d'équipement de sécurité et un Document de l'effectifs de sécurité.

Name of vessel – Nom du bâtiment	Official number Numéro matricule	Port of registry – Port d'immatriculation	Gross tonnage Jauge brute	Date on which keel laid Date de pose de la quille (dd-mm-yyyy / jj-mm-aaaa)
G. PEDDLE S.C.	837558	OTTAWA, ON	253.00	13-07-2012

Total number of persons for which life-saving appliances are provided – Nombre total de personnes pour lesquelles des engins de sauvetage sont prévus: 14

Vessel type – Type de bâtiment: Special - Patrol

That a Life Raft Register – Qu'un registre de radeaux

☐ has been issued – a été délivré ☑ has not been issued – n'a pas été délivré

THIS IS TO CERTIFY that the above-mentioned vessel has been duly inspected in accordance with the provisions of the ***Canada Shipping Act, 2001***, that the provisions of that Act respecting the inspection of vessels that are applicable to that vessel, have been complied with and that the vessel is, subject to such limitations as may be specified herein, fit to ply on voyages not beyond

Near Coastal Voyage, Class 1

LA PRÉSENTE FAIT FOI que le bâtiment précité a été dûment inspecté conformément à la ***Loi de 2001 sur la marine marchande du Canada***, que les dispositions de ladite Loi relatives à l'inspection des bâtiments à vapeur applicables à ce bâtiment ont été observées et que celui-ci est, sous réserve des limitations pouvant être mentionnées au présent certificat, apte à effectuer des voyages dans les limites

LIM HT2

Limitation(s) on use of certificate – Limitations du présent certificat

- Voyages between places in Canada, the United States (except Hawaii) or Saint Pierre and Miquelon.
- Voyages on the Atlantic coast where the vessel does not go south of the port of New York.
- Voyages on the Pacific coast where the vessel does not go south of Portland, Oregon.
- Vessel to remain within 120 nautical miles from shore.
- Vessel to remain within 200 nautical miles from a place of refuge.

Terms and conditions - Conditions

This document is supplemented by Record of Safety Equipment Document No. 2018-47047-040.

Active Board Decisions granted to the vessel – Décisions du bureau actives accordées au bâtiment

MTRB #S 5583 - (OWS EXEMPTION), #M10025 - (FM200)

This certificate is issued under the authority of the Government of Canada and is valid until:

Le présent certificat est délivré avec l'autorisation du gouvernement du Canada et est valide jusqu'au :

06-03-2019
Date (dd-mm-yyyy / jj-mm-aaaa)

Issued at – Délivré à: SHELBURNE, NS (Place – Endroit)

on – le: 07-03-2018 (Date (dd-mm-yyyy / jj-mm-aaaa))

The undersigned is duly authorized by the Government of Canada to issue this certificate.

Le soussigné est dûment autorisé par le gouvernement du Canada à délivrer le présent certificat.

H.ERKAL

HAKAN ERKAL

Signature of authorized official – Signature de l'agent autorisé

ORIGINAL

Lloyd's Register

(SEAL – CACHET)

Hakan Erkal
Marine and Offshore
Halifax, NS Office
Senior Surveyor
Lloyd's Register Canada Limited

LR5322-2016-CO

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Wyse, David E

From:	Wyse, David E	
Sent:	Wednesday, March 14, 2018 5:49 PM	
To:	Li, Meng	
Cc:	Molokopoy, Vitaliy	s.19(1)
Subject:	agenda and topics for mspv face to face	
Attachments:	MECTS-#3887419-v1-face_to_face_2018_MSPV.XLSX	

Hey Meng,

Can you sort out and write up the agenda from this below and attached? You can ask Vitaliy to help you if you have any questions.

I might have some more stuff for you later in week.

But can you finalize the agenda and then print out 25 copies (staple) and bring to meeting?

More agenda topics as well as ones in the spreadsheet.

- Allied Crane FSR [redacted] to present and discuss the cranes – 10am to 12pm Thursday. Topics to cover – CT mode, how winches work, how belly pack works with CT mode, how to make adjustments, update on secondary safety system, wish list (load on belly pack, move crane boxes lower, etc)
- Maximo update 30 minutes wherever fits
- Drawing updates and way forward for as fitted drawing verification and redlining on Thursday for 45 minutes
- Wednesday morning with Wajax and Cullen – topics to cover – valve pitting, private Robertson and Constable Carriere failures, spares, Northern Lights generators
- Discussion on davit, rescue boat and Car hook maintenance – 1 hour either Tuesday or Thursday
- Stabilizers on Tuesday at 2pm with Lengkeek. Update on stabilizer study.
- Lunches 12 to 1pm each day, breaks around 10 and 3 for 15 minutes each day
- First day – roundtable and action item update
- Discussion on Lloyds survey schedules, continuous surveys, overboard valves at drydock and DSIP 1 hour
- Electrical items I sent you previously – 1 hour
- Wednesday night group dinner at Saltys (can you look up on internet and get address?) Dinner reservations at 6pm
-
-
-

David Wyse
Project Engineer | Mécanicien de Projet
Marine Engineering | Ingénierie Navale
Integrated Technical Services | Services Techniques Intégrés
Canadian Coast Guard | Garde Côtière Canadienne
200 Kent Street, Office 7W076, Mail Drop 7W064
Ottawa, ON, K1A 0E6
David.Wyse@dfo-mpo.gc.ca
Telephone | Téléphone 613-302-6503

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MSPV face to face 2018 - Delta Barrington Halifax, March 20 to 22

MSPV Face to face draft agenda

Day	Agenda	OPI	Desired Outcome
Tuesday AM	CCRs and engineering studies	David Wyse	
Tuesday PM	Stabilizer presentation from Naval Architects and Lengkeek engineering will be at meeting to answer questions about the stabilizer engineering.	Vladan Kozarski	Information to the group about stabilizers on the Hero Class vessels
Wednesday AM	Main Engine, SSG and Lufkin gearbox discussion with Wajax and Cullen representatives. Investigation reports	David Wyse	Discussion and way forward for equipment maintenance on the Hero Class vessels. National Spares, LCM and maintenance
Wednesday PM	Concept Naval presentation on solution for engine swapping at overhaul period and in situ engine overhaul.	Marcel Darveau	Information and questions concerning the engine overhaul solutions.
Thursday AM	Open		
Thursday PM	Open		

Participant List		
David Wyse	National LCM	
Donovan Byrd	Naval Arc engine overhaul	
Vladan Kozarski	Naval Arc stabilizers	Tuesday only
Greg Wilkie	Captain Corporal Mclaren	
Guillaume Noel	Chief Engineer A. Leblanc	
Yves Gervais	Captain Caporal Kaeble	
Bill Cheal	Chief Officer Western	
David Steel	1st Engineer Western	
Cody Mcmillan	VMM Western	
[redacted]	Wajax [redacted]	Wednesday Only
[redacted]	Wajax [redacted]	Wednesday Only
[redacted]	Wajax [redacted]	Wednesday Only
[redacted]	Hamilton [redacted]	Wednesday Only
[redacted]	Wajax [redacted]	Wednesday Only
[redacted]	Cullen [redacted]	Wednesday Only

s.19(1)

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Wyse, David E

From: Wyse, David E
Sent: Monday, March 19, 2018 8:46 PM
To: McBride, Blaine; Ivany, Gary
Subject: Stabilizer presentation at MSPV
Attachments: J18009-R02-RA- Stabilizer Comparison Spreadsheet.pdf

I don't think that there is anything earth shattering here – the stabilizers fitted to most other Damen 4207s is the recommended solution for us.

The Quantum model S-QC1200.

Dave

From: [redacted]
Sent: March-15-18 3:51 PM
To: Wyse, David E; Kozarski, Vladan
Cc: [redacted] s.19(1)
Subject: RE: Presentation in Halifax to Hero Class annual working group

Hi Dave,

Following are our preliminary results:

CONCLUSION REVIEW OF DAMEN REPORT

If the Quantum P-QC1500 stabilizer fins would fit the hull and if the components would fit in the vessel, this would give the best results with regards to roll reduction and Sea Sickness Index.

Generally, second best with close results to the above is the Quantum Underway S-series active stabilizer system, model S-QC1200, which is fitted on several other Spa 4207s.

The Rudder Stabilization, combined with Rudder Stabilization with improved controls, works reasonable well at low speed, but not as good on speeds above 5 knots.

The Rudder Stabilization, combined with Rudder Stabilization without improved controls, works not as well, and we expect that the steering system will be overloaded and wear out fast, therefore not a good practical solution.

The bilge keels don't seem to do much in the RAO plots, but have reasonable effect at lower speeds in reducing roll angles, bridge transverse accelerations, and a small reduction in Sea Sickness Index .

RECOMMENDATION BASED ON SUPPLIER PROVIDED INFORMATION AND PRACTICALITY OF INSTALLATION.

The Quantum P-QC1500 fins do not fit the vessel's hull. The required HPU is too big and heavy. Large power requirement

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The Quantum Underway S-series active stabilizer system, model S-QC1200, which is fitted on several other Spa 4207s is a feasible and is the recommended option. The best location is in the forward part of the engine room, similar to Damen design.

Rudder Stabilization is not recommended. It is very expensive, HPU heavy in weight and no room can be found Automatic control Unit and will require significant strengthening in the aft hull.

Bilge keels are the easiest / cheapest solution to add, consideration might be given to combine it with the active stabilizers.

More details for Quantum QC1200 active stabilizer system with 1.4m2 fins:

- System can be powered from supplied HPU (20ph) or likely from the existing hydraulic system onboard (hydraulic pumps driven from Main Engine PTO's). Possible to use generator PTO's if available (question has been posed to the Chief about this).
- Expect 80-85% roll-reduction at cruising speed of 15knots, 2m seas.
- Capable of partial zero-speed roll-reduction (approx. 30% @ 1m seas) – Requires optional HPU however.
- For active fin only option (i.e. minus HPU); this provides the greatest roll-reduction with the least installed weight (includes components, minus additional plate and stiffening i.w.o stabilizer units) and places that additional weight in the mid-ship area. By including the HPU (required for partial zero-speed capability), this places an additional 525kg in the aft end of the vessel. Otherwise, the main engines may have to be sped-up while idling.
- System will clash with some components and piping in the forward corners of the Engine Room and will require some relocation and re-routing of piping in these areas.

Attached is a spreadsheet with the information provided from suppliers and information about installation on the vessel.

I hope that is satisfactory for now. If you have any questions or comments, please do not hesitate to contact me.

Kind regards,

[redacted] **s.19(1)**

LENGKEEK VESSEL ENGINEERING INC.
11 Portland Street, Suite 301
Dartmouth, Nova Scotia B2Y 1H1
Tel +1 (902) 468-3094
Cell [redacted]
[redacted] | www.lengkeek.ca

From: Wyse, David E <David.Wyse@dfo-mpo.gc.ca>
Sent: Wednesday, March 14, 2018 11:26 AM
To: [redacted] Kozarski, Vladan <Vladan.Kozarski@dfo-mpo.gc.ca>
Cc: [redacted]
Subject: RE: Presentation in Halifax to Hero Class annual working group

Thanks [redacted]

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[redacted]

Is it possible to send in email? I can then pass around to directors.

Dave

s.19(1)

From: [redacted]
Sent: March-14-18 10:24 AM
To: Wyse, David E; Kozarski, Vladan
Cc: [redacted]
Subject: RE: Presentation in Halifax to Hero Class annual working group

Hi David,

I will be back in the office tomorrow and will call you then, after I have had a change to see what [redacted] has received for information and has put in his spreadsheets for comparison.

Best regards,

[redacted]

From: Wyse, David E <David.Wyse@dfo-mpo.gc.ca>
Sent: Tuesday, March 13, 2018 6:03 PM
To: Kozarski, Vladan <Vladan.Kozarski@dfo-mpo.gc.ca>; [redacted]
Subject: RE: Presentation in Halifax to Hero Class annual working group

Hi [redacted]

Are you able to give me a heads up on what the conclusions or recommendations are that you will be presenting at the MSPV face to face? I don't want management to have any surprises.

Thanks
Dave

From: Kozarski, Vladan
Sent: February-14-18 4:43 PM
To: Wyse, David E; [redacted]
Cc: [redacted]
Subject: RE: Presentation in Halifax to Hero Class annual working group

Yes.

From: Wyse, David E
Sent: Wednesday, February 14, 2018 4:32 PM
To: [redacted] Kozarski, Vladan
Cc: [redacted]
Subject: RE: Presentation in Halifax to Hero Class annual working group

I will slot you in for Tuesday March 20 at 2pm. Does that work?

Thanks
Dave

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From: [redacted]
Sent: February-14-18 11:05 AM
To: Kozarski, Vladan; Wyse, David E
Cc: [redacted]
Subject: RE: Presentation in Halifax to Hero Class annual working group

s.19(1)

Hi Vladan,

Tuesday afternoon is no problem for me. Thursday could work also, but I need to know which day, so I can make firm plans for the other vessel survey.

Kind regards,

[redacted]

LENGKEEK VESSEL ENGINEERING INC.
11 Portland Street, Suite 301
Dartmouth, Nova Scotia B2Y 1H1
Tel +1 (902) 468-3094
Cell [redacted]
I www.lengkeek.ca

From: Kozarski, Vladan [mailto:Vladan.Kozarski@dfo-mpo.gc.ca]
Sent: Wednesday, February 14, 2018 11:59 AM
To: [redacted] Wyse, David E <David.Wyse@dfo-mpo.gc.ca>
Cc: [redacted]
Subject: RE: Presentation in Halifax to Hero Class annual working group

Hi there,

[redacted] It would be tight for me, but I will try. If I decide to travel on Tuesday morning (Feb. 20), could we pin the presentation early afternoon?

Thanks.

Vladan.

From: [redacted]
Sent: Wednesday, February 14, 2018 10:54 AM
To: Wyse, David E; Kozarski, Vladan
Cc: [redacted]
Subject: RE: Presentation in Halifax to Hero Class annual working group

Hi David and Vladan,

I have to go out of town for a vessel survey the same week as the presentation. Would it be possible to pin the presentation on the 20th, so that I can have the rest of the week for the survey?

Kind regards,

[redacted]

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I www.lengkeek.ca

s.19(1)

From:
Sent: Tuesday, January 23, 2018 4:05 PM
To: Wyse, David E <David.Wyse@dfo-mpo.gc.ca>
Cc: Kozarski, Vladan <Vladan.Kozarski@dfo-mpo.gc.ca>;
Subject: Re: Presentation in Halifax to Hero Class annual working group

Hi Dave,

Regarding the 3D model, can you work with Rhino?
Because we have the model in that format only and unfortunately it is without any equipment and systems in it.

Kind Regards,

Damen Services

DAMEN SHIPYARDS GORINCHEM
P.O. Box 1
4200 AA Gorinchem
The Netherlands
Direct:
Mobile:
E-mail:
Internet: www.damen.com

Op 23 jan. 2018 om 20:45 heeft Wyse, David E <David.Wyse@dfo-mpo.gc.ca> het volgende geschreven:

> Maybe can bring the 3d model with him? And discuss the davit and stern launch systems?
>
> Dave
>
> ---
>
> **From:**
> **Sent:** January-23-18 2:43 PM
> **To:**
> **Cc:** Wyse, David E; Kozarski, Vladan;
> **Subject:** Presentation in Halifax to Hero Class annual working group
>
> Hi

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I have been asked to do a presentation at the MSPV annual working group meeting detailing the results of the comparative analysis of the Hero Class stabilizers.
I have suggested that they also invite you are the author of the report and have the theoretical background. Would you be available and interested? It will be on either March 20th or March 22nd in Halifax, NS.

If yes, would Damen be able to fund the travel costs as a part of relationship building with Canadian Coast Guard?

Kind regards,

[redacted]

s.19(1)

LENGKEEK VESSEL ENGINEERING INC.
11 Portland Street, Suite 301
Dartmouth, Nova Scotia B2Y 1H1
Tel +1 (902) 468-3094
Cell [redacted]
[redacted] I www.lengkeek.ca

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s.20(1)(b)

Hero Class - Preliminary Stabilizer Options Comparison

Type	Active Fin (Partial Zero-Speed Optional)	Active Fin	Active Fin	Active Rudder	Bilge Keels - Single Plate	Bilge Keels - Double Plate
Model	Quantum QC1200	Rolls Royce Gemini 10	Naiad	Jastram & RH Marine	None. Fabricated	None. Fabricated
Major Components	**HPU** - (1 off) MPU20 **Stabilizer Unit** - (2-Off) QC1200 **Stabilizer Fins** -1.4m2 (2-Off) - QC1200	**HPU** - TBD **Stabilizer Unit** - (2-Off) Gemini 10 **Stabilizer Fins** -1.4m2 (2-Off) Gemini	TBD	**HPU** - (2-Off) Jastram Supply **Automatic Control Unit** - (1-Off) RH Marine Supply	(2-Off) Bilge Keels	(2-Off) Bilge Keels
Minor Components	- Adaptive Stabilizer Control - HPU Starter	- Bridge Operator Panel - Central Control Panel - Smart Roll Sensor - Servo Junction Box - Motor Starter Panel	TBD	- Bridge Control Panel - Control Selectors	N/A	N/A
Weight of Major Components (kg)	**HPU** - 524kg(wet) **Stabilizer Units** - 2 x 290kg(dry) **Stabilizer Fin** - Neutrally Buoyant	TBD	TBD	**HPU's (2-Off)** - 1540kg(wet)	**Bilge Keels** (assume 200x9mm BP+T) 2 x 300kg	**Bilge Keels** (assume 350x6mm) 2 x 535kg
Total (kg)	**1105kg** (approx.)			**1540kg** (approx.)	**600kg** (approx.)	**1070kg** (approx.)
Powering Arrangements	Existing Hydraulic System or Dedicated HPU	Exisitng Hydraulic System or Dedicated HPU	Exisitng Hydraulic System or Dedicated HPU	HPU's (2-Off)	N/A	N/A
Power Requirements(kW)	15kW	TBD	TBD	2 x 15kW	N/A	N/A
Location of Major Components	**Stabilizer Units** - Fr.16 - Engine Room (P&S) **HPU** - Steering Gear Compartment (Stbd Side)	**Stabilizer Units** - Fr.16 - Engine Room (P&S) **HPU** - Steering Gear Compartment (Stbd Side)	**Stabilizer Units** - Fr.16 - Engine Room (P&S) **HPU** - Steering Gear Compartment (Stbd Side)	**HPU's** - Steering Gear Compartment **Automatic Control Unit** - No Space Available	**Bilge Keels** - Fr.13-26 (P&S)	**Bilge Keels** - Fr.13-26 (P&S)
Clashes with Existing Arrangement	**Port Side - Engine Room Fwd** - F.O. Continuous Transfer Pump and Connected Piping - F.O. Transfer Pump and Connected Piping - Small S.W. Line and Pump Servicing Refrigeration System Above - Misc. Small-Bore S.W. Cooling Lines **Stbd Side - Engine Room Fwd** - S.W. Cooling Return Line w/Valve to Sea-Chest Connection - S.W. O/B Disharge - Small Dia. S.W. Cooling Line - Outboard End of S.W. Pipe Manifold and Connected Piping - Lube-Oil Piping i.w.o Sea-Chest and S.W. Pipe Manifold **Steering Gear Compartment** - Hydraulic Oil Piping Stbd Side of CL post	**Port Side - Engine Room Fwd** - F.O. Continuous Transfer Pump and Connected Piping - F.O. Transfer Pump and Connected Piping - Small S.W. Line and Pump Servicing Refrigeration System Above - Misc. Small-Bore S.W. Cooling Lines **Stbd Side - Engine Room Fwd** - S.W. Cooling Return Line w/Valve to Sea-Chest Connection - S.W. O/B Disharge - Small Dia. S.W. Cooling Line - Outboard End of S.W. Pipe Manifold and Connected Piping - Lube-Oil Piping i.w.o Sea-Chest and S.W. Pipe Manifold **Steering Gear Compartment** - Hydraulic Oil Piping Stbd Side of CL post	**Port Side - Engine Room Fwd** - F.O. Continuous Transfer Pump and Connected Piping - F.O. Transfer Pump and Connected Piping - Small S.W. Line and Pump Servicing Refrigeration System Above - Misc. Small-Bore S.W. Cooling Lines **Stbd Side - Engine Room Fwd** - S.W. Cooling Return Line w/Valve to Sea-Chest Connection - S.W. O/B Disharge - Small Dia. S.W. Cooling Line - Outboard End of S.W. Pipe Manifold and Connected Piping - Lube-Oil Piping i.w.o Sea-Chest and S.W. Pipe Manifold **Steering Gear Compartment** - Hydraulic Oil Piping Stbd Side of CL post	Does Not Appear Available Space for Automatic Control Unit	N/A	N/A
Additional Installation Requirements	- HPU Supports - Hull Plate Inserts - Additional Stiffening i.w.o. Stabilizers - Ancillary Cooling - Possible Save-All around Stabilizer Units	- HPU Supports - Hull Plate Inserts - Additional Stiffening i.w.o. Stabilizers - Ancillary Cooling - Possible Save-All Around Stabilizers	- HPU Supports - Hull Plate Inserts - Additional Stiffening i.w.o. Stabilizers - Ancillary Cooling - Possible Save-All Around Stabilizers	- Analysis and Possible Strengthening of Aft Hull - Analysis and Possible Replacement of Rudder Bearing and Strengthening of Rudder Shaft Supports	- Final Design - Fabrication	- Final Design - Fabrication
Base Price of Supplied Components	[redacted] CAD	TBD	TBD	[redacted] CAD	TBD	TBD
Delivery Time	20-24 weeks	TBD	TBD	TBD	N/A	N/A

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McMillan, Cody

From: Wyse, David E
Sent: March-19-18 6:21 PM
To: Falconer, William; Dort, Christopher G; Li, Meng; Byrd, Donovan; Kozarski, Vladan; March, Rod; Richardson, Dena; McBride, Blaine; McMillan, Cody; Mkrtychan, Sergey; Couillard-Desjardins, Isabelle; Mercier, Jeffrey; Guillaume Noel [redacted] yves.gervais@ccgs-ngcc.gc.ca; Alicia Smith (Alicia.Smith@ccgs-ngcc.gc.ca)
Subject: Most up to date MSPV agenda
Attachments: 2018 final agenda- updated.docx

s.19(1)

David Wyse
Project Engineer | Mécanicien de Projet
Marine Engineering | Ingénierie Navale
Integrated Technical Services | Services Techniques Intégrés
Canadian Coast Guard | Garde Côtière Canadienne
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AGENDA/ORDRE DU JOUR
MSPV Face to Face/FRENCH
Halifax, 20- 22 March 2018/ Halifax, Mars les 20 – 22, 2018
Delta Barrington Halifax

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DAY 1 – Sackville Room

Item #	Time/ Temps	Agenda Topic	Type of Topic	Desired Outcome	Sujets à l'ordre du jour	Type de sujets	Résultat escompté	OPI\BPI
	Tuesday /Mardi, 20-03							
1	08:30 – 09:00 (0.5 h)	Welcome - Roundtable - Action Items - Expectations			Bienvenue - Table ronde - Mesures à prendre			Dave Wyse
2	09:00 – 1100 (2 hour)	Visit to the CCGS Corporal Mclaren at BIO						Dave Wyse
3	11:15 –12:00 (45 mins)	Drawing updates and way forward for as fitted drawing verification and redlining	Information		Mises-à-jour pour les dessins et marche à suivre pour la verification et redlining de dessins	Information		Stephen Wheeler (tele-conference) 709-772-2276
4	**12:00 – 13:00 Lunch**							
5	1300 - 1400	E&I CCRs	Discussion	Way forward for CCRs				Dave Wyse and guests [redacted]

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6	14:00-15:00 (1 h)	Information to the group about stabilizers on the Hero Class vessels	Information	Stabilizer presentation from Naval Architects. Lengkeek Engineering will be at meeting to answer questions about the stabilizer engineering	Information pour le groupe sur stabilisateurs dans la classe Héro	Information	Presentation sur stabilisateurs par les Architectes Navales. Lengkeek Engineering sera présent pour répondre à questions concernant le travail d'ingénierie	Vladan Kozarski
7	**15:00 – 15:15 Break – Pause santé**							
8	1515 - 1630	Alarm and Monitoring System & Electrical Issues discussion	Discussion	MSPV Group ask questions or comments about "Alarm and Monitoring System"; Candidate items for CCR (Attachment)	Système d'alarme et surveillance	Discussion	Groupe NPSH demande des question et fait des commentaires sur le « Système d'alarme et surveillance »; Discussion sur problèmes électriques aux NPSV	Bill Falconer
9	1630 to 1700	Parking lot						

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DAY 2 – Sackville Room

Item #	Time/ Temps	Agenda Topic	Type of Topic	Desired Outcome	Sujets à l'ordre du jour	Type de sujets	Résultat escompté	OPI/BPI
	Wednesday/ Mercredi, 21-03							
11	8:30 – 12:00 (1.5 hr)	Main Engine, SSG and Lufkin gearbox discussion with Wajax and Cullen representatives. Investigation reports	Discussion	Discussion and way forward for equipment maintenance on the Hero Class vessels. National Spares, LCM and maintenance; valve pitting, private Robertson and Constable Carriere failures, spares, Northern Lights generators.	Discussion avec représentants de Wajax et Cullen sur le Moteur principal, SSG et boite de vitesse Lufkin	Discussion	Discussion et marche à suivre pour l'entretien d'équipement de la classe Héro. Pièces de rechange nationale, SGCV et entretien; les piqures de valves, défaillances du Private Robertson et Constable Carrière, generatrices Northern Lights.	Dave Wyse
12	**10:00 – 10:15 Break – Pause santé**							
16	**Lunch 12:00-13:00**							
17	13:00-16:30 (3.5 hrs)	Concept Naval presentation on solution for engine swapping at overhaul period and in situ engine overhaul.	Discussion	Information and questions concerning the engine overhaul solutions.	Présentation par Concept Naval concernant la solution pour l'échange des moteurs dans le période de révision ou révision des moteurs sur place	Discussion	Information et questions concernant les solutions pour la révision des moteurs	Marcel Darveau
19	**15:00 -15:15 Break – Pause santé**							

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21	18:00- 20:00 (2hrs)	Group dinner at Salty's Seafood Restaurant	Discussion	1877 Upper Water St, Halifax, NS B3J 1S7 **Phone:** (902) 423-6818	Souper avec le groupe chez Salty's Seafood Restaurant	Discussion	1877 Upper Water St, Halifax, NS B3J 1S7 **Phone:** (902) 423-6818	Dave Wyse

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Item #	Time/ Temps	Agenda Topic	Type of Topic	Desired Outcome	Sujets à l'ordre du jour	Type de sujets	Résultat escompté	OPI/BPI
	Thursday /Jeudi, 22-03							
	0830 to 0930	Any operational issues? Gary Ivany will be present	Discussion					
23	0930 - 1000 (1.5 hours)	Engineering studies and CCR continuation	Discussion			Discussion		Dave Wyse
24	**10:00 – 10:15 Break – Pause santé**							
25	10:15-12:15 (2 hrs)	Allied Crane FSR [redacted] to present and discuss the cranes	Discussion	CT mode, how winches work, how belly pack works with CT mode, how to make adjustments, update on secondary safety system, wish list (load on belly pack, move crane boxes lower, etc)	Présentation par [redacted] RSR de la Grue Allied concernant les grues	Discussion	Mode TC, fonctionnement des treuils, fonctionnement du « belly pack » avec mode TC, comment faire des ajustements, mise à jour du système de sécurité secondaire, liste de souhaits (charge sur « belly pack », déménager les boites du grue plus bas, etc.)	[redacted]
26	**12:15 – 13:15 Lunch - Dîner**							
27	13:15-14:00)	Discussion on Lloyds survey schedules, continuous surveys, overboard valves at dry dock and DSIP.	Discussion		Discussion sur le calendrier des enquêtes, sondage continue, soupapes à la mer dans la cale seche et PDIO.	Discussion		Group

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28	14:00-16:30 (2.5 hrs)	Discussion on davit, rescue boat and Car hook maintenance	Discussion		Discussion sur le bossoir, le canot de sauvetage et l'entretien du crochet de voiture	Discussion		Craig Williams
	1630 to 1700	Roundtable						
29	**15:00 -15:15 Break – Pause santé**							

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Joint Management Team Meeting
CCG and C&P
March 21, 2018 – DAY 2

1. Meeting details

Type:	In person				
Purpose:	Canadian Coast Guard/Conservation & Protection Joint Management Team meeting				
Meeting date:	March 21, 2018	Start	8:30	End	16:00
Meeting location:	1110 Howe Street, Holiday Inn & Suites – Vancouver, BC				
Co-chaired by:	Cédric Kinnard (CCG) for Tanya Alvaro and Brent Napier (C&P) for Judy Dwyer				
Secretariat:	Emilie Plows / Lise Loiselle				

2. Participants

Participant	Organization – Region	Title
Belliveau, Ron	C&P - Gulf - Moncton	Chief, Enforcement Operations
Byatt, Cyndi	CCG - Atlantic - Dartmouth	Superintendent, Operational Business
Emeneau, Fred	CCG - Atlantic - MSPV *G. Peddle S.C.*	Commanding Officer
Fulks, Jay	RCMP - Pacific - Vancouver	Liaison Officer
Gallant, Nicole	C&P - Pacific - Vancouver	Chief, Enforcement Operations
Grace, Michael	C&P - Maritimes - Dartmouth	Supervisor, Offshore Surveillance
Higgins, Linda	C&P - Pacific - Nanaimo	South Coast Area Chief
Hurley, Mike	C&P - Newfoundland - St. John's	Supervisor, Offshore Surveillance
Ivany, Gary	CCG - Headquarters - Ottawa	Director, Operational Support
Jersch, Russell	CCG - Western - Victoria	Marine Superintendent
Langlois, Jimmy	CCG - Central and Arctic - MSPV *A. LeBlanc*	Commanding Officer
Jones Larose, Nicole	C&P - Headquarters - Ottawa	Staff Officer
Kinnard, Cédric	CCG - Headquarters - Ottawa	National Manager, Maritime Security Operations
Loiselle, Lise	CCG - Headquarters - Ottawa	C&P Liaison Officer, Maritime Security Operations
Ludlow, Mandy	C&P - Pacific - Victoria	Acting North Coast Area Chief for Andy Lewis
Lynden, Al	CCG - Western - MSPV *M. Charles M.B.*	Commanding Officer
Morphet, Jason	CCG - Headquarters - Ottawa	Acting Manager, Readiness
Napier, Brent	C&P - Headquarters - Ottawa	Chief, Enforcement Programs
Burniston, Nancy	RCMP - Great Lakes - Niagara-on-the-Lake	Officer in charge, Marine Security Enforcement Team, Ontario
Picard, Marcel	C&P - Quebec - Québec	Chief, Enforcement Operations
Plows, Emilie	CCG - Headquarters - Ottawa	Acting National Liaison Officer, Maritime Security Operations
St-Pierre, Lisa	CCG - Central and Arctic - Québec	Marine Superintendent
Thirkell, Darcene	CCG - Western - Victoria	Superintendent, Operational Business
Wasson, Thomas	CCG - Central and Arctic - Sarnia	Deputy Marine Superintendent

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	Joint Management Team Meeting **CCG and C&P** **March 21, 2018 – DAY 2**	

3. Agenda

Item	Topic	Presenter
1	Introductory Remarks and Roundtable	Cédric Kinnard/Brent Napier and All
2	Summary of Discussions from Day 1	Cédric Kinnard/Brent Napier
3	Requested CCR Updates	All
4	Vessel Class Standardization	Brent Napier
5	Season Summaries	CCG Commanding Officers and C&P Chiefs of Enforcement Operations
6	Future Meetings	Emilie Plows
7	Potential Support to Overall C&P Program – REMOVED	Emilie Plows
8	Potential Support to Other Programs	Al Lynden
9	LEFT Input from C&P	Emilie Plows
10	Summary of Action Items	Emilie Plows
11	Roundtable and closing Remarks	All

4. Meeting Report

1. Introductory Remarks and Roundtable

Welcoming remarks by Brent and Cédric and introduction of participants. Cédric says that the participants can express themselves in French or English.

2. Summary of Discussions from Day 1

Cédric briefly summarizes the items discussed with the Canadian Coast Guard (CCG) participants on Day 1 and Brent does the same for the items discussed with the Conservation and Protection (C&P) representatives.

3. Requested Change Configuration Request (CCR) Updates

RHIB

Brent says that the most important concern for C&P is deploying the RHIB (launch and recovery). After discussing the same problem for several years, the frustration level is high. C&P Senior management and Regions are very concerned by long-standing issue and ask that a solution be found as soon as possible to mitigate safety concerns.

Al Lynden says that this is not a safety issue, but one of convenience. There is a difference in perspective. Brent asks the CCG to find a short-term solution to bridge the gap between the two perspectives and to look at alternatives that will ensure that Fishery Officers feel safe. It is

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proposed that a working group involving C&P, the CCG, the RCMP, and technical personnel focus on this concern and determine a critical path.

Gary acknowledges the importance of this technical concern. He mentions the challenges faced by the CCG when it wants to change or adjust a component on the MSPV. He also mentions that it (the CCG) must take into account the impacts on other factors such as the eventual installation of stabilizers and how the CCG could provide a safe platform. He adds that there will be compromises to make because there are several factors to consider.

Jay says that it is important to work together as opposed to the CCG working alone. Brent agrees. He asks Gary how long it will take to find a solution to this problem.

Nicole Gallant says that C&P spends 8-10 hours in the RHIB and that this is ineffective for what C&P needs to do. She asks to find a solution or mitigate the risk before installing stabilizers. Nicole mentions that they are considering towing the RHIBS behind them as a solution if nothing is done to address the issue.

[redacted]

s.16(2)
s.21(1)(b)

Gary says that communication is through the Joint Management Team meetings and adds that the stabilizers will have an impact and determine what happens next. He adds that this concern will be part of the discussions that he will be having with the MSPV Working Group the next day. He acknowledges that what is in place for now is not working well. What is wanted and needed for the RHIB must also be discussed. Gary mentions a feasibility study and consultations with engineering to look at different designs and that program and operational requirements will drive the technical requirements.

Ron says the RHIB used is not made for C&P and would like to see an improvement. He adds that after four years, C&P is frustrated at not receiving answers to their questions in terms of how long and what option will be implemented so they will be safe and comfortable.

Brent said that C&P is working within the scope of occupational health and safety, but they see no results. [redacted] Brent would like to see the critical path to finding a solution to this concern.

The launch and retrieval system currently in place results in safety concerns among Fishery Officers regarding foot entrapment, as well as fear of collision with the metal bars.

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Gear Hauler

The *Corporal McLaren* will be the first of two vessels to receive it. The *G. Peddle* was not ready when it left dry dock. Fred reports that progress has been made and that once the vessel is ready, it will take about half a day to put them on. Mike Grace emphasizes the greatest need is for the vessel going to Gulf. Ron says that the same needs to be done for *G. Peddle* because while the old one works, it is not ideal; the issue is with resetting gear and not hauling.

Server & Storage / Connectivity

The needs on the East and the West Coasts are different. West coast would benefit from same solution as RCMP. Michael Grace says that he needs the satellite, but it is difficult to explain the problem to the Coast Guard technical personnel. He says that when working, the current connectivity suits their needs; he does not believe it to be the main issue and that he knows it comes at a cost. Both Maritimes and Newfoundland and Labrador Regions have a solution through the purchase of stand-alone mobile satellite unit (MSRTC system) that they will test. Jay mentions the *Privacy Act* and data integrity; should have unfettered access to the central data system.

Stabilizers

After the meeting with the MSPV Working Group, Gary will pass on the latest news about the solution. He estimates that it will take a few years to install them on the nine vessels.

Radar Transceivers

The noise is louder and higher pitched on the *Captain Goddard* than on the *M. Charles*, but it is not clear why. Mandy suggests that it is noise travelling through the vent. Using a shorter pulse was a suggestion to see if it would reduce noise. No complaints from *M. Charles*.

RHIB Operator Training

Emilie says that she has collected comments from C&P and will forward them to the CCG. There are some areas where Fishery Officers can operate the RHIBS, but not in all cases.

Brent stresses the importance of looking at various options and having training that is well-suited to their needs. C&P can take part in this training to feel at ease.

Nancy and Michael Grace share how the organization trains officers to maintain or develop improved skills.

Brent asks Emilie to follow up on this.

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4. Vessel Class Standardization

Brent asks Gary how open and flexible the CCG is in the CCR process when it comes to particularities in each region. Gary explains that CCR processes are for more formalized changes. CCG acknowledges the program's differences in each region and are open to differences but not if change is significant. Common sense approach: vessels do not have to be identical but changes should be for a good reason.

Gary replies that the CCG needs to follow the program requirements. However, there may be particularities, as in the case of lobster trap haulers, where if you can't pull gear, it affects program requirements. C&P would like to note that a system is required to haul all forms of set gear and set nets where the appropriate hauler is attached. Jason adds that CCG fishery research vessels (e.g., the *Vladykov*) have some particularities that the other vessels do not.

Gary left the meeting at this point to go to the MSPV Working Group meeting in Halifax.

5. Season Summaries (from October 2017 to February 2018)

The following are additional comments made after the presentations by the CCG Commanding Officers and the C&P Enforcement Chiefs. A copy of these presentations is kept at Headquarters in Emilie's JMT file.

M. Charles / Captain Goddard

Al adds the importance of fully covering the region and welcoming another organization, such as the Canada Border Services Agency (CBSA) on board, to improve surveillance of the region. He also mentions that turnover of fishery officers is a challenge.

Jay also mentions that it would be beneficial, when the program allows, to work with other organizations in the coming years.

Nicole Gallant asks for a long-term solution to transceiver problems and data storage. Nicole adds that the CCG Electronics and Informatics group was fantastic at finding a short-term solution.

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G. Peddle / Corporal McLaren

Fred Emeneau for the CCG:

- *G. Peddle* was not used a lot due to sea conditions, spent 2 weeks in dry dock
- Would like to see the return of "constant tension mode" on the RHIB crane.
- The RHIB was used a lot for seizures this past fall; he says that the vessel still has no rope cutters but the other five do. Al says that the one on the *M. Charles* fell off anyway.
- Although the experience on-board the MSPV is interesting, not recognizing sea time is causing issues with employee retention.
- Other issues mentioned include seakeeping capability (high winds), exhaust flap, ice, and gangway.

Michael Grace for C&P:

- Presents a table showing the various sea conditions by situation; this table shows the probabilities of the MSPVs being anchored based on wind speeds and sea conditions.
- Also presents a video showing the situation that Fishery Officers and the CCG operator face during retrieval of the RHIB.
- Would like to be able to operate in a 20- to 25-knot winds to have more time on program.

A. LeBlanc

Marcel Picard for C&P:

- To present their work to the public, he suggested that his region do an advertising blitz. This was done through various media in the region, proved very effective and was much appreciated. This made it possible to promote C&P's, the CCG's and DFO's work, tools and equipment.

Other comments

s.16(2)

- Ron Belliveau thanks CCG personnel for their participation in the whale file.

s.21(1)(b)

- Marcel also mentions the collaboration with the Regional Operations Centre (ROC) and that the air surveillance aircraft was helpful.
- Mike Hurley says that the working relationship between C&P and the CCG is very good in Newfoundland and Labrador, [redacted] He also brings up the importance of properly communicating time frames during refitting.

6. Future Meetings

Emilie presents the list of current CCG-C&P meetings to discuss the possibility of improving the discussions at the Joint Management Team meeting.

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CCG-C&P Joint Management Team meeting: Acknowledges that the meetings in their current form are interesting and allow CCG and C&P concerns to be shared. Emilie suggests one meeting per year instead of two in the future and the participants agree.

It is suggested that the Joint Management Team meeting be held at the same time and colocated with the MSPV Working group meeting so that David Wyse, marine engineer and person responsible for following up on CCRs, can attend.

Brent agrees and asks how to add the RCMP to the meetings (Joint Management Team or other). It (the RCMP) could share its experience and certain elements because they also work on MSPVs.

Emilie suggests that it would be a good idea for Liaison Officers to attend some of these meetings. Agreement on the advantage of their presence as an opportunity to learn, to further improve working relationships, and to ensure the continuity of national files. Michael Grace and Cyndi also believe that the presence of Liaison Officers at the meetings would be helpful. Brent likes the continuity of their presence at the meetings.

Brent suggests that one RCMP representative and one C&P representative be involved in the MSPV Working Group meeting. Linda adds that a member from the law enforcement community would bring another perspective.

7. Potential Support to Overall C&P Program

Topic removed from agenda. More of a conversation for the program at Headquarters.

8. Potential Support to Other Programs

Al discusses an initiative on the west coast to use MSPVs to provide support to other departments. He says that the Vancouver area is a hub for drug trafficking and has a high crime rate. It is known as the "Vancouver model."

s.16(2)
s.21(1)(b)

Claire Doucette of C&P had been approached by the Canada Border Services Agency (CBSA) to spend 4-5 days on the vessel; this was moderately successful. The next time they were even busier and that started a working relationship between them.

[redacted] Jay says that sharing data—even sensitive information—with the CCG requires a risk assessment. Some information cannot be shared (e.g., regarding investigations). He adds that enforcement is complicated for all organizations. The discussion on security clearance levels resumes.

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Brent cautiously approves the work with the CBSA from a Headquarters perspective. There are other departments that request support, such as Transport Canada and the Canadian Food Inspection Agency; the opportunity is there, but resources are needed so that assistance can be provided beyond the current program requirements. This would require further discussion and the relationship would have to be formalized, especially on the intelligence side. For the Coast Guard, this means including the work in the Fleet Operational Plan.

The relationship with the Marine Security Operations Centres is mentioned briefly in that it could be strengthened. Organizations in the centres were invited to give presentations at the Western Region MSPV Conference to discuss collaboration. Working in silos should be avoided.

9. Law Enforcement Familiarization Training (LEFT) Input from C&P

s.19(1)

It is mentioned that the C&P training chiefs should be involved in updating the curriculum. [redacted] a Fishery Officer on the West Coast, would be a good resource as a weapons specialist. Mike Hurley says that there are training standards for the Newfoundland and Labrador Region that Michael Grace could send us and he has provided comments on this previously. Brent decides that C&P at Headquarters funnel all relevant information to Emilie.

Jay says that it is possible to take some training online through the RCMP website, but taking online training is difficult for crew members. He encourages Brent and Emilie to get in touch with the RCMP training team in Ottawa; they can help provide access to certain training files. Emilie will work on this file after the G7 in June.

Russell says that it would be a good idea to formalize the live-fire training for the Arctic. Jason adds that someone at the CCG (Pierre Guilbeault) was hired under the Commissioner for the firearms file. He will see that a weapons safety policy is drawn up. Brent asks for follow-up on this file.

10. Summary of Action Items

- Harmonize the changes between the CCG and C&P into the following items:
  - Terms of Reference
  - Concept of Operations

- Create a working group to explore options and solutions for replacing the RHIB launch and recovery system. Determine the critical path.

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- Continue providing monthly CCR updates, especially on gear haulers, server and storage/connectivity, stabilizers, and radar transceivers.

- Coordinate CCG-C&P meetings:
  - Participation of Liaison Officers
  - Colocation of Joint Management Team and MSPV Working Group meetings
  - Program personnel representation on the MSPV Working Group

- Ensure prompt communication for any incidents on vessels (i.e., crane incident). Need a streamlined process.

- Collect feedback from program personnel on the Law Enforcement Familiarization Training course.

- Have a discussion between Fishery Officers and Commanding Officers on practice for RHIB operators.

- Share information on the installation of Toughpad docking stations.

11. Roundtable and Closing Remarks

Several people from both organizations acknowledge the collaborative effort between the CCG and C&P. These meetings help with the working relationship and it is nice to be able to demonstrate their value. Jay comments on both organizations' obvious enthusiasm.

Jimmy says that the same problems have been discussed for three years so there is a lot of work to do.

C&P comments that they are eager to see a solution for the RHIB cage. Brent is pleased with the progress made and requests focus on that item. He is also pleased to see the Maritime Security Operations group's desire to promote the resolution of issues. Cédric explains that Liaison Officers are not subject matter experts, but are listening and will make every effort to be transparent and to move things forward.

Nancy says that it is good to have C&P and the RCMP together in the same meeting. She also appreciates the CCG taking their concerns seriously.

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12. Other Topics Not on the Agenda

s.21(1)(b)

Whales: Gary asks if the plan is still to use MSPVs for towing whales. [redacted]

Toughpad installation: Michael Grace provides a presentation on the installation of Toughpads on vessels. The purpose of this solution is to address the issue of movement on vessels with equipment that will be installed permanently for all Fishery Officers. Michael is working with Tara Roberts (Fleet Delivery Planning Officer) on coordination.

Communication: Emilie explains that Liaison Officers share InfoPol bulletins with C&P when they concern health and safety; the information is also found on all vessels. Nancy asks Emilie to also keep the RCMP officers at Headquarters (Steve Barker and Jamie Solesme) in the loop.

5. Annex

- Agenda: EKME# 3890682 (English and French)
- Terms of Reference: EKME# 3784300 (available only in English for now)
- Concept of Operations: EKME# 2146863 (available only in English for now)
- Summary of C&P comments with regard to CCG RHIB operators: EKME# 3912878 (English) / 3912879 (French)
- CCG-C&P meetings table. Presentation summarized in the Annex only: EKME# 3913061 (English) / 3916435 (French)
- CCG-C&P Joint Management Team Meeting Action Plan: EKME# 3913328 (English) / 3914537 (French)

6. Approval

_____ _____

Cédric Kinnard for Tanya Alvaro

Date:

Brent Napier for Judy Dwyer

Date:

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Lengkeek Vessel Engineering

"CCG Hero Class Vessels"
Comparative Analysis of Stabilizer Options

For

Canadian Coast Guard, Integrated Technical Services
200 Kent Street, Ottawa

s.19(1)

Prepared By:
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Report Number: J18009-R01, rev 0

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Revision Matrix

Rev	Brief description of revisions made	Date of Issue
0	Issued to client	28/Mar/18

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1 INTRODUCTION

The Hero Class vessels are based on the Damen DSP 4207 design. This proven design was equipped with active stabiliser fins. Due to many changes to the original design the vessel had become too heavy and it was decided to drop the stabilizers to save weight and reduce hull resistance. The vessels are now known to be uncomfortable due to their rolling characteristics. Lengkeek Vessel Engineering Incorporated (LVE) has been tasked with performing a Comparative Analysis and a feasibility study for the installation of several roll stabilization configurations on the Hero Class vessels, based on the Seakeeping Analysis Report, prepared by Damen Shipyards Gorinchem (Damen). Damen Project number 253739, attached in Appendix C.

2 STABILIZER CONFIGURATIONS

The following stabilization configurations were analyzed by Damen:

a) None- current situation
b) Active stabilizer fin Quantum S-QC1200
c) Active zero-speed stabilizer fin Quantum P-QC1500
d) Bilge keels
e) Active rudder (existing rudder controls)
f) Active rudder (existing rudder controls) & bilge keels
g) Active rudder (new rudder controls)
h) Active rudder (new rudder controls) & bilge keels

3 REVIEW OF RAO PLOTS AND POLAR PLOT

3.1 RAO PLOTS

It appears that on all RAO plots, except the plots 7.1.7 V=0, 7.1.8 V=0, 7.1.9 V=0, the red line is the lowest (=best) response to the incoming waves, which is the Quantum Zero Speed & Underway P-Series, model QC-1500. In the 3 plots, where it was not lowest, it was still second best. In these conditions, where the vessel is at rest, (zero speed), it was outperformed by the bilge keels alone, and the combination of bilge keels and Active rudder, where the contribution of the Active rudders is minimal.

Except for zero speed, the 2nd best response is the dark green line, which is the Quantum Underway S-series active stabilizer, model QC-1200, which is fitted on several other Spa 4207s.

3.2 POLAR PLOTS

a) The polar plots for Great Lakes Sea State 5 and 6 – Roll, Departure condition confirm that at very low speed the bilge keels, with or without Active rudders provide the best roll reduction. At speeds over 5 knots the P-QC1500 work best, with the S-QC1200 being a close 2nd.
b) The polar plots for Great Lakes Sea State 5 and 6 – Bridge accelerations, Departure condition, give the same scoring results as above in section a).
c) The polar plots for Great Lakes Sea State 5 and 6 – Motion Seasickness Index show the worst approach angle of the waves is at between 210 and 240 degrees get and at higher speeds. In these analyses the P-QC1500 work slightly best both at low speeds as well as speeds higher than 5 knots, with the S-QC1200 being a close 2nd over 5 knots and

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active rudder (new rudder controls) & bilge keels scoring 3rd at lower speeds. However, none of the systems shows to provide a significant improvement.

d) The polar plots for North Atlantic / Pacific, Sea State 5 and 6 – Roll, Departure condition confirm that at very low speed the bilge keels, with or without Active rudders provide the best roll reduction. At speeds over 5 knots the P-QC1500 work best, with the S-QC1200 being a close 2nd.
e) The polar plots for North Atlantic / Pacific, Sea State 5 and 6 – Bridge accelerations, Departure condition, give the same scoring results as above in section d).
f) The polar plots for North Atlantic / Pacific, Sea State 5 and 6 – Bridge transverse accelerations, Departure condition, show again that the P-QC1500 work best both at low speeds as well as speeds higher than 5 knots, with the S-QC1200 being a close 2nd and bilge keels with or without the active rudders scoring 3rd but only better at zero speed.
g) The polar plots for North Atlantic / Pacific, Sea State 5 and 6 – RHIB station, Seasickness index, Departure condition, show that just bilge keels at very speed give the best reduction. The P-QC1500 work best at speeds higher than 5 knots, with the S-QC1200 being a close 2nd over 5 knots. However, none of the systems shows to provide a significant improvement.

3.3 CONCLUSION REVIEW OF DAMEN REPORT

If the Quantum P-QC1500 stabilizer fins would fit the hull and if the components would fit in the vessel, this would give the best results with regards to reduction of roll, transverse accelerations in the wheelhouse and Sea Sickness Index.,

Generally, second best with close results to the above is the Quantum Underway S-series active stabilizer system, model S-QC1200, which is fitted on several other Spa 4207s.

The Rudder Stabilization, combined with Rudder Stabilization with improved controls, works reasonable well at low speed, but not as good on speeds above 5 knots.

The Rudder Stabilization, combined with Rudder Stabilization without improved controls, works not as well, and we expect that the steering system will be overloaded and wear out fast, therefore not a good practical solution.

The bilge keels don't seem to do much in the RAO plots, but have reasonable effect at lower speeds in reducing roll angles, bridge transverse accelerations, and a small reduction in Sea Sickness Index. It is the easiest / cheapest solution to add, and if no room can be found for installation of the active systems, it may be the only feasible option.

4 STABILIZER ARRANGEMENT OPTIONS

4.1 ACTIVE STABILIZING FINS

Initially three manufacturers of stabilizer fin systems were contacted to provide options for active and/or zero-speed stabilizers for the Hero Class vessels. At the time of this report, two manufacturers have provided to LVE, adequate information (i.e. dimensional drawings and component specifications) to allow a preliminary arrangement of components to be completed to determine the feasibility of having stabilizer fins installed on these vessels.

The first manufacturer to respond was Quantum who have provided two options for fin stabilizers. The first are model QC1200 stabilizers with S-Series active fins (1.4m2/fin) and the

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second are QC1500 stabilizers with P-Series active/zero-speed fins (3m2/fin). Both systems can be supplied with a dedicated HPU suitable for active and zero-speed stabilizing of the vessel.

Rolls Royce also provided an option with the Gemini 10 model active fin stabilizer supplied with 1.1m2 fins. An HPU can be provided by Rolls Royce for this stabilizer model however at the time of this report, no dimensional or weight information was provided to LVE for the HPU. The Rolls Royce stabilizer units are approximately twice the weight of the Quantum units and included as part of their supply, a baseplate for installation that weighs more than the stabilizer unit itself. However, this baseplate can be modified to reduce some of the excess weight.

Dimensional drawings of the major components were provided by the manufacturers for the stabilizer systems and used with the ships machinery arrangement and structural section drawings to determine the arrangement and installation location options for the stabilizers within the middle third of the vessels waterline length. In addition, onboard surveys were conducted to view the potential locations to determine the extent of any clashes with existing components and with installed piping at these locations.

Two locations for installing stabilizer fins on the Hero Class vessels were investigated. The first area looked at was just forward of the Engine Room within the Motor Control Room on the port side and the Laundry/Stores room on the starboard side. Space and access limitations in these areas and a lack of available service space for the stabilizer units preclude any installation at these locations.

The second area considered was in the forward area of the engine room in the same general location where stabilizers have been installed on other Damen designed 4207's. This area provides more open space for installation and access to the stabilizer units, however both locations have existing components and piping installed that will require relocation and re-routing to allow room for the stabilizer units to be installed.

While arranging the stabilizer fins at Fr.16 within the engine room, it was determined only the smaller active fins (1.4m2) from both manufacturers could properly be installed without the fin width extending below the bottom of the vessel, or the fin length clashing with the hull chine when rotated upward. It has been indicated to LVE that the Quantum QC1200 system controller can be set-up to provide "partial zero-speed" capacity with the smaller fin still installed. It is assumed this is possible with the Rolls Royce option as well.

Sketches of the stabilizer components arranged within the vessel can be seen on LVE drawing. J18009-SK1, however these arrangements do not show the required structural supports for the installations. A list of components and piping affected by an installation at this location is included as part of the stabilizer comparison spreadsheet, J18009-R02. Section 4.1.1 below shows pictures of the stabilizer unit installation locations as seen on the Corporal McLaren.

The above comments apply to both the Quantum and Rolls Royce stabilizer options.

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4.1.1 INSTALLATION LOCATIONS FOR STABILIZER UNITS

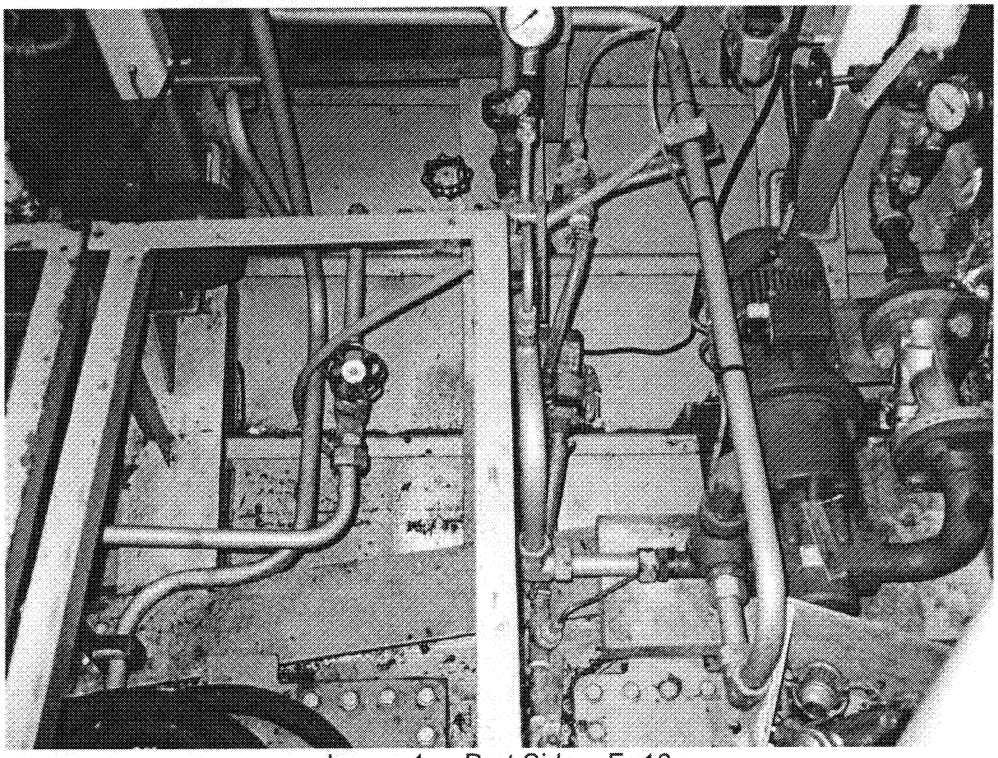

Image 1 Port Side – Fr.16

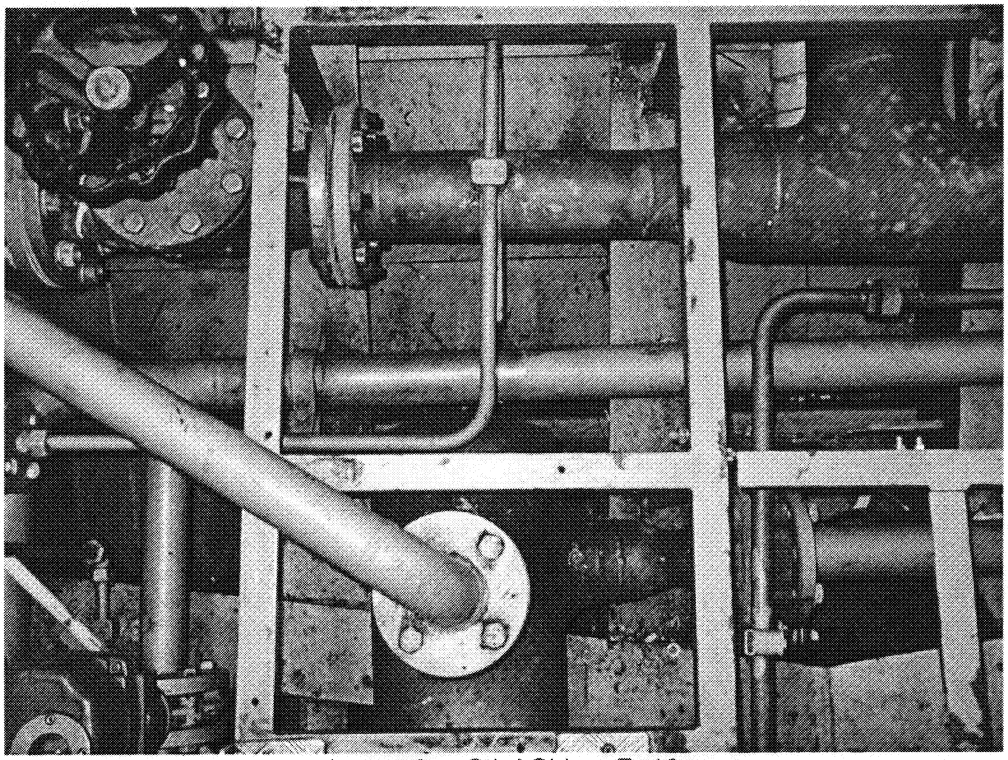

Image 2 Stbd Side – Fr.16

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4.1.2 POWERING OPTIONS FOR STABILIZERS

Both Quantum and Rolls Royce can provide dedicated HPU's suited for the stabilizer models they have specified. An HPU provides a stand-alone, dedicated hydraulic system for actuating the fins while also providing partial zero-speed stabilizer capacity when the vessel is stationary, and the engines are idling. However, a new HPU represents additional weight on a vessel that is already weight sensitive with little available space onboard to accommodate the unit. The HPU's would require cooling water supplied from the ships sea water cooling system. LVE drawing J18009-SK1 shows a location for possible installation of an HPU within the steering gear compartment, however this restricts access within the compartment and is not ideal.

As zero-speed capacity is not a requirement for these vessels, this allows an alternate hydraulic system to be utilized. The existing ship hydraulic system currently powering the bow thruster and other components on the Main Deck should be investigated further to determine suitability for use with the stabilizing fins. A second possibility for powering the stabilizer fins would see the installation of a dedicated hydraulic system powered from a new hydraulic pump driven from an available PTO on the main engine or gearbox. If either option proves viable, the HPU would no longer be required thus freeing up space and reducing added weight to the vessels.

4.2 RUDDER ROLL STABILIZING SYSTEM

The option to modify the existing steering system to include roll stabilizing through rudder actuation was investigated briefly. The supplier of the existing steering system (Jastram) was contacted to determine suitability of the existing steering system to be modified/upgraded to provide rudder stabilization. In addition, RH Marine in Holland was contacted for their consideration on the suitability of installing this type of stabilization system onboard vessels like the Hero Class.

It was indicated to LVE that the Hero Class vessels are not suited for this type of stabilizing system. Firstly, the vessels are too small to warrant the installation while the system itself requires two new HPU's (larger and heavier) to replace the existing steering system pumps and a large control cabinet as well. Rudder roll stabilizing is usually planned during design stage of a vessel, not as a refit. To install this stabilizing system on the Hero Class vessels also requires a strength analysis of the existing rudder system and the aft end structure of the vessel and will likely require that both areas be significantly reinforced to account for the increased loads. The costs of the system components and the redesign of the rudder, supports and aft end structure will be significant in addition to not providing optimal stabilizing ability preclude the installation of this system

For these reasons, rudder stabilizing was no longer considered as a viable option.

4.3 BILGE KEELS (SINGLE AND DOUBLE-PLATE OPTIONS)

The installation of bilge keels has also been considered. Bilge keels provide decent stabilizing at zero-to-low speeds; however, their effectiveness drops off as speed increases. Bilge keels also increase hull resistance more than the stabilizer fins, which provide superior stabilizing at lower-to-high speeds. The main benefit of installing bilge keels on the Hero Class vessels is the simple nature of the installation. Fabrication and installation of bilge keels is straight-forward, and no interior space is needed within the vessel.

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Bilge keels can be of single-plate, or double-plate construction depending on the depth of the plate and operating profile of the vessel. Options for both style of bilge keel can be seen on LVE drawing J18009-SK1.

The option to install both fin stabilizers with short bilge keels can be considered. The combination would provide additional zero-speed stabilizing in addition to very effective stabilizing at speed with the active fins but have a fair impact on speed and range.

4.4 STABILIZER DEFLECTORS AND SUITABILITY OF INSTALLATION ON WEST COAST VESSELS

The Hero Class vessels do experience an issue with catching lobster trap lines and other lines near the surface with the transducer appendage. With this in mind; installation of any stabilizer fin system should also consider the installation of line deflectors forward of the leading edge of the fins, or other measure to prevent the pinching of lines between the hull plating and the inboard edge of the fin. Any installation of bilge keels should have a sloped forward edge to direct any incoming lines out and past the bilge keels.

The Hero Class vessels on the west coast of Canada regularly encounter drifting logs also called deadheads. This issue shall be considered heavily when making the determination to install either fin stabilizers, on those vessels. Rope deflectors as described above will not be adequate to protect any new large appendages from hitting a wooden mass at speed.

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5 SUMMARY AND CONCLUSION

The Quantum Zero Speed & Underway P-Series, model QC-1500 fins would give the best performance in reducing roll and accelerations of the vessel. However, the P-QC1500 fins do not fit the vessel's hull and the required HPU is large, heavy and difficult to install in the vessel.

The Quantum Underway S-series active stabilizer system, model QC1200, which is fitted on several other Spa 4207s is feasible given the relocation of components and re-routing of piping at the installation locations is acceptable. The best location is in the forward part of the engine room at Fr.16, similar to the Damen design.

Rudder Stabilization is not recommended. The system requires two larger HPU's to replace the existing steering system hydraulics with little space available and is very expensive. There appears no room available for the Automatic Control Unit and this system will require significant strengthening in the aft hull and rudder support structure. All added weight to the aft end of the vessel.

Bilge keels are the easiest / cheapest solution to add and give the best roll reduction at zero speed. For the vessels on the West Coast this may well be the best solution as floating logs in the waters will likely damage the fin stabilizers at speed. In the Great Lakes and on the Atlantic Coast consideration might be given to combine the bilge keels with the active stabilizers to improve both zero-speed and higher speed roll reduction.

More details for Quantum QC1200 active stabilizer system with 1.4m2 fins:

- System can be powered from supplied HPU (20hp) or likely from the existing hydraulic system onboard (hydraulic pumps driven from gearbox PTO's). Possible to use generator PTO's if available (question has been posed to the Chief about this).
- Expect 80-85% roll-reduction at cruising speed of 15knots, 2m seas.
- Capable of partial zero-speed roll-reduction (approx. 30% @ 1m seas) – Requires optional HPU however.
- For active fin only (i.e. minus HPU); this provides the greatest roll-reduction with the least installed weight (includes components, minus additional plate and stiffening i.w.o stabilizer units) and places that additional weight in the mid-ship area. By including the HPU (required for partial zero-speed capability), this places an additional 525kg in the aft end of the vessel. Otherwise, the main engines may have to be sped-up while idling.
- System will clash with some components and piping in the forward corners of the Engine Room and will require some relocation and re-routing of piping in these areas.

The launching / retrieval of a FRC in high sea states is most likely the operation in which the rolling of the vessel makes it difficult to perform. If this operation needs to be performed at zero speed, adding bilge keels will probably be the best solution. If this operation can be performed at 5 knots speed or more, the addition of stabilizer fins will be a much more effective solution.

If DFO / CCG decide to go with any stabilizer system installation, LVE recommends the following steps:

1. Install one or more of the candidate vessels with accelerometers to measure motion characteristics of the vessel(s). Crew to log wave height, speed and heading to verify calculated values. Record power / vs speed.

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2. Perform a full engineering package for the installation, including strength analysis of hull i.w.o. stabilizers, repositioning of equipment and rerouting of piping and wiring in way of installation, design of foundations for stabilizers and ancillary equipment. Load analysis and one-line diagrams for powering and control of equipment.

3. After installation, repeat the measurements with accelerometers and verify the effectiveness in roll reduction prior to installation on other vessels.

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APPENDIX A: STABILIZER OPTION COMPARISION SPREADSHEET

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Hero Class - Stabilizer Options Comparison

Type	Active Fin	Active Fin	Active Rudder	Bilge Keels - Single Plate	Bilge Keels - Double Plate
Model	Quantum QC1200	Rolls Royce Gemini 10	Jastram & RH Marine	None. Fabricated	None. Fabricated
Major Components	**HPU** - (1 off) MPU20 **Stabilizer Unit** - (2-Off) QC1200 **Stabilizer Fins** - (2-Off) 1.4m2 QC1200	**HPU** -(1 Off) Gemini 10 **Stabilizer Unit** - (2-Off) Gemini 10 **Stabilizer Fins** - (2-Off) 1.1m2 Gemini 10	**HPU** - (2-Off) Jastram Supply **Automatic Control Unit** - (1-Off) RH Marine Supply	(2-Off) Bilge Keels	(2-Off) Bilge Keels
Minor Components	- Adaptive Stabilizer Control - HPU Starter	- Bridge Operator Panel - Central Control Panel - Smart Roll Sensor - Servo Junction Box - Motor Starter Panel	- Bridge Control Panel - Control Selectors	N/A	N/A
Weight of Major Components (kg)	**HPU** - 524kg(wet) **Stabilizer Units** - 2 x 306kg(dry) **Stabilizer Fin** - Neutrally Buoyant	**HPU** - TBD **Stabilizer Units** - 2 x 674kg(dry) **Stabilizer Fin** - Neutrally Buoyant **Base Plate** - 2 x 750kg - (can be reduced)	**HPU** - (2-Off) 768kg(wet)	**Bilge Keels** (assume 200x9mm BP+T) 2 x 300kg	**Bilge Keels** (assume 350x6mm) 2 x 535kg
Total (kg)	**approx. 1136kg ****	**TBD**	**approx. 1536kg ***	**approx. 600kg**	**approx. 1070kg**
Powering Options	Existing Hydraulic System, New Hydraulic System (PTO) or Supplied HPU	Existing Hydraulic System, New Hydraulic System (PTO) or Supplied HPU	HPU's (2-Off)	N/A	N/A
Power Requirements(kW)	15kW	TBD	30kW	N/A	N/A
Location of Major Components	**Stabilizer Units** - Fr.16 - Engine Room (P&S) **HPU** - Steering Gear Compartment (Stbd Side)	**Stabilizer Units** - Fr.16 - Engine Room (P&S) **HPU** - Steering Gear Compartment (Stbd Side)	**HPU's** - Steering Gear Compartment **Automatic Control Unit** - No Space Available	**Bilge Keels** - Fr.13-26 (P&S)	**Bilge Keels** - Fr.13-26 (P&S)
Clashes with Existing Arrangement	**Port Side - Engine Room Fwd** - F.O. Continuous Transfer Pump and Connected Piping - F.O. Transfer Pump and Connected Piping - Small S.W. Line and Pump Servicing Condenser System Above - Misc. Small-Bore S.W. Cooling Lines **Stbd Side - Engine Room Fwd** - S.W. Cooling Return Line w/Valve to Sea-Chest Connection - S.W. O/B Disharge - Small Dia. S.W. Cooling Line - Outboard End of S.W. Pipe Manifold and Connected Piping - Piping i.w.o Sea-Chest and S.W. Pipe Manifold **Steering Gear Compartment** - Hydraulic Oil Piping Stbd Side of CL post	**Port Side - Engine Room Fwd** - F.O. Continuous Transfer Pump and Connected Piping - F.O. Transfer Pump and Connected Piping - Small S.W. Line and Pump Servicing Condenser System Above - Misc. Small-Bore S.W. Cooling Lines **Stbd Side - Engine Room Fwd** - S.W. Cooling Return Line w/Valve to Sea-Chest Connection - S.W. O/B Disharge - Small Dia. S.W. Cooling Line - Outboard End of S.W. Pipe Manifold and Connected Piping - Piping i.w.o Sea-Chest and S.W. Pipe Manifold **Steering Gear Compartment** - Hydraulic Oil Piping Stbd Side of CL post	Does Not Appear Available Space for Automatic Control Unit	N/A	N/A
Additional Installation Requirements	- HPU Supports - Hull Plate Inserts - Additional Stiffening i.w.o. Stabilizers - Ancillary Cooling - Possible Save-All around Stabilizer Units	- HPU Supports - Hull Plate Inserts (manuf. Supplied) - Additional Stiffening i.w.o. Stabilizers - Ancillary Cooling - Possible Save-All Around Stabilizers	- Analysis and Possible Strengthening of Aft Hull - Analysis and Possible Replacement of Rudder Bearing and Strengthening of Rudder Shaft Supports	- Final Design - Fabrication	- Final Design - Fabrication
Base Price of Supplied Components	[redacted] CAD	TBD	[redacted] CAD	[redacted]	[redacted]
Delivery Time	20-24 weeks	TBD	TBD	N/A	N/A

*** Does not include weight of structural supports required for installation**
**** Does not include weight of structural supports or insert plating required for installation**

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APPENDIX B: STABILIZER OPTION ARRANGEMENTS

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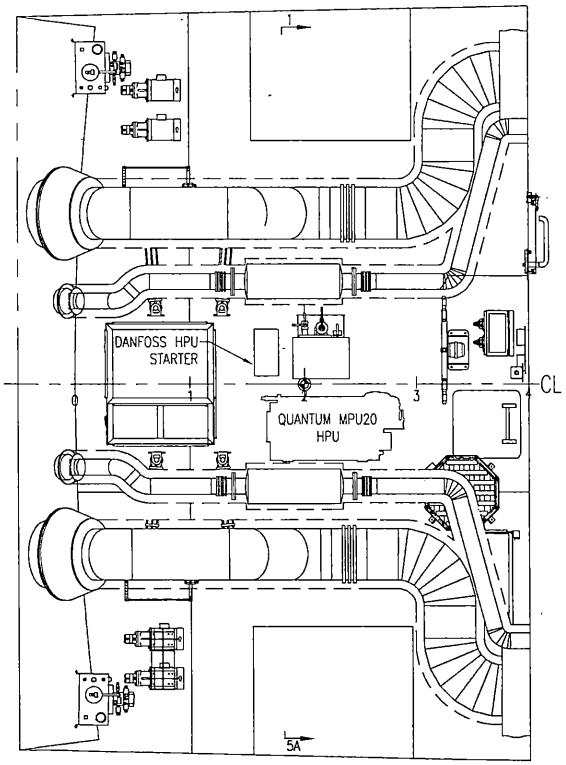
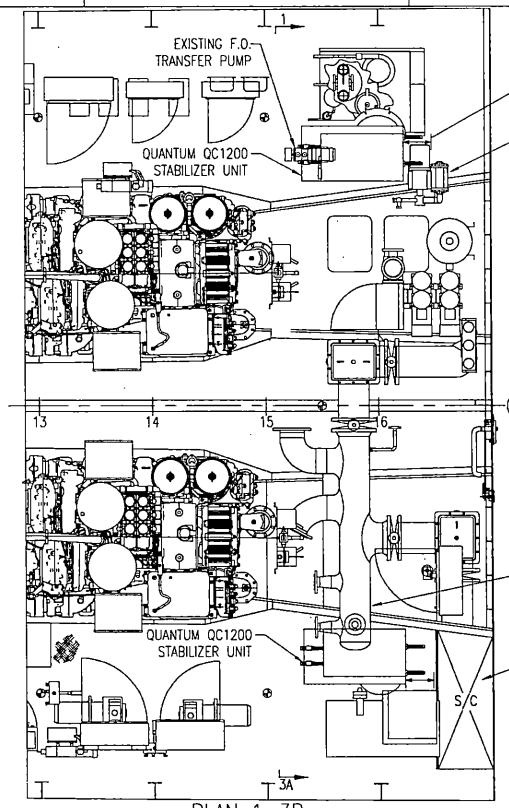


PLAN 1-5B

BELOW MAIN DECK – STEERING GEAR COMPARTMENT



PLAN 1-3B

BELOW MAIN DECK – ENGINE ROOM FORWARD

REFERENCE PLANS:

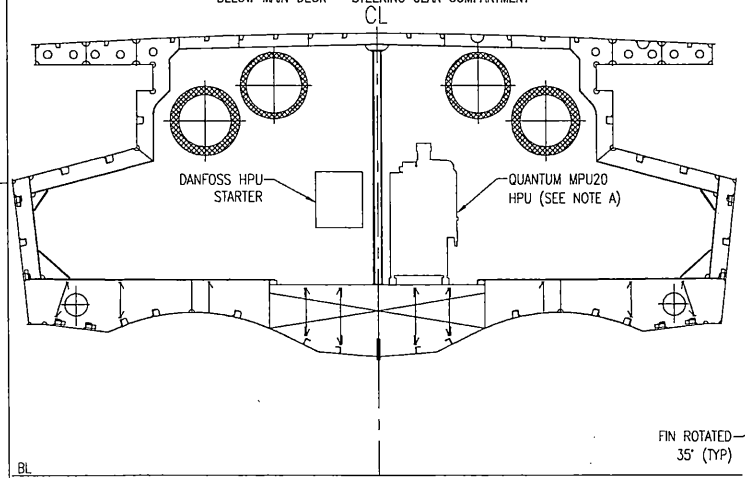
No.	Dwg No.	DESCRIPTION

NOTE A

HPU SHOWN FOR ARRANGEMENT PURPOSES ONLY. SOURCE OF HYDRAULIC POWER FOR OPERATING STABILIZERS TBD.

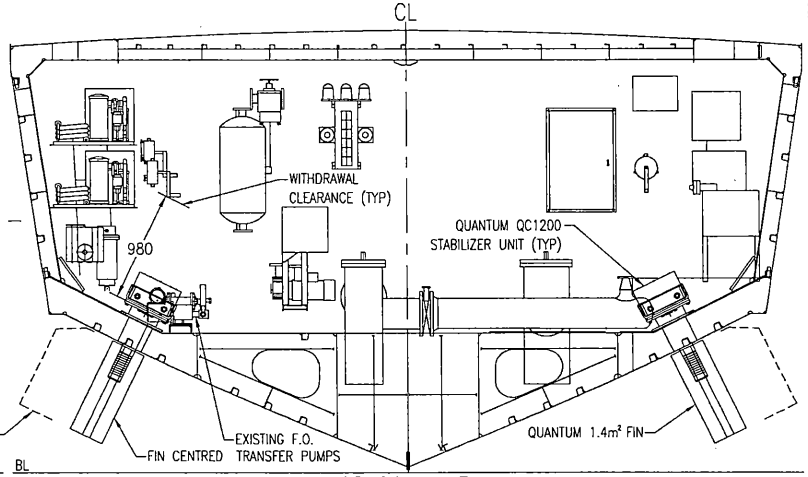
OPTION 1

QUANTUM QC1200 ACTIVE STABILIZING FINS (PARTIAL ZERO-SPEED CAPABLE w/HPU)



SECTION 1-5A

STEERING GEAR COMPARTMENT FR.2 – LOOKING FORWARD



SECTION 1-3A

ENGINE ROOM FR.16 – LOOKING FORWARD

Rev	Date	By	Remarks
0	29/03/18	D.O'R.	ISSUED TO CLIENT

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Client: DFO-CCG

Title: CCG MID-SHORE PATROL VESSELS

ROLL STABILIZING OPTIONS ARRANGEMENT

Drawn By:	D.O'R.	Date:	26/03/18
Checked By:	M.F.	Scale:	1:30
	Approval/Rev	Rev:	0
Client		DWG NO:	J18009-SK1
Class			
Flag		Sht No:	1 of 4

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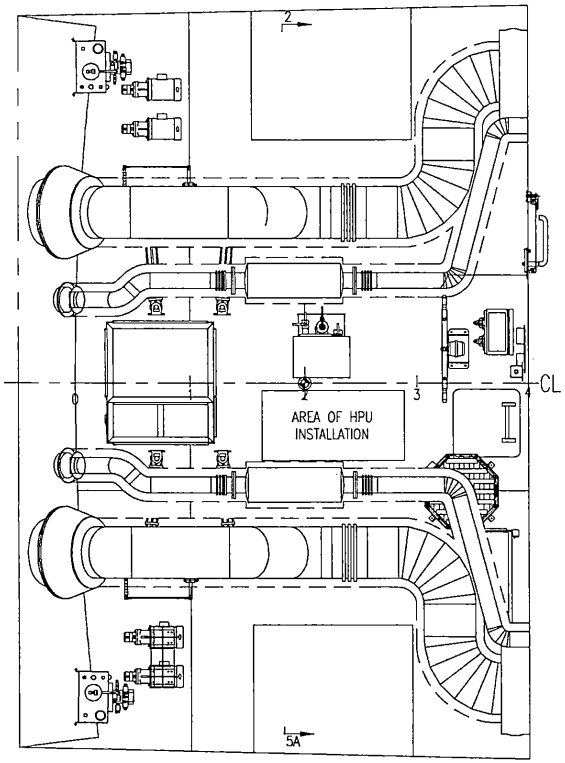
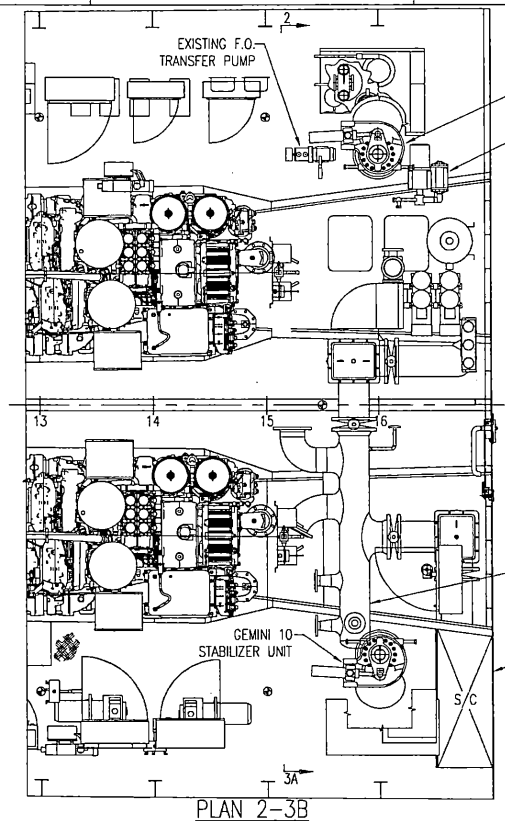


PLAN 2-5B

BELOW MAIN DECK – STEERING GEAR COMPARTMENT



PLAN 2-3B

BELOW MAIN DECK – ENGINE ROOM FORWARD

REFERENCE PLANS:

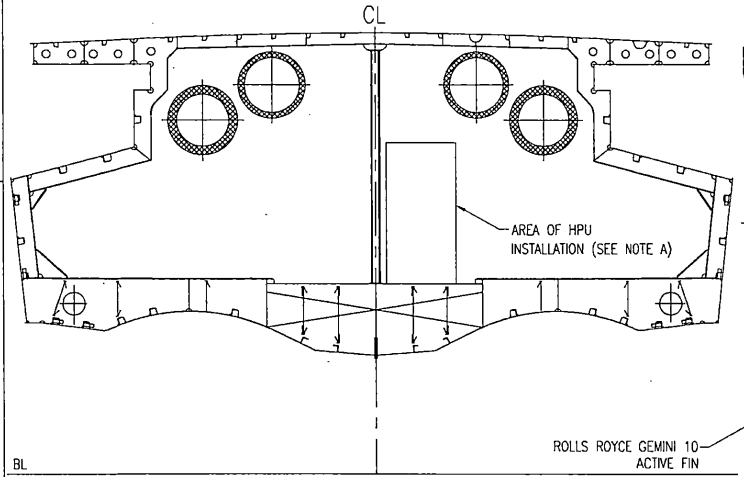
No.	Dwg No.	DESCRIPTION

NOTE A

HPU SHOWN FOR ARRANGEMENT PURPOSES ONLY. SOURCE OF HYDRAULIC POWER FOR OPERATING STABILIZERS TBD.

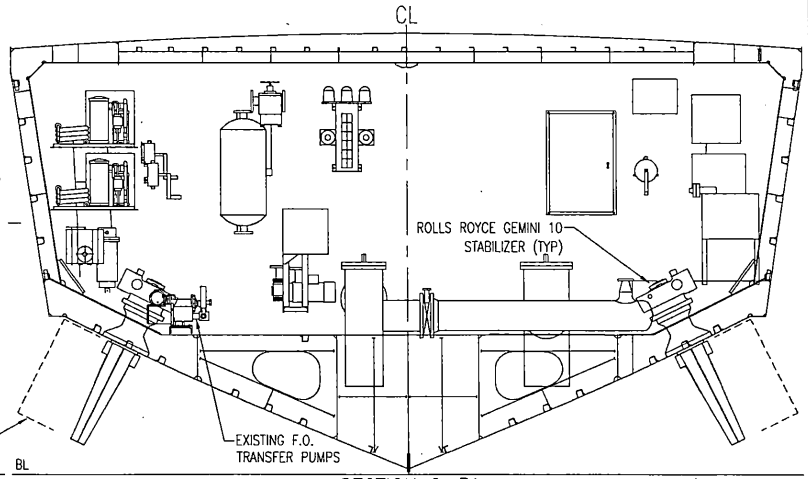
OPTION 2

ROLLS ROYCE GEMINI 10 ACTIVE STABILIZING FINS



SECTION 2-5A

STEERING GEAR COMPARTMENT – LOOKING FORWARD



SECTION 2-3A

ENGINE ROOM – LOOKING FORWARD

Rev	Date	By	Remarks
0	29/03/18	D.O'R.	ISSUED TO CLIENT

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Lengkeek Vessel Engineering
11 Portland St. Suite 301 Dartmouth NS Canada B2Y 1H1 Tel: (902) 468-3094 www.lengkeek.ca

Client: DFO-CCG

Title: CCG MID-SHORE PATROL VESSELS

ROLL STABILIZING OPTIONS ARRANGEMENT

Drawn By: D.O'R.		Date: 26/03/18	
Checked By: M.F.		Scale: 1:30	Rev: 0
	Approval/Rev	DWG NO:	
Client		J18009-SK1	
Class			
Flag		Sht No:2 of 4	

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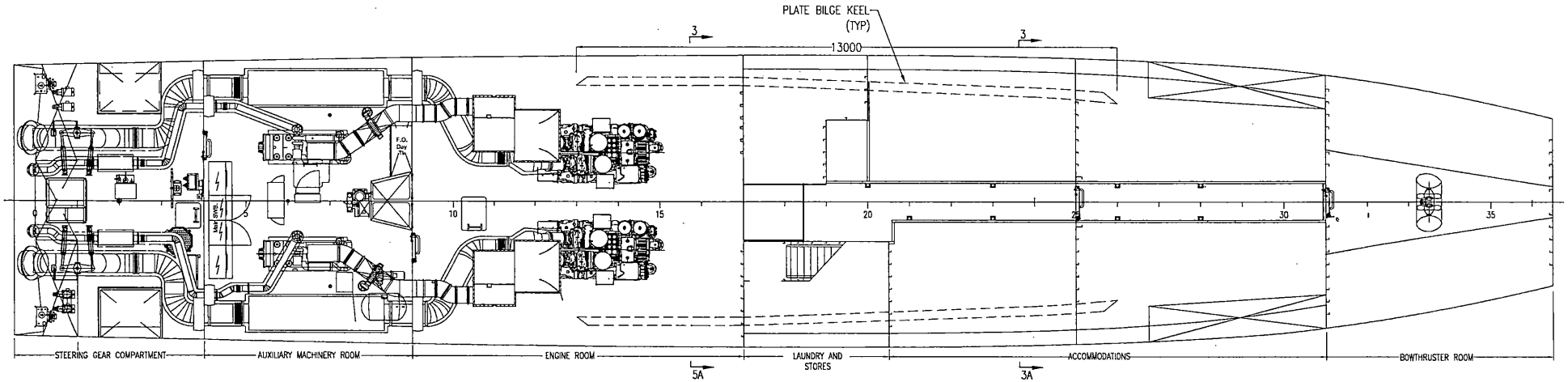
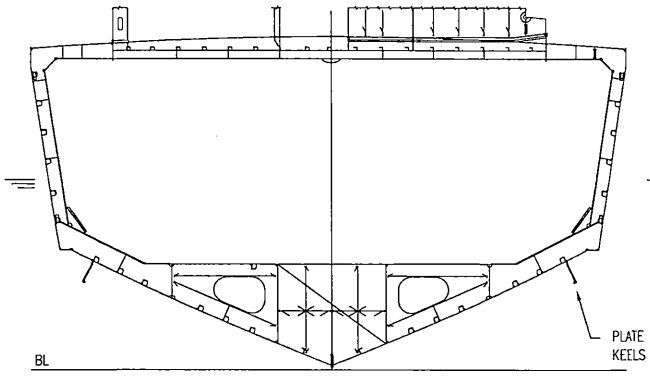
REFERENCE PLANS:		
No.	Dwg No.	DESCRIPTION

** SIZE AND LOCATION OF BILGE KEELS SHOWN FOR GUIDANCE PURPOSES ONLY. FINAL DESIGN TBD.

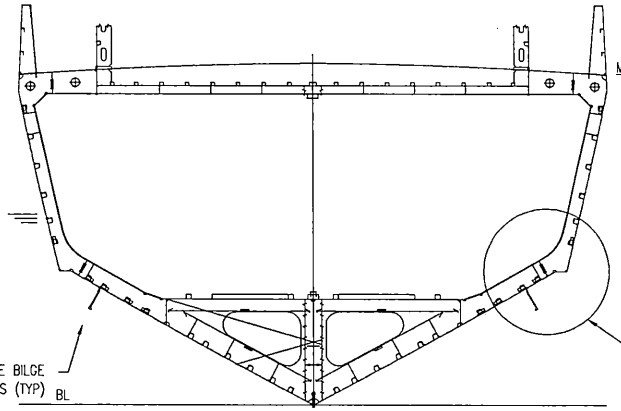


PLAN 3-4B
BELOW MAIN DECK
SCALE – NTS

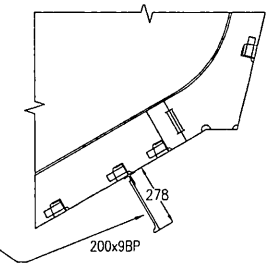
OPTION 3
SINGLE PLATE BILGE KEELS



SECTION 3-5A
FRAMNE 16 – LOOKING FORWARD
SCALE 1:40



SECTION 3-3A
SECTION FR.24 – LOOKING FORWARD
SCALE 1:40



DETAIL 3-2A
PLATE BILGE KEEL
SCALE 1:15

Rev	Date	By	Remarks
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11 Portland St. Suite 301 Dartmouth NS Canada B2Y 1H1 Tel: (902) 468-3094 www.lengkeek.ca

Client: DFO-CCG

Title: CCG MID-SHORE PATROL VESSELS
ROLL STABILIZING OPTIONS
ARRANGEMENT

Drawn By:	D.O'R.	Date:	26/03/18
Checked By:	M.F.	Scale:	AS SHOWN
		Rev:	0
	Approval/Rev	DWG NO:	
Client		J18009-SK1	
Class			
Flag		Sht No:	3 of 4

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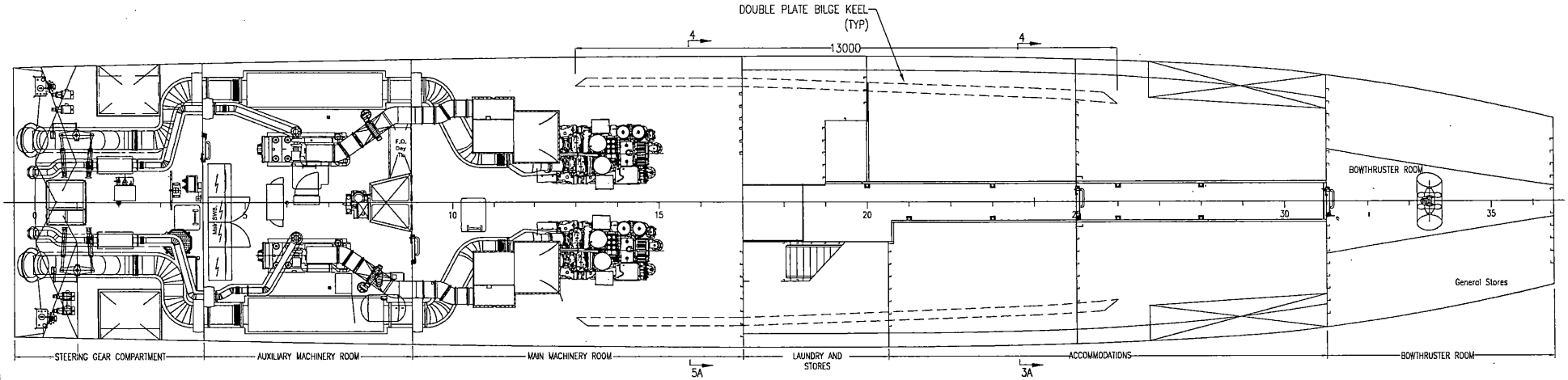
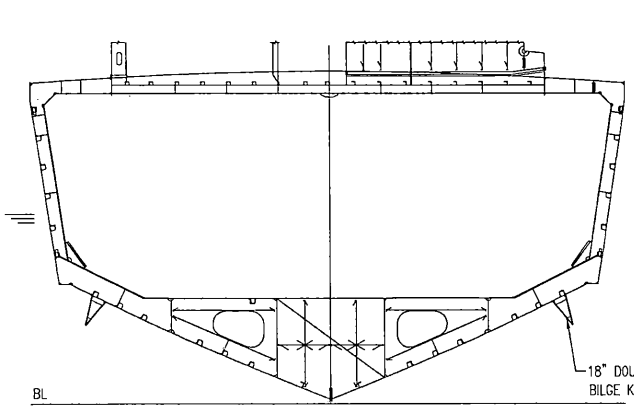
REFERENCE PLANS:		
No.	Dwg No.	DESCRIPTION

** SIZE AND LOCATION OF BILGE KEELS SHOWN FOR GUIDANCE PURPOSES ONLY. FINAL DESIGN TBD.

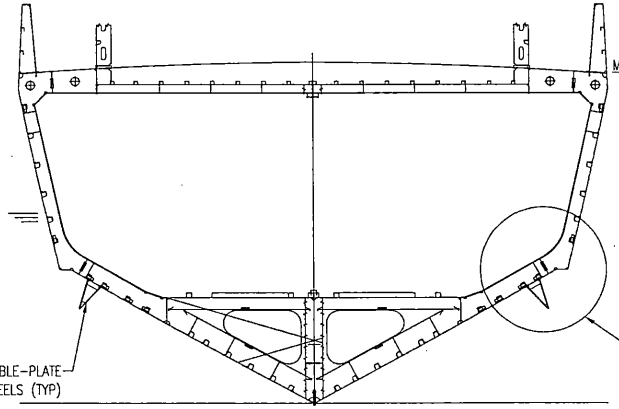


PLAN 4-4B
BELOW MAIN DECK
SCALE – NTS

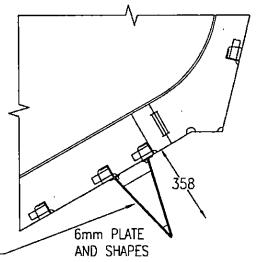
OPTION 4
DOUBLE PLATE BILGE KEELS



SECTION 4-5A
FRAME 16 – LOOKING FORWARD
SCALE 1:40



SECTION 4-3A
FR.24 – LOOKING FORWARD
SCALE 1:40



DETAIL 4-2A
DOUBLE PLATE BILGE KEEL
SCALE 1:15

Rev	Date	By	Remarks
0	29/03/18	D.O'R.	ISSUED TO CLIENT

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11 Portland St. Suite 301 Dartmouth NS Canada B2Y 1H1 Tel: (902) 468-3094 www.lengkeek.ca

Client: DFO-CCG

Title: CCG MID-SHORE PATROL VESSELS
ROLL STABILIZING OPTIONS
ARRANGEMENT

Drawn By:	D.O'R.	Date:	26/03/18
Checked By:	M.F.	Scale: AS SHOWN	Rev: 0
	Approval/Rev	DWG NO:	
Client		J18009-SK1	
Class			
Flag		Sht No:4 of 4	

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Wyse, David E

From: G Peddle, Commanding Officer <GPeddleCO@ped.ccgs-ngcc.gc.ca>
Sent: Friday, April 20, 2018 7:37 AM
To: Wyse, David E
Subject: RE: Hero Class load line meeting

Hi Dave,

I'm thinking that a teleconference may be the way to go on this. I believe it would be the best way to get most of the CO's, including those that are on shift, input.

Regards,

Christopher Cyr
Commanding Officer | Commandant
CCGS G. Peddle S.C.| NGCC G. Peddle S.C.
Canadian Coast Guard | Garde côtière canadienne
Atlantic Region | Région de l'Atlantique
Telephone | Téléphone: 902-478-9806
Email | courriel: gpeddleCO@ped.ccgs-ngcc.gc.ca
Government of Canada | Gouvernement du Canada

From: Wyse, David E [mailto:David.Wyse@dfo-mpo.gc.ca]
Sent: Thursday, March 29, 2018 2:49 PM
To: (corporalmclarenCO@mcl.ccgs-ngcc.gc.ca); A leblanc CO (aleblancCO@ccgs-ngcc.gc.ca); Carriere; carriere chief officer; CCGS-NGCC, Corporal Teather Commanding Officer (CorporalTeatherCO@ccgs-ngcc.gc.ca); G Peddle, Commanding Officer; goddard-captain@god.ccgs-ngcc.gc.ca; Kaeble; M Charles; Private Robertson; private robertson chief officer; Teather chief officer
Cc: McMillan, Cody; Mkrtychan, Sergey; Couillard-Desjardins, Isabelle; Mercier, Jeffrey; aleblancCE@ccgs-ngcc.gc.ca; Carriere 1st engineer; ConstableCarriereCE@ccgs-ngcc.gc.ca; CorporalMcLarenMMVCE. CCGS@dfo-mpo. gc. ca (CorporalMcLarenCE@MCL.ccgs-ngcc.gc.ca); CorporalTeatherCE@ccgs-ngcc.gc.ca; G Peddle, Chief Engineer; Goddard-ChiefEngineer@GOD.ccgs-ngcc.gc.ca; KaebleCE@ccgs-ngcc.gc.ca; mcharlesce@cha.ccgs-ngcc.gc.ca; PrivateRobertsonCE@ccgs-ngcc.gc.ca; Robertson 1st eng; Teather 1st eng
Subject: Hero Class load line meeting

Good morning Captains,

After our face to face meeting in Halifax, it is apparent that we need to have a meeting with Hero Class vessel captains to determine the way forward with the vessel load lines and weight issues. With all the new CCRs including possibility of stabilizers we have to make decisions on the way forward.

What is the best and realistic way to get a majority number of Captains in a meeting to make some decisions on the way forward in regards to Load line and weight management? This meeting has to happen shortly (months) for us to plan the way forward with some major CCRs (stabilizers)

- Face to face meeting?
- Teleconference?

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- Webex?

Thanks
Dave

David Wyse
Project Engineer | Mécanicien de Projet
Marine Engineering | Ingénierie Navale
Integrated Technical Services | Services Techniques Intégrés
Canadian Coast Guard | Garde Côtière Canadienne
200 Kent Street, Office 7W076, Mail Drop 7W064
Ottawa, ON, K1A 0E6
David.Wyse@dfo-mpo.gc.ca
Telephone | Téléphone 613-302-6503

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Wyse, David E

From: Plows, Emilie
Sent: Tuesday, May 15, 2018 1:06 PM
To: Morphet, Jason (NCR); Wyse, David E
Subject: RE: Meeting notes review

Thanks again to you both. I'll make the updates and circulate.

Emilie

From: Morphet, Jason (NCR)
Sent: May-15-18 12:36 PM
To: Wyse, David E; Plows, Emilie
Subject: RE: Meeting notes review

concur

Jason R. Morphet

A/Manager, Readiness | Gestionnaire, disponibilité Opérationnelle, int.
Jason.Morphet@dfo-mpo.gc.ca
Tel : (613) 355-2879

Saluti Primum, Auxilio Semper

From: Wyse, David E
Sent: May 15, 2018 12:16
To: Plows, Emilie; Morphet, Jason (NCR)
Subject: RE: Meeting notes review

My suggestions

Gary recommended that Emilie set up two separate meetings with the RCMP and C&P to review the Technical Statement of Operational Requirements (TSOR) for their organizations. David can provide the document to Emilie for circulation. One of the items Gary would like to review with the RCMP is the requirement to have two RHIBs to be able to be launched in a sea state 4 condition. David would also like to review the requirement to have gasoline outboards instead of diesel inboards on the Rhibs.

Before looking at options on modifying the RHIB launch and retrieval system, the impact of the installation of stabilizers (for seakeeping) needs to be evaluated. The recommended solution for the MSPV class of vessel is an active fin stabilizer. The least intrusive way to install the stabilizers would be to have an independent hydraulic power pack installed with the stabilizers. This would add more weight to the aft of the vessel. The vessels are currently at the weight margin and discussions will have to take place shortly on next steps to control the weight and deal with the load line.

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From: Plows, Emilie
Sent: May-15-18 11:44 AM
To: Morphet, Jason (NCR); Wyse, David E
Subject: Meeting notes review

Hi Jason and Dave,

Can you do a quick review of the notes and action items from the meeting on Friday?

From this point on, will one of you be official chair of the meetings/teleconferences? I'll take care of the logistics for them.

I'll send out the TSOR to the program heads for RCMP and C&P. I'm not sure I'll be able to organize something for next week before I'm on travel for a week and half, so I'll aim to set up those meetings when I'm back in the office first or second week of June.

Thank you,

Emilie Plows
A/Maritime Security Operations Analyst
Canadian Coast Guard / Government of Canada
emilie.plows@dfo-mpo.gc.ca / Tel: 613-998-8514

Analyste des opérations de la sûreté maritime p/i
Garde côtière canadienne / Gouvernement du Canada
emilie.plows@dfo-mpo.gc.ca / Tél : 613-998-8514

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Wyse, David E

From: DeAngelis, Vincenzo
Sent: Tuesday, May 22, 2018 6:51 AM
To: Wyse, David E
Subject: RE: stabilizers

Let's find time to discuss with Natasa and Vladan.

Best Regards,

Vince

Vince De Angelis
Marine Engineering | Ingénierie Navale
Integrated Technical Services | Services Techniques Intégrés
Canadian Coast Guard | Garde Côtière Canadienne
200 Kent Street, Office | Bureau 7W077
Ottawa, ON, K1A 0E6
vincenzo.deangelis@dfo-mpo.gc.ca
Telephone | Téléphone 613-219-2733

From: Wyse, David E
Sent: Thursday, May 17, 2018 5:01 PM
To: DeAngelis, Vincenzo <Vincenzo.DeAngelis@dfo-mpo.gc.ca>
Subject: stabilizers

Email about stabilizers I received this week. Just for info that this is a pressing problem for years now.

Stabilizers – I know this isn't E&I but we need these. I'm rolling 15 degrees port and starboard (30 degrees in total) out here today and the winds are less than 10 kts and seas are less than 1m. We need to make this platform more workable. Can we get the installed in our refit in November?

Dave

David Wyse
Project Engineer | Mécanicien de Projet
Marine Engineering | Ingénierie Navale
Integrated Technical Services | Services Techniques Intégrés
Canadian Coast Guard | Garde Côtière Canadienne
200 Kent Street, Office 7W076, Mail Drop 7W064
Ottawa, ON, K1A 0E6
David.Wyse@dfo-mpo.gc.ca
Telephone | Téléphone 613-302-6503

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Van Doormaal, Kimberly

From: Kozarski, Vladan
Sent: May-25-18 10:46 AM
To: Wyse, David E
Cc: Kozarski, Natasa; DeAngelis, Vincenzo
Subject: MSPV stabilizers study

s.19(1)

Dave,

Here is the MSPV stabilizers study that we got from LVE. It includes Damen seakeeping study in the Annex. Name of the file is 'J18009-R01-R0 Seakeeping assessment with different stabilizer options.pdf', and it resides at:
X:\ME\14_NavArch\Projects\MSPV\MSPV roll stabilizers\Feasibility Study

[redacted] presented it on the MSPV face-to-face in March. If you find it useful please send it to the crew and regions. I recall someone asking for the study at the face-to-face.

Regards.

Vladan Kozarski
Naval Architecture Officer
Marine Engineering, Integrated Technical Services / Ingénierie navale, Services techniques intégrés
Canadian Coast Guard / Garde côtière canadienne
200 rue Kent Street, Ottawa, Ontario, K1A 0E6, mailstop 7W063
(613) 993-1627

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Wyse, David E

From: Wyse, David E
Sent: Wednesday, May 30, 2018 11:57 AM
To: Kozarski, Natasa
Cc: DeAngelis, Vincenzo
Subject: MSPV items

Hey Natasa,

Just following up on the Gangway standard ISO 7061 and also our plan to move forward with CCRs including the stabilizers. Meeting with Quantum rep right now.

Thanks
Dave

David Wyse
Project Engineer | Mécanicien de Projet
Marine Engineering | Ingénierie Navale
Integrated Technical Services | Services Techniques Intégrés
Canadian Coast Guard | Garde Côtière Canadienne
200 Kent Street, Office 7W076, Mail Drop 7W064
Ottawa, ON, K1A 0E6
David.Wyse@dfo-mpo.gc.ca
Telephone | Téléphone 613-302-6503

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Wyse, David E

From: Wyse, David E
Sent: Tuesday, June 5, 2018 12:15 PM
To: Kozarski, Natasa
Cc: DeAngelis, Vincenzo; Kozarski, Vladan
Subject: RE: Pour respecter la ligne de flottaison en eau salé

Thanks Natasa,

I have approval from Operations to have a face to face meeting with the Commanding Officers of the Hero Class to come to a decision whether they agree with moving the loadline up and increasing the weight margin. My question is – do I move forward with organizing this meeting or does a lightship and incline on the ships have to be done first?

2nd question – in order to determine weight growth and VCG increase, is that a lightship and incline experiment respectively?

Dave

From: Kozarski, Natasa
Sent: June-05-18 11:29 AM
To: Wyse, David E
Cc: DeAngelis, Vincenzo; Kozarski, Vladan
Subject: RE: Pour respecter la ligne de flottaison en eau salé

Hi David,

I'm not sure what caused CCGS A. Leblanc to be heavier after the winter refit period, however it is an indication that either lightship weight, or deadweight, or both grew over the time. If crew can verify the effects, spares and tools, and other typical deadweight items as well as the cumulative weight impact of the CCRs implemented on the CCGS A. Leblanc over the past years, we could comment on the possible reasons for the current situation with the load line.

Before proceeding, it is important to note that the results of the following study were presented to Operational Support and it was decided by Operations that no change in the Load Line was to be accepted at that time. Can you please confirm that you have the approval of Operation to proceed with this request?

ITS/ME conducted "*Hero Class Life Service Weight Growth Assessment*" in 2015, for details of the assessment see EKME #3502569. In the executive summary it was concluded that Hero Class vessels:

- have very good intact stability with a good intact stability margin for potential lightship weight and vertical center of gravity (VCG) growth,
- have achieved values for deck wetness indices that are acceptable i.e. lay within the range of typical criteria and
- are shown to have good damage stability for all loading conditions considered in the existing damage stability book and to fully meet requirements of TCMSS *Passenger Vessels Operations and Damaged Stability Standards* TP10943 Part II, Sections 7(2) &9(1). This is all subject to the lightship weight growth margin of 4.406 tonnes and lightship VCG growth of 6 mm. Potential lightship weight growth over that margin is very small if the ship is required to meet fully the requirements of the same passenger damage stability standard.

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Since the Hero Class ships are not classed as passenger vessels, ITS/ME has researched alternate standards for damage stability that could be considered applicable and then assessed them against these alternate standards. Based on the work done in this regard, ITS/ME has derived a new lightship weight and VCG growth margin of 10.5 tonnes and 30 mm.

It was also emphasized that increase in life service weight would mean increase in design draft, and if acceptable to Class, will require further verification of existing scantlings, speed performance and revision of stability books.

At that time CCGS Private Robertson was selected to be assessed based on the facts that it is the first ship in the class, it operates in fresh water and results in fresh water are more conservative than those in salt water. This meant that we considered all nine vessels as a class and this study was applicable across the Hero class.

In order to revisit this study it is necessary to confirm:

- what the actual weight growth and VCG increase is from the date each vessel was delivered to CCG and
- if the weight growth is consistent across the Hero class i.e. is the study still applicable for all nine vessels.

If weight growth and VCG increase is such that it does not impact results of the study, next step would be to verify existing scantlings, speed performance and revise stability books for the new design draft. This work would be subject to the Class approval.

If weight growth and VCG increase significantly changed and does impact results of the study we will have to revise study first. Also, if the weight growth is not consistent across the Hero class, results from analysis that considered CCGS Private Robertson only may not be applicable across the class.

If information on weight growth and VCG increase is not available, and there is a clear indication that weight (deadweight or lightship or both) increased like in a case of CCGS A. Leblanc, we cannot use the existing study as is to move forward and revise the load line until we confirm the lightship weight and VCG of all nine vessel. For example, if the A. Leblanc must now carry 4 tonnes of fuel less, that is an indication that the weight growth on that vessel could be in the order of 7.5 tonnes at this point, and a weight growth from this point would not be 10.5 tonnes, but 3 tonnes (VCG – unknown). With the proposed 50 CCRs as well as the desired stabilizers, these vessels could well be left with a very minimal through life growth.

Natasa

From: Wyse, David E
Sent: Friday, May 25, 2018 3:42 PM
To: Kozarski, Natasa
Cc: Kozarski, Vladan; Morphet, Jason (NCR); DeAngelis, Vincenzo; Plows, Emilie
Subject: FW: Pour respecter la ligne de flottaison en eau salé

Hi Natasa,

The email thread below shows that after the winter refit period the A. Leblanc has to take on 4000 litres less fuel to keep the load line above salt water.

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My plan along with operations was to have a meeting with the Captains of the Hero Class to revisit moving the load line up on the vessels to give us more weight margin. It is a high priority for Hero Class program partners to add stabilizers to the vessels along with approximately 50 other CCRs that have been approved that may add weight to the vessel.

I would like to confirm that stability wise it is still ok for the Hero Class to move forward with plans of moving the load line and adding more weight to the vessel.

Thank you
Dave

From: CCGS-NGCC, ALeblanc Chef Mecanicien [mailto:AleblancCE@ccgs-ngcc.gc.ca]
Sent: May-01-18 5:30 PM
To: Wyse, David E
Subject: RE: Pour respecter la ligne de flottaison en eau salé

34000 litres l'année passé
Yves

De : Wyse, David E [mailto:David.Wyse@dfo-mpo.gc.ca]
Envoyé : 1 mai 2018 15:12
À : CCGS-NGCC, ALeblanc Chef Mecanicien; CCGS-NGCC, Aleblanc Commandant; CCGS-NGCC, ALeblanc Chef Officier; CCGS-NGCC, ALeblanc Salle Controle
Cc : Couillard-Desjardins Isabelle
Objet : RE: Pour respecter la ligne de flottaison en eau salé **s.21(1)(b)**

[redacted] merci Yves,

Est-ce que vous pouviez me dire la maximum fuel a bord avant que c'est poids on était ajouté en réparation de la dernière hiver ? 35000 litres ?

Dave

From: CCGS-NGCC, ALeblanc Chef Mecanicien [mailto:AleblancCE@ccgs-ngcc.gc.ca]
Sent: May-01-18 3:09 PM
To: CCGS-NGCC, Aleblanc Commandant; CCGS-NGCC, ALeblanc Chef Officier; CCGS-NGCC, ALeblanc Salle Controle
Cc: Couillard-Desjardins, Isabelle; Wyse, David E
Subject: Pour respecter la ligne de flottaison en eau salé

Bonjour à vous,

PVI

Pour respecter la ligne de flottaison en eau salé, suite au poids ajouté en réparation de la dernière hiver.

Maximum de fuel à bord : 31 000 litres
DAY TANK : 1200 LITRES
RES. :1 8000 LITRES
RES. :2 8500 LITRES
RES. :3 8500 LITRES
RES. :9 4800 LITRES

Merci

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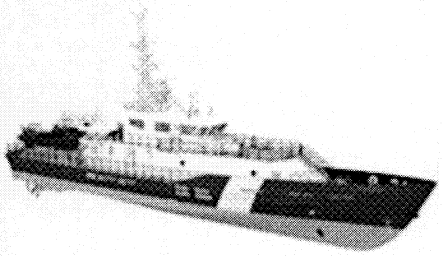
Yves Arbour

Chef Mécanicien / Chief Engineer
NGCC A. LeBlanc / CCGS A. LeBlanc
Pêches et Océans Canada / Fisheries and Oceans Canada
Garde Côtière Canadienne / Canadian Coast Guard
Région du Centre et de l'Arctique / Central and Arctic region
101 boul Champlain, Quebec QC G1K 7Y7

s.16(2)

Tél : 418-509-9402
Cell :
aleblancce@ccgs-ngcc.gc.ca



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Wyse, David E

From: Plows, Emilie <emilie.plows@dfo-mpo.gc.ca>
Sent: Friday, June 15, 2018 8:46 AM
To: Plows, Emilie; Wyse, David E
Subject: Conversation with Plows, Emilie

s.21(1)(b)

emilie.plows@dfo-mpo.gc.ca [8:29 AM]:
Hi Dave! Did you have the conversation with the COs about the weight issue/load line as it relates to the stabilizers yet? I'm just updating the action plan to send out and wondering if there was anything new to add on that side.

Wyse, David E [8:33 AM]:
Not yet, [redacted] I am trying to figure out with my manager now if he will pay to have that meeting

Plows, Emilie [8:34 AM]:
ok, thanks for the update

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Wyse, David E

From: Wyse, David E
Sent: Tuesday, June 26, 2018 12:44 PM
To: 'CCGS-NGCC, Constable Carriere Commanding Officer'
Subject: RE: Sea state operation of vessels

s.16(2)

Thanks a lot Steve,

Yes that helps.

Dave

From: CCGS-NGCC, Constable Carriere Commanding Officer <ConstableCarriereCO@ccgs-ngcc.gc.ca>
Sent: Tuesday, June 26, 2018 12:41 PM
To: Wyse, David E <David.Wyse@dfo-mpo.gc.ca>
Cc: CCGS-NGCC, Corporal Teather Commanding Officer <CorporalTeatherCO@ccgs-ngcc.gc.ca>; CCGS-NGCC, Private Robertson Commanding Officer <PrivateRobertsonCO@ccgs-ngcc.gc.ca>; CCGS-NGCC, Caporal Kaeble Commandant <kaebleCO@ccgs-ngcc.gc.ca>
Subject: RE: Sea state operation of vessels

Hello Dave,

You are correct that the MSPV TSOR says up to sea state 5 for programs and sea state 6 for secondary missions, and that is all we have ever received for instruction. Design and size definitely plays a big part. As well as area of operations.

I would like to point out that the Beaufort scale we use for sea state is based on events on the Ocean. I have always had trouble with the numbers in the TSOR as I know that sea state 6 says winds of 22-27 and waves heights 3-4M. On the ocean a 3-4 M swell would not be too bad, but a wave of that height on the lakes would be un workable in my opinion. The wave period is much shorter and would be very violent for the ship. I personally feel It would be unsafe to operate in that condition. I certainly would not want to have work in a beam too sea in anything more than a 1.5M sea without stabilizers. This ships rock like crazy tied to the dock!

Not sure if this is what you are looking for or not, but I hope it is a help.

Regards

Steve

Steve Arniel / Commanding Officer
CCGS Constable Carriere | NGCC Constable Carriere
Marine Security Enforcement Team (MSET) | Équipes de la sûreté maritime (ESM)
Canadian Coast Guard | Garde côtière canadienne
520 Exmouth St. | 520 Rue Exmouth
Sarnia, ON N7T 8B1| Sarnia, ON N7T 8B1

ConstableCarriereCO@ccgs-ngcc.gc.ca
arniel.steve@dfo-mpo.gc.ca
Captains Cellular [redacted]

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Ships Cellular [redacted]
Government of Canada | Gouvernement du Canada

s.16(2)

From: Wyse, David E [mailto:David.Wyse@dfo-mpo.gc.ca]
Sent: June-26-18 11:54 AM
To: (corporalmclarenCO@mcl.ccgs-ngcc.gc.ca); CCGS-NGCC, Aleblanc Commandant; CCGS-NGCC, Constable Carriere Commanding Officer; CCGS-NGCC, Constable Carriere Chief Officer; CCGS-NGCC, Corporal Teather Commanding Officer; G Peddle Captain; goddard-captain@god.ccgs-ngcc.gc.ca; CCGS-NGCC, Caporal Kaeble Commandant; M Charles; CCGS-NGCC, Private Robertson Commanding Officer; CCGS-NGCC, Private Robertson Chief Officer; CCGS-NGCC, Corporal Teather Chief Officer
Cc: Desmarais Laurent
Subject: Sea state operation of vessels

Good day Captains,

There is a risk based analysis of maritime SAR being done and there is questions concerning what sea state the vessels can operate in. As Captains how do you know this? Is there anything in writing? I can find that in the MSPV TSOR it says primary programs up to sea state 5 and secondary missions up to sea state 6.

So does it go by vessel design or is it always up to the Captain and then the question is how do you decide?

Thanks for your help

Dave

David Wyse
Project Engineer | Mécanicien de Projet
Marine Engineering | Ingénierie Navale
Integrated Technical Services | Services Techniques Intégrés
Canadian Coast Guard | Garde Côtière Canadienne
200 Kent Street, Office 7W076, Mail Drop 7W064
Ottawa, ON, K1A 0E6
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Telephone | Téléphone 613-302-6503

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Wyse, David E

From: Wyse, David E
Sent: Thursday, August 2, 2018 1:27 PM
To: DeAngelis, Vincenzo
Cc: Kozarski, Natasa
Subject: FW: Sea state operation of vessels

s.19(1)

Hey Vince,

Stabilizers are still a high priority as seen below. I just wanted to touch base to ensure that these are the next steps and give updates to the MSPVs and program personnel.

1. Any further work for the installation of stabilizers is on hold
2. Meeting next week with Ops to recommend that all the Hero Class be lightship surveyed and inclined tested ASAP.
3. Lightship survey and incline test will give next set of information required to determine if the load lines can be moved?
4. Once Ops determines that the load lines can be moved then that is the information we require to begin engineering on the stabilizers.

Thanks
Dave

From: CCGS-NGCC, Caporal Kaeble Commandant <kaebleCO@ccgs-ngcc.gc.ca>
Sent: Thursday, August 2, 2018 1:07 PM
To: Wyse, David E <David.Wyse@dfo-mpo.gc.ca>
Subject: RE: Sea state operation of vessels

Hi Dave,

Sorry for taking so long to answer,

I've been on this ship for 2 years now and I've seen 4 m waves a few times in the Gulf. I would not be pleased to head out for SAR in these conditions. The ship will take it, but the crew would be in bad shape upon arrival on scene.

Right now we are in the middle of the Gulf with a SW wind on the beam of just 15-20 kt and 1.5-2.0m waves , and I have to divert 20 degrees off my direct course to have the sea a little more on the hip to avoid rolling 20° either side. And the 10 kt speed limit doesn't help at all !!

So before going out for SAR in these conditions, I would consider my crew's state of fatigue, the distance to go, the course relative to the waves, and of course the vessel design.

By the way, stabilisers should never have been removed from the original design, please put them back asap ! Losing a few cubic meters of fuel space will be a minor factor compared to the huge gain in stability, safety and comfort for the crew.

Hope this helps,

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François Lanouette
Commandant, Équipe B | Commanding officer, B Crew
NGCC Caporal Kaeble V.C. | CCGS Caporal Kaeble V.C.
Garde côtière canadienne | Canadian Coast Guard
Navire | Ship:
Cell:
Email: kaebleco@ccgs-ngcc.gc.ca

s.16(2)

De : CCGS-NGCC, Constable Carriere Commanding Officer
Envoyé : 26 juin 2018 12:41
À : Wyse David
Cc : CCGS-NGCC, Corporal Teather Commanding Officer; CCGS-NGCC, Private Robertson Commanding Officer; CCGS-NGCC, Caporal Kaeble Commandant
Objet : RE: Sea state operation of vessels

Hello Dave,

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I would like to point out that the Beaufort scale we use for sea state is based on events on the Ocean. I have always had trouble with the numbers in the TSOR as I know that sea state 6 says winds of 22-27 and waves heights 3-4M. On the ocean a 3-4 M swell would not be too bad, but a wave of that height on the lakes would be un workable in my opinion. The wave period is much shorter and would be very violent for the ship. I personally feel It would be unsafe to operate in that condition. I certainly would not want to have work in a beam too sea in anything more than a 1.5M sea without stabilizers. This ships rock like crazy tied to the dock!

Not sure if this is what you are looking for or not, but I hope it is a help.

Regards

Steve

Steve Arniel / Commanding Officer
CCGS Constable Carriere | NGCC Constable Carriere
Marine Security Enforcement Team (MSET) | Équipes de la sûreté maritime (ESM)
Canadian Coast Guard | Garde côtière canadienne
520 Exmouth St. | 520 Rue Exmouth
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arniel.steve@dfo-mpo.gc.ca
Captains Cellular
Ships Cellular
Government of Canada | Gouvernement du Canada

From: Wyse, David E [mailto:David.Wyse@dfo-mpo.gc.ca]
Sent: June-26-18 11:54 AM
To: (corporalmclarenCO@mcl.ccgs-ngcc.gc.ca); CCGS-NGCC, Aleblanc Commandant; CCGS-NGCC, Constable Carriere

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Commanding Officer; CCGS-NGCC, Constable Carriere Chief Officer; CCGS-NGCC, Corporal Teather Commanding Officer; G Peddle Captain; goddard-captain@god.ccgs-ngcc.gc.ca; CCGS-NGCC, Caporal Kaeble Commandant; M Charles; CCGS-NGCC, Private Robertson Commanding Officer; CCGS-NGCC, Private Robertson Chief Officer; CCGS-NGCC, Corporal Teather Chief Officer
Cc: Desmarais Laurent
Subject: Sea state operation of vessels

Good day Captains,

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So does it go by vessel design or is it always up to the Captain and then the question is how do you decide?

Thanks for your help

Dave

David Wyse
Project Engineer | Mécanicien de Projet
Marine Engineering | Ingénierie Navale
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Telephone | Téléphone 613-302-6503

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Wyse, David E

From: Plows, Emilie
Sent: Thursday, August 9, 2018 2:25 PM
To: Gallant, Nicole; Napier, Brent; Jones Larose, Nicole; Parsons, Derreck J; Pye, Brad; Bungay, Kerry; Hurley, Mike; Belliveau, Ron; Picard, Marcel; Sturch, Adrian D; Lewis, Jordan; Higgins, Linda; Wyse, David E; Morphet, Jason (NCR); McBride, Blaine; Morelli, Carolyn
Subject: RE: MSPV TSOR Review Notes / Notes de l'examen de l'ÉTBO des patrouilleurs semi-hauturiers

Good morning Nicole,

Op Support and Marine Engineering are aware that changing the launch and retrieval system is C&P's number one priority, but before they can make any modifications, they need to install the stabilizers. As part of that process, as the vessel's load line is currently at maximum, they need to see where adjustments can be made to minimize the weight, which is why they did a review of the TSOR with each program. I've tried to capture this on the action plan I've been sending out each month.

The Coast Guard has a safety requirement that all the RHIBs need to be self-righting and a cover would impede that. The RCMP are talking about a "clip on" type shelter, but it only covers the operator and it hasn't been approved yet by Op Support. I'm not sure if they can provide other options.

Emilie Plows
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Canadian Coast Guard / Government of Canada
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Garde côtière canadienne / Gouvernement du Canada
emilie.plows@dfo-mpo.gc.ca / Tél : 613-998-8514

From: Gallant, Nicole
Sent: August-08-18 7:41 PM
To: Plows, Emilie; Napier, Brent; Jones Larose, Nicole; Parsons, Derreck J; Pye, Brad; Bungay, Kerry; Hurley, Mike; Belliveau, Ron; Picard, Marcel; Sturch, Adrian D; Lewis, Jordan; Higgins, Linda; Wyse, David E; Morphet, Jason (NCR); McBride, Blaine; Morelli, Carolyn
Subject: RE: MSPV TSOR Review Notes / Notes de l'examen de l'ÉTBO des patrouilleurs semi-hauturiers

Thank you Emilie for putting this together. Below I noticed that we do not mention changes to the RHIB to have some kind of cover or change to the launching system. Is this being reviewed? s.16(2)

Comment(s):

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- C&P: modified launching by stopping the vessel and people climb into the RHIB once it is lowered. 99% of the time, the vessel is stationary.

From: Plows, Emilie
Sent: August-08-18 11:57 AM
To: Napier, Brent; Jones Larose, Nicole; Parsons, Derreck J; Pye, Brad; Bungay, Kerry; Hurley, Mike; Belliveau, Ron; Picard, Marcel; Sturch, Adrian D; Gallant, Nicole; Lewis, Jordan; Higgins, Linda; Cauffope, Genevieve; Wyse, David E; Morphet, Jason (NCR); McBride, Blaine; Morelli, Carolyn
Subject: MSPV TSOR Review Notes / Notes de l'examen de l'ÉTBO des patrouilleurs semi-hauturiers

Hi everyone,

As part of the MSPV Partner Working Group, on June 28, Operational Support, Marine Engineering, and C&P reviewed the Technical Statement of Operational Requirements (TSOR) for the MSPVs. Representing C&P were: Marcel Picard, Andy Lewis, and Genevieve Cauffopé.

Please find attached the English and French versions of the notes from that teleconference. For those who have access to EKME 3933971 and 3949599.

If you have any questions, please let me know.

Bonjour à tous,

Dans le cadre du Groupe de travail de partenaires sur les patrouilleurs semi-hauturier, le groupe de Soutien aux opérations, l'Ingénierie navale, et la C&P on fait une révision de l'énoncé technique des besoins opérationnels (ÉTBO) pour les MSPV. Les représentants pour C&P étaient : Marcel Picard, Andy Lewis, et Genevieve Cauffopé.

Veuillez trouver ci-joints les notes de l'appel téléconférence. Si vous avez accès à EKME, ce sont les documents 3933971 et 3949599.

N'hésitez-pas à communiquer avec moi si vous avez des questions.

Emilie Plows
A/Maritime Security Operations Analyst
Canadian Coast Guard / Government of Canada
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Analyste des opérations de la sûreté maritime p/i
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emilie.plows@dfo-mpo.gc.ca / Tél : 613-998-8514

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Wyse, David E

From: Wyse, David E
Sent: Tuesday, August 14, 2018 7:43 AM
To: DeAngelis, Vincenzo
Subject: CCRs for Hero Class vessels that may increase weight

Hey Vince,

Here are some CCRs to be done to the Hero Class vessels that might increase the weight of the vessels over 100kg. Also note there are other CCRs that may decrease the current weight of the vessels.

CCR 2587 – Stern Quarter reinforcement – already done on Private Robertson
CCR 2693 – fuel tank #9 venting arrangement – done on various vessels
CCR 2699 – fire main piping replacement – sections done on various vessels
CCR 2850 – Hero Class flooring replacement – sections done on various vessels
CCR 2864 – Hero Class biofouling solution – done on M. Charles and Captain Goddard
CCR 2867 – Hero Class impressed current installation
CCR 3103 – Hero Class stabilizers
CCR 3219 – Hero Class engine removal and overhaul
CCR 2396 and 3220 – Hero Class galley reconfiguration

Dave

David Wyse
Project Engineer | Mécanicien de Projet
Marine Engineering | Ingénierie Navale
Integrated Technical Services | Services Techniques Intégrés
Canadian Coast Guard | Garde Côtière Canadienne
200 Kent Street, Office 7W076, Mail Drop 7W064
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Wyse, David E

From: Wyse, David E
Sent: Tuesday, August 14, 2018 1:54 PM
To: Jersch, Russell; Smith, Mike
Subject: FW: Hero Class CCR update
Attachments: MECTS-#3111144-v8-CCR_Prioritization_List_for_Hero_Class.XLSX

FYI

From: Wyse, David E
Sent: Tuesday, August 14, 2018 12:58 PM
To: McMillan, Cody <cody.mcmillan@dfo-mpo.gc.ca>; Mkrtychan, Sergey <Sergey.Mkrtychan@dfo-mpo.gc.ca>; Couillard-Desjardins, Isabelle <Isabelle.Couillard-Desjardins@dfo-mpo.gc.ca>; Mercier, Jeffrey <Jeffrey.Mercier@dfo-mpo.gc.ca>; Smith, Alicia J <Alicia.Smith@dfo-mpo.gc.ca>; Plows, Emilie (Emilie.Plows@dfo-mpo.gc.ca) <Emilie.Plows@dfo-mpo.gc.ca>; (corporalmclarenCO@mcl.ccgs-ngcc.gc.ca) <corporalmclarenCO@mcl.ccgs-ngcc.gc.ca>; A leblanc CO (aleblancCO@ccgs-ngcc.gc.ca) <aleblancCO@ccgs-ngcc.gc.ca>; Carriere <ConstableCarriereCO@ccgs-ngcc.gc.ca>; carriere chief officer <constablecarriereCHO@ccgs-ngcc.gc.ca>; CCGS-NGCC, Corporal Teather Commanding Officer (CorporalTeatherCO@ccgs-ngcc.gc.ca) <CorporalTeatherCO@ccgs-ngcc.gc.ca>; G Peddle Captain <gpeddleCO@ped.ccgs-ngcc.gc.ca>; goddard-captain@god.ccgs-ngcc.gc.ca; Kaeble <KaebleCO@ccgs-ngcc.gc.ca>; M Charles <MCharles-Captain@cha.ccgs-ngcc.gc.ca>; Private Robertson <PrivateRobertsonCO@ccgs-ngcc.gc.ca>; private robertson chief officer <privaterobertsoncho@ccgs-ngcc.gc.ca>; Teather chief officer <corporalteathercho@ccgs-ngcc.gc.ca>; aleblancCE@ccgs-ngcc.gc.ca; Carriere 1st engineer <constablecarriereER@ccgs-ngcc.gc.ca>; ConstableCarriereCE@ccgs-ngcc.gc.ca; CorporalMcLarenMMVCE. CCGS@dfo-mpo. gc. ca (CorporalMcLarenCE@MCL.ccgs-ngcc.gc.ca) <CorporalMcLarenCE@MCL.ccgs-ngcc.gc.ca>; CorporalTeatherCE@ccgs-ngcc.gc.ca; G Peddle Chief Engineer <gpeddleCE@ped.ccgs-ngcc.gc.ca>; Goddard-ChiefEngineer@GOD.ccgs-ngcc.gc.ca; KaebleCE@ccgs-ngcc.gc.ca; mcharlesce@cha.ccgs-ngcc.gc.ca; PrivateRobertsonCE@ccgs-ngcc.gc.ca; Robertson 1st eng <privaterobertsonER@ccgs-ngcc.gc.ca>; Teather 1st eng <corporalteatherER@ccgs-ngcc.gc.ca>
Subject: Hero Class CCR update

Good day all,

Here is my most recent list of Hero Class CCRs attached in the excel file. Remind me if I am missing any.

Any large weight implication CCRs are on hold by the Naval Architecture manager and HME manager. There is a meeting with Ops support tomorrow to request that lightship surveys and incline tests be done on all ships before installation of such items as stabilizers or stern fendering, etc.

The table below shows the E&I priority list we have delivered for engineering. Priorities 3 and 4 have regional teams developing solutions. Priority 1 – a new CCR had to be registered because the dual dome was rejected and Priority 2 was just approved for engineering. I hope to get engineering leads soon. CCR 3281 – Chart table and CCR 3284 AIS antenna relocation are new ones added. I put them as priority 5 and 6. Let me know if they have to move up or down.

Voici ma liste la plus récente des DCC de la classe Héros jointe au fichier Excel. Rappelez-moi si j'en manque.

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Les principaux DCC à implication de poids sont en attente par le gestionnaire de l'architecture navale et le gestionnaire HME. Il y a une réunion avec les Opérations a AC demain pour demander que les lightship survey et incline test soient effectués sur tous les navires avant l'installation d'éléments tels que des stabilisateurs.

Le tableau ci-dessous présente la liste de priorités E & I que nous avons livrée pour l'ingénierie. Les priorités 3 et 4 ont des équipes régionales développant des solutions. Priorité 1 - un nouveau RCC doit être enregistré car le double dôme a été rejeté et la priorité 2 vient d'être approuvée pour l'ingénierie. J'espère obtenir rapidement des groupes d'ingénierie dans les regions. DCC 3281 - La table à cartes et le repositionnement des antennes AIS du DCC 3284 sont des nouvelles ajoutées. Je les mets en priorité 5 et 6. Dites-moi s'ils doivent monter ou descendre.

Engineering	Priority	
CCR 3271 improve satellite reception	1	
CCR 3148 Secure AIS for MSPV Rhibs	2	
CCR 2712 Navigation information in the CO Cabin/Office	3	Great lakes region developed solution?
CCR 3089 Echo Sounder Replacement	4	Western region developing solution for September drydock
CCR 3281 Chart table reconfiguration	5	
CCR 3284 AIS Antenna relocation	6	
CCR 3016 GMDSS Sailor 5000 replacement	7	
CCR 3222 ICS Replacement solution	8	
CCR 3258 Wind information in Vision Master	9	

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CCR Prioritization List for MSPVs

EKME # 3045742v1 Updated 2014/03/07 *(J. Richardson original author)*

Hero Class AIS Antenna Relocation	Relocate Automatic Identification System (AIS) antenna to improve system performance.	AP5091-44180-01 Antenna Arrangement	18A05	Automatic Identification System (AIS)	Andrew de Haan	All Assets	Vessel Communications and Navigation	Approved for engineering	2018-07-04 Ack. CCR Registration. Major CCR will be sent for Review/Support by CCR Committee, then to DCB for Approval. 2018-07-11 CCR Supported by Committee. Routed to DCB for Approval, Seeking Approval for Engineering. 2018-07-26 Installation Specification document added in EKME. will do a Trial on one vessel before asking for implementation. 2018-08-03 DCB Approved for Engineering.		3MCCR0004							
Hero Class Allied Crane local controls	The local crane controls are mounted approximately 8 feet aft the deck. They cannot be reached by the operators. Engineer a way to move the controls down to a level that crane operators can access them.	Deck Equipment / Ship Support Systems	Deck Crane		David Wyse			Approved for engineering	2018-07-23. Ack. CCR Registration. sections 3 and 4 should be completed. 5 and 6 must be Supported (E-Signatures) by Regional Authorities. CCR must be Signed and returned to HCCR Coord. with documentation. Major CCR will be sent for Review/Support by CCR Committee, then to DCB for Approval. 2018-07-25 CCR Supported by Committee. Routed to DCB Seeking Appr for Engineering. 2018-08-03 DCB Approved for Engineering.		3MCCR0011		Atlantic Region	7/18/2018	Routed to DCB			
Hero Class Allied crane remote control connections	Either a secondary connection should be established on the aft bridge deck to allow for the connection of the mobile crane pack umbilical cord thus leaving the stairway free of tripping hazards when the crane is operated from the aft bridge deck or a wireless control pack must be engineered	Deck Equipment / Ship Support Systems	Deck Crane		David Wyse			Approved for engineering	2018-07-23. Ack. CCR Registration. sections 3 and 4 should be completed. 5 and 6 must be Supported (E-Signatures) by Regional Authorities. CCR must be Signed and returned to HCCR Coord. with documentation. Major CCR will be sent for Review/Support by CCR Committee, then to DCB for Approval. 2018-07-25 CCR Supported by Committee. Routed to DCB Seeking Appr for Engineering. 2018-08-03 DCB Approved for Engineering.		3MCCR0005							
Hero Class Stern light pole modification	The aft stern light / flag pole is in the way while the RHIBS are being launched overboard. A hinge is required on the pole to lower it while the RHIBs are being launched	Deck Equipment / Ship Support Systems	Stern Light pole		David Wyse			Approved for engineering	2018-07-23. Ack. CCR Registration. sections 3 and 4 should be completed. 5 and 6 must be Supported (E-Signatures) by Regional Authorities. CCR must be Signed and returned to HCCR Coord. with documentation. Major CCR will be sent for Review/Support by CCR Committee, then to DCB for Approval. 2018-07-25 CCR Routed to CCR Committee to Rev./Support.		3MCCR0007							

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CCR Prioritization List for MSPVs

EKME # 3045741v1 Updated 2014/03/07 (*L. Richardson original author*)

MSPV Internal Communication System (ICS) modification	Existing Conditions Heise McCann ICP Internal Communication System is the as fitted ICS system on the MSPV vessels. It has been difficult and costly to maintain the PA portion due to low reliability of the speakers. There are also nine different models of speakers on the vessel which makes keeping them all in stock a challenge. Heise McCann, located in Florida, is the only distributor of their products. They do not have any authorized resellers and much of their equipment is made to order and ships internationally so the lead time to order spares is quite long (average of 3 months). In FY 2015/17 the cost to maintain the ICS systems on the two Atlantic Region MSPV's combined was $37.3K and in FY 2015/16 the cost was $28.7K. Recommended Solution: Replace with a modular system whose manufacturer has local suppliers and/or service representative. Standardization with other new vessels in the fleet would also be of benefit to minimize training requirements for staff and required held spares would decrease with commonality of systems. Anticipated Benefits: Decrease maintenance costs. Impact on Maintenance/Operational Budget: High maintenance costs and difficulty acquiring spares.		Select System	N/A	Jodie Lechere			Acknowledged	2018-02-14: Ack. CCR Registration. To MSPV Committee. Sections 3 and 4 should be completed. 5 and 6 must be Supported (E-Signatures) by Committee. CCR will be sent for Review/Support by CCR Committee, then to CCB for Approval										
MSPV pompe circulation eau chaude	Présentement la pompe pour la circulation d'eau chaude du réservoir est une pompe en provenance d'Europe. Les pièces sont dispendieuses et donnent de fois. Cette pompe est alimenté avec du 600V pour une pompe qui fait seulement que circuler de l'eau chaude dans le navire. Solution : Il est recommandé de remplacer la pompe avec une petite pompe de circulation TACO 110-24. En acier inox certifié NSF61 pour lequelle les pièces sont facilement disponible. L'alimentation pour cette pompe viendra du panneau principal. L1-24. Nous pourrons utiliser l'alimentation 600V pour la pompe dédiée au levage de la chaine d'ancre et réutiliser le démarreur. Impacts: Nous aurons de la facilité à avoir des pièces de rechange pour ce système. Si la pompe n'est pas remplacée nous condamnerons d'avoir des problèmes apprentissonnement pour les pièces et nous devrons avoir un nouveau démarreur pour la pompe de levage de chaine d'ancre.		Kenworth Systems	Hot water circulation pump	Isabelle Caillard Deschênes			Approved for engineering	2018-05-25: Ack. CCR Registration. sections 3 and 4 should be completed. 5 and 6 must be Supported (E-Signatures) by Regional Authorities. CCR must be Signed and returned to NCCR Coord with documentation. Major CCR will be sent for Review/Support by CCR Committee, then to CCB for Approval. 2018-06-06 CCR Supported by Region Routed to Committee to Rev./Support. 2018-07-26 Supported by Committee Routed to CCB seeking Engineering App't. 2018-08-03 CCB: Approved for Engineering	3001305							
MSPV pompe traitreat système d'eau noires	Présentement l'alimentation électrique de la pompe macérateur de transfert est une pompe monophasée 230V. Ceci a pour conséquence que le moteur travaille plus fort pour faire des démarrages et ce système est un système qui est appelé à démarrer et arrêter souvent. Solution : Il est recommandé d'acheter un moteur triphasé de 1.1 KW pour faire tourner une pompe équivalente que propose Hoverarm le remplacer du système d'eaux noires. Il est recommandé d'ajouter l'électricité triphasée à partir du panneau L1 Jodies 18. Impacts : Le bénéfice anticipé est de remplacer moins souvent le moteur électrique.	système électrique/ système eaux noires	18D	Systèmes de collecte, de traitement et d'évacuation des eaux	Isabelle Caillard Deschênes	All Vessels	Auxiliary Systems	Approved for engineering	2018-05-25: Ack. CCR Registration. sections 3 and 4 should be completed. 5 and 6 must be Supported (E-Signatures) by Regional Authorities. CCR must be Signed and returned to NCCR Coord with documentation. Major CCR will be sent for Review/Support by CCR Committee, then to CCB for Approval. 2018-06-06 CCR Supported by Region Routed to Committee to Rev./Support. 2018-07-26 Supported by Committee Routed to CCB seeking Engineering App't. 2018-08-03 CCB: Approved for Engineering	3001345							

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CCR Prioritization List for MSPVs

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Crab pot hauler arm extension	the trap hauler modification is to extend the arm as depicted in the engineering drawings to gain clearance over the railing. The arm would be fitted with a small block for the rope to travel on and the hauler would be mounted to the deck, that way when traps were raised to the ships side crew aren't leaning over the railing trying to pull them over the railing, instead the bottom of the traps should clear the railing making it a lot easier to bring on board. By not having the hauler hanging from the arm it also makes it easier to get the traps on board because someone doesn't have to guide the lead line on each trap through the hauler while two other people are trying to haul the trap over the railing Lobster traps in the Bay of Fundy region have concrete bottoms to combat the tide and can weigh 80-100lbs per trap without bait or catch so hauling them over the rail in strings of 18 or 21 traps per set has been very labour intensive.					Dave Wyse	Captain G. Peddle			Approved for prototype										
MSPV Additional at will whistle button	The only at-will whistle control within the bridge is located on the far starboard side. It is a tiny button mixed in on a panel with 28 other very similar buttons. Add an at-will whistle push button near the centre of the bridge consoles. This would require a cable to be run from the whistle control panel under the consoles and a hole to be drilled in a suitable space near the middle of the consoles. This should be a straightforward job. Able to sound the ship's whistle at-will quickly and without error from any of the forward bridge positions. Consequent increase in safety of navigation. There is a safety risk that in an emergency or close-quarters situation, when a sound signal is immediately required, it will not be sounded, in a timely fashion, or the wrong signal will be sounded, or some of the bridge team will be distracted trying to find the correct button. This could result in a collision			Vessel Communications and Navigation	Whistle	David Wyse	david.wyse@dfo-mpo.gc.ca	8133628263	Routed to CCB	2018-01-01: Ack. CCR Registration. CCR Supported (E-Signatures) by Regional Authorities. Major CCR will be sent for Review/Support by CCR Committee. then to CCB for Approval 2018-01-30 Supported by CCR Committee routed to CCB for Rev./Approval.									
[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]									
Hare Class searchlight replacement and relocation of controls	Replace the searchlights with movable that provide more light for trap hauling operations. As a temporary measure relocate the controls to their respective wings and an umbilical cord.			Vessel Communications and Navigation	Searchlight	david wyse			Routed to CCB	2018-01-30: Ack. CCR Registration in replacement of CCR 3087 CCR Supported (E-signatures) by committee. Sent to CCB for Rev./Approval										
Hare Class main engine removal and overhaul	there is no current way to remove or overhaul the engines in situ. Create a physical way and plan to remove and overhaul the engines			Hull and Related Structures	Hull and structure	David Wyse			Approved for Engineering/Prototype	2018-02-02: Ack. CCR Registration, sections 3 and 4 should be completed, 5 and 6 must be Supported (E-Signatures) by Regional Authorities. 2018-02-02 Supported by CCR Committee routed to CCB for Rev./Approval. 2018-02-06 CCB Approved for Engineering/Prototype this CCR. DFF, David Wyse, to present Report to CCB to get final Approval before proceeding with installation.									
Hare Class galley reconfiguration	Current galley does not meet cook requirements, industry standards and has many failures that need to be addressed. Re engineer and plan a new galley configuration			Domestic Systems	Galley	David Wyse			Routed to CCB	2018-02-02, Ack, CCR Registration, sections 3 and 4 should be completed, 5 and 6 must be Supported (E-Signatures) by Regional Authorities. 2018-02-02 Supported by CCR Committee routed to CCB for Rev./Approval									

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Remplacement valve VS20055	Suite à un exercice d'une procédure ISM de l'armatrissement du compartiment du propulseur d'étrave, une situation préoccupante a été observée. Pour activer le pompage du compartiment envahi il faut démarrer la pompe incendie d'urgence et ouvrir manuellement et directement sur place la valve (VS20055) qui alimente le venturi d'aspiration directe (ES20003). L'effet venturi provoqué va aspirer l'eau et la diriger par-dessous bord en passant par la valve de risque(VS20058). L'Ouverture ou la fermeture de cette valve (VS20055) se fait directement à l'intérieure du compartiment inondé Donc il y a un risque d'ouvrir la porte étanche et inondé le compartiment adjacent. Il y a un risque hypothermie pour le personnel qui doit activer cette valve. Je propose de remplacer cette valve (VS20055) par une valve à ouverture et fermeture à distance et d'ajouter le contrôle dans la page CCAM (contrôle valve bouchain)			Auxiliary Systems	Venturi d'aspiration directe	Yves Arbour	(Guillaume Noel												
Secure AIS for Hero Class program Rhibs	Installation of a Secure AIS System similar to that of the offshore CSP vessels in Atlantic region, that will permit the ship to track the RHIB on AIS, yet remain undetected to any other vessels in the area that may be receiving AIS information			Communications Systems (Comms)	AIS	David Wyse													
Conversion au DEL compartiment de machinerie	Il y a 24 lumières fluorescentes dans les compartiments de machinerie (10 dans le MMR, 8 dans l'AMR, et 6 dans le compartiment d'appareil à gouverner). Ces lumières ne sont pas assez brillantes. Ils ne durent pas due à la vibration ou la chaleur produits dans ces compartiments. (plus particulièrement dans l'appareil à gouverner). En 2015 et 2016 nous avons eu besoin de réparer plusieurs lumières. Les Ballons d'ampoules et les démarreurs brûlent quand les composantes des lumières deviennent moins bien ajusté, la situation actuelle présente un risque d'incendie mineur			Electrical Power Distribution	Éclairage fluorescent	Sheldon Colley	Matthew Stares												
MSPV Alarm Monitoring System replacement	The major components of this critical system have all been designated as mothered. This designation basically means that there is no further OEM support for the software or hardware which will make both technical support and spare part acquisition increasingly more difficult as time progresses. Existing software hacks up from time to time and requires a system reset to bring the monitoring system back online. Failure of this system will impact vessel operations and without OEM support, could lead to extended non operational periods until access and/or technical support can be acquired. This system also implements automation for critical sub systems such as bilge suction valves, engine-room fans and distributed monitoring of fire zones in the event of a fire. The tank level monitoring system requires continuous attention to maintain proper level indication			Integrated Control Systems	Alarm and monitoring system	William Falconer	william.falconer@dnd-mdn.gc.ca	902 440 8231	Approved for prototype	2017-12-07 AIS, CCR Registration, Major Additional CCR Supported by Tech Authority is Routed to CCR Committee to Rec./Support, 2017-12-13, OCR Supported by Committee. 2018-01-18 Appendix D added to OCR, for design and Total including contracting steps. 2018-02-06 OCR Approved for Engineering/Prototype and one installation for Trial. CCR, OPI Vitaly Mokliakov, William Falconer to present Trial Report to CCB to get final Approval before proceeding with installation for Class.								

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CCR Prioritization List for MSPVs

EKME # 3045742v1 Updated 2014/03/07 *(L Richardson original author)*

Hero Class removal of air supply box in Engine room	Remove the air supply boxes which are located above the Main Engines in the engine room. Removal of the air supply boxes will allow maintenance to be done on top of the engines and will remove weight from the vessel.		Domestic Systems	N/A	David Wyse															
Hero Class Battery isolation switches	The main 24V back-up battery supply and the GMDSS back-up battery supply do not have isolation switches. Therefore, there is no way to isolate the current from these systems without removing the battery cable from the battery. In the event of an emergency, such as a		Electrical Power Distribution	N/A	David Wyse															
Hero Class voltage control for shore power synchronization	engineering and documentation necessary to upgrade the main switchboard to provide automatic and manual generator voltage adjust capability The objective of this upgrade is to improve the Load Transfer functionality on the Hero Class vessels and reduce the mechanical and electrical stress on the vessels main switchboard network which will ultimately translate into reduced maintenance costs and enhance system reliability.		Electrical Power Distribution	N/A	David Wyse															
Hero Class stabilizers	The parent Hero Class design vessels are delivered with stabilizers. The Hero Class vessels do not have stabilizers installed. All vessel operators agree the vessels require stabilizers in all areas of operation. Program and operations can suffer do the fact that the vessels have extreme roll in high sea state conditions. Engineering and implementation plans are required		Auxiliary Systems	N/A	David Wyse			Approved for engineering												
Hero Class recleanslly ballast tanks to void spaces	The ballast tanks are not currently used on board the Hero Class vessels due to weight and stability of the vessels. Reclassify the ballast tanks to void spaces which will create less survey work during inspections. Also will be a weight savings if any fittings or piping can be removed		Hull and Related Structures	Ballast	David Wyse															

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CCR Prioritization List for MSPVs

EKME # 5045742v1 **Updated** 2014/03/07 *(a Richardson original author)*

Hero Class depth sounder replacement	During fire drills the Chief Mate is in charge of the Fire Team, the First engineer in charge of Fire Support and the Chief Engineer is in the control room. Currently 4 UHF radios are installed on the vessel which are given to the bridge, Chief Mate, First Engineer and Chief Engineer. The fire team does not have one and they are the ones being sent without radio communications to a space that may be hazardous. The Chief Mate cannot follow due to smoke, heat etc so in reality the situation temporarily the First Engineer/Chief Mate is giving their radio to the fire team.	MSPV	Vessel Communications and Navigation	echo sounder	David Wyse												

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CCR Prioritization List for MSPVs

EKME # 3045742v1 Updated 2014/08/07 *(J. Richardson original author)*

Decca Sound Reception System Replacement	Decca issued Technical Bulletin TB05-2013 on Dec 12, 2013, stating that the Type Approval against Dec 31, 2013 and once the SAS100 does not meet ISO standard 14139:2012. Type Approval will not be re-issued. HO supports the conclusion that there is no way to make the current system usable, and it must be replaced. There are many other makes and models of vessel reception systems on the market, and multiple systems should be analyzed before deciding on a new system. Whichever system is decided on, needs to be thrifted before making a final decision. Recommend that once a new inspector system is chosen, it becomes the new standard.	MSPV	Sound Reception System	Vessel Equipment Aides and Navigation	Norman Poppe		2/13/2014	Approved for Engineering	2017-08-14 Ack. CCR Registration. CCR raised by EE at HCR. Document forwarded to Operation to Plan /Support. 2017-07-19 CCR Supported by Committee, sent to CCB for Approval.	2017-03-01 - System does not work on all vessels. Robertson - this is a condition of class: in 4 months (very) will be another survey and the inspector will look at this. It has to be must forward.	2.4 MAR							
Life Cycle Replacement of VHF Direction Finding Systems	The current Very High Frequency (VHF) Direction Finder (DF) standard is becoming very difficult and expensive to maintain. Parts are in short supply and in some cases no longer available and lead times to execute replacement are typically 7 months minimum. Develops a new National Standard and deploys as the current systems require a service or replacement.	AIR Assets	VHF Direction Finder		Rod Pike		3/27/2013	Approved for Engineering/Prototype	2017-03-10_Ack. CCR Registration. CCR raised by HQ, Components are routed to CCR Committee for Rev / Support. 2017-04-07 approved for engineering - although some do not meet transport requirement, Transport not enforcing with CCG. to rewrite of regulation may require current measurement, Doc to determine Op. requirement.	2017-03-21- Controller Centers has the CURAC brand.	1.5 MAR							

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M Charbin M B SAB Silencer	Existing Conditions: The Current 60dB SAB Sil-X_87 Silencer is rated for a reflection of 29-35 dBA. It is most efficient at lower Exhaust Frequency and loses its efficiency very quickly. The current set up is extremely basic, and has escaped a number of noise nonconformity across the country. It would be in the best interest of the client to encourage trains with a higher quality exhaust silencer to reduce the noise over a WIDER range of operating conditions. The current silencers are 42" long and 12" in diameter. Spacemastered Solution, SilenTech, developed through ADF Distributors makes a better model SDUE-36-96-1 4 T that has a noise reduction rating of 29-33DBA but over a much larger range of the generators exhaust frequencies. In the frequency range that the SMS product is most efficient (35dBa reduction) the MinT-Tech Product is actually closer to 45DBA reduction, almost double that of the current Silencer. The SilenTech Product is 70.5" Long and 14" in diameter. There is room in the current installation but the exhaust piping will have to be cut back to accomplish the new length, and additional bracing installed on the deck beam. The increased diameter is negligible. The work could be done by engine crew if confident with welding, but I would suggest hiring a welding company to complete the exhaust modifications as it requires pressure by welding on thin metal. The silencer is a spark arrestor type and meets all requirements of the currently installed ones, including back pressure requirements from the generators. The silencers have a back pressure of less than 25 of the maximum allowable back pressure on the generators at max load. The quoted price from ADF is $ 7,079 per silencer Plus the cost to install. Each silencer weighs 121 pounds, the weight of the current fitted ones is not provided by the manufacturer but could be estimated at 60-80 pounds. Contact for ADF is Brandon Guevara brandon.guevara@adfdistributors.com Anticipated Benefits: Generator exhaust noise should be substantially lower. Reducing issues with noise pollution in the various areas of operation that we work in, it will also reduce the noise level on the aft deck of the vessel creating a better work environment for engine crew Impact on Maintenance Budget: Continued high noise levels	MSPV	Major Success Electrical Generation Systems	Major Service Electrical Power Generation	Core Isolation				2016-07-26 As a CCR Registrant, Scope need to know business line CCR should be applicable to MSPV Class. CCR Form Scanned Send e-mail or Completed (Electronic Signature) by Organizers and Regional Authorities Please return PDF to CCR Committee to Rev./Support. 2014-09-25 Update Kirsten Regrets OCR deficit Lastworking holiday and approval is attached is in progress this DEPs in 2012-2013	2017-03-01- Everyone agrees this is a good idea																		
Accès aux équipements de l'aire stable du rebl	Il faut agrandir l'accès du bas vers le haut de la cheminée pour le démontage et le remplacement des silencieux. Les silencieux sont trop bas pour permettre le démontage et le remplacement. Il faut agrandir l'accès du bas vers le haut de la cheminée pour le démontage et le remplacement des silencieux. Les silencieux sont trop bas pour permettre le démontage et le remplacement.	CAPITAL KAIZEN VID	Added as mod	Hull and Related Structures	Bilateral Clarifier	CSA	12/29/2016	Approved for Engineering	2016-11-08 ADJ Registration) El la DCC n'est pas actuelle prévue que remplir les sections 3 a 5, sera lors approuvée par le Région (section 6 signée), retourner à l'administration central pour Rev./Support. 2017-02-14 CCR Form Supported by Region and documents are Routed to Operation to Rev. Support. 2017-02-02 CCR Supported by Committee, recommend for Concept/Engineering Appl by OCB		000215																		

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EKME # 3045742v1 Updated 2014/03/07 *(J. Richardson original author)*

Custom Weapons Enclosure MSPV-MBET RHIB	Modify the Console on the MBET RHIB to allow for the storage of RCAP Carbide G8	MSPV	RHIB	Hull structure	Jason Rimmer			Approved by Engineering/Production	2014-04-22, AJI CCR Registration, Documentation and CCR Note Passed to CCP Committee for Rev /Support. 2014-04-29 Ops contacted the company that supplied the equipment to obtain Kubota RM40 Engineer to estimate what this weight addition should mean/ stability. The door will be fashioned out of aluminium and the net gain in weight on the RHIB will be 15 to 20 lbs. 2014-05-05 CCR Supported by CCP Committee, sent to ECR for Approval. 2014-05-16 Approved for Engineering/Prototype. Engineering OPI Dave Wyse. OPI explained the problem, project scope and planned phases, a custom large weapons enclosure is needed.	2017-05-01 : Drawings just received. Will trial on one vessel									

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CCR Prioritization List for MSPVs

EXAME # 8045742v1 Updated 2014/03/07 *(L Richardson original author)*

Gearbox cooler replacement solution Hero Class	There has been several gearbox cooler failures on the Hero Class vessels that have resulted in oil leaking out the cooling water discharge. A long term solution is required to avoid	MSPV		Gearbox cooler	David Wyse	NCR	3/11/2016	Approved for Engineering/Prototype	2018-03-19 Acknowledge Reception of CCR Form Completed document are Routed to CCR Committee for Rev / Support 2018-03-23, CCR Supported for Engineering Study by CCR Committee, sent to CCB for approval. 2018-04-06 CCR Approved for Engineering by CCB / Approuvée pour ingénierie par CCC. Phase 1: Interim solution is to replace the Cu/Ni shell and tube coolers in the fresh water vessels to admiralty brass shell and tube coolers which have been recommended to be a better material against corrosion in fresh water applications. Phase 2- Have an engineering study performed to recommend a class wide solution for salt and fresh water which will include titanium plate coolers and a jacket water cooling system. Phase 3- Management accepts a solution and solution is implemented class wide. Engineering OPI / SPR Ingénierie : Dave Wyse. 2016-12-29 Reminder sent to originator: CCR was approved for Engineering April 2016, is the CCR ready to be sent to CCB for final Approval?	2017-03-01 - Titanium will be used on all the vessels.								
Hero Class sacrificial anode protection improvement	The sacrificial anodes on the hull and underwater equipment have been dissolving twelve the vessel reaches drydock periods. It has also been reported that the sacrificial anodic system is not adequate enough to prevent corrosion on the Hero Class vessels	MSPV		Cathodic Protection system	David Wyse	NCR	3/11/2016	Approved for Engineering/Prototype	2018-03-16, Acknowledge Reception of CCR Form Completed, document are Routed to CCR Committee for Rev / Support, 2018-03-06 CCR Supported by Committee for Phase 1 to 3, sent to CCB for Approval. 2018-04-06 CCR Approved for Engineering by CCB / Approuvée pour ingénierie par CCC. Phase 1- Have corrosion surveys done on vessels to determine the efficiency of the current system. Phase 2- Have an engineering study done to determine the best solution for the Hero Class System to upgrade the cathodic protection system. Phase 3- Have management accept a solution and implement on the Hero Class vessel. Engineering OPI : Dave Wyse, 2016-12-29 Reminder sent to originator: CCR was approved for Engineering April 2016, is the CCR ready to be sent to CCB for final Approval?								
Machinery Room Air Inlets- Replacing Isolating Louvres with Fire Dampers	The large covers that isolate the Air inlet system in the event of a fire will be replaced with fire dampers. These manually actuated dampers will improve the emergency response time by making air intakes faster and more maneuverably closed	MSPV		Air ducting system	David Wyse			Approved for Engineering/Prototype	2018-04-06 , Ack. CCR Registration, CCR Form and documentation Routed to CCR Committee for Rev./Support,2018-04-09 CCR supported by CCR Committee. Routed to CCB for approval. 2018-04-18 CCR Approved for Engineering/ Prototype Engineering OPI : SPR Ingénierie : Dave Wyse. DPI explained the problem, project scope and planned process, the large covers that isolate the Air inlets system used in case of fire will be replaced with fire dampers. 2016-12-08 Reminder sent to originator: CCR was approved for Engineering April 2016, is the CCR ready to be sent to CCB for final Approval?	2017-03-01 - Going to PSPC.								

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CCR Prioritization List for MSPVs

EKME # 3045742v1 Updated 2014/03/07 *(J. Richardson original author)*

Block water transfer/evacuation system Hero Class	The block water transfer/evacuator pumps on the Hero Class have been failing prematurely. A solution is required to ensure that the pumps last more than months. The pumps are roughly 10k each to replace.	MSPV		Block water transfer/evacuation pump	David Wyss	NCR	3/11/2013	Approved for Engineering/Project	2014-02-15 Acknowledge Reception of CCR Form Completed, document are Posted to CCA Committee for Rev. / Support. 2014-03-25 CCR Supported for Engineering Study by CCR Committee, sent to CCB for approval. 2014-04-08 CCR Approved for Engineering by CCB / Approuvée pour ingénierie par CCC. Phase 1- Have an engineering study done to give CCC recommendations for solutions for a sea grate system that will last the service life of the vessels. Phase 2- Management decision on solution and implementation of the solution. Engineering OPI / BPR Ingénierie Dave Wyss. 2014-12-29 Reminder sent to originator: CCR was approved for Engineering April 2015, is the CCR ready to be sent to CCB for final Approval?									

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Installation of E-Stops on Deck Hydraulics	Existing Conditions Currently none of the deck hydraulics on board have a local emergency stop. Should there be a failure the only emergency stop is located on the bridge and in the Main Machinery Room (MMR) at the Hydraulic Power Unit (HPU) Recommended Solution Install an emergency stop on the main crane pedestal which will shut off the main crane and fishing gear hydraulics A new wire transit will need to be welded onto the main deck at the base of the crane Install an emergency stop at the low reel / aft capstan operators station There is an existing Rockech transit here No welding required Install an emergency stop at the wheelhouse operators location A new transit will need to be welded back through the main deck, refer to attached pics for new wire transits All Emergency stops to be wired up in series to the control circuit located at the HPU local control panel in the MMR, refer to attached drawing for proposed change to control circuit Stainless steel weatherproof boxes will house the mushroom type E-stop buttons protective covers installed over push buttons to prevent accidental stop of hydraulic units Anticipated Benefits 1) Compliance with National Legislation The Cargo Fumigation and Tackle Regulations state "Lifting appliances shall have an emergency stop button at the operator?s position." 2) Vastly increase safety reducing the amount of time it would take to activate the Emergency Stop Impact on maintenance Budget Safety Hazard Should a hydraulic failure occur the operator must phone or radio the bridge to activate the Emergency Stop Potential pollution hazard if burst hydraulic lines cannot be isolated in a timely manner Very little impact on maintenance budget after installation.	DWG 84000021 MSPC Electrical System Diagram	17 Windlass Main Crane, Capstan Tow Reel, Fishing Gear	Deck Equipment	MSPV	CAPTAIN GODSARD M & M	Deck Equipment / Ship Support Systems	On Hold	Ben Aarssen 2015-12-02, Ack, CCR Registration CCR Form Section 1 to 5 should be completed, Section 6 Signed by Regional Authorities, then returned to National CCR Committee for Review/Support 2016-02-19 CCR Scope Issued to Major National will be applicable for MSPV Class Received CCR Form Supported by Region, document Routed to Operation for Review/Support 2016-03-09 CCR put on Hold by CCR committee, Mechanic Engineer Dennis Wyse and is team are already evaluating new E-Stop button to ship equipment, 2016-07-22 Update from Region Waiting for NHQ decision	2017-03-01 - Charles and Goddard Done on the crane							

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CCR Prioritization List for MSPVs

EKME # 3045742v1 Updated 2014/03/07 (L Richardson original author)

Pump pc power supply reconfiguration	Request for engineering study to connect the following pumps to Emergency Switch Board hotels: CCR P3 pump x 2 , MMR Offgoff fire pump x 1, Sea Water Cooling pump x 1			Propulsion/Main surveing Systems			pitch control, bilge and sea water cooling (clean tube) pump	Approved for Engineering/Prototype	Waiting on Lloyds approval. 2017-02-13 - Has been approved by Lloyds and spec sent to the regions.	2015-09-29: Acti. OCR Registration, OCR Form Section 1 to 3 should be completed. Section 4 Signed by Regional Authorities, then returned to National OCR Committee for Rec./Support; 2015-09-30 Routed to OpsnStore for Rev/Support; 2015-10-01 OCR Supported by CCR Committee. Sent to CCB for Approval.	$15,000		william.falcon@dfo-mpo.gc.ca	902-440-8221						

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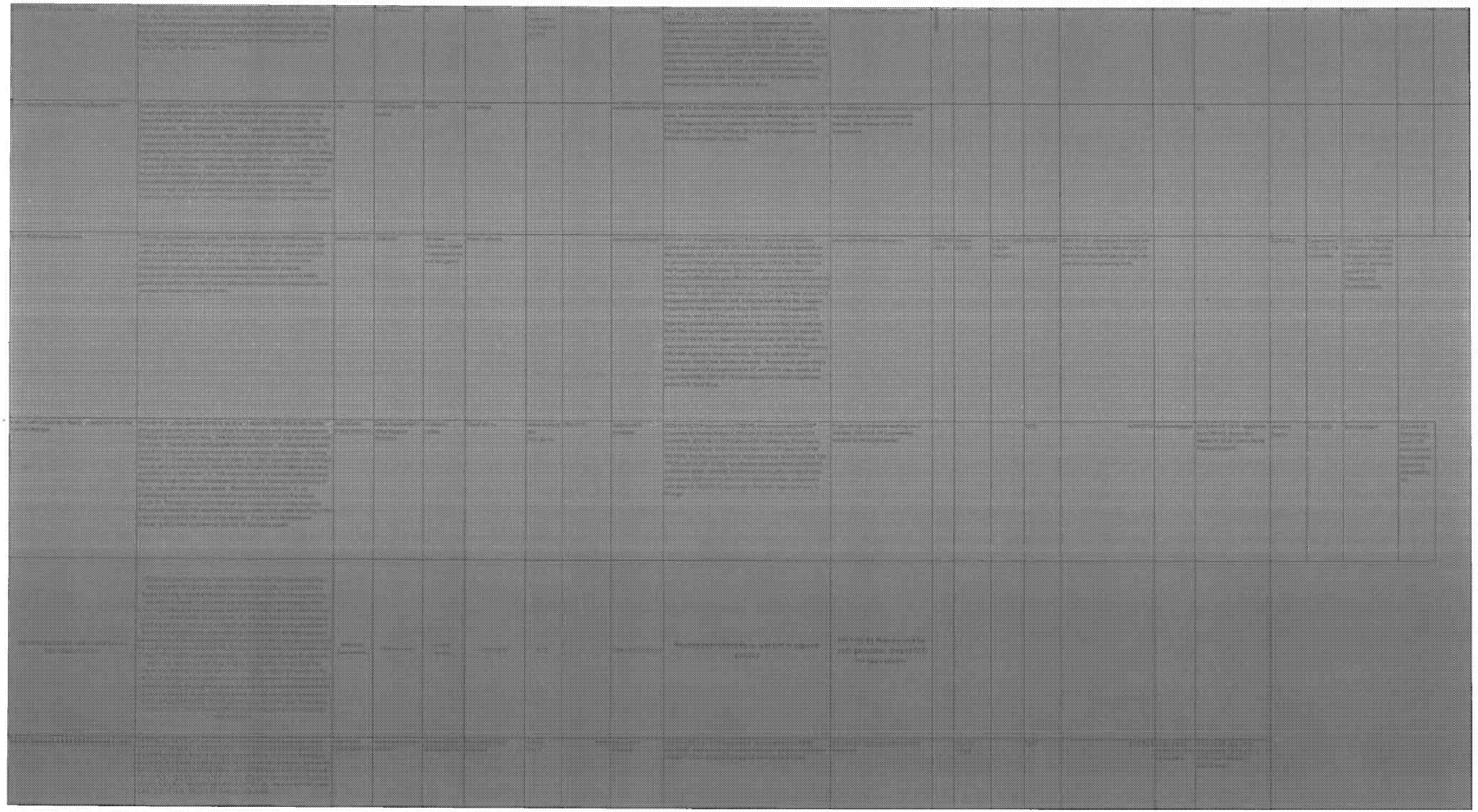
CCR Prioritization List for MSPVs

EKME # 3045742v1 Updated 2014/08/07 (*L. Richardson original author*)



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CCR Prioritization List for MSPVs

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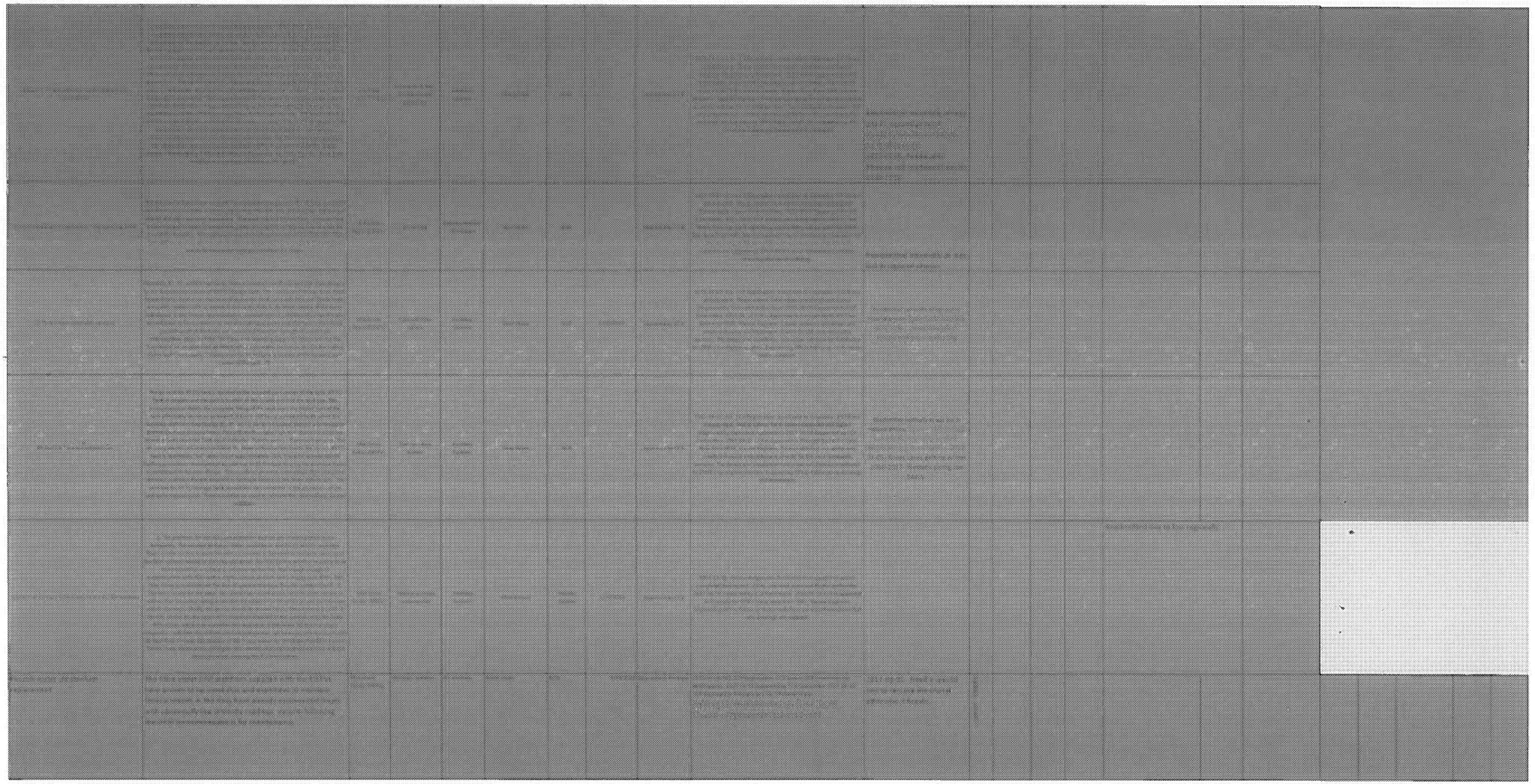

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CCR Prioritization List for MSPVs

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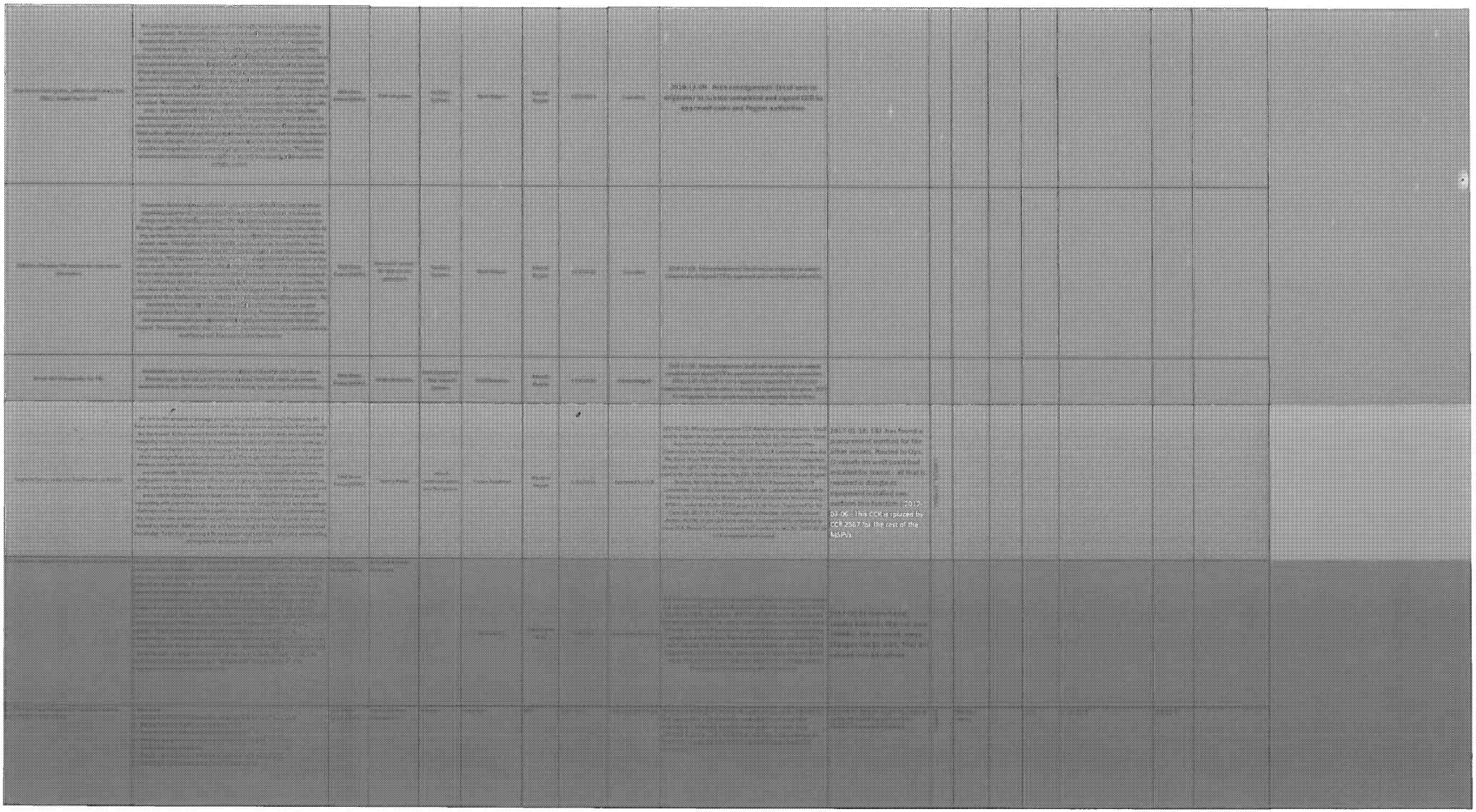

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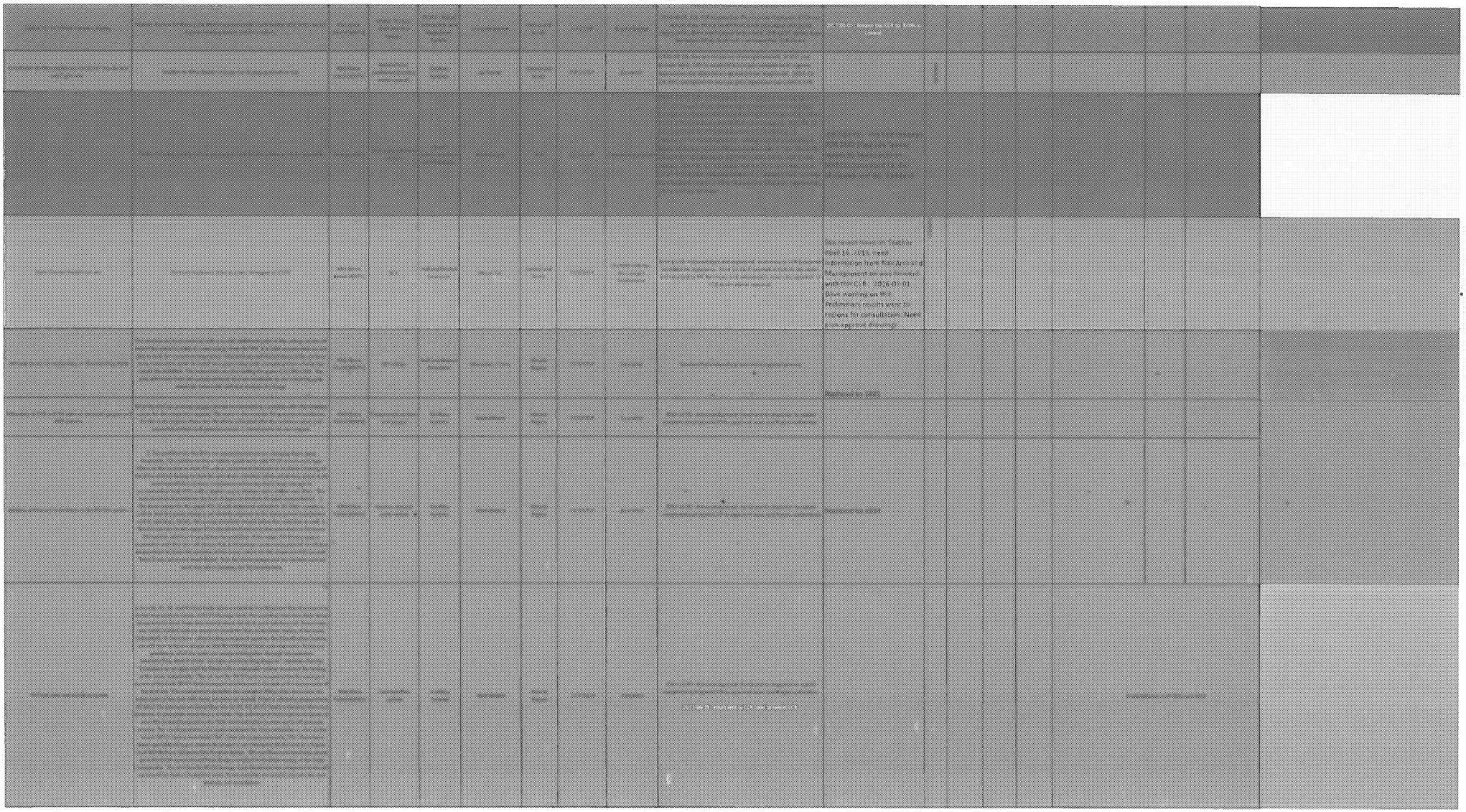
CCR Prioritization List for MSPVs

EKME # 3045742v1 Updated 2014/03/07 *(J. Richardson original author)*



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CCR Prioritization List for MSPVs

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Bunker gear location moved to Aft Passageway	A plate installed to be used as a mounting bracket for Scott Air pack holders along with hangers attached for the bunker gear and a shelf for an AED located in the Aft Passageway once the removal of gun cabinets has been completed.	Mid-Shore Patrol (MSPV)	Bunker gear	Safety and Security Equipment	Fred Severson	Atlantic Region	2014-03-01	Acknowledged	2014-03-04 Ack. CCR Registration Email sent to Originator. Work already done. Please submit CCR Form when Completed and Signed (Approved by Users and Region Authorities)							

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CCR Prioritization List for MSPVs

EKME # 3045742v1 Updated 2014/03/07 (L. Richardson original author)

Modification de l'horizon/ligne des radars des MSPV	Ajouter le bruit causé par les radars/brouillis dans le calcul de corrélation/amont, par une rationalisation et/ou un remplacement de ceux-ci.	Mid-Shore Patrol (MSPV)	Modern Vessels 2 et 3	Vessel Communications and Navigation	Longchamps, Thomi	ecm-pr-ent Archi	2013-12-19	Approved for Engineering Prototype	2013-12-20_Accord réception Energie/promet/DCC. Courriel envoyé en demandant: Est produit DCC ici pas déjà fait et nouvelle le formulaire lorsque Complété/Approuvé? ingénieurs demandeurs et autorité fédérale. 2014-12-02: Sent/points. courriel acheminé à l'ingénieure et envoyé au courriel d'Coordination des CCR. 2016-12-01 Update from Operations: Radar replacement as suggested by CSA Project is not supported. Operations Support to Test & Trial the Development and develop the radar reduction tooling solution from Western Region on board the Gaudaut for one month, which allows both crews a full tour to test and experience the new system. After if any patentiel modifications identified that may need to be made to the final design, the system is to be constructed and installed on all remaining MSPVs at the earliest opportunity. 2016-12-03_CCR Approved for Engineering. DCC approuvée pour ingénierie. Engineering DPP/BPR d'Ingénierie final Plan, to conclude with result for Rev./Approbation for MSPV Class. Le BPR doit terminé avec les résultats pour Rev / Approbation pour la Classe MSP.	Need confirmation from RCAMP that this is an issue for all crews on all vessels. Options are being investigated. 2017-02-01: Western region trialing noise dampening solution (dampers). Awaiting for feedback from Western region and then going to CCB for way forward 2017-04-01: Also sent an email to Western region requesting info on how so many owners for remaining vessels. Waiting on Fred's input and CCB approval. 2017-05-24 - Feed back from C&S for E&A materials and have to be ordered and owners made for the radar transceivers. Expected implementation for CGC this winter. Grant takes it is a medium priority. For ATI, the package is being developed by Engineering for the work and Production will schedule as opportunity/workload permits. They will advise when it is scheduled to be done.			TBD	TBD				

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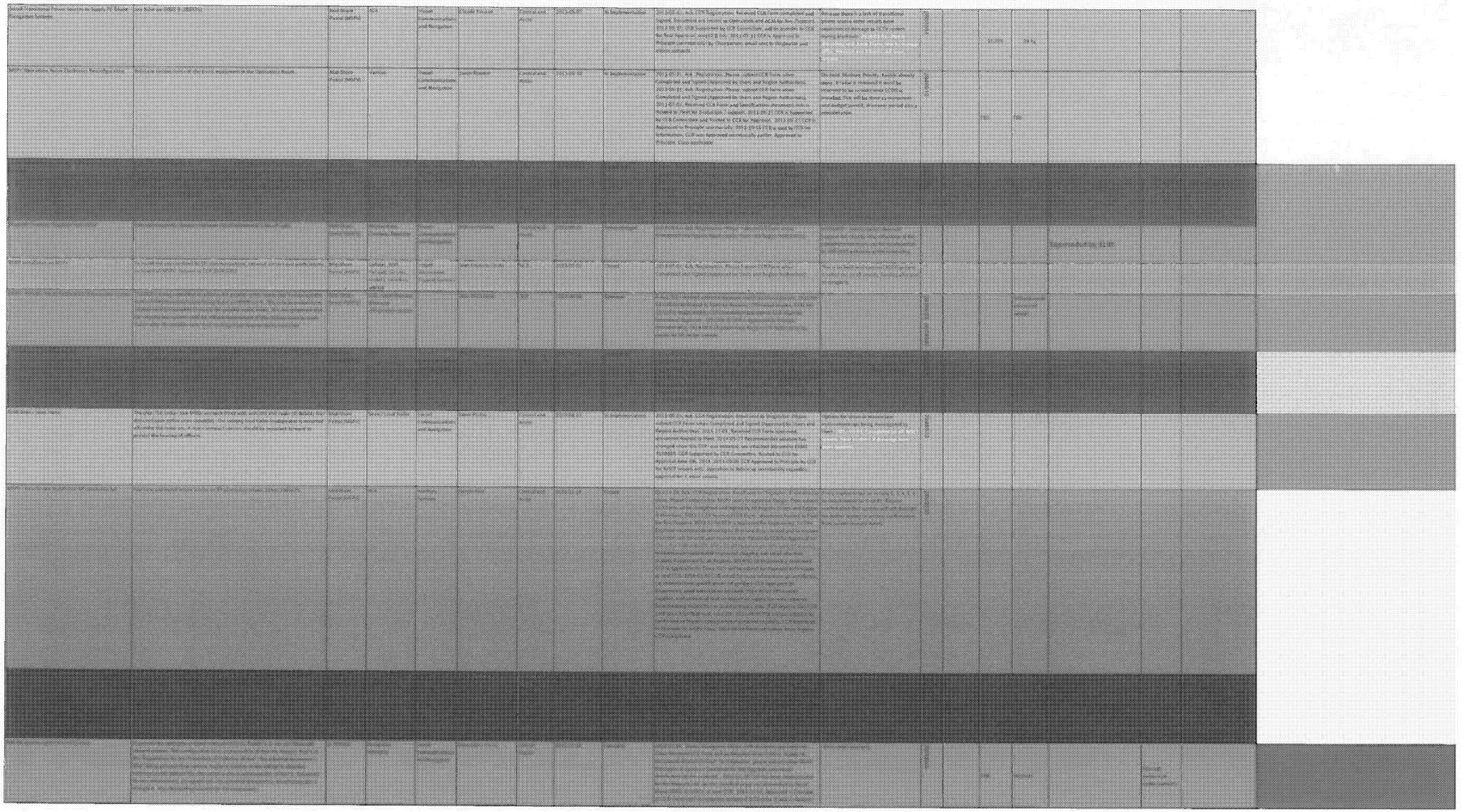
CCR Prioritization List for MSPVs

EKME # 3045742v1 Updated 2014/03/07 *[i.e. #chardstan original number]*



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CCR Prioritization List for MSPVs

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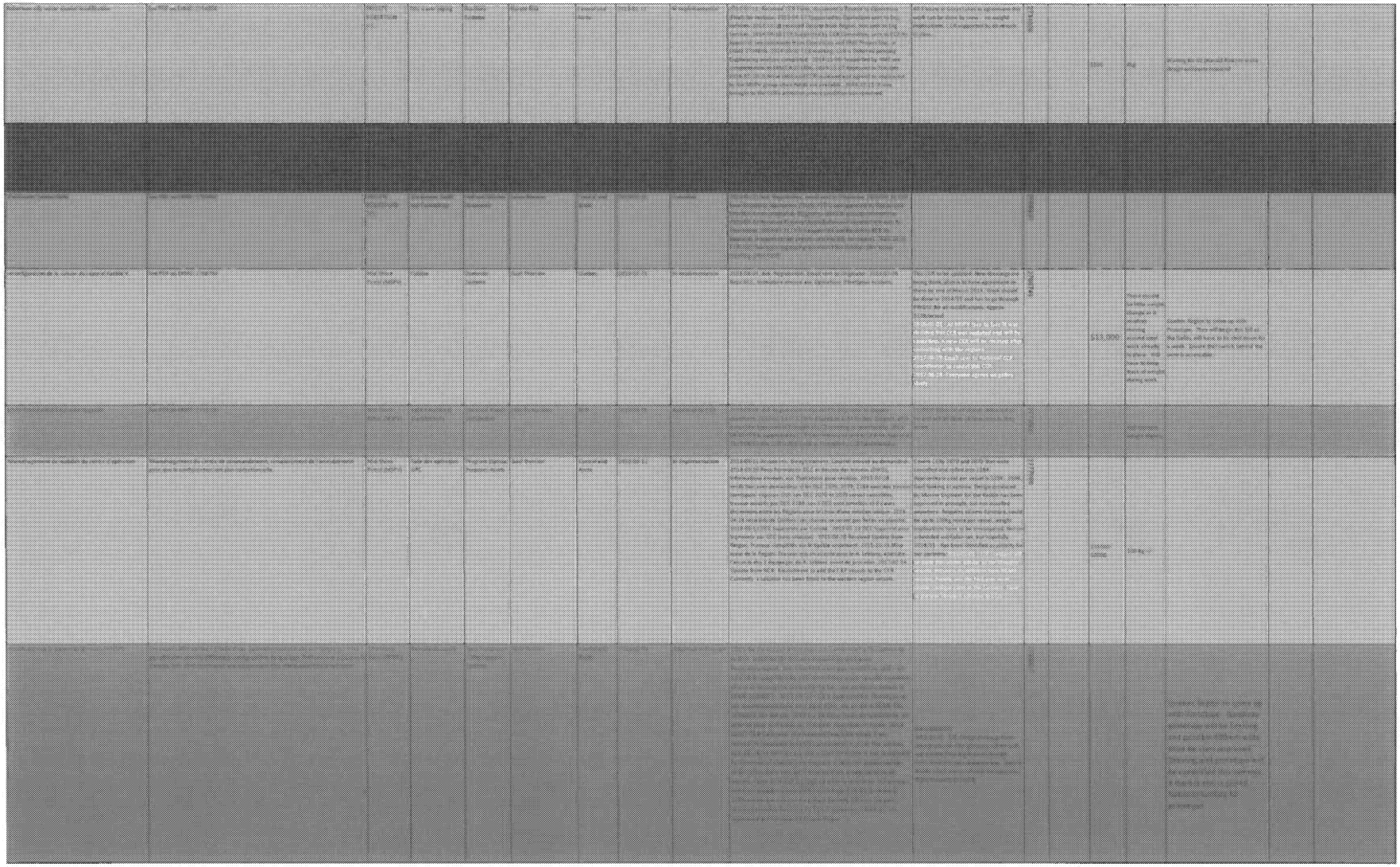

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CCR Prioritization List for MSPVs

EKME # 3045742v1 Updated 2014/03/07 (J. Richardson original author)

Title	Work Description	Asset	On Hand Equipment	System	Originator	Region originator	Approved for Planning Timestamp	Status	Comments	Notes	EKME #	Priority	Estimated Cost	Estimated Weight Impact	Comments	Reasons for cancelling	Reasons for rejection

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Wyse, David E

From: Wyse, David E
Sent: Wednesday, August 15, 2018 3:24 PM
To: Morphet, Jason (NCR); DeAngelis, Vincenzo
Cc: Kozarski, Natasa
Subject: Lightship and incline surveys for the Hero Class vessels

Hey Jason,

In light of the ITS/Ops meeting being cancelled today, I am wondering if a meeting is required to start moving forward again with Hero Class CCRs such as the stabilizers and the stern strengthening that might add additional weight to the vessels. Is it possible from operations to give approval over email to begin the process of planning lightship surveys and incline tests for the Hero Class vessels?

Currently the CCRs are on hold with ITS marine engineering due to the fact that we are not confident that the same vessel stability numbers and displacement number as when the vessels first arrived for program. Having a zero point similar to the NSFRVs will help to make future decisions about upcoming CCRs.

Thanks
Dave

David Wyse
Project Engineer | Mécanicien de Projet
Marine Engineering | Ingénierie Navale
Integrated Technical Services | Services Techniques Intégrés
Canadian Coast Guard | Garde Côtière Canadienne
200 Kent Street, Office 7W076, Mail Drop 7W064
Ottawa, ON, K1A 0E6
David.Wyse@dfo-mpo.gc.ca
Telephone | Téléphone 613-302-6503

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Wyse, David E

From: [redacted]
Sent: Thursday, August 16, 2018 9:15 AM
To: Wyse, David E
Cc: Kozarski, Vladan; DeAngelis, Vincenzo
Subject: RE: Point Of Contact

s.19(1)

Hi Dave:

Thank you for your reply, I appreciate the update.

I will stand by, however if you need me to re-run any calculations on my side, please let me know, I happy to do that.

Sincerely,

[redacted]
Quantum Marine
Cell: [redacted]
Skype: [redacted]
www.quantumstabilizers.com

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From: Wyse, David E <David.Wyse@dfo-mpo.gc.ca>
Sent: Thursday, August 16, 2018 6:58 AM
To: [redacted]
Cc: Kozarski, Vladan <Vladan.Kozarski@dfo-mpo.gc.ca>; DeAngelis, Vincenzo <Vincenzo.DeAngelis@dfo-mpo.gc.ca>
Subject: RE: Point Of Contact

Good morning [redacted]

We are trying to work out the current displacement and stability of the vessels to make the right decision about the hydraulics. Hoping to have a plan shortly.

Thanks
Dave

From: [redacted]
Sent: Wednesday, August 8, 2018 12:15 PM
To: Wyse, David E <David.Wyse@dfo-mpo.gc.ca>
Cc: Kozarski, Vladan <Vladan.Kozarski@dfo-mpo.gc.ca>; DeAngelis, Vincenzo <Vincenzo.DeAngelis@dfo-mpo.gc.ca>
Subject: RE: Point Of Contact

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Hi David:

I hope you are well and enjoying the summer.

It's been a few weeks, but I wanted to follow up on the HERO class refit you guys were considering – is the project still moving forward or has it been put on hold?

Sincerely,

s.19(1)

Quantum Marine
Cell:
Skype:
www.quantumstabilizers.com

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From:
Sent: Monday, May 28, 2018 1:36 PM
To: Wyse, David E <David.Wyse@dfo-mpo.gc.ca>
Cc: Kozarski, Vladan <Vladan.Kozarski@dfo-mpo.gc.ca>; DeAngelis, Vincenzo <Vincenzo.DeAngelis@dfo-mpo.gc.ca>
Subject: RE: Point Of Contact

Hi David:

I just left you a VM – I think you are possibly in training, but I wanted to make sure we are still ok for tomorrows meeting at 11:30 at the Minto food court you mentioned previously.

Also I wanted to make sure you received the preliminary drawings and brochures I sent on the 17th?

I look forward to meeting you tomorrow Dave.

Sincerely,

Quantum Marine
Cell:
Skype:
www.quantumstabilizers.com

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From:
Sent: Thursday, May 17, 2018 1:35 PM
To: Wyse, David E <David.Wyse@dfo-mpo.gc.ca>
Cc: Kozarski, Vladan <Vladan.Kozarski@dfo-mpo.gc.ca>; DeAngelis, Vincenzo <Vincenzo.DeAngelis@dfo-mpo.gc.ca>
Subject: RE: Point Of Contact

Hi David:

Brochures attached as mentioned previously and a partial reference list of Coast Guard and Navy projects.

Sincerely,

s.19(1)

Quantum Marine
Cell:
Skype:
www.quantumstabilizers.com

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From: Wyse, David E [mailto:David.Wyse@dfo-mpo.gc.ca]
Sent: Thursday, May 17, 2018 10:51 AM
To:
Cc: Kozarski, Vladan <Vladan.Kozarski@dfo-mpo.gc.ca>; DeAngelis, Vincenzo <Vincenzo.DeAngelis@dfo-mpo.gc.ca>
Subject: FW: Point Of Contact

Hi

I am the national lifecycle manager for the Hero Class vessels. I would like to meet you but unfortunately I am in training that whole week of May 31st. Can we meet at a lunch hour around 1130 to 1 one day at the Minto food court on Kent and Laurier streets on a day during that week? Tuesday the 29th doesn't work for me.

I would like to discuss the quantum model that best suits our Hero Class vessels and our weight and hydraulic issues.

I will get back to you on which model that was.

Thanks
Dave

From:
Sent: May-17-18 10:06 AM

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To: Kemp, Gerry
Subject: RE: Telephone Message

Hi Gerry:

Yes that was my VM – sorry I missed you.

I just left another – basically we have been contacted by some of your colleagues over in Vancouver about TANU and the HERO class regarding stabilizer supply and support.

Since I will be in your area for CANSAC, I thought it might be of value to your technical dept., if I drop by and discuss some of the newer technologies we are now using for Zero Speed and low speed (loitering) for your ships.

Also since the request for the HERO class feasibility (through Langkreek out in Newfoundland and DAMEN [redacted], that it may help with any questions about the potential use of stabilizers – if in fact the CCG does refit them.

Would you be available for a short chat?

s.19(1)

Sincerely,

s.20(1)(c)

[redacted]
Quantum Marine
Cell: [redacted]
Skype: [redacted]
www.quantumstabilizers.com

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From: Kemp, Gerry [mailto:Gerry.Kemp@dfo-mpo.gc.ca]
Sent: Thursday, May 17, 2018 8:08 AM
To: [redacted]
Subject: Telephone Message

Good morning [redacted]

I believe that I had a telephone message from you yesterday that I deleted by mistake, so please this excuse me if this email is a bit of a shot in the dark.
Just wanted to inform you that I am not involved to any extent in the technical requirements and work specifications for the Canadian Coast Guard Vessel Life Extensions. That work is all taken care of by the Marine Engineering group and the Project Officers.

However, if you can confirm that you were in fact the individual that called me, as well as the dates that you were planning on being in Ottawa, I can pass this information on to one or more of those folks. Unfortunately, I am not in a position to share their contact information directly.

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Regards,

Gerry Kemp
613-716-8949 | facsimile / télécopieur 993-5333
Gerry.Kemp@dfo-mpo.gc.ca

Vessel Life Extension – National Project Manager
Prolongation de la vie du navire - Gestionnaire de projet national

Canadian Coast Guard | Garde côtière canadienne
200 Kent St. Ottawa, ON K1A 0E6 | 200, rue Kent Ottawa, ON K1A 0E6
Government of Canada | Gouvernement du Canada

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Wyse, David E

From: Wyse, David E
Sent: Wednesday, August 22, 2018 8:33 AM
To: Kozarski, Vladan
Cc: Knapp, Valerie
Subject: FW: DFO contract F5211-170139 - Hero Class Seakeeping assessment, SC253739, Can
Attachments: 253739 017 ctr-signed.pdf; FW: DFO contract F5211-170139 - Hero Class Seakeeping assessment, SC253739, Can; 253739 031 amendment ctr-signed.pdf

Here you go, they are using the contract as invoice. See total below. 15400 Euros.

Dave s.19(1)

From: [redacted]
Sent: Wednesday, August 22, 2018 3:10 AM
To: Wyse, David E <David.Wyse@dfo-mpo.gc.ca>
Subject: RE: DFO contract F5211-170139 - Hero Class Seakeeping assessment, SC253739, Can

Dear Mr. Wyse,

Please find enclosed the signed contract + bank details that had been sent separately. We understood that the signed contract was considered as a PO and thus would function as an invoice.

The original contract concerned EUR 14.740 and the amendment concerned EUR 660, so total would be EUR 15.400.

Kind regards,

[redacted]

From: Wyse, David E [mailto:David.Wyse@dfo-mpo.gc.ca]
Sent: dinsdag 21 augustus 2018 20:39
To: [redacted]
Subject: RE: DFO contract F5211-170139 - Hero Class Seakeeping assessment, SC253739, Can

Hi [redacted]

Can you send me a copy of the invoice?

Thanks
Dave

From: [redacted]
Sent: Tuesday, August 21, 2018 4:38 AM
To: DeVink, Jean-Pierre <Jean-Pierre.DeVink@dfo-mpo.gc.ca>
Cc: [redacted]; Wyse, David E <David.Wyse@dfo-mpo.gc.ca>
Subject: RE: DFO contract F5211-170139 - Hero Class Seakeeping assessment, SC253739, Can

Dear Mr. DeVink,

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Could you be so kind to inform us if there is any news upon the payment?

Thank you,

Kind regards,

s.19(1)

DAMEN SHIPYARDS GORINCHEM
Industrieterrein Avelingen West 20
P.O. Box 1
4200 AA, Gorinchem
The Netherlands
Phone:
E-mail:
Internet: www.damen.com

FOLLOW DAMEN AMERICAS

From:
Sent: maandag 9 juli 2018 14:22
To: 'Jean-Pierre.DeVink@dfo-mpo.gc.ca' <Jean-Pierre.DeVink@dfo-mpo.gc.ca>
Cc:
Subject: RE: DFO contract F5211-170139 - Hero Class Seakeeping assessment, SC253739, Can

Dear Mr. DeVink,

With respect to the Seakeeping assessment, please be advised that we were unable to trace the payment of the Canadian Coastguard for this contract and amendment. Could you please advise if the amount has been transferred and if so, on which date?

Thank you,

Kind regards,

DAMEN SHIPYARDS GORINCHEM
Industrieterrein Avelingen West 20
P.O. Box 1
4200 AA, Gorinchem
The Netherlands
Phone:
E-mail:

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Internet: www.damen.com

FOLLOW DAMEN AMERICAS

s.19(1)

From: [redacted]
Sent: *donderdag 10 augustus 2017 11:36* s.20(1)(b)
To: 'Jean-Pierre.DeVink@dfo-mpo.gc.ca' <Jean-Pierre.DeVink@dfo-mpo.gc.ca>
Cc: [redacted]
Subject: FW: DFO contract F5211-170139 - Hero Class Seakeeping assessment, SC253739, Can

Dear Mr. deVink,

Please find below our bank details for payment in EURO's. Tax code information indeed is not necessary for payments from Canada to The Netherlands.

[redacted]

In case you have any further questions, please let us know.

Kind regards,

[redacted]

DAMEN

DAMEN SHIPYARDS GORINCHEM
Industrieterrein Avelingen West 20
P.O. Box 1
4200 AA, Gorinchem
The Netherlands
Phone: [redacted]
E-mail:
Internet: www.damen.com

FOLLOW DAMEN AMERICAS

From: DeVink, Jean-Pierre [mailto:Jean-Pierre.DeVink@dfo-mpo.gc.ca]
Sent: 08 August 2017 18:31
To: [redacted]
Cc:
Subject: RE: DFO contract F5211-170139 - Hero Class Seakeeping assessment

Hi [redacted]

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I have attached the new vendor form to obtain billing information to set up payment.
I did my best to fill out all the sections I had information to input, we are missing the "tax code information and direct deposit information".
As you are an international company, I don't believe we require any tax code information, however if you do have this information, please fill it in.

Thank you,

Jean-Pierre deVink

s.19(1)

Contracting Officer | Agent de marché
(506) 452-3619

From: [redacted]
Sent: 8 août 2017 11:49
To: DeVink, Jean-Pierre
Cc: Kozarski, Vladan
Subject: RE: DFO contract F5211-170139 - Hero Class Seakeeping assessment

Hi Jean-Pierre,

Thanks, I expect from now on it will indeed be only technical matters popping up.

Best regards,

[redacted]

From: DeVink, Jean-Pierre [mailto:Jean-Pierre.DeVink@dfo-mpo.gc.ca]
Sent: 08 August 2017 16:39
To: [redacted]
Cc: Kozarski, Vladan <Vladan.Kozarski@dfo-mpo.gc.ca>
Subject: RE: DFO contract F5211-170139 - Hero Class Seakeeping assessment

Hi [redacted]

Here is a copy of the signed contract for filing purposes.

Yes – you may now begin the work, for all technical questions regarding the work, please contact Vladan Kozarski.

Thank you,

Jean-Pierre deVink

Contracting Officer | Agent de marché
(506) 452-3619

From: [redacted]
Sent: 8 août 2017 11:24
To: DeVink, Jean-Pierre
Cc: Kozarski, Vladan; [redacted]
Subject: RE: DFO contract F5211-170139 - Hero Class Seakeeping assessment

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Hello Jean-Pierre,

Please find attached a copy of the final contract, signed by [redacted]

I expect you will now process the paperwork and give a clear signal when it is okay for me to start?

If you have any questions or remarks, please let me know.

Best regards,

s.19(1)

[redacted]

From: DeVink, Jean-Pierre [mailto:Jean-Pierre.DeVink@dfo-mpo.gc.ca]
Sent: 03 August 2017 14:01
To: [redacted]
Subject: RE: DFO contract F5211-170139 - Hero Class Seakeeping assessment

Hello [redacted]

I have attached the latest version of the contract with adjusted dates for your review and signature.

Feel free to contact me should you have any questions or concerns.

Thank you,

Jean-Pierre deVink

Contracting Officer | Agent de marché
(506) 452-3619

From: DeVink, Jean-Pierre
Sent: 11 juillet 2017 14:24
To: [redacted]
Subject: RE: DFO contract F5211-170139 - Hero Class Seakeeping assessment

Hi [redacted]

Below you will find the described am trying to finalize the contract and wanted to confirm with you that the following paragraph was the only modification we required?

A.3 Scope

CCG requires that the Contractor produce a new seakeeping assessment of several roll stabilization configurations on the Hero Class. The Contractor must produce a seakeeping assessment of the vessels as delivered with no stabilization and the following configurations:

- *Active fin (roll) stabilization,*
- *Rudder roll stabilization*
- *Bilge keels,*
- *Rudder roll stabilization plus bilge keels,*
- *'Zero Speed' stabilizers. P or XT Series (Quantum: www.quantumhydraulic.com)*

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Then the Contractor must analyze and compare the un-stabilized vessel against the five/six configurations.

Also, I have attached a copy of the contract document with the above revision.

Please ensure that this copy is executed on behalf of the Contractor by their duly authorised officers / agents or other person(s) legally authorised to bind the party and returned to the undersigned by email at your earliest convenience.

Please ensure the signatory signs and a scanned copy is provided at your earliest convenience.

Upon receipt and after execution on behalf of the minister, a copy will be forwarded to you for your retention.

Thank you,

Jean-Pierre deVink

s.19(1)

s.20(1)(c)

Contracting Officer | Agent de marché
(506) 452-3619

From:
Sent: 7 juillet 2017 11:25
To: Kozarski, Vladan; DeVink, Jean-Pierre
Subject: RE: DFO contract F5211-170139 - Hero Class Seakeeping assessment

Hi Vladan,

Sorry about the delays on our side. I would like to inform you about the following:

The sales director agreed with the contract and had no further remarks. The remark I made earlier about the "P or XT series" would then be the only change in the contract.

However, I ran into an issue. I started the base analysis (no stabilizers) and found out that the wave spreading function is not working in the tool. I've been in contact a lot with the tool manufacturers this week and they created a workaround for me. However, the workaround is still not working properly. The spreading is not included in head waves and there are issues with zero encounter frequencies, leading to very large responses.

At this moment we have 3 options, as I see it:

1. Hold off on signing the contract until I have figured this out completely
2. Do not take wave spreading into account anymore. This has only a negligible effect on the assessment of the effectiveness of the different roll stabilizers, as the spreading would affect all solutions more or less equally. The RAOs are completely independent of spreading anyway. There is also no effect on the budget, as spreading was supposed to be fully automatic, so excluding it does not lead to time savings.
3. Put in the contract some hybrid form, where wave spreading excluded is acceptable, but spreading included is preferable. In that case I will both start the calculations and continue to solve this in time if we can.

I apologize for this inconvenience and look forward to your views on this.

Enjoy the weekend!

Best regards,

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From: Kozarski, Vladan [mailto:Vladan.Kozarski@dfo-mpo.gc.ca]
Sent: 30 June 2017 18:58
To: [redacted] DeVink, Jean-Pierre <Jean-Pierre.DeVink@dfo-mpo.gc.ca>
Subject: Re: DFO contract F5211-170139 - Hero Class Seakeeping assessment

s.19(1)

Hi [redacted]

This weekend we celebrate 150 years in Canada. It is 'chaos' in Ottawa. Will be back in office on Tuesday.

Regards.

Vladan.

Sent from my BlackBerry 10 smartphone on the Rogers network.

From: [redacted]
Sent: Friday, June 30, 2017 10:03 AM
To: Kozarski, Vladan; DeVink, Jean-Pierre
Subject: RE: DFO contract F5211-170139 - Hero Class Seakeeping assessment

Hi Vladan and Jean-Pierre,

Just a short update:

The contract is still with our sales director for reviewing, as soon as he's given his approval or comments I will pass it on to you.

Enjoy the weekend,

Best regards,

[redacted]

From: Kozarski, Vladan [mailto:Vladan.Kozarski@dfo-mpo.gc.ca]
Sent: 23 June 2017 17:22
To: [redacted] DeVink, Jean-Pierre <Jean-Pierre.DeVink@dfo-mpo.gc.ca>
Subject: RE: DFO contract F5211-170139 - Hero Class Seakeeping assessment

[redacted] and Jean-Pierre,

I do agree with the change. Damen will analyze only one 'Zero Speed' stabilizer, so it should be P or XT series. Although we decided to go with the P series only, I would keep **P or XT Series** in the recommended text:

'Zero Speed' stabilizers. P **or** XT Series (Quantum: www.quantumhydraulic.com).

Hope this clears out the contract wording.

Regards.

Vladan.

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From: [redacted]
Sent: Friday, June 23, 2017 10:29 AM
To: DeVink, Jean-Pierre
Cc: Kozarski, Vladan s.19(1)
Subject: RE: DFO contract F5211-170139 - Hero Class Seakeeping assessment

Hi Jean-Pierre,

Thanks for the contract. I've looked it over and noticed just 1 last detail: on page 7 it mentions 'Zero Speed' stabilizers. P and XT Series (Quantum: www.quantumhydraulic.com)

But this should be
'Zero Speed' stabilizers. P **or** XT Series (Quantum: www.quantumhydraulic.com)

Vladan has already indicated that this will be the P-series.

If you and Vladan agree, could you send a revised contract? I will forward this version to the right people so they can have a look already.

Best regards,

[redacted]

From: DeVink, Jean-Pierre [mailto:Jean-Pierre.DeVink@dfo-mpo.gc.ca]
Sent: 23 June 2017 15:04
To: [redacted]
Subject: DFO contract F5211-170139 - Hero Class Seakeeping assessment

Hello [redacted]

Please find enclosed the referenced contract document which is forwarded for your review and execution.

Please ensure that this copy is executed on behalf of the Contractor by their duly authorised officers / agents or other person(s) legally authorised to bind the party and returned to the undersigned by email at your earliest convenience.

Please ensure the signatory signs and a scanned copy is provided at your earliest convenience.

Upon receipt and after execution on behalf of the minister, a copy will be forwarded to you for your retention.

Regards,

Jean-Pierre deVink

Material and Procurement Services | Services du matériel et des acquisitions
Financial and Materiel Management Operations | Opérations financières et Gestion du Matériel
Fisheries and Oceans Canada | Pêches et Océans Canada
301 Bishop Drive | 301 promenade Bishop

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Fredericton, NB E3C 2M6 | Fredericton N-B E3C 2M6
Telephone | Téléphone (506)-452-3619
Facsimile | Télécopieur (506)-452-3676
Email | Courriel: jean-pierre.devink@dfo-mpo.gc.ca

- Si vous voulez reçevoir ceci en français, n'hésitez pas de me laisser savoir.
- I encourage you to reply to this e-mail in the official language of your choice. je vous encourage à répondre à ce courriel dans la langue officielle de votre choix

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Fisheries and Oceans Canada | Pêches et Océans Canada

Purchasing Office - Bureau des achats:

Procurement Hub | Centre d'approvisionnement
Fisheries and Oceans Canada | Pêches et Océans Canada
301 Bishop Drive | 301 promenade Bishop
Fredericton, NB E3C 2M6

Email - courriel: DFOinvoicing-MPOfacturation@DFO-MPO.GC.CA

CONTRACT – CONTRAT

s.19(1)

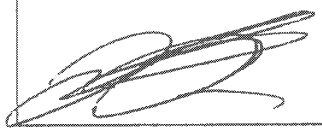
Your proposal is accepted to sell to Her Majesty the Queen in right of Canada, in accordance with the terms and conditions set out herein, referred to herein or attached hereto, the supplies and/or services listed herein and on any attached sheets at the price or prices set out therefore.

[redacted]

For the Contractor Pour le fournisseur

Damen Shipyards Gorinchem
P O Box 1
4200 AA Gorinchem
The Netherlands

[redacted]

Title – Sujet Hero Class (MSPV) Seakeeping Assessment		**Date** August 3rd 2017
Client Reference No. - No. de référence du client F6074-170005		
Contract No. - N° du contrat F5211-170139		
Financial Codes - Codes financiers 11310-810-120-4103-61751		
F.O.B. - F.A.B. see herein-ci-inclus	**GST - TPS** see herein-ci-inclus	**Duty - Droits** see herein-ci-inclus
Destination of Goods and Services: Destinations des biens et services: Aquatic Ressources NAFC BLDG. White Hills, PO BOX 5667 St. John's NL. A1C 5X1		
Invoices - Original and two copies to be sent to: **Factures - Envoyer l'original et deux copies:** DFOinvoicing-MPOfacturation@DFO-MPO.GC.CA		
Address Inquiries to: - Adresser toute demande de renseignements : Jean-Pierre deVink **Email - Courriel:** jean-pierre.devink@dfo-mpo.gc.ca		
Telephone No. – No. de téléphone 506-452-3619		**Fax:** 506-452-3676
Total Estimated Cost - Coût total estimatif $ 14,740.00		**Currency - Devise** EUR
For the Minister - Pour le Ministre  Date Aug 8th 2017		

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The following clauses and conditions apply to and form part of any contract resulting from the bid solicitation.

6.1 Security Requirements

There is no security requirement applicable to this Contract.

6.2 Statement of Work

The Contractor must perform the Work in accordance with the Statement of Work at Annex "A".

6.3 Standard Clauses and Conditions

All clauses and conditions identified in the Contract by number, date and title are set out in the *Standard Acquisition Clauses and Conditions Manual* (https://buyandsell.gc.ca/policy-and-guidelines/standard-acquisition-clauses-and-conditions-manual) issued by Public Works and Government Services Canada.

Revision to Departmental Name: As this contract is issued by Fisheries and Oceans Canada (DFO), any reference to Public Works and Government Services Canada or PWGSC or its Minister contained in any term, condition or clause of this contract, including any individual SACC clauses incorporated by reference, will be interpreted as reference to DFO or its Minister.

6.3.1 General Conditions

2010B **2015-07-03**, General Conditions - Professional Services (Medium Complexity) apply to and form part of the Contract.

Section 31 – Integrity Provisions – Contract of F5211-170139 referenced above is amended as follows:

Delete section 31 in its entirety.

6.4 Term of Contract

6.4.1 Period of the Contract

The Work is to be performed from the point of contract award to October 27th 2017.

6.5 Authorities

6.5.1 Contracting Authority

The Contracting Authority for the Contract is:

Name:	Jean-Pierre deVink
Title:	Procurement Officer
Department:	Fisheries and Oceans Canada
Directorate:	Material and Procurement services
Address:	301 Bishop drive Fredericton, NB E3C 2M6
Telephone:	506-452-3619
Facsimile:	506-452-3676
E-mail address:	jean-pierre.devink@dfo-mpo.gc.ca

2

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The Contracting Authority is responsible for the management of the Contract and any changes to the Contract must be authorized in writing by the Contracting Authority. The Contractor must not perform work in excess of or outside the scope of the Contract based on verbal or written requests or instructions from anybody other than the Contracting Authority.

6.5.2 Project Authority

The Project Authority for the Contract is:

Name: Vladan Kozarski
Title: Naval Architecture Officer
Organization: Canadian Coast Guard Services
Address: 200 Kent Street
Ottawa, ON
K1A 0E6
Telephone : 613-993-1627
E-mail address: Vladan.kozarski@dfo-mpo.gc.ca

The Project Authority is the representative of the department or agency for whom the Work is being carried out under the Contract and is responsible for all matters concerning the technical content of the Work under the Contract. Technical matters may be discussed with the Project Authority, however the Project Authority has no authority to authorize changes to the scope of the Work. Changes to the scope of the Work can only be made through a contract amendment issued by the Contracting Authority.

6.5.3 Contractor's Representative

s.19(1)

Name: [redacted]
Organization: Damen Shipyards
Address: P.O. Box 1
4200 AA Gorinchem
The Netherlands
Telephone: [redacted]
Facsimile: +31 183 65 54 74
E-mail address: [redacted]

6.6 Proactive Disclosure of Contracts with Former Public Servants

By providing information on its status, with respect to being a former public servant in receipt of a *Public Service Superannuation Act* (PSSA) pension, the Contractor has agreed that this information will be reported on departmental websites as part of the published proactive disclosure reports, in accordance with Contracting Policy Notice: 2012-2 of the Treasury Board Secretariat of Canada.

6.7 Payment

6.7.1 Basis of Payment

6.7.1.1 The Contractor will be reimbursed for the costs reasonably and properly incurred in the performance of the Work, as determined in accordance with the Basis of Payment in Annex "B", to a limitation of expenditure of $14,740.00 (EUR). Customs duties are included and Applicable Taxes are extra.

6.7.1.2 All prices and amounts of money in the Contract are exclusive of the Goods and Services Tax (GST) or Harmonized Sales Tax (HST), whichever is applicable, unless

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otherwise indicated. GST or HST, to the extent applicable, will be incorporated into all invoices and progress claims for goods supplied or work performed and will be paid by Her Majesty. The Contractor agrees to remit to Canada Revenue Agency any GST or HST paid or due.

6.7.1.3 Any payment by Her Majesty under this contract is subject to there being an appropriation for the fiscal year in which the payment is to be made.

6.7.2 Limitation of Expenditure

SACC Manual clause C6001C (2013-04-25), Limitation of Expenditure

6.7.2 Multiple Payments

SACC Manual clause H1001C (2008-05-12), Multiple Payments

6.8 Invoicing Instructions

6.8.1 Payments will be made provided that:

6.8.1.1 The invoice(s) must be emailed to DFO Accounts Payable, at the email address indicated below:

Email: DFOinvoicing-MPOfacturation@DFO-MPO.GC.CA

The Contractor must submit invoices in accordance with the section entitled "Invoice Submission" of the general conditions. Invoices cannot be submitted until all work identified in the invoice is completed.

The original and one (1) copy must be forwarded to the address shown above and on page 1 of the Contract for certification and payment.

6.9 Certifications

6.9.1 Compliance

The continuous compliance with the certifications provided by the Contractor in its bid and the ongoing cooperation in providing associated information are conditions of the Contract. Certifications are subject to verification by Canada during the entire period of the Contract. If the Contractor does not comply with any certification, fails to provide the associated information, or if it is determined that any certification made by the Contractor in its bid is untrue, whether made knowingly or unknowingly, Canada has the right, pursuant to the default provision of the Contract, to terminate the Contract for default.

6.10 Applicable Laws

The Contract must be interpreted and governed, and the relations between the parties determined, by the laws in force in **the province or territory where the goods and/or services are to be rendered**.

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6.11 Priority of Documents

If there is a discrepancy between the wording of any documents that appear on the list, the wording of the document that first appears on the list has priority over the wording of any document that subsequently appears on the list.

(a) the Articles of Agreement;
(b) the general conditions 2010B **2015-07-03**, General Conditions - Professional Services
(c) Annex A, Statement of Work;
(d) Annex B, Basis of Payment;
(e) Annex C, Security Requirements Check List;
(f) the Contractor's bid dated June 1st 2017.

6.12 Procurement Ombudsman

6.12.1 The Contractor confirms that it has read the Code of Conduct for Procurement and agrees to be bound by its terms.

6.12.2 The office of the Procurement Ombudsman (OPO) was established by the Government of Canada to provide an independent avenue for suppliers to raise complaints regarding the award of contracts under $25,000.00 for Goods and under $100,000.00 for Services. You have the option of raising issues or concerns regarding the solicitation, or the award resulting from it,. With the OPO by contacting them by telephone at 1-866-734-5169 or by e-mail at opo-boa@opo-boa.gc.ca. You can also obtain more information on OPO services available to you on their website at www.opo-boa.gc.ca.

6.12.3 For further information, the Contractor may refer to the following PWGSC site:

http://www.tpsgc-pwgsc.gc.ca/app-acq/cndt-cndct/contexte-context-eng.html

6.13 Insurance G1005C (2016-01-28)

The Contractor is responsible for deciding if insurance coverage is necessary to fulfill its obligation under the Contract and to ensure compliance with any applicable law. Any insurance acquired or maintained by the Contractor is at its own expense and for its own benefit and protection. It does not release the Contractor from or reduce its liability under the Contract.

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ANNEX "A" STATEMENT OF WORK

A.1 Background

A.1.1 Vessel Info

Canadian Coast Guard (CCG) took acceptance of nine new Hero Class Vessels built by Irving Shipyards between 2012 and 2014 under "Lloyd's Rules and Regulations for the Classification of Special Service Craft, 2009".

Ships Particulars	
Length	42.8 m
Breadth	7.0 m
Draft	2.218 m
Freeboard	1.7 m
Gross Tonnage	253.0 t
Cruising Range	200 nm
Endurance	14 d
Cruising Speed	14.0 kts
Maximum Speed	25.0 kts

Class Notations:
Hull Notation: *+100A1 SSC PATROL, MONO, HSC, G4, EP.*
Descriptive Notes: *ABBREVIATED NOTE GREEN PASSPORT*

The Hero Class vessels operate in different environments. Five vessels of the Marine Surveillance (MS) variant operate in the Great Lakes and St. Lawrence River in predominantly fresh and brackish water. Two vessels of the Conservation and Protection (CP) variant operate in the North Pacific, and two others operate in the North Atlantic. All four ships in this variant sail within the cruising range of up to 200 nautical miles (370 km) from the coast at a maximum speed of 25 knots (46 km/h).

Each MS vessel carries two rigid-hulled inflatable boats (RHIBs) while each CP vessel carries one RHIB. The vessels have a single point davit launching arrangement for launching the RHIBs. Each vessel has accommodation for nine CCG personnel as well as up to five Department of Fisheries and Oceans or RCMP officers.

The Hero Class is a variant of the Damen 4207 particularized for service with CCG, and retains the same basic hull design of the parent vessel. As such, the Hero Class shares similar seakeeping characteristics as the parent 4207. However, the Hero Class vessels do not have fin roll stabilizers. The majority, but not all, of the international variants based on the 4207 parent hull are equipped with fin roll stabilizers.

CCG is looking to improve seakeeping performance of the Hero Class vessels. There are several applicable solutions on the market. However there are many restrictions for the application of stabilizers on the Hero Class that may stipulate some solutions rather than others. CCG is looking for the configuration that provides the best compromise between improved seakeeping performance on one side and increased lightship weight, reduced internal space and installation cost on the other side.

A.1.2 Existing Seakeeping Assessment

A seakeeping assessment of the Hero Class was conducted during the vessels' design phase by Damen Group and the report was delivered to Canadian Coast Guard. The report as well the analysis, conclusions and other details of the assessment are given in the [Ref. A].

A.2 Scope

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CCG requires that the Contractor produce a new seakeeping assessment of several roll stabilization configurations on the Hero Class. The Contractor must produce a seakeeping assessment of the vessels as delivered with no stabilization and the following configurations:

- Active fin (roll) stabilization,
- Rudder roll stabilization
- Bilge keels,
- Rudder roll stabilization plus bilge keels,
- 'Zero Speed' stabilizers. P or XT Series (Quantum: www.quantumhydraulic.com)

Then the Contractor must analyze and compare the un-stabilized vessel against the five/six configurations.

A.2.1 Vessel Modeling

The seakeeping of the vessel at the following five locations must be assessed:

1. Bridge (accelerations) [m]: 20.92; 0.93; 7.2
2. RHIB Launching (accelerations) [m]: 5; 3.5; 3.9
3. Deck at 0.9L (deck wetness) [m]: 38.5; 1.75; 5.72 (or 4.54)
4. Forefoot (slamming) [m]: 38.5; 0 ; 0,
5. Center of Gravity

Coordinates are given in the following order: longitudinal, transversal and vertical.

Axes of the coordinate system are:

- Longitudinal axis is in the vessel's centerline plane and pointing positive towards bow,
- Transversal axis is in the frame 0 plane and pointing positive towards starboard side,
- Transversal axis is in the baseline plane and pointing positive upwards.

Origin of the coordinate system is located at the frame 0, Baseline and Centerline plane

Vertical coordinate of deck wetness location could be taken at the deck side or bulwark [Ref. C & D]. The Contractor must advise CCG on what location will be better to apply and take the most appropriate one.

Vessel radii of gyration (roll, pitch and yaw) must be taken as per values recommended in the [Ref. F].

The following motions, accelerations and probabilities must be assessed.

- Vertical and lateral accelerations at the locations 1, 2, 3 and 5,
- Roll and pitch motions,
- Probability of deck wetness (green water shipping) for the location 3,
- Probability of slamming must be assessed for the location 4.

This makes total of twelve variables to be analyzed.

The seakeeping assessment must be done for the following loading condition [Ref.B]:

- Departure:
  - Displacement: 264 tonnes,
  - Mean draft: 2.197m (draft @ 20.5m in salt water),
  - Trim by stern: 0.077m (per 36.7m length between draft marks in salt water),
  - Mean draft: 2.228m (draft @ 20.5m in fresh water),
  - Trim by stern: 0.076m (per 36.7m length between draft marks fresh water),

2

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LCG: 16.709m,
TCG: 0,
VCG: 2.912m.

Hull appendages: rudders and shafts must be modeled.

Vessel speed range must be from zero to 25 knots in 5 knots step (total of six speeds).

A.2.3 Enviromental modeling and conditions.

The definition of wave direction in respect to vessel's heading must be as follows:

1. 0 degrees angle between waves' direction and vessel's heading are stern or following waves,
2. 90 degrees angle between waves' direction and vessel's heading are beam waves,
3. 180 degrees angle between waves' direction and vessel's heading are head waves.

The waves on the seaway must be modeled to represent as close as possible the sea environment and waves in which the vessels operate.

The seaway must be modelled using the following assumptions:

1. Bretschneider spectrum for North Atlantic and Pacific,
2. JONSWAP spectrum for Great Lakes area,
3. A uni-directional wave spectrum must be modelled using a point wave spectrum (Bretschneider, JONSWAP, ...).
4. The mean significant wave height and most probable peak period for sea states 5 and 6 statistics [Ref. F] must be applied for spectra modeling in North Atlantic and Pacific as well as Great Lakes,
5. Deep water.

Sea states 5 and 6 for North Atlantic and Pacific as well as appropriate states for Great Lakes must be applied.

A.2.4 Seakeeping Assessment Results

The contractor must deliver the seakeeping assessment results of all proposed stabilizers as raw data and as polar and RAO plots.
Raw data must be delivered for all twelve variables as required in A.3.1 in the Departure condition as well as in all waves' directions, all ship speeds and sea states.
Plots must be delivered in the two formats for selected motions, accelerations and probabilities in the Departure loading condition and environmental conditions as required in A.3.3. The required formats are:

- Polar plots for 360 degrees wave direction and all ship speeds. Polar plots must be delivered for the following variables:
  - Vertical and lateral accelerations at the locations 1 and 5,
  - Roll and pitch motions,
  - Probability of deck wetness (green water shipping) for the location 3.

  RMS values for the motions and accelerations must be used.

- Response Amplitude Operators (RAO) plots for 180 degrees wave direction, all six speeds and for roll motion only; each plot must show and compare curves of un-stabilized vessel against all stabilizing configurations.

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The Contractor must also add applicable seakeeping criteria as defined by NORDFORSK 1987 [Ref. F] to the plots. In addition, the Contractor must assess motion sickness against ISO 2634-1:1997 for the locations: 1 – Bridge, 2 - RHIB launching and 5 - Centre of Gravity.

The results of the seakeeping analysis must be presented in such way to provide enough information that the stabilizers can be compared by roll reduction efficiency. This seakeeping assessment will be used as an input for the comparative analysis and feasibility study of the stabilizers' implementation on the Hero Class. In that study several features of the stabilizers will be compared and one of them will be their ability and efficiency to reduce the roll motion.

A.3 Tasks

The following tasks are required to be completed but may be undertaken in any order the Contractor chooses:

- Carry out seakeeping assessment with vessel particulars, loading and environmental conditions as provided in the scope,
- Provide the results and analysis of the assessment,
- Review of expected roll reduction at different speeds and show the results in a comparative form,
- Review of effect on speed and range performance,
- Produce a report of all findings.

A.4 Deliverables

All deliverables shall be in an unprotected format to allow CCG full editing rights into the future.

Final report shall be delivered to CCG as one hard copy and a soft copy. Preferred report formats are Microsoft Word Document (.docx), AutoCAD (.dwg) and Adobe Acrobat (.pdf).

A soft copy shall include report both in Adobe Acrobat and Microsoft Word format as well as all source files used to create report (Excel tables, AutoCAD drawings, photos ...).

Drafts of Microsoft Word documents and drawings to be reviewed by CCG can be delivered by e-mail, or prepared for download from remote servers or web drives (such as FTP, OneDrive, Google Drive, etc.)

A.5 Schedule

Draft report of the seakeeping assessment, must be delivered to the project officer for review within the six weeks after the project initiation.

CCG must review the draft of the study and provide comments to the Contractor within two weeks of the receipt.

The final report of the seakeeping assessment must be delivered to the project officer within three weeks after receiving comments for the draft.

Additional meetings to discuss any issues can be organized at the request of either the Contractor or CCG on an ad hoc basis as the need arises.

If in any case the Contractor is not able to complete and submit the work by required deadline, an extension of up to three weeks may be granted.

Anticipated starting date is August 7th 2017. Anticipated date of the final report submission is October 27th 2017.

A.6 Applicable Documents

Ship drawings and reports (seakeeping report, stability books) available upon request.

2

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A.7 References

A. Conclusions of Hero Class Seakeeping Analysis Done by Damen (EKME #3723113), ITS CCG, January 2017.

B. CA-024-000-EQ-WB-009, "CCGS Private Robertson V.C" (Hull 6094) Approved Final Trim & Stability Booklet, Irving Shipbuilding Inc., July 23, 2012.

C. AF6094-89940-01_AF, General Arrangement, "CCGS Private Robertson V.C", Irving Shipbuilding Inc., November 25, 2012.

D. AF6094-E1203-4010-01, Bridge Arrangement and Layout, "CCGS Private Robertson V.C", Irving Shipbuilding Inc., June 28, 2011.

E. Sellars F., Martin J., Selection and Evaluation of Ship Roll Stabilization Systems, Marine Technology, April 1992. http://www.sname.org/HigherLogic/System/DownloadDocumentFile.ashx?DocumentFileKey=b543cbc1-6923-485e-ad06-32e45b8ecc57

F. J.M.J. Journée and W.W. Massie, Offshore Hydromechanics, Delft University of Technology, January 2001. www.shipmotions.nl/DUT/LectureNotes/OffshoreHydromechanics.pdf

G. Van der Klugt, P. G. M., Rudder Roll Stabilization – The Dutch Solution, Naval Engineers Journal, May 1990.

H. Jeffrey Bowles, Dwight Escalera, Modern Options for Vessel Stabilization, Presentation, IBEX, October 2016.

I. AF6094-83530-01, Rudder Hydrodynamic Characteristics, "CCGS Private Robertson V.C", Irving Shipbuilding Inc., August 16, 2011.

2

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ANNEX "B" BASIS OF PAYMENT

BASIS OF PAYMENT:	
For the work described in Annex "A" Statement of work, a fixed price of:	14,740.00 (EUR) $
Total contract value :	14,740.00 (EUR) $

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ANNEX "C" SECURITY REQUIREMENTS CHECK LIST

Gouvernement du Canada

Contract Number / Numéro du contrat: F7044-170282

Security Classification / Classification de sécurité: UNCLASSIFIED

SECURITY REQUIREMENTS CHECK LIST (SRCL)
LISTE DE VÉRIFICATION DES EXIGENCES RELATIVES À LA SÉCURITÉ (LVERS)

PART A - CONTRACT INFORMATION / PARTIE A - INFORMATION CONTRACTUELLE

1. Originating Government Department or Organization / Ministère ou organisme gouvernemental d'origine
2. Branch or Directorate / Direction générale ou Direction: ITS CCG
3. a) Subcontract Number / Numéro du contrat de sous-traitance — 3. b) Name and Address of Subcontractor / Nom et adresse du sous-traitant

4. Brief Description of Work / Brève description du travail:
ITS CCG would like to award a contract to Damen through DFO Lorette Bay. CCG Hero Class vessels were built in Canada and used Damen Patent design for the hull as the original design. Canadian vessels were delivered without modifications. After a few years of service, CCG considers installation of the stabilizers and would like to get a comparative analysis of the two available systems on the market. Damen was chosen for this work as the owner of the original design and for their knowledge and the experience with the various roll stabilizers.

5. a) Will the supplier require access to Controlled Goods? / Le fournisseur aura-t-il accès à des marchandises contrôlées? — No / Non ☑ — Yes / Oui ☐

5. b) Will the supplier require access to unclassified military technical data subject to the provisions of the Technical Data Control Regulations? / Le fournisseur aura-t-il accès à des données techniques militaires non classifiées qui sont assujetties aux dispositions du Règlement sur le contrôle des données techniques? — No / Non ☑ — Yes / Oui ☐

6. Indicate the type of access required / Indiquer le type d'accès requis

6. a) Will the supplier and its employees require access to PROTECTED and or CLASSIFIED information or assets? / Le fournisseur ainsi que les employés auront-ils accès à des renseignements ou à des biens PROTÉGÉS et/ou CLASSIFIÉS? — No / Non ☑ — Yes / Oui ☐
(Specify the level of access using the chart in Question 7. c) / (Préciser le niveau d'accès en utilisant le tableau qui se trouve à la question 7. c)

6. b) Will the supplier and its employees (e.g. cleaners, maintenance personnel) require access to restricted access areas? No access to PROTECTED and/or CLASSIFIED information or assets is permitted. / Le fournisseur et ses employés (p. ex. nettoyeurs, personnel d'entretien) auront-ils accès à des zones d'accès restreintes? L'accès à des renseignements ou à des biens PROTÉGÉS et/ou CLASSIFIÉS n'est pas autorisé. — No / Non ☑ — Yes / Oui ☐

6. c) Is this a commercial courier or delivery requirement with no overnight storage? / S'agit-il d'un contrat de messagerie ou de livraison commerciale sans entreposage de nuit? — No / Non ☑ — Yes / Oui ☐

7. a) Indicate the type of information that the supplier will be required to access / Indiquer le type d'information auquel le fournisseur devra avoir accès

Canada ☐ — NATO / OTAN ☐ — Foreign / Étranger ☐

7. b) Release restrictions / Restrictions relatives à la diffusion

Canada	NATO / OTAN	Foreign / Étranger
No release restrictions / Aucune restriction relative à la diffusion ☐	All NATO countries / Tous les pays de l'OTAN ☐	No release restrictions / Aucune restriction relative à la diffusion ☐
Not releasable / À ne pas diffuser ☐		
Restricted to / Limité à ☐	Restricted to / Limité à ☐	Restricted to / Limité à ☐
Specify country(ies) / Préciser le(s) pays	Specify country(ies) / Préciser le(s) pays	Specify country(ies) / Préciser le(s) pays

7. c) Level of information / Niveau d'information

Canada	NATO	Foreign / Étranger
PROTECTED A / PROTÉGÉ A ☐	NATO UNCLASSIFIED / NATO NON CLASSIFIÉ ☐	PROTECTED A / PROTÉGÉ A ☐
PROTECTED B / PROTÉGÉ B ☐	NATO RESTRICTED / NATO DIFFUSION RESTREINTE ☐	PROTECTED B / PROTÉGÉ B ☐
PROTECTED C / PROTÉGÉ C ☐	NATO CONFIDENTIAL / NATO CONFIDENTIEL ☐	PROTECTED C / PROTÉGÉ C ☐
CONFIDENTIAL / CONFIDENTIEL ☐	NATO SECRET / NATO SECRET ☐	CONFIDENTIAL / CONFIDENTIEL ☐
SECRET / SECRET ☐	COSMIC TOP SECRET / COSMIC TRÈS SECRET ☐	SECRET / SECRET ☐
TOP SECRET / TRÈS SECRET ☐		TOP SECRET / TRÈS SECRET ☐
TOP SECRET (SIGINT) / TRÈS SECRET (SIGINT) ☐		TOP SECRET (SIGINT) / TRÈS SECRET (SIGINT) ☐

TBS/SCT 350-103(2004/12)

Security Classification / Classification de sécurité: UNCLASSIFIED

Canada

Document Released Under the Access to Information Act / Document divulgué en vertu de la Loi sur l'accès à l'information.

Government of Canada / Gouvernement du Canada

Contract Number / Numéro du contrat
F7044_170302

Security Classification / Classification de sécurité
UNCLASSIFIED

PART A (continued) / PARTIE A (suite)

8. Will the supplier require access to PROTECTED and/or CLASSIFIED COMSEC information or assets? / Le fournisseur aura-t-il accès à des renseignements ou à des biens COMSEC désignés PROTÉGÉS et/ou CLASSIFIÉS? — ☑ No / Non ☐ Yes / Oui
If Yes, indicate the level of sensitivity / Dans l'affirmative, indiquer le niveau de sensibilité

9. Will the supplier require access to extremely sensitive INFOSEC information or assets? / Le fournisseur aura-t-il accès à des renseignements ou à des biens INFOSEC de nature extrêmement délicate? — ☑ No / Non ☐ Yes / Oui

Short Title(s) of material / Titre(s) abrégé(s) du matériel:
Document Number / Numéro du document:

PART B - PERSONNEL (SUPPLIER) / PARTIE B - PERSONNEL (FOURNISSEUR)

10. a) Personnel security screening level required / Niveau de contrôle de la sécurité du personnel requis

☐ RELIABILITY STATUS / COTE DE FIABILITÉ
☐ CONFIDENTIAL / CONFIDENTIEL
☐ SECRET / SECRET
☐ TOP SECRET / TRÈS SECRET
☐ TOP SECRET - SIGINT / TRÈS SECRET - SIGINT
☐ NATO CONFIDENTIAL / NATO CONFIDENTIEL
☐ NATO SECRET / NATO SECRET
☐ COSMIC TOP SECRET / COSMIC TRÈS SECRET
☐ SITE ACCESS / ACCÈS AUX EMPLACEMENTS

Special comments:
Commentaires spéciaux: NO requirement for the security clearance

NOTE: If multiple levels of screening are identified, a Security Classification Guide must be provided.
REMARQUE: Si plusieurs niveaux de contrôle de sécurité sont requis, un guide de classification de la sécurité doit être fourni.

10. b) May unscreened personnel be used for portions of the work? / Du personnel sans autorisation sécuritaire peut-il se voir confier des parties du travail? — ☑ No / Non ☐ Yes / Oui
If Yes, will unscreened personnel be escorted? / Dans l'affirmative, le personnel en question sera-t-il escorté? — ☐ No / Non ☐ Yes / Oui

PART C - SAFEGUARDS (SUPPLIER) / PARTIE C - MESURES DE PROTECTION (FOURNISSEUR)

INFORMATION / ASSETS / RENSEIGNEMENTS / BIENS

11. a) Will the supplier be required to receive and store PROTECTED and/or CLASSIFIED information or assets on its site or premises? / Le fournisseur sera-t-il tenu de recevoir et d'entreposer sur place des renseignements ou des biens PROTÉGÉS et/ou CLASSIFIÉS? — ☑ No / Non ☐ Yes / Oui

11. b) Will the supplier be required to safeguard COMSEC information or assets? / Le fournisseur sera-t-il tenu de protéger des renseignements ou des biens COMSEC? — ☑ No / Non ☐ Yes / Oui

PRODUCTION

11. c) Will the production (manufacture, and/or repair and/or modification) of PROTECTED and/or CLASSIFIED material or equipment occur at the supplier's site or premises? / Les installations du fournisseur serviront-elles à la production (fabrication et/ou réparation et/ou modification) de matériel PROTÉGÉ et/ou CLASSIFIÉ? — ☑ No / Non ☐ Yes / Oui

INFORMATION TECHNOLOGY (IT) MEDIA / SUPPORT RELATIF À LA TECHNOLOGIE DE L'INFORMATION (TI)

11. d) Will the supplier be required to use its IT systems to electronically process, produce or store PROTECTED and/or CLASSIFIED information or data? / Le fournisseur sera-t-il tenu d'utiliser ses propres systèmes informatiques pour traiter, produire ou stocker électroniquement des renseignements ou des données PROTÉGÉS et/ou CLASSIFIÉS? — ☑ No / Non ☐ Yes / Oui

11. e) Will there be an electronic link between the supplier's IT systems and the government department or agency? / Disposera-t-on d'un lien électronique entre le système informatique du fournisseur et celui du ministère ou de l'agence gouvernementale? — ☑ No / Non ☐ Yes / Oui

TBS/SCT 350-103(2004/12)

Security Classification / Classification de sécurité
UNCLASSIFIED

Canada

2

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Contract Number / Numéro du contrat
F7044-170702
Security Classification / Classification de sécurité
UNCLASSIFIED

PART C - (continued) / PARTIE C - (suite)

For users completing the form manually use the summary chart below to indicate the category(ies) and level(s) of safeguarding required at the supplier's site(s) or premises.
Les utilisateurs qui remplissent le formulaire manuellement doivent utiliser le tableau récapitulatif ci-dessous pour indiquer, pour chaque catégorie, les niveaux de sauvegarde requis aux installations du fournisseur.

For users completing the form online (via the Internet), the summary chart is automatically populated by your responses to previous questions.
Dans le cas des utilisateurs qui remplissent le formulaire en ligne (par Internet), les réponses aux questions précédentes sont automatiquement saisies dans le tableau récapitulatif.

SUMMARY CHART / TABLEAU RÉCAPITULATIF

Category / Catégorie	PROTECTED / PROTÉGÉ			CLASSIFIED / CLASSIFIÉ				COMSEC			
	A	B	C	CONFIDENTIAL / CONFIDENTIEL	SECRET	TOP SECRET / TRÈS SECRET	TOP SECRET (SIGINT) / TRÈS SECRET (SIGINT)	Restricted Access / Accès restreint	Controlled Goods / Marchandises contrôlées		
Production											
IT Media / Support TI											
IT Link / Lien informatique											

12. a) Is the description of the work contained within this SRCL PROTECTED and/or CLASSIFIED?
La description du travail visé par la présente LVERS est-elle de nature PROTÉGÉE et/ou CLASSIFIÉE?

☑ No / Non ☐ Yes / Oui

If Yes, classify this form by annotating the top and bottom in the area entitled "Security Classification".
Dans l'affirmative, classifier le présent formulaire en indiquant le niveau de sécurité dans la case intitulée « Classification de sécurité » au haut et au bas du formulaire.

12. b) Will the documentation attached to the SRCL be PROTECTED and/or CLASSIFIED?
La documentation associée à la présente LVERS sera-t-elle PROTÉGÉE et/ou CLASSIFIÉE?

☑ No / Non ☐ Yes / Oui

If Yes, classify this form by annotating the top and bottom in the area entitled "Security Classification" and indicate with attachments (e.g. SECRET with Attachments).
Dans l'affirmative, classifier le présent formulaire en indiquant le niveau de sécurité dans la case intitulée « Classification de sécurité » au haut et au bas du formulaire et indiquer qu'il y a des pièces jointes (p. ex. SECRET avec des pièces jointes).

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Fisheries and Oceans Canada
Security in Contracting Organization Security Authorities (OSA) Guideline

APPENDIX A – DFO SECURITY CLAUSES

Security Clauses #1 – No Security Requirement, escort required at DFO site(s)

- The supplier and all individuals assigned to work on the contract MUST NOT have access to PROTECTED or CLASSIFIED information/assets.
- The supplier and all individuals assigned to work on the contract MUST NOT have unescorted access to restricted access areas at Fisheries and Oceans Canada facilities or Canadian Coast Guard vessels.
- The supplier and all individuals assigned to work on the contract MUST NOT remove any PROTECTED or CLASSIFIED information/assets from DFO site(s).
- Subcontracts which contain security requirements are not to be awarded without the prior written permission of the Contracting Authority.

2

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Wyse, David E

From: [redacted]
Sent: Thursday, August 10, 2017 5:36 AM
To: DeVink, Jean-Pierre
Cc: [redacted]
Subject: FW: DFO contract F5211-170139 - Hero Class Seakeeping assessment, SC253739, Can

Dear Mr. deVink,

Please find below our bank details for payment in EURO's. Tax code information indeed is not necessary for payments from Canada to The Netherlands.

[redacted]

In case you have any further questions, please let us know.

Kind regards,

[redacted]

DAMEN

DAMEN SHIPYARDS GORINCHEM
Industrieterrein Avelingen West 20
P.O. Box 1
4200 AA, Gorinchem
The Netherlands
Phone: [redacted]
E-mail: [redacted]
Internet: www.damen.com

FOLLOW DAMEN AMERICAS

From: DeVink, Jean-Pierre [mailto:Jean-Pierre.DeVink@dfo-mpo.gc.ca]
Sent: 08 August 2017 18:31
To: [redacted]
Cc: [redacted]
Subject: RE: DFO contract F5211-170139 - Hero Class Seakeeping assessment

Hi [redacted]

I have attached the new vendor form to obtain billing information to set up payment.
I did my best to fill out all the sections I had information to input, we are missing the "tax code information and direct deposit information".
As you are an international company, I don't believe we require any tax code information, however if you do have this information, please fill it in.

Thank you,

Jean-Pierre deVink

Contracting Officer | Agent de marché
(506) 452-3619

From: [redacted]
Sent: 8 août 2017 11:49
To: DeVink, Jean-Pierre
Cc: Kozarski, Vladan
Subject: RE: DFO contract F5211-170139 - Hero Class Seakeeping assessment

Hi Jean-Pierre,

s.19(1)

s.20(1)(b)

Document Released Under the Access to Information Act / Document divulgué en vertu de la Loi sur l'accès à l'information.

Thanks, I expect from now on it will indeed be only technical matters popping up.

Best regards,

[redacted] s.19(1)

From: DeVink, Jean-Pierre [mailto:Jean-Pierre.DeVink@dfo-mpo.gc.ca]
Sent: 08 August 2017 16:39
To: [redacted]
Cc: Kozarski, Vladan <Vladan.Kozarski@dfo-mpo.gc.ca>
Subject: RE: DFO contract F5211-170139 - Hero Class Seakeeping assessment

Hi [redacted]

Here is a copy of the signed contract for filing purposes.

Yes – you may now begin the work, for all technical questions regarding the work, please contact Vladan Kozarski.

Thank you,

Jean-Pierre deVink

Contracting Officer | Agent de marché
(506) 452-3619

From: [redacted]
Sent: 8 août 2017 11:24
To: DeVink, Jean-Pierre
Cc: Kozarski, Vladan; [redacted]
Subject: RE: DFO contract F5211-170139 - Hero Class Seakeeping assessment

Hello Jean-Pierre,

Please find attached a copy of the final contract, signed by [redacted]

I expect you will now process the paperwork and give a clear signal when it is okay for me to start?

If you have any questions or remarks, please let me know.

Best regards,

[redacted]

From: DeVink, Jean-Pierre [mailto:Jean-Pierre.DeVink@dfo-mpo.gc.ca]
Sent: 03 August 2017 14:01
To: [redacted]
Subject: RE: DFO contract F5211-170139 - Hero Class Seakeeping assessment

Hello [redacted]

I have attached the latest version of the contract with adjusted dates for your review and signature.

Feel free to contact me should you have any questions or concerns.

Thank you,

Jean-Pierre deVink

Contracting Officer | Agent de marché
(506) 452-3619

From: DeVink, Jean-Pierre
Sent: 11 juillet 2017 14:24
To: [redacted]
Subject: RE: DFO contract F5211-170139 - Hero Class Seakeeping assessment

Hi [redacted]

Document Released Under the Access to Information Act / Document divulgué en vertu de la Loi sur l'accès à l'information.

Below you will find the described am trying to finalize the contract and wanted to confirm with you that the following paragraph was the only modification we required?

A.3 Scope

CCG requires that the Contractor produce a new seakeeping assessment of several roll stabilization configurations on the Hero Class. The Contractor must produce a seakeeping assessment of the vessels as delivered with no stabilization and the following configurations:

- *Active fin (roll) stabilization,*
- *Rudder roll stabilization*
- *Bilge keels,*
- *Rudder roll stabilization plus bilge keels,*
- *'Zero Speed' stabilizers. P or XT Series (Quantum: www.quantumhydraulic.com)*

Then the Contractor must analyze and compare the un-stabilized vessel against the five/six configurations.

Also, I have attached a copy of the contract document with the above revision.

Please ensure that this copy is executed on behalf of the Contractor by their duly authorised officers / agents or other person(s) legally authorised to bind the party and returned to the undersigned by email at your earliest convenience.

Please ensure the signatory signs and a scanned copy is provided at your earliest convenience.

Upon receipt and after execution on behalf of the minister, a copy will be forwarded to you for your retention.

Thank you,

Jean-Pierre deVink **s.19(1)**

Contracting Officer | Agent de marché **s.20(1)(c)**
(506) 452-3619

From: [redacted]
Sent: 7 juillet 2017 11:25
To: Kozarski, Vladan; DeVink, Jean-Pierre
Subject: RE: DFO contract F5211-170139 - Hero Class Seakeeping assessment

Hi Vladan,

Sorry about the delays on our side. I would like to inform you about the following:

The sales director agreed with the contract and had no further remarks. The remark I made earlier about the "P or XT series" would then be the only change in the contract.

However, I ran into an issue. I started the base analysis (no stabilizers) and found out that the wave spreading function is not working in the tool. I've been in contact a lot with the tool manufacturers [redacted] this week and they created a workaround for me. However, the workaround is still not working properly. The spreading is not included in head waves and there are issues with zero encounter frequencies, leading to very large responses.

At this moment we have 3 options, as I see it:

1. Hold off on signing the contract until I have figured this out completely [redacted]
2. Do not take wave spreading into account anymore. This has only a negligible effect on the assessment of the effectiveness of the different roll stabilizers, as the spreading would affect all solutions more or less equally. The RAOs are completely independent of spreading anyway. There is also no effect on the budget, as spreading was supposed to be fully automatic, so excluding it does not lead to time savings.
3. Put in the contract some hybrid form, where wave spreading excluded is acceptable, but spreading included is preferable. In that case I will both start the calculations and continue [redacted] to solve this in time if we can.

I apologize for this inconvenience and look forward to your views on this.

Enjoy the weekend!

Best regards,
[redacted]

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From: Kozarski, Vladan [mailto:Vladan.Kozarski@dfo-mpo.gc.ca]
Sent: 30 June 2017 18:58
To: [redacted] DeVink, Jean-Pierre <Jean-Pierre.DeVink@dfo-mpo.gc.ca>
Subject: Re: DFO contract F5211-170139 - Hero Class Seakeeping assessment

Hi [redacted]

This weekend we celebrate 150 years in Canada. It is 'chaos' in Ottawa. Will be back in office on Tuesday.

Regards.

s.19(1)

Vladan.

Sent from my BlackBerry 10 smartphone on the Rogers network.

From: [redacted]
Sent: Friday, June 30, 2017 10:03 AM
To: Kozarski, Vladan; DeVink, Jean-Pierre
Subject: RE: DFO contract F5211-170139 - Hero Class Seakeeping assessment

Hi Vladan and Jean-Pierre,

Just a short update:

The contract is still with our sales director for reviewing, as soon as he's given his approval or comments I will pass it on to you.

Enjoy the weekend,

Best regards,

[redacted]

From: Kozarski, Vladan [mailto:Vladan.Kozarski@dfo-mpo.gc.ca]
Sent: 23 June 2017 17:22
To: [redacted] DeVink, Jean-Pierre <Jean-Pierre.DeVink@dfo-mpo.gc.ca>
Subject: RE: DFO contract F5211-170139 - Hero Class Seakeeping assessment

[redacted] and Jean-Pierre,

I do agree with the change. Damen will analyze only one 'Zero Speed' stabilizer, so it should be P or XT series. Although we decided to go with the P series only, I would keep **P or XT Series** in the recommended text:

'Zero Speed' stabilizers. P **or** XT Series (Quantum: www.quantumhydraulic.com).

Hope this clears out the contract wording.

Regards.

Vladan.

From: [redacted]
Sent: Friday, June 23, 2017 10:29 AM
To: DeVink, Jean-Pierre
Cc: Kozarski, Vladan
Subject: RE: DFO contract F5211-170139 - Hero Class Seakeeping assessment

Hi Jean-Pierre,

Thanks for the contract. I've looked it over and noticed just 1 last detail: on page 7 it mentions
'Zero Speed' stabilizers. P and XT Series (Quantum: www.quantumhydraulic.com)

But this should be
'Zero Speed' stabilizers. P **or** XT Series (Quantum: www.quantumhydraulic.com)

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Vladan has already indicated that this will be the P-series.

If you and Vladan agree, could you send a revised contract? I will forward this version to the right people so they can have a look already.

Best regards,

[redacted] s.19(1)

From: DeVink, Jean-Pierre [mailto:Jean-Pierre.DeVink@dfo-mpo.gc.ca]
Sent: 23 June 2017 15:04
To: [redacted]
Subject: DFO contract F5211-170139 - Hero Class Seakeeping assessment

Hello [redacted]

Please find enclosed the referenced contract document which is forwarded for your review and execution.

Please ensure that this copy is executed on behalf of the Contractor by their duly authorised officers / agents or other person(s) legally authorised to bind the party and returned to the undersigned by email at your earliest convenience.

Please ensure the signatory signs and a scanned copy is provided at your earliest convenience.

Upon receipt and after execution on behalf of the minister, a copy will be forwarded to you for your retention.

Regards,

Jean-Pierre deVink

Material and Procurement Services | Services du matériel et des acquisitions
Financial and Materiel Management Operations | Opérations financières et Gestion du Matériel
Fisheries and Oceans Canada | Pêches et Océans Canada
301 Bishop Drive | 301 promenade Bishop
Fredericton, NB E3C 2M6 | Fredericton N-B E3C 2M6
Telephone | Téléphone (506)-452-3619
Facsimile | Télécopieur (506)-452-3676
Email | Courriel: jean-pierre.devink@dfo-mpo.gc.ca

- Si vous voulez reçevoir ceci en français, n'hésitez pas de me laisser savoir.
- I encourage you to reply to this e-mail in the official language of your choice. je vous encourage à répondre à ce courriel dans la langue officielle de votre choix

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Fisheries and Oceans Canada | Pêches et Océans Canada

Purchasing Office - Bureau des achats:

Procurement Hub - Fredericton
Fisheries and Oceans Canada
301 Bishop Drive
Fredericton, New Brunswick E3C 2M6

CONTRACT AMENDMENT

The referenced document is hereby amended: unless otherwise indicated, all other terms and conditions of the contract remain the same.

s.19(1)

Ce document est par la présente modifié : sauf indications contraire, les modalités du contrat demeurent les mêmes.

[redacted]

For the Contractor-Pour le fournisseur

Return signed copy forethwith.

Damen Shipyards Gorinchem
P O Box 1
4200 AA Gorinchem
The Netherlands

[redacted]

Title-Sujet Hero Class (MSPV) Seakeeping Assessment		**Date** October 27th, 2017
Client Reference No. - No. De Référence du Client F6074-170005		
Contract No. - N° du contract F5211-170139		**Amend No. - N° Modif.** 01
Financial Codes - Codes financiers 11310-810-120-4103-61751		
F.O.B. - F.A.B. see herein-ci-inclus	**GST - TPS** see herein-ci-inclus	**Duty - Droits** see herein-ci-inclus
Destination of Goods and Services: Destinations des biens et services: Aquatic Ressources NAFC BLDG. White Hills, PO Box 5667 St. John's NL, A1C 5X1		
Invoices - Original and two copies to be sent to: **Factures - Envoyer l'original et deux copies:** DFO.invoicing-facturation.MPO@canada.ca		
Address inquiries to: - Adresser toute demande de renseignements : Jean-Pierre deVink Contracting Officer Fisheries and Oceans Canada		
Telephone No.: 506-452-3619		**Fax:** 506-452-3676
Increase $ 660.00		**Decrease** $ 0
Total Estimated Cost $ 15,400.00		**Currency - Devise** EUR
For the Minister - Pour le Ministre Date Oct 28 2017		

Document Released Under the Access to Information Act / Document divulgué en vertu de la Loi sur l'accès à l'information.

This amendment is being issued to increase the amount of time and funding utilized to carry out the work.

The amendment is to be incorporated into the contract as follows:

DELETE:

6.4.1 Period of the Contract

The Work is to be performed from the point of contract award to October 27th 2017.

INSERT:

6.4.1 Period of the Contract

The Work is to be performed from the point of contract award to January 15th 2018.

DELETE:

6.7.1 Basis of Payment

6.7.1.1 The Contractor will be reimbursed for the costs reasonably and properly incurred in the performance of the Work, as determined in accordance with the Basis of Payment in Annex "B", to a limitation of expenditure of $14,740.00 (EUR). Customs duties are included and Applicable Taxes are extra.

INSERT:

6.7.1 Basis of Payment

6.7.1.1 The Contractor will be reimbursed for the costs reasonably and properly incurred in the performance of the Work, as determined in accordance with the Basis of Payment in Annex "B", to a limitation of expenditure of $15,400.00 (EUR). Customs duties are included and Applicable Taxes are extra.

This Amendment shall form part of the above-mentioned Contract. All other terms and conditions of the said mentioned Contract shall remain unchanged and in force.

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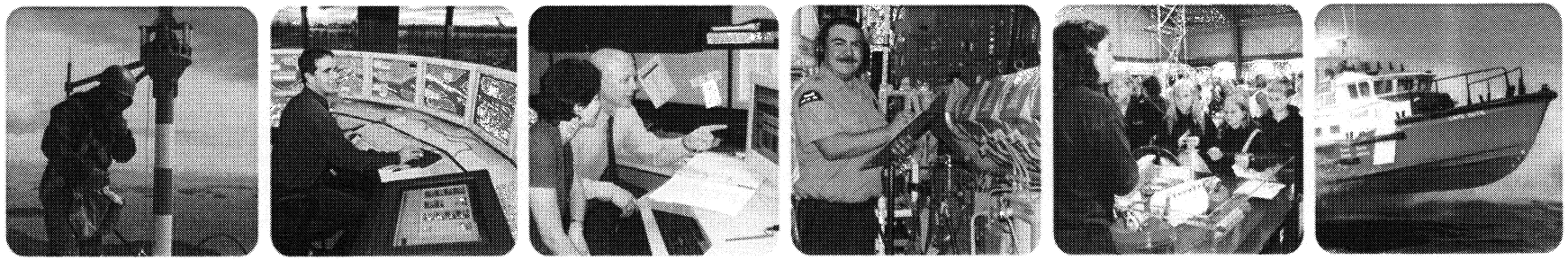
Fisheries and Oceans Canada | Pêches et Océans Canada

Canadian Coast Guard | Garde côtière canadienne

Safety First, Service Always



MSPV Seakeeping Assessment and Roll Stabilizers Comparative Analysis

Canada

Document Released Under the Access to Information Act / Document divulgué en vertu de la Loi sur l'accès à l'information.

Overview

- Introduction
- Seakeeping – Roll Stabilization
- Stabilizers
- Pro's and Con's and Comparison
- Existing Seakeeping analysis and Effectiveness of Roll Stabilizing Systems

Document Released Under the Access to Information Act / Document divulgué en vertu de la Loi sur l'accès à l'information.

Introduction

- CCG took acceptance of nine new Hero Class Vessels built by Irving Shipyards between 2012 and 2014 under Lloyd's Special Service Craft Rules 2009.

- The Hero Class is a variant of Damen 4207 particularized for service with CCG.

- Other Administration such as USCG, Mexico Navy, and a number of Caribbean countries have in service patrol boats designed and built as a variant of Damen 4207.

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Introduction

- The issue of sea kindliness of the Hero Class vessels has been raised through discussions with Regional personnel.
- According to crew experience, Hero Class vessel experience excessive roll motions in Atlantic, Pacific and Great Lakes regions.
- Hero Class vessels are not fitted with any type of roll stabilization systems.
- The majority, but not all, of the international variants based on Damen 4207 parent hull are equipped with fin roll stabilizers.

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Introduction

- CCG is looking to improve seakeeping performance of the Hero Class vessels.

- A new seakeeping assessment and comparative analysis shall be conducted to consider several different roll stabilization configurations.

- There is a number of constrains that should be regarded in the application of roll stabilization systems:
  - Effectiveness of the stabilization system (roll reduction),
  - Weight,
  - Available space for the installation ,
  - Cost ,
  - Power requirements.

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Roll Reduction of Ship Motions

- Methods of motion reduction are often known by the generic name of motion "stabilization" - incorrect word to use!

- The oscillatory motions of all practical conventional ship designs are already "stable" i.e. they return to an equilibrium datum level after some small disturbance.

- Motion stabilization in terms of seakeeping indicates the reduction in motion which can be achieved by:
  - Increase the dumping,
  - Increase the inertia,
  - Reduce the exciting moment.

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Vessel Stability v.s. Roll Stabilization

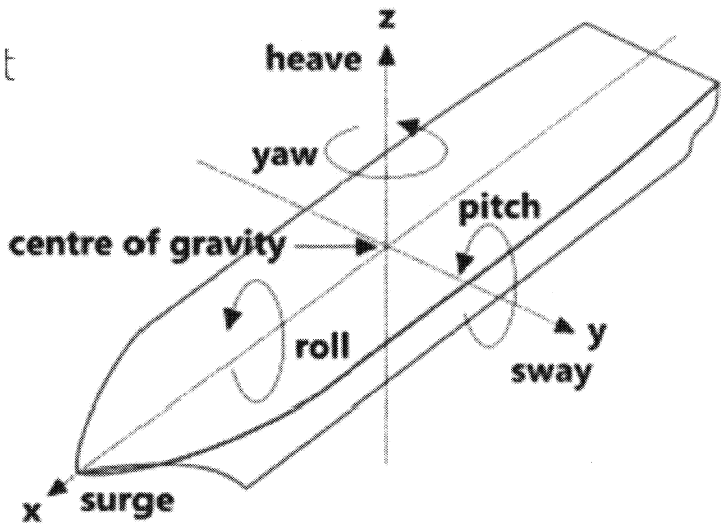
Roll Motion

A ship motion can be described with six degrees of freedom i.e. three translations and three rotations:

X axis – Surge and Roll

Y axis – Sway and Pitch

Z axis – Heave and Yaw



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Seakeeping – Roll Stabilisation

Effects of Roll Motion on Ship Performance

- Operability - transversal acceleration due to roll induce interruptions in the task performed by the crew.
- Seasickness – vertical accelerations induced by roll at locations away from the ship's centerline and in bow quartering waves.
- Injury due to roll accelerations.
- Large roll angles limit the capability to handle equipment on board.

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Stabilizers

- **Roll stabilizing systems to be analyzed in the study:**
  - Active fin (roll) stabilization,
  - Rudder roll stabilization,
  - Bilge keels,
  - Rudder-roll stabilization plus bilge keels,
  - Gyro,
  - Trim tabs.

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Stabilizer Systems

Active fin (roll) stabilization

- a pair of hydrofoils mounted on rotatable stocks at the turn of the bilge located about amidships.
- As the ship rolls, this motion is sensed via gyroscopes and fed back to the control system, which commands the actuator to modify the angle of incidence of the fins.
- Once there is an angle between the flow and the fin, hydrodynamic lift is generated, and a stabilizing moment is obtained as a result of the generated lift and the location of the fins on the hull.
- As in any lifting device, the amount of lift, and hence the generated moment, depend on the vessel speed.
- Two types considered: retractable an non-retractable.
- Not efficient at zero and low speed.

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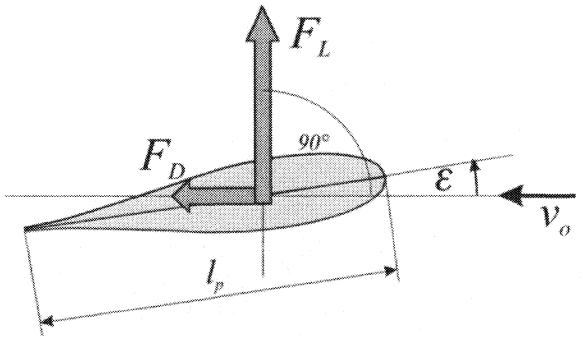
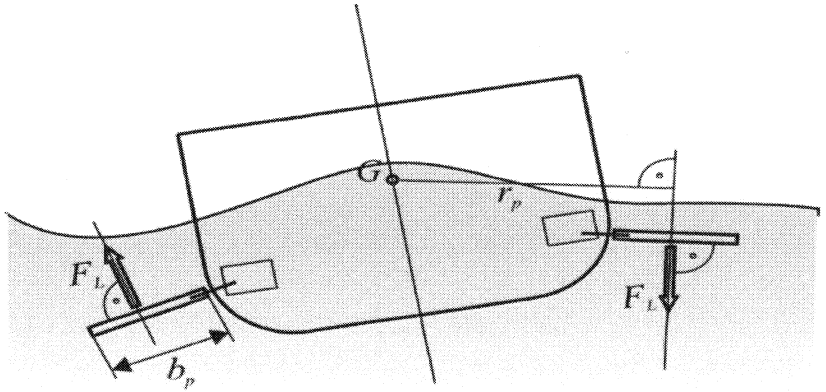
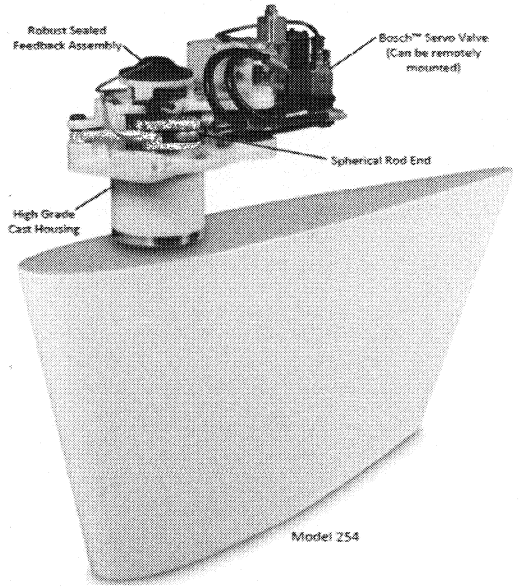
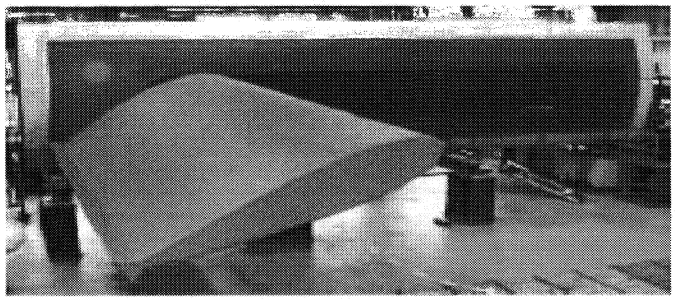
Stabilizer Systems

- **High performance: normally estimated in the range of 60-90% of roll reduction (RMS)**









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Stabilizers

Rudder Roll Stabilization (RRS)

- Rudder roll stabilization is a technique based on the fact that the rudder is located aft and also below the center of gravity of the vessel, and thus the rudder imparts not only yaw but also roll moment

- Most of the drawbacks of conventional active fin stabilizers and anti-roll tanks are overcome by RRS. Provided the speed of the ship and the rudder rate are sufficiently high, this technique can be applied to different ship types:
  - small and large naval vessels,
  - patrol (coastguard) vessels,
  - ferries and some,
  - Ro-Ro vessels .

- Not efficient at zero and low speed, need responsive steering gear, and to be closer to CG.

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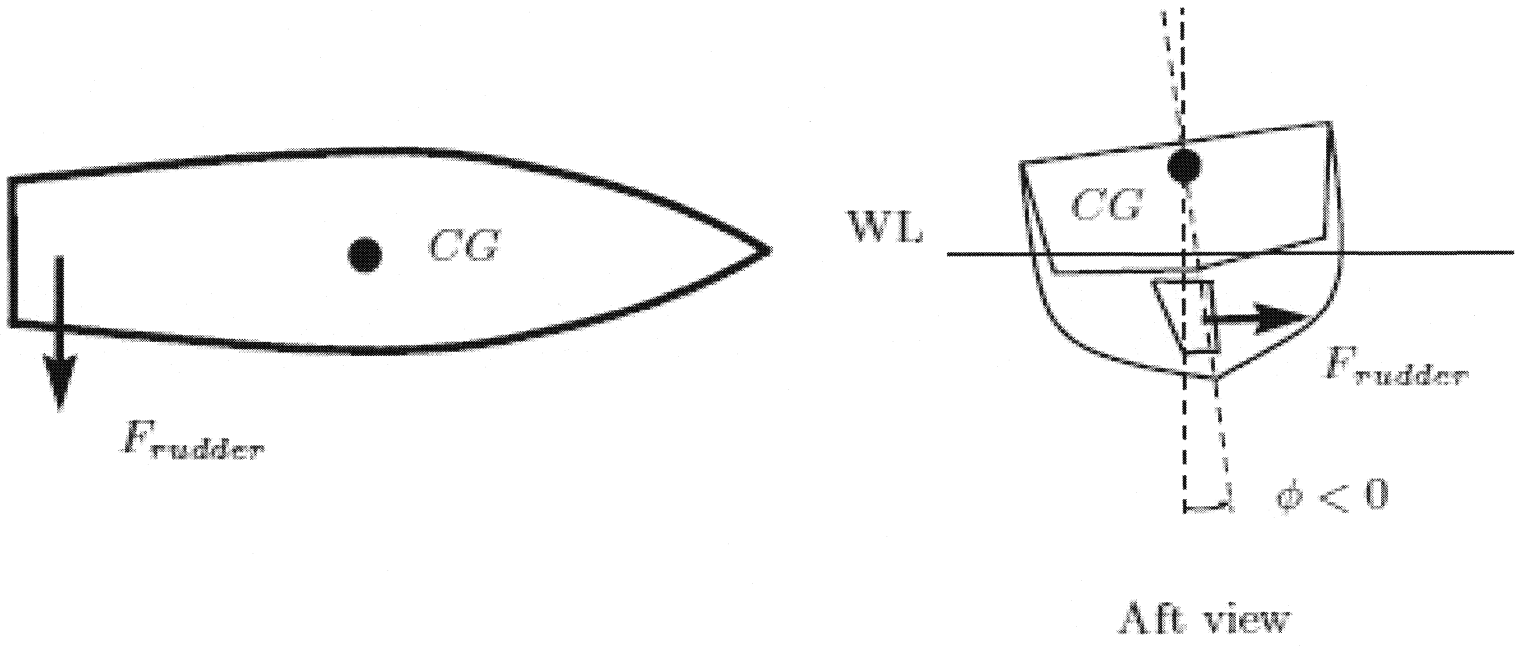
Stabilizers

Medium to high performance – range of 50-75% of roll reduction (RMS)



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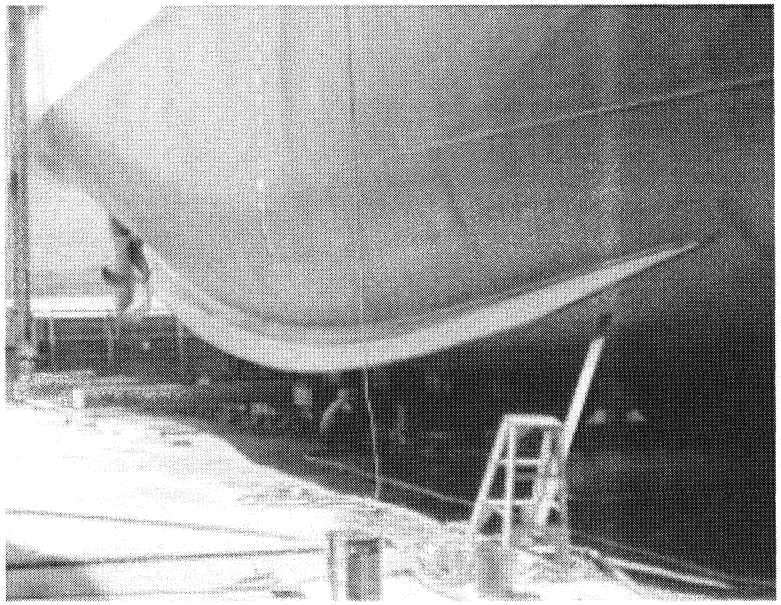
Stabilizer Systems

Bilge keels

- The simplest form of roll stabilization device - long narrow keels mounted at the turn of the bilge.
- They work by generating drag forces that acts perpendicular to the keel which oppose the rolling motion of the ship.
- The performance is in the range of 10-20% of roll angle reduction(RMS).
- Effective at zero and low speeds.
- Create extra resistance as a hull appendage.



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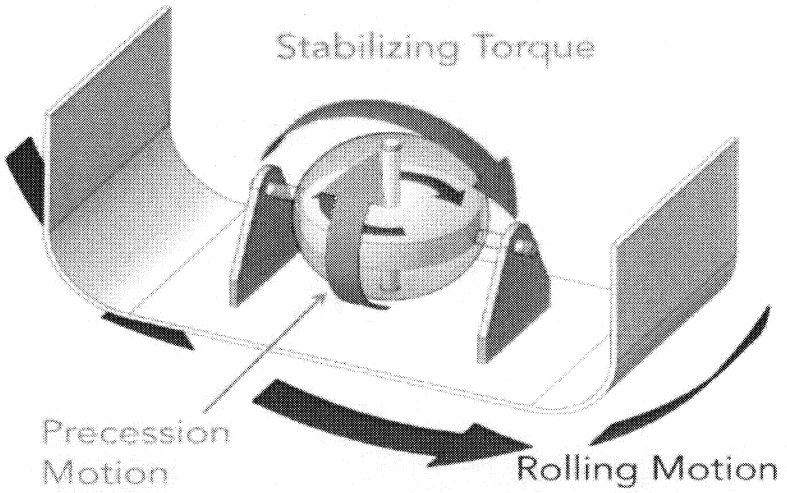
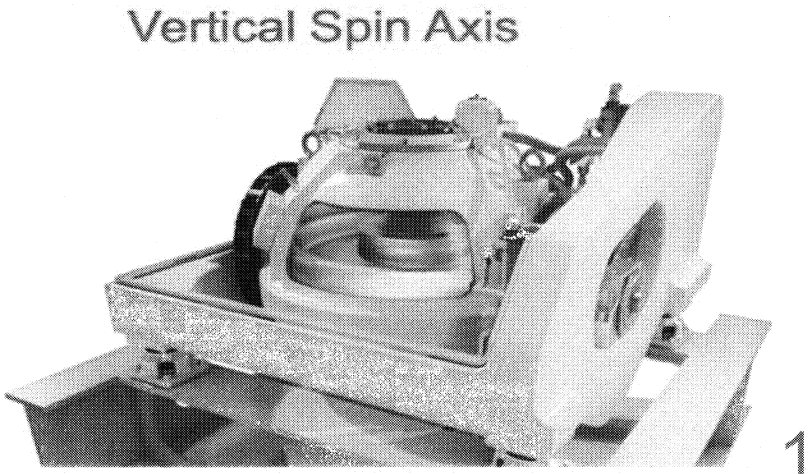
Stabilizers

Gyro

- A large spinning mass.
- Produces a righting moment by resisting movement of a rotating mass.
- Size of mass and rotational speed affects amount of righting moment.
- Effect decreases with increasing forward speed.
- Works while cruising (moderate speed) or at anchor.





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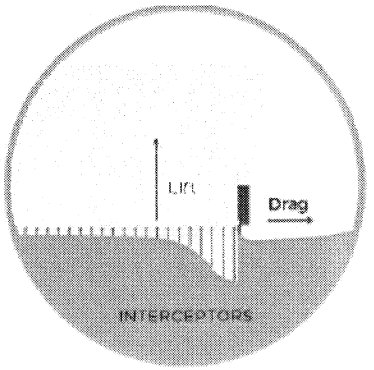
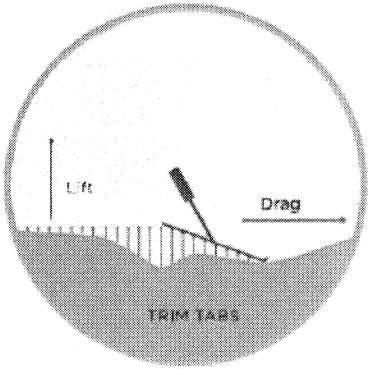
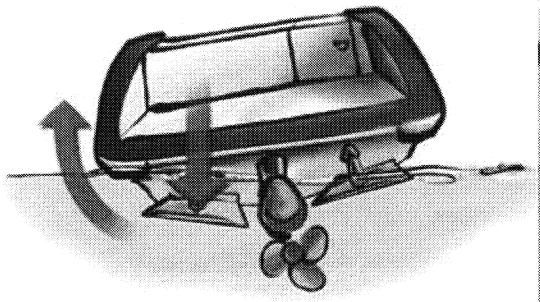
Stabilizers

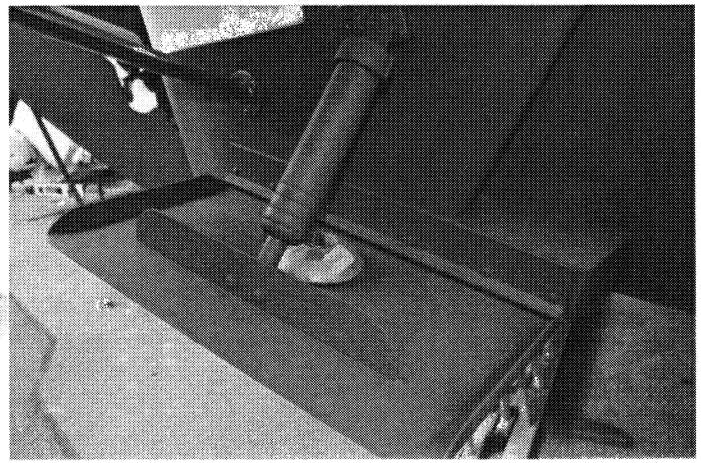
Trim Tabs

- Small surfaces connected to the trailing edge of a larger control surface on a boat.
- Counteracts hydro-dynamic forces and stabilize the boat.
- Effective at medium and higher speeds.
- Small pitch reduction at medium speeds, also can fix trim.
- Resistance reduction?









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Pro's and Con's and Comparison

Stabilizer Systems	Weight	Space	Maintenance	Resistance	Underway Stabilization	Low Speed Stabilization	Power Req's	Cost
Active Fin (roll) Stabilization	medium, non-retractable are lighter, require less internal space.	Retractable fins may require large space	High. In addition easily damaged and with high risk of grounding when operating in shallow water	Increased resistance in calm water if they are non-retractable. A rough estimate of speed loss due to fin activity is 10%	At speeds higher than 10-15 knots it is the most effective stabilizer. 60 – 90%	Ineffective at low speed.	High – needs control system with sensors and powerful hydraulic actuator	High - Retractabl fins are more expensive
Rudder Roll Stabilization (RRS)	No significant increase in the lightship?	No large space required.	Medium - High. Steering gear??	No resistance?	Effective at medium to higher speeds. 50 – 75 %	ineffective at low speeds	Existing. May need steering gear upgrade.	Relatively inexpensiv ??
Bilge keels	No significant increase in lightship	No occupied space.	Low maintenance – no more than normally done to hull	Increase in hull resistance in calm water condition	Yes. 10 – 20%	Relatively effective source of damping at low speed	No. Simplest form of all stabilizers	Low price and easy installatior
Gyro	High	High.	Low??	No?	Yes.	Yes.	High?	Medium t high.
Trim tabs	Medium?	No. Ship size restrictions?	Low??	Improve?	Yes. Not effective as active fins or RRS.	No stabilization at zero speed	Medium to high.	Medium?

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Existing Seakeeping Analysis

Existing Seakeeping Analysis:

- The following parameters were assessed: significant amplitudes of the vertical and lateral accelerations at the Bridge and RHIB location, significant amplitudes of roll and pitch motions as well as probabilities of green water shipping (deck wetness) at Deck @0.9L and probabilities of slamming at Forefoot.

- Two loading conditions: Departure and Arrival.

- Sea states 5 and 6 on north Atlantic and Pacific and Class I and II on Great Lakes. Wave spreading is assumed ± 35 deg. from main wave direction.

- Range of speeds was taken from 0 to 25knots with the increment of 2.5knots.

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Seakeeping Criteria:

General Operability Limiting Criteria for Ships (NORDFORSK, 1987)			
Description	Merchant Ships	Navy Vessels	Fast Small Craft
RMS of vertical acceleration at FP	0.275 g ($L \leq$ 100 m) 0.050 g ($L \geq$ 330 m)	0.275 g	0.65 g
RMS of vertical acceleration at Bridge	0.15 g	0.20 g	0.275 g
RMS of lateral acceleration at Bridge	0.12 g	0.10 g	0.10 g
RMS of Roll	6.0 deg	4.0 deg	4.0 deg
Probability of Slamming	0.03 ($L \leq$ 100 m) 0.01 ($L \geq$ 300 m)	0.03	0.03
Probability of Deck Wetness	0.05	0.05	0.05

Criteria for Accelerations and Roll (NORDFORSK, 1987)			
Description	RMS Vertical Acceleration	RMS Lateral Acceleration	RMS Roll Motion
Light Manual Work	0.20 g	0.10 g	6.0°
Heavy Manual Work	0.15 g	0.07 g	4.0°
Intellectual Work	0.10 g	0.05 g	3.0°
Transit Passengers	0.05 g	0.04 g	2.5°
Cruise Liner	0.02 g	0.03 g	2.0°

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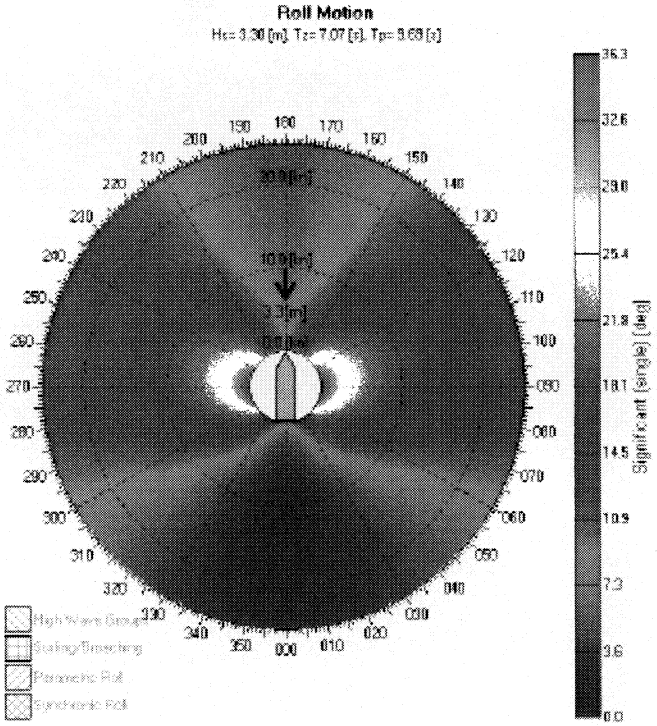
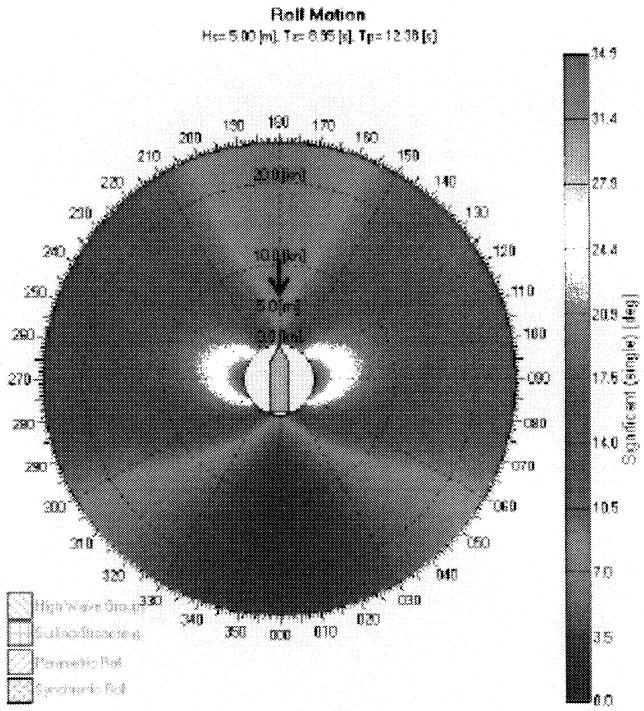
Existing Seakeeping Analysis





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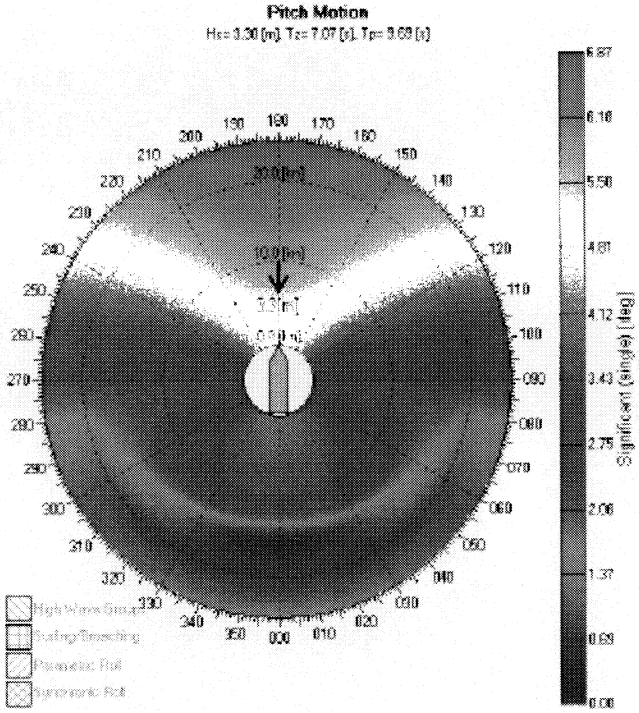
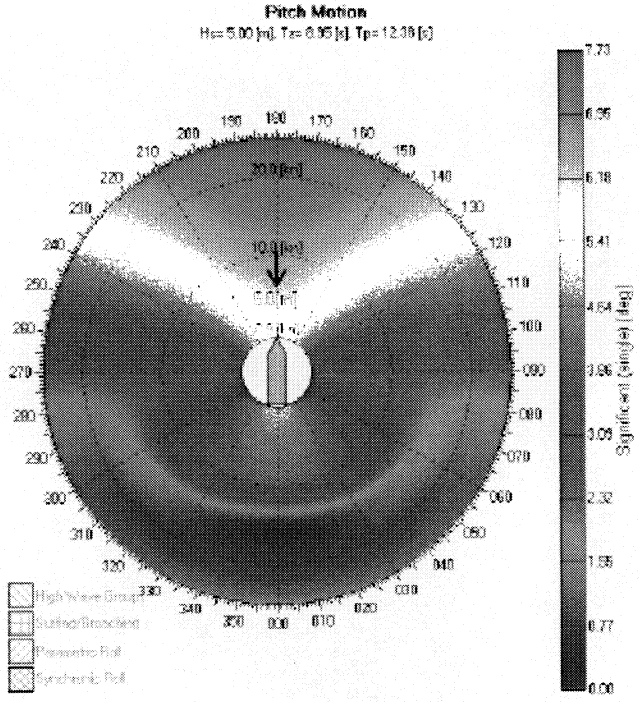
Existing Seakeeping Analysis





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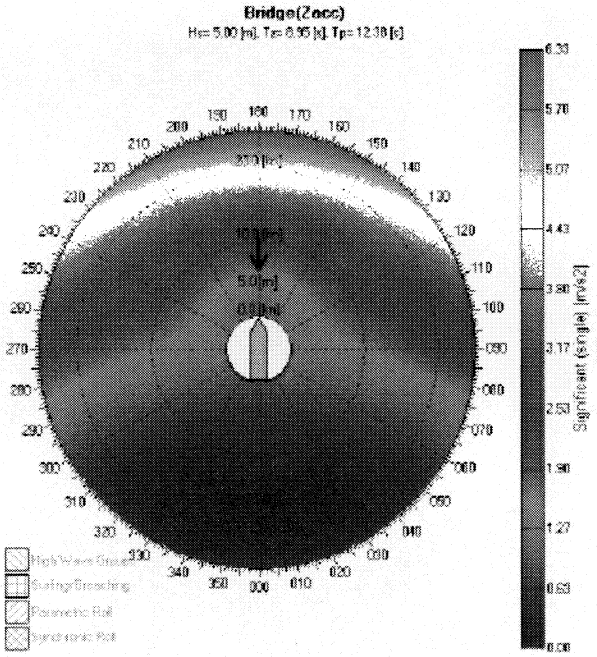
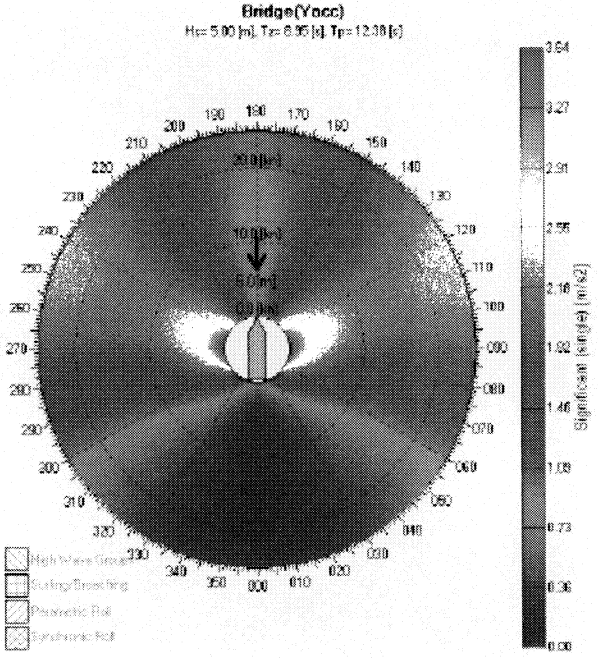
Existing Seakeeping Analysis





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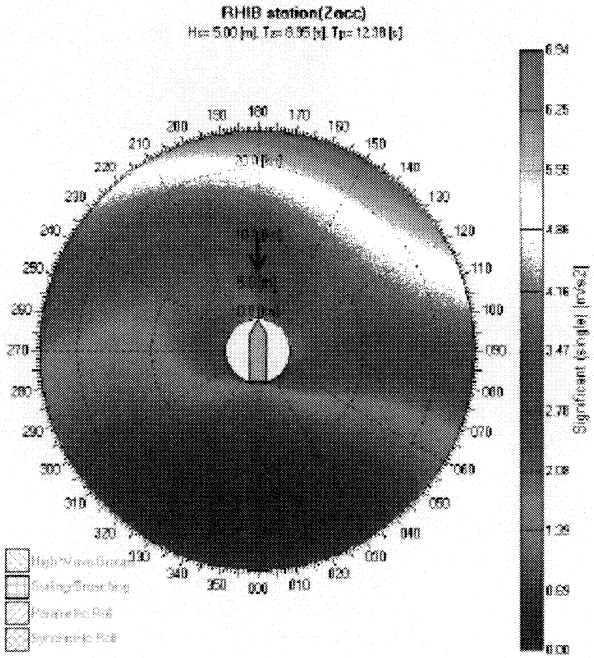
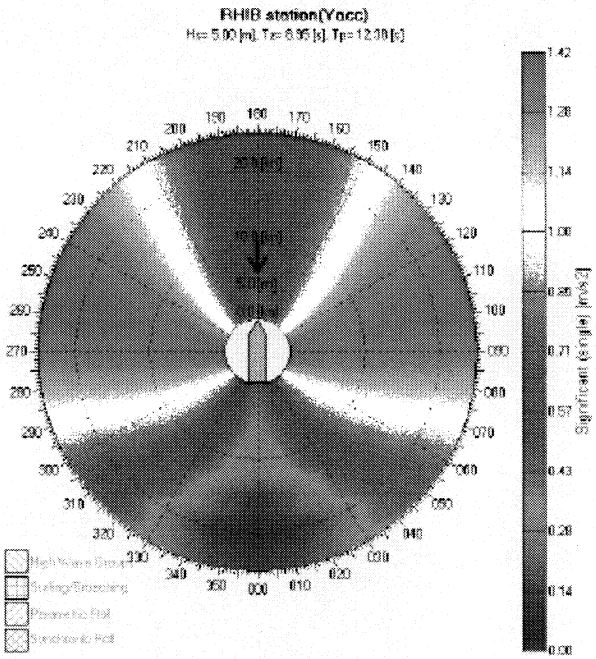
Existing Seakeeping Analysis





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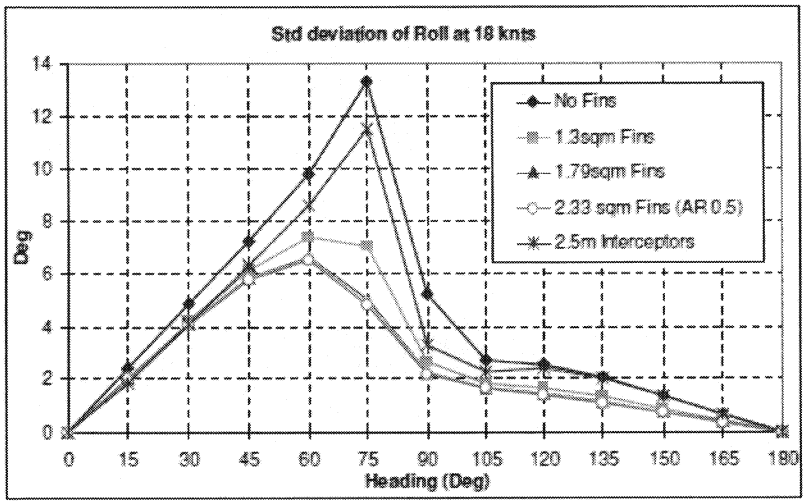
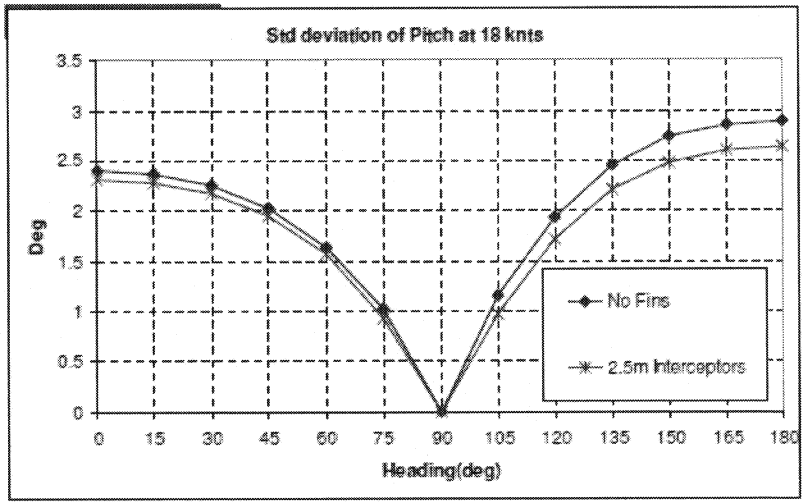
Effectivness of Roll Stabilizing Systems

Active Fins and Trim Tabs Comparison:





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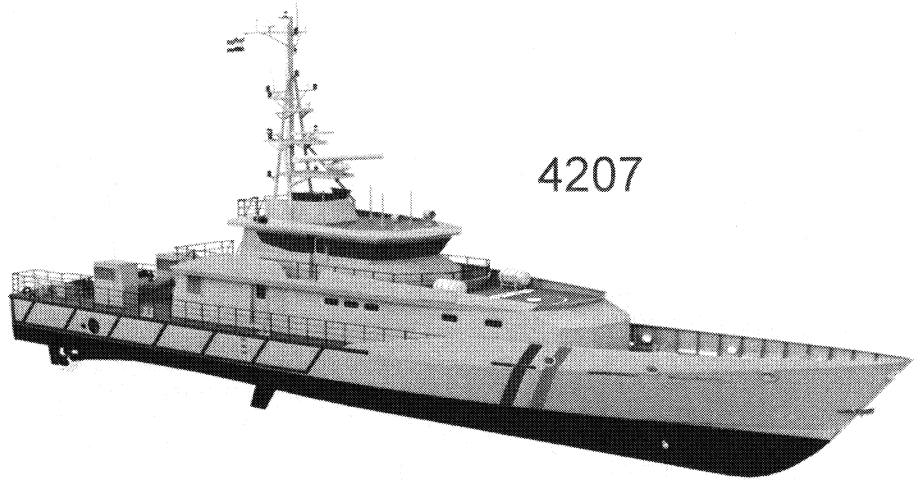
Effectivness of Roll Stabilizing Systems

Hull Design:

4207



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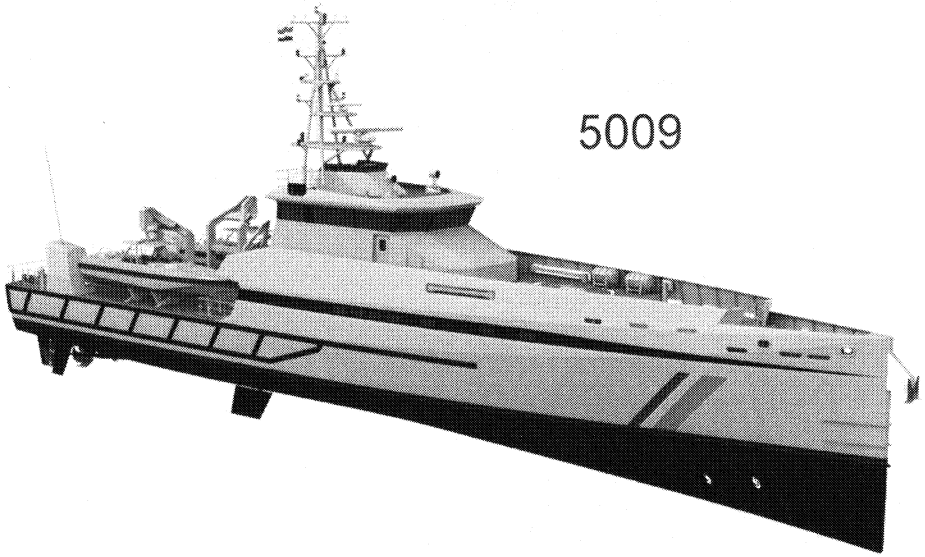

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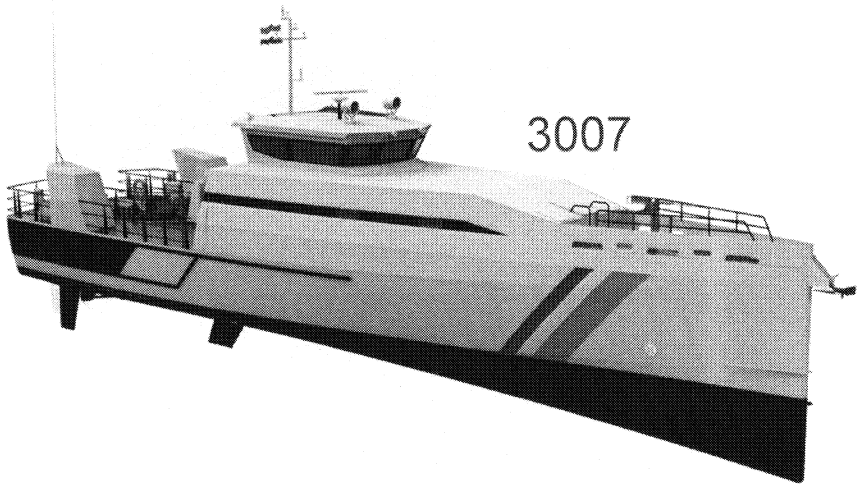

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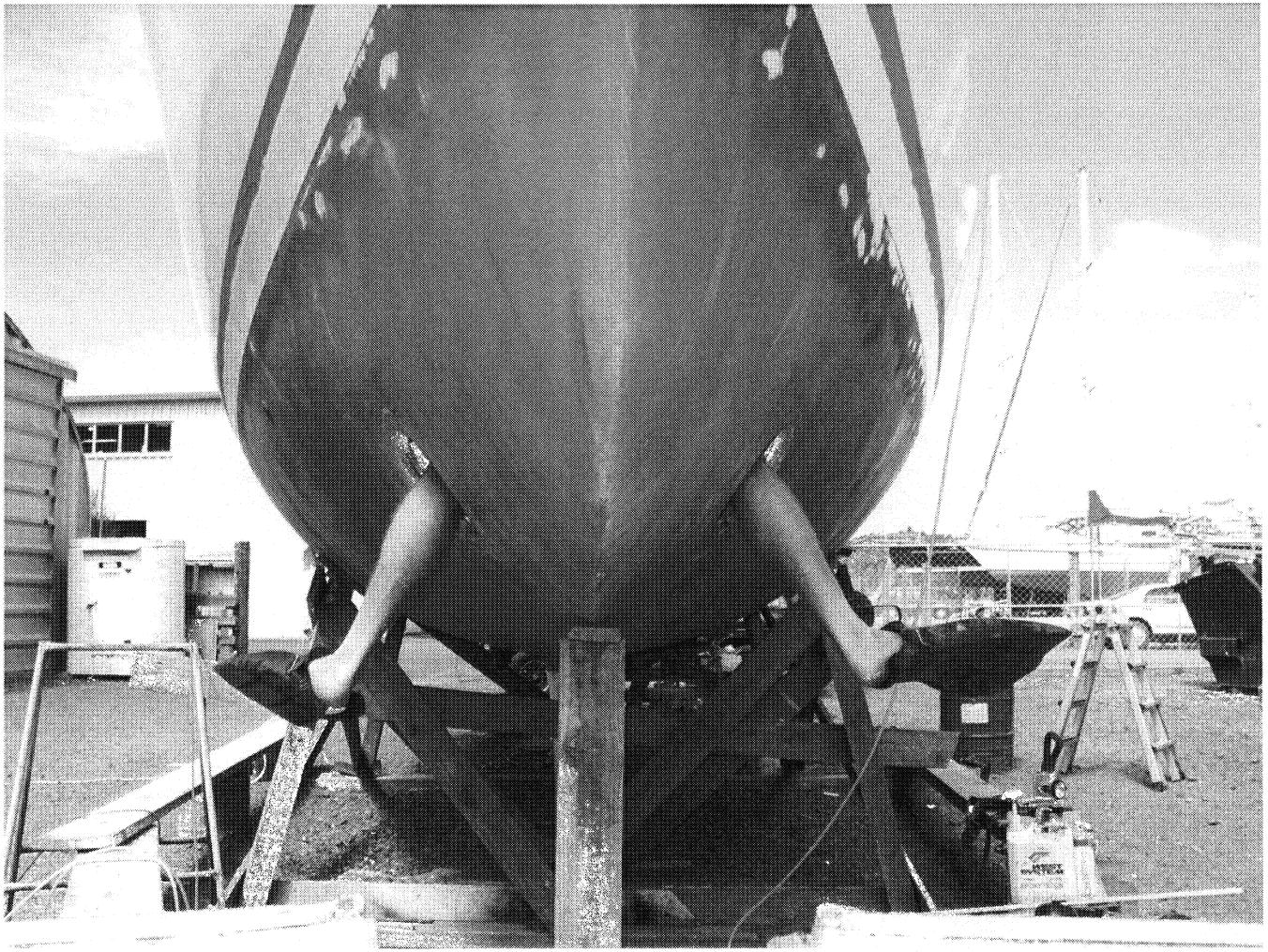
Questions.



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Fisheries and Oceans Canada | Pêches et Océans Canada

Canadian Coast Guard | Garde côtière canadienne

Safety First, Service Always

Hero Class Seakeeping Assessment and Roll Stabilizers Option Study

Canada

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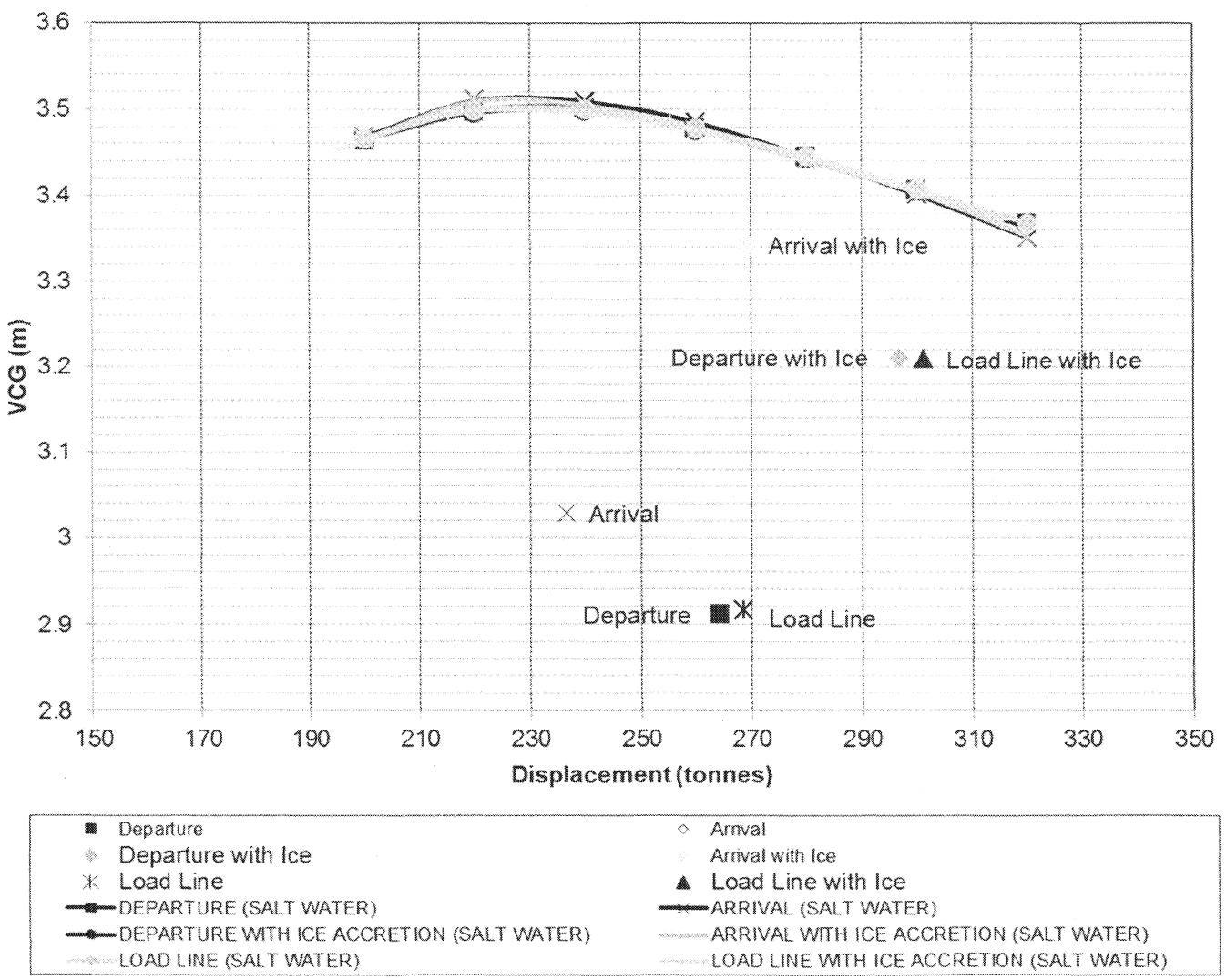
Intact Limiting KG Curve



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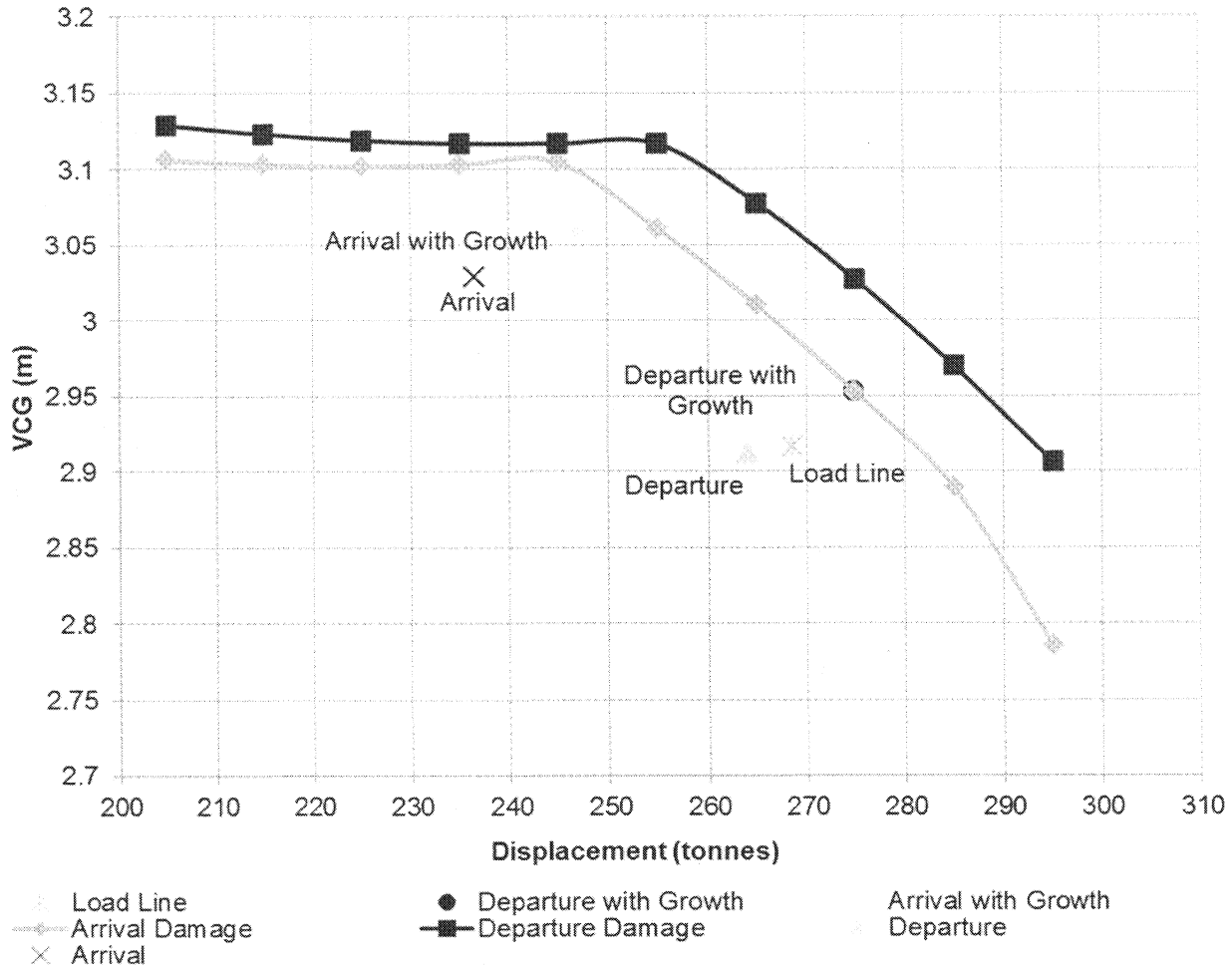
Damage Limiting KG Curve



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Gyro	High	High.	Low??	No?	Yes.	Yes.	High?	Medium t high.
Trim tabs	Medium?	No. Ship size restrictions?	Low??	Improve?	Yes. Not effective as active fins or RRS.	No stabilization at zero speed	Medium to high.	Medium?

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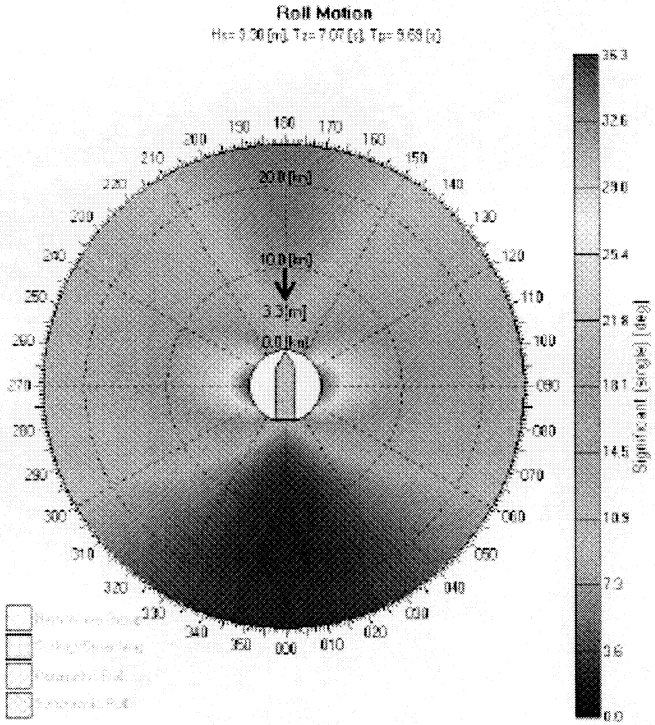
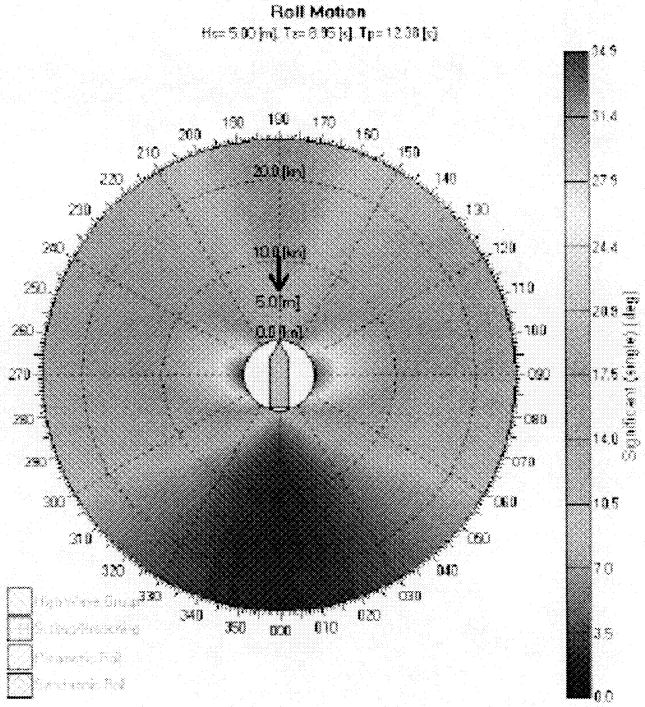
Existing Seakeeping Analysis





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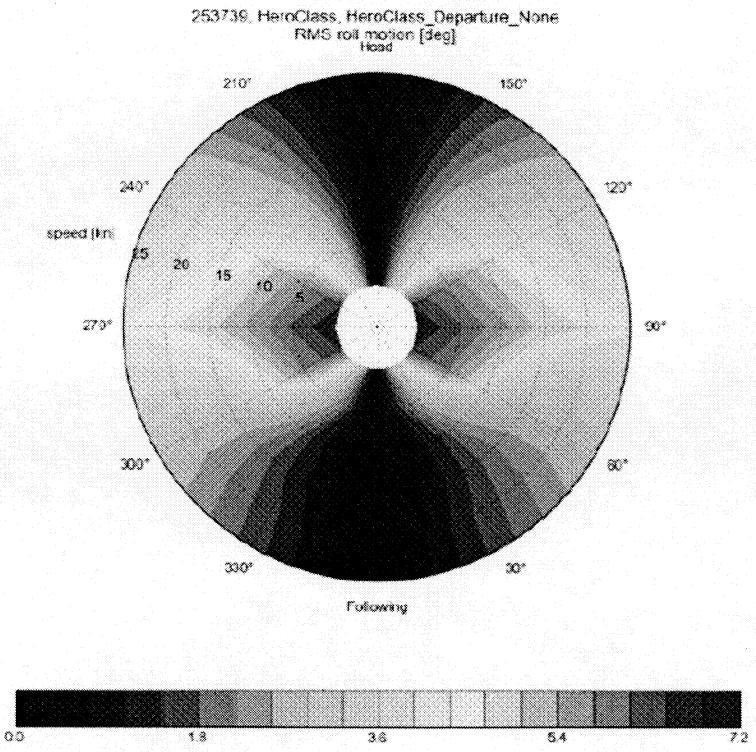
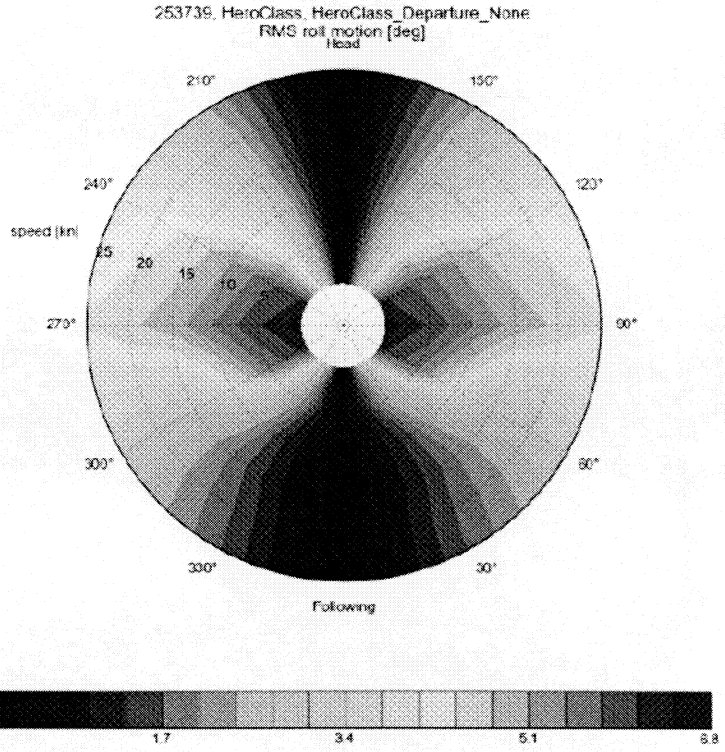
New Seakeeping Analysis





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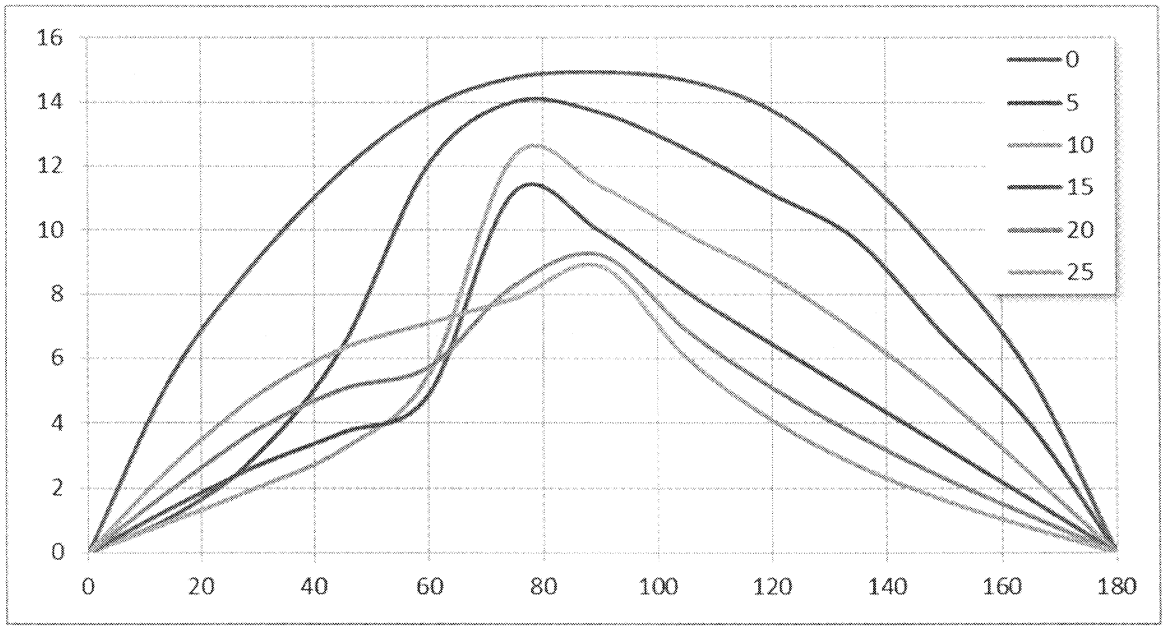
ITS ME Seakeeping Analysis



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COPY

Certificate of Class

This certificate is issued to the	**G PEDDLE S.C.**
LR Number	**9586071**
Date of Build	**24/07/2013**
Port of Registry	**Ottawa**
Gross tons	**253**
Geographical Limits	**Near Coastal Voyage, Class 1, Limited Home Trade 2, (NC1, limited HT2)**

to confirm that having been surveyed by Lloyd's Register North America, Inc. and having been found in compliance with the Rules and Regulations for the Classification of Special Service Craft, the aforesaid craft has been assigned the class

✠100A1SSC Patrol, Mono, HSC, EP, G4

MCH, UMS, CCS, ICC

Descriptive Note: Green Passport, PSMR

Date Special Survey Assigned	**24 July 2013**
This Certificate is valid until*	**23 July 2018**

* Unless extended after completion of a Special Survey (see page 3) or in accordance with Part 1, Chapter 2, Section 4.5.11 of the Rules and Regulations (see page 3) and is subject to surveys as prescribed (see page 2) being satisfactorily completed. (See notes 1 to 4, page 3)

Issued at **Halifax, NS** on **24 July 2013**

Lloyd's Register Canada Limited

Daniel Bell Initials DJB

Surveyor to Lloyd's Register North America, Inc.

Lloyd's Register

A member of the Lloyd's Register Group

Note:
1. To establish the classification status of this ship, the ClassDirect Live web site and the Interim Certificates issued on completion of classification surveys should be consulted in addition to this certificate. Access to ClassDirect Live is available via http://www.cdlive.lr.org.
2. Where an operational envelope is assigned, it will be attached as an appendix to this certificate.

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Craft Name G PEDDLE S.C. LR Number 9586071

Annual/Intermediate survey endorsements

1st Annual Survey endorsement

Signed: _____
Place of Survey
Date

2nd Annual Survey / Intermediate Survey* endorsement

Signed: _____
Place of Survey
Date

3rd Annual Survey / Intermediate Survey* endorsement

Signed: _____
Place of Survey
Date

4th Annual Survey endorsement

Signed: _____
Place of Survey
Date

** Delete as appropriate*

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Craft Name G PEDDLE S.C. LR Number 9586071

Extension of special survey completion date

In accordance with the Rules and Regulations for the Classification of Special Service Craft this certificate is extended until (see note 2)

Signed: _____

Place of survey

Date

Special survey completion

This Special Survey having been completed, this certificate is extended until

Signed: _____

Place of survey

Date

Notes

1. In accordance with the Rules and Regulations for the Classification of Special Service Craft, class will be automatically suspended and this certificate becomes invalid if not endorsed annually within three months of the due date of the Annual or Intermediate Surveys.
2. This certificate expires on the due date of the Special Survey. Consideration can be given at the discretion of the Committee to any exceptional circumstances justifying an extension to the Special Survey completion date for a maximum period of three months beyond the validity of this certificate.
3. Prior to the endorsement of this certificate all overdue hull and machinery surveys should be dealt with or postponed by agreement.
4. In normal circumstances the Annual or Intermediate Survey is to be held in conjunction with the Periodical Load Line Inspection and the Safety Construction Annual Survey.

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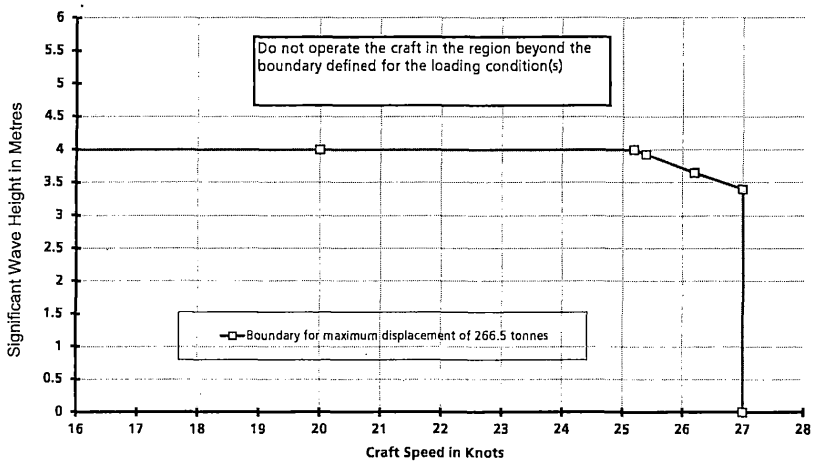
Operational Envelope (Special Service Craft)

Craft Name:	**CORPORAL MCLAREN M.M.V**	Builder:	**HALIFAX SHIPYARD LTD**
Yard Number:	**6099**	IMO Number:	**9586083**
Class Notation:	**✠100A1 SSC Patrol, Mono, HSC, G4**		



Information for the Owner and Operator:
The Operational Envelope shown above is an integral part of the Certificate of Class and must be permanently displayed in the wheelhouse within the viewing area of the Master and/or Helmsman.

Under the terms and conditions of Classification it is the responsibility of the operator to load and operate this craft at all times in a seamanlike manner and in accordance with the conditions of classification and restrictions shown in the Operational Envelope and Service Area Restriction. Failure to comply with these requirements may result in the suspension or withdrawal of class.

The Operational Envelope has been calculated using the Rules and Regulations for the Classification of Special Service Craft to indicate the limiting speed and significant wave height combinations at which the craft may operate. The significant wave height of a fully developed irregular sea is the average of the one third highest waves in a short term wave measurement record, and closely approximates wave heights reported by experienced seafarers. Where the prevailing sea state exceeds the approved parameters the Master must adjust speed accordingly and seek calmer waters or refuge.

The Service Area Restriction "**G4**", as defined in the Rules and Regulations for the Classification of Special Service Craft as "Service Group **4**", covers craft **intended for service in waters where the range to refuge is 250 nautical miles or less**

Issued at ***Toronto*** on **24 July 2014**

Jerry Bulkowski
Surveyor to Lloyd's Register Canada Ltd

A subsidiary of Lloyd's Register Group Limited

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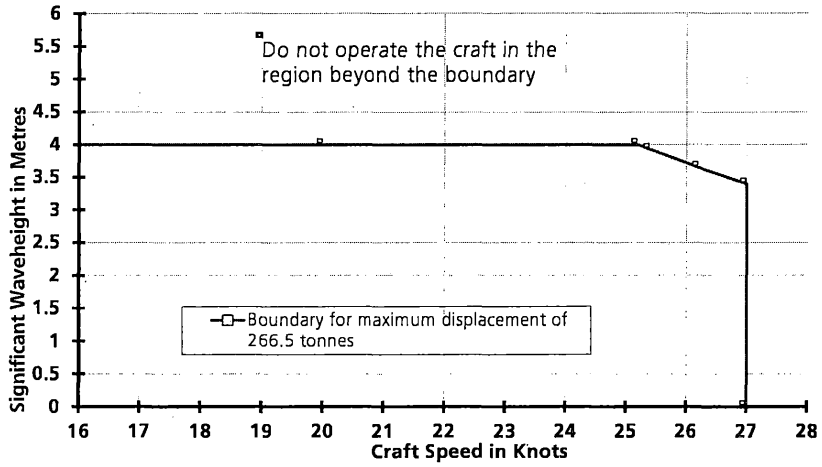
Operational Envelope (Special Service Craft)

Craft Name:	**G PEDDLE**	Builder:	**HALIFAX SHIPYARD LTD**
Yard Number:	**6098**	IMO Number:	**9586071**
Class Notation:	**✠100A1 SSC Patrol, Mono, HSC, G4**		



Information for the Owner and Operator:
The Operational Envelope shown above is an integral part of the Certificate of Class and must be permanently displayed in the wheelhouse within the viewing area of the Master and/or Helmsman.

Under the terms and conditions of Classification it is the responsibility of the operator to load and operate this craft at all times in a seamanlike manner and in accordance with the conditions of classification and restrictions shown in the Operational Envelope and Service Area Restriction. Failure to comply with these requirements may result in the suspension or withdrawal of class.

The Operational Envelope has been calculated using the Rules and Regulations for the Classification of Special Service Craft to indicate the limiting speed and significant wave height combinations at which the craft may operate. The significant wave height of a fully developed irregular sea is the average of the one third highest waves in a short term wave measurement record, and closely approximates wave heights reported by experienced seafarers. Where the prevailing sea state exceeds the approved parameters the Master must adjust speed accordingly and seek calmer waters or refuge.

The Service Area Restriction "**G4**", as defined in the Rules and Regulations for the Classification of Special Service Craft as "Service Group **4**", covers craft **intended for service in waters where the range to refuge is 250 nautical miles or less**

Issued at **Burlington, ON** on **03 October 2014**

Jerry Bulkowski
Surveyor to Lloyd's Register Canada Ltd

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Class Rules

Rule Reference	Rules Denomination	Authority	Available	Comments
LRS SSC 2009	Lloyd's Register Special Service Craft	LRS	Y	TSOR 2.3.1
	Lloyd's Register Rules and Regulations for the Classification of Ships, July 2009, Part 5, Ch. 22	LRS		Items related to PSMR to be listed as a "Descriptive Note" for the ship's notation
	Lloyd's Register Rules and Regulations for the Classification of Ships, July 2009, Part 6, Ch. 1	LRS		Items related to ICC to be listed as a "Descriptive Note" for the ship's notation

Technical Statutory Regulations

Code	Rules Denomination	Authority	Available	Applicability
ASPPR	Arctic Shipping Pollution Prevention Regulations [ASPPR]	TCMS	Y	Applicable only as far as TSOR 9.1.1
AWPPA	Arctic Waters Pollution Prevention Act	TCMS	Y	Applicable only as far as TSOR 9.1.1
C.R.C., c. 1418	Crew Accommodation Regulations	TCMS	Y	
C.R.C., c. 1422	Fire detection and extinguishing equipment regulations	TCMS	Y	Class B Vessel
C.R.C., c. 1431	Hull Construction Regulations	TCMS	Y	Reg I, II, VI, VIII, and X
C.R.C., c. 1436	Life Saving Equipment Regulations	TCMS	Y	Part II, Class IX
CSA 2001	Canada Shipping Act 2001	TCMS	Y	TSOR 2.2.1, 6.2.1
SOR/2000-260	Ship Station (Radio) Regulations, 1999	TCMS	Y	Radio equipment certification to be according to regulation. Final Radio Inspection and Certificate to be issued by TC
SOR/2000-265	Ship Station (Radio) Technical Regulations, 1999	TCMS	Y	As above
SOR/2005-134	Navigation Safety Regulations	TCMS	Y	
SOR/2005-280	Boat and Fire Drill and Means of Exit Regulations	TCMS	Y	
SOR/2007-99	Load Line Regulations	TCMS	Y	
SOR/83-810	Steering Appliances and Equipment Regulations	TCMS	Y	
SOR/90-264	Marine Machinery Regulations (MMR)	TCMS	Y	
TP 11469	Guide to structural fire protection	TCMS	Y	
TP 127	Ships Electrical Standards (2008)	TCMS	Y	Group 5
TP 1861	Standards for Navigation Lights, Shapes, Sound Signal Appliances and Radar Reflectors (1991).pdf	TCMS	Y	
TP 3668	Standards for Navigating Appliances and Equipment (1983) ?????	TCMS	Y	
TP 7301 STAB 7	TP 7301 STAB 7 - Stability, Subdivision and Load Line Standards	TCMS	Y	
SOR/2007-86	Regulations for the Prevention of Pollution from Ships and for Dangerous Chemicals	TCMS	Y	
C.R.C., c. 1416	Collision Regulations	TCMS	Y	
SOR/2007-115	Marine Personnel Regulations	TCMS	Y	
A 603(15) 7	International Maritime Organization (IMO) A 603(15) 7 Standard Symbols	IMO	?	ISO 17631 Symbols
SOR/2007-126	Vessel Registration and Tonnage Regulations (SOR/2007-126)	TCMS		
	AFS – International Convention on the Control of Harmful Anti-Fouling Systems on Ships, 2001	IMO		Applies to underwater coating spec only
DSIP	Delegated Statutory Inspection Program (DSIP)	TCMS	Y	Referenced in SOW 2.3.1 and TSOR 2.2.1. Regulations governing reporting process, delegation
TP 13585	Tier I – Policy and Tier II – Procedures Marine Safety Management System	TCMS	Y	

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Can be found at http://www.imo.org/en/OurWork/Safety/Regulations/Documents/International.pdf

InternationalConference on Fast Sea Transportation
FAST'2005, June 2005, St.Petersburg, Russia

INTERNATIONAL REGULATIONS FOR HIGH-SPEED CRAFT AN OVERVIEW*

Heike Hoppe
International Maritime Organization (IMO)
4 Albert Embankment, London SE1 7SR, United Kingdom

ABSTRACT

The paper presents an overview of the international regulations in force concerning high-speed craft, i.e. the Code of Safety for Dynamically Supported Craft (DSC Code) and the International Codes of Safety for High-Speed Craft 1994 and 2000. The historical background of the development of regulations for high-speed craft is briefly highlighted and the technical contents of the Codes are described. The status of the Codes, i.e. mandatory or recommendatory, is explained, together with their association with the International Convention for the Safety of Life at Sea (SOLAS) 1974. Finally, on-going work in IMO regarding the review of the Codes and the preparation of appropriate amendments is outlined.

INTRODUCTION

The international conventions ratified in respect of conventional ships and the regulations applied as a consequence of such conventions have largely been developed with construction and operation aspects in mind. Traditionally, ships have been made of steel and have been expected to operate on a world-wide basis with a minimum of operational controls.

The requirements for ships engaged on long international voyages are therefore framed in such a way that, providing the ship is presented for survey and a Ship Safety Certificate is issued, the ship may go anywhere in the world without any operational restrictions being imposed. Providing the ship is not involved in a casualty, all that is needed is to make it available to the Administration for the purpose of a satisfactory renewal survey before the Ship Safety Certificate expires and the Certificate will be reissued.

However, the traditional method of regulating ships should not be accepted as being the only possible way of providing an appropriate level of safety. Nor should it be assumed that another approach, using different criteria, could not be applied. Over a long period of time, numerous new designs of marine vehicles have been developed and have been in service. While these do not fully comply with the provisions of the international conventions relating to conventional ships built of steel, they have demonstrated an ability to operate at an equivalent level of safety when engaged on restricted voyages under restricted operational weather conditions and with approved maintenance and supervision schedules.

1. HISTORICAL DEVELOPMENT OF HIGH-SPEED CRAFT REGULATIONS

1.1. General

The safety philosophy of the regulations for high-speed craft (HSC) is based on the management and reduction of risk as well as the traditional philosophy of passive protection in the event of an accident. Management of risk through accommodation arrangements, active safety systems, restricted operation, quality management and human factor engineering should be considered in evaluating safety equivalent to current conventions. The application of mathematical analysis to assess risk and determine the validity of safety measures is encouraged.

The regulations take into account that a high-speed craft is of a light displacement compared with a conventional ship. This displacement aspect is the essential parameter to obtain fast and competitive sea transportation and consequently the regulations allow for use of non-conventional shipbuilding materials, provided that a safety standard at least equivalent to conventional ships is achieved.

To clearly distinguish such craft, criteria based on speed and volumetric Froude number have been used to delineate those craft to which these regulations apply from other, more conventional, craft.

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* Views expressed in this paper are those of the author and should not be construed as necessarily reflecting the views of IMO or its Secretariat.

Pages 307 to / à 312

are withheld pursuant to section

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68(a)

of the Access to Information Act

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CCR Prioritization List for MSPVs

EKME # 3045742v1 Updated 2014/03/07 *(J. Richardson original author)*

							Requested/ In Progress	On Hold	Approved by CCB	Cancelled/Rejected	Resubmit as National	Approved for Engineering	In Implementation	Completed	Closed							
Year	CCR #	Scope	Priority	Variant	Title	Work Description	Asset	Equipment	System	Originator	Region originator	Timestamp	Status	Comments	Notes	EKME #	Priority	Estimated Cost	Estimated Weight Impact	Comments	Reasons for cancelling	Reasons for rejection
2011	1642	Major	Normal		IMIC3 System for 44 Vessels	Install IMIC3.	MSPVs	IMIC3	Vessel Communications and Navigation	Grant MacDonald	NCR	10/06/2011		Ack and Routed to ACM, 2011-06-15. 2011-06-17 CCR is Approved in Principle by CCB.		2401947						
2012	2070	Major	Urgent		Ré-aménagement centre de commande	See PDF on EKME 2731816	CAPORAL KAEBLE V.C.	Equipement salle de commande	Vessel Communications and Navigation	René Longchamps	Central and Arctic	26/11/2012	Cancelled	2012-11-26, Accusé reception d'enregistrement, courriel envoyé au demandeur. 2013-01-04 Status change a Majeure, raison: nouveau navire Classe NSFRV. 2013-01-08 DCC est tranferee au GCA et Operations pour Rev/Support. Priorité change pour: URGENT. 2013-05-03, DCC est cancellée les travaux seront aussures par la DCC 2184.		2731816					DCC est cancellée les travaux seront aussures par la DCC 2184.	
2012	2076	Major	Normal		alarm & monitoring		CAPORAL KAEBLE V.C.	Security alarm	Auxillary Systems	Marc Rochette	Central and Arctic	2012-11-30	Approved by CCB	2012-12-03, Ack. Registration, email sent to Originator. 2012-12-13 DCC reçue et transférée au GCA pour pour Rev. / Support. CCR for new MSPV Class, Status changed to Major. 2013-02-07 DCC Approvée pour le Principe par le CCC.	Done on the Kaeble and the Teather, Robertson and Carrière should be done in 2014/15	2723024						
2012	2078	Major	Normal		Replace MSPV desktop computer in mess with laptop	See PDF on EKME: 2717982	PRIVATE ROBERTSON V.C.	Mess Room Computer	Vessel Information Support Systems	Michael Mei	Central and Arctic	2012-12-04	Rejected	2012-12-04, Ack. Registration email sent to Originator. Routed to ACM, Not approved by Region, Region noticed. 2012-12-04, Ack. Registration email sent to Originator. Routed to ACM, Not approved by Region, Region noticed. 2013-02-20 Subject CCR is Rejected by CCR Committee. Note: The Business Data Exchange Improvement for Ships (BDEIS) will be looking at standardizing ships bones networks, All MSPVs are in the scope of this project, No change should occur prior to BDEIS implementation. Yves Gascon.		2717982						Rejected by CCR Committee. The Business Data Exchange Improvement for Ships (BDEIS) will be looking at standardizing ships bones networks. All MSPVs are in the scope of this project. No change should occur prior to BDEIS implementation.
2012	2079	Major	Normal		MSPV Operations Room Reconfiguration	See PDF on EKME 2717983	PRIVATE ROBERTSON V.C.	Electronic Equipment and shelving in ops room	Select System	Jason Rimmer	Central and Arctic	2012-12-04	Cancelled	2012-12-04, Ack. Registration, CCR Form Routed to ACM / Fleet, email sent to Originator. 2013-04-23 CCR Form routed to Operations / ACM for revision. 2013-05-03, DCC est cancellée les travaux seront aussurés par la DCC 2184 / This CCR is Cancelled, work will be covered by CCR 2184, consult desing on EKME and send your comments to Project Officer Gael Therrien.		2717983					Work will be covered by CCR 2184	
2012	2080	Major	Normal		Communications terre/navire	See PDF on EKME: 2721679	CAPORAL KAEBLE V.C.	HSPA/ Fortigate	Vessel Communications and Navigation	Denis Tardif	Central and Arctic	2012-12-07	Routed to Fleet	2012-12-11 Ack. Enregistrement de DCC, Courriel envoyé au demandeur. CCR applicable for MSPV Class, Status change to Major. Routed to ACM/Operations (Fleet).	Interim solution until BDEIS is deployed, cost approx $2K/ship. Done on Kaeble already.	2721679		$2,000		follow up on BDEIS changes, network drives full, not working on vessels		

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CCR Prioritization List for MSPVs

EKME # 3045742v1 Updated 2014/03/07 *(J. Richardson original author)*

2012	2113	Major	Normal		Réaménagement console de navigation	See PDF on EKME: 2743483	CAPORAL KAEBLE V.C.	ECS	Vessel Communications and Navigation	René Longchamps	Central and Arctic	2013-01-08	Routed to Fleet	2012-01-08, Ack. Registration. Courriel envoye au demandeur. Les DCC pour cette classe de navires sont toujours de satut Majeure. 2013-01-24 Reçu formulaire de DCC, documents envoyés aux Opérations (Fleet) pour revision. 2017-0124 Update: Screens, equipment, etc. were moved around on various MSPV bridge consoles, Dave Wyse.	Kaeble done already, will be sent back to region to confirm whether other vessels have same issue - no changes should be made until new ECDIS unitls are procured and installed to determine any potential impact	2743483		$5,000		Superseded by 3198		
2012	2114	Major	Normal		Modification système téléphonique	See PDF on EKME: 2743484	CAPORAL KAEBLE V.C.	ICS ICP Hose-McCann	Vessel Communications and Navigation	René Longchamps	Central and Arctic	2013-01-08	Routed to Fleet	2013-01-08, Ack. Registration, Courriel envoye au demandeur. Les DCC pour cette classe de navires sont toujours de satut Majeure. 2013-01-24 Reçu formulaire de DCC, documents envoyés aux Opérations (Fleet) pour revision.	Involves reprogramming numbering system and making it wireless - same system as on large vessels desired. Approx $10K	2743484		$10,000		Issues with phones number, were reprogramm ed, no wireless, wireless handset on bridge on - can we get different rings?		
2012	2116	Major	Normal	Both	Robertson Modification to engine sump hand pump	See PDF on EKME: 2734804	PRIVATE ROBERTSO N V.C.	Engine sump hand pump	Propulsion/ Maneuverin g Systems	Harold Rink	Central and Arctic	2013-01-11	In Implementatio n	2013-01-11, Received CCR Form, document is Routed to Operations (Fleet) for revision. 2013-04-17 Supported by Operations sent to Eng. Services. 2013-11-18 received Update from Region, Info sent to Eng Services. 2014-04-10 CCR Supported by CCR Committee, sent to CCB for Approval, see comments from Operations and HME Project Eng., in EKME 2734804. 2014-05-02 CCB meeting: CCR is Deferred pending Engineering analysis completed. 2014-11-06: Supported by HME see complete note in EKME #:2734804. 2014-11-07 Approved in Principle with condition:To be further discussed at the MSPV Working Group - decision will be communicated. 2014-12-10: D.Wyse informed CCR reviewed and agreed to implement by the MSPV group when funds are available. 2014-12-11: It was brought to the CCB's attention where condition was removed.	All 3 boats in Great Lakes in agreement this work can be done by crew - no weight implications, CCR supported by all vessels in class	2734804		$1,500	9 kg	Waiting for GL (Harold Rink) to make design and parts required		
2012	2117	Major	Normal	Both	Robertson Bilge and Dewatgering System	See PDF on EKME : 2734805	PRIVATE ROBERTSO N V.C.	Bilge piping	Auxiliary Systems	Harold Rink	Central and Arctic	2013-01-11	In Implementatio n	2013-01-11, Received CCR Form, document is Routed to Operations (Fleet) for revision. 2013-04-17 Supported by Operations sent to Eng. Services. 2013-11-18 received Update from Region, Info sent to Eng Services. 2014-04-10 CCR Supported by CCR Committee, sent to CCB for Approval, see comments from Operations and HME Project Eng., in EKME 2734805. 2014-05-02 CCB meeting: CCR is Deferred pending Engineering analysis completed. 2014-11-06: Supported by HME see complete note in EKME #:2734805. 2014-11-07 Approved in Principle. 2014-12-10: D.Wyse informed CCR reviewed and agreed to implement by the MSPV group when funds are available. 2014-12-11: It was brought to the CCB's attention where condition was removed.	All 3 boats in Great Lakes in agreement this work can be done by crew - no weight implications, CCR supported by all vessels in class.	2734805		$500	4 kg	Waiting for GL (Harold Rink) to make design and parts required		

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CCR Prioritization List for MSPVs

EKME # 3045742v1 Updated 2014/03/07 *(J. Richardson original author)*

2012	2118	Major	Normal	Both	Robertson oily waste system modification	See PDF on EKME: 2734806	PRIVATE ROBERTSON V.C.	Oily waste piping	Auxiliary Systems	Harold Rink	Central and Arctic	2013-01-11	In Implementation	2013-01-11, Received CCR Form, document is Routed to Operations (Fleet) for revision. 2013-04-17 Supported by Operations sent to Eng. Services. 2013-11-18 received Update from Region, info sent to Eng Services. 2014-04-10 CCR Supported by CCR Committee, sent to CCB for Approval, see comments from Operations and HME Project Eng., in EKME 2734806. 2014-05-02 CCB meeting: CCR is Deferred pending Engineering analysis completed. 2014-11-06: Supported by HME see complete note in EKME #:273806. 2014-11-07 Approved in Principle. 2014-12-10: D Wyse informed CCR reviewed and agreed to implement by the MSPV group when funds are available. 2014-12-11: It was brought to the CCB's attention where condition was removed.	All 3 boats in Great Lakes in agreement this work can be done by crew - no weight implications. CCR supported by all vessels in class.	2734806		$500	4kg	Waiting for GL (Harold Rink) to make design and parts required		
2012	2120	Major	Normal	Both	RHIB Cradle Modification	See PDF on EKME: 2759470	PRIVATE ROBERTSON V.C.	RHIB Cradle	Deck Equipment / Ship Support Systems	Jason Rimmer	Central and Arctic	2013-01-21	Completed	2013-01-21 Ack. Registration, email sent to Originator. 2013-02-11 CCR is Routed to AOM and CCR Committee, noted URGENT. 2013-02-21 CCR is Approved in principle by CCB for prototype installation on PRIVATE ROBERTSON V.C. After completion of test and approbation, a confirmation will be issued to vessels managers of this Class to inform they can proceed with modification. 2014-05-05 Received Update from Region: CCR Completed.	Contract has been awarded to begin work, cradles are being delivered in early March 2014, money has been sent to regions for this work.	2759470						
2012	2121	Major	Normal		Washroom Cabinet Refit	See PDF on EKME: 2755841	PRIVATE ROBERTSON V.C.	Washroom Outfit and Furnisihngs	Hull and Related Structures	Jason Rimmer	Central and Arctic	2013-01-21	Cancelled	2013-01-21 Ack. Registration, email sent to Originator. 2013-02-13 CCR form Routed to Operations (Fleet). CCR is not approved by Region and checklist is not completed. Originator asked to provide information. 2013-02-14 Received Regional Approbation and checklist info sent to Operations. 2013-07-11 CCR is Supported and Routed to CCB for Approval, if urgent can be process secretarially on request. 2013-10-11 CCR 2121 has been regionally canceled at the October 8th review meeting, John Odell.		2755841						
2012	2170	Major	Normal		reconfiguration de la cuisine du caporal Kaeble V.	See PDF on EKME: 2768749	Mid-Shore Patrol (MSPV)	Cuisine	Domestic Systems	Gael Therrien	Quebec	2013-02-25	In Implementation	2013-03-04, Ack. Registration, Email sent to Originator. 2013-03-06 Recu DCC, formulaire envoyé aux Operations (Fleet)pour revision.	This CCR to be updated: New drawings are being done, plan is to have agreement on them by end of March 2014. Work should be done in 2014/15 and has to go through PWGSC for all modifications. Approx $13K/vessel	2768749		$13,000	There should be little weight change as it involves moving around steel work already in place. Will have to keep track of weight during work.	Quebec Region to come up with Prototype. They will begin this fall as the Galley will have to be shut down for a week. Ensure that switch behind the oven is accessable.		

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CCR Prioritization List for MSPVs

EKME # 3045742v1 Updated 2014/03/07 *(J. Richardson original author)*

2012	2183	Major	Normal	Both	MSPV Transformer Enclosure Upgrade	See PDF on EKME: 2773500	Mid-Shore Patrol (MSPV)	14D04 Electrical Transformers	Electrical Power Distribution	John Richardson	NCR	2013-03-06	Approved by CCB	2013-03-08, Ack Registration email sent to originator to request document. 2013-02-13 CCR Form Routed to ACM for Rev. Support, after it must be Approved in Principle at CCB meeting or secretarially. 2013-04-10 CCR is supported by CCR Committee and sent to CCB for Approval. 2013-04-10 this CCR is Approved in Principle by CCB (Secretarially).	CLOSED: Done on all vessels delivered so far and will be done on new ones as they arrive.	2773500			Will increase weight slightly			
2012	2184	Major	Normal	RCMP only, Amended to add C&P	Réaménagement du mobilier du centre d'opération	Réaménagement du centre de commandement, remplacement de l'ameublement pour que la configuration soit plus opérationnelle.	Mid-Shore Patrol (MSPV)	Salle des opération GRC	Program (Special Purpose) Assets	Gael thernen	Central and Arctic	2013-03-12	In Implementation	2013-03-12 Accuse rec. Enregistrement, Courriel envoye au demandeur. 2013-03-20 Reçu Formulaire DCC et dessins des travaux (DWG), Informations envoyés aux Opérations pour revision. 2013-03-28 verifiction avec demandeur si les DCC 2070, 2079, 2184 sont des travaux identiques: réponse OUI. Les DCC 2070 et 2079 seront cancellées, travaux assurés par DCC 2184. Les 3 DCC sont jumelées et il y aura discussions entre les Régions pour le choix d'une solution unique. 2013-04-18 reçu info de Quebec: Les chaises ne seront pas fixées au planché. 2013-05-13 DCC Supportée par Comite, 2013-05-14 DCC Supporte pour Ingenierie par CCC (sans reunion). 2015-04-28 Received Update from Reigon, Travaux completes sur le Kaeble seulement. 2015-10-26 Mise ajour de la Region: Travaux mis en attente pour le A. Leblanc, attendre l'accords des 2 equipages du A. Leblanc avant de procéder. 2017-02-14 Update from NCR: Amendment to add the C&P vessels to the CCR. Currently a solution has been fitted to the western region vessels.	Covers CCRs 2070 and 2079 that were cancelled and rolled into 2184. Approximate cost per vessel is $35K - $50K, Gael looking at options. Design produced by Marine Engineer for the Kaeble has been approved in principle, but not installed anywhere. Requires all new furniture, could be up to 100kg more per vessel, weight implications have to be investigated. Not on scheduled workplan yet, but hopefully 2014/15 - Has been identified as priority for our partners	2777699		$35000-50000	100 Kg +/-			
2013	2211	Major National	Urgent	Both	Modification de la paserrelle des navires MSPV	Les navires MSP ont livré à l'aide d'une paserrelle donnat accès aux usager qui n'est pas utilisable dans les différentes configurations de quai que l'ont retrouve à travers le Canada, Afin d'ere fonctionnel une solution doit être établis pour être fonctionnel.	Mid-Shore Patrol (MSPV)	Paerelle du navire	Deck Equipment / Ship Support Systems	Gaël therrien	Central and Arctic	2013-04-04	Approved in Principle	2013-04-05 Accus? R?ception, courriel envoy? a l'initiateur de la DCC. 2013-04-09 DCC est envoy?e au GCA pour Revision/support. Att. Checklist n'est pas compl?t?e. 2012-04-12 CCR is Supported by CCR Committee under specific condition of not removing the RHIB and the ber, see complete details in EKME 2786927. 2013-04-22 CCR is Approved for Prototype as per recommendations sent April 12th, see email or EKME file: 2786927, for details. 2014-01-28 Recu ?tude de faisabilit?e, en attente pour pr?senter au CCB pour Approbation finale. 2014-02-07 CCR Deferred. We received feasibility study from NAVTECH (available in EKME), and submit to CCB; the options (2A, 2B, 3) of having only one zodiac for RCMP is not acceptable for Director of Operational Support. CCR is not supported by CCB. CCR is Deferred, until final solution is approved by all parties. Note CCR 2397: Scope of work is similar to Temporary solution already Approved for prototype CCR 2211. If the 2 CCRs scope are not similar please identify differences and return to me for Revision by CCR Committee. 2014-12-11: Approved in Principle, OPI Dave Wyse.	HIGH PRIORITY 2016-03-01 - F2F: Design drawings have been produced. One gangway will be built and trialled.Then buy 8 more through PSPC.Davit trial was unsatisfactory. Have to decide which vessel will trial the gangway. Mclaren wants to trial it.	2786927				Quebec Region to come up with Prototype. Gangway prototype will be 5m long and possible 600mm wide. Must be class approved. Drawing and prototype will be completed this summer. A davit is also required. National funding for prototype		

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CCR Prioritization List for MSPVs

EKME # 3045742v1 Updated 2014/03/07 *(J. Richardson original author)*

2013	2219	Major	Urgent		Install Transitional Power Sources to Supply PC BAsed Navigation Systems	see form on EKME #: 2805351	Mid-Shore Patrol (MSPV)	N/A	Vessel Communications and Navigation	Claude Renaud	Central and Arctic	2013-05-02	In Implementation	2013-05-02, Ack. CCR Registration. Received CCR Form completed and Signed, Document are routed to Operations and ACM for Rev./Support. 2013-05-29, CCR Supported by CCR Committee, will be transfer to CCB for final Approval, next CCB July. 2013-05-31 CCR is Approved in Principle (secretarially) by Chairperson, email sent to Originator and others contacts.	Because there is a lack of transitional power source some vessels have expierienced damage to CCTV system during blackouts [illegible]	2805351		$1,200	28 kg			
2013	2268	Major	Urgent	RCMP only	MSPV Operations Room Electronics Reconfiguration	Relocate various items of electronic equipment in the Operations Room.	Mid-Shore Patrol (MSPV)	Various	Vessel Communications and Navigation	Jason Rimmer	Central and Arctic	2013-05-30	In Implementation	2013-05-31, Ack. Registration. Please, submit CCR Form when Completed and Signed (Approved by Users and Region Authorities). 2013-05-31, Ack. Registration. Please, submit CCR Form when Completed and Signed (Approved by Users and Region Authorities). 2013-07-03, Received CCR Form and Specifications document, info is Routed to Fleet for Evaluation / support. 2013-09-27 CCR is Supported by CCR Committee and Routed to CCB for Approval. 2013-09-27 CCR is Approved in Principle secretarially. 2013-10-16 CCR is sent to CCB for information, CCR was Approved secretarially earlier, Approved in Principle, Class applicable.	On Hold: Medium Priority. Kaeble already done. If radar is removed it must be reserved to be re-used once ECDIS is installed. This will be done as manpower and budget permit. Warranty period also a consideration	2809919		TBD	TBD			

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CCR Prioritization List for MSPVs

EKME # 3045742v1 Updated 2014/03/07 *(J. Richardson original author)*

2013	2271	Major National	Urg	Both	2013 - 0506 MSPV Shore Power Cable Reversed Interior	Due to the fact that the MSPV shore power cables supplied are male at both end there is a safety concern that the inboard end could be accidentally energized creating a shock hazard for personnel. The intention of this CCR is to modify the inboard end of the shore power cable and receptacle with a reversed interior (female) thereby mitigating the associated risk.	Mid-Shore Patrol (MSPV)	Shore Power Cable	Ships Service Electrical Power Generation	John Richardson	NCR	2013-06-03	Completed	2013-06-06, Ack. Registration. Please Submit CCR Form when Completed and Signed (Approved by Users and Region Authorities). 2013-06-11 Major CCR Form is Routed to Operations and CCB Committee for Key V Support. 2013-07-11 CCR is Supported and Routed to CCB for Approval. If urgent can be process secretarially on request. 2013-07-12 CCR is Approved In Principle (Secretarially). 2014-06-03 Received Update from Region CCR Completed.	Underway	23233							
2013	2274	Major	High		Magnetic Compass Repeater Relocation	Remount magnetic compass repeater out of wheelsman's line of sight.	Mid-Shore Patrol (MSPV)	Marine Data Compass Repeater	Vessel Communications and Navigation	Ted van Gaalen	Central and Arctic	2013-06-11	Acknowledged	2013-06-11, Ack. Registration. Please Submit CCR Form when Completed and Signed (Approved by Users and Region Authorities).	DEFERRED - Johnny Leclair does not support this change. Any relocation of this equipment necessary can be incorporated in CCR 2113 and done at the same time.						Superseded by 3198		
2013	2282	Major National	Normal		BDEIS installation on MSPV	To install the standardized BDEIS communications, network servers and workstations on board all MSPV. Related to CCR 2009-1052	Mid-Shore Patrol (MSPV)	Cellular, WiFi, Firewall, Servers, routers, switches, workst	Vessel Information Support Systems	Jean-Francois Coutu	NCR	2013-07-03	Closed	2013-07-03, Ack. Registration. Please Submit CCR Form when Completed and Signed (Approved by Users and Region Authorities).	This is on hold until national BDEIS project is rolled out on all vessels, funding allocated to complete.								
2013	2293	Major National	Urgent		MSPV - Potable Water Purification Chlorination System	This CCR is being submitted to address the potable water issues due to unacceptable levels of ethyl benzene/xylene being found on MSPV's 1-4. This is to be a short term solution until it is possible to recoat the potable water tanks. It is also proposed that the chlorination system could be utilized downstream of the reverse osmosis water maker after the potable water tank coatings have been properly recoated.	Mid-Shore Patrol (MSPV)	VOC rated charcoal filter and chlorination system		John Richardson	NCR	2013-08-06	Deferred	8 Aug 2013 Receipt acknowledgement email sent to originator. 2013-08-13 CCR Form Routed to Fleet for Revision, CCR noted Urgent. 2013-08-13 CCR is Supported by CCR Committee and sent to CCB Chair for Secretarial Approval. 2013-08-15 CCR is Approved In Principle (Secretarially). 2014-06-03 Update from Region CCR Deferred by GL sector for GL Sector Vessels.		28799\5, 23233				Will add small amount of weight			

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CCR Prioritization List for MSPVs

EKME # 3045742v1 Updated 2014/03/07 *(J. Richardson original author)*

2013	2310	Major National	High	RCMP only	RHIB Structural Amendment	Fiberglass single hull with foam perimeter and a strong central skid light with extra anchoring and storage for vessel operations	Mid-Shore Patrol (MSPV)	N/A	Vessel Communications and Navigation	Steven Pauley	Central and Arctic	2013-03-16	Completed	2013-06-16: Ack. CCR Registration. Email sent to Originator: Please, submit CCR Form when Completed and Signed (Approved by Users and Region Authorities). 2013-11-13 Received CCR (signed document) from Region. 2013-12-03 Received CCR Form approved, document Routed to Fleet. 2014-03-03 file with Engineering to advise formal weight for proposed mast configuration. 2014-12-11: Approval in Principle with condition that the section 9 & 10 checklist is to be completed.	2014/02/21 Response received from TC re: lights email outlining conditions for CCR consideration sent to BCMP for review	2946528							
2013	2311	Major National	High		RHIB Siren / Loud Hailer	The ship 753 Zodiac two RHIBs are each fitted with an ICOM VHF radio (IC-M604) that does not have police siren capability. The existing loud hailer loudspeaker is mounted aft under the radar arc. A more compact version should be mounted forward to protect the hearing of officers.	Mid-Shore Patrol (MSPV)	Siren / Loud Hailer	Vessel Communications and Navigation	Steve Pauley	Central and Arctic	2013-08-16	In Implementation	2013-08-16, Ack. CCR Registration. Email sent to Originator: Please, submit CCR Form when Completed and Signed (Approved by Users and Region Authorities). 2013-12-03. Received CCR Form approved, document Routed to Fleet. 2014-05-27 Recommended solution has changed since this CCR was initiated, see attached document EKME 3108889. CCR Supported by CCR Committee. Routed to CCB for Approval June 6th, 2014. 2014-06-06 CCR Approved in Principle by CCB for MSET vessels only, operation to follow up secretarially regarding approval for 5 other vessels.	Options for sirens in marine law enforcement ops being investigated by Fleet. [illegible] completed on all MSET vessels. Five of those in compliance [illegible]	2946528							
2013	2379	Major National	Normal	Both	MSPV - New Screen Installation ER ventilation fan	fabricate and install intake screen on ER ventilation intake. EKME 2980670	Mid-Shore Patrol (MSPV)	N/A	Auxillary Systems	Harold Rink	Central and Arctic	2013-11-18	Closed	013-11-18, Ack. CCR Registration. Email sent to Originator: If not already done, Please Contact other MSPV users to agree on Design. Then submit CCR Form when Completed and Signed by All Regions (Users and Region Authorities). 2013-11-19 Received CCR Form , document Routed to Fleet for Rev/Support. 2013-12-06 CCR is Approved for Engineering. To OPI: Engineer recommends ensuring no Pressure drop created and to explore if screens will be used year round or not. Return to CCB for Approval for Class. See RoD in EKME. 2013-12-09 Update from OPI: used 12 months, maintenance is scheduled to prevent clogging, see email attached. Wating if approved by all Regions. 2014-01-08 Engineering confirmed CCR is Applicable for Class, CCR will be submit for Approval in Principle at next CCB. 2014-02-07 CCB asked for more information on installation, i.e. manufacturer specifications off product. CCR Approved for Engineering untill information supplied. 2014-06-03 OPI contact supplier, and confirmed that no impact on supply fan, only required housekeeping on product to avoid pressure drop. (Full detail in file). CCR sent to CCB for Approval, June 6th. 2014-06-06 PM contact supplier to confirmed no impact if equipment maintained regularly. CCR Approved in Principle for MSPV Class. 2014-06-03 Received Update from	Being implemented on vessels 1, 3, 4, 5, 6 - no requirement for it on #2. Require confirmation that screens will not damage fan (either testing or written confirmation from screen manufacturer).	2980670							

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CCR Prioritization List for MSPVs

EKME # 3045742v1 Updated 2014/03/07 *(J. Richardson original author)*

2013	2340	Major National	Urgent		MSPV - RHIB Footpad Modification	Install solid footpads on RHIB (Proper name: Identified by CCG as "Solid Gel Pads" Also known as Hardened Rubber Pads under the EPI part #'s)	Mid-Shore Patrol (MSPV)	Hull and Related Structures	N/A	Jason Rimmer	Central and Arctic	2013-11-13	Completed	2013-11-18, Ack. CCR Registration. Email sent to Originator: It is already done. Please submit CCR Form when Completed and Signed (Approved by Users and Region Authorities). 2014-11-19 Received CCR form approved document Routed to Fleet for Rev/Support. 2014-12-1: Engineering PM Lindsay Fyfe to do some clarifications to ESOR for RHIB and explain that with the actual locker seat configuration, adding foot pads can have the opposite effects. see e-mail e-mail attached in EKME	Approved in principle	29796664							
2013	2381	Minor	Urgent		Side Navigation Light Inboard Screens	At present the sidelights as fitted onboard CCGS G. Peddle S. C. are not fitted with inboard screens. This configuration is in	G. PEDDLE	Navigation Sidelights	Vessel Communications and Navigation	Alexander J. Curry	Atlantic Region	2013-11-18	Cancelled	2013-11-18, Status Changed to Major, CCR should be applicable for Class. Received CCR Form and Justification form CCGS G. Peddle SC, documents Routed to Fleet. To Originator; please contact other MSPV Managers to agree on Standards for this Upgrade, (see email distribution list for contacts).	Done under warranty	29796664		TBD	Minimal			This was performed under warranty	
2013	2394	Major National	High		Modification de l'installation des radars des MSPV	Éliminer le bruit causé par les radars, installés dans la salle de commandement, par une relocalisation et/ou un remplacement de ceux-ci.	Mid-Shore Patrol (MSPV)	Radars bande X et S	Vessel Communications and Navigation	Longchamps, René	Central and Arctic	2013-12-19	Approved for Engineering /Protoype	2013-12-20, Accusé réception Enregistrement DCC. Courriel envoyé au demandeur; SVP produire DCC (si pas déjà fait) et soumettre le formulaire lorsque Complété/Approuvé? (signatures demandeurs et autorité Régional. 2014-12-03: Enregistré, courriel acheminé à l'originateur et envoyé au comité d'Évaluation des CCR. 2016-12-05 Update from Operation: Radar replacement as suggested by C&A Region is not supported. Operation Support to Test & Trial the implement and develop the noise reduction baffling solution from Western Region on board the Goddard for one month, which allows both crews a full tour to test and experience the new system. After if any potential modifications identified that may need to be made to the final design, the system is to be constructed and installed on all remaining MSPVs at the earliest opportunity. 2016-12-07, CCR Approved for Engineering. DCC approuvée pour Ingénierie. Engineering OPI/BPR d'ingénierie Rod Pike: to comeback with result for Rev./Approbation for MSPV Class. Le BPR doit revenir avec les résultats pour Rev./ Approbation pour la Classe PSH.	Need confirmation from RCMP that this is an issue for all crews on all vessels. Options are being investigated. 2017-03-01: Western region trialing noise dampening solution (dynamatt). Rod waiting for feedback from Western region and then going to CCB for way forward. 2017-03-03 - Lisa sent an email to Western region requesting info on how to make covers for remaining vessels. Waiting on Rod's report and CCB approval. 2017-05-26 - Feed back from E&I: For C&A materials still have to be ordered and covers made for the radar transceivers. Expected implementation for QBC this winter Great Lakes it is a medium priority. For ATL the package is being developed by Engineering for the work and Production will schedule as opportunity/workload permits. They will advise when it is			TBD	TBD				
2014	2396	Major	Normal		Refaire et repositionner la sortie air extérieur du ventilateur de la hotte de la cuisine	Le besoin est d'effectuer le repositionnement et agrandir la sortie d'air extérieur du ventilateur de la hotte pour éliminer deux 90 du conduit de ventilation. Présentement la sortie d'air est de 26 cm X 21 cm mais dû au défecteur celle-ci est réduit à 18.7 cm X 10 cm.	Mid-Shore Patrol (MSPV)	hotte de cuisine	Domestic Systems	Luc Poirier	Central and Arctic	2014-01-03	Approved by CCB	2014-01-03, Ack. CCR Registration. Email sent to Originator: If CCR not already done, Please submit Form when Completed and Signed (Approved by Users and Region Authorities).	Need regional consensus on this issue and confirmation that removal of any sections of ducting will not impact water trap in line; ensure no other potential issues. Needs further research 2017-03-01: Include ducting in the new galley CCR. There needs to be an engineering study. The steam ovens generate a lot of vapour.	30319196		Minimal	Minimal				

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CCR Prioritization List for MSPVs

EKME # 3045742v1 Updated 2014/03/07 *(J. Richardson original author)*

2014	2397	Major	Urgent		Removable Railing For Gangway Placement Bridge Deck	Our plan is to cut out sections of railing on the bridge deck in order to allow the gang way to have an access on the bridge deck ahead of the life rafts which we remove when tied up in order to utilize our gangway. Once they are cut our chains with securing devices will be put in place to act as railing while at sea.	Mid-Shore Patrol (MSPV)	Gangway	Deck Equipment / Ship Support Systems	Alexander J Curry	Atlantic Region	2014-01-06	In Implementation	2014-01-07, MSPV Class: Scope changed to Major. Ack. CCR Registration. Email sent to Originator: If CCR not already done, Please submit Form when Completed and Signed (Approved by Users and Region Authorities). 2014-02-06 Received CCR Form approved by Region, document are Routed to CCR Committee for Revision. Note CCR 2211 gangway modification may cover the scope of this CCR. 2014-02-07, Status: Scope of work is similar to Temporary solution already Approved CCR 2211. If not identical please identify differences and return to me for Revision by CCR Committee. 2014-11-06: Supported by CCR Committee. See complete HME note in EKME # 3287153. 2014-11-07 Approved in Principle with condition.To be further discussed at the MSPV Working Group - decision will be communicated. 2014-12-01: Informed that all	Can be combined with CCR 2211. Has been done on vessels 2, 5 and 6.	3029850		Minimal	Minimal			
2014	2398	Major	Normal		Removal Of Mounted Pedestal Bridge Chair	At present there are three mounted pedestal chairs on the bridge of the vessel. Given the size of the bridge, movement around these chairs is difficult given the space limitations. The Navigation Officers have found it difficult and time consuming to maneuver around the center pedestal chair in order to access electronic equipment, Main Engine, and steering controls on the forward console. Navigation Officers must have easy access to the maneuvering controls of the vessel at all times. The center pedestal chair is to be removed and placed in storage ashore. Deck mounting lugs are to be left in place. Ergonomic mat to be	Mid-Shore Patrol (MSPV)	Bridge Chair	Deck Equipment / Ship Support Systems	Alexander J Curry	Atlantic Region	2014-01-06	Acknowledged	2014-01-07 MSPV Class: Scope changed to Major. Ack. CCR Registration. Email sent to Originator: If CCR not already done, Please submit Form when Completed and Signed (Approved by Users and Region Authorities).	Some vessels have already removed or changed the chairs, this should be confirmed amongs all vessels so best option can be found and implemented.			TBD	TBD			

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CCR Prioritization List for MSPVs

EKME # 3045742v1 Updated 2014/03/07 *(J. Richardson original author)*

2014	2399	Major	Normal		Shelf Removal Wet Gear Locker	At present the design configuration for the Wet Gear Locker does not allow for effective storage and drying of wet gear due to lack of space. There is insufficient space, with the current arrangement, to hang the gear that would be hung in the space during normal operations. There is no other space within the vessel to hang gear that is wet. When wet gear is placed in this locker it is dripping onto any items stored on the shelf unit in question. See attachment. The larger of the two shelf units that are presently located in the Wet Gear Locker is to be removed from the vessel and placed in storage ashore. The smaller of the two	Mid-Shore Patrol (MSPV)	Wet Locker	Deck Equipment / Ship Support Systems	Alexander J Curry	Atlantic Region	2014-01-06	Approved by CCB	2014-01-07 This CCR is MSPV Class, Scope is changed to Major. Ack. CCR Registration. Email sent to Originator: If CCR not already done, Please submit Form when Completed and Signed (Approved by Users and Region Authorities). 2014-01-24 Received CCR Form Completed and signed, Documents are routed to CCR Committee.	Shelf has been removed on Vessel 5 and kept in storage in case it needs to be put back.	3021266						
2014	2400	Major	Normal		Installation Of Night Bells On Vessels Telephone/PA System	The present telephone communication system is not equipped with the Night Bells feature. When in port duty personnel are required to carry out Fire and Security rounds. If the vessel is on SAR standby duty personnel must be available to answer the telephone in the event of a SAR call. The Night Bell feature to be installed in telephone communication system. Installation of Night Bells will ensure that the telephones are answered even when duty personnel are carrying out other responsibilities onboard. Important calls, such as SAR calls, will not be missed.	Mid-Shore Patrol (MSPV)	Telephone/ PA System	Vessel Information Support Systems	Alexander J Curry	Atlantic Region	2014-01-06	Routed to Fleet	2014-01-07 MSPV Class: Scope changed to Major. Ack. CCR Registration. Email sent to Originator: If CCR not already done, Please submit Form when Completed and Signed (Approved by Users and Region Authorities). 2014-06-23, Received CCR Form Signed (Approved) by Region and upgrade CRR scope to Major, documents routed to CCR Committee.	This CCR could be combined with CCR 2114. CCR Cancelled by Originator. Scope of work will be included into CCR 2737.	3226735		NII				

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CCR Prioritization List for MSPVs

EKME # 3045742v1 Updated 2014/03/07 *(J. Richardson original author)*

2014	2408	Major	Normal	Both	MSPV - Removal of UHF Antennae in way of Running Lights	Remove two UHF antennae (1 each on port and starboard side) that produce reflected light in way of the port and starboard side (red and green) running lights on all vessels of the MSPV Class. Existing wiring to be preserved in place and waterproofed in case of future requirements.	Mid-Shore Patrol (MSPV)	UHF radio Antennae	Vessel Communications and Navigation	Michael Glew	NCR	2014-01-20	Approved by CCB	2014-01-21, Ack. CCR Registration. Email sent to Originator: If CCR not already done, Please submit Form when Completed and Signed (Approved by Users and Region Authorities). 2014-02-06 Received CCR Form, Request is Supported by Manager Operational Requirements Jim Hann, info is Routed to CCR Committee for Revision. 2014-02-11 CCR is Supported by CCR Committee. CCR is Approved in Principle by CCB, Radio must be removed if still installed. E & I would prefer that cable be removed, also DWG should be updated.	Work must be completed exactly as described in the CCR: remove antenna and tape ends. Antennas have been removed on Kaeble, other vessels should be done by end of March.	3030103						
2014	2409	Major National	Urgent		MSPV RHIB Lifting Frame Anti-pendulum Spacer	In consultation with Newfoundland Marine Safety Systems, DBC Marine Safety Systems, and Ned-Deck Marine it was proposed that an 8.5° extension block would be engineered and fabricated. Engineering and a Finite Element Analysis (FEA) was done by Mechanicus Designworks Inc. and the extension block proved suitable according to their simulations.	Mid-Shore Patrol (MSPV)	RHIB Lifting Frame	Deck Equipment / Ship Support Systems	John Richardson	NCR	2014-01-24	Cancelled	2014-01-29, Ack. CCR Registration. Email sent to Originator: If CCR not already done, Please submit Form when Completed and Signed (Approved by Users and Region Authorities). 2014-01-31 Received CCR Form and supporting dcouments, info is Routed to CCR Committee for Revision. 2014-02-26 CCR is Supported by CCR Committee. This Major CCR is for MSPV Class and will have to be approved by CCB, CCB meeting is every first Friday of the month. (If it's urgent, can be process accordingly, let me know). 2014-03-07 CCR Approved for Prototype by CCB.	HIGH PRIORITY. This was supported by CCR Committee 02/26 and approved at next CCB. Once trial is completed on Pebble solution will be rolled out to other vessels.	3020948		Funded by SCAP Ken Akel	68.9 kg per RHIB			
2014	2433	Minor	Urgent		Bunker gear location moved to Aft Passageway	A plate installed to be used as a mounting bracket for Scott Air pack holders along with hangers attached for the bunker gear and a shelf for an AED located in the Aft Passageway once the removal of gun cabinets has been completed.	Mid-Shore Patrol (MSPV)	Bunker gear	Safety and Security Equipment	Fred Emeneau	Atlantic Region	2014-03-01	Acknowledged	2014-03-04 Ack. CCR Registration. Email sent to Originator: If not already done, Please submit CCR Form when Completed and Signed (Approved by Users and Region Authorities).								
2014	2434	Minor	Urgent		Fuel Oil Pressure Indication at Generators and on Alarm & Monitoring Sys.	Implement fuel oil pressure indication locally as well as remotely in our alarm and monitoring system along with an alarm point. As well as the implementation of gauges on the generators.	Mid-Shore Patrol (MSPV)	Ship Service generators Fuel Oil System	Ship's Service Electrical Power Generation	Alexander J. Curry	Atlantic Region	2014-03-01	Cancelled	2014-03-04 Ack. CCR Registration. Email sent to Originator: If not already done, Please submit CCR Form when Completed and Signed (Approved by Users and Region Authorities).								

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CCR Prioritization List for MSPVs

EKME # 3045742v1 Updated 2014/03/07 *(I. Richardson original author)*

2014	2435	Minor	Urgent		Location change of Immersion Suits	Change the location of immersion suits from a locker below on the lowest deck to an outer locker where it would be more likely and more accessible to obtain and put on the immersion suits in an emergency situation. A heater would also be installed in this locker to prevent moisture and condensation	Mid-Shore Patrol (MSPV)	Immersion suit locker	Safety and Security Equipment	Alexander J. Curry	Atlantic Region	2014-03-01	Acknowledged	2017-05-23 Cancelled. Superseded by CCR 2504								
2014	2558	Major National	Normal	Both	MSPV - Trash compactor removal (C&A GL sector vessels)	Removal of trash compactors onboard that are not in use. Consists of unbolting the compactor and removal from space. Space will then be used for storing addition deck equipment. 2014-06-06 CCR Approved in Principle for MSPV Class.	Mid-Shore Patrol (MSPV)			Mehm Tun	Central and Arctic	04/04/2014	In Implementation	2014-04-09 Ack. CCR Registration. Email sent to Originator: If CCR Form not already produced, please submit when completed and signed (Approved by Users and Region Authorities). 2014-04-17 Received CCR Form and DWG. Documents are Routed to CCR Committee for Rev / Support. 2014-04-25. CCR Raised to Major (applies to MSPV Class), CCR Supported by CCR Committee, see complete comments from Operation. 2014-06-06 CCR Approved in Principle for MSPV Class. Storage part of the proposed solution is not approved at this time, until weight control analysis is completed and program in place. Greg Lick Dir. Operations.	Supported by all MSPVs, supported by fleet, waiting for CCB approval	3050137						
2014	2504	Major National	High		Required Changes to Safety Control Plan and Fire Control Plans on MSPV's	Changes proposed were adopted shortly before transiting vessels back to C & A region for safety reasons. Extra lifejackets required and/or immersion suits depending on the number provided by shipyard at time of delivery. Plan approval cost $1,500.00 per vessel. Extra 5 Life Jackets.	Mid-Shore Patrol (MSPV)	Fire Plan Update and approval	Select System	Christian Jensen	Central and Arctic	23/05/2014	Approved in Principle	2014-05-27, Ack. CCR Registration. Email sent to Originator: If CCR not already done, Please submit Form when Completed and Signed (Approved by Users and Region Authorities). 2014-12-05:Registered, routed for signatures and email sent to originator. Issue already discussed at the MSPV Group level. There was no agreement between all the boats within the Class. Even that COs agree on the change there are several proposals in regard to the new location for safety and fire equipment and additional equipment to be purchased Change already done on the two Western region boats as requested for transit from Eastern to Western Coast. 2015-12-14 CCR Supported by CCR Committee. 2015-12-21 CCR approved In Principle by CCB Secretarially. 2017-01-24 Update: No common solution agreement. Different per vessel, Dave Wyse.	2016-05-04 Mclaren waiting on Lloyd's approved plans. Paddle will have plans later.							

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CCR Prioritization List for MSPVs

EKME # 3045742v1 Updated 2014/03/07 *(J. Richardson original author)*

2014	2511	Major	Urgent		Replacement of Air to Ground Antenna on MSPV	Antennas currently fitted on the MSPV generate a High VSWR outside specification. The existing grounding plane is a 6"x6" and manufacturer confirmed that there was a misprint in documentation and a 6'x6' grounding plane was required for existing antenna. This can't be achieved on this class of vessel. To replace the existing antenna with the SG238-SF1SNM as this is the Standard throughout the Fleet. Substantially improve performance by meeting the VSWR Standard specification.	Mid-Shore Patrol (MSPV)	Jotron TR7725	Vessel Communications and Navigation	Pierre Lampron	Atlantic Region	02/06/2014	Approved in Principle	2014-06-02, Ack. CCR Registration. Email sent to Originator: If CCR not already done, Please submit Form when Completed and Signed (Approved by Users and Region Authorities). 2014-06-25 CCR Urgent, Routed to Operation for Rev. / Support. 2014-11-06: Supported by HME see complete note in EKME #:3287153. 2014-11-07 CCB agreed to return to CCR cmte for E&I support.	2017-03-01 - Rod didn't know. Not a priority at this time							
2014	2513	Major National	High		MSPV - MMR Additional CCTV Cameras	Rearrange existing cameras and add an additional third camera to space to help improve visibility of space as per attached plan.	Mid-Shore Patrol (MSPV)	CCTV Camera System	Vessel Information Support Systems	Christian Jensen	NCR	03/06/2014	Cancelled	2014-06-02, Ack. CCR Registration. Email sent to Originator: If CCR not already done, Please submit Form when Completed and Signed (Approved by Users and Region Authorities).								
2014	2527	Major	High	CP variant	Conservation & Protection, VMS (Vessel Monitoring System) Installation	Installation of the VMS on board six vessels: - CCGS Dudka, CCGS G. Paddle S.C., CCGS	Mid-Shore Patrol (MSPV)	VMS (Vessel Monitoring System)	Vessel Information Support Systems	Kenneth Aker	Atlantic Region	22/07/2014	Request/In Progress	2014-07-23, Ack. CCR Registration. Email sent to Originator: If CCR not already done, Please submit Form when Completed and Signed (Approved by Users and Region Authorities)	2017-03-01: Not on Western Vessels							

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CCR Prioritization List for MSPVs

EKME # 3045742v1 Updated 2014/03/07 *(J. Richardson original author)*

2014	2529	Major National	High		Lubrication Program Modifications for the Hero Class Mid Shore Patrol Vessels	The modification of lubrication related equipment aboard the vessel both minor, such as the addition of breathers, filters , ISO quick disconnects and offline / delivery filtration units. The optimization of lubricants using lubricant identification labels on equipment and reservoirs with the standardisation of the storage and handling practices based on industrial best practice and WHIMIS recommendations. The standardisation of the process for the collection of oil samples, using sample ports with the setup of equipment specific lubricant alarm limits and recommended actions.	Mid-Shore Patrol (MSPV)	Systems modified are detailed in the EKME Document #3286567	Propulsion/ Maneuvering Systems	John Riga	NCR	24/07/2014	Approved in Principle	2014-07-25, Ack. CCR Registration. Email sent to Originator: If CCR not already done, Please submit Form when Completed and Signed (Approved by Users and Region Authorities). 2014-08-15 Received CCR form signed by Originator, with specification document: EKME: 3337804, also Lubrication Program available on EKME: 3286567. 2014-11-05, CCR supported by CCR Committee, Routed to CCB for Approval.	2017-03-01: Mclaren and Peddle will be installing soon.								
2014	2548	Major	Urgent		MSPV - Bridge Blinds	Add tinted roller blinds to forward 3 windows (which do not have blinds currently).	Mid-Shore Patrol (MSPV)	Window Blinds	Deck Equipment / Ship Support Systems	Christian Jensen	Central and Arctic	04/09/2014	Acknowledged	2014-09-05, Ack. CCR Registration. Email sent to Originator: If CCR not already done, Please submit Form when Completed and Signed (Approved by Users and Regional Authorities). 2017-05-23: Cancelled. A CCR is not required to add or change bridge blinds as they are not permanent fixtures									
2014	2549	Major National	High		Zodiac 753 ECS Multi-Function Display	Replace Garmin GPSMap 4208 Multi-Function Display with Model 6212 MFD. Install Garmin heading sensor and AIS reciever.	Mid-Shore Patrol (MSPV)	Zodiac 753 ECS Multi-function Display	INNAV - Vessel Information and Nagivation System	Christian Jensen	Central and Arctic	04/09/2014	Acknowledged	2014-09-05, Ack. CCR Registration. Email sent to Originator: If CCR not already done, Please submit Form when Completed and Signed (Approved by Users and Regional Authorities). 2016-12-05 Update from Operation: AIS on small craft is not supported. CCR Closed.	2017-03-01 - Reopen this CCR for RHIBs in Central								
2014	2559	Major	High		Installation de filtre duplex sur circuit ref. eau de mer sur 2 gén. aux.	Installer un filtre duplex en brass our chaque génératrice (2x)	Mid-Shore Patrol (MSPV)	Génératrices auxilliaires (Cooling water system)	Auxillary Systems	Luc Poirier	Central and Arctic	17/09/2014	Cancelled	2014-09-18, Accusé reception d'enregistrement. Si DCC pas encore faite, SVP la soumettre lorsque completee et signee; Approuvee par Operateurs et Autoritees Regionale. 2014-12-29: DCC enregistré et envoyé pour signature aux comité CCR.		3361218							

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CCR Prioritization List for MSPVs

EKME # 3045742v1 Updated 2014/03/07 *(J. Richardson original author)*

2014	2567	Major National	High	Large Vessel Radar-ECDIS Replacements		Replace ECS and radars with an integrated radar-ECDIS system on the large vessels	Various assets	ECS, radar affiliated sensors	Vessel Communications and Navigation	Thomas Lane	NCR	09/10/2014	Approved in principle	2014-10-14, Ack. CCR Registration. Email sent to Originator: If CCR not already done, Please submit Form when Completed and Signed (Approved by Users and Regional Authorities). 2014-10-21 CCR Form Routed to ACM for Rev./support. 2015-08-26 File supported by all three Departments To be sent to Operations for initial signatures. Change will be covered by a National project Signed Off by Operation sent to E&I. File to be closed after all signatures and notification will be sent to the regions. 2016-01-13 CCR Supported by CCR Committee. 2016-01-15 At CCB E&I LCM mentionned that change will be covered by a National project. CCR is Approved In Principle, Engineering OPI is Andrew de Haan.	2017-03-06 - This CCR replaces CCR 2643 (Upgrade Sperry radars to TotalWatch on MSPVs).Completed on the M.Charles and the Goddard.								
2014	2587	Major National	Urgent		Stern Quarter Reinforcement	Port and Starboard stern quarters damaged on CCGS	Mid-Shore Patrol (MSPV)	N/A	Hull and Related Structures	Mehm Tun	Central and Arctic	03/12/2014	On hold with Nav Arcs weight implications	2014-12-05: Acknowledged and registered. In process to CCR Evaluation members for signatures. 2014-12-11: Presented to CCB for discussion and returned to ME for review and subsequently return for signature to CCB or secretarial approval.	See recent issue on Teather April 16, 2015, need information from Nav Arcs and Management on way forward with this CCR. 2016-03-01 - Dave working on this. Preliminary results went to regions for consultation. Need plan approve drawings.	3352957							
2014	2989	Minor	Normal		Aft Gate Access for embarking or disembarking RHIB	The solution we have come up with is to add additional gates in the railings on the aft end of the vessel in order to come and go from the RHI in a safer manner that we are able to with the current arrangement. Attached you will find pictures of the sections to be removed in order to install new gates along with a sample picture of what we would like installed. The estimated cost of installing the gates is $1750-2200. The only difference from the sample pictures that we would like to see is that the gate simply be removable with pins instead of a hinge.	Mid-Shore Patrol (MSPV)	Aft railings	Hull and Related Structures	Alexander J. Curry	Atlantic Region	06/12/2014	Cancelled	Resubmitted nationally a year lost in regional process	Replaced by 2691								

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CCR Prioritization List for MSPVs

EKME # 3045742v1 Updated 2014/03/07 *(J. Richardson original author)*

2014	2590	Major National	Normal		Relocation of M/E and S/S start air pressure guages and M/E sensors	All of the start air pressure gauges should be relocated to a position after the isolation valves for the respective engines. The same is also true for the pressure transducers for the main engines; these too should be relocated after the isolation valves and separated so that each pressure sensor is connected to its own engine.	Mid-Shore Patrol (MSPV)	Compressed air lines and guages	Auxillary Systems	Matt Klebert	Atlantic Region	06/12/2014	Cancelled	2014-12-09: Acknowledgement: Email sent to originator to submit completed and signed CCR by approved users and Region authorities.								
2014	2591	Minor	High		Addition of Primary Sock Filters to the RO SW suctions	1. The prefilters for the RO's are expensive and we are changing them quite frequently. The solution to this problem would be to add 20-25 micron sock type filters on the suction to each RO with a crossover in between to facilitate cleaning of the filter without having to shut the unit down. Another option which may prove to be more beneficial is to have a common suction line that's large enough to accommodate both RO's with a duplex course strainer and a duplex sock filter. This may prove to maximize on the lack of space in the bow thruster compartment. 2. The boost pump for the upper RO, should be turned around on the other vessels as well so	Mid-Shore Patrol (MSPV)	Reverse osmosis water maker	Auxillary Systems	Matt Klebert	Atlantic Region	06/12/2014	Cancelled	2014-12-09: Acknowledgement: Email sent to originator to submit completed and signed CCR by approved users and Region authorities.	Replaced by 2694							

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CCR Prioritization List for MSPVs

EKME # 3045742v1 Updated 2014/03/07 *(J. Richardson original author)*

2014	2692	Major National	High		FO Tank vent and overflow system	Currently, #1, #2, and #3 Fuel tanks share a common overflow/vent line that connects to the forward port corner of #3 FO Storage Tank. The overflow/vent lines from those forward tanks have loops that extend above the deck, port side forward. These loops are solidly welded with no means to break the lines to facilitate testing of the tanks individually. In the future, when testing is required again by the Classification Society, we will have to have a means to test the individual tanks and at present, that is not possible as all of the tanks are connected together through this common vent/overflow. Note 9 of the "Air Pipes and Sounding Diagram" [illegible] that the	Mid-Shore Patrol (MSPV)	Fuel overflow system	Auxillary Systems	Matt Klebert	Atlantic Region	06/12/2014	Cancelled	2014-12-09: Acknowledgement: Email sent to originator to submit completed and signed CCR by approved users and Region authorities. 2017-06-19 - email sent to CCR cood to cancel CCR.						Resubmitted as CCR 2692 and 2693			
2014	2693	Minor	High		Ship Service Fuel System_addition of Primary fuel filters, Duplex Racor Unit	[illegible] currently have no primary means of filtration for the fuel system on the ship service diesels. The secondary filters that are fitted directly on the engine have become the only method of filtration and water separation. This arrangement has resulted in a number of "blackouts" due to the plugging of the respective filter. Suction and discharge pressure gauges were fitted on either side of the filter but these have proven to be inadequate as a tell-tale for when the filters need to be changed. When the generator shuts down on loss of fuel oil, the emergency bus momentarily dies until the Emergency Generator starts up and goes online. All of the	Mid-Shore Patrol (MSPV)	Fuel oil system	Auxillary Systems	Matt Klebert	Atlantic Region	06/12/2014	Cancelled	2014-12-09: Acknowledgement: Email sent to originator to submit completed and signed CCR by approved users and Region authorities.									

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CCR Prioritization List for MSPVs

EKME # 3045742v1 Updated 2014/03/07 *(J. Richardson original author)*

2014	2594	Minor	High		Addition of Duplex SW strainer for ship service Generators	At present, there is no means of cleaning the strainer fitted inside the Sea Water regulating valve for the auxiliary generators without having to shut it down and change over to the standby generator. This has become problematic because the filtering capability of the small mesh screen is insufficient. It takes very little debris to clog up the strainer which in turn causes the jabsco impeller sw pump to go into a vacuum state. This has the potential to damage the vanes on the impeller. There is often a frequent requirement to clean the filters due to the water the vessel may be operating in. This has become very tedious and has also subjected the strainer in the valve, as	Mid-Shore Patrol (MSPV)	Sea water system for ship service generators	Auxillary Systems	Matt Klebert	Atlantic Region	06/12/2014	Cancelled	2014-12-09: Acknowledgement: Email sent to originator to submit completed and signed CCR by approved users and Region authorities.									
2014	2595	Minor	Urgent		Secure AIS Transponder for FRC	Installation of a Secure AIS System similar to that of the offshore C&P vessels in Atlantic region, that will permit the ship to track the RHIB on AIS, yet remain undetected to any other vessels in the area that may be receiving AIS information.	Mid-Shore Patrol (MSPV)	RHIB electronics	Deck Equipment / Ship Support Systems	Fred Emeneau	Atlantic Region	06/12/2014	Acknowledged	2014-12-09: Acknowledgement: Email sent to originator to submit completed and signed CCR by approved users and Region authorities. 2016-12-05 This CCR is not a regulatory requirement. CCR is not supported by operations unless a change to regulations take place. 2017-01-24 Update: Some vessels have already installed. Dave Wyse.									

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CCR Prioritization List for MSPVs

EKME # 3045742v1 Updated 2014/03/07 *(J. Richardson original author)*

2015	2643	Major	Normal		Upgrade Sperry radars to TotalWatch on MSPVs	We are in the process of passage planning for our transit through Panama to BC. I have encountered a number of issues with trying to secure appropriate ENC coverage for the transit. 1) Our current build of Aldebaran (from 2008) does not support the Admiralty Vector Chart Service. 2) Because we could not get Vector chart coverage, I have ordered Raster Charts for the voyage. There are two problems with the raster chart coverage that we have obtained: 2.1) The majority of the charts for Central America have terrible definition and coverage. When zoomed in some of the charts are unreadable. 2.2) Aldebaran (the build we have) is not capable of	Mid-Shore Patrol (MSPV)	Sperry Radar	Vessel Communications and Navigation	Tristan Readman	Western Region	16/01/2015	Approved by CCB	2015-01-26: Missing signatures on CCR therefore cannot process. Email sent to Region to complete and return. 2015-02-11, Received CCR Form Approved by Region, document are Routed to CCR Committee (Operation) for Review/Support. 2015-07-22 CCR Committee review the file, Dave Wyse MSPV Class Officer will investigate tofind if equipemnt already bought, CCR will have an impact with other projects and file was sent to Benoit Guyon Manger Ship E&I. 2016-07-22 Update from Region: Waiting for NHQ decision. 2017-01-26 CCR Supported by CCR Committee, Work has been completed on the Captain Goddard and M. Charles for transiting to Western, and will continue on the remaining MSPV's under the Radar-ECDIS project. A. de Haan, Supported for the Class LM. 2017-01-27 CCR Approved In Principle, and to be closed. Action: NCCRC to get CCR form section 10 completed by originator to close CCR..Benoit Guyon to transmit WO number to NCCRC. 2017-02-16 CCR completed and Closed.	2017-01-18: E&I has found a procurement method for the other vessels. Routed to Ops. (2 vessels on west coast had installed for transit - all that is required is dongle as equipment installed can perform this function.) 2017-03-06 - This CCR is replaced by CCR 2567 for the rest of the MSPVs.	3389524, 3390641							
2015	2647	Major National			Modification compartiment à batterie devant timonerie	Le compartiment utilisé pour le rangement des batteries d'urgences est très grand et ne contient que 4 batteries. Le compartiment est situé sur le devant de la timonerie avec un accès par deux écoutilles extérieurs. Le compartiment est muni d'une entré d'aire et de deux sorties. Il est de plus muni d'une élément chauffant. Le navire ne dispose pas de rangement pour l'entreposage des boyaux et de l'équipement utilisé pour les ravitaillement en eau potable. Selon la procedure 7.A.12 Qualité de l'eau Potable du manuel de sécurité de la flotte, les boyaux utilisé pour l'eau potable doivent être purgés,	Mid-Shore Patrol (MSPV)	Hull and Related Structures		Rene Hardy	Central and Arctic	07/07/1905	Approved in Principle	2015-02-09: Acknowledged and waiting for Region to submit completed and signed CCR to create the file and start the CCR process. 2015-02-12: Routed to CCR for signatures. 2015-07-22 CCR Committee review the file, Dave Wyse MSPV Class Officer will investigate to update CCR Status. 2016-01-07, This CCR pertains to a vessel that has been deemed to be managed as a vessel class. Therefore this CCR has been escalated to a major national. This CCR is supported by operations. 2016-02-23 CCR Supported by CCR Committee, Status raised to Major National (MSPV Class), CCR sent to CCB for Approval. 2016-03-07, CCR Approved In Principal by CCB Engineering OPI is Dave Wyse.	2017-03-01-Gabe found smaller batteries that can save 1000lbs, 10K to install, same chargers can be used. They are Lithium iron phosphate.							

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CCR Prioritization List for MSPVs

EKME # 3045742v1 Updated 2014/03/07 *(J. Richardson original author)*

2015	2649	Major National	High	Risk Assessment - Transformers - Mitigation Plan	Implement mitigation plan as it relates the the Risk Assessment - Transformers	1 pilot vessel 1. Change location of the emergency generator fuel tank vent to outside 2. Metal protective shields around transformers 3. Addition of ground fault monitoring capabilities 4. Move discharge for inline drains from duct work in AmR 5. Install heat trace on hatches 6. Replace battery boxes in emergency gen room with proper type 7. Installation of burst pipe protection on certain pipes	Mid-Shore Patrol (MSPV)	Electrical Power Distribution	Various	Chris Dort	NCR	18/02/2015	Approved in Principle	2015-02-19: Routed to CCR Cmte for approval/signatures. 2015-02-02 CCR supported by CCR Committee, note added to file from RME engineering: " From Hull perspective the weigh is the only issue, estimated to 450 lb.", this modification will reduce the actual margin. Technically it looks all right. 2015-03-13 CCR is Supported by CCB Secretariatly.	2017-03-01-Atlantic region has done all except #3. Dave will get info (from Atlantic?) and send to Isabelle.	3434971	Navires / Vessel		2649	19/02/2015	02/03/2015	
2014	2690	Minor	High		Addition of Duplex SW strainer for ship service Generators	At present, there is no means of cleaning the strainer fitted inside the Sea Water regulating valve for the auxiliary generators without having to shut it down and change over to the standby generator. This has become problematic because the filtering capability of the small mesh screen is insufficient. It takes very little debris to clog up the strainer which in turn causes the jabsco impeller sw pump to go into a vacuum state. This has the potential to damage the vanes on the impeller. There is often a frequent requirement to clean the filters due to the water the vessel may be operating in. This has become very tedious and has also subjected the strainer in the valve, as	Mid-Shore Patrol (MSPV)	Sea water system for ship service generators	Auxillary Systems	Dave Wyse	NCR		Approved by CCB	2015-04-07: Ack. CCR Registration. Email sent to Originator: If CCR not already done, Please submit Form when Completed and Signed (Approved by Users and Authorities). 2015-04-09 Supported by CCR Committee. 2015-04-10 CCR is Approved in Principle, This CCR will replace CCR 2559 raised by Québec Region. Note from HME, Marine Engineer: The MSPV group will decide how the parts will be sourced and a vessel will have the installation done. The installation instructions and equipment details will then be delivered to the rest of the class to be installed. The Engineering OPI will then ensure the completion of the CCR and any drawings that need to be changed.	Resubmitted nationally as was lost in regional process Contract is in the technical evaluation stage 2017-03-01-Peddle and Mclaren will implement winter 2016-2017.							

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CCR Prioritization List for MSPVs

EKME # 3045742v1 Updated 2014/03/07 *(J. Richardson original author)*

2015	2691	Major	Normal		Aft Gate Access for embarking or disembarking RHIB	The solution we have come up with is to add additional gates in the railings on the aft end of the vessel in order to come and go from the RHI in a safer manner that we are able to with the current arrangement	Mid-Shore Patrol (MSPV)	Aft railings	Hull and Related Structures	Dave Wyse	NCR		Approved by CCB	2015-04-07: Ack. CCR Registration. Email sent to Originator: If CCR not already done, Please submit Form when Completed and Signed (Approved by Users and Authorities). 2015-04-09 Supported by CCR Committee. 2015-04-10 CCR is Approved in Principle for MSPV Class. Notes from Ops and Engineering stakeholders will be added to EKME file. Note from HME, Marine Engineer: The G. Peddle is to champion this change and give the rest	Resubmitted nationally as was lost in regional process								
2015	2692	Major National	High		FO Tank vents removable sections	Currently, #1, #2, and #3 Fuel tanks share a common overflow/vent line that connects to the forward port corner of #9 FO Storage Tank. The overflow/vent lines from those forward tanks have loops that extend above the deck, port side forward. These loops are solidly welded with no means to break the lines to facilitate testing of the tanks individually. In the future, when testing is required again by the Classification Society, we will have to have a means to test the individual tanks and at present, that is not possible as all of the tanks are connected together through this common vent/overflow. Note 9 of the "Air Pipes and Sounding Diagram" stipulates that the	Mid-Shore Patrol (MSPV)	Fuel overflow system	Auxillary Systems	Dave Wyse	NCR	05/12/2014	Approved by CCB	2015-04-07: Ack. CCR Registration. Email sent to Originator: If CCR not already done, Please submit Form when Completed and Signed (Approved by Users and Authorities). 2015-04-09 Supported by CCR Committee. 2015-04-10 CCR is Approved in Principle for MSPV Class. Note from HME, Marine Engineer: A naval architect will design and create a drawing and statement of work for the vent removable sections. The design and installation instruction will then be distributed to VMM's for implementation. Engineering OPI to follow up on drawings and installation.	Resubmitted nationally as was lost in regional process Spec and drawings sent to have implemented. Lloyds can approve locally								

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CCR Prioritization List for MSPVs

EKME # 3045742v1 Updated 2014/03/07 *(J. Richardson original author)*

2015	2693	Major National	High		#9 Fuel Oil Tank reconfiguration	The air vent for #9 FO tank is located at the forward port corner of the tank. #9 FO Tank is stepped and the vent is located at the lowest point of the tank top. This arrangement prohibits the complete filling of the tank since the higher part of the tank effectively becomes air locked. If fuel is still being pumped into #9 when the common vent/overflow line for #1, #2, #3 FO Tanks is blocked, there is a potential to pressurize those forward tanks. This will result in false high level alarms in all of the forward tanks since the Tank Level Indication System works off pressure sensors. The resulting alarms can cause confusion for	Mid-Shore Patrol (MSPV)	Fuel overflow system	Auxillary Systems	Dave Wyse	NCR		Approved by CCB	2015-04-07: Ack. CCR Registration. Email sent to Originator. If CCR not already done, Please submit Form when Completed and Signed (Approved by Users and Authorities). 2015-04-09 Supported by CCR Committee. 2015-04-10 CCR is Approved in Principle for MSPV Class. Note from HME, Marine Engineer: A naval architect will design and create a drawing and statement of work for the vent removable sections. The design and installation instruction will then be distributed to VMM's for implementation. Engineering OPI to follow up on drawings and installation.	Resubmitted nationally as was lost in regional process Spec and drawings sent to have implemented. Lloyds can approve locally. 2017-03-01- Great Lakes getting winter 2016-2017. Western piping too heavy.							
2015	2694	Major	High		Addition of Primary Sock Filters to the RO SW suctions	1. The premiers for the RO's are expensive and we are changing them quite frequently. The solution to this problem would be to add 20-25 micron sock type filters on the suction to each RO with a crossover in between to facilitate cleaning of the filter without having to shut the unit down. Another option which may prove to be more beneficial is to have a common suction line that's large enough to accommodate both RO's with a duplex course strainer and a duplex sock filter. This may prove to maximize on the lack of space in the bow thruster compartment. 2. The boost pump for the upper RO, should be turned around on the other vessels as well s	Mid-Shore Patrol (MSPV)	Reverse osmosis water maker	Auxillary Systems	Matt Klebert	Atlantic Region	06/12/2014	Approved by CCB	2014-12-09: Acknowledgement: Email sent to originator to submit completed and signed CCR by approved users and Region authorities. 2015-04-09 Supported by CCR Committee. 2015-04-10 CCR is Approved in Principle for MSPV Class. Note from HME, Marine Engineer: Engineering OPI to follow up that installations were performed and that any drawings are updated.						Resubmitted due to loss regionally		

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2015	2696	Major	High	Both	Potable water UV sterilizer replacement	The Ultra-Violet (UV) sterilizers supplied with the MSPVs have proven to be unreliable and expensive to maintain. Several vessels in the class have already experienced issues with abnormally low intensity readings, despite	Mid-Shore Patrol (MSPV)	Domestic Systems	UV sterilizer	David Wyse	NCR	15/04/2015	Approved in Principle	2015-04-16: Ack. CCR Registration. CCR sent to CCR Committee for Rev/Support.. 2015-05-11 Supported by CSR Committee. 2012-06-12 CCR Approved in Principle by CCB, OPI David Wyse. Waiting for trial information from the M. Charles - implementation went well	2017-03-01 - Need a special tool to remove the crystal otherwise it breaks.	3458956, 3458977							
2015	2697	Minor	High	CP variant	MSPV FRC Crab Pot Hauler Installation	C & P has the requirement to haul / check recreational crab & prawn gear from the FRC. FRC has no means at present other than pulling the gear by hand, the vessel has size & draft restrictions trying to get to many of the recreational gear.Install a 12 volt crab pot hauler similar to what is currently used on CCGS Gordon Reid's FRC. Shawn Tibbs - Inflatable Craft Maintenance Shop Manager has full specs and scope of work required to install the crab pot hauler.	17	Deck MAchinery	SC	Bob Bennet	Deck Equipment / Ship Support Systems	Crab Pot Hauler	Approved in Principle	Waiting for OEM information. 2015-04-07: Ack. CCR Registration. Email sent to Originator: Please submit Form Signed (Approved by Users and Authorities)... 2016-09-09 CCR Supported by Committee, sent to CCB for Approval. 2016-09-13 Approved in Principle by CCB. / Approuvée pour le principe par le CCC. OPI/BPR: David Wyse. Operation recommend to approved for Western Region only, waiting for other Region to manifest if needed. / Les opérations recommande d'approuver pour la région de l'ouest seulement et d'attendre que les autres régions le demande, si besoin est. 2017-01-24 Update: Some vessels had installed without CCR, Dave Wyse.	2017-03-01-Atlantic will not implement.	3458698						Western Region
2015	2699	Major National	Urgent		Hero Class Water Fire Main Piping Replacement	Existing Condition: Currently 8 out of the 9 hero class vessels have stainless piping in the water extinguishing fire system.. The incident reports and failure analysis have shown that the stainless steel piping is corroding and allowing water to leak. See attached reports. Recommended Solution: 1. 2 vessels in the C&A region have had a boroscope inspection of the piping. The vessels in the Atlantic region will then be inspected and a priority list for a solution to be implemented will be formed. 2. An engineering study must be done to create a solution for the replacement of the piping (material, piping, class approved drawings,	100	Fixed fire fighting system	MSPV	Dave Wyse			Approved in Principle	2015-04-24, Received CCR Form completed, DB updated to reflect CCR Form, document routed to CCR Committe for Review/Support. 2015-05-13 CCR Supported by CCR committee. 2012-06-12 CCR Approved in Principle by CCB, OPI David Wyse. 2017 01-24 System replacement before common solution, Dave Wyse.	Final solution to be determined by senior management. The decision has been finalised. Three phase solution to be implemented.							NCR

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2015	2700	Major	Normal		MSPV RHIB Wireless Intercoms	Currently, communication on board a Rigid Hull Inflatable Boat (RHIB) traveling at speed is very challenging. Wind and engine noise force boat operators to have VHF radios turned to MAX volume, and any communication between boat operators is done through shoulder taps and hand signals. Taking these safety issues into consideration and combining that with increased operational / program requirements, wireless headset communications is necessary aboard the RHIB's paired with the MSPV's. Install David Clarke wireless headset communication system, standard to Western Region SAR RHIB's.	Small Craft (SC)	18B02B07	Wireless Headsets, Vessel Communications and Navigation	Adam Cochrane			Approved in Principle	2015-04-24, Acknowledgement: CCR forms need to be completed, signed and forwarded to HQ. 2015-06-10 CCR Routed to Operation to Rev/ Support. 2015-07-22 CCR Committee review the file, Dave Wyse Engineering Officer will investigate to update CCR Status. 2015-10-14 Not Supported by Operations. This CCR indicates an improvement and/or a modification to gain efficiency in operations but is not bound by regulatory or program requirements. CCR is not supported by operations unless a change to regulations takes place. 2015-10-28 After review CCR is supported by OPS Sent to Tech. Authority Rod Pike for Rev./Support. Supported by Rod sent to Dave Wyse.2016-01-06 CCR Supported by Committee, sent to CCB for Approval. 2016-03-07 Discussion at CCB regarding operational requirements for this vessel class, CCR deferred. Marc Mes to investigate Operational Requirements and to respond to CCB. 2016-04-08 CCR is Approved in Principle for MSPV, RHIBS only. / Approuvée pour le Principe, seulement pour les PSH, RHIBS. Engineering OPI / BPR Ingénierie: Andrew deHaan. 2016-12-06 Update from Operations: David Clark Wireless Headsets – Proceed with generating a Major National CCR to implement on 47' and MSPV class vessels and associated RHIB's. 2017-01-24 Some vessels had solution implement before CCR, Dave	adam.cochrane@dfo-mpo.gc.ca	250-419-2853	Gabriel Chaikin	Gabriel.Chaikin@dfo-mpo.gc.ca	250-363-0228	2017-03-13 - Atlantic just received info from Western region. Atlantic will put this CCR in their refit plan for next year and will start engineering work.		
2015	2701	Major National	Normal		Hero Class Crane ram design change and remote control changes	Shorten the crane cylinder RAM to be able to engage the RHIB in the cradle. Belly pack remote controls do not allow for booming in and out simultaneously hoisting or lowering the crane. This function is required for safe operations with the crane. This must be rectified with the manufacturer. An engineering study must first be done to develop solutions and a prototype for the class. Existing Condition: 1. Currently the cranes on board the Hero Class vessels do not have enough veitical movement to reach the lifting hooks on the RHIB(s) while they are sitting the in the cradle. 2. The cranes cannot be	Mid-Shore Patrol (MSPV)	Deck Equipment / Ship Support Systems	Hydraulic Crane	David Wyse	david.wyse@dfo-mpo.gc.ca	993-2710	Approved in Principle	2015-04-24, CCR registered by LCM HQ, document routed to CCR Committe for Review/Support. 2015-05-13 CCR Supported by CCR committee. 2012-06-12 CCR Approved for Engineering- Prototype by CCB, OPI David Wyse. 2016-05-04 Update from OPI (detail on EKME 3612546). The first step would be to purchase one new lift cylinder P/N 77875, cost 13,135.72 US$. Specification document from ALLSWATER available in EKME: 3612546. Estimate lead-time after receipt of order (10) weeks. CCR is sent to next CCB to inform members and proceed with phase 2. 2016-05-16 Approved in Principle / Approuvée pour le Principe.	Engineering contractor working on a solution. 2017-02-10 Engineering solution to be implemented.				NCR	24/04/2015	Acknowledged	2015-04-24, CCR registered by LCM HQ, document routed to CCR Committe for Review/Support.

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2015	2702	Minor	High		Ship Service Fuel System_addition of Primary fuel filters, Duplex Racor Unit	We currently have no primary means of filtration for the fuel system on the ship service diesels. The secondary filters that are fitted directly on the engine have become the only method of filtration and water separation. This arrangement has resulted in a number of "blackouts" due to the plugging of the respective filter. Suction and discharge pressure gauges were fitted on either side of the filter but these have proven to be inadequate as a tell-tale for when the filters need to be changed. When the generator shuts down on loss of fuel oil, the emergency bus momentarily dies until the Emergency Generator starts up and goes online. All of the	Mid-Shore Patrol (MSPV)	Fuel oil system	Auxillary Systems	Dave Wyse	NCR		Approved in Principle	Resubmitted nationally as was lost in regional process	2017-03-01-Require one for each generator. Amend CCR for two systems.							
	2703	Major National	High		MSPV Techsol A&M HMI Screen Install	EXISTING CONDITIONS:There is no Techsol Alarm and Monitoring Human Machine Interface (HMI) screen in Cabin 209 where the Senior Engineer will occupy if the Engine Room is going to be operating in Unmanned Machinery Space (UMS) mode and working 0700-1900 or if gender confliction requires the Senior Engineer to occupy that Cabin. RECOMMENDED SOLUTION: Install Techsol Alarm and Monitoring HMI in Cabin 209 and have the Senior Engineer occupy that cabin. Require Cat 5 Cable from PC #A. Require 24V DC power supply from UPS-B. Require 15" Seaview HMI screen.	Mid-Shore Patrol (MSPV)	Integrated Control Systems	Techsol Alarm and Monitoring	M.Charles Chief Engineer	Western Region	42122	Approved in Principle	2015-05-05, Ack. CCR Registration, form available on EKME #3463568. Status changed to Major National, could be Applicable to MSPV Class. Waiting for Regional Approval to process.	2017-03-01- Western region will not implement.		Navires / Vessel		NGR	24/04/2015	Supported by ACM and CCR Committee	2015-04-24, Ack. CCR Registration. CCR sent to CCR Committee for Rev/Support.

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2015	2709	Major National	High		Install Maximo on MSPVs	MSPV's require an asset management system to be installed on ship servers to provide a comprehensive maintenance solution. As per the CCG commissioners guidelines, the AMS to be used on CCG vessels is to be Maximo.	Mid-Shore Patrol (MSPV)	Informatics Systems (IT)	N/A	Jordan Dinn	NCR	13/05/2015	Approved in Principle	2015-05-13, Ack. CCR Registration, CCR Form available on EKME:#3471724. Routed to CCR Committee (Operations) for Rev./Support. 2015-05-21 CCR Supported by CCR Committee and Routed to CCB for Approval, next CCB meeting June 12th. Engineering OPI at HQ is Jordan Dinn supported by Regional VMM.	2017-05-17-Closed. No drawings to update.	3471724						
	2712	Major National	Normal		Hero Class (MSPV) Navigation information in CO cabin/office	The new video collection/switching equipment and spare outputs already provides the basic capability. All that is required is a single cable run from the Operations Room cabinet to the Commanding Officers cabin. The cable distance may require a VGA to Ethernet converter.	Mid-Shore Patrol (MSPV)	Vessel Communications and Navigation	Navigation video collection	David Wyse		27/05/2015	Approved in Principle	2015-05-29, Ack. CCR Registration, CCR Form and documentations available on EKME:#3477522, 3477524, 3477525. Documents Routed to CCR Committee (Ops.) for Rev./Support.	2017-03-01 - Keep original request or follow-up with SSI to see if info could be put on a tablet.	3477522, 3477524, 3477525						
	2713	Major National	Normal	Both	Hero Class (MSPV) Automatic Chlorination system	install in-line sanitation system between the ROs and the fresh water tanks. The system comprises mainly of a flow meter (to monitor the amount of water being sent from the ROs to the tanks), a dosing controller and pump (to analyze the volume of water produced, according to the flow meter, and add the appropriate amount of chlorine), and a static mixer to distribute the chlorine (this is a length of plastic pipe with baffles inside to promote turbulence. It is installed in the RO product water line)	Mid-Shore Patrol (MSPV)	Domestic Systems	Chlorinator	David Wyse		27/05/2015	Approved in Principle	2015-05-29, Ack. CCR Registration, CCR Form available on EKME:#, Routed to CCR Committee (Ops.) for Rev./Support.		3477533, 3477534						

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2015	2737	Major National	High		Hero Class General and Fire Alarm Tones	The General and Fire alarms aboard the Hero Class vessels are two different tones. Ships officers and crew do not believe the general alarm has the minimum sound pressure levels to alert crew. The General and Fire alarms should be the same tone and ensure that the desibel levels meet requirements as per the Life Saving Appliances code and to satisfaction of the Commanding Officer. Merged with CCR 2400 - The present telephone communication system is not equipped with the Night Bells feature. When in port duty personnel are required to carry out Fire and Security rounds. If the vessel is on SAR standby duty personnel must be	Mid-Shore Patrol (MSPV)	Safety and Security Equipment	Fire and General alarm bells	David Wyse	NCR	14/07/2015	Approved in Principle	2015-07-14, Ack. CCR Registration, request raised by HQ OPI David Wyse. CCR is Routed to Operation for Rev./Support.		8555358						
2015	2755	Major	Urgent	C&P	MSPV Hinged Gate installation	Insert a gated section in the vessels main deck railing adjacent to the line hauler. This will allow a section of the railing to be secured outboard. The deck crew will be able to land traps and line aboard without having to lift them over the deck rail.	Mi. Charles	Railings					Approved in Principle	2015-07-28, Ack. CCR Registration, CCR Form Section 1 to 6 should be completed and Signed by Regional Authorities, then returned to National CCR Committee for Rev./Support. 2015-12-22 Update from Region: Make opening in railing wide enough to be a gangway access, Status raised to Urgent, CCR is Supported by Region. Document are Routed to Operation for Rev. / Support. 2015-12-23 Operation suggests that CCR modification be applicable only to C&P MSPV (5). 2016-07-22 Update from Region: Waiting for NHQ decision. 2016-07-28 CCR Supported by CCR Committee, Solution to be applied to only the 5 Conservation and Protection MSPVs, CCR sent to CCB. 2016-10-07, CCR Approved in Principle, Modification for MSPV 5 C&P vessels only, not for entire Class.		8507408						
2015	2775	Major National	High		Hydraulic bow thruster damper	on the bow thruster damper module to slow down the valve on the closing motion. This will help to stop hydraulic hammer on the Bow Thruster hydraulic							Approved in Principle	Parts to be sent to all vessels									
2015	2776	Major National	High	Both	Bilge drainage for Hero Class	Install limber holes for proper drainage in the outboard girders that support the main engines.							Approved in Principle	Spec and drawings sent to vessels. Lloyds has given us the go ahead									

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2015	2792	Major National	Normal	Both	Hero Class (MSPV) New Cellular Repeaters instal'n	Install signal boosters on board for mobile phones. Hardware would consist of three wired components: 1) External antenna 2) Booster 3) Three indoor antennae located in the following areas a) On the main deck in the vicinity of the senior officers cabin/office areas. b) On the lower deck, aft in the vicinity of the MCR and c) on the lower deck forward outside the LEO cabins. Hardware cost estimate $1500.00.	16B03	Portable radio telephones	Communications Systems (Comms)			Cellular telephone signal booster	Approved in Principle	Routed to Operation	2015-09-22, Received CCR Form completed, document are Routed to Operation for Rev. / Support. This CCR will cover scope of work of CCR 2716 (Cancelled).	3853801						
2015	2798	Major National	Normal	Both	Hero Class (MSPV) Rope Locker ventilation	The compartment located on the forward, starboard end of the superstructure, adjacent to the HVAC compartment is not ventilated. On the Constable Carriere, this compartment is used to store mooring lines and other deck gear. Mold easily grows in this compartment due to the zero air flow. This poses a health hazard for the crew and has been brought up by the vessel's MOSH committee. It also prevents any damp lines or deck gear from drying properly. The wet gear locker is used in a similar way and is equipped with a supply inlet and exhaust outlet with an in-line fan. The addition of an intake line and an	11J05	Deckhockers	Hull and Related Structures			Rope Locker	Approved in Principle	Waiting for final spec and drawings to send out. 2017-02-13 - regions have the spec. 2017-03-01 - One fan was added on the Great Lake vessels.	2015-07-29, Received CCR Form Supported by Region (Signed Section 6), document are Routed to Operation for Rev. / Support. After support this Major CCR will be sent to CCB for Approval, next meeting October 2, 2015-10-01 CCR Supported by CCR Committee.	3853840						
2015	2797	Major National	High	Both	Pumps power supply reconfiguration	Request for engineering study to connect the following pumps to Emergency Switch Board supply: CCP P3 pump x 2, MMR Bilge/Fire pump x 1, Sea Water Cooling pump x 1.			Propulsion/ Maneuvering Systems			pitch control, bilge and sea water cooling (stern tube) pump	Approved for Engineering/Prototype	Waiting on Lloyds approval. 2017-02-13 - Has been approved by Lloyds and spec sent to the regions.	2015-09-29, Ack. CCR Registration, CCR Form Section 1 to 5 should be completed, Section 6: Signed by Regional Authorities, then returned to National CCR Committee for Rev./Support. 2015-09-30 Routed to Operations for Rev/Support. 2015-10-01 CCR Supported by CCR Committee, Sent to CCB for Approval.	3531518	william.falconer@dfo-mpo.gc.ca	902-440-6231				

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2015	2802	Major	High	Both	CCGS Goddard Install Techsol Alarm Beacon's in BT and SG	Currently there is no Techsol CCAM Alarm indication in the Bow Thruster Compartment or the Steering Flat. This prevents the Engineering Officers from being notified of triggered alarms on our Alarm and Monitoring System when working in these spaces as the Alarm Horn is not audible in these compartments. Recommended Solution: Install rotating amber alarm beacon in the Bow Thruster and Steering Gear Compartments to allow the Engineers to be aware of triggered alarms on Techsol CCAM's when working in these spaces. Mat?l: - Vitalite 121A-024A Rotating light, 24VDC, surface mount, amber, - A cable between the	CAPTAIN GODDARD M.S.M.	Integrated Control Systems	Alarm Beacon Rotating Light	Simon Williamson		08/10/2015	Approved in Principle	2015-10-09, Ack. CCR Registration, CCR Form Section 1 to 5 should be completed, Section 6: Signed by Regional Authorities, then returned to National CCR Committee for Rev./Support. 2015-12-22 Received CCR form Supported by Region, Document Routed to Operation to Rev. / Support. 2016-07-22 Update from Region: Waiting for NHQ decision. 2016-10-06 Supported by CCR Committee. If similar conditions exist on other vessels in class, this CCR shall be utilized. Operation. 2016-10-07 CCR Approved in Principle for MSPV Class. OPI/BPR: David Wyse.	2017-03-01 - Might be done this year on Great Lake vessels.	2532					
2015	2818	Minor	Urgent	Both	Installation of E-Stops on Deck Hydraulics	Existing Conditions: Currently none of the deck hydraulics on board have a local emergency stop. Should there be a failure the only emergency stop is located on the bridge and in the Main Machinery Room (MMR) at the Hydraulic Power Unit (HPU). Recommended Solution: Install an emergency stop on the main crane pedestal which will shut off the main crane and fishing gear hydraulics. A new wire transit will need to be welded onto the main deck at the base of the crane. Install an emergency stop at the tow reel / aft capstan operators station. There is an existing Roxteck transit here. No welding required. Install an	DWG 84000021 MSPC Electrical System Diagram.	17 Windlass, Main Crane, Capstan, Tow Reel, Fishing Gear	Deck Equipment	MSPV	CAPTAIN GODDARD M.S.M.	Deck Equipment / Ship Support Systems	On hold	Ben Axmann 2015-12-02, Ack. CCR Registration, CCR Form Section 1 to 5 should be completed, Section 6: Signed by Regional Authorities, then returned to National CCR Committee for Rev./Support. 2016-02-19 CCR Scope raised to Major National will be applicable for MSPV Class. Received CCR Form Supported by Region, document Routed to Operation for Rev./support. 2016-03-09 CCR put on Hold by CCR committee, Mechanic Engineer David Wyse and is team are already evaluating new E-Stop button to stop equipment. 2016-07-22 Update from Region: Waiting for NHQ decision.	2017-03-01 - Charles and Goddard done on the crane.						

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2015	2820	Minor	High	Both	Power Supply for Emerg. Generator Control and Battery Monitor	Existing conditions: There is no indication of the current voltage of the start batteries, the only indication that they may be charged is the green LED on the battery charger, indicating that it is on and not outputting current, there is no low voltage alarm on CCAM's for the Emergency Generator control batteries. Recommended Solution: Install 30A battery monitoring module similar to what we have on UPS A and UPS B, refer to attached pic. For this we will have to add a cable between the generator?s battery and the AM01 panel, add TMH02 modules, add point in the HMI and set the alarm, so in the event of low voltage an	CAPTAIN GODDARD M.S.M.	Power Systems	Emergency Generator Control System and Batteries	Simon Williamson	goddard-Chiefengineer@gcd.ccgs.ngcc.ca		Approved in Principle	2015-12-03, Ack. CCR Registration, Received CCR Form Completed/Signed, CCR Routed to Operation for Rev./Support. 2016-05-13 CCR Scope raised to Major National. CCR will be applicable for MSPV Class. CCR Routed to Operation to Rev./Support. 2016-05-13 CCR Supported by CCR Committee, sent to CCB for Approval. 2016-05-16 CCR Approved in Principle /Engineeringing OPI : Dave Wyse.		SSSSSS				2015-12-03, Ack. CCR Registration, Received CCR Form Completed/ Signed, CCR Routed to Operation for Rev./Suppor t.		
2015	2834	Major National	Normal	Both	Ship service generator fuel oil pressure indicators Hero Class	Install local fuel oil pressure gauges to the Ship service generators. Install remote fuel oil pressure indication and alarm points into the alarm and monitoring system.				David Wyse			Approved in Principle	2015-11-12, Ack. CCR Registration, CCR 2434 is cancelled and will be replace by this CCR. On reception CCR Form completed will be Routed to CCR Committee for Rev./Support. 2016-02-22 CCR Supported by CCR Committee, sent to CCB for Approval. 2016-03-07, Engineering OPI: Dave Wyse, CCR Approved in Principle by CCB.									
2015	2825	Major National	Normal	Both	Hero Class engine room camera rearrangement and addition	Rearrange existing cameras and add an additional third camera to the engine room space to improve visibility. The Hero Class engine room is classified as an unmanned space.		CCTV Camera System		David Wyse		10/12/2015	Approved in Principle	2015-12-03, Ack. CCR Registration, CCR Form Section 1 to 5 should be completed. 2015-12-14 CCR Form Routed to Operation for Rev./Support. 2016-01-22 CCR Committee is waiting for guidance on CCTV camera policy and requirements. On January 20th Deirdra Finn provided an update:" The draft almost ready to go, anticipating final answer to be ready within a few weeks". 2016-02-25, As per recommendation of Director Health and Safety, this CCR does not require a legal opinion to be implemented. CCR Supported by CCR Committee, sent to CCB for Approval. 2016-03-16, CCR Deferred by CCB, Get legal Opinion and Bring forward to next meeting. 2016-03-17, Update from Director Health and Safety, This CCR doesn't require a legal opinion from Safety Security, Engineering OPI is Dave Wyse, CCR can be Approved in Principle by CCB. 2016-03-17 Approved in Principle Secretarially.	2017-03-01 - Pre-wired for the St. Lawrence and Great Lakes Vessels.								

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2015	2826	Major National	Normal	Both	Relocation of M/E and S/S start air pressure guages and M/E	All of the start air pressure gauges should be relocated to a position after the isolation valves for the respective engines. The same is also true for the pressure transducers for the main engines; these too should be relocated after the isolation valves and separated so that each pressure sensor is connected to its own engine.		Start air gauges		David Wyse		10/12/2015	Approved in Principle	2015-12-03, Ack. CCR Registration, This CCR is replacing CCR 2590, CCR Form Section 1 to 5 should be completed, then returned to National CCR Committee for Rev./Support. 2016-02-22 CCR Supported by CCR Committee, sent to CCB for Approval. 2016-03-07, Engineering OPI is Dave Wyse CCR is Approved in Principle by CCB.									
2015	2829	Major National	Normal	Both	Install drain to ship side on forward flush escape hatches	The flush design of these hatches and the inability to drain off the water is contributing to increased maintenance inside the space due moisture and corrosion, and a safety risk due to freezing and inaccessibility during the winter. The hatches are designed with a drain, but the shipyard capped this pipe and there was no contractual requirement to connect it. We are proposing to connect the existing 1-1/4 NPT drain valve on the underside of the hatch drain line to a new shell penetration above the waterline.		Hatches				18/12/2015	Approved in Principle	2015-12-18, Ack. CCR Registration, Received CCR Form completed, Document Routed to Operation for Rev./Support. 2015-12-23 Agree with work to be done. Once solution is identified it should be applied to all 9 MSPV's. JRM. CCR Supported by CCR Committee. 2016-01-15 CCR is Approved in Principle, Engineering OPI David Wyse.									

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EKME # 3045742v1 Updated 2014/03/07 *(J. Richardson original author)*

2015	2830	Major National	Normal	Both	Install isolation valve for ME manual priming pump	here are no isolation valves between the day tank and the port or starboard main engine fuel oil manual priming pumps. In the event of a failure of the diaphragm inside the manual hand priming pump, there is presently no means to isolate the pump to make repairs unless the main engine supply valve is closed at the day tank. We are proposing to insert a shutoff valve on the supply side of each manual priming pump. There is room to modify the existing DN15 piping to insert a new DN15 bronze globe valve complete with compression fittings and seals below the manual priming pump in front of each main engine.		Fuel oil system				18/12/2015	Routed HME Engineering	2015-12-18, Ack. CCR Registration, Received CCR Form completed, Document Routed to Operation for Rev./Support. 2015-12-18 Supported by Operations, sent to ME Davis Wyse for Signature. 2016-02-22 CCR Supported by CCR Committee, on list for next CCB for Approval. 2016-03-07, Engineering OPI is Dave Wyse CCR is Approved in Principle by CCB.									
2015	2831	Major National	Normal	Both	Stern draft marks on Hero Class	The stern draft markings are on the port and starboard aft quarter. Due to the hight of most docks that we secure at it is almost impossible to read the after draft marks when we are dockside. Add another set of draft marks on the transom.		Draft marks				18/12/2015	Approved in Principle	2015-12-18, Ack. CCR Registration, Received CCR Form completed, Document Routed to Operation for Rev./Support. 2015-12-23 CCR Supported by CCR Committee, 2016-01-15 CCR is Approved in Principle, Engineering OPI David Wyse.	Vladykov has done something similar, must be Lloyds approved during implementation							
2015	2833	Major National	Normal	Both	Hero Class HVAC condensing receiver	The receivers installed on the HVAC system do not have a safety margin for increases of pressure in the system which have caused refrigerant discharges. A new receiver and safety valve are required for this type of refrigerant and system with a greater safe working pressure.		HVAC unit				04/01/2016	Acknowledged	2016-01-05, Ack. CCR Registration, CCR Form Section 1 to 5 should be completed, Section 6: Signed by Regional Authorities, then returned to National CCR Committee for Rev./Support. 2017-01-24 Implemented before CCR (none), Dave Wyse.								

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CCR Prioritization List for MSPVs

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2015	2850	Major National	Normal	Both	Hero Class flooring replacement	Replacement of the vessel linoleum flooring on an as required basis. Hero Class linoleum flooring is cracking and bubbling on every vessel. New marine flooring and sub floor will be trialed and if successful will be installed on the Hero Class vessels when required.							Approved in Principle	2016-02-24, Ack. CCR Registration, CCR Form Section 1 to 5 should be completed, Section 6: Signed by Regional Authorities, then returned to National CCR Committee for Rev./Support. 2016-02-26 CCR Form and supporting documentation are Routed to Operation to Rev./Support. 2016-03-08 CCR Supported by CCR Committee will be sent to CCB for Approval. 2016-04-08 CCR Approved in Principle by CCB /. Engineering OPI.: Dave Wyse.	2017-03-01 - Ongoing. Not working on the Kaeble.							
2015	2851	Major National	Normal	Both	Hero Class HVAC controllers	he HVAC controller aboard the CCGS A. Leblanc has been deemed by the OEM Bronswerk to be unserviceable and is not supported by the OEM anymore. A new controller is required.							Approved in Principle	2016-02-23, Ack. CCR Registration, CCR Form Section 1 to 5 should be completed, Section 6: Signed by Regional Authorities, then returned to National CCR Committee for Rev./Support. 2016-02-26 CCR Form and supporting documentation are Routed to Operation to Rev./Support. 2016-03-08 CCR Supported by CCR Committee will be sent to CCB for Approval. 2016-04-08 CCR Approved in Principle by CCB /. Engineering OPI: Dave Wyse.	2017-03-01 - When fails will be replaced on other vessels. CCR will stay open.							
2016	2852	Major National	High		Performance Fuel Management System	Consists of fuel metering on supply and return lines on each main engine and ship generator. Fuel computer installed in MCR and repeaters in								2016-02-26, Ack. CCR Registration, CCR Form Section 1 to 5 should be completed, Section 6: Signed by Regional Authorities, then returned to National CCR Committee for Rev./Support.		3585145 (Folder), 3585154						
2016	2860	Major National	Normal		Replacement of handheld VHF radios- Hero Class	The current handheld radio communications (transmitting and receiving) is unreliable, there is a delay when keying the mic, and the range has been poor. We consistently loose communications within visual sight. We need these radios to communicate during Shipboard operations as well as ship to small vessel operations	MSPV		VHF Handheld radio	David Wyse	NCR	11/03/2016	Routed to Operation	Rejected by Operations - Icoms are sufficient		5589597						

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2016	2861	Major National	Normal		Sea Chest grate failures Hero Class	Sea chest grates fitted to the Hero Class hulls are failing by losing fasteners and weld tabs. This in turn allows the grate to vibrate loosely on the hull of the ship and if lost will allow large debris or foreign objects to enter the cooling water system.	MSPV		Sea chest grate	David Wyse	NCR	11/03/2016	Approved in Principle	2016-03-15 Acknowledge Reception of CCR Form Completed, document are Routed to CCR Committee for Rev. / Support. 2016-03-23, CCR Supported for Engineering Study by CCR Committee, sent to CCB for approval. 2016-04-08 CCR Approved for Engineering by CCB / Approuvée pour Ingénierie par CCC. Phase 1- Have an engineering study done to give CCG recommendations for solutions for a sea grate system that will last the service life of the vessels. Phase 2- Management decision on solution and implementation of the solution. Engineering OPI / BPR Ingénierie : Dave Wyse. 2016-08-31, specification and drawings for modification on the vessels added. CCR sent to CCB for final Approval. 2016-09-13 Approved in Principle by CCB. OPI: David Wyse.	2017-03-01 - Will be done on the Robertson winter 2016-2017.	Folder: 3589590, CCR: 3589592 and 3,4,5						
2016	2862	Major National	Normal		Black water transfer system Hero Class	The black water transfer/macerator pumps on the Hero Class have been failing prematurely. A solution is required to ensure that the pumps last more than months. The pumps are roughly 10k each to replace.	MSPV		Black water transfer/macerator pump	David Wyse	NCR	11/03/2016	Approved for Engineering/Prototype	2016-03-15 Acknowledge Reception of CCR Form Completed, document are Routed to CCR Committee for Rev. / Support. 2016-03-23, CCR Supported for Engineering Study by CCR Committee, sent to CCB for approval. 2016-04-08 CCR Approved for Engineering by CCB / Approuvée pour Ingénierie par CCC. Phase 1- Have an engineering study done to give CCG recommendations for solutions for a sea grate system that will last the service life of the vessels. Phase 2- Management decision on solution and implementation of the solution. Engineering OPI / BPR Ingénierie : Dave Wyse. **2016-12-20 Reminder sent to originator: CCR was approved for Engineering April 2016. Is the CCR ready to be sent to CCB for final Approval?**		3589703						
2016	2863	Major National	Normal		Gearbox cooler replacement solution Hero Class	There has been several gearbox cooler failures on the Hero Class vessels that have resulted in oil leaking out the cooling water discharge. A long term solution is required to avoid	MSPV		Gearbox cooler	David Wyse	NCR	11/03/2016	Approved for Engineering/Prototype	2016-03-15 Acknowledge Reception of CCR Form Completed, document are Routed to CCR Committee for Rev. / Support.2016-03-23, CCR Supported for Engineering Study by CCR Committee, sent to CCB for approval. 2016-04-08 CCR Approved for Engineering by CCB / Approuvée pour Ingénierie par CCC. Phase 1- Interim solution is to replace the CuNi shell and tube coolers in the fresh water vessels to admirality brass shell and tube coolers which have been recommended to be a better material against corrosion in fresh water applications. Phase 2- Have an engineering study performed to recommend a class wide solution for salt and fresh water which will include titanium plate coolers and a jacket water cooling system. Phase 3- Management accepts a solution and solution is implemented class wide. Engineering OPI / BPR Ingénierie : Dave Wyse. **2016-12-20 Reminder sent to originator: CCR was approved for Engineering April 2016. Is the CCR ready to be sent to CCB for final Approval?**	2017-03-01 - Titanium will be used on all the vessels.	3589848, 3589852						

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CCR Prioritization List for MSPVs

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2016	2864	Major National	Normal		Hero Class cooling system biofouling (mussel infestation)	Hero Class vessels in fresh water are having zebra mussel infestations in the cooling water systems that block the flow of cooling water. Hero Class vessels in salt water are having blue mussel infestations in the cooling water systems that are blocking the flow of cooling water. It takes a lot of time and man hours to clean the cooling water systems. A solution is required to prevent mussel build up in the cooling system	MSPV		Cooling water system	David Wyse	NCR	11/03/2016	Approved in Principle	2016-03-10 Acknowledge Reception of CCR Form Completed, documents are Routed to CCR Committee for Rev. / Support.CCR Supported for Engineering Study by CCR Committee, sent to CCB for approval. 2016-04-06 CCB Approved for Engineering by CCB / Approuvée pour Ingénierie par CCC. Phase 1- Have an engineering study done to determine which solution is most effective and cost effective including ultrasonics, copper and aluminum anodes and chlorination. Phase 2- Management accepts a solution and the solution is implemented on the Hero Class vessels. Engineering OPI / BPR Ingénierie : Dave Wyse. 2016-08-31, specification and drawing for implementation on the vessels added. CCR sent to CCB for final Approval. 2016-09-13 Approved in Principle by CCB. /OPI/. David Wyse.		3586881, 3586882, 3586883						
2016	2865	Major National	Normal		Wet exhaust transom corrosion Hero Class	The transom at the wet exhaust ports are corroding. The steel plate at the transom is only 4mm thick. The flaps at the exhaust ports are made of aluminum and are being deformed which in turn is allowing water to enter the exhaust system and damage the silencers. The fasteners holding the exhaust flaps are also loosening and being lost at sea. A solution is required to prevent corrosion of the transom and not to allow water to enter back into the exhaust system.	MSPV		Transom and exhaust	David Wyse	NCR	11/03/2016	Approved in Principle	2016-03-15 Acknowledge Reception of CCR Form Completed, document are Routed to CCR Committee for Rev. / Support.CCR Supported for Engineering Study by CCR Committee, sent to CCB for approval. 2016-04-06 CCB Approved for Engineering by CCB / Approuvée pour Ingénierie par CCC. Phase 1- Have an engineering study done to provide a solution to prevent corrosion at the transom and to not allow water to enter back in the exhaust system. Phase 2- Management accepts the recommendation and the solution is implemented on the Hero Class vessels. Engineering OPI / BPR Ingénierie : Dave Wyse. 2016-08-31, engineering and drawings to have class wide solution implemented. CCR sent to CCB for final Approval. 2016-09-13 Approved in Principle by CCB. OPI/: David Wyse.		3586967, 3586968						

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CCR Prioritization List for MSPVs

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2016	2866	Major National	Normal		Hero Class Pilot chair rails	Problème : Les chaises de pilote sont grosses et encombrantes. Ce qui cause des problèmes de circulation en autres lors des manouvres d'approches et de départ en situation de pilotage en endroits restreints. Les contrôles moteurs, propulseur, gouverne sont situés au centre de la console et les radars carte électronique, projecteurs et sifflet sont situés à tribord. Ce sont toutes des commandes dont nous sommes susceptibles de nous servir rapidement et souvent, sans compter que devons-nous déplacer de chaque côté de la timonerie pour avoir une bonne vision. Il est difficile de le faire car il faut se glissar et frotter entre les chaises et la console	MSPV		Pilot chair rail system	David Wyse	NCR	11/03/2016	Approved for Engineering/Prototype	2016-03-16 Acknowledge Reception of CCR Form Completed, document are Routed to CCR Committee for Rev. / Support. 2016-03-30 CCR Supported by CCR Committee for one chair as a test for the rail system. Would like to explore the possibility of a lighter / less bulky chair to determine which is the best solution. Sent to CCB to get Approved for trial. 2016-04-08 CCR Approved for Engineering by CCB / Approuvée pour Ingénierie par CCC. OPs: Approved for one chair as a test for the rail system. Would like to explore the possibility of a lighter / less bulky chair to determine which is the best solution. Engineering OPI : Dave Wyse.	2017-03-01 - Rails athwartships on the Peddle. Isabelle will let us know for St. Lawrence vessels.	3590028, 3590029						
2016	2867	Major National	Normal		Hero Class sacrificial anodic protection improvement	The sacrificial anodes on the hull and underwater equipment have been dissolving before the vessel reaches drydock periods. It has also been reported that the sacrificial anodic system is not adequate enough to prevent corrosion on the Hero Class vessels.	MSPV		Cathodic Protection system	David Wyse	NCR	11/03/2016	Approved for Engineering/Prototype	2016-03-16, Acknowledge Reception of CCR Form Completed, document are Routed to CCR Committee for Rev. / Support. 2016-03-30 CCR Supported by Committee, for Phase 1 to 3, sent to CCB for Approval. 2016-04-08 CCR Approved for Engineering by CCB / Approuvée pour Ingénierie par CCC. Phase 1- Have corrosion surveys done on vessels to determine the efficiency of the current system. Phase 2- Have an engineering study done to determine the best solution for the Hero Class System to upgrade the cathodic protection system. Phase 3- Have Management accept a solution and implement on the Hero Class vessel. **Engineering OPI : Dave Wyse. 2016-12-20 Reminder sent to originator: CCR was approved for Engineering April 2016. Is the CCR ready to be sent to CCB for final Approval?**		3590032, 3590033						
2016	2876	Major National	Normal		Machinery Room Air Inlets: Replacing Isolating Covers with Fire Damper	The large covers that isolate the Air inlet system in the event of a fire will be replaced with fire dampers. These manually actuated dampers will improve the emergency response time by making air intakes faster and more conveniently closed.	MSPV		Air ducting system	David Wyse			Approved for Engineering/Prototype	2016-04-06, Ack. CCR Registration, CCR Form and documentation Routed to CCR Committee for Rev./Support.2016-05-09 CCR supported by CCR Committee. Routed to CCB for approval. 2016-05-16 CCR Approved for Engineering/ Prototype. Engineering OPI / BPR Ingénierie : Dave Wyse. OPI explained the problem, project scope and planned phases; the large covers that isolate the Air inlets system used in case of fire, will be replaced with fire dampers. **2016-12-20 Reminder sent to originator: CCR was approved for Engineering April 2016. Is the CCR ready to be sent to CCB for final Approval?**	2017-03-01 - Going to PSPC.	3589198, 3589199						

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CCR Prioritization List for MSPVs

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2016	2879	Major National	Normal		Removal of Ship Security Alert System (SSAS)	One of the action items identified at the MSPV face-to-face meeting held in Montreal in March 2016 was the need to test the Ship Security Alert System (SSAS) on each vessel and confirm the response triggered; i.e. what happens when the anti-piracy button is pressed. Background: When the MSPVs were built, they were outfitted with SSAS, even though they were not required to have it as they are exempt from the SOLAS Convention and ISPS Code requiring it on newly built vessels. To date, they are the only CCG vessels equipped with the SSAS. As it is an installed system, the equipment is inspected annually by Lloyd?s	MSPV	TT-300055A Ship Security Alert System	Vessel communication	Jason Rimmer			Approved in Principle	2016-04-06, Ack. CCR Registration, CCR Form and documentation Routed to CCR Committee for Rev./Support. 2016-05-12 CCR Supported by CCR Committee. 2016-05-16 CCR Approved in Principle to remove. Engineering OPI : Dave Wyse. When the MSPVs were built, they were outfitted with SSAS, even though they were not required to have them as they were exempt from the SOLAS Convention.		3600190, 3600194						
2016	2881	Major National	Urgent		Custom Weapons Enclosure MSPV-MSET, RHIBs	Modify the Console on the MSET RHIBS to allow for the storage of RCMP Carbide C8.	MSPV	RHIB	Hull structure	Jason Rimmer			Approved for Engineering/Prototype	2016-04-22, Ack. CCR Registration, Documentation and CCR Form Routed to CCR Committee for Rev./Support. 2016-04-29 Ops contacted the company that supplied the equipment to inform Natasa HME Engineer to estimate what this weight addition should impact stability. The door will be fashioned out of aluminium and the net gain in weight on the RHIB will be 15 to 20 lbs. 2016-05-05 CCR Supported by CCR Committee, sent to CCB for Approval. 2016-05-16 Approved for Engineering/Prototype. Engineering OPI Dave Wyse. OPI explained the problem, project scope and planned phases; a custom large weapons enclosure is needed.	2017-03-01 - Drawings just received. Will trial on one vessel.	3606828, 3606830						
2016	2888	Major National	Normal		Maritimes Trunked Mobile Radio system for Hero Class vessels	Hero Class vessels that operate in the Maritime region require radios that can be programmed with both TMR and VHF programming to make use of the radio communications in the Maritime provinces.	Maritime C&P only	Vessel Communications and Navigation	Conservation and protection radios	David Wyse	Glenn Coady		Approved in Principle	2016-05-05, Ack. CCR Registration, Documentation and CCR Form Routed to CCR Committee for Rev./Support. 2016-05-06 Weight added to CCR Form. 2016-05-13 CCR Supported by CCR Committee, sent to CCB for Approval. 2016-05-16 CCR on Hold / DCC en retenue. Engineering OPI / BPR Ingénierie : Dave Wyse. Clarification: this radio is for emergency services only. This is not a regulatory or operational requirement but rather a nice to have one. Benoit Guyon will gather more information in order to validate the need for an operational requirement. Action: Benoit Guyon: to provide information. 2016-07-25 CCR Supported by CCR Committee, sent for Secretarial Approval. 2016-07-26 CCR Approved in Principle Secretarially.		3613250		NCR	04/05/2016	Approved in Principle		

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CCR Prioritization List for MSPVs

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2016	2885	Major National	Normal		MSPV (Hero Class) Fire door panel power reconfiguration	Current configuration closes the fire doors when the electrical supply is changed over from the main electrical bus to the emergency bus in the case of a blackout. The fire doors are powered by AC voltage with no battery back up. This change will power the fire doors with a 24vDC battery supply that will keep the doors open in case of blackout but will allow them to close in case of fire.	MSPV	Fire Door		David Wyse			Approved in Principle	2016-05-05, Ack. CCR Registration, CCR Form and documentation Routed to CCR Committee (Ops) for Rev./Support. 2016-05-13 CCR Supported by CCR Committee, sent to CCB for Approval. 2016-05-16 CCR Approved in Principle./ DCC Approuvée pour le Principe. 2016-09-20 Update: Western Regions CCR outlook (assuming funding and approval is obtained) is to progress this CCRs in 2017-2018. 2017-01-24 Implemented before CCR on some vessels. Dave Wyse.	2017-03-01 - C&A will be done winter 2016-2017.	3613695						
2016	2890	Major National	Normal		Hero Class vessels 4-9 rudder coating	Hero Class vessels 1-3 were delivered with rudders coated. Hero Class vessels 4-9 were delivered without any coating on the rudders. This creates an extra load on the sacrificial anodic system. It has been found that the anodic system is weak in the aft area of the vessels.	MSPV	Rudder	Propulsion/ Maneuverin g Systems	David Wyse			Approved in Principle	2016-05-12, Ack. Ack. CCR Registration, Documentation and CCR Form Routed to CCR Committee for Rev./Support. 2016-05- 12 Weight of paint added to CCR document; Sum for 2 Rudders: 74.4 Kg. 2016-05-13 CCR Supported by CCR Committee, sent to CCB for Approval. 2016-05-16 CCR Approved in Principle.		3615379						
2016	2920	Major National	Normal		VHF-AM Radio Replacement	The VHF-AM radio supplied by the original builder has not proven to be acceptable for efficient wheelhouse operations. While it did meet the terms of the contract, the supplied unit's intended purpose is meet the communication requirements of air traffic control (ATC) applications at land based ATC centers where physical size is not an issue. The unit is designed to be installed in a 19" rack with other components and would not meet CCG requirements if procured by CCG. Replace the radio with a suitable compact mobile radio.	MSPV	Radio Communicatio n Systems	Jotron TR-7750 VHF-AM	Rod Pike			Approved in Principle	2016-04-05, Ack. CCR Registration, CCR Form and documentation from Rod Pike E&I HQ are Routed to Operation for Rev./Support. 2016-08-04 CCR Supported by CCR Committee, Comment: CCR committee has selected the Icom IC-A110 as the replacement radio. Notify the National Headquarters' Technical Authority should a different model be considered. RP. CCR Sent to CCB for Approbation. 2016-10-07 Approved in Principle, OPI David Wyse. 2016-11-22 Update from LCM Rod Pike: CCR 2915 is cancelled and 2920 should be amended to include all assets as radios need replacement. 2017-01-24 Implemented before CCR on some vessels. Dave Wyse.		3636293, 3636294						

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CCR Prioritization List for MSPVs

EKME # 3045742v1 Updated 2014/03/07 *(J. Richardson original author)*

2016	2927	Major National	High		Galley Grease Trap Overboard	Existing Conditions: Currently the galley sink and food disposal drains go into the black water system, this causes issues with floats getting stuck do to food particles. we have already installed a dosing system that alleviates some of these issues, but they are still occurring. it is standard practice in most vessels on the west coast for these over-boards to go directly overboard (but have the option of being directed through black water treatment to satisfy protected water laws). Recommended Solution: I recommend adding a 3 way valve inside of the MCR that can be set to direct the flow from the grease trap directly overboard, or through to	MSPV	Solid Waste Collection and Treatment Systems	Grease trap piping arrangemen t	Cody McMillan				AF6102-59300-02_AS-BUILT BLACK GREY WATER AND SANITARY FLUSHING SYSTEM 2016-07-25, Ack. CCR Registration, Scope raised to Major National this CCR should be applicable to MSPV Class. CCR Form Sections 5 and 6 must be Supported (Electronic Signatures) by Originators and Regional Authorities. Please return PDF to CCR Committee to Rev./Support.	AF6102-59300-02_AS-BUILT BLACK GREY WATER AND SANITARY FLUSHING SYSTEM 2017-03-01- Western requested this CCR. Great Lakes can't do this.	3646749						
2016	2928	Major National	Normal		M Charles M.B. SSG Silencers	Existing Conditions: The Current SMS SM1SA-5_ST Silencer is rated for a reduction of 20-25 DbA, it is most efficient at lower Exhaust Frequency and loses its efficiency very quickly. The current set up is extremely loud, and has caused a number of noise complaints across the country. It would be in the best interest of the class to exchange these with a higher quality exhaust silencer to reduce the noise over a wider range of operating conditions. The current silencers are 42" long and 12" in diameter. Recommended Solution: MiraTech, distributed through ADP Distributors makes a better model SCUE-05-981417 that has a noise reduction rating	MSPV	Ship's Service Electrical Generation Systems	Ship's Service Electrical Power Generation	Cody McMillan				2016-07-25, Ack. CCR Registration, Scope raised to Major National this CCR should be applicable to MSPV Class. CCR Form Sections 5 and 6 must be Supported (Electronic Signatures) by Originators and Regional Authorities. Please return PDF to CCR Committee to Rev./Support. 2016-09-20 Update: Western Regions CCR outlook (assuming funding and approval is obtained) is to progress this CCRs in 2017-2018.	2017-03-01- Everyone agrees this is a good idea.							

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CCR Prioritization List for MSPVs

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2016	2941	Major National	Normal	Hero Class 2 Knife Rope Cutters	CCG requires a 2 knife approach cutter solution that will cut lines and nets before they tangle and foul the propeller.	Propeller Hub, Propeller shaft assembly, shaft arrangement	MSPV	CPP propeller	Rope Cutter	David Wyse				2016-08-23, Ack. CCR Registration, CCR Form Sections 3 and 4 must be Completed, 5 and 6 Supported (Electronic Signatures) by Originators and Regional Authorities. Please return PDF to CCR Committee for Rev./Support.	2017-03-01 - Equipment will be purchased for next year. 2017-05-11-Signed PDF Nat CCR Coord							
2016	2942	Major National	High	Hero Class MSET program satellite connectivity	A solution for RCMP connectivity is required to ensure their access to radio and network resources. Due to space, weight, and vessel stability concerns, only one satellite antenna can be mounted on the vessel. Preliminary research with the parent company, Telesat Canada, has been positive and has indicated that the existing, separate RCMP and CCG networks on board the vessel will require a ?Y? connection to allow sharing of the BUC and single satellite antenna by both agencies. This scheme has been approved by the RCMP Departmental Security and will prevent the sharing of sensitive law enforcement	Seatel antennae wiring diagram	MSPV	Satellite communications	Communications Systems (Comms)	David Wyse				Approved in Principle	2016-08-23, Ack. CCR Registration, CCR Form Sections 3 and 4 must be Completed, 5 and 6 Supported (Electronic Signatures) by Originators and Regional Authorities. Please return PDF to CCR Committee for Rev./Support.2016-11-09 CCR is supported, solution to be applied to all 4 MSET MSPVs. If required should use same solution for the 5 C&P MSPVs. JRM. Technical solution will require updating the BUC from 8W to 25W and rebalancing the antenna, which our technicians are trained to do. A "Y" will be required in receive and combiner in transmit. A new version of the power tracker will also be required to manage transmission of both modems. RCMP responsible for their modem+net and costs. 2017-01-25 On CG request, RCMP agreed to cover all cost involved in: acquisition, installation, utilisation and maintenance of the equipment. 2017-01-27 Decision/ Décision: CCR Approved in Principle. DCC Approuvée pour le Principe. Engineering CPI/BPR d'ingénierie: David Wyse.	2017-03-01 - No agreement in place yet for the payment of this service by the RCMP. Wait before installing. 2017-03-13 - From Operations meeting in MTL - C&P might be interested later depending on the cost.							

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CCR Prioritization List for MSPVs

EKME # 3045742v1 Updated 2014/03/07 *(J. Richordson original author)*

2016	3007	Major National	Normal		Install 240VAC heater in FWD Deck Locker Stbd Side	Not enough heated hanging space in stbd/port aft lockers for Fisheries Officers, Divers, and CG crew to dry their gear, nor is there a heater in the stbd side locker to prevent moisture.Turn the FWD Rope locker into a drying area with the addition of a Stelpro 3kw 240VAC heater at Frame 31(same as the one in the Port AFT Deck Locker) Refer to attached pic of propsed location of heater. Run 14/3 Bostrig Cable through Roxtek transit from HVAC compartment where P5 Convection Heating Panel is located, approx 8 feet of cable. Install 16A 240V 2 pole breaker in P5-7 spare slot in breaker panel. Relocate the minimal amount of	CAPTAIN GODDARD M.S.M.	Heater	Domestic Systems	Simon Williamson	Western Region	25/11/2016	Acknowledged	2016-11-28, Ack. CCR Registration, CCR Form sections 3 and 4 should be completed, sections 5 and 6 Supported (Electronic Signatures) by Originators and Regional Authorities. Then return CCR form to NCCR Coord. for Rev./Support by Committee.	CCR planned change in weight arm moment (WAM) Item. Fixed Mass [kg] : 9, Free Mass [kg] :0, LCG [m]: 30, TCG [m]: 1.2, ABL [m]: 4.5, for a 3kw heater. 2017-05-05-Email sent to other vessels for concurennce. There is concurrence from the group.	3681051						
2016	3015	Major National	Normal		Accès aux équipements du 3em palier du mât	Il faut agrandir l'arceau du 3em niveau afin qu'un technicien puisse utiliser l'échelle et le rail d'ascension. Idéalement il faudrait aussi modifier celui du 2em niveau pour que tous les	CAPORAL KAEBLE V.C.	Accès au mât	Hull and Related Structures	Samuel Cormier	C&A	20/12/2016	Approved for Engineering	2016-11-08 Ack. Registration. Si la DCC n'est pas encore produite, svp remplir les sections 3 a 5, une fois approuvée par la Région (section 6 signée), retourner à l'administration central pour Rev./Support. 2017-02-14 CCR Form Supported by Region and documents are Routed to Operation to Rev, /support. 2017-02-02 CCR Supported by Committee		3736603					
2016	3016		Normal		Sailor 5000 Series GMDSS Life Cycle Replacement	Recommend beginning life-cycle replacement of all Sailor 5000 series GMDSS consoles immediately. A standing offer for the Sailor 6000 series GMDSS system is currently active, significantly simplifying the planning and procurement.	Various assets	GMDSS - Inmarsat C Message Terminal	Vessel Communications and Navigation	Keenan Papps		20/12/2016	Approved in Principle	2016-12-21, Ack. CCR Registration, CCR Form completed is sent to Committee for Rev./Support. 2017-01-26 Title and assets updated. 2017-01-26, CCR Supported by CCR Committee, Recommend Region create a CCR to implement interim solution for Inmarsat C terminal problem that originally highlighted the problem. 2017-01-27 CCR Approved In Principle. DCC Approuvée pour le Principe. Engineering OPI: Rod Pike.		3715981, 3727926					
2017	3025	Regional	High		Retrofit SD Card Module into Sailor TT-3606E Sat C Terminal	On the Corporal Teather, the Sailor 5000 series GMDSSS there was a failure of the message terminal floppy drive which is no longer available for purchase. Temporary solution until the replacement of all Sailor 5000 series	Corporal Teather	Sailor TT-3606E Sat C Terminal	Vessel Communications and Navigation	Mike Larue		27/01/2017	Cancelled taken over by 3016	2017-01-31, Ack. CCR Registration, CCR Form sections 3 and 4 should be completed, sections 5 and 6 Supported (Electronic Signatures) by Originators and Regional Authorities. Return documents to NCCR Coord. for Rev./Support by Committee. CCR 3025 is cancelled Superseded by CCR 3016. 2017-02-09 CCR change to Minor. This CCR is recommended from LCM and E&I Technologist HQ, complementary to CCR 3016.							

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CCR Prioritization List for MSPVs

EKME # 3045742v1 Updated 2014/03/07 *(J. Richardson original author)*

2017	3029	Major National	Normal		Jotron Sound Reception System Replacement	Jotron issued Technical Bulletin TB05-2013 on Dec 12, 2013, stating that the Type Approval expired Dec 31, 2013 and since the SR8200 does not meet ISO standard 14859:2012, Type Approval will not be re-issued. HQ supports the	MSPV	Sound Reception System	Vessel Communications and Navigation	Keenan Papps		13/02/2017	Approved for Engineering	2017-02-14 Ack. CCR Registration, CCR raised by E&I at NCR. Document forward to Operation to Rev./Support. 2017-02-16 CCR Supported by Committee, sent to CCB for Approval.	2017-03-01 - System does not work on all vessels. Robertson - this is a condition of class. In 4 months there will be another survey and the inspector will look at this. It has to move forward.	3736147						
2017	3037	Major National	Normal	Both	Life Cycle Replacement of VHF Direction Finding Systems	The current very High Frequency (VHF) Direction Finder (DF) standard is becoming very difficult and expensive to maintain. Parts are in short supply	All assets	VHF Direction Finder		Rod Pike		17/03/2017	Approved for Engineering/Prototype	2017-03-20, Ack. CCR Registration, CCR raised by HQ, Documents are routed to CCR Committee for Rev. / Support. 2017-04-07 approved for engineering - although some do not meet transport requirement, Transport not enforcing with CCG, as rewrite of regulations [illegible] current requirements. Ops to	2017-03-21: Constable Carriere has the CUBIC brand.	3752987						
2017	3040	Major	Normal	MSET	MSPV RHIB Wireless Headsets and Intercom	David Clark makes a simple system that acts as both intercom between wireless headsets and interface to existing radios. For single radio solutions the 3800 series intercom is ideal as it is light weight, compact and simple to install and remove. This system would allow 4 wireless headsets to operate as an intercom as well as an interface to an existing radio. This will cover the 4 regional C&A MSPVS (Private Robertson, Corporal Teather, Corporal Kaeble, Constable Carriere).		Wireless Headsets	Communications Systems (Comms)	Victor Gharman			Approved in Principle	2017-03-22, Ack. CCR Registration, CCR Form sections 3 and 4 should be completed, sections 5 and 6 Supported (Electronic Signatures) by Originators and Regional Authorities. Then return CCR form to NCCR Coord. for Review/Support by Committee. 2017-03-20, Ack. CCR Registration, This CCR look similar to CCR 2700, submitted April 2015 and Approved in Principle by CCB. I recommend you to contact Engineering OPI to discuss and find out if CCR 2700 can suit your needs. OPI will decide what we do about this CCR, continu or close it. 2017-03-28 CCR Status change for National, CCR Routed to Ops to Rev./support. 2017-04-06 This is an interim solution for the RCMP until the internal communications system can be brought up to a national standard. -RP Supported as an interim solution for the vessels mentioned in the actual CCR File LM; CCB 2017-04-07 secure radio requirement came from Olympics; interim solution - RCMP - mspv vessels in C&A- RHIBS + Kaeble; Apprvd. Eng. later will have a major national to deal with wireless comms. CCR 2700 in approv status & 3024 (already approvd) Fox will be superceded. C. Morelli asked that 2700 remain open until she finds info of something installed. Action: A. DeHaan to provide Major National; C. Morelli to contact NCCRC to cancel (2700,3024); NCCRC to process and cross-	Email from Blaine 2017-05-11- CCR 3040 was approved in principle at the CCB meeting held on April 7, 2017; it is an interim measure to install the existing equipment purchased by the RCMP until a full CCG wireless solution is developed and implemented. Installation of the RCMP pre-purchased equipment has had a green light to proceed since April 7, 2017. CCG is working towards a national wireless communication solution; once determined, a new Major/National CCR will be issued.							
2017	3048	Minor	Urgent		Marshaling Boat Davit	The Lifeboat cannot be properly launched. When the brake is operated it does not apply due to the spring force (used to apply the brake) overcome by (friction force) not allowing the spring to work as originally designed. The brake is operated by a	M.Charles	Marshaling Boat Davit	Safety and Security Equipment	Tyler Twordik	Western Region	27/04/2017	Routed to ACM	2017-05-01 Ack and routed to ACM to verify scope;	2017-05-05-Email sent to other vessels for concurennce. There is concurrence from the group if it works.	37700209						

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CCR Prioritization List for MSPVs

EKME # 3045742v1 Updated 2014/03/07 *(I. Richardson original author)*

2017	3049	Minor	Normal		Allied Crane Seat	Currently, the Allied crane is very difficult to operate using the Remote Belly Pack system. The Belly packs are prone to failure and the vessel only has one currently as the other unit failed. Running the crane from the local levers on the crane has been tested and proven to function very well . It is much easier to control the crane from the local controls. Propose a removable chair be installed on the crane so that the local controls can be used if wanted. This solution could prove simple yet very effective to the class wide issues to date with the operations of the crane. Estimated Cost $500.00	M.Charles	Allied Crane	Deck Equipment / Ship Support Systems	Tyler Twordik	Western Region	27/04/2017	Routed to ACM	2017-04-28 Routed to ACM to verify scope.	2017-05-05-Email sent to other vessels for concurennce. No, there are safety issues.	3770211						
2017	3050	Minor	Normal		Galley Garland Induction Cooker	Currently on board the CCGS M. Charles the Counter top Induction cooking units are too high and placed too far back on the counter top making it difficult for the cook to lift and remove pots and pans safely from the cooking units. Al so, the current configuration of the counter top cooking units causes the cook to be subjected to extra fatigue from always having to reach up so high and far back. Modify current top Induction cooking units with Galley Garland Induction Cooker. Estimated cost $2000.00. See EKME doc.	M. Charles	Garland Countertop Induction Cooker	Domestic Systems	Tyler Twordik	Western Region	27/04/2017	Routed to ACM	2017-05-05 Routed to ACM to verify scope.	2017-05-05-Email sent to other vessels for concurennce. No,there will be a new CCR for the reconfig of the galley. The chef of the LSSL is going on the Mclaren.	3770208						

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CCR Prioritization List for MSPVs

EKME # 3045742v1 Updated 2014/03/07 *(J. Richardson original author)*

2017	3051	Major	Urgent		Fire Main Piping	Currently, the ships fire main piping has five leaks. Four of the leaks have caused damage to the asset. The leaks have been temporarily repaired with Emergency pipe repair tape. Risk the possibility of failing Lloyds inspection, if not fixed properly. Remove all piping between valve VS55004 and flange located between Fr 22 & Fr 23. Replace pipe with Lloyds approved Pro-press CUNI for wet or dry fire systems. 73.025mm SS tube to be replaced with 76.1 mm*2.0W Seamless Tube: CUNI 90/1 O Alloy 706. 60.325mm SS tube to be replaced with 54mm*2W Seamless Tube: CUNI 90/10 Alloy 706. Remove through hull bend fitting @ fr 21	M. Charles	Fire Main	Safety and Security Equipment	Tyler Twordik	Western Region	27/04/2017	Routed to ACM	2017-05-01 Routed to ACM to verify scope.		3770206						
2017	3052	Minor	Normal		MCR Desk Modification	There is no adequate desk space for the Chief Engineer and Senior Engineer to properly conduct day to day operations such as recording in log books and developing procedures. The Desk in the C/E cabin is not always possible to work in as it is small and in rough weather it is virtually impossible to work there. Move fire extinguisher from existing location in MCR to a better suited location in the MCR. Remove the phone from the large wooden box and mount the phone where the fire extinguisher used to be. Discard the large wooden box that the phone was mounted in. Move two electrical	M. Charles	MCR Desk, Computer, Telephone	Communications Systems (Comms)	Tyler Twordik	Western Region	27/04/2017	Routed to ACM	2017-05-01 Routed to ACM to verify scope.	2017-05-05-Email sent to other vessels for concurennce. No, concurrence.	3770210						

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CCR Prioritization List for MSPVs

EKME # 3045742v1 Updated 2014/03/07 *(J. Richardson original author)*

2017	3079	Major National	Normal	Both	Hour meter installation on Hero Class equipment	Various machinery including pumps on board the Hero Class vessels do not have running hour meters. Running hours are required for hourly based maintenance and information to provide to safety surveyors.	Various assets	Various	Control and Monitoring Systems	David Wyse	NCR	29/05/2017	Approved in principle	2017-06-01: Routed to OPS.								
2017	3088	Major National	High	Both	Hero Class Firefighting UHF radio	During fire drills the Chief Mate is in charge of the Fire Team, the First engineer in charge of Fire Support and the Chief Engineer is in the control room. Currently 4 UHF radios are installed on the vessel which are	MSPV	Communications Systems (Comms)	Portable UHF radio	David Wyse												
2017	3089	Major Na	High	Both	Hero Class depth sounder replacement	During fire drills the Chief Mate is in charge of the Fire Team, the First engineer in charge of Fire Support and the Chief Engineer is in the control room. Currently 4 UHF radios are installed on the vessel which are given to the bridge, Chief	MSPV	Vessel Communications and Navigation	echo sounder	David Wyse												
2017	3090	Major	Normal		Dual Satellite Dome Installation	[redacted] The current fitted SeaTel model 4009 Satellite antenna has a very large blind spot disabling communications when the ship is heading anywhere between 40 degrees and 130 degrees course. This gives the vessel a blind spot of 90 degrees. When the MSVP's are transiting on the above headings, and		Vessel Communications and Navigation	Telesat Satellite Communications System	Simon Williamson	Gabriel Chaikin											

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CCR Prioritization List for MSPVs

EKME # 3045742v1 Updated 2014/03/07 *(J. Richardson original author)*

2017	3091	Major	Normal		Relocate Searchlight Controls	Vessel has two searchlights mounted on the bridge top, port and starboard. Each has its own control panel to direct the light and to focus the beam. However, both control panels are located on the far starboard side of the console. In order to use either, the operator must be sitting in the starboard chair, or standing at the starboard bridge door. Even then, the port searchlight controls are barely in reach. From these operating positions, it is not possible to see anything abaft the port beam or close to the ship on the port side, and so the port searchlight cannot be directed effectively. Additionally, it is not ergonomically		Visual Navaids	Searchlights	CCGS M Charles MB	Gabriel Chaikin													
2017	3092	Major	Normal		Additional At-Will Whistle Button	The only at-will whistle control within the bridge is located on the far starboard side. It is a tiny button mixed in on a panel with 20 other very similar buttons. Add an at-will whistle push button near the centre of the bridge conso e. This would require a cable to be run from the whistle control panel under the console, and a hole to be drilled in a suitable space near the middle of the console. This should be a straightforward job. Able to sound the ship's whistle at will quickly and without error from any of the forward bridge positions. Consequent increase in safety of navigation. There is a safety risk that in an emergency or close quarters situation, when		Navaids	Whistle Controls	CCGS M Charles MB	Gabriel Chaikin													
2017	3097	Major National	Normal		Commanding Officer Cabin/Office	The office for the Commanding Officer		Hull and Related	Living compartme	David Wyse														

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CCR Prioritization List for MSPVs

EKME # 3045742v1 Updated 2014/03/07 *(I. Richardson original author)*

2017	3098	Major National	Normal		Hero Class removal of air supply box in Engine room	Remove the air supply boxes which are located above the Main Engines		Domestic Systems	N/A	David Wyse												
2017	3099	Major National	Normal		Hero Class Battery Isolation switches	The main 24V back-up battery supply and the GMDSS back-up battery		Electrical Power Distribution	N/A	David Wyse												
2017	3100	Major National	Normal		Hero Class Tie breaker UV trip removal and EM1 Q5 breaker relocate	Remove the under voltage (UV) trip from the buss tie breaker. This buss tie breaker has no capability for generators to parallel across it. Should the 24VDC backup supply fail the system automatically opens this buss tie breaker and the operator must run two ships service generators to power up both halves of the buss. Under this control philosophy, to get back to single generator operation the operator must black out one half of the switchboard to close the Tie Breaker. Under certain conditions (Close Quarters Operations) this blackout operation may not permit the operator to get back to single generator		Ship's Service Electrical Power Generation	N/A	David Wyse											
2017	3101	Major National	Normal		Hero Class voltage control for shore power synchronization	engineering and documentation necessary to upgrade the main switchboard to provide automatic and manual generator voltage adjust capability The objective of this upgrade is to improve the Load Transfer functionality on the Hero Class vessels and reduce the mechanical and electrical stress on the vessels main switchboard network which will ultimately translate into reduced maintenance costs and enhance system reliability.		Electrical Power Distribution	N/A	David Wyse											

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CCR Prioritization List for MSPVs

EKME # 3045742v1 Updated 2014/03/07 *(J. Richardson original author)*

2017	3102	Major National	High		Hero Class blue vision repairs	The Hero Class vessels have been experiencing cluster alarms and unrequested propulsion engine clutch outs due to issues with the blue vision propulsion. An MTU engineer was hired to investigate and found 21 issues that need to be addressed on the Hero Class vessels		Propulsion/Maneuvering Systems	MTU bluevision propulsion system	David Wyse															
2017	3103	Major National	Normal		Hero Class stabilizers	The parent Hero Class design vessels are delivered with stabilizers. The Hero Class vessels do not have stabilizers installed. All vessel operators agree the vessels require stabilizers in all areas of operation. Program and operations can suffer do the fact that the vessels have extreme roll in high sea state conditions. Engineering and implementation plans are required		Auxiliary Systems	N/A	David Wyse			Approved for engineering											
2017	3107	Major National	Normal		Hero Class reclassify ballast tanks to void spaces	The ballast tanks are not currently used on board the Hero Class vessels due to weight and stability of the vessels. Reclassify the ballast tanks to void spaces which will create less survey work during inspections. Also will be a weight savings if any fittings or piping can be removed		Hull and Related Structures	Ballast	David Wyse														

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CCR Prioritization List for MSPVs

EKME # 3045742v1 Updated 2014/03/07 *(J. Richardson original author)*

2017	3110	Major	High		MSPV PIM4 Reconfigure	System design overview: The MSPV platform uses MTU main engines. MTU uses a propitiatory program language for their engine control system. To allow 3rd party remote control and alarm systems to communicate with the MTU engines a PIM4 translation box is used. This box takes the MTU language and translates it to a CAN BUS signal that Techsol can interpret. As well the PIM4 box translates inputs from the remote control system into the MTU language for the main engines. Currently configuration: The PIM4 connection box for both port and starboard main engines is installed in the MMR. The PIM4 box has no IP rating as the		Integrated Control Systems	Main Engine Control System	Andrew McIlrath	Gabriel Chaikin													
2017	3140	Major National	High		Remplacement valve V520055	Suite à un exercice d?une procédure ISM de l?envahissement du compartiment du propulseur d?étrave, une situation préoccupante a été observée. Pour activer le pompage du compartiment envahi il faut démarrer la pompe incendie d?urgence et ouvrir manuellement et directement sur place la valve (V520055) qui alimente le venturi d?aspiration directe		Auxiliary Systems	Venturi d'aspiration directe	Yves Arbour	Guillaume Noel													
2017	3148	Major National	Normal		Secure AIS for Hero Class program Rhibs	Installation of a Secure AIS System similar to that of the offshore C&P vessels in Atlantic region, that will permit the ship to track the RHIB on AIS.		Communications Systems (Comms)	AIS	David Wyse														

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CCR Prioritization List for MSPVs

EKME # 3045742v1 Updated 2014/03/07 *(J. Richardson original author)*

2017	3149	Major National	Normal		Diesel Outboards for Hero Class Rhibs	Currently there is gasoline outboard engines fitted to the Rhibs on board the Hero Class vessels. This requires that the mothership carries gasoline tanks on board the vessel. By moving to diesel outboards then the mothership does not require the gasoline and tank system aboard the vessel.		Deck Equipment / Ship Support Systems	Outboard motor for RHIBS	David Wyse														
2017	3157	Major National	Normal		Conversion au DEL compartiment de machinerie	Il y a 24 lumières fluorescentes dans les compartiments de machinerie (10 dans le MMR, 8 dans l'AMR, et 6 dans le compartiment d'appareil à gouverner). Ces lumières ne sont pas assez brillantes. Ils ne durent pas due à la vibration ou la chaleur produits dans ces compartiments (plus particulièrement dans l'appareil à gouverner). En 2015 et 2016, nous avons eu besoin de réparer plusieurs lumières. Les fixations d'ampoules et les démarreurs brûlent quand les composantes des lumières deviennent moins bien ajusté; la situation actuelle présente un risque d'incendie mineur.		Electrical Power Distribution	Éclairage fluorescent	Sheldon Ottley	Matthew Stares													
2017	3187	Major National	Normal		MSPV Alarm Monitoring System replacement	The major components of this critical system have all been designated as matured. This designation basically means that there is no further OEM support for the software or hardware which will make both technical support and spare part acquisition increasingly		Integrated Control Systems	Alarm and monitoring system	William Falconer	william.falconer@dfo-mpo.gc.ca	902 440 6231	Approved for prototype	2017-12-07 Ack. CCR Registration, Major National CCR Supported by Tech Authoritie is Routed to CCR Committee to Rev./Support. 2017-12-13, CCR Supported by Committee. 2018-01-18 Appendix D added to CCR; for design and Trial including contracting steps. 2018-02-09 CCB Approved for Engineering/Prototype and one installation for Trial. CCR. OPI: Vitaliy Molokopoy, William Falconer; to present Trial Report to CCB to get final Approval before proceeding with installation for Class.								

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CCR Prioritization List for MSPVs

EKME # 3045742v1 Updated 2014/03/07 *(I. Richardson original author)*

2018	3198	Major	Normal		MSPV relocate Navigation Data display locations	Some MSPV currently have their Speed through Water displayed on a Sperry multi-function display mounted in their navigation dash in the wheelhouse. These vessels also have a Gyro Bearing displayed on a multi-function display mounted in the overhead dash panel (see attached photos). The location of the Gyro bearing display can cause fatigue to the wheels-man, having to constantly look up to check on the current bearing. RECOMMENDED SOLUTION: It is highly recommended to have the inputs of the TWO repeaters swapped, thus having the Speed now displayed on the overhead dash panel,		Sperry speed log and sperry gyro	Vessel Communications and Navigation	Jeff English													
2018	3212	Major National	High	RCMP	Remove VHF bow speaker from MSET RHIBS	In order install C9 bracket (CCR 2881) on the RHIBs the VHF speaker at the bow has to be removed. It is not a requirement to have this speaker anymore				Dave Wyse	Paul Wright			Approved in Principle									
2018	3213	Major National	Normal	C&P	Crab pot hauler arm extension	the trap hauler modification is to extend the arm as depicted in the engineering drawings to gain clearance over the railing. The arm would be fitted with a small block for the rope to travel on and the hauler would be mounted to the deck, that way when traps were raised to the ships side crew aren't leaning over the railing trying to pull them over the railing, instead the bottom of the traps should clear the railing making it a lot easier to bring on board. By not having the hauler				Dave Wyse	Captain G. Peddle			Approved for prototype									

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CCR Prioritization List for MSPVs

EKME # 3045742v1 Updated 2014/03/07 *(J. Richardson original author)*

2018	3215	Major National	High	both	MSPV Additional at will whistle button	The only at-will whistle control within the bridge is located on the far starboard side. It is a tiny button mixed in on a panel with 20 other very similar buttons. Add an at-will whistle push button near the centre of the bridge console. This would require a cable to be run from the whistle control panel under the console, and a hole to be drilled in a suitable space near the middle of the console. This should be a straightforward job. Able to sound the ship's whistle at-will quickly and without error from any of the forward bridge positions. Consequent increase in safety of navigation. There is a safety risk that in an emergency or close-quarters situation, when		Vessel Communications and Navigation	Whistle	David Wyse	david.wyse@dfo-mpo.gc.ca	6133026053	Routed to CCB	2018-01-01, Ack. CCR Registration, CCR Supported (E-Signatures) by Regional Authorities. Major CCR will be sent for Review/Support by CCR Committee, then to CCB for Approval. 2018-01-30 Supported by CCR Committee routed to CCB for Rev./Approval.										
2018	3216	Major National	Normal	Both	Hero Class Relocate Navigation Data Display locations	Some MSPV currently have their Speed through Water displayed on a Sperry multi-function display mounted in their navigation dash in the wheelhouse, These vessels also have a Gyro Bearing displayed on a multi-function display mounted in the overhead dash panel (see attached photos). The location of the Gyro bearing display can cause fatigue to the wheels-man, having to constantly look up to check on the current bearing. It is highly recommended to have the inputs of the TWO repeaters swapped, thus having the Speed now displayed on the overhead dash panel, and the Bearing now displayed on the the		Vessel Communications and Navigation	Navigation dash	David Wyse			Routed to CCB	2018-01-30, Ack. CCR Registration,in replacement of CCR 3198 CCR. Supported (E-Signatures) by Regional Authorities. Major CCR will be sent for Review/Support by CCR Committee, then to CCB for Approval. 2018-01-30 Supported by CCR Committee routed to CCB for Rev./Approval.										

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CCR Prioritization List for MSPVs

EKME # 3045742v1 Updated 2014/03/07 *(J. Richardson original author)*

2018	3217	Major National	Normal	Both	Hero Class searchlight replacement and relocation of controls	Replace the searchlights with models that provide more light for trap hauling operations. As a temporary measure relocate the controls to their respective sides and an umbilical cord.		Vessel Communications and Navigation	Searchlight	david wyse			Routed to CCB	2018-01-30, Ack. CCR Registration in replacement of CCR 3091. CCR Supported (E-Signatures) by committee. Sent to CCB for Rev./Approval.								
2018	3219	Major National	Normal	Both	Hero Class main engine removal and overhaul	there is no current way to remove or overhaul the engines in situ. Create a physical way and plan to remove and overhaul the engines		Hull and Related Structures	Hull and structure	David Wyse			Approved for Engineering/Prototype	2018-02-02, Ack. CCR Registration, sections 3 and 4 should be completed, 5 and 6 must be Supported (E-Signatures) by Regional Authorities. 2018-02-02 Supported by CCR Committee routed to CCB for Rev./Approval. 2018-02-09 CCB Approved for Engineering/Prototype this CCR. OPI: David Wyse; to present Report to CCB to get final Approval before proceeding with installation.								
2018	3220	Major National	Normal	Both	Hero Class galley reconfiguration	Current galley does not meet cook requirements, industry standards and has many failures that need to be addressed. Re engineer and plan a new galley configuration.		Domestic Systems	Galley	David Wyse			Routed to CCB	2018-02-02, Ack. CCR Registration, sections 3 and 4 should be completed, 5 and 6 must be Supported (E-Signatures) by Regional Authorities. 2018-02-02 Supported by CCR Committee routed to CCB for Rev./Approval.								
2018	3221	Major National	High		Hero Class relocate PIM4 box	System design overview: The MSPV platform uses MTU main engines. MTU uses a propitiatory program language for their engine control system. To allow 3rd party remote control and alarm systems to communicate with the MTU engines a PIM4 translation box is used. This box takes the MTU language and translates it to a CAN BUS signal that Techsol can interpret. As well the PIM4 box translates inputs from the remote control system into the MTU language for the main engines . Currently configuration: The PIM4 connection box for both port and starboard main engines is installed in the MMR. The PIM4 box has no IP rating as the		Propulsion/Maneuvering Systems	Propulsion control	David Wyse			Approved in Principle	2018-02-02, Ack. CCR Registration, sections 3 and 4 should be completed, 5 and 6 must be Supported (E-Signatures) by Regional Authorities. 2018-02-06 Supported by CCR Committee routed to CCB for Rev./Approval. 2018-02-09 CCB Approved in Principle this CCR. OPI: David Wyse to forward Work instruction.								

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CCR Prioritization List for MSPVs

EKME # 3045742v1 Updated 2014/03/07 *(J. Richardson original author)*

2018	3222	Major National	Normal		MSPV, Internal Communication System (ICS) modification	Existing Conditions: Hose McCann ICP Internal Communication System is the as fitted ICS system on the MSPV vessels. It has been difficult and costly to maintain the PA portion due to low reliability of the speakers. There are also nine different models of speakers on the vessel which makes keeping them all in stock a challenge. Hose McCann, located in Florida, is the only distributer of their products. They do not have any authorized resellers and much of their equipment is made to order and ships internationally so the lead time to order spares is quite long (average of 3 months). In FY 2016/17 the cost to maintain the ICS systems on the two		Select System	N/A	Julie Leclerc			Acknowledged	2018-02-14, Ack. CCR Registration, To MSPV Committee: Sections 3 and 4 should be completed, 5 and 6 must be Supported (E-Signatures) by Committee. CCR will be sent for Review/Support by CCR Committee, then to CCB for Approval.								
2018	3240	Major National	High		Asset tracker for Hero Class MSET RHIBS	Install an asset tracker onto the MSET RHIBS.	All Assets	Vessel Communications and Navigation	N/A	David Wyse	david.wyse@dfo-mpm		Ashish Bector	2018-04-03, Ack. CCR Registration, sections 3 and 4 should be completed, 5 and 6 must be Supported (E-Signatures) by Regional Authorities. CCR must be Signed and returned to NCCR Coord. with documentation, Major CCR will be sent for Review/Support by CCR Committee, then to CCB for Approval.								
2018	3258	Major Na	normal		Données de l'anémomètre dans VisionMaster	Présentement il n'a a pas d'indication du vent sur l'ECDIS VisionMaster. Il faudrait entrer l'input de l'anémomètre de façon à ce que les données du vent soient affichés sur le système VisionMaster. Les données du vent sont importantes pour la navigation et les man?uvres du navire.		Vessel Communications and Navigation	ECDIS Vision master	Francois Lanouette				2018-05-10, Ack. CCR Registration, sections 3 and 4 must be completed, 5 and 6 must be Supported (E-Signatures) by Regional Authorities. CCR form and documentation must be returned to NCCR Coord. Then Minor can be implemented, Major will need CCB Approval. Note: Scope should be review if applicable for MSPV Class and raised to Major. 2018-06-22 CCR Supported by Region Routed to Committee for Rev./Support. 2018-06-29 CCR Scope upgraded to Major National, added David Wyse as contact for HQ and MSPV Committee. Supported by Committee, Routed to CCB seeking Approval for Engineering. 2018-07-06 At CCB, after discussion with Manager Benoit Guyon on scope work/Engineering, CCR is Approved in Principle. OPI HQ: Andrew deHaan.		3928702, 3932974						

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2018	3265	Major National	Normal		MSPV pompe circulation eau chaude	Présentement la pompe pour la circulation d'eau chaude du navire est une pompe en provenance d'Europe. Les pièces sont dispendieuses et viennent de loin. Cette pompe est alimenté avec du 600V pour une pompe qui fait seulement que circuler de l'eau chaude dans le navire. Solution : Il est recommandé de remplacer la pompe avec une petite pompe de circulation TACO 110-24. En acier inox certifié NSF61 pour laquelle les pièces sont facilement disponible. L'alimentation pour cette pompe viendra du panneau principal. L1-34. Nous pourrons utiliser l'alimentation 600V pour la pompe dédiée au lavage de la chaîne		domestic Systems	Hot water circulation pump	Isabelle Couillard Desjardins			Approved for engineering	2018-05-28, Ack. CCR Registration, sections 3 and 4 should be completed, 5 and 6 must be Supported (E-Signatures) by Regional Authorities. CCR must be Signed and returned to NCCR Coord. with documentation, Major CCR will be sent for Review/Support by CCR Committee, then to CCB for Approval. 2018-06-08 CCR Supported by Region Routed to Committee to Rev./Support. 2018-07-26 Supported by Committee; Routed to CCB seeking Engineering App'l. 2018-08-03 CCB: Approved for Engineering.		3924350						
2018	3266	Major National	Normal		MSPV pompe triphasé système d'eau noires	Présentement l?alimentation électrique de la pompe macératrice de transfert est une pompe monophasée 230V. Ceci a pour conséquence que le moteur travaille plus fort pour faire des démarrages et ce système est un système qui est appelé à démarrer et arrêter souvent. Solution : Il est recommandé d'acheter un moteur triphasé de 1.1 KW pour faire tourner une pompe équivalente que propose Hamann la compagnie du système d'eaux noires. Il est recommandé d'amener l'électricité triphasée à partir du panneau L1 3pôles 18. Impacts : Le bénéfice anticipé est de remplacer moins souvent le moteur	système électrique/ / système eaux noires	16D	Systèmes de collecte, de traitement et d'évacuation des eaux	Isabelle Couillard Desjardins	All Assets	Auxiliary Systems	Approved for engineering	2018-05-28, Ack. CCR Registration, sections 3 and 4 should be completed, 5 and 6 must be Supported (E-Signatures) by Regional Authorities. CCR must be Signed and returned to NCCR Coord. with documentation, Major CCR will be sent for Review/Support by CCR Committee, then to CCB for Approval. 2018-06-08 CCR Supported by Region Routed to Committee to Rev./Support. 2018-07-26 Supported by Committee; Routed to CCB seeking Engineering App'l. 2018-08-03 CCB: Approved for Engineering.		3924351						

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EKME # 3045742v1 Updated 2014/03/07 *(J. Richardson original author)*

2018	3271	Major National	High		Hero Class Satellite Antenna communication	A solution is required so there is not a large blindspot in satellite communications and signals. Currently there can be a blindspot from 40 degrees to 130 degrees heading due to the mast.	TBD	18B	Vessel satellite communications	David Wyse	All Assets	Vessel Communications and Navigation	Acknowledged	2018-06-26, Ack. CCR Registration, sections 3 and 4 should be completed, 5 and 6 must be Supported (E-Signatures) by Regional Authorities. CCR must be Signed and returned to NCCR Coord. with documentation, Major CCR will be sent for Review/Support by CCR Committee, then to CCB for Approval.									
2018	3281	Major National	High		MSPVs Reconfiguration of Chart Table	Chart is difficult to use from the forward side of the bridge, which is not fit on "chart table". Top shelf makes it difficult to use full use of chart. Shelf on top of charts has many electronics. If shelf is to be removed, electronics will have to be relocated.		Vessel Information Support Systems		David Wyse			Acknowledged	2018-06-29, Ack. CCR Registration, sections 3 and 4 should be completed, 5 and 6 must be Supported (E-Signatures) by Regional Authorities. CCR must be Signed and returned to NCCR Coord. with documentation, Major CCR will be sent for Review/Support by CCR Committee, then to CCB for Approval.									
2018	3284	Major National	Normal		Hero Class AIS Antenna Relocation	Relocate Automatic Identification System (AIS) antenna to improve system performance.	AF6094-44100-01 Antenna Arrangement	18A05	Automatic Identification System (AIS)	Andrew de Haan	All Assets	Vessel Communications and Navigation	Approved for engineering	2018-07-06, Ack. CCR Registration, Major CCR will be sent for Review/Support by CCR Committee, then to CCB for Approval. 2018-07-11 CCR Supported by Committee, Routed to CCB for Approval, Seeking Approval for Engineering. 2018-07-25 Installation Specification document added in EKME, will do a Trial on one vessel before asking for Implementation. 2018-08-03 CCB: Approved for Engineering.		3933010, 3942250							
2018	3288	Major	High		CAPORAL KAEBLE V.C. Modification de l'accès aux réservoirs dans le MMR	Actuellement, le réservoir 6 n'est accessible qu'en passant par le réservoir 15. L'accès au réservoir 15 se fait par l'avant, dans la cale, plutôt que par le haut. L'accès au réservoir 15 nécessite soit l'enlèvement de diverses tuyauteries, y compris la tuyauterie pour les échangeurs de chaleur pour les moteurs principaux, soit la recherche d'une personne suffisamment petite pour s'adapter entre les canalisations. Le chemin de la seconde option est indirect. La recommandation est d'ajouter l'accès au dessus des deux réservoirs. Cela impliquerait de déplacer la tuyauterie directement au-dessus	aménagement de la salle des machines et tuyauterie	16	Système d'eau grise/noire, Système d'huile de moteur	Sheldon Ottley	CAPORAL KAEBLE V.C.	Domestic Systems	Acknowledged	2018-07-17, Ack. CCR Registration, sections 3 and 4 must be completed, 5 and 6 must be Supported (E-Signatures) by Regional Authorities. CCR form and documentation must be returned to NCCR Coord. for Rev. by CCR Committee. Next step is CCB Approval.									

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CCR Prioritization List for MSPVs

EKME # 3045742v1 Updated 2014/03/07 *(J. Richardson original author)*

2018	3292	Major National	Normal		Hero Class Allied Crane local controls	The local crane controls are mounted approximately 8 feet off the deck. They cannot be reached by the operators. Engineer a way to move the controls down to a level that crane operators can access them.	Deck Equipment / Ship Support Systems	Deck Crane		David Wyse			Approved for engineering	2018-07-23, Ack. CCR Registration, sections 3 and 4 should be completed, 5 and 6 must be Supported (E-Signatures) by Regional Authorities. CCR must be Signed and returned to NCCR Coord. with documentation, Major CCR will be sent for Review/Support by CCR Committee, then to CCB for Approval. 2018-07-25 CCR Supported by Committee, Routed to CCB Seeking App'l for Engineering. 2018-08-03 CCB: Approved for Engineering.		3940971, 3940973		Atlantic Region	19/07/2018	Routed to CCB		
2018	3293	Major National	Normal		Hero Class Allied crane remote control connections	Either a secondary connection should be established on the aft bridge deck to allow for the connection of the mobile crane pack umbilical cord thus leaving the stairway free of tripping hazards when the crane is operated from the aft bridge deck or a wireless control pack must be engineered.	Deck Equipment / Ship Support Systems	Deck Crane		David Wyse			Approved for engineering	2018-07-23, Ack. CCR Registration, sections 3 and 4 should be completed, 5 and 6 must be Supported (E-Signatures) by Regional Authorities. CCR must be Signed and returned to NCCR Coord. with documentation, Major CCR will be sent for Review/Support by CCR Committee, then to CCB for Approval. 2018-07-25 CCR Supported by Committee, Routed to CCB Seeking App'l for Engineering. 2018-08-03 CCB: Approved for Engineering.		3940988						
2018	3294	Major National	Normal		Hero Class Stern light pole modification	The aft stern light / flag pole is in the way while the RHIBS are being launched overboard. A hinge is required on the pole to lower it while the Rhibs are being launched.	Deck Equipment / Ship Support Systems	Stern Light pole		David Wyse			Approved for engineering	2018-07-23, Ack. CCR Registration, sections 3 and 4 should be completed, 5 and 6 must be Supported (E-Signatures) by Regional Authorities. CCR must be Signed and returned to NCCR Coord. with documentation, Major CCR will be sent for Review/Support by CCR Committee, then to CCB for Approval. 2018-07-25 CCR Routed to CCR Committee to REv./Support.		3941022, 3941027						

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Approved by CCB	On Hold	Requested/In Progress	Cancelled by client	Resubmit as National															
Year	CCR #	Scope	Priority	Variant	Title	Work Description	Asset	Equipment	System	Originator	Region originator	Timestamp	Status	Comments	Notes	EKME #	Priority	Estimated Cost	Estimated Weight Impact	Comments	Reasons for cancelling	Reasons for rejection
2012	2076	Major	Normal		alarm & monitoring		CAPORAL KAEBLE V.C.	Security alarm	Auxiliary Systems	Marc Bochette	Central and Arctic	2012-11-30	Approved by CCB	2012-12-03, Acb. Registration, email sent to Originator. 2012-12-13 DCC reçue et transférée au GCA pour pour Rev. / Support. CCR for new MSPV Class, Status changed to Major. 2013-02-07 DCC Approvée pour le Principe par le CCC.	Owner on the Kaeble and the Teather, Robertson and Carriere should be done in, [illegible]	2734805						
2012	2116	Major	Normal	Both	Robertson Modification to engine sump hand pump	See PDF on EKME: 2734804	PRIVATE ROBERTSON V.C.	Engine sump hand pump	Propulsion/Maneuvering Systems	Harold Rink	Central and Arctic	2013-01-11	Approved in Principle	2013-01-11, Received CCR form, document is Routed to Operations (Fleet) for revision. 2013-04-17 Supported by Operations sent to Eng. Services. 2013-11-18 received Update from Region, info sent to Eng Services. 2014-04-10 CCR Supported by CCR Committee, sent to CCB for Approval, see comments from Operations and HME Project Eng., in EKME 2734804. 2014-05-02 CCB meeting: CCR is Deferred pending Engineering analysis completed. 2014-11-06: Supported by HME see complete note in EKME #:2734804. 2014-11-07 Approved in Principle with condition:To be further discussed at the MSPV Working Group - decision will be communicated. 2014-12-10: D.Wyse informed CCR reviewed and agreed to implement by the MSPV group when funds are available. 2014-12-11: It was brought to the CCB's attention where condition was removed.	All 3 boats in Great Lakes in agreement this work can be done by crew - no weight implications, CCR supported by all vessels in class	2734804		$1,580	9 kg	Waiting for GL (Harold Rink) to make design and parts required		
2012	2117	Major	Normal	Both	Robertson Bilge and Dewatgering System	See PDF on EKME : 2734805	PRIVATE ROBERTSON V.C.	Bilge piping	Auxiliary Systems	Harold Rink	Central and Arctic	2013-01-11	Approved in Principle	2013-01-11, Received CCR Form, document is Routed to Operations (Fleet) for revision. 2013-04-17 Supported by Operations sent to Eng. Services. 2013-11-18 received Update from Region, info sent to Eng Services. 2014-04-10 CCR Supported by CCR Committee, sent to CCB for Approval, see comments from Operations and HME Project Eng., in EKME 2734805. 2014-05-02 CCB meeting: CCR is Deferred pending Engineering analysis completed. 2014-11-06: Supported by HME see complete note in EKME #:2734805. 2014-11-07 Approved in Principle. 2014-12-10: D.Wyse informed CCR reviewed and agreed to implement by the MSPV group when funds are available. 2014-12-11: It was brought to the CCB's attention where condition was removed.	All 3 boats in Great Lakes in agreement this work can be done by crew - no weight implications, CCR supported by all vessels in class.	2734805		$300	4 kg	Waiting for GL (Harold Rink) to make design and parts required		
2012	2118	Major	Normal	Both	Robertson oily waste system modification	See PDF on EKME: 2734806	PRIVATE ROBERTSON V.C.	Oily waste piping	Auxiliary Systems	Harold Rink	Central and Arctic	2013-01-11	Approved in Principle	2013-01-11, Received CCR Form, document is Routed to Operations (Fleet) for revision. 2013-04-17 Supported by Operations sent to Eng. Services. 2013-11-18 received Update from Region, info sent to Eng Services. 2014-04-10 CCR Supported by CCR Committee, sent to CCB for Approval, see comments from Operations and HME Project Eng., in EKME 2734806. 2014-05-02 CCB meeting: CCR is Deferred pending Engineering analysis completed. 2014-11-06: Supported by HME see complete note in EKME #:2734806. 2014-11-07 Approved in Principle. 2014-12-10: D.Wyse informed CCR reviewed and agreed to implement by the MSPV group when funds are available. 2014-12-11: It was brought to the CCB's attention where condition was removed.	All 3 boats in Great Lakes in agreement this work can be done by crew - no weight implications, CCR supported by all vessels in class.	2734806		$500	4kg	Waiting for GL (Harold Rink) to make design and parts required		
2012	2120	Major	Normal	Both	RHIB Cradle Modification	See PDF on EKME: 2753470	PRIVATE ROBERTSON V.C.	RHIB Cradle	Deck Equipment / Ship Support Systems	Jason Ritsmer	Central and Arctic	2013-01-21	Approved by CCB	2013-01-21 Acb. Registration, email sent to Originator. 2013-02-11 CCR is Routed to ACM and CCR Committee, noted URGENT. 2013-02-21 CCR is Approved in principle by CCR for prototype installation on PRIVATE ROBERTSON V.C. After completion of test and approbation, a confirmation will be issued to vessels managers of this class to inform they can proceed with modification. 2014-06-03 Received Update from Region: CCR Completed.	Contract has been awarded to begin work, cradles are being delivered in early March 2014, money has been sent to regions for this work.	2753470						

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2012	2170	Major	Normal		reconfiguration de la cuisine du caporal Kaeble V.	See PDF on EKME: 2768749	Mid-Shore Patrol (MSPV)	Cuisine	Domestic Systems	Gaël Therrien	Quebec	2013-02-25	Routed to Fleet	2013-03-04, Ack. Registration, Email sent to Originator. 2013-03-06 Reçu DCC, formulaire envoyé aux Opérations (Fleet)pour revision.	This CCR to be updated= New drawings are being done, plan is to have agreement on them by end of March 2014. Work should be done in 2014/15 and has to go through PWGSC for all modifications. Approx $13K/vessel	2768749		$13,000	There should be little weight change as it involves moving around steel work already in place. Will have to keep track of weight during work.	Quebec Region to come up with Prototype. They will begin this fall as the Galley will have to be shut down for a week. Ensure that switch behind the oven is accessable.		
2012	2183	Major	Normal	Both	MSPV Transformer Enclosure Upgrade	See PDF on EKME: 2773500	Mid-Shore Patrol (MSPV)	14D04 Electrical Transformers	Electrical Power Distribution	John Blotardiere	NCR	2013-03-06	Approved by CCB	2013-03-08, Ack Registration email sent to originator to request document. 2013-02-13 CCB form routed to ACM for Rev. Support, after it must be Approved in Principle at CCB meeting or secretarially. 2013-04-10 CCR is supported by CCR Committee and sent to CCB for Approval. 2013-04-10 this CCR is Approved in Principle by CCB.Documentation	CLOSED: Done on all vessels delivered so far and will be done on new ones as they [illegible]	2773500			Will increase weight slightly			
2012	2184	Major	Normal	RCMP only	Réaménagement du mobilier du centre d'opération	Réaménagement du centre de commandement, remplacement de l'ameublement pour que la configuration soit plus opérationnelle.	Mid-Shore Patrol (MSPV)	Salle des opération GRC	Program (Special Purpose) Assets	Gaël therrien	Central and Arctic	2013-03-12	Approved by CCB	2013-03-12 Accusé rec. Enregistrement, Courriel envoyé au demandeur. 2013-03-20 Reçu Formulaire DCC et dessins des travaux (DWG), informations envoyés aux Opérations pour revision. 2013-08-28 verification avec demandeur si les DCC 2070, 2079, 2184 sont des travaux identiques: réponse OUI. Les DCC 2070 et 2079 seront cancellées. travaux assurés par DCC 2184. Les 3 DCC sont jumelées et il y aura discussions entre les Régions pour le choix d'une solution unique. 2013-04-18 reçu info de Québec: Les chaises ne seront pas fixées au plancher. 2013-05-13 DCC Supportée par Comité, 2013-05-14 DCC Supporté pour ingénierie par CCC (sans réunion).	Covers CCRs 2070 and 2079 that were cancelled and rolled into 2184. Appxcidmate cost per vessel is $35K 50K, Gael looking at options. Design produced by Marine Engineer for the Kaeble has been approved in principle, but not installed anywhere. Requires all new furniture, could be up to 100kg more per vessel, weight implications have to be investigated. Not on scheduled workplan yet, but hopefully 2014/15 - Has been	2777089		$35000-50000	100 kg +/-			

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2013	2211	Major National	Urgent	Both	Modification de la passerelle des navires MSPV	Les navires MSP ont livré à l'aide d'une passerelle donnat accès aux usager qui n'est pas utilisable dans les différentes configurations de quai que l'ont retrouve à travers le Canada, Afin d'ere fonctionnel une solution doit être établis pour être fonctionnel.	Mid-Shore Patrol (MSPV)	Paerelle du navire	Deck Equipment / Ship Support Systems	Gael therrien	Central and Arctic	2013-04-04	Approved in Principle	2013-04-05 Accus? R?ception, courriel envoy? a l'initiateur de la DCC. 2013-04-09 DCC est envoy?e au GCA pour Revision/support. Att. Checklist n'est pas compl?t?e. 2012-04-12 CCR is Supported by CCR Committee under specific condition of not removing the RHIB and the ber, see complete details in EKME 2786927. 2013-04-22 CCR is Approved for Prototype as per recommendations sent April 12th, see email or EKME file: 2786927, for details. 2014-01-28 Recu ?tude de faisabilit?e, en attente pour pr?senter au CCB pour Approbation finale. 2014-02-07 CCR Deferred. We received feasibility study from NAVTECH (available in EKME) and submit to CCB; the options (2A, 2B, 3) of having only one zodiac for RCMP is not acceptable for Director of Operational Support. CCR is not supported by CCB. CCR is Deferred, until final solution is approved by all parties. Note CCR 2397: Scope of work is similar to Temporary solution already Approved for prototype CCR 2213. If the 2 CCRs scope are not similar please identify differences and return to me for Revision by CCR Committee. 2014-12-11: Approved in Principle, OPI Dave Wyse.	HIGH PRIORITY	2786927				Quebec Region to come up with Prototype. Gangway prototype will be 5m long and possible 600mm wide. Must be class approved. Drawing and prototype will be completed this summer. A davit is also required. National funding		
2013	2219	Major	Urgent		Install Transitional Power Sources to Supply PC BAsed Navigation Systems	see form on EKME #: 2805351	Mid-Shore Patrol (MSPV)	N/A	Vessel Communications and Navigation	Claude Renaud	Central and Arctic	2013-05-02	Approved by CCB	2013-05-02, Ack. CCR Registration. Received CCR Form completed and Signed, Document are routed to Operations and ACM for Rev./Support. 2013-05-29, CCR Supported by CCR Committee, will be transfer to CCB for final Approval, next CCB July. 2013-05-31 CCR is Approved in Principle (secretarially) by Chairperson, email sent to Originator and others contacts.	Because there is a lack of transitional power source some vessels have expierienced damage to CCTV system during blackouts	2805351			$1,200	28 kg			
2013	2268	Major	Urgent	RCMP only	MSPV Operations Room Electronics Reconfiguration	Relocate various items of electronic equipment in the Operations Room.	Mid-Shore Patrol (MSPV)	Various	Vessel Communications and Navigation	Jason Kimmer	Central and Arctic	2013-05-30	Approved by CCB	2013-05-31, Ack. Registration. Please, submit CCR Form when Completed and Signed (Approved by Users and Region Authorities). 2013-05-31, Ack. Registration. Please, submit CCR Form when Completed and Signed (Approved by Users and Region Authorities). 2013-07-03, Received CCR Form and Specifications document, info is Routed to Fleet for Evaluation / support. 2013-09-27 CCR is Supported by CCR Committee and Routed to CCB for Approval. 2013-09-27 CCR is Approved in Principle secretarially. 2013-10-16 CCR is sent to CCB for information, CCR was Approved secretarially earlier, Approved in Principle, Class applicable.	On Hold: Medium Priority. Kaeble already done. If radar is removed it must be reserved to be re-used once ECDIS is installed. This will be done as manpower and budget permit. Warranty period also a consideration	2849519			TBD	TBD			
2013	2271	Major National	High	Both	2013 - 0606 MSPV Shore Power Cable Reversed Interior	Due to the fact that the MSPV shore power cables supplied are male at both end there is a safety concern that the inboard end could be accidentally energized creating a shock hazard for personnel. The intention of this CCR is to modify the inboard end of the shore power cable and receptacle with a reversed interior (female) thereby mitigating the associated risk.	Mid-Shore Patrol (MSPV)	Shore Power Cable	Ship's Service Electrical Power Generation	John Richardson	NCR	2013-06-06	Approved by CCB	2013-06-06, Ack. Registretion. Please Submit CCR Form when Completed and Signed (Approved by Users and Region Authorities). 2013-06-13 Major CCR Form is Routed to Operations and CCR Committee for Rev./ Support. 2013-07-11 CCR is Supported and Routed to CCB for Approval, if urgent can be process secretarially on request. 2013-07-17 CCR is Approved in Principle (secretarially). 2014-06-03 Received Update from Region CSR Completed.	Underway	2843952						
2013	2310	Major National	High	RCMP only	RHIB Strobe Light Amendment	The upgraded single blue light does not provide a strong enough light with sufficient visibility and coverage for vessel operations.	Mid-Shore Patrol (MSPV)	N/A	Vessel Communications and Navigation	Steven Pasley	Central and Arctic	2013-08-16	Approved in Principle	2013-08-16, Ack. CCR Registration. Email sent to Originator: Please, submit CCR Form when Completed and Signed (Approved by Users and Region Authorities). 2013-11-18 received Approved (Signed document) from Region , info sent to Fleet. 2014-06-03 file with Engineering Service to evaluate weight for proposed mast configuration. 2018-12-11: Approved in Principle with condition that the section 9 & 10 checklist is to be completed.	2014/02/21 Response received from TC re: 2 lights, email outlining conditions for CCR consideration sent to RCMP for review	2894824						

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2010	2311	Major National	High		RHIB Siren / Loud Hailer	The ship 753 Zodiac two RHIBs are each fitted with oniCOM VHF radio (IC-M604) that does not have police siren capability. The existing loud hailer loudspeaker is mounted aft under the radar arc. A more compact version should be mounted forward to protect the hearing of officers.	Mid-Shore Patrol (MSPV)	Siren / Loud Hailer	Vessel Communications and Navigation	Steve Pauley	Central and Arctic	2013-08-16	Approved by CCB	2013-08-16, Ack. CCR Registration. Email sent to Originator: Please, submit CCR Form when Completed and Signed (Approved by Users and Region Authorities). 2013-12-03, Received CCR Form approved, document Routed to Fleet. 2014-05-27 Recommended solution has changed since this CCR was initiated, see attached document EKME 3108889. CCB Supported by CCB Committee, Routed to CCB for Approval June 4th, 2014. 2014-08-06 CCR Approved in Principle by CCB for MSET vessels only, operation to follow up separately regarding approval for 5 other	Options for sirens in marine low environment ope being investigated by fleet.	2948523							
2013	2379	Major National	Normal	Both	MSPV - New Screen Installation ER ventilation fan	fabricate and install intake screen on ER ventilation intake. EKME:2980670.	Mid-Shore Patrol (MSPV)	N/A	Auxiliary Systems	Harold Bink	Central and Arctic	2013-11-18	Completed	2013-11-18, Ack. CCR Registration. Email sent to Originator: If not already done, Please Contact other MSPV users to agree on Design. Then submit CCR form when Completed and Signed by All Regions (Users and Region Authorities). 2013-11-19 Received CCR Form , document Routed to Fleet for Rev/Support. 2013-12-06 CCR is Approved for Engineering. To OPI: Engineer recommends ensuring no Pressure drop created and to explore if screens will be used year round or not. Return to CCB for Approval for Class. See BoD in EKME. 2013-12-09 Update from OPI: used 12 months, maintenance is scheduled to prevent clogging, see email attached. Waiting if approved by all Regions. 2014-01-08 Engineering confirmed CCR is Applicable for Class, CCR will be submit for Approval in Principle at next CCB. 2014-02-07 CCB asked for more information on installation, i.e. manufacturer specifications off product. CCR Approved for Engineering until information supplied. 2014-06-03 OPI contact supplier, and confirmed that no impact on supply fan, only required housekeeping on product to avoid pressure drop. (Full detail in file), CCR sent to CCB for Approval, June 4th. 2014-06-06 PM contact supplier to confirmed no impact if equipment maintained regularly, CCR Approved in Principle for MSPV Class. 2014-06-03 Received Update from Region: CCR Completed.	Being implemented on vessels 1, 3, 4, 5, 6 - no requirement for 6 on R2. Require confirmation that screens will not damage fan (either testing or written confirmation from screen manufacturer).	2980670							
2013	2380	Major National	Urgent		MSPV - RHIB Footpegs Modification	Install spring loaded footpegs on RHIB jockey seats. Identified by RCMP as an OSH issue. These RHIBs were purchased under the EAP not via ISI.	Mid-Shore Patrol (MSPV)	Hull and Related Structures	N/A	Jason Rasmuss	Central and Arctic	2013-11-18	Completed	2013-11-18, Ack. CCR Registration. Email sent to Originator: If not already done, Please submit CCR Form when Completed and Signed (Approved by Users and Region Authorities). 2013-11-19 Received CCR Form approved, document Routed to Fleet for Rev/Support. 2013-12-17, Engineering PM Lindsay Fyfe bring some clarifications to TSOR for RHIB, and explain that with the actual Jockey seat configuration, adding foot pegs can have the opposite effect; see details email attached in EKME.	Approved in principle	2980885							
2014	2396	Major	Normal		Refaire et repositionner la sortie air extérieur du ventilateur de la hotte de la cuisine	Le besoin est d'effectuer le repositionnement et agrandir la sortie d'air extérieur du ventilateur de la hotte pour éliminer deux 90 du conduit de ventilation. Présentement la sortie d'air est de 26 cm X 21 cm mais dû au défecteur celle-ci est réduit à 18.7 cm X 10 cm.	Mid-Shore Patrol (MSPV)	hotte de cuisine	Domestic Systems	Luc Poirier	Central and Arctic	2014-01-03	Approved by CCB	2014-01-03, Ack. CCR Registration. Email sent to Originator: If CCR not already done, Please submit Form when Completed and Signed (Approved by Users and Region Authorities).	Need regional consensus on this issue and confirmation that removal of any sections of ducting will not impact water trap in line; ensure no other potential issues. Needs further research	3019149			Minimal	Minimal			
2014	2397	Major	Urgent		Removable Railing For Gangway Placement Bridge Deck	Our plan is to cut out sections of railing on the bridge deck in order to allow the gang way to have an access on the bridge deck ahead of the life rafts which we remove when tied up in order to utilize our gangway. Once they are cut our chains with securing devices will be put in place to act as railing while at sea.	Mid-Shore Patrol (MSPV)	Gangway	Deck Equipment / Ship Support Systems	Alexander J Carey	Atlantic Region	2014-01-06	Approved in Principle	2014-01-07, MSPV Class: Scope changed to Major. Ack. CCR Registration. Email sent to Originator: If CCR not already done, Please submit Form when Completed and Signed (Approved by Users and Region Authorities). 2014-02-05 Received CCR Form approved by Region, documents are routed to CCB Committee for Revision. Note CCR 2211 gangway modification may cover the scope of this CCR. 2014-02-07, Status: Scope of work is similar to Temporary solution already Approved CCR 2211, If not identical please identify differences and return to me for revision by CCB Committee. 2014-11-06: Supported by CCB Committee. See complete eNME note in EKME R:3287153. 2014-11-07 Approved in Principle with condition: to be further discussed at the MSBV Working Group - decision will be communicated. 2014-12-01: Informed that all vessels have agreed to implement - email has been sent to MSPV members.	Can be combined with CCR 2211. Has been done on vessels 2, 5 and 6.	3028685			Minimal	Minimal			

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2014	2398	Major	Normal		Shelf Removal Wet Gear Locker	At present the design configuration for the Wet Gear Locker does not allow for effective storage and drying of wet gear due to lack of space. There is insufficient space, with the current arrangement, to hang the gear that would be hung in the space during normal operations. There is no other space within the vessel to hang gear that is wet. When wet gear is placed in this locker it is dripping onto any items stored on the shelf unit in questions. See attachment. The largest of the two shelf units that are presently located in the Wet Gear Locker is to be removed from the vessel and placed in storage ashore. The smaller of the two shelf units is to be re-positioned to allow for easy access to the locker. Removal of the shelf unit will allow for wet gear to be properly hung and dried in the space. The shelf unit weighs approximately 120lbs. Given the restrictions regarding the addition of weight on this vessel the removal of this shelf would be a benefit in this regard.	Mid-Shore Patrol (MSPV)	Wet Locker	Deck Equipment / Ship Support Systems	Alexander J Curry	Atlantic Region	2014-01-06	Routed to ACM	2014-01-07 This CCR is MSPV Class, Scope is changed to Major. Ack. CCR Registration. Email sent to Originator: If CCR not already done, Please submit Form when Completed and Signed (Approved by Users and Region Authorities). 2014-01-24 Received CCR Form Completed and signed, Documents are routed to CCR Committee.	Shelf has been removed on Vessel 5 and kept in storage in case it needs to be put back.	3041-1388							
2014	2608	Major	Normal	Both	MSPV - Removal of UHF Antennae in way of Running lights	Remove two UHF antennae (1 each on port and starboard side) that produce reflected light in way of the port and starboard side (red and green) running lights on all vessels of the MSPV Class. Existing wiring to be preserved in place and waterproofed in case of future requirements.	Mid-Shore Patrol (MSPV)	UHF Radio Antennae	Vessel Communications and Navigation	Michael Glew	NCR	2014-01-20	Approved by CCB	2014-01-21, Ack. CCR Registration. Email sent to Originator: If CCR not already done, Please submit Form when Completed and Signed (Approved by Users and Region Authorities). 2014-02-06 Received CCR Form, Request is Supported by Manager Operational Requirements Jim Nunn, info is Routed to CCR Committee for Revision. 2014-02-13 CCR is Supported by CCR Committee. CCB is Approved in Principle by CCB, Radio must be removed if still installed. E & I would prefer that cable be removed, also DWG should be updated.	Work must be completed exactly as described in the ECR: remove antenna and tape ends. Antennas have been removed on Kaeble, other vessels should be done by end of March.	3041-1388							
2014	2498	Major National	Normal	Both	MSPV - Trash compactor removal (C&A G1 sector vessels)	Removal of trash compactors onboard that are not in use. Consists of unbolting the compactor and removal from space. Space will then be used for storing addition deck equipment. 2014-06-06 CCR Approved in Principle for MSPV Class.	Mid-Shore Patrol (MSPV)			Melvin Tun	Central and Arctic	04/04/2014	Approved in Principle	2014-04-09 Ack. CCR Registration. Email sent to Originator: If CCR Form not already produced, please submit when completed and signed (Approved by Users and Region Authorities). 2014-04-17 Received CCR Form and DWG, Documents are Routed to CCR Committee for Rev / Support. 2014-04-25, CCR Raised to Major (applies to MSPV Class), CCR Supported by CCR Committee, see complete comments from Operation. 2014-05-06 CCR Approved in Principle for MSPV Class. Storage part of the proposed solution is not approved at this time, until weight control analysis is completed and program in place, Greg Lick Dir. Operations.	Supported by all MSPVs, supported by fleet, waiting for CCB approval	3041-127							
2014	2504	Major National	High		Required Changes to Safety Control Plan and Fire Control Plans on MSPV's	Changes proposed were adopted shortly before transiting vessels back to C & A region for safety reasons. Extra lifejackets required and/or immersion suits depending on the number provided by shipyard at time of delivery. Plan approval cost $3,500.00 per vessel. Extra 5 Life Jackets.	Mid-Shore Patrol (MSPV)	Fire Plan Update and approval	Select System	Christian Jensen	Central and Arctic	23/05/2014	Approved in Principle	2014-05-27, Ack. CCR Registration. Email sent to Originator: If CCR not already done, Please submit Form when Completed and Signed (Approved by Users and Region Authorities). 2014-12-05:Registered. routed for signatures and email sent to originator.								
2014	2511	Major	Urgent		Replacement of Air to Ground Antenna on MSPV	Antennas currently fitted on the MSPV generate a High VSWR outside specification. The existing grounding plane is a 6"x6" and manufacturer confirmed that there was a misprint in documentation and a 6'x6' grounding plane was required for existing antenna. This can't be achieved on this class of vessel. To replace the existing antenna with the SG2.5B-SF15NM as this is the Standard throughout the Fleet. Substantially improve performance by meeting the VSWR Standard specification.	Mid-Shore Patrol (MSPV)	Jotron TR7725	Vessel Communications and Navigation	Pierre Lamycon	Atlantic Region	02/06/2014	Supported by ACM and CCB committee	2014-06-02, Ack. CCR Registration. Email sent to Originator: If CCR not already done, Please submit Form when Completed and Signed (Approved by Users and Region Authorities). 2014-06-25 CCR Urgent, Routed to Operation for Rev. / Support. 2014-11-06: Supported by MME see complete note in EKME #3287158. 2014-11-07 CCB agreed to return to CCB note for E&I support.								
2014	2529	Major National	High		Lubrication Program Modifications for the Hero Class Mid Shore Patrol Vessels	The modification of lubrication related equipment aboard the vessel both minor, such as the addition of breathers, filters, ISO quick disconnects and offline / delivery filtration units. The optimization of lubricants using lubricant identification labels on equipment and reservoirs with the standardization of the storage and handling practices based on industrial best practice and WHMIS recommendations. The standardization of the process for the collection of oil samples, using sample ports with the setup of equipment specific lubricant alarm limits and recommended actions.	Mid-Shore Patrol (MSPV)	Systems modified are detailed in the EKME Document #3286567	Propulsion/Maneuvering Systems	John Riga	NCR	24/07/2014	Supported by ACM and CCB committee	2014-07-25, Ack. CCR Registration. Email sent to Originator: If CCR not already done, Please submit Form when Completed and Signed (Approved by Users and Region Authorities). 2014-08-15 Received CCR form signed by Originator, with specification document: EKME: 3337804, also Lubrication Program available on EKME: 3286567. 2014-11-06, CCR supported by CCB Committee, Routed to CCB for Approval.								
2013	1647	Major National			Modification compartiment à batterie devant timonerie	Le compartiment utilisé pour le rangement des batteries d'urgences est très grand et ne contient que 4 batteries. Le compartiment est situé sur le devant de la timonerie avec un accès par deux écoutilles extérieurs. Le compartiment est muni d'une entré d'air et de deux sorties. Il est de plus muni d'une élément chauffant. Le navire ne dispose pas de rangement pour l'entreposage des boyaux et de l'équipement utilisé pour les ravitaillement en eau potable. Selon la procedure 7.A.12 Qualité de l'eau Potable du manuel de sécurité de la flotte, les boyaux utilisé pour l'eau potable doivent être purgés, scellés et entreposés dans un caisson propre, sécuritaire et utilisé exclusivement pour l'entreposage d'équipement d'approvisionnement en eau potable. Déplacer deux batteries avec leurs assises sur le côté bâbord du compartiment. Fabrication et soudure d'une cloison en aluminium étanche au milieu du compartiment afin de créer une séparation. Garder la ventillation naturel des deux compartiments. Protéger l'isolation sur les parois à l'aide de grillage. Installer un drain dans le fond du compartiment. Déplacement (re-localisation) de deux extincteurs dans le même compartiment.	Mid-Shore Patrol (MSPV)	Hull and Related Structures		Rene Hardy	Central and Arctic	07/07/1905	Approved in Principle								

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2013	2649	Major National	High	Risk Assessment - Transformers Mitigation Plan	Implement mitigation plan as it relates the the Risk Assessment - Transformers	1 pilot vessel 1. Change location of the emergency generator fuel tank vents to outside 2. Metal protective shields around transformers 3. Addition of ground fault monitoring capabilities 4. Move discharge for inline drains from duct work in AmR 5. Install heat trace on hatches 6. Replace battery boxes in emergency gen room with proper type 7. Installation of burst pipe protection on certain pipes	Mid-Shore Patrol (MSPV)	Electrical Power Distribution	Various	Chris Dort	NCR	18/02/2015	Approved in Principle	2015-02-19: Routed to CCR Coste for approval/signatures. 2015-02-02 CCR supported by CCR Committee, note added to file from HME engineering: " From Hull perspective the weigh is the only issue, estimated to 450 lb.", this modification will reduce the actual margin. Technically it looks all right. 2015-03-13 CCR is Supported by CCB Secretariatly.	1424971		Glassey	Nanires / Vessel		2649	19/02/2015	02/03/2015	
2014	2690	Minor	High		Addition of Duplex SW strainer for ship service Generators	At present, there is no means of cleaning the strainer fitted inside the Sea Water regulating valve for the auxiliary generators without having to shut it down and change over to the standby generator. This has become problematic because the filtering capability of the small mesh screen is insufficient. It takes very little debris to clog up the strainer which in turn causes the Jabsco impeller sw pump to go into a vacuum state. This has the potential to damage the vanes on the impeller. There is often a frequent requirement to clean the filters due to the water the vessel may be operating in. This has become very tedious and has also subjected the strainer in the valve, as well as the valve itself to suffer damage due to the number of times it's had to have been opened up. The screens located in the regulator are also inadequate in that it still allows debris to pass by and clog up the cooler tubes on the engine. This was observed on the 2000 hour inspections for both generators. The recommended solution is to fit a duplex sw strainer on the main sw supply line to the generators. The best location for minimal interference would be aft of the port main engine underneath the flow meter for the stern tube cooling. The main sw supply piping to the generators would have to be modified slightly to accommodate the duplex strainer. The sw piping to the stern tube cooling water regulator may also have to be modified as well to accommodate the strainer.	Mid-Shore Patrol (MSPV)	Sea water system for ship service generators	Auxillary Systems	Dave Wyse	NCR		Approved by CCB	Resubmitted nationally as was lost in regional process Contract is in the technical evaluation stage									
2016	2691	Major	Normal		Aft Gate Access for embarking or disembarking RHIB	The solution we have come up with is to add additional gates in the railings on the aft end of the vessel in order to come and go from the RHI in a safer manner that we are able to with the current arrangement. Attached you will find pictures of the sections to be removed in order to install new gates along with a sample picture of what we would like installed. The estimated cost of installing the gates is $1750-2200. The only difference from the sample pictures that we would like to see is that the gate simply be removable with pins instead of a hinge.	Mid-Shore Patrol (MSPV)	Aft railings	Hull and Related Structures	Dave Wyse	NCR		Approved by CCB	Resubmitted nationally as was lost in regional process									
2015	2692	Major National	High		FO Tank vents removable sections	Currently, #1, #2, and #3 Fuel tanks share a common overflow/vent line that connects to the forward port corner of #9 FO Storage Tank. The overflow/vent lines from those forward tanks have loops that extend above the deck, port side forward. These loops are solidly welded with no means to break the lines to facilitate testing of the tanks individually. In the future, when testing is required again by the Classification Society, we will have to have a means to test the individual tanks and at present, that is not possible as all of the tanks are connected together through this common vent/overflow. Note 9 of the "Air Pipes and Sounding Diagram" stipulates that the "Combined air escapes shall be fitted with a removable section to permit the testing of the tanks individually." The air vent for #9 FO tank is located at the forward port corner of the tank. #9	Mid-Shore Patrol (MSPV)	Fuel overflow system	Auxillary Systems	Dave Wyse	NCR	08/12/2014	Approved by CCB	Resubmitted nationally as was lost in regional process Spec and drawings sent to have implemented. Lloyds can approve locally									
2015	2693	Major National	High		#9 Fuel Oil Tank reconfiguration	The air vent for #9 FO tank is located at the forward port corner of the tank. #9 FO Tank is stepped and the vent is located at the lowest point of the tank top. This arrangement prohibits the complete filling of the tank since the higher part of the tank effectively becomes air locked. If fuel is still being pumped into #9 when the common vent/overflow line for #1, #2, #3 FO Tanks is blocked, there is a potential to pressurize those forward tanks. This will result in false high level alarms in all of the forward tanks since the Tank Level Indication System works off pressure sensors. The resulting alarms can cause confusion for those unfamiliar or new to the vessel. #9 FO Tank is essentially "full" when it's at approximately 75%. There have been special fuelling procedures developed in an attempt to fill the tank to a higher level but that is a compensation for poor design. The overflow/vent line loops above deck should be removed and have flanges installed to facilitate testing of the tanks individually. The vent line for #9 FO Storage Tank should also be connected to the aft section of the tank at its highest point. There would be no need to relocate the vent entirely, just an addition.	Mid-Shore Patrol (MSPV)	Fuel overflow system	Auxillary Systems	Dave Wyse	NCR		Approved by CCB	Resubmitted nationally as was lost in regional process Spec and drawings sent to have implemented. Lloyds can approve locally									

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2015	2694	Major	High		Addition of Primary Sock Filters to the RO SW suctions	1. The prefilters for the RO's are expensive and we are changing them quite frequently. The solution to this problem would be to add 20-25 micron sock type filters on the suction to each RO with a crossover in between to facilitate cleaning of the filter without having to shut the unit down. Another option which may prove to be more beneficial is to have a common suction line that's large enough to accommodate both RO's with a duplex course strainer and a duplex sock filter. This may prove to maximize on the lack of space in the bow thruster compartment. 2. The boost pump for the upper RO, should be turned around on the other vessels as well so that the pump casing is not directly adjacent to the shore power transformer and its openings. Ideally, this pump should be moved below the waterline as well. 3. The SW suction for the upper RO's should be lowered to the same level as the lower RO suction, which is to say below the waterline. If the upper RO Boost pump is lowered as well then this will ensure that both pumps can be easily primed. It will also be beneficial to lower the position of the 2-way valves for the respective RO's as well. These 2-way valves are much higher than the boost pumps and sea suctions and are used only when cleaning the RO membranes.	Mid-Shore Patrol (MSPV)	Reverse osmosis water maker	Auxiliary Systems	Matt Riebert	Atlantic Region	06/12/2014	Approved by CCB	2014-12-09: Acknowledgement: Email sent to originator to submit completed and signed CCR by approved users and Region authorities.						Resubmitted due to less regional		
2015	2698	Major	High	Both	Potable water UV sterilizer replacement	The Ultra-Violet (UV) sterilizers supplied with the MSPVs have proven to be unreliable and expensive to maintain. Several vessels in the class have already experienced issues with abnormally low intensity readings, despite following the OEM recommendations for maintenance.	Mid-Shore Patrol (MSPV)	Domestic Systems	UV sterilizer	David Wyse	NCR	15/04/2015	Routed to ACM	2015-04-16: Ack. CCR Registration. CCR sent to CCR Committee for Rev/Support. Waiting for trial information from the M. Charles - implementation went well		3H3098, 3H3097						
2015	2699	Major National	Urgent		Hero Class Water Fire Main Piping Replacement	Existing Condition: Currently 8 out of the 9 hero class vessels have stainless piping in the water extinguishing fire system. The incident reports and failure analysis have shown that the stainless steel piping is corroding and allowing water to leak. See attached reports. Recommended Solution: 1. 2 vessels in the C&A region have had a borescope inspection of the piping. The vessels in the Atlantic region will then be inspected and a priority list for a solution to be implemented will be formed. 2. An engineering study must be done to create a solution for the replacement of the piping (material, piping, class approved drawings, weight analysis, etc.) 3. A solution to be implemented for the Class. Anticipated Benefits: A solution to provide reliability of the water fire extinguishing system and solve the corrosion and leak issues. Impact on maintenance budget: High maintenance costs by implementing band aids whenever a leak is found, increase the life cycle of the system, ensure that the system is operational, ensure that no other equipment or materials or damaged due to leaks.	100	Fixed fire fighting system	MSPV	Dave Wyse				Final solution to be determined by senior management								NCR
2015	2700	Major	Normal		MSPV RHIB Wireless Intercoms	Currently, communication on board a Rigid Hull Inflatable Boat (RHIB) traveling at speed is very challenging. Wind and engine noise force boat operators to have VHF radios turned to MAX volume, and any communication between boat operators is done through shoulder taps and hand signals. Taking these safety issues into consideration and combining that with increased operational / program requirements, wireless headset communications is necessary aboard the RHIB's paired with the MSPV's. Install David Clarke wireless headset communication system, standard to Western Region SAR RHIB's.	Small Craft (SC)	16802807	Wireless Headsets	Adam Cochrane			Approved	Vessel Communications and Navigation	adam.cochrane@dfo-mpo.gc.ca	250-413-2853	Gabriel Chaikin	Gabriel.Chaikin@dfo-mpo.gc.ca	250-363-0228			
2015	2701	Major National	Normal		Hero Class Crane ram design change and remote control changes	Shorten the crane cylinder RAM to be able to engage the RHIB in the cradle. Belly pack remote controls do not allow for booming in and out simultaneously hoisting or lowering the crane. This function is required for safe operations with the crane. This must be rectified with the manufacturer. An engineering study must first be done to develop solutions and a prototype for the class. Existing Condition: 1. Currently the cranes on board the Hero Class vessels do not have enough vertical movement to reach the lifting hooks on the RHIB(s) while they are sitting the in the cradle. 2. The cranes cannot be operated safely because the control does not allow simultaneously hoisting or lowering and booming in or out using the remote belly packs. Recommended Solution: 1. An engineering study must be completed to acquire a solution for the issues above. 2. The solution must be planned and implemented across the class. Anticipated Benefits: The solutions will ensure safety and proper handling of the crane throughout the life cycle of the vessels. Impact and Maintenance Budget: Safety risks to personnel and risk of damaging assets.	Mid-Shore Patrol (MSPV)	Deck Equipment / Ship Support Systems	Hydraulic Crane	David Wyse	david.wyse@dfo-mpo.gc.ca	993-2710	Requested/ In Progress	Engineering contractor working on a solution					NCR	24/04/2015	Acknowledged	2015-04-24, CCR registered by LCM HQ, document routed to CCR Committe for Review/Support.

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2015	2702	Minor	High		Ship Service Fuel System_addition of Primary fuel filters, Duplex Racor Unit	We currently have no primary means of filtration for the fuel system on the ship service diesels. The secondary filters that are fitted directly on the engine have become the only method of filtration and water separation. This arrangement has resulted in a number of "blackouts" due to the plugging of the respective filter. Suction and discharge pressure gauges were fitted on either side of the filter but these have proven to be inadequate as a tell-tale for when the filters need to be changed. When the generator shuts down on loss of fuel oil, the emergency bus momentarily dies until the Emergency Generator starts up and goes online. All of the navigation equipment is on that bus and those pieces of equipment vital to the safe navigation of the vessel do not have a dedicated UPS. The equipment all shuts down and takes time to restart. This could have extremely negative consequences especially in high traffic areas. It is recommend that Racor (Duplex) 75500MAMX with the 2010 filter elements be installed in the fuel supply line. This duplex unit can be installed in the main line fuel supply and is capable of servicing both generators. These units are also fitted with a differential gauge that gives a clear indication of when the filter element needs to be changed. It removes the guesswork of when the engine mounted filter should be changed especially since the gauges cannot be relied upon. This problem arises more commonly when new staffs are aboard the vessel and are not familiar with the system.	Mid-Shore Patrol (MSPV)	Fuel oil system	Auxiliary Systems	Dave Wyse	NCR			Resubmitted nationally as was lost in regional process									
	2703	Major National	High		MSPV Techsol A&M HMI Screen Install	EXISTING CONDITIONS:There is no Techsol Alarm and Monitoring Human Machine Interface (HMI) screen in Cabin 209 where the Senior Engineer will occupy if the Engine Room is going to be operating in Unmanned Machinery Space (UMS) mode and working 0700-1900. or if gender confliction requires the Senior Engineer to occupy that Cabin. RECOMMENDED SOLUTION: Install Techsol Alarm and Monitoring HMI in Cabin 209 and have the Senior Engineer occupy that cabin. Require Cat 5 Cable from PC #A. Require 24V DC power supply from UPS-B. Require 12" Seaview HMI screen.	Mid-Shore Patrol (MSPV)	Integrated Control Systems	Techsol Alarm and Monitoring	M.Charles Chief Engineer	Western Region	42122	Acknowledged	2015-06-05, Ack. CCR Registration, form available on EKME ID483968. Status changed to Major National, could be Applicable to MSPV Class. Waiting for Regional Approval to process.			Nanoose / Vessel		NCR	24/04/2015	Supported by ACM and CCR Committee	2015-04-24, Ack. CCR Registration. CCR sent to CCR Committee for Rev/Support
2015	2709	Major National	High		Install Maximo on MSPVs	MSPV's require an asset management system to be installed on ship servers to provide a comprehensive maintenance solution. As per the CCG commissioners guidelines, the AMS to be used on CCG vessels is to be Maximo.	Mid-Shore Patrol (MSPV)	Informatics Systems (IT)	N/A	Jordan Dim	NCR	13/05/2015	Supported by ACM and CCR Committee	2015-06-13, Ack. CCR Registration, CCR Form available on EKME:#3471224. Routed to CCR Committee (Operations) for Rev./Support. 2015-06-21 CCR Supported by CCR Committee and Routed to CCB for Approval, next CCB meeting June 12th. Engineering OPI at HQ is Jordan Dim supported by Regional VMM.		3471224							
	2712	Major National	Normal		Hero Class (MSPV) Navigation information in CO cabin/office	The new video collection/switching equipment and spare outputs already provides the basic capability. All that is required is a single cable run from the Operations Room cabinet to the Commanding Officers cabin. The cable distance may require a VGA to Ethernet converter.	Mid-Shore Patrol (MSPV)	Vessel Communications and Navigation	Navigation video collection	David Wyse		27/05/2015	Routed to Operation	2015-05-29, Ack. CCR Registration, CCR Form and documentations available on EKME:#3477622, 3477624, 3477525. Documents Routed to CCR Committee (Ops.) for Rev./Support.		3477622, 3477525, 3477624,							
	2713	Major National	Normal	Both	Hero Class (MSPV) Automatic Chlorination system	install in-line sanitation system between the ROs and the fresh water tanks. The system comprises mainly of a flow meter (to monitor the amount of water being sent from the ROs to the tanks), a dosing controller and pump (to analyze the volume of water produced, according to the flow meter, and add the appropriate amount of chlorine), and a static mixer to distribute the chlorine (this is a length of plastic pipe with baffles inside to promote turbulence. It is installed in the RO product water line)	Mid-Shore Patrol (MSPV)	Domestic Systems	Chlorinator	David Wyse		27/05/2015	Routed to Operation	2015-05-29, Ack. CCR Registration, CCR Form available on EKME:# , Routed to CCR Committee (Ops.) for Rev./Support.		3477533, 3477534							
2015	2737	Major National	High		Hero Class General and Fire Alarm Tones	The General and Fire alarms aboard the Hero Class vessels are two different tones. Ships officers and crew do not believe the general alarm has the minimum sound pressure levels to alert crew. The General and Fire alarms should be the same tone and ensure that the decibel levels meet requirements as per the Life Saving Appliances code and to satisfaction of the Commanding Officer. Merged with CCR 2400 - The present telephone communication system is not equipped with the Night Bells feature. When in port duty personnel are required to carry out Fire and Security rounds. If the vessel is on SAR standby duty personnel must be available to answer the telephone in the event of a SAR call. The Night Bell feature to be installed in telephone communication system. Installation of Night Bells will ensure that the telephones are answered even when duty personnel are carrying out other responsibilities onboard. Important calls, such as SAR calls, will not be missed. and 2114 - reprogramming numbering system	Mid-Shore Patrol (MSPV)	Safety and Security Equipment	Fire and General alarm bells	David Wyse	NCR	14/07/2015	Routed to Operation	2015-07-14, Ack. CCR Registration, request raised by HQ OPI David Wyse. CCR is Routed to Operation for Rev/Support.		3501378							
2015	2738	Major National	High		Hydraulic bow thruster damper	addition of a timer circuit on the bow thruster damper module to slow down the valve on the closing motion. This will help to stop hydraulic hammer on the Bow Thruster hydraulic circuit.								Parts to be sent to all vessels									

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2015	2776	Major National	High	Both	Bilge drainage for Hero Class	install limber holes for proper drainage in the outboard girders that support the main engines.								Spec and drawings sent to vessels. Lloyds has given us the go ahead									
2015	2758	Major National	Normal	Both	Hero Class (MSPV) Rope Locker ventilation	The compartment located on the forward, starboard end of the superstructure, adjacent to the HVAC compartment is not ventilated. On the Constable Carriere, this compartment is used to store mooring lines and other deck gear. Mold easily grows in this compartment due to the zero air flow. This poses a health hazard for the crew and has been brought up by the vessel's MOSH committee. It also prevents any damp lines or deck gear from drying properly. The wet gear locker is used in a similar way and is equipped with a supply inlet and exhaust outlet with an in-line fan. The addition of an intake line and an exhaust line with extraction fan would allow fresh air to circulate through the space.	11J05	Deckl ockers	Hull and Related Structures			Rope Locker		Waiting for final spec and drawings to send out	2015-07-29, Received CCR Form Supported by Region (Signed Section 6), document are Routed to Operation for Rev. / Support. After support this Major CCR will be sent to CCB for Approval, next meeting October 2, 2015-10-01 CCR Supported by CCR Committee.	3801306							
2015	2757	Major National	High	Both	Pumps power supply reconfiguration	Request for engineering study to connect the following pumps to Emergency Switch Board supply: CCP P3 pump x 2, MMR Bilge/Fire pump x 1, Sea Water Cooling pump x 1.			Propulsion/Manoeuvering Systems			pitch control, bilge and sea water cooling (stern tube) pump		Waiting on Lloyds approval	2015-09-29, Ack. CCR Registration, CCR Form Section 1 to 5 should be completed, Section 6: Signed by Regional Authorities, then returned to National CCR Committee for Rev./Suppor t. 2015-09-30 Routed to Operations for Rev/Support . 2015-10-01 CCR Supported by CCR Committee, Sent to CCB for Approval.	3801819	william.falco ner@dfo-mpo.gc.ca	902-440-6231					
2015	2326	Minor	High	Both	Power Supply for Emerg. Generator Control and Battery Monitor	Existing conditions: There is no indication of the current voltage of the start batteries, the only indication that they may be charged is the green LED on the battery charger, indicating that it is on and not outputting current, there is no low voltage alarm on CCAM's for the Emergency Generator control batteries. Recommended Solution: Install 30A battery monitoring module similar to what we have on UPS A and UPS B, refer to attached pic For this we will have to add a cable between the generator?s battery and the AMOI panel, add TMH32 modules, add point in the HMI and set the alarm, so in the event of low voltage an alarm will be triggered on the CCAM prior to losing the battery start function. (refer to UPS B 24 V wiring diagram for how the EGEN battery Charger should be wired up from 120V Emergency Switchboard panel breaker 3C04 with the battery monitor. Anticipated Benefits: Full monitoring of the voltage of the Emergency Generator's Start batteries. Triggered alarm point in the event that the DC voltage drops below a specified set point. Ensure the reliable operation of the redundant EGEN start function. Impact on Maintenance Budget: Without implementing this change, there could be the potential of a safety hazard if the Emergency Generator does not start up when required in the event of an emergency if the batteries are not fully charged. Maintenance cost of the proposal change will be minimal.	CAPTAIN GODDARD M.S.M.	Power Systems	Emergency Generator Control System and Batteries	Simon Williamson	goddard-chiefengineer@gpd.gc.gc.ca					3805288				2015-12-03, Ack. CCR Registration, Received CCR Form Completed/Signed, CCR Routed to Operation for Rev./Support.		
2015	2324	Major National	Normal	Both	Ship service generator fuel oil pressure indicators Hero Class	Install local fuel oil pressure gauges to the Ship service generators. Install remote fuel oil pressure indication and alarm points into the alarm and monitoring system.				David Wyse													
2015	2816	Major National	Normal	Both	Relocation of M/E and S/S start air pressure guages and M/E	All of the start air pressure gauges should be relocated to a position after the isolation valves for the respective engines. The same is also true for the pressure transducers for the main engines, these too should be relocated after the isolation valves and separated so that each pressure sensor is connected to its own engine.		Start air gauges		David Wyse		10/12/2015	Acknowledged								

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2015	2829	Major National	Normal	Both	Install drain to ship side on forward flush escape hatches	The flush design of these hatches and the inability to drain off the water is contributing to increased maintenance inside the space due moisture and corrosion, and a safety risk due to freezing and inaccessibility during the winter. The hatches are designed with a drain, but the shipyard capped this pipe and there was no contractual requirement to connect it. We are proposing to connect the existing 1-1/4 NPT drain valve on the underside of the hatch drain line to a new shell penetration above the waterline.		Hatches				18/12/2015	Approved In Principle													
2015	2830	Major National	Normal	Both	Install isolation valve for ME manual priming pump	here are no isolation valves between the day tank and the port or starboard main engine fuel oil manual priming pumps. In the event of a failure of the diaphragm inside the manual hand priming pump, there is presently no means to isolate the pump to make repairs unless the main engine supply valve is closed at the day tank. We are proposing to insert a shutoff valve on the supply side of each manual priming pump. There is room to modify the existing DN15 piping to insert a new DN15 bronze globe valve complete with compression fittings and seals below the manual priming pump in front of each main engine.		Fuel oil system				18/12/2016	Routed HME Engineering													
2015	2831	Major National	Normal	Both	Stern draft marks on Hero Class	The steri draft markings are on the port and starboard aft quarter. Due to the hight of most docks that we secure at it is almost impossible to read the after draft marks when we are dockside. Add another set of draft marks on the transom.		Draft marks				18/12/2015	Approved In Principle	Vladykov has done something similar, must be Lloyds approved during implementation											
2015	2833	Major National	Normal	Both	Hero Class HVAC condensing receiver	The receivers installed on the HVAC system do not have a safety margin for increases of pressure in the system which have caused refrigerant discharges. A new receiver and safety valve are required for this type of refrigerant and system with a greater safe working pressure.		HVAC unit				04/01/2016	Acknowledged												
2015	2850	Major National	Normal	Both	Hero Class flooring replacement	Replacement of the vessel linoleum flooring on an as required basis. Hero Class linoleum flooring is cracking and bubbling on every vessel. New marine flooring and sub floor will be trialed and if successful will be installed on the Hero Class vessels when required.																			
2015	2851	Major National	Normal	Both	Hero Class HVAC controllers	he HVAC controller aboard the CCGS A. Leblanc has been deemed by the OEM Bronswerk to be unserviceable and is not supported by the OEM anymore. A new controller is required.																			
2016	2863	Major National	Normal		Sea Chest grate failures Hero Class	Sea chest grates fitted to the Hero Class hulls are failing by losing fasteners and weld tabs. This in turn allows the grate to vibrate loosely on the hull of the ship and if lost will allow large debris or foreign objects to enter the cooling water system.	MSPV		Sea chest grate	David Wyse	NCR	11/03/2016	Routed to Operation	2016-03-15 Acknowledge Reception of CCR Form Completed, document are Routed to CCR Committee for Rev. / Support.		Folder: 9999999, CCR: 3999999, rev:3.4.5							
2016	2861	Major National	Normal		Black water transfer system Hero Class	The black water transfer/macerator pumps on the Hero Class have been failing prematurely. A solution is required to ensure that the pumps last more than months. The pumps are roughly 10k each to replace.	MSPV		Black water transfer/macerator pump	David Wyse	NCR	11/03/2016	Routed to Operation	2016-03-15 Acknowledge Reception of CCR Form Completed, document are Routed to CCR Committee for Rev. / Support.		9999999, 3999999, rev:3.4.5							
2016	2863	Major National	Normal		Gearbox cooler replacement solution Hero Class	There has been several gearbox cooler failures on the Hero Class vessels that have resulted in oil leaking out the cooling water discharge. A long term solution is required to avoid	MSPV		Gearbox cooler	David Wyse	NCR	11/03/2016	Routed to Operation	2016-03-15 Acknowledge Reception of CCR Form Completed, document are Routed to CCR Committee for Rev. / Support.		9999999, 3999999, rev:3.4.5							
2016	2864	Major National	Normal		Hero Class cooling system biofouling (mussel infestation)	Hero Class vessels in fresh water are having zebra mussel infestations in the cooling water systems that block the flow of cooling water. Hero Class vessels in salt water are having blue mussel infestations in the cooling water systems that are blocking the flow of cooling water. It takes a lot of time and man hours to clean the cooling water systems. A solution is required to prevent mussel build up in the cooling system	MSPV		Cooling water system	David Wyse	NCR	11/03/2016	Acknowledged	2016-03-15 Acknowledge Reception of CCR Form Completed, document are Routed to CCR Committee for Rev. / Support.		9999999, 3999999, rev:3.4.5							
2016	2865	Major National	Normal		Wet exhaust transom corrosion Hero Class	The transom at the wet exhaust ports are corroding. The steel plate at the transom is only 4mm thick. The flaps at the exhaust ports are made of aluminum and are being deformed which in turn is allowing water to enter the exhaust system and damage the silencers. The fasteners holding the exhaust flaps are also loosening and being lost at sea. A solution is required to prevent corrosion of the transom and not to allow water to enter back into the exhaust system.	MSPV		Transom and exhaust	David Wyse	NCR	11/03/2016	Acknowledged	2016-03-15 Acknowledge Reception of CCR Form Completed, document are Routed to CCR Committee for Rev. / Support.		9999999, 3999999, rev:3.4.5							

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2016	2456	Major National	Normal		Hero Class Pilot chair rails	Problème : Les chaises de pilote sont grosses et encombrantes. Ce qui cause des problèmes de circulation en autres lors des manœuvres d'approches et de départ en situation de pilotage en endroits restreints. Les contrôles moteurs, propulseur, gouverne sont situés au centre de la console et les radars carto électronique, projecteurs et sifflot sont situés à tribord. Ce sont toutes des commandes dont nous sommes susceptibles de nous servir rapidement et souvent, sans compter que devons-nous déplacer de chaque côté de la timonerie pour avoir une bonne vision. Il est difficile de le faire car il faut se glisser et trotter entre les chaises et la console.	MSPV		Pilot chair rail system	David Wyse	NCR	11/03/2016	Routed to Operation	2016-03-16 Acknowledge Reception of CCR Form Completed, document are Routed to CCR Committee for Rev. / Support.		3560/0269							
2016	2457	Major National	Normal		Hero Class sacrificial anodic protection improvement	The sacrificial anodes on the hull and underwater equipment have been dissolving before the vessel reaches drydock periods. It has also been reported that the sacrificial anodic system is not adequate enough to prevent corrosion on the Hero Class vessels.	MSPV		Cathodic Protection system	David Wyse	NCR	11/03/2016	Acknowledged	2016-03-16, Acknowledge Reception of CCR Form Completed, document are Routed to CCR Committee for Rev. / Support.		3560/0262, 3560/0263/3560/0268, 3560/0269							

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High Priority	Year	CCR #	Scope	Priority	Variant	Title	Work Description	Dave Wyse Comments
High	2014	2504	Major National	High		Required Changes to Safety Control Plan and Fire Control Plans on MSPV's	Changes proposed were adopted shortly before transiting vessels back to C & A region for safety reasons. Extra lifejackets required and/or immersion suits depending on the number provided by shipyard at time of delivery. Plan approval cost $3,307.00 per vessel. Extra 5 life jackets.	Dave Wyse is comparing drawing submissions from RCMP vessels. Will go back to vessels to agree on one drawing to be approved. / Dave Wyse compare les soumissions de dessin à partir de navires de la GRC. J'y retournerai aux navires pour se mettre d'accord sur un dessin pour être approuvé.
High	[illegible]	2648	Major National	High	Risk Assessment - Transformers - Mitigation Plan	Implement mitigation plan as it relates the the Risk Assessment - Transformers	1 pilot vessel 1. Change location of the emergency generator fuel tank vent to outside 2. Metal protective shields around transformers 3. Addition of ground fault monitoring capabilities 4. Move discharge for inline drains from duct work in AMR 5. Install heat trace on hatches 6. Replace battery boxes in emergency gen room with proper type 7. Installation of burst pipe protection on certain pipes	Installed on G. Peddle and A. Leblanc, will send information to other vessels / Installé sur G. Peddle et A. Leblanc, va envoyer des informations à d'autres navires
High	2014	2690	Minor	High		Addition of Duplex SW strainer for ship service Generators	At present, there is no means of cleaning the strainer fitted inside the Sea Water regulating valve for the auxiliary generators without having to shut it down and change over to the standby generator. This has become problematic because the filtering capability of the small mesh screen is insufficient. It takes very little debris to clog up the strainer which in turn causes the jabsco impeller sw pump to go into a vacuum state. This has the potential to damage the vanes on the impeller. There is often a frequent requirement to clean the filters due to the water the vessel may be operating in. This has become very tedious and has also subjected the strainer in the valve, as well as the valve itself to suffer damage due to the number of times it's had to have been opened up. The screens located in the regulator are also inadequate in that it still allows debris to pass by and clog up the cooler tubes on the engine. This was observed on the 2000 hour inspections for both generators. The recommended solution is to fit a duplex sw strainer on the main sw supply line to the generators. The best location for minimal interference would be aft of the port main engine underneath the flow meter for the stern tube cooling. The main sw supply piping to the generators would have to be modified slightly to accommodate the duplex strainer. The sw piping to the stern tube cooling water regulator may also have to be modified as well to accommodate the strainer.	First trial set of strainers will be sent to the A. Leblanc in Mid May, once trialled ok, the rest of strainers will be ordered for July delivery / Première série de crépines d'essai sera envoyé à la A. Leblanc dans la mi-mai, une fois mis à l'essai ok, le reste de crépines sera commandé pour livraison Juillet
High	2015	2692	Major National	High		FO Tank vents removable sections	Currently, #1, #2, and #3 Fuel tanks share a common overflow/vent line that connects to the forward port corner of #9 FO Storage Tank. The overflow/vent lines from those forward tanks have loops that extend above the deck, port side forward. These loops are solidly welded with no means to break the lines to facilitate testing of the tanks individually. In the future, when testing is required again by the Classification Society, we will have to have a means to test the individual tanks and at present, that is not possible as all of the tanks are connected together through this common vent/overflow. Note 9 of the "Air Pipes and Sounding Diagram" stipulates that the "Combined air escapes shall be fitted with a removable section to permit the testing of the tanks individually." The air vent for #9 FO tank is located at the forward port corner of the tank. #9	Specification available, already installed on Caporal Kaeble and A. Leblanc / Spécification disponibles, déjà installé sur Kaeble et Caporal A. Leblanc
High	2015	2693	Major National	High		#9 Fuel Oil Tank reconfiguration	The air vent for #9 FO tank is located at the forward port corner of the tank. #9 FO Tank is stepped and the vent is located at the lowest point of the tank top. This arrangement prohibits the complete filling of the tank since the higher part of the tank effectively becomes air locked. If fuel is still being pumped into #9 when the common vent/overflow line for #1, #2, #3 FO Tanks is blocked, there is a potential to pressurize those forward tanks. This will result in false high level alarms in all of the forward tanks since the Tank Level Indication System works off pressure sensors. The resulting alarms can cause confusion for those unfamiliar or new to the vessel. #9 FO Tank is essentially "full" when it's at approximately 75%. There have been special fuelling procedures developed in an attempt to fill the tank to a higher level but that is a compensation for poor design. The overflow/vent line loops above deck should be removed and have flanges installed to facilitate testing of the tanks individually. The vent line for #9 FO Storage Tank should also be connected to the aft section of the tank at its highest point. There would be no need to relocate the vent entirely, just an addition,	Specification available, already installed on Caporal Kaeble and A. Leblanc / Spécification disponibles, déjà installé sur Kaeble et Caporal A. Leblanc
High	2015	2699	Major National	Urgent		Hero Class Water Fire Main Piping Replacement	Existing Condition: Currently 8 out of the 9 hero class vessels have stainless piping in the water extinguishing fire system. The incident reports and failure analysis have shown that the stainless steel piping is corroding and allowing water to leak. See attached reports. Recommended Solution: 1. 2 vessels in the C&A region have had a boroscope inspection of the piping. The vessels in the Atlantic region will then be inspected and a priority list for a solution to be implemented will be formed. 2. An engineering study must be done to create a solution for the replacement of the piping (material, piping, class approved drawings, weight analysis, etc.) 3. A solution to be implemented for the Class. Anticipated Benefits: A solution to provide reliability of the water fire extinguishing system and solve the corrosion and leak issues. Impact on maintenance budget: High maintenance costs by implementing band aids whenever a leak is found, increase the life cycle of the system, ensure that the system is operational, ensure that no other equipment or materials or damaged due to leaks.	Engineering study completed, waiting for Superintendants of Marine Engineering to decide on material to be used for piping, in the meantime vessels doing interim repairs to leaks / étude d'ingénierie terminée, en attente pour les surintendants de génie maritime de décider sur le matériel à utiliser pour la tuyauterie, dans les navires Entre-temps, faire des réparations provisoires quand il a des fuites

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High	2015	2701	Major National	Normal		Hero Class Crane ram design change and remote control changes	Shorten the crane cylinder RAM to be able to engage the RHIB in the cradle. Belly pack remote controls do not allow for booming in and out simultaneously hoisting or lowering the crane. This function is required for safe operations with the crane. This must be rectified with the manufacturer. An engineering study must first be done to develop solutions and a prototype for the class. Existing Condition: 1. Currently the cranes on board the Hero Class vessels do not have enough vertical movement to reach the lifting hooks on the RHIB(s) while they are sitting the in the cradle. 2. The cranes cannot be operated safely because the control does not allow simultaneously hoisting or lowering and booming in or out using the remote belly packs. Recommended Solution: 1. An engineering study must be completed to acquire a solution for the issues above. 2. The solution must be planned and implemented across the class. Anticipated Benefits: The solutions will ensure safety and proper handling of the crane throughout the life cycle of the vessels. Impact and Maintenance Budget: Safety risks to personnel and risk of damaging assets.	All vessels need to have hydraulic flow meters installed on power pack and then belly packs can be reprogrammed. Approval will be sought by Dave Wyse to install shortened ram on crane. / Tous les navires doivent avoir hydrauliques débitmètres installés sur bloc d'alimentation, puis les paquets de ventre peuvent être reprogrammées. L'approbation sera demandée par Dave Wyse pour installer ram raccourci sur grue.
High	2015	2776	Major National	High	Both	Bilge drainage for Hero Class	Install limber holes for proper drainage in the outboard girders that support the main engines.	Specification available / Spécification disponibles
High	2015	2650	Major National	Normal	Both	Hero Class flooring replacement	Replacement of the vessel linoleum flooring on an as required basis. Hero Class linoleum flooring is cracking and bubbling on every vessel. New marine flooring and sub floor will be trialed and if successful will be installed on the Hero Class vessels when required.	Dex o tec installed at certain locations on A. Leblanc and Caporal Kaeble, pictures available / Dex o tec installés à certains endroits sur A. Leblanc et Caporal Kaeble, photos disponibles
High	2016	2864	Major National	Normal		Hero Class cooling system biofouling (mussel infestation)	Hero Class vessels in fresh water are having zebra mussel infestations in the cooling water systems that block the flow of cooling water. Hero Class vessels in salt water are having blue mussel infestations in the cooling water systems that are blocking the flow of cooling water. It takes a lot of time and man hours to clean the cooling water systems. A solution is required to prevent mussel build up in the cooling system	Engineering study on going / étude d'ingénierie en cours
High	2014	2805	Major National	Normal		Wet exhaust transom corrosion Hero Class	The transom at the wet exhaust ports are corroding. The steel plate at the transom is only 4mm thick. The flaps at the exhaust ports are made of aluminum and are being deformed which in turn is allowing water to enter the exhaust system and damage the silencers. The fasteners holding the exhaust flaps are also loosening and being lost at sea. A solution is required to prevent corrosion of the transom and not to allow water to enter back into the exhaust system.	Engineering study on going / étude d'ingénierie en cours
High	2016	2867	Major National	Normal		Hero Class sacrificial anodic protection improvement	The sacrificial anodes on the hull and underwater equipment have been dissolving before the vessel reaches drydock periods. It has also been reported that the sacrificial anodic system is not adequate enough to prevent corrosion on the Hero Class vessels.	Engineering study on going / étude d'ingénierie en cours

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CCR	Status
3070 – Hour meters	**Approved in principle**
3089 – echo sounders	
3103 – Stabilizers	
3107 – Reclassify ballast tanks to void tanks	
3187 – Alarm and monitoring renewal	Approved for prototype
3212 – removal of FWD speaker	
3213 – Crab pot hauler arm extension	Approved for prototype
3215 – At will whistle button	
3216- Navigation display relocation	
3140 – Remote control valve	
CCR 2017-3141 OFSV Class - Cabin Re-alignment	

New to be signed this week for CCB list

3219 Hero Class engine removal and overhaul	Approved for engineering
3220- Hero Class galley reconfiguration – replace CCR 2170.	
3221 – CCR 3102 to be broken up into pieces and CCR 3110 sent as major from region	**Approved in principle**

Cancel

CCR 2170 – replace with 3220.
CCR 3040 – not safe
CCR 3050 – replace with 3220
CCR 3051 – Already have CCR 2699
CCR 3110 – replace with 3221
CCR 3149- trials did not work out
CCR 3102 – CCB wants broken up into 21 different CCRs

Engineering to Implementation

2587 – Stern Quarter reinforcement
2797 – pumps on emergency power supply
2687 – Hero Class hull protection system – impressed current
2881 – Hero Class RHIB rifle case bracket

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Mid-Shore Patrol Vessel (MSPV)

Technical Statement of Operational Requirements (TSOR)

Published under the Authority of:

Major Crown Projects Directorate
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Canadian Coast Guard
Ottawa, Ontario
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ANNEX "B" to F7045-060001/E
MSPV TSOR

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Acronyms

AC	Alternating Current
AIS	Automatic Identification System
AM	Amplitude Modulation
AMR	Auxiliary Machinery Room
ARPA	Automatic Radar Plotting (or piloting) Aids
ATU	Automatic Tuner Unit
AVOS	Automatic Voluntary Observation Ship's
BCS	Bridge Control Station
C&P	Conservation and Protection
CCAMS	Centralized Control, Alarm and Monitor System
CCG	Canadian Coast Guard
CCS	Centralized Control Station
CCTV	Closed Circuit Television System
CD	Compact Disc
CLASS	Classification Society
cm	centimetre
COTS	Commercial Off the Shelf
CSA	Canadian Shipping Act 2001
DC	Direct Current
DGPS	Differential Global Positioning System
DND	Department of National Defence
DSC	Digital Selective Calling
DVD	Digital Video Device
ECS	Electronic Chart System
EEBD	Emergency Escape Breathing Device
EER	Electronic Equipment Room
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EP	Environmental Protection
EPIRB	Emergency Position Indicating Radio Beacon
FM	Frequency Modulation
G4	Service Group 4
GA	General Arrangement
GFE	Government Furnished Equipment
GMDSS	Global Maritime Distress and Safety System
GPS	Global Positioning System
HAZMAT	Hazardous Material
HD	High Definition
HP	Horsepower
HSC	High Speed Craft
HVAC	Heating, Ventilation, and Air Conditioning
ICC	Integrated Computer Control

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IEC	International Electrotechnical Commission
IICS	Integrated Internal Communications System
IMO	International Maritime Organization
ISO	International Organization for Standardization
ITU	International Telecommunications Union
kg	Kilogram
kts	Knots
l	litres
LAN	Local Area Network
LCD	Liquid Crystal Display
LED	Light Emitting Diode
LR	Lloyd's Register
m	metre
m/s	Metres per second
MCR	Machinery Control Room
MCS	Machinery Control Station
MF/HF	Medium Frequency/High Frequency
mm	millimetre
MMR	Main Machinery Room
MOSH	Marine Occupational Safety and Health
MS	Maritime Security
MSPV	Mid Shore Patrol Vessel
nm	Nautical Miles
NMEA	National Marine Electronics Association
OEM	Original Equipment Manufacturer
OPI	Office of Primary Interest
PA	Public Address
PSMR	Propulsion Steering Machinery Redundancy
RCMP	Royal Canadian Mounted Police
RF	Radio Frequency
RHIB	Rigid Hull Inflatable Boat
SART	Search and Rescue Radar Transponders
SCIP	Secure Communications Interoperability Protocol
SCN	S (Service Power), C (Continuous Power), N (Brake Power) with only the essential dependent auxiliaries, at the declared engine speed
SCST	Secure Communications Satellite Terminal
SI	International System of Units
SSC	Special Service Craft
STA	Standard Technical Architecture
STP	Sewage Treatment Plant
SWL	Safe Working Load
TA	Technical Authority
TCMS	Transport Canada Marine Safety
UHF	Ultra High Frequency

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UMS	Unattended Machinery Space
UPS	Uninterruptible Power Supply
VCG	Vertical Centre of Gravity
VCR	Video Cassette Recorder
VHF	Very High Frequency
VSCS	Vessel Satellite Communication System
WHMIS	Workplace Hazardous Materials Information System

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1 INTRODUCTION

1.1 INTRODUCTION

1.1.1 This is the Technical Statement of Requirements (TSOR) for the Mid-Shore Patrol Vessel (MSPV) that is to be capable of sustained operations out to 120 nautical miles (nm) offshore at high speeds. These vessels will be designed and built in a manner that meets each of the requirements set out in this TSOR.

1.1.2 The MSPV will be required to conduct patrols on Canada's sea coasts and on the Great Lakes and St. Lawrence Seaway System. The operational area extends from Canada's southern borders to approximately 55° North Latitude.

1.1.3 The MSPV shall meet all standards and references as detailed herein and shall be a steel mono-hull based on an existing proven parent design, as defined herein. There shall be no change to the underwater portion of the MSPV hull form as compared to that same portion of the proven parent design, except in way of appendages. The proven parent design shall have been used in the construction of a steel mono-hull vessel that has been in service for a minimum of two (2) years, and a minimum of 1000 hours in-service operation.

1.1.4 The MSPV shall be built and delivered in two variants. The first variant is the MSPV Maritime Security (MS) variant configured to accommodate two (2) Rigid Hull Inflatable Boats (RHIB). The second variant is the MSPV Conservation and Protection (C&P) variant configured to accommodate the port RHIB normally embarked and fitted for but not with either the starboard RHIB or the necessary system(s) and equipment to accommodate the starboard RHIB. Both MSPV variants are detailed herein.

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2 GENERAL REQUIREMENTS

2.1 REFERENCE DOCUMENTS

2.1.1 The MSPV shall be designed and built in accordance with the references and standards stated herein.

2.1.2 Except where otherwise noted, the latest official version at time of bid closing of the listed references shall be used.

2.2 REGULATIONS AND STANDARDS

2.2.1 In addition to the specifications described herein, the MSPV shall be designed, built, and outfitted in accordance with:

a. Classification rules of a single approved Classification Society (Class) as listed in TP 13585 - Marine Safety Management System; and

b. All national statutory and regulatory requirements for certification as required by the *Canada Shipping Act 2001* (CSA) for a cargo vessel on Near Coastal Voyage, Class I, wholly between Canadian ports.

2.2.2 The Contractor shall be responsible to ensure that all the MSPVs are certified in accordance with CSA, including all related regulations and Class. Any TCMS or Class conflict must be resolved by the Contractor to the satisfaction of Canada.

2.3 REGISTRATION AND CLASSIFICATION

2.3.1 The MSPV shall be designed, built and outfitted to receive a Certificate of Class equivalent to a Lloyd's Register (LR) ✠100A1, Special Service Craft (SSC), High Speed Craft (HSC), Patrol Vessel (Patrol), Service Group 4 (G4), Unattended Machinery Space (UMS), Environmental Protection (EP), Propulsion Steering Machinery Redundancy (PSMR), Centralized Control Station (CCS), Integrated Computer Control (ICC).

2.3.2 Notwithstanding the MSPV's gross tonnage, the MSPV shall comply with Lloyd's Register HSC Code or equivalent.

2.3.3 The UMS Notation shall not include any automatic fuel transfer system. The size of any service tank(s) shall be in accordance with the fuel system requirements described herein.

2.3.4 The Contractor shall be responsible to demonstrate all Class equivalencies to Canada's satisfaction.

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3 GENERAL TECHNICAL REQUIREMENTS

3.1 DESIGN CONSTRAINTS

3.1.1 The general MSPV configuration shall meet all requirements identified herein.

3.1.2 Length Overall, the distance, in metres, measured parallel to the static load waterline from the foreside of the stem to the after side of the stern or transom, excluding rubbing strakes and other projections of the MSPV shall be between 37.0 metres and 43.0 metres (m).

3.1.3 Extreme appendage draft of the MSPV MS variant shall not exceed 3.0 m in the port departure condition as defined in TSOR paragraph 3.2.1.b in fresh water, with allowance for the 2.0 tonnes Contract Modification Margin applied at 0.3m above the MSPV design lightship VCG and Construction Margin of ½% of the MSPV design lightship displacement applied at 0.3m above the MSPV design lightship VCG. The Contract Modification Margin is to allow for any weight increases as a result of GFE being installed and to allow for approved design changes that may result in a Contract Amendment. Only Canada has the right to use this Contract Modification Margin for modifications.

3.1.4 Air draft of the MSPV C&P variant shall be less than 35.5 m in salt water in the arrival condition defined as one (1) RHIB embarked, 13% of the total installed diesel fuel tank capacity, 10% of the total installed potable water tank capacity, 90% of the total installed black and grey tank capacity and 10% of the total installed upper deck RHIB gasoline fuel tank capacity.

3.1.5 There shall be an enclosed Bridge with a Command Centre immediately aft of it on the upper level of the deckhouse. Port and Starboard Bridge Wing control stations shall be supplied and installed.

3.1.6 There shall be a clear view of the aft work deck such that deck operations can be visually monitored from the Bridge machinery control station (MCS) or the Bridge Wing control stations.

3.1.7 The aft deck of the MSPV MS variant shall be configured to accommodate two (2) RHIBs as detailed at Appendix 1 of the TSOR complete with suitable launching and recovery system(s).

3.1.8 On the MSPV C&P variant, only the port RHIB will normally be embarked on the aft deck. When only the port RHIB is embarked, the aft deck unoccupied space shall be at least 30.0m^2 of continuous deck space and shall have a minimum deck loading capacity of five (5) tonnes spread over the 30.0m^2 deck.

3.1.9 A liquid ballast system shall be supplied and installed to enable the crew to trim and heel the MSPV to design trim and within a 0.5° list to port or starboard when, respectively, only the port or starboard RHIB is embarked.

3.1.10 Provisions stowage shall be for a fourteen (14) day operational period for a complement of fourteen (14) personnel.

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3.1.11 Potable water tank capacity of the MSPV, based on a daily allowance of 150.0 litres per person and a complement of fourteen (14) personnel, shall be for a three (3) day period as a minimum and shall not include any potable water production.

3.1.12 The solid waste handling system shall be capable of handling waste for a complement of fourteen (14) personnel for a fourteen (14) day operational period in accordance with Table 4 as a minimum.

3.1.13 Black and grey water systems of the MSPV shall be designed and built to have a combined tank holding capacity for two days, 150.0 litres per day per person for fourteen (14) persons, and a sewage treatment facility designed for a complement of eight (8) to fourteen (14) personnel.

3.1.14 The MSPV shall be designed and built to be fitted-for-but-not-with two (2) 0.50 calibre heavy machine guns port and starboard side forward.

3.1.15 The MSPV shall have cabin accommodation for fourteen (14) personnel in either single or double cabins as described herein.

3.2 SPEED

3.2.1 The maximum speed of the MSPV shall not be less than 25.0 knots (kts) under the following conditions:

a. At a maximum propulsive power not exceeding a SCN with only the essential dependent auxiliaries of 5000.0 kW at the declared engine speed as defined in ISO 3046-1: 2002 (E) and ISO 15550: 2002(E). "Propulsive power" means the power in kilowatts that is specified in a vessel's certificate of registry or the total installed power in kilowatts that can be directed to propel the vessel, whichever is greater; and

b. In the port departure condition which is defined as fully crewed with fourteen (14) persons, fully provisioned, spared, ready for sea with diesel fuel at 95% of the total installed diesel fuel tank capacity including all fitted day and service diesel tank(s), if any, upper deck RHIB gasoline tank(s) at 95% of the total installed gasoline fuel tank capacity, potable water tank(s) at 100% full, black and grey water tanks empty, lube oil storage tank(s) at 100% full, and working deck fully outfitted in the MSPV MS variant with both RHIBs embarked with 100% of their total internal gasoline tank capacity in each as detailed at Appendix A1 of the TSOR; and

c. In Sea State 2 as detailed at Appendix 3 of the TSOR, or calculated equivalent; and

d. In salt water or calculated equivalent; and

e. Construction Margin and Contract Modification Margin as defined in TSOR paragraph 3.1.3 added.

3.3 RANGE

3.3.1 The range of the MSPV shall not be less than 2000.0 nm under the following conditions:

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a. At a constant cruising speed of 14.0 kts; and

b. Not trailing or locking any shaft; and

c. Commencing in the port departure condition, as per paragraph 3.2.1.b above; and

d. For range calculation purposes, the total available diesel fuel shall be 82% of the total installed diesel fuel tank capacity including all fitted day and service diesel tank(s), if any, less the ship service generators' fuel consumption of the period traveled based on a preliminary electrical load analysis provided by the Bidder (Contractor). The 82% available diesel fuel is derived from:

i) A maximum diesel fuel tank capacity of the total installed diesel tank capacity at 95%; and

ii) A 3% deduction from the total installed diesel fuel tank capacity including all fitted day and service diesel tank(s), if any, to account for unusable diesel fuel; and

iii) A further 10% deduction from the total installed diesel fuel tank capacity including all fitted day and service diesel tank(s), if any, to allow for reserve diesel fuel; and

e. In Sea State 2 as detailed at Appendix 3 of the TSOR, or calculated equivalent; and

f. In salt water or calculated equivalent; and

g. Construction Margin and Contract Modification Margin as defined in TSOR paragraph 3.1.3 added.

3.4 HIGH SPEED ENDURANCE

3.4.1 For the MSPV, a sustained speed of no less than 25.0 kts shall be maintained for 24 continuous hours, as detailed at Appendix 2 of the TSOR Mission Profiles, under the following conditions:

a. At a maximum propulsive power, as per paragraph 3.2.1.a above, not exceeding a SCN of 5000.0 kW at the declared engine speed; and

b. Commencing in the port departure condition; as per paragraph 3.2.1.b above; and

c. For endurance calculation purposes, the total available diesel fuel shall be 82% of the total installed diesel fuel tank capacity including all fitted day and service diesel tank(s), if any, less the ship's service generators' fuel consumption for the period traveled based on a preliminary electrical load analysis provided by the Bidder (Contractor). The 82% available diesel fuel is derived from:

i) A maximum diesel fuel tank capacity of this total installed tank capacity at 95%; and

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ii) A 3% deduction from the total installed diesel fuel tank capacity including any fitted day and service diesel tank(s) to account for unusable diesel fuel; and

iii) A further 10% deduction from the total installed diesel fuel tank capacity including all fitted day and service diesel tank(s), if any, to allow for reserve diesel fuel; and

d. In Sea State 2 as detailed at Appendix 3 of the TSOR, or calculated equivalent; and

e. In salt water or calculated equivalent; and

f. Construction Margin and Contract Modification Margin as defined in TSOR paragraph 3.1.3 added.

3.5 LOW SPEED ENDURANCE

3.5.1 The MSPV shall be capable of continuous slow speed operation, at 2.0 kts ahead for a minimum of eight (8) continuous hours as detailed at Appendix 2 of the TSOR Mission Profiles, in Sea State 1 as detailed at Appendix 3 of the TSOR, or calculated equivalent. The MSPV shall operate in all air and water environmental conditions listed at Table 1 - Environmental Conditions. If low speed endurance for the MSPV is achieved by not running all main engines, the MSPV propulsion system shall incorporate a method to trail a shaft(s) such that the non-running main propulsion engine(s) and shaft(s) shall be brought on line for propulsion in less than one (1) minute.

3.6 SERVICE LIFE

3.6.1 The MSPV shall be designed and built to meet a 25 year service life based upon the Mission Profiles as detailed at Appendix 2 of the TSOR.

3.6.2 All equipment utilized in the MSPV shall be of a commercial marine standard; durable and reliable enough to withstand the rigors of the intended service.

3.7 OPERATING ENVIRONMENTS

3.7.1 The MSPV shall be able to operate year round, day and night, in freezing rain, spray and icing conditions and, will occasionally transit through loose ice (less than 8/10 coverage). No icebreaking capabilities are required.

3.7.2 The MSPV, its propulsion and auxiliary equipment, and the associated fluid systems shall be designed and built to conduct operations, as per Mission Profiles as detailed at Appendix 2 of the TSOR, in up to and including Sea State 6 as detailed at Appendix 3 of the TSOR.

3.7.3 The MSPV and its systems shall be able to conduct operations as per Mission Profiles as detailed at Appendix 2 of the TSOR, in the environmental conditions listed in Table 1 below:

Air Temperature & Humidity	Minimum -20.0°C, 30% RH (fall and

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	winter) Maximum 35.0°C, 95% RH (summer)
Water Temperature Range	Minimum -1.8°C to Maximum 30.0°C
Water Types	Fresh and Salt water
Sea Conditions	Primary Missions – Up to and including Sea State 5 (as detailed at TSOR Appendix 3) Secondary Missions – Up to and including Sea State 6 (as detailed at TSOR Appendix 3)

TABLE 1 - ENVIRONMENTAL CONDITIONS

3.7.4 The exterior equipment and machinery, excluding RHIB stowing and securing arrangements, shall be protected with secured waterproof covers. All machinery, structure, and outfit shall be designed and built to withstand the resultant loads from the ship and sea interactions and the environmental conditions.

3.8 OPERABILITY

3.8.1 Operability is defined as the sea keeping characteristics of the MSPV and the ability to put to sea and safely maintain program activities and tasks in the specified areas of operation and environmental conditions.

3.8.2 Any appendage based stabilizing systems shall be designed and built to shed, and prevent entanglement by, ropes and nets.

3.8.3 All horizontal surfaces, except the aft working deck, exposed to wind-driven spray on the MSPV shall be angled or cambered to minimize build-up of ice.

3.8.4 The MSPV shall be capable of holding station relative to a fixed or moored object to within ten (10) metres (m) in all conditions up to and including Sea State 5 as detailed at Appendix 3 of the TSOR.

3.8.5 The MSPV shall be capable of station keeping relative to a free floating object to within ten (10) m in all conditions up to and including Sea State 6 as detailed at Appendix 3 of the TSOR.

3.8.6 Safe access to all areas of the MSPV's open decks shall be maintained at speeds up to 5.0 kts in Sea State 6 as detailed at Appendix 3 of the TSOR.

3.8.7 The MSPV shall be capable of maintaining a course within 1.0° of desired heading in all conditions, with wind and seas from any direction relative to the MSPV's heading, within three (3) minutes at a speed of 14.0 kts.

3.8.8 The MSPV shall be capable of turning 180.0° to port or starboard at zero speed within its own length in up to and including Sea State 2 as detailed at Appendix 3 of the TSOR.

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3.8.9 The MSPV shall be capable of turning to port or starboard under power from a full stop, safely in all conditions up to and including Sea State 6, as detailed at Appendix 3 of the TSOR, with wind and seas from any direction relative to MSPV heading.

3.8.10 The MSPV shall be capable of steering effectively in all conditions up to and including Sea State 5 as detailed at Appendix 3 of the TSOR, while towing a vessel of similar displacement.

3.9 HULL DESIGN

3.9.1 There shall be no modification of the proven parent design except as set forth in paragraph 1.1.3 of the TSOR.

3.10 PROPULSION AND AUTOMATIC MACHINERY CONTROL SYSTEMS

3.10.1 The MSPV's propulsion and automatic machinery control systems shall be of a proven marine design configuration. The MSPV shall not have a propulsive power greater than a SCN of 5000.0 kW at the declared engine speed.

3.10.2 The main propulsion system and control equipment shall be selected from current models supported in Canada.

3.10.3 The MSPV's main propulsion system shall not be a water jet.

3.11 GENERAL ARRANGEMENT (GA)

3.11.1 The MSPV shall be designed and built with, as a minimum, the following separate spaces:

a. Fore Peak, Chain Locker and store for anchor, chain and rope storage; and

b. Cabins to accommodate fourteen (14) persons. There shall be two (2) adjacent single cabins, for the Captain and Chief Engineer, one (1) single cabin for the Program/Incident Commander and one (1) additional single cabin for a minimum of four (4) single cabins, and a maximum of five (5) double cabins; and

c. Galley and associated cold and cool rooms; and

d. Mess to seat at least ten (10) in one sitting; and

e. Four (4) washrooms; and

f. Command Centre; and

g. Electronic Equipment Room (EER); and

h. Wet Gear Locker; and

i. Bridge; and

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j. Central Storeroom as detailed in Appendix 6 of the TSOR; and

k. Machinery Control Room (MCR); and

l. Main Machinery space(s) for propulsion machinery and electrical generators; and

m. Auxiliary Machinery Room(s) (AMR), if fitted; and

n. Steering Gear Compartment; and

o. Emergency Generator Compartment; and

p. Storerooms for provisions and equipment spares; and

q. Deck Workshop (does not need to be a separate space but facility needs to be provided); and

r. Garbage Handling Room; and

s. Sewage Treatment Room; and

t. Lockers as required for linen, tools, cleaning gear, spill control and disposal kits, Medical/SAR equipment and small arms.

3.11.2 The superstructure shall have safe exterior walkways on both port and starboard sides of the weather deck.

3.11.3 The open deck areas shall be designed and built for:

a. Anchor handling; and

b. Mooring; and

c. Equipment stowage; and

d. Ship to shore safe access; and

e. Transfer on and off MSPV when docked; and

f. Medical evacuation via helicopter off forecastle deck; and

g. Crab Trap and Gill Net Hauler handling and operations; and

h. RHIB and rescue boat operations; and

i. Crane operations; and

j. Towing; and

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k. Search and rescue; and

l. Mast signalling; and

m. Use of the fitted for but-not-with two (2) 0.50 calibre heavy machine gun mounts.

3.12 ENVIRONMENTAL PROTECTION

3.12.1 The MSPV shall meet all Canadian Federal Environmental Legislation, as well as the provincial environmental Acts of all provinces adjacent to waters in the patrol areas described in paragraph 1.1.2. A system engineering approach shall be used to consider all applicable environmental aspects associated with the particular MSPV system(s). All ways in which the MSPV will interact with its surroundings shall be considered.

3.13 STABILITY AND SUBDIVISION

3.13.1 The MSPV shall not have a static list greater than 0.5° from upright in all loaded conditions as defined in TP 7301- Stability, Subdivision and Load Line Standards STAB7, excluding crane and RHIB operations. The MSPV shall not be trimmed by the bow in any loading condition.

3.13.2 The MSPV in all loaded conditions shall meet the requirements of TP 7301 - Stability, Subdivision and Load Line Standards STAB7 without the use of permanent water or solid ballast. Crane and RHIB operations are excluded.

3.13.3 When launching and recovering the RHIB over the side and in all crane operations, the MSPV shall not heel more than 7.0° and the freeboard shall not be reduced by more than 50%. In no case shall the freeboard be reduced to less than 0.30 m at any point along the MSPV.

3.13.4 The MSPV shall meet the damaged stability requirements of TP10943 (Part II) – Passenger Vessel Operations and Damaged Stability Standards for two-compartment flooding at the end of life, i.e. incorporating a growth margin defined as 2% of the MSPV design lightship displacement applied at 0.3m above the MSPV lightship VCG.

3.14 ELECTROMAGNETIC INTERFERENCE (EMI) AND ELECTROMAGNETIC COMPATIBILITY (EMC)

3.14.1 The MSPV shall be constructed such that all electric and electronic equipment is electromagnetically compatible in accordance with IEEE 45-2002 Section 4.5 and 4.6 and CCG 70-000-000-EU-JA-001 - Chapter 6 that sets limits for Electromagnetic Interference (EMI).

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4 HULL STRUCTURES

4.1 GENERAL

4.1.1 The hull construction of the MSPV shall be designed, built and outfitted to withstand loads up to and including Sea State 6 as detailed at Appendix 3 of the TSOR for all environmental conditions noted in Table 1.

4.1.2 All hull structure shall be of welded design.

4.2 MATERIALS

4.2.1 The superstructure of the MSPV shall be of marine quality aluminum alloy.

4.2.2 Inter-connections between steel structures and the aluminum superstructure shall be made by using explosive-bonded bi-metal strips.

4.2.3 Subject to Class approval, the certified marine grade aluminum alloys shall be 5083/5086-H32/H116 for plates, and 5083/5086-H111 or 6061-T6 or 6082-T6 for extrusions and shapes. 6061 alloys shall not be used in critical high stress areas.

4.2.4 There shall not be any direct contact of electrolytically dissimilar metals except as described in paragraph 4.2.2.

4.2.5 Paint, insulation, adhesives, or other items containing materials or components that emit noxious or toxic fumes at temperatures below 94.0°C shall not be installed or applied on hull structural material and superstructure. For paints and adhesives, this requirement applies after drying or curing is complete. Chromate based paints shall not be used.

4.2.6 Aluminum structural components shall not be threaded or tapped. Helical coil or pressed-in galvanically compatible threaded inserts shall be used when directed threading is required.

4.2.7 Nuts which are inaccessible shall be captured to allow reassembly and prevent backing off. Unless otherwise specified, self-locking nuts of plastic insert type or all-metal self-locking nuts of distorted type shall be supplied and installed to prevent bolt loosening caused by shock or vibration. Fasteners on walking areas of the upper deck shall be flush mounted to eliminate tripping hazards.

4.2.8 In the assembly of machinery units subjected to large reversing stresses such as screw gear and hydraulic steering cylinders, the forces tending to shift the unit on its foundation shall be countered by the use of fitted bolts, keys and dowel pins or other OEM approved methods. Propulsion machinery shall be secured by means of fitted bolts or other OEM approved methods. Bolts shall be inserted from the bottom of the foundation with the nut on top.

4.3 SHELL AND SUPPORTING FRAMING

4.3.1 To avoid propeller induced vibration, the lowest natural frequency of stiffened bottom shell plating in the after quarter of the MSPV shall not lie within a band of ± 20% of an excitation

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frequency throughout the range of operating speeds of the MSPV and shall be subject to Class approval.

4.3.2 There shall be a minimum of 75 mm clearance between structural members and parallel plate butts and seams. Longitudinals shall be made continuous with butt welds, with those welds at least 75 mm from all shell butts. Frames shall be butt welded, with those welds at least 75 mm from any shell seam.

4.4 PILLARS AND STANCHIONS

4.4.1 Pillars and stanchions shall be landed on structural framing members and aligned with the webs of the supporting structure in the longitudinal and transverse planes.

4.5 INNER BOTTOM AND FOUNDATIONS

4.5.1 Wells constructed in a double bottom for the purpose of drainage shall all be capable of being emptied by mechanical pumping other than a hand pump.

4.5.2 Foundations shall be arranged in such a way to provide adequate clearance for servicing and disassembling modules or parts such as pumps, filters, valves and pistons without dismantling other machinery, structure or piping.

4.6 WEATHER DECK AND INTERNAL DECKS

4.6.1 Deck longitudinals shall be butt-welded throughout with those welds separated from all deck butts by at least 75 mm.

4.6.2 Openings shall be kept to a minimum in particular in the strength decks within the 3/5 length amidships.

4.6.3 All exposed decks shall have a camber set at 2% of beam, except for the aft working deck. A camber of 2% of beam or less is permissible on the aft working deck providing no deck equipment overhangs the deck-edge.

4.7 MINOR BULKHEADS

4.7.1 Outside corners of interior steel bulkheads in way of living and working spaces shall be rounded to prevent hazard to personnel.

4.7.2 The periphery of minor bulkheads shall not allow dust, sound and light to penetrate.

4.7.3 Non-structural steel or joiner bulkheads surrounding wet spaces shall have all-welded coaming extending a minimum of 10 cm above the deck covering.

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4.8 SUPERSTRUCTURE

4.8.1 The boundaries of all superstructures shall be of weather tight construction. Casings, houses, bulkheads, and other surfaces shall be fair, without buckles, kinks, or other similar surface irregularities. Where trunks penetrate decks, the deck cuts shall have rounded corners.

4.9 STRUCTURAL CASTINGS, FORGINGS

4.9.1 All finished forgings and castings shall have Original Equipment Manufacturer (OEM) or serial numbered identification markings.

4.10 DRAIN PLUGS

4.10.1 Docking drain plugs, minimum diameter 38 mm, fitted to heavy steel weld-in spigot insert plates, shall be fitted in all bottom compartments, skeg(s) and tanks to permit complete drainage of the MSPV when in drydock. Plugs shall be flush with the outside of the shell when installed. Plugs shall be identified by two (2) shapes of key recesses, one (1) for oil fuel tanks and lube oil tanks, and a different shape for other spaces. Two (2) stainless steel keys for each shape shall be supplied and stowed aboard in the Chief Engineer's Cabin, clearly marked as to purpose.

4.10.2 The position and key recess shape of each drain plug shall be specified on the as-fitted docking plan.

4.11 MAST

4.11.1 The mast structure and the associated platforms and overhangs shall be designed and built to provide rigid foundations to support the electronic navigation equipment such as radar and antennae. The magnitudes of vibration shall be designed so that the maximum vibration does not exceed the manufacturer's limitations for all pieces of equipment mounted on the mast or, if not stated by the manufacturer, that the vibration level in all operating condition does not adversely affect the performance of each piece of equipment.

4.11.2 A mast shall be fitted to carry radars, antennae, navigating lights, navigational aids, yard-arms with signal flag hoisting attachment, signals and sirens. The mast and supporting structure shall be designed and built to withstand wind loads up to and including eighty (80) kts, the weights of the structure and equipment and, the dynamic inertia loads due to ship motion.

4.11.3 The mast's first fundamental frequency shall not lie within a band of ± 20% of an excitation frequency throughout the complete range of operating speeds of the MSPV and shall be subject to Class approval.

4.11.4 Cleats for signal halyards including masthead flag and gaff shall be supplied and installed. Standing rigging shall be reduced to a minimum.

4.11.5 The mast shall be fitted with anchor points for fall protection and ladder rungs as required by MOSH regulations.

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4.12 RUDDERS

4.12.1 The rudders shall be streamlined in horizontal section and be of the type, area and contour suitable for the intended service. The rudders shall be double plated with internal horizontal plate stiffeners and round bar leading edge and shall be made watertight by welding, and then tested via an upper and lower plugs made of stainless steel. The internal surfaces shall be treated to prevent corrosion.

4.13 CHAIN LOCKER(S)

4.13.1 The chain locker(s), designed and built so that the chain(s) will be self-stowing, shall be sized to accommodate the chain(s) and to give at least 60 cm headroom when cable(s) is stowed.

4.13.2 The chain locker(s) shall be fitted with perforated removable floor plates suitably stiffened at a height of 150 mm above the bottom of the locker(s). Access to the chain locker(s) shall be within the MSPV fore peak by means of a hinged manhole(s). If a single chain locker is intended to house two chains, it shall be divided with a non-watertight centreline bulkhead. The bulkhead shall have semi-circular holes in line with access manhole(s) to act as toe and hand holes when inspecting the locker. Otherwise, alternate arrangements shall be installed to allow access to the locker bottom.

4.13.3 The bitter end connection(s) shall be located at the top of the locker(s), in protected but accessible locations to permit emergency release of the chain(s). The bitter end connection(s) shall be designed for shear failure under a runaway chain load equal to the breaking strength of the anchor chain.

4.14 RUBBING STRIPS

4.14.1 Deck edges shall be protected with smooth, steel, Schedule 80, half-round pipe moulding, welded to the hull and deck and fitted in way of, and for a minimum length of 0.5 m, each side of all mooring fittings.

4.14.2 A continuous, shock-absorbing rubbing strip shall be mounted on the MSPV's hull, approximately 800 mm below the deck edge, from the aft edge of the house on the port side, around the bow to the aft edge of the house on the starboard side. This rubbing strip shall be constructed using lengths of hollow, rubber, D-section fendering which shall be held between steel channel sections by vertical steel pins. The steel pins shall be welded to the channels at both ends of each pin. The steel channels shall be continuously welded to the MSPV's hull, be waterproof and shall be the only connection to the hull. Rubbing strips shall be sized appropriately for the MSPV, considering the hull thickness and local strengthening.

4.14.3 A smooth, steel, Schedule 80, half-round pipe moulding shall be continuously welded to the deck edge and hull aft of the shock-absorbing rubbing strip, butted to that strip with an aft-angled lap joint, to continue the rubbing strip protection along both sides of the working deck.

4.14.4 On the areas of the ship's side where launching and recovering of RHIBs and lifting of seized nets, traps and anchors could damage the hull, steel half-round pipe protection shall be

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welded to the hull. These hull protection strips shall extend downward, butted at their top ends to the horizontal, half-round pipe, rubbing strip mentioned above, down to the deepest operating waterline. They shall be continuously welded on an angled pattern, be waterproof and be one (1) metre apart, with the lower ends diagonally aft of the upper ends, so as to deflect spray outward and cause the smallest possible reduction to speed. The lower ends of these half-round protection strips shall be tapered down to the hull over a 25 cm length and all rubbing strips shall be welded watertight.

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5 HULL OUTFITTING

5.1 MOORING AND TOWING SYSTEMS

5.1.1 A set of six (6) appropriately sized synthetic mooring lines shall be supplied with a one (1) m eye splice at each end. Stowage for the mooring lines shall be supplied and installed in the fore peak and aft peak.

5.1.2 Cleats and fairleads shall be arranged to support RHIB operations on the port and starboard side.

5.1.3 Arrangements shall be made for being towed and for towing another vessel of similar displacement in head seas, up to and including Sea State 5 as detailed at Appendix 3 of the TSOR. One (1) cruciform bollard and bow fairlead shall be supplied and installed for the lead of the towing gear when the MSPV is being towed. One (1) cruciform bollard and stern fairlead shall be supplied and installed on the centreline for use when towing another vessel.

5.1.4 The towline reel shall be installed in close proximity to the aft towing arrangement. The reel shall accommodate the towing line and shall have a reserve capacity equal to one layer warp of line to compensate for imperfect warping of the line during retrieval operations.

5.1.5 The towline reel shall be electrically or hydraulically driven and shall be designed to minimize its deck footprint. The reel shall be located so as to provide unobstructed access to the aft work deck and towing area. Local control shall be supplied and installed to pay in and pay out the rope. The control shall be of the safety type which, when released by the operator, will return to the off position. The reel shall be fitted with a mechanical release arrangement to allow emergency retrieval or release in the event of loss of power.

5.1.6 One (1) electrically or hydraulically driven capstan with local control and overload protection shall be installed on the aft work deck to provide hauling capability to either side of the MSPV. It shall have a minimum pull of 1,000.0 kg.

5.2 ANCHOR HANDLING AND STOWING SYSTEM

5.2.1 The MSPV shall be designed, built and outfitted with at least one working anchor and eight (8) shots of chain. A second anchor is required only as a spare and shall be stored onboard. The storage location shall be approved by the Technical Authority (TA) during the design review process. However, if the second anchor is intended to be fitted as a working anchor, it too shall be supplied and installed with eight (8) shots of chain. Two (2) of the eight (8) shots of each fitted chain shall be galvanized - one (1) fitted at the bitter end, and one (1) fitted at the anchor's end. The forecastle deck shall have a working area available for the operation of the anchor windlass and for normal deck operations.

5.2.2 Facilities and wash down points shall be fitted for washing the anchor(s) and chain(s).

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5.2.3 A common anchor windlass and capstan shall be supplied and installed for anchor handling and warping operations. The windlass and capstan shall be electrically or hydraulically driven and shall be capable of hoisting home the anchor and fully extended chain.

5.2.4 Anchor chain stoppers shall be designed and installed and aligned in the path of the anchor chain(s). An arrangement shall be supplied and installed to ensure that the anchor(s) consistently trip and seat home firmly.

5.2.5 The design of the anchoring system shall be such that there is positive starting of the anchor(s) and the chain(s) upon release under all conditions of intact stability.

5.2.6 Arrangements shall be supplied and installed to stop water on the deck from flooding the chain locker(s). The chain locker(s) shall be designed and built such that the chain(s) is self-stowing. The chain locker(s) shall incorporate a non-manual pumping arrangement or drainage arrangement for the removal of water.

5.3 DECK CRANE

5.3.1 The MSPV shall have an articulated, marine, knuckle-boom hydraulic crane capable of lifting a minimum of 1.5 tonnes at a minimum distance of 2.5 m over both the port and starboard side of the MSPV in a minimum of Sea State 4 as detailed at Appendix 3 of the TSOR. The deck crane may form part of the specified launch and recovery system for the RHIBs, see Section 5.8. The crane shall be capable of rotating 360.0° and shall be installed on the aft work deck of the MSPV. The safe working loads (SWL) of the crane up to an including the maximum design sea state shall be indicated on the crane.

5.3.2 The crane shall be designed, built and certified in accordance with the Lloyd's Register Code for Lifting Appliances in the Marine Environment, or equivalent.

5.4 CRAB AND GILL NET HAULER

5.4.1 A removable, hydraulically driven, Marco Pot Line Hauler, J0117, Crab Trap Hauler shall be supplied and installed on the starboard side of the aft work deck area on the MSPV C&P variant. The Crab Trap Hauler shall be fitted to the deck crane or another suitable removable appliance capable of withstanding the vertical and side loads associated with retrieving 2.4 m conical crab traps requiring a maximum pull capacity of 800-kg in Sea States up to and including Sea State 4 as detailed at Appendix 3 of the TSOR. Hydraulic power shall be supplied and installed to the Crab Trap Hauler's hydraulic motor for operation.

5.4.2 A removable, hydraulically driven, Rapp Marine Power Block Type KB-08, Gill Net Hauler shall be supplied and installed on the starboard side of the aft work deck area on the MSPV C&P variant. The Gill Net Hauler shall be fitted to the deck crane or the same removable appliance used to mount the Crab Trap Hauler. Hydraulic power shall be supplied and installed to the Gill Net Hauler's hydraulic motor for operation.

5.4.3 The location of the Crab Trap Hauler, Gill Net Hauler, and removable appliance shall not interfere with the operation of the MSPV's fitted towing equipment.

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5.4.4 Any fittings or mountings associated with the Crab Trap Hauler, Gill Net Hauler, and removable appliance shall not interfere with the MSPV's ability to embark and deploy a starboard RHIB.

5.5 HYDRAULIC OIL SYSTEMS

5.5.1 Hydraulic power unit(s) shall be supplied and installed to provide hydraulic fluid to permanent and removable equipment fitted in and on the MSPV as required. Stainless steel quick-connections shall be supplied and installed on the aft working deck to provide fluid to removable equipment.

5.5.2 Deck hydraulic systems shall be equipped with heaters to prevent condensation and excess pressures on start up. The same type of hydraulic fluid shall be used for all the machinery, if approved by the OEM.

5.6 RIGID HULL INFLATABLE BOATS (RHIBS)

5.6.1 The aft working deck shall have work area available for the launch and recovery system(s) of Zodiac-Hurricane (SAR configuration) H753 RHIBs, embarkation and disembarkation of personnel, stowage of the RHIBs, transfer of stores and equipment and, the conduct of RHIB refuelling, troubleshooting and maintenance.

5.6.2 The MSPV MS variant shall be supplied and installed with two (2) RHIBs as detailed at Appendix 1 of the TSOR.

5.6.3 The MSPV MS variant shall be supplied and fitted with one (1) common system or with two (2) identical systems and equipment to launch, recover and stow one (1) port side RHIB and one (1) starboard side RHIB.

5.6.4 The MSPV C&P variant shall be outfitted with the necessary system(s) and equipment to launch, recover and stow one (1) RHIB on the port side using the identical system(s) and equipment as the MSPV MS variant. The MSPV C&P variant RHIB is an additional item listed in Schedule A and is described in the SOW Appendix 2.5.

5.6.5 The MSPV C&P variant shall be configured to accommodate the port RHIB and fitted for but not with either the starboard RHIB or the necessary system(s) and equipment to launch, recover, and stow the starboard RHIB.

5.6.6 If the MSPV C&P starboard RHIB has its own dedicated launch and recovery system, the launch and recovery system, equipment and the starboard RHIB stowage arrangement shall be removable such that the MSPV C&P variant has at least thirty (30) m^2 of continuous open deck space and is able to carry and operate the Crab Trap Hauler, Gill Net Hauler, and removable appliances as noted in paragraphs 5.4.1 above and 5.4.2 above.

5.6.7 One (1) Zodiac RIBO 420, or equivalent, SOLAS rigid hull inflatable rescue boat, shall be supplied and installed on each MSPV. Each rescue boat shall be supplied and equipped with one (1) 4-stroke gasoline outboard engine of 25 Horsepower (HP).

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5.6.8 Chocks, cradles, gunwale guards and all necessary fittings and support for the stowage of the rescue boat shall be supplied and installed.

5.7 RIGID HULL INFLATABLE BOATS (RHIBS) FUELLING

5.7.1 Twenty five hundred (2500.0) litres of gasoline for refuelling the RHIBs and rescue boat shall be stored on the aft working deck. The gasoline may be stored in one or more baffled tanks. Each tank shall be constructed of non-ferrous metal and shall be equipped with:

a. an automatic pressure and vacuum vent complete with flame arrestor; and

b. a low level, lockable drain valve; and

c. top-mounted, filling and pumping connections complete with lockable isolation valves; and

d. a tank level indicating system; and

e. a top-mounted, removable tank inspection plate; and

f. a save all under the tank; and

g. a lockable, quick release mechanism to jettison the fuel tank(s) overboard in an emergency; and

h. connections to a RHIB and rescue boat refuelling system.

5.7.2 The RHIB and rescue boat refuelling system shall have the following features:

a. be constructed of non-ferrous materials; and

b. be contained within a storage cabinet with lockable doors; and

c. be equipped with a hand operated or pneumatic pump; and

d. be equipped with a grounded flexible hose of an approved rubber material and length to reach the embarked RHIBs' onboard tank filling arrangements; and
be equipped with a hand gun on the end of the flexible hose to allow control of the refuelling operation onboard the RHIBs; and

e. be fitted with a means to ensure there is no build up or dangerous discharge of static electricity during the refuelling operation; and

f. be designed to allow transfer of gasoline from ashore into the onboard RHIB gasoline storage tank(s).

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5.8 LAUNCH AND RECOVERY SYSTEMS FOR THE RHIBS

5.8.1 The H753 SAR version RHIB launch and recovery system(s) shall be capable of launching and recovering two (2) fully loaded RHIBs containing four (4) occupants per RHIB (weighing a maximum total of 500.0 kg), each fully fuelled, at a speed of 5.0 knots and up to and including Sea State 5 as detailed at Appendix 3 of the TSOR.

5.8.2 The H753 SAR version RHIB launch and recovery system(s) shall be capable of stowing two (2) fully loaded, fully fuelled RHIBs in all conditions in which the MSPV will operate.

5.8.3 For each of the two (2) H753 SAR version RHIBs onboard the MSPV MS variant and the one (1) H753 SAR version RHIB onboard the MSPV C&P variant and the associated fittings, including shackles, webbing, quick release device(s), such as Cranston Eagle Hook, shall be supplied and installed to facilitate the safe launch and recovery of the RHIBs with four (4) personnel embarked. Handling lines, cleats and or stoppers shall be supplied and installed as necessary for RHIB launching, recovery and handling alongside port and starboard. A 6-inch snatch block shall be secured to the head of the launch and recovery system(s) and another 6-inch snatch block shall be secured to an eye on the deck to provide a lead for a diver recovery line.

5.8.4 The launch and recovery systems and stowing arrangements shall not interfere with towing operations.

5.8.5 The launch and recovery systems, stowing and securing arrangements, control stations and power packs and sub-assemblies shall be secured to seating arrangements that are flush-fitted to the deck plate structure. All securing arrangements and bolt patterns required to secure the launch and recovery systems, control stations, power packs and sub-assemblies shall be fitted with stainless steel socket head screws which shall also be flush with the deck plate.

5.8.6 The launch and recovery system controls shall be fitted such that the operator can clearly view the RHIB(s) and rescue boat at all times during the launch, recovery and stowage operations.

5.8.7 The rescue boat shall be able to be manually launched, recovered and stowed in the event of a MSPV power failure.

5.9 DECK TIE DOWNS

5.9.1 Flush mounted deck tie downs, each with a 0.5 tonne (SWL), shall be spaced approximately 1.5 m apart along the entire aft working deck area. The tie downs shall have rolled edges to prevent chaffing of lines.

5.10 LIFTING STRONG POINTS

5.10.1 Lifting strong points shall be designed and installed to facilitate machinery and equipment maintenance, repair and removal.

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5.11 EMERGENCY RESPONSE GEAR

5.11.1 Pallets with Emergency Response Gear for both variants may be loaded on the aft deck. The pallets will be loaded using the deck crane and secured using deck tie-downs. The total weight of all pallets will not exceed three (3) tonnes.

5.12 SIGNAL FLAG LOCKER

5.12.1 A signal flag locker shall be supplied and installed in the Bridge. The signal flag locker shall be sized appropriately to house a complete set of signal flags in individual compartments.

5.13 JACK AND ENSIGN STAFFS

5.13.1 The staffs shall be 1.8 m high and constructed of 50 mm diameter galvanized steel or aluminum pipe.

5.13.2 The jack staff shall be permanently fitted vertically at the stem. The ensign staff shall be removable and raked to 10.0° aft from the vertical on the main deck at the stern. Each staff shall be fitted with two halyard sheaves and cleats.

5.14 GANGWAY

5.14.1 A gangway with a minimum length of 6.5 m shall be supplied. The gangway shall have a clear width of at least 760 mm with an anti-slip serrated tread walking surface to prevent snow and ice accumulation. It shall have permanently fitted rollers at one end and removable railings to facilitate onboard stowage. Eye plates and fittings shall be fitted on the MSPV and to the gangway to secure the safety net beneath the gangway.

5.14.2 Gangway access areas shall be supplied on both port and starboard sides of the main deck of the MSPV.

5.15 PORTLIGHTS AND WINDOWS

5.15.1 Windows and portlights shall be constructed and installed to preserve the watertight and fire-rated integrity of bulkheads and the structure in which they are fitted. All glass shall be heat-treated safety glass.

5.15.2 All portlights shall be at least 450 mm in diameter with deadlights hinged up and the means of retaining deadlights in the "up" position shall be rigid and secure.

5.15.3 Each cabin on or above the main deck shall be supplied and installed with an opening type portlight. Each cabin below the main deck shall be supplied and installed with a non-opening type portlight.

5.15.4 All fixed Bridge windows shall be electrically heated using a vinyl film design for defrosting and de-icing.

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5.15.5 The Bridge front windows, non-drop type, shall be fitted with straight-line wipers and a system to permit de-icing and potable water wash-down. A locally mounted wiper speed controller and ON/OFF switch shall be fitted to each front window.

5.15.6 See-through window films that roll up shall be supplied and installed to reduce sun glare and interior heating while still preserving full visibility.

5.15.7 A minimum of two (2) Bridge front windows shall be weather tight and drop-type opening or raised-type opening. Two (2) side windows, one (1) each port and starboard, shall also be weather tight and drop-type opening.

5.15.8 To reduce reflections from internal lighting, all Bridge windows are to be inclined from the vertical plane top out, at an angle of not less than 10.0° and not more than 35.0°.

5.16 BLACKOUT AND PRIVACY CURTAINS

5.16.1 Blackout curtains shall be impervious to the transmission of any light and shall be installed around all access doors leading to the weather decks. Blackout curtains shall be laced to overhead curtain rails that are fixed stationary to overhead curtain plates. The curtains shall be overlapping and doors shall be fitted with the necessary rods and magnets or Velcro® fasteners to ensure complete blackout conditions when the curtains are closed. Provisions shall be made to secure curtains in the fully opened and fully closed positions.

5.16.2 Blackout curtains shall be supplied and installed at the navigation display, chart table and all entrances to the Bridge. Blackout curtains shall be fitted in the Command Centre to completely exclude light transmission via portlights and windows.

5.16.3 Where deadlights are not installed, black-out curtains with tie backs shall be fitted to completely exclude light transmission from all windows and portlights in cabins, in the mess and in the galley. All house front curtains shall have Velcro® fasteners to hold the curtain against the window.

5.16.4 All cabin doors shall be fitted with privacy curtains so that when the cabin door is secured open with a hook, the curtain may be closed across the door way.

5.16.5 All curtains shall be lined and weighted and shall have top hems of 50 mm and bottom hems of 100 mm. All tops of curtains shall be pleated and shall be at least 150% of the width of the track. All curtains shall extend beyond the deadlight or window or door trim and overlap by 50 mm.

5.17 PROTECTIVE COVERS

5.17.1 Protective covers shall be supplied and installed for the anchor windlass, RHIBs, searchlights, signal lights, floodlights, wire rope and tow rope reels, and other upper deck equipment or lockers requiring protection from the weather. All protective covers shall be made of commercial, marine grade, waterproof coated nylon cloth with stainless steel lacing grommets. Velcro® fastenings and chafing pieces of leather are to be fitted where there are pressure points on the cover.

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5.18 LIFE LINES AND STANCHIONS

5.18.1 In order to facilitate the use of the 0.50 cal heavy machine guns, the main deck forward shall be fitted with removable, coated wire life lines and galvanized steel stanchions. The life lines shall be made taut by means of turnbuckles.

5.18.2 Closed link chain and removable stanchions shall be supplied and installed around all low coamings and flush hatches, and where ever necessary for the protection of personnel. The stanchion supports shall be pocketed.

5.19 DECK PLATES AND GRATINGS

5.19.1 Deck plates shall be aluminum chequered plates, 4.5 mm thick with a raised 4-bar pattern non-skid type surface. Individual deck plates shall not be greater than one (1) m^2 for ease of lifting and removal. Deck plates shall be constructed in accordance with Class.

5.19.2 Deck plates shall be firmly secured to steel angle bar ledges with counter sunk and stainless steel threaded socket head screws. Securing arrangements shall not extend above the surface of the grating and deck plating.

5.19.3 Piano hinged sections of deck plates or gratings shall be fitted in areas where access is required below them to carry out operation and periodic inspection, maintenance and cleaning of equipment.

5.19.4 All grating panels shall be secured to the supporting framework by clips or bolts to ensure positive locking and ready disassembly. Clips and J-bolts shall not extend above the surface of the grating.

5.20 STRUCTURAL BULKHEADS, DOORS AND PARTITIONS

5.20.1 All fire doors shall be fitted with magnetic hold backs. All non-fire doors shall be fitted with suitable non-rattling holdbacks.

5.20.2 All watertight doors and hatches shall have open and closed indicators located on the Bridge.

5.20.3 All accommodation doors shall be supplied and installed with kick-out panels.

5.20.4 Exterior access to the Bridge shall be by means of supplied and installed port and starboard weather tight doors. The door windows shall be fixed and the doors shall be supplied and installed with a four (4) point single lever dogging arrangement. The Bridge doors shall have keyed dead bolt locks and shall be keyed-to-like.

5.21 NAME PLATES, NOTICES AND MARKINGS

5.21.1 Bilingual label plates for compartments, warnings, ventilation, lifting appliances, exits, means of escape, life saving appliances, fire-fighting, damage control, and safety related items and equipment shall be made using an aluminum metal photo process.

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5.21.2 Self-adhesive safety labels and markings within compartments, warning signs, exits, life-saving appliances, fire-fighting, damage control, and other safety related items and equipment shall be in accordance with International Maritime Organization (IMO) A 603(15) 7 Standard Symbols.

5.22 IMMERSION SUITS STORAGE

5.22.1 Allocated lockers with storage space for eighteen (18) Transport Canada Marine Safety (TCMS) approved immersion suits shall be provided as follows: one (1) immersion suit in each cabin for each occupant and two (2) immersion suits in both the Bridge and in the MCR.

5.23 LIFE PRESERVERS

5.23.1 Eighteen (18) TCMS approved life preservers shall be supplied and installed. Allocated storage space shall be supplied and installed as follows: one (1) life preserver in each cabin for each occupant and two (2) life preservers in both the Bridge and in the MCR.

5.24 JACOB'S LADDERS

5.24.1 Two (2) Jacob's ladders shall be supplied and installed on each MSPV. The Jacob's ladders shall reach the waterline with at least two rungs submerged when secured on either side of the vessel from the highest point of the main deck edge at the MSPV's arrival condition in salt water.

5.25 PAINTING AND PRESERVATION

5.25.1 The exterior hull and deckhouse plating of the MSPV shall be painted in accordance with standard Canadian Coast Guard colours as detailed in Fleet Circular - Canadian Coast Guard Identity Colour Standard –CF-08-2007 and Canadian Coast Guard Identity Program TP-4011.

5.25.2 The MSPV shall be fitted for, but not with, removable markings to be provided by Canada as required by CCG and the RCMP for identifying the MSPV MS variant.

5.26 DECK COVERINGS

5.26.1 Deck coverings shall be installed as shown in Table 2 – Deck Coverings.

AREA	FINISH
Bridge and Command Centre	shock absorbing rubber
Cabins and Mess	vinyl flooring or tiles on underlay
Galley	3 inch x 3 inch or metric equivalent non-slip type ceramic tiles on underlay
Washrooms, Wet Gear Locker & Laundry	"Terrazzo Reversa Tile" or similar quality slip resistant tile on underlay
Switchboards, UPS, control consoles	Switchboard Mat; ASTM 30,000 Volt Dielectric Rated Standard in accordance with IEEE 45-2002, Standard Specification for Rubber Insulating Matting.
Exterior Deck	non-slip high performance paints

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Passageways	12 inch x 12 inch or metric equivalent non-slip asbestos-free vinyl tile on underlay
Tank top if used for working area	perforated rubber matting

TABLE 2 - DECK COVERINGS

5.26.2 Deck coverings fitted in galley, showers and laundry areas shall be contoured to ensure proper drainage to scuppers.

5.27 FIREARMS AND AMMUNITION

5.27.1 The MSPV shall be designed and built to be fitted-for-but-not-with two (2) 0.50 calibre heavy machine guns. The main forward deck in way of the port and starboard mount locations for the two (2) 0.50 calibre heavy machine guns shall be strengthened for the firing loads.

5.27.2 The firearms locker shall be designed and built so that the following firearms can be stored. The stowage arrangement shall be designed and built to meet the requirement of Canadian Coast Guard National Firearms Policy (Doc #817221v5).

a. Three (3) – Long Rifles; and

b. Three (3) – Long Rifle Scopes; and

c. Three (3) - Shot Guns; and

d. Two (2) – 0.50 cal heavy machine guns without barrels; and

e. Three (3) – 0.50 cal heavy machine gun barrels.

5.27.3 The firearms locker shall be fitted with two (2) independent locking devices.

5.27.4 The MSPV's firearms locker shall be located inside on the main deck level.

5.27.5 A secure locker shall be supplied and installed in the Captain's Cabin for stowage of all the breech blocks for all the firearms noted above.

5.27.6 RCMP and C&P personal firearms shall be secured in lockers located in each cabin as specified in the cabin outfit.

5.27.7 Two (2) lockable watertight ammunition lockers shall be supplied and installed on the main deck, one (1) port and one (1) starboard, with appropriate capacity for each to hold 1000 rounds for the 0.50 cal heavy machine guns.

5.27.8 One (1) lockable ammunition locker, separate and apart from the 0.50 cal heavy machine gun ammunition stowage lockers, shall be supplied and installed inside on the main deck level so that the following ammunition can be stored:

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a. Long Rifle: TBD (200 rounds); and

b. 9mm pistol: 9mm (2000 rounds); and

c. Shot Gun: TBD (250 rounds).

5.27.9 All ammunition lockers shall be fitted with a fixed fire-fighting system.

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6 PROPULSION

6.1 GENERAL

6.1.1 All controls for operating the machinery, equipment, instruments, pumping systems, cocks, air pipes, inlets, sounding pipes, switches and associated items shall be permanently marked with bilingual, mechanically-fastened, engraved plates of plastic or corrosion resistant metal, clearly showing their purpose. All hand-wheels shall be marked to show the direction of closure. Valves shall have brass label plates securely attached to them in accordance with ASTM F99-86(2006) Standard Specification for Valve Label Plates.

6.1.2 All portions of exhaust pipe surfaces and other hot surfaces which could be a hazard to personnel shall be properly insulated so that the surface temperature does not exceed 60.0°C or otherwise shall be protected to prevent accidents or burns.

6.1.3 All fuel discharge lines shall be double-walled.

6.2 MAIN ENGINES

6.2.1 All main engines shall be supplied and installed. Every engine shall be a non-reversible, self contained, turbo-charged, after-cooled, four cycle marine diesel engine. Every main engine shall meet the requirements as stated in CSA 2001 -Main Machinery Regulations Schedule IV Part II Plans Division I Internal Combustion Oil Engines.

6.2.2 The main engines shall be capable of operation on high output diesel single-or multi-grade commercially available (API/SAE graded) lubricating oil. Each diesel engine shall have its own OEM supplied pre-heater and pre-lube pump and its own lube oil, fresh water-cooling and raw water system. There shall be no interconnection between the engines' lube oil, fresh water and raw water systems although the raw water systems may be connected to a common sea chest.

6.2.3 Each engine shall be supplied and installed with all accessories recommended by the OEM for continuous service at sea.

6.3 GEARING, SHAFTING, BEARINGS

6.3.1 Each main engine shall be connected to a separate gearbox in accordance with the OEMs recommended method. Coupling bolts shall be supplied and installed with locking devices. The gearboxes shall be identical except that they shall be configured such that the propellers have opposite rotation. Propellers shall have rotation such that the propeller blades will rotate outboard over the top for ahead propulsion.

6.3.2 Stern tube bearings shall be water cooled. To permit operation in shallow waters, a filtration device shall be supplied and installed on the water supply to the bearings.

6.3.3 The stern tube mechanical watertight seal shall be readily accessible to allow for checking and replacement of wearing elements without shaft disassembly and with the MSPV afloat.

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6.3.4 Means shall be supplied and installed to prevent propellers from being fouled by ropes up to and including 2.0 cm in diameter.

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7 AUXILIARY SYSTEMS

7.1 PUMPS

7.1.1 All pumps shall be supplied, installed and fitted with mechanical seals. The pump casings and impellers shall be stainless steel or naval bronze, and all shafting shall be constructed of stainless steel. Pumps handling black and grey water, fuel, and lubricating oils shall have drip trays or save-alls installed to contain possible leakage. All pump configurations shall be standardized where pumping requirements are the same or similar.

7.1.2 All instrumentation for machinery, pumps, piping and mechanical systems shall display readings in the international system of units (SI). Instrumentation shall be installed to ensure the safe and proper operation of equipment and systems.

7.2 PIPING SYSTEMS

7.2.1 Piping systems shall be designed and installed to afford access to valves, manifolds, strainers, filters and other items incorporated in the systems requiring periodic servicing. Duplex filters with changeovers shall be fitted in critical systems for the purpose of enabling cleaning without disturbing the normal functioning of the systems. Where piping is attached to resiliently mounted machinery, rotating flange expansion joints or 321 stainless steel braided flexible hoses with ridged male and swivel female couplings shall be used.

7.2.2 Mechanical joints shall be avoided and only used where absolutely necessary to allow for maintenance. Pipe runs shall be engineered to ensure no interference with equipment access for maintenance and operation. All piping carrying potable water and raw water shall be supplied and installed with drain plugs to allow complete drainage by gravity for maintenance. All piping arrangements shall be designed and installed to avoid air pockets. Where piping systems are inherently prone to air pockets by design, piping shall be fitted with threaded spigots or vent plugs. All joints shall be either welded or brazed sleeved. All pipe sections shall be thoroughly cleaned and be free from oil, dirt, rust, weld splatter and all other foreign matter prior to installation. After installation, all piping systems shall be flushed and blown clear, to be proven free of oil, dirt, rust, weld splatter and all other foreign matter or contaminant prior to putting into service.

7.2.3 Valves shall be suitable for the intended application and shall be readily accessible for inspection, operation, maintenance and removal. Sandwich-type, butterfly valves shall not be used to provide watertight integrity between any system and the ship's hull. Where possible, all valves shall be grouped in a manifold. Valves that are not readily accessible shall be fitted with fixed extension spindles upon approval by Canada.

7.2.4 Piping systems shall be identified in accordance with the Colour Coding Standard for Piping Systems CCGS 30-000-000-ES-TE-001.

7.2.5 Valves shall have bilingual brass label plates securely attached to them in accordance with ASTM F99-86(2006) Standard Specification for Valve Label Plates.

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7.2.6 All potable water (hot and cold), raw water, ballast water, black and grey water, sanitary water and refrigerant piping throughout the MSPV shall be insulated, however, the raw water, ballast water and black and grey water piping and potable water filling pipes in the machinery space(s) shall not be insulated. Where piping passes through a tank, a void, or a cofferdam there is no requirement to insulate the pipe. Insulation on valves shall be arranged to permit easy removal and replacement of insulation without disturbing pipe insulation.

7.2.7 All deck-filling and pump-out connections shall be lockable and located to permit use when the MSPV is moored both port and starboard side to. All fuel oil, waste oil, lubrication oil, and black water connections shall be fitted with a save-all.

7.3 FUEL OIL SYSTEM

7.3.1 Notwithstanding the overall intent to design, build, outfit and certify to Lloyd's Register Rules and Regulations for the Classification of Special Service Craft, or equivalent, the MSPV shall be designed, built and outfitted with a fuel oil system allowing storage, transfer, treatment, cleaning, supply, use and discharge of the appropriate fuel in accordance with OEM requirements and in accordance with Lloyd's Register Rules and Regulations for the Classification of Ships Chapter 14 Section 2, 3, and 4, or equivalent.

7.3.2 The transfer pump(s) shall be supplied and installed to allow transfer of diesel fuel to, or from, or between, any of the diesel fuel oil storage tanks via duplex filter(s) and water separator(s) to all of the day and service tank(s), or directly to a deck connection(s) to de-fuel.

7.3.3 The following requirements shall apply to the fuel system:

a. two (2) diesel filling stations shall be located on the main deck one (1) starboard and one (1) port. Alternatively, one (1) central filling station that is accessible from both sides of the MSPV is acceptable; and

b. one (1) simplex coarse strainer shall be supplied and installed in the main fuel line at each filling station; and

c. bronze lockable closing caps and connections shall be supplied and installed on each filling connection; and

d. each fuelling station shall be supplied and installed with a means of communication with the Bridge, Main Machinery Room (MMR) and MCR.

7.3.4 All fuel tanks shall have access for internal examination and cleaning and shall be fitted with sounding tubes on the main deck level.

7.4 LUBRICATING OIL SYSTEM

7.4.1 All lubricating oils shall be the same for similar equipment, subject to the approval of the OEM.

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7.4.2 The lubricating oil transfer system shall allow transfer of oil from storage tank(s) to the diesel sumps. If the same grade of lubricating oil is approved for main engines, gear boxes and generator engines, the minimum capacity of the storage tank(s) shall include one (1) complete oil change of one (1) main engine, one (1) gear box and one (1) generator engine and all bearing(s), plus 20%. If more than one lubricating oil type is used, the capacity of the tanks shall be as follows:

a. 1.2 times the quantity required for one main engine; and

b. 1.2 times the quantity required for one gear box; and

c. 1.5 times the quantity required for one generator engine.

7.4.3 The dirty oil tank(s) shall be capable of holding all the oil removed during one complete oil change. A complete oil change comprises one main engine, one gear box, one generator engine and all bearing(s) plus 20%. The dirty oil tank(s) contents shall be capable of being discharged to shore through a deck connection(s) by means of an electrically driven pump.

7.4.4 Tank(s) that supply make-up oils for engines shall be of the type, capacity and general location as recommended by the OEM. Tank(s) in the system shall be built and installed with approved oil level indicators, sounding tubes, filling pipes, vent pipes, manholes, cleanout holes, and all necessary connections and fittings. The storage tank(s) shall have a lockable drain valve(s) and suitable save-all(s).

7.4.5 At the lube oil filling station(s) on the main deck there shall be sufficient deck area to store a standard forty-five (45) gallon drum or metric equivalent. The filling line(s) to the storage tank(s) shall be fitted with a fine mesh strainer with removable element and drain.

7.4.6 The lubricating oil storage tank(s) shall have a rundown valve and distribution line terminating at a stop valve convenient to each main propulsion engine, generator engine and each gearbox. A length of quick connecting flexible hose terminating in a spring-loaded cock or nozzle shall be used to introduce oil into the engine sump. An electric pump, with a hand pump in parallel, shall be supplied and installed for supplying oil(s) to diesel sumps and gearboxes.

7.4.7 The transfer system for diesel engine and gearbox clean lubricating oil(s) shall be segregated from the dirty oil system.

7.5 DIESEL ENGINE COMBUSTION AIR INTAKES AND EXHAUSTS

7.5.1 Combustion air shall be conditioned to supply air in accordance with the OEM's recommendations in all environmental conditions noted in Table 1 of the TSOR.

7.5.2 The installation of the diesel exhaust system(s) shall comply with both the OEM's recommendations and the Class acoustic requirements for maximum noise reduction. Each engine outlet shall be supplied and installed with a stainless steel expansion bellows which shall be installed as recommended by the OEM. Piping and silencers shall be secured to accommodate thermal expansion and motion of the engines. The exhaust systems shall be installed with supports to minimize loading of the flexible connections and expansion joints, and be effectively isolated

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from the ship's structure. Flexible sections shall be installed at the engine exhaust outlets to facilitate engine maintenance including engine mounts and vibration isolators.

7.5.3 The exhaust gases from each engine shall exit through a spark-arresting exhaust silencer, complete with clean-out ports, drain pot, drain line and valve.

7.5.4 The exhaust system shall not run through habitable spaces and shall be designed and built such that it does not interfere with the aft working deck area, specifically the boat launching and recovery operations, and be streamlined to reduce air drag. Arrangements shall be supplied and installed to prevent spray and all water ingress into the exhaust system.

7.6 COMPRESSED AIR SYSTEM

7.6.1 A compressed air system shall be used for engine starting. The compressors shall be supplied and installed with provision for making one compressor as lead and another compressor as lag. Drains shall be led to an outlet near deck plate level and piped via a "Pig's Ear" back to the oily bilge water tank, if fitted.

7.6.2 A compressed air system shall be fitted to provide a compressed air supply for power hand tools. The system shall provide a minimum of 140.0 l/m @ 6.2 bar from a self contained compressor and air receiver. Air outlets shall be fitted with shutoff ball valves and spring-loaded quick-connect female couplings. A quick connect air hose of 15 m minimum length complete with one (1) male and one (1) female quick connect coupling shall be supplied and installed at the following locations:

a. MMR; and

b. Main deck at forward and aft ends of main deckhouse; and

c. Deck workshop; and

d. Steering Gear compartment; and

e. If fitted, Auxiliary Machinery Room (AMR).

7.7 FIREMAIN SYSTEM

7.7.1 The firemain system shall be normally dry. The firemain shall be supplied and installed with drains at suitable points to ensure that the system can be completely drained.

7.7.2 An international shore connection shall be supplied and installed.

7.7.3 Cooling of auxiliary systems using firemain water shall not be permitted under any circumstances.

7.7.4 The firemain shall be used to provide a wash-down for the anchor and anchor chain. A means of draining the firemain directly overboard after the wash-down shall be included.

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7.7.5 Fire pumps shall have the capability of being operated both locally and remotely.

7.8 SEA CHESTS AND SEA BAYS

7.8.1 To avoid ice accumulation in sea chests and sea bays Transport Canada Ship Safety Bulletin No.08/1989 shall be adhered to.

7.9 STEERING SYSTEM

7.9.1 The rudder bearings must be of the self-lubricating type.

7.9.2 The rudders shall be capable of being individually locked in the mid-ship position. Each rudder shall be capable of being worked from each of the steering operating stations over the full range of 35.0° port and starboard while the other rudder is locked mid-ships

7.9.3 A hand-operated emergency steering gear pump and associated piping and valves shall be supplied and installed in the Steering Gear compartment. This pump shall be operable by one (1) person and capable of moving both rudders to any desired position within the working range without disconnecting any part of the steering gear.

7.9.4 The MCS in the Bridge shall be fitted with a steering wheel. The other control stations should utilize steering wheels or joysticks. Each control station shall have a take-over switch and rudder angle indicators which shall be back-lit with dimmers.

7.9.5 It shall be possible to steer the MSPV from each control positions using a follow-up and a non-follow-up system.

7.10 REFRIGERATION SYSTEMS

7.10.1 All refrigerants that are currently scheduled to be phased out of use within the design life of the MSPV shall not be used in MSPV refrigeration systems. The refrigeration systems shall utilize an approved refrigerant and shall be fitted with all components necessary for successful and safe operation of the system when utilizing that refrigerant.

7.10.2 Two (2) identical co-located refrigeration units shall be supplied and installed. The units shall be raw water cooled and shall have identical but separate control and auxiliary systems. Each unit and its associated system components shall be sized so that they are individually capable of initially achieving and then maintaining the required temperatures simultaneously in the refrigerated rooms. The temperatures of the refrigerated rooms shall be monitored locally and through the Centralized Control, Alarm and Monitoring System (CCAMS) which shall be set to alarm when the temperature is +/- 2.0° C outside the required range.

7.10.3 The required temperature ranges are:

a. Freezer (cold) Room: -18.0°C to -15.0°C; and

b. Refrigeration (cool) Room: 3.0°C to 5.0°C.

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7.11 HEATING VENTILATION AND AIR CONDITIONING (HVAC)

7.11.1 Accommodation spaces, including the Bridge, Command Centre, MCR, Galley and common areas, shall be supplied and installed with heating, ventilation and air conditioning (HVAC). The HVAC system(s) shall provide the following:

a. Heating (not less than 19.0°C under winter conditions listed in Table 1); and

b. Cooling (not more than 22.0°C under summer conditions listed in Table 1); and

c. humidification; and

d. dehumidification; and

e. required number of air changes.

7.11.2 Air-conditioning fans shall be capable of being used as ventilation fans when spaces are not being heated or cooled.

7.11.3 The HVAC system shall be designed and built with a 20% makeup fresh air supply.

7.11.4 The HVAC system shall meet the following requirements:

a. upper deck louvered openings should be directed aft and protected from the weather; and

b. non-return dampers shall be mounted in the discharge ducting of each exhaust fan; and

c. HVAC intakes shall be located to prevent short-circuiting of all exhaust gases.

7.11.5 Manual dampers shall be supplied and installed in HVAC trunking to isolate ventilation in case of fire and in suitable locations to permit system balancing.

7.11.6 Dampers in the HVAC trunking at watertight boundaries shall be supplied and installed with fusible links to isolate the HVAC system in case of fire.

7.11.7 Primary heating shall be by means of electric heating elements in the HVAC system augmented by local, individual, fixed electric space heaters.

7.11.8 Non air-conditioned spaces, such as workshops and storage spaces, shall be locally heated, cooled and ventilated with local temperature controls. Minimum temperatures shall be 10.0°C in storage spaces and 19.0°C in workshops.

7.11.9 Air vents shall be placed such that they do not blow directly on workstations or berths. Air vent exit air velocity shall as a minimum meet the specified air change rate, Table 3, and shall not exceed 2.5 m/s. The 2.5 m/s air velocity maximum does not apply to unattended machinery spaces. Ventilation trunking shall be accessible and designed and built for efficient cleaning.

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7.11.10 Machinery spaces shall be independently heated, cooled, and ventilated. Local controls for each of the spaces shall be supplied and installed.

7.11.11 All fans and air-conditioning units shall be resiliently mounted.

7.11.12 No part of the ship's structure shall be used as air ducting for the HVAC system.

7.11.13 Intake fans shall be fitted with silencers to minimize noise transmission to the machinery space and to the working deck area.

7.11.14 The required air changes shall be as listed below in Table 3 – Air Changes.

SPACE	# of air changes/hour
MMR	20 (minimum)
Auxiliary Machinery Room(s), if fitted (AMR)	20 (minimum)
Garbage Handling Room	30
Sewage Treatment Room	30
Toilets and Washrooms	30
Wet Gear Locker	20
Paint locker and other storage spaces	10
Accommodation spaces	20
Galley	20

TABLE 3 - AIR CHANGES

7.11.15 The temperature in machinery spaces shall not exceed 50.0°C with all the machinery operated at full power or full load nor fall below 10.0°C in all machinery states.

7.11.16 There shall be a minimum of two (2) air changes per hour when the vessel is in hot lay-up.

7.11.17 Washrooms, including toilets, and the galley shall have separate exhaust systems from those used for accommodation spaces. The galley exhaust system trunking shall be designed, built and installed with access ports to facilitate in-situ internal cleaning.

7.11.18 The following compartments shall have natural supply and mechanical exhaust:

a. central store; and

b. washrooms; and

c. laundry; and

d. workshops; and

e. garbage handling room; and

f. sewage treatment room; and

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g. paint locker; and

h. Wet Gear locker.

7.11.19 Ventilation shall be supplied and installed for the fore peak compartment.

7.11.20 The main and auxiliary machinery spaces shall be served by variable speed supply and exhaust fans.

7.11.21 Insulation and vapour barrier shall be applied to the ducting and equipment to ensure minimum acceptable heat loss or gain and to prevent condensation. Metal sheathing shall be supplied and installed in areas where insulation may be subject to damage.

7.12 POTABLE WATER SYSTEM

7.12.1 The potable water system comprises the equipment used for embarking, producing, testing and treating, heating, cooling, storing and distributing potable water. The potable water system shall be fitted with two (2) reverse-osmosis type potable water makers each capable of producing a no less than 150.0 litres (l)/hour (hr) of potable water, from sea water and fresh water at a minimum temperature of 5.0°C. The system shall be fitted with a minimum of two (2) stainless steel storage tanks capable of storing a no less than the total volume of 6,300.0 l of potable water, based on a consumption rate of 150.0 l/day/person x 3 days x 14 persons.

7.12.2 The potable water system shall be designed and built to comply with:

a. Guidelines for Canadian Drinking Water Quality and the Guideline Technical Documents, as published by Health Canada; and

b. Canadian Coast Guard (CCG) Fleet Safety and Security Manual Section 7 – Potable Water Quality; and

c. Potable Water Regulations for Common Carriers, C.R.C., c. 1105, as published by Health Canada.

7.12.3 The potable water system shall be designed, built and installed to comply with NSF/ANSI Standard 61 Drinking Water System Components – Health Effects.

7.12.4 Each potable water storage tank shall be fitted with: a vent, a drain, a salinity monitor, a connection to each of the reverse-osmosis type potable water makers, a connection to a common upper deck filling station, a connection to the potable water distribution system, a tank inspection access opening and, connections for sampling, and treating tank contents. Each tank shall have tank level sensor alarms integrated into the CCAMS. The alarms shall also be displayed on a local control panel. The potable water makers shall be able to be started and stopped manually from a local control panel and remotely from the MCS. Each water maker shall be fitted with a salinity monitor and an automatic dump valve or shut down control.

7.12.5 The cap on the fill connection shall be padlocked and a bilingual label plate stating "Potable Water Only" shall be installed at the fill valve and connection. Every outlet used for

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drinking and culinary purposes shall be supplied and installed with a filter(s) capable of removing suspended solids down to one (1.0) micron and shall have a bilingual plate affixed stating the water is safe for drinking and culinary purposes.

7.12.6 Potable water shall be distributed to the:

a. cabin sinks; and

b. lavatory sinks; and

c. showers; and

d. galley; and

e. mess; and

f. chilled-water drinking fountains; and

g. laundry; and

h. sanitary flushing system; and

i. MCR; and

j. MMR; and

k. Bridge; and

l. Command Centre; and

m. Bridge window wash-down system; and

n. wet gear locker; and

o. garbage handling room; and

p. deck workshop; and

q. all other systems or locations that require potable water.

7.12.7 Water heaters shall be equipped with temperature regulating devices to maintain the hot water temperature at 60.0°C. Temperature and pressure sensors shall be integrated into the alarm and monitoring system and shall be displayed on a local control panel as well as the CCAMS. Should the internal tank temperature reach 66.0°C or the tank pressure exceed the OEM's recommended pressure setting, power to the water heater shall be cut off and an alarm shall be activated.

7.12.8 All hot water piping and flanges shall be insulated to minimize heat losses and ensure personnel safety. All cold water lines and flanges shall be insulated to minimize heat gain and to

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prevent condensation. Hot and cold water piping in shower enclosures shall be installed behind the paneling to ensure personnel safety. Isolating valves shall be fitted at each hot and cold branch from the main system and at each fixture.

7.13 BLACK, GREY WATER AND SANITARY FLUSHING SYSTEMS

7.13.1 The MSPVs shall be fitted with marine-type sanitary flushing and vacuum collection systems capable of collecting black water in a collection tank(s). Grey water shall be handled and collected separately from the black water system using a gravity-type system capable of collecting grey water in a collection tank(s). The black water tank(s) shall be sized to store a no less than 420 l of black water. The grey water tank(s) shall be sized to store a no less than of 3,780 l of grey water.

7.13.2 The grey water system shall be designed and built to transfer grey water collected in the grey water collection tank(s) either directly overboard or to the black water collection tank(s). The grey water system shall be designed to prevent black water from contaminating the grey water system.

7.13.3 The black water system shall be designed and built to transfer black water collected in the black water collection tank(s) to an IMO MEPC.159(55) certified sewage treatment plant (STP) for discharge of the treated effluent overboard or, additionally, to transfer untreated black water to a standard IMO MARPOL deck shore connection.

7.13.4 The STP shall be capable of treating influent streams containing black water only and black and grey water combined containing fresh water and salt water. The STP shall be capable of providing continuous operation for complement of between eight (8) and fourteen (14) persons while meeting the treated effluent discharge requirements specified in IMO MEPC.159(55). The grey and black water tank level indicators and, high and low sensor alarms shall be integrated into the CCAMS and shall be displayed on a local control panel. The influent piping immediately prior to the STP and the outlet piping immediately prior to the overboard discharge shall each contain a sampling valve to allow for the collection of influent and effluent samples, respectively.

7.13.5 The black water and grey water collection, discharge, and treatment system(s) shall be capable of full automation with the ability to be operated locally and remotely from the MCS.

7.13.6 Hydrogen sulphide (H_2S) sensors shall be supplied and installed in the black and grey water tank spaces as well as the STP space. The sensor shall monitor the level of H_2S in the spaces and provide an audible alarm in the space as well as providing an alarm to the CCAMS when a H_2S level exceeds set limits.

7.14 FIRE DETECTION, EXTINGUISHING AND FIREFIGHTING SYSTEMS

7.14.1 Each MSPV shall be equipped with fire detection system(s), fire-extinguishing systems, and a fire plan.

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7.14.2 The MMR and, if fitted, the AMR fixed fire-extinguishing systems' extinguishing agent shall be located outside of the protected space with direct access to an open deck and shall be capable of local actuation.

7.14.3 The galley exhaust hood, trunking, and cooking appliances requiring automatic protection shall be fitted with approved fire-extinguishing systems which shall also be capable of manual activation from outside the galley. The system shall meet the requirements of the Underwriters Lab ULC / ORD-1254.6-1995 Fire Testing of Restaurant Cooking Area Fire Extinguishing System Units.

7.15 PORTABLE FIREFIGHTING EQUIPMENT

7.15.1 Portable fire fighting equipment shall be supplied and installed.

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8 ELECTRICAL

8.1 POWER SUPPLIES

8.1.1 The MSPV shall be supplied and installed with the following:

a. Primary power shall be 600 volts AC, 3-phase, 3-wire insulated, 60 Hz, ungrounded delta connected; (this does not exclude the option of a high resistance ground to limit available fault current if required); and

b. All Alternating Current (AC) voltages for power distribution shall be 60 Hz frequency; and

c. The emergency source of electrical power shall be a diesel driven generator. It shall be capable of automatically assuming the emergency switchboard load within 45 seconds after failure of the normal electrical power source; and

d. Backup power shall be supplied and installed to power computer systems and peripherals, machinery control, alarm and monitoring and other vital systems as required. There shall be an automatic, no-break battery back up. Where an Uninterruptible Power Supply (UPS) is selected, refer to paragraph 8.8.3 below.

8.1.2 Apparatus containing transistors, diodes and other solid-state devices shall be internally or externally supplied with protection against voltage transients or surges caused by load switching, fault or failures of the MSPV power systems.

8.2 GENERATORS

8.2.1 The MSPV shall have normal electrical power supplied by at least two identical, independent, diesel engine driven ship service generating sets, rated 600 volts AC, 3-phase, 3-wire insulated, 60 Hz at 0.8 PF at a 50.0°C ambient temperature, and arranged for continuous parallel operation of the units when required.

8.2.2 The generators shall be rated such that either one can continuously supply the peak cruising load at sea plus transient loads, with an allowance for 20% future growth. The ship's service standby generator set shall be capable of automatically assuming the ship's service electrical load within thirty (30) seconds after the failure of the on-line generator.

8.2.3 Each engine shall be a non-reversible, self contained, turbo-charged, after-cooled, four cycle marine diesel engine and shall have a normal continuous capacity at its marine rating and shall be capable of meeting the rating of its generator.

8.2.4 All fuel discharge lines shall be double-walled.

8.2.5 Diesel engines shall be capable of operation on a high output diesel single or multi-grade commercially available (API/SAE graded) lubricating oil. Each diesel engine shall have its own OEM supplied pre-heater and pre-lube pump and its own lube oil, fresh water-cooling and raw

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water system. There shall be no interconnection between the engines' lube oil, fresh water and raw water systems although the raw water systems may be connected to a common sea chest.

8.2.6 Each generator-engine set shall be supplied and installed with all accessories recommended by the OEM for service at sea in all conditions specified in Table 1 and shall be installed complete with all attached and unattached auxiliaries.

8.2.7 Each generator and its engine shall be installed on a common rigid frame that is suitable for resilient mounting.

8.2.8 Each ship service generator and the emergency generator shall be supplied and installed with a minimum of one imbedded temperature detector per phase to allow the monitoring of the winding temperatures at the appropriate switchboard section and also by the CCAMS. In addition, an automatic insulation resistance monitor shall continuously monitor each ship service generator's and the emergency generator's stator insulation leakage to ground and shall initiate an alarm at the CCAMS at values of one (1) megohm or less.

8.3 SHORE CONNECTIONS

8.3.1 The shore power isolation transformer shall be one (1) – 3 phase, 600 V: 600 V, dry type transformer. The transformer shall incorporate an electrostatic shield. Taps shall be supplied and installed on the primary side of the transformer as follows:

a. Two (2) capable of increasing voltage 2.5% above normal full capacity; and

b. Two (2) taps capable of decreasing voltage 2.5% below normal full capacity.

8.3.2 A 30 m interconnecting 3 phase 4 wire cable suitable for 600 V 200 amp service fitted with two male plugs at each end of the cable with either CROUSE-HINDS AR2042 or APPLETON ADR20034 plugs for the shore-to-ship connection, shall be supplied and installed. A stowage reel, weatherproof caps for the plugs and weatherproof covering for the cable and reel shall be supplied and installed for onboard storage.

8.3.3 Watertight shore connection capability, located on the weather deck and readily accessible to shore power from both sides, shall be supplied and installed. The shore connection box(es) shall be at least 0.5 m above the deck and shall be located in weather protected area(s) to ensure the portable supply cable does not impede weather deck walkways or interfere with deck activities on both the port and starboard sides. Nameplate(s) shall be supplied and installed to clearly identify the connection box(es). A warning plate instructing personnel to isolate all supplies prior to working within the enclosure shall also be supplied and installed on every connection box.

8.4 SWITCHBOARDS

8.4.1 The generator and distribution switchboards shall be arranged for operation of generator circuit breakers and for distribution of power throughout the MSPV.

8.4.2 Bus bars shall be marked A, B, C to identify each of the three phases.

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8.4.3 All switchboards shall be supplied and installed with fluorescent canopy lighting under the front, and back if access is required, drip-shields. Front and rear lighting shall be individually switched.

8.4.4 Two (2) of each distribution breaker frame size shall be supplied and installed within each switchboard and shall act as spares.

8.4.5 Each switchboard circuit breaker shall be of the draw-out type. Lifting and handling equipment shall be supplied for the removal of the circuit breakers from the switchboards.

8.4.6 In addition to manual paralleling capability, all generator combinations shall be supplied and installed with automatic paralleling capabilities.

8.5 DISTRIBUTION PANELS

8.5.1 All distribution panel bus-bars and connectors shall be made of copper. Distribution panels shall be from the same manufacturer and shall be supplied and installed with lockable doors. All locks shall be keyed alike and the quantity of keys to be supplied shall be equal to the number of locks supplied and installed.

8.5.2 Each distribution panel shall also be supplied and installed with four (4) blanked, double-pole circuit breaker spaces, to allow for future growth as well as four (4) spare circuit breakers that are representative in amperage of what is installed in the panel.

8.6 ELECTRICAL CABLES

8.6.1 All cable shall be low smoke, zero halogen and, unless otherwise required, unarmoured. All cables shall have an insulation rating of at least 85.0°C.

8.6.2 All cables shall be designated by an identification number that shall be permanently marked on non-ferrous metal tags, securely affixed to each end of the cable run in each main compartment and subdivision and, on both sides where passing through decks and watertight bulkheads.

8.6.3 Cableways and cables shall be installed clear of machinery access routes and maintenance envelopes. The strength and watertight integrity of the decks and bulkheads shall not be affected by the installation of the cable penetrations. Upon MSPV delivery, a minimum of 10% spare space shall be available in all cableways and deck and bulkhead multi-cable penetrations.

8.6.4 All cables supplying power to equipment, fixtures and electrical apparatus exposed to the weather shall be run internal to the ship's hull and superstructure as much as practicable. Where unavoidable, or where the length of the cables exposed to the weather exceeds one (1) metre, the cable selected shall be of a type that includes basket weave bronze braid armour covered with an external impervious non-metallic jacket.

8.6.5 To minimize EMI, spacing between cables shall conform to CCG Standard 70-000-000-EU-JA-001, or where this is not practical, additional approved shielding shall be supplied and installed, except where entering associated equipment, or where cables cross at a 90° angle.

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8.7 MOTORS AND CONTROLLERS

8.7.1 All motors shall be totally enclosed fan cooled while those installed on deck exposed to weather shall be watertight to NEMA 4X.

8.7.2 All motors greater than one (1) HP shall be suitable for 575 volt, 3-phase, 60 Hz operation, and rated for continuous duty, with Class F insulation, and equipped with anti-friction, factory sealed pre-lubricated ball bearings.

8.7.3 Grouping of motor controls in Motor Control Centres (MCC) centralized in proximity to the source of supply, the main or emergency switchboards, is a requirement and shall be maximized. MCC bus bars and connectors shall be made of copper. Starter units shall be draw-out type, and shall include an incoming circuit breaker. Reduced voltage starters, where required, shall be solid state type. Starter front covers shall include shrouded start and stop pushbuttons and run and stop indicating lights.

8.7.4 Individual motor starters and controllers shall be mounted within line of sight of the auxiliary they serve. They shall be supplied and installed with local control and indicating lights. Local control shall be mounted in drip proof enclosures. An overload/reset button shall be supplied and installed on the enclosure door of each motor controller unless the operation of the auxiliary necessitates remote reset. Indicating lights mounted in the enclosure door shall notify the operator of equipment status. A complete wiring diagram of each controller shall be permanently attached, with a transparent, oil resistant protective covering, to the inside surface of the control cabinet door.

8.7.5 Auxiliaries with remote control positions shall be supplied and installed with a "Remote/Local" control switch in its motor starter/controller enclosure. In addition to the remote push button start and stop controls, remote motor running status indicators shall be supplied and installed. When the "Remote/Local" switch is in the "Local" position, it shall not inhibit the remote "Stop" function.

8.7.6 All motors connected to power feeds from static power converters shall be rated for inverter use.

8.8 POWER CONVERSION EQUIPMENT

8.8.1 All transformers shall be dry type, single phase and, with the exception of the shore power isolation transformer, rated at least Class F. Transformer ratings shall be standardized wherever possible.

8.8.2 Where an UPS is required by an individual system it shall be approved for marine use, shall have input and output isolation transformers, and, if hard-wired, an external manual bypass capability.

8.8.3 UPSs shall have an input voltage of 115 volts, 60 Hz. Batteries shall be sealed, suitable for deep discharge cycling and shall have as a minimum the capacity to provide the rated output for no less than 15 minutes.

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8.9 115 V AND 230 V RECEPTACLES

8.9.1 All receptacles shall be "Specification Grade" duplex U-ground and, where used for general-purpose, rated for 15 amp, 115 volt, single phase, 60 Hz. Receptacles shall be installed in each compartment, except hazardous areas in which outlets are prohibited, and there shall be at least one receptacle installed for every eight (8) m^2 of deck area, defined by the compartment boundaries.

8.9.2 Passageways, washrooms, laundry area and other spaces not specifically listed shall have at least one (1) receptacle installed. For every three (3) metres of passageway, or fraction thereof, regardless of the presence of equipment, there shall be at least one (1) receptacle installed.

8.9.3 Cabins shall be supplied and installed with a minimum of three (3) receptacles regardless of the presence of furniture. In addition, the mirror/medicine cabinet in each cabin shall be supplied and installed with a shaver outlet, separate from the cabinet's fluorescent lighting and integral switch.

8.9.4 Sufficient receptacles shall be installed to provide power for all specified equipment in the Command Centre plus an equal number of spare receptacles.

8.9.5 Additional, non-duplex receptacles on dedicated circuits shall be installed in the galley and mess for all countertop equipment and audio visual equipment.

8.9.6 Additional, non-duplex receptacles shall be installed elsewhere for all test equipment, portable tools, communication equipment, computers and other electrical equipment and appliances not specifically listed herein.

8.9.7 Internal work stations shall have at least one (1) non-duplex receptacle installed.

8.9.8 There shall not be more than eight (8) outlets per circuit for general purpose branch circuits.

8.9.9 Single (non-duplex) watertight 115V receptacles shall be installed for each radar antenna, in the steering gear compartment, in the MMR, in the fore peak, in all machinery spaces and other areas and compartments exposed to raw water. Six (6) exterior receptacles, three (3) each side port and starboard located at the forward, the middle and the aft end of the superstructure on the main deck, shall be installed for general utilities purposes. Each exterior receptacle shall be on a separate branch circuit.

8.9.10 As a minimum, four (4) exterior single watertight receptacles shall be installed on the Bridge top, each supplied from a separate branch circuit.

8.9.11 230V / 20 amp receptacles shall be installed to supply portable galley equipment requiring that service.

8.9.12 230 V / 30 amp receptacles shall be installed to supply laundry equipment requiring that service.

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8.9.13 One (1) 230 V / 20 amp and one (1) 230 V / 30 amp three phase watertight receptacles shall be installed on each side of the external working decks for auxiliary machinery and equipment, such as winches, portable pumps or other specialized equipments. At each end of the MMR, there shall be one (1) water tight receptacle of 230 V / 30 amp single phase.

8.10 LIGHTING

8.10.1 Interior lighting fixtures shall be installed and shall be of the fluorescent or compact fluorescent type wherever possible. The number of different fixture types shall be minimized in order to reduce the quantity and type of spare parts and lamps to be carried on board. Fixtures shall be constructed of corrosion resistant materials. Fixtures shall be suitable for direct mounting to bulkheads or decks, without the need for vibration isolation mounts. Fixtures shall use 115 volts, single phase, 60 hertz, and shall have solid state high efficiency ballasts.

8.10.2 Lamps shall be standard North American types, to fit common, commercially available sockets.

8.10.3 Lighting shall be controlled locally by specification grade switches installed at the entrance to each space. Where spaces have two (2) or more entrances, switches shall be located at each entrance. Passageway lighting shall be switched from the distribution panel. Specific task lights shall have integral switches. All lighting switches shall be double-pole to ensure complete isolation of the lamps when switched off.

8.10.4 Where emergency lighting cannot be supplied and installed integral with the normal lighting, separate non-rechargeable, battery-powered fixtures providing a minimum of two (2) hours of lighting shall be installed. These fixtures shall be automatically energized upon power interruption.

8.10.5 Switches to control lighting at hatches and doors shall not restrict neither the size of the hatchway and door opening nor the clear operation of the hatchway and door.

8.10.6 Watertight fixtures installed in outside spaces shall be constructed of corrosion-resistant material and have a corrosion resistant finish. Lamps shall be capable of being replaced without the use of special tools.

8.10.7 Levels of illumination in specific compartments and areas shall be as follows:

a. 55.0 lux for storerooms, fan compartments and Bridge; and

b. 110.0 lux for machinery space(s), emergency switchboard compartment, passageways, and steering gear compartment; and

c. 220.0 lux for toilets, washrooms and showers, cabins, Mess and wet gear locker; and

d. 300.0 lux for galley.

8.10.8 The levels of illumination shall vary within the Command Centre: 110.0 lux for the area in general, 500.0 lux at the program staff's work surface, and 220.0 lux at the Program/Incident

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Commander's workstation. The Command Centre shall have a variable light control for the room and at specific zones so that illumination within the room is capable of being dimmed individually or globally. Primary light controls shall be labelled and located at the Program/Incident Commander's station. A light control at the door is required to facilitate a safe passage to the Program/Incident Commander's station.

8.10.9 Illumination levels in other areas of the MSPV shall meet the Marine Occupational Safety and Health Regulations for vessels that are five hundred (500) tons or greater registered tonnage.

8.10.10 Illumination for the Bridge Control Station (BCS) shall be the minimum level necessary to maintain a visual gradient with the alarm, signal and indicating lights, and to readily recognize all information cues from the BCS. Glare reducing features such as anti-glare coatings and individual dimmable light switches shall be installed on all displays.

8.10.11 All space illumination in the Bridge shall be capable of being dimmed as a group in addition to the standard fluorescent fixtures. The Bridge shall be equipped with red illumination for use at night.

8.10.12 The chart table shall be supplied and installed with supplementary dimmable red and white lighting to produce from zero up to 220.0 lux at the chart table.

8.10.13 Dimming capability for indicator lights in the Bridge shall be supplied and installed, except that no dimming is permissible for warning and alarm indicating lights.

8.10.14 All principal illumination fixtures shall be flush mounted with the deckhead, false deckhead and bulkhead, unless otherwise specified.

8.10.15 Each cabin shall be supplied and installed with a minimum of one fluorescent type overhead fixture for general illumination, controlled by a switch at the entrance. A desk light in way of each desk with an integral switch, a mirror light over each mirror and a berth light at the head of each bunk, each with an integral switch, shall also be supplied and installed.

8.10.16 All passageways shall be equipped with red illumination for use at night in addition to the standard fluorescent fixtures.

8.10.17 Drip proof fluorescent light fixtures shall be installed in all machinery spaces. Machinery space lighting shall not be switched.

8.10.18 Lights illuminating store and locker spaces shall be housed in drip proof guarded fixtures. Switches adjacent to access entry shall control the lighting.

8.10.19 Workbench general lighting shall be fluorescent.

8.10.20 Fixtures shall be placed to illuminate ladders, walkways, obstructions, abrupt changes in deck level and other hazards to personnel safety.

8.10.21 Exterior lighting shall be switch controlled from the Bridge.

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8.10.22 Deck lighting and exterior lights shall be watertight types with guards. Fixtures shall be connected to the ship's service power via through-bulkhead fittings, so that the cabling runs internal to the hull.

8.10.23 Portable fixtures shall be supplied and installed to illuminate the gangway areas, along with dedicated switched receptacles.

8.10.24 Four (4) portable floodlights, watertight, corrosion resistant, and at least 200 Watts (quartz halogen) types shall be supplied and installed for the rescue boat and life raft areas, shore transfer and connection station(s), embarkation and disembarkation station(s), and mooring areas.

8.10.25 Two (2) floodlights of at least 1000 Watts each shall be permanently mounted on brackets facing aft on port and starboard sides to illuminate the aft working deck.

8.10.26 One (1) additional floodlight of at least 500 Watts shall be mounted on a portable arm, with fittings located at various locations around the working deck. The locations of these fittings will enable the floodlight to illuminate the port and starboard sides and the stern. The floodlight on the portable arm shall be supplied by a three (3) m power cord and watertight plug, and shall not interfere with deck equipment operation.

8.10.27 One (1) floodlight of at least 500 Watts shall be supplied and positioned to illuminate the forecastle. The fixture shall be hooded to help prevent light spill over into the Bridge.

8.10.28 Stowage for the portable floodlights and portable arm shall be supplied and installed onboard. Protective covers shall be supplied and installed as per paragraph 5.17.1 above. Watertight receptacles shall be arranged for the floodlight supplies and control shall be from the Bridge.

8.10.29 Two (2) searchlights shall be fitted on the Bridge top, forward near each side. The searchlights shall have a minimum output of ten (10) million candelas each, and shall be complete with anti-icing heaters and remote control of slew, tilt and focus. All searchlight functions shall be controlled electrically from a remote panel mounted on the BCS. The searchlights shall be capable of moving through a minimum of 360.0° horizontal sweep and a minimum of 35.0° vertical sweep both above and below the horizontal plane of the light. The searchlights shall be mounted as high as practical. Search beam blockage from other mounted equipment or superstructure shall be minimized as much as practical. The searchlights shall not weigh more than 30 kg each. At least one (1) searchlight shall be supplied from the emergency bus. Each searchlight shall be installed with vibration isolation mountings.

8.10.30 A central navigation light control panel for all navigation lights shall be fitted at the BCS. The vessel's blue flashing warning light shall also be controlled from the central navigation light control panel.

8.11 24 V DC DISTRIBUTION AND 12 V DC DISTRIBUTION

8.11.1 24V and 12V Direct Current (DC) systems, where required for engine starting, or other systems not listed in this Section, shall be supplied and installed.

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8.11.2 Batteries and charging systems shall be designed and installed for the following purposes:

a. Group 1 Generator set engine starting (if electric start selected); and

b. Group 2 Emergency generator set engine starting (if electric start selected); and

c. Group 3 Battery backup systems, including UPS.

8.11.3 Group 1 and 2 batteries shall be located as close as practicable to the engines concerned. Each set of Group 1 and Group 2 batteries shall be sized to have as a minimum the capacity to meet IEEE Std. 45 requirements for engine starting.

8.11.4 Battery chargers, certified for marine application, shall be of constant voltage type, fully automatic, featuring float or boost charge arrangements and be selected and sized to suit the application. The battery chargers shall be equipped with, as a minimum, "on/off" switch, power "on" indicating light, voltmeter, ammeter, boost operation indicator, manual boost override, protection against overload and overcharging. Printed circuit boards in chargers shall have conformal coating.

8.11.5 Each set of Group 1 and 2 batteries shall have no other connected loads and shall be supplied and installed with a dedicated battery charger.

8.11.6 One (1) portable battery charger shall be supplied for charging spare batteries of all sizes fitted in the MSPV.

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9 NAVIGATIONAL, COMMUNICATION & MACHINERY CONTROL SYSTEMS

9.1 GENERAL

9.1.1 The MSPVs shall be supplied and installed with navigation equipment, communication equipment, collision avoidance signals, and all miscellaneous equipment needed for the safe handling of the MSPVs. Additionally, the MSPVs are to be in compliance with the Navigation Safety Regulations under Arctic Waters Pollution Prevention Act and the Standards for Navigating Appliances and Equipment (1983) – TP 3668.

9.1.2 All equipment shall be capable of withstanding momentary loss of power as described by the OEM for that particular piece of equipment without damage.

9.2 BRIDGE LAYOUT

9.2.1 The Bridge shall incorporate the radar, electronic chart system (ECS), and all other navigation aids necessary to:

a. determine and plot the ship's position, course, track and speed; and

b. analyze the traffic situation; and

c. decide on collision avoidance manoeuvres; and

d. effect internal and external communications related to navigation and manoeuvring, radio communication on the Very High Frequency (VHF); and

e. give sound signals and hear sound signals; and

f. monitor course, speed, track, and depth of water; and

g. record navigational data.

9.2.2 It shall incorporate all gauges, instrumentation, and alarms required to fully monitor the ship's propulsion system and auxiliaries as well as permit the helmsman to control rudder, MSPV speed and propulsion both ahead and astern.

9.2.3 A chart table shall be supplied and installed on the Bridge and should face forward. The chart table shall not face aft.

9.3 SHIP'S INFORMATION SYSTEMS

9.3.1 All internal communications, external communications, navigation equipment and materials shall be supplied and installed.

9.3.2 All cables shall be protected against mechanical damage, water ingress and EMI.

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9.3.3 All coaxial cables for radio transceivers shall be RG-214, unless otherwise specified herein.

9.3.4 Cable runs shall be segregated and grouped in accordance with CCGS 70-000-000-EU-JA-001.

9.4 RADIO FREQUENCY (RF) EXPOSURE SURVEY

9.4.1 A survey to determine radio frequency radiation shall be conducted on all parts of all upper decks.

9.4.2 To ensure that personnel shall not be exposed to harmful radio frequency radiation while conducting training and working on deck, each radar shall be fitted with RF emission keys or fuses that shall be capable of ceasing RF transmission and antenna rotation.

9.5 INTERFACING REQUIREMENTS

9.5.1 All navigational equipment and applicable communication equipment shall be interfaced utilizing the National Marine Electronics Association (NMEA) 0183 Industrial Standard for Communication between Marine Electronics Devices.

9.6 HARDWARE STANDARDS

9.6.1 All radio transmitting equipment installed on the MSPVs shall be type approved by Industry Canada.

9.6.2 All navigating appliances and equipment shall be supplied and installed. They shall comply with the International Electrotechnical Commission (IEC) and International Organization for Standardization (ISO) technical standards, where applicable.

9.6.3 An Administrative Local Area Network (LAN) shall be supplied and installed and shall comply with the Standard Technical Architecture (STA) for Shipboard Computer Systems 46-000-000-ES-TE-001.

9.7 SOFTWARE STANDARDS

9.7.1 All software for the Administrative LAN shall be supplied and installed and shall comply with the STA for Shipboard Computer Systems 46-000-000-ES-TE-001.

9.8 NAVIGATING APPLIANCES AND EQUIPMENT

9.8.1 All the equipment specified and the associated hardware, such as antennae, shall be supplied, installed, integrated and commissioned in accordance with the recommendation and guidance of the respective OEMs. Electrical and electronic equipment shall be arranged and installed so that EMI does not affect the proper function of navigational or other systems and equipment.

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9.9 GYRO COMPASS

9.9.1 One (1) C Plath 2100 fibre optic gyro compass shall be supplied and installed in the EER. Bearing repeaters with pelorus capability shall be supplied and installed on each of Bridge Wings. Bearing repeaters are to be mounted on longitudinal slide rails to enable the user to relocate the repeater fore and aft.

9.9.2 A steering repeater shall also be supplied and installed at the BCS and at the emergency steering location. A numeric repeater shall be installed on the forward Bridge bulkhead at deckhead level. The fibre optic gyro system shall be supplied and installed to provide a digital heading data in NMEA 0183 format (HDT) to the radars, ECS, Autopilot, Automatic Identification System (AIS) and the E-mail-at-sea system.

9.10 NAVIGATIONAL RADARS

9.10.1 Two (2) navigation radar systems shall be supplied and installed complete with collision avoidance display, Automatic Radar Plotting Aid (ARPA) and alarm system. The radar system shall provide ARPA information to the ship's ECS and the Trackplot computer in the Command Centre.

9.10.2 The radars shall be Sperry Marine VisionMaster FT X-Band and S-Band inter-switched radars (bulkhead transceiver). The system shall consist of the following units:

a. VisionMaster FT Radar CAT2 252/6/BT/VM2 complete with buffered video output, Interface unit required for AIS input, Keyboard and Joystick Human Machine Interfaces and performance monitor; and

b. VisionMaster FT Radar CAT2 253/12/BT/VM2 complete with buffered video input, Interface unit required for AIS input, Keyboard and Joystick Human Machine Interfaces; and

c. Interswitch unit.

9.10.3 In addition, both radars shall be supplied and installed complete with bi-directional couplers having a 20dB forward and reverse coupling and a directivity of 40dB. The X-Band radar shall be supplied and installed with a rigid waveguide (RG51). Along with the bi-directional coupler, the waveguide shall be supplied and installed complete with a pressure gauge and pressure windows. The S-Band waveguide shall be LDF5-50A.

9.10.4 A remote radar display shall be supplied and installed in the Command Centre. This remote display shall be capable of being switched to either radar.

9.10.5 The radar antennas shall have a minimum vertical separation of one (1) m. The antennae shall be located so that any radar blind arcs which may occur as a result of masts or funnel casings are not dead ahead or dead astern. All attempts shall be made to minimise blind arcs by rounding the mast surfaces and by not fitting items such as lights, and ladders at the antenna radiation level on the mast. A bilingual cautionary notice shall be placed at each entrance to the radar platforms warning of dangers associated with rotating and radiating antennae.

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9.10.6 Each antenna shall be supplied with a safety switch, located at the entry point or at the base of the respective mast to stop the antenna rotation.

9.10.7 Each radar shall be connected to the differential global positioning system (DGPS) receiver, the (AIS), the ECS Trackplot computer, fibre optic gyro and speed log.

9.11 DIFFERENTIAL GLOBAL POSITIONING SYSTEM

9.11.1 The MSPV shall be fitted with a Saab R4 Differential Global Positioning System (DGPS) Nav Sensor, Saab R4 Control and Display unit and associated J4N junction box. The DGPS system output shall be connected via a two position data selection switch to a data buffer unit. A second input to the two position data selection switch will be from the DGPS to the AIS. The Data Buffer unit will provide NMEA 0183 connectivity to the radars, AIS, Autopilot, echo sounder, ECS, and the Trackplot computer in the Command Centre

9.11.2 A combined Global Positioning System (GPS) beacon and antenna shall be supplied and installed on the mast.

9.12 AUTOMATIC IDENTIFICATION SYSTEM (AIS)

9.12.1 An automatic identification system (AIS) shall be supplied and installed to automatically provide MSPV position and vessel information to systems ashore and to other vessels.

9.12.2 The AIS shall provide AIS information to the ship's ECS and radars.

9.12.3 The AIS system is to include the Saab R4 transponder, Saab R4 DGPS Nav Sensor, Saab R4 Control and Display unit and associated J4 and J4N junction boxes. DGPS output shall be connected to the two position data collection switch noted in the DGPS paragraph 9.11.1.

9.12.4 The AIS Nav Sensor shall connect to both ECSs, Trackplot computer and DGPS for bi-directional waypoint transfer.

9.12.5 The antenna for the AIS transceiver shall be supplied and installed in accordance with the accepted antenna arrangement.

9.13 ELECTRONIC CHART SYSTEM (ECS)

9.13.1 Two (2) computers capable of running GFE software, ICAN ALDEBARAN CCG Version application shall be supplied and installed on the MSPV.

9.13.2 The first system shall be supplied and installed in the Bridge. A 19" viewing area flat panel design chart display shall be located at the BCS with a 19" viewing area flat panel design remote display at the chart table in the Bridge. Each Bridge Wing shall have a remote display that shall be at least a 14" viewing area flat panel design. All monitors shall be complete with dimming capability to one candela per square metre for night operation.

9.13.3 A separate 19" viewing area flat panel display area ECS shall be supplied and installed in the Command Centre.

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9.13.4 Inputs from the speed log, navigational radars, fibre optic gyro, DGPS, echo sounder, AIS and anemometer shall be supplied to the ECS.

9.13.5 The ECSs shall be capable of displaying ARPA targets, AIS targets, depth soundings, wind speed and direction information, and electronic chart data in the selected area.

9.14 AUTOPILOT

9.14.1 An autopilot system shall be provided and installed.

9.14.2 The autopilot shall be interconnected to the fibre optic gyro and DGPS.

9.14.3 The autopilot shall employ adaptive steering technology.

9.15 ECHO SOUNDER AND SONAR

9.15.1 One (1) dual frequency recording type echo sounder with display shall be supplied and installed in the Bridge at the chart table with a remote display at the BCS. The echo sounder shall be capable of providing accurate depth indication in feet, fathoms and metres from zero (0) to a maximum depth of at least 200 m with a high contrast Liquid Crystal Display (LCD) display. The echo sounder system shall have an adjustable shallow depth alert and shall be capable of paper recording, electronic recording and storage of data for the depth(s) and the associated time for 12 hours. In addition, the system supplied by the Contractor shall provide a means to retrieve the recorded information. The echo sounder shall be a Simrad ES60 38/200 KHz.

9.15.2 The recorder shall be console supplied and installed at the chart table with digital indicators supplied and installed at the Bridge Wings.

9.15.3 The Simard ES60 illuminated display shall be supplied and installed in the vicinity of the chart table and shall have the capability of being dimmed. The echo sounder shall interface to the DGPS Receiver and ECS.

9.15.4 The transducer shall be supplied and installed in the hull in a location recommended by the OEM. Upon completion of installation, the hull surface in the vicinity of the transducer shall be smoothed and all holes or gaps filled with a suitable marine compound and smoothed.

9.15.5 Space shall be supplied to install an optional sonar with display in the Bridge. The footprint shall be based on a Wesmar HD800. Space shall also be supplied to install its associated transducer and electrical connections. Its location shall be in accordance with the OEM's installation instructions.

9.16 SPEED AND DISTANCE LOG

9.16.1 A speed and distance log shall be supplied and installed to conform to HSC Code rules. It shall supply the ship's velocities in digital format and direction (fore and aft), with respect to the water, at low ship's speed in relatively shallow water and with high resolution. The speed and distance log shall provide the MSPV speed information to the ship's radars and ECSs.

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9.17 VHF DIRECTION FINDER

9.17.1 One (1) automatic VHF direction finder shall be supplied and installed.

9.17.2 The receiver indicator shall be supplied and installed in the Bridge and the antenna shall be supplied and installed at the top of the main mast.

9.17.3 The VHF direction finder shall be a Cubic OAR4400.

9.18 NAVIGATIONAL AND SIGNALLING EQUIPMENT, NON-ELECTRICAL NAVIGATION AIDS

9.18.1 The Bridge shall be supplied and installed with lockers for miscellaneous navigational aids such as chart folios, publications, documents, signalling lamps, three (3) binoculars, two (2) night vision goggles, and other required items.

9.18.2 A control panel integrated with only the ship's whistle system shall be supplied and installed to automatically sound the ship's whistle in fog conditions.

9.18.3 The ship's fitted loudhailer system shall be interfaced to the CCAMS and shall provide an audible indication for set abnormal conditions onboard when the MSPV is unoccupied. An external yellow flashing 200 Watt light interfaced to the CCAMS shall also be supplied and installed to similarly indicate abnormal conditions.

9.18.4 One (1) 300 mm high by 320 mm diameter brass ship's bell complete with mounting brackets, clapper, striking lanyard shall be supplied and installed at a location to be designated by the TA. The MSPV's name shall be engraved on the bell. The bell engraving shall be as follows:

a. Canadian Coast Guard – 29 mm;

b. Ship name – 38 mm; and

c. Date of completion in full (day/month/year) – 12 mm.

9.18.5 The proposed font shall be approved by the TA prior to engraving the bell.

9.18.6 Hoisting arrangements shall be supplied and installed for displaying the day shapes and international code flags.

9.19 METEOROLOGICAL SYSTEM

9.19.1 The MSPV shall be supplied and installed with a meteorological system as follows:

a. A wind speed and direction indicator with an indicating instrumentation system, installed in the Bridge; and

b. Exterior air temperature unit capable of displaying in the range of –50.0°C to 50.0°C with an accuracy of +/-1.0 °C, installed in the Bridge; and

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c. A recording barometer, installed in the Bridge; and

d. A non-recording barometer, installed in the Captain's Cabin; and

e. An atmospheric Environmental Services of Canada compliant automatic voluntary observation ship's (AVOS) system, supplied as government furnished equipment (GFE) shall be installed. Location to be designated by the TA.

9.19.2 The ship's anemometer shall provide the wind speed and direction data to the ship's ECSs.

9.20 EXTERNAL DATA TRANSMISSION

9.20.1 All components installed in areas exposed to the weather shall be fully protected by waterproof enclosures or shall be watertight to NEMA 4X.

9.21 SATELLITE TERMINAL

9.21.1 An INMARSAT FleetBroadband 250 terminal shall be supplied and installed in the vicinity of the chart table.

9.21.2 Connection shall be made to the Telephone System to allow for voice communications.

9.21.3 Connection shall be made to the Telephone System to allow for facsimile communications.

9.22 SECURE COMMUNICATIONS SATELLITE TERMINAL

9.22.1 The Secure Communications Satellite Terminal (SCST) system shall consist of a Sailor SC4000 Iridium satellite phone with encryption devices. One (1) Iridium Satellite phone shall be supplied and installed in the Command Centre. The SCST shall be compatible with the Secure Communications Interoperability Protocol (SCIP). Space for one (1) SCIP unit, a General Dynamics BDI Sectera encryption device, shall be allocated in the Command Centre. The SCIP unit will be supplied by the Canadian Security Establishment after delivery of each MSPV.

9.22.2 One (1) remote handset for the Iridium satellite phone shall be supplied and installed in the Bridge at the BCS. The unit shall be interfaced to the telephone system to allow authorized telephones access to this system. One (1) antenna shall be supplied and installed in accordance with the accepted antenna arrangement.

9.22.3 For clarity and to summarize, the SCST system shall include one of each of the following specific components:

a. transceiver; and

b. multifunctional handset; and

c. hands free microphone; and

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d. antenna electronics unit; and

e. security device (GFE); and

f. remote handset.

9.23 EMAIL-AT-SEA

9.23.1 A Vessel Satellite Communication System (VSCS) for E-mail-at-sea system, supplied as GFE, shall be installed as follows:

a. One (1) SeaTel antenna model 4006 for the VSCS system shall be mounted in accordance with the accepted antenna arrangement; and

b. Equipment rack with shelve(s) shall be installed in the Electronic Equipment Room (EER) to house the VSCS equipment. The equipment shall be installed in a standard 19" 40 RU rack which provides a minimum of 77.5 cm useable depth. The rack shall be of welded steel construction as per "Specification for the Installation of Shipboard Electronic Equipment (70-000-000-EU-JA-001 July 2003; and

c. All power, interconnect and antenna cables are not GFE and shall be supplied, installed, terminated and set-to-work.

9.24 HF COMMUNICATIONS

9.24.1 One (1) Medium Frequency/High Frequency (MF/HF) radio telephone shall be supplied and installed in the Bridge. The antenna shall be installed in accordance with the accepted antenna arrangement. Units shall be Motorola Model Micom 2 complete with F2260 Antenna Tuner.

9.24.2 The radio-telephone shall have the following features:

a. R.F. power output of 125 Watts P.E.P.; and

b. fully synthesized and capable of 120 channel selection over 1.6 MHz to 30 MHz range; and

c. fully automatic tuning, within 15 seconds of channel selection; and

d. channels shall be field programmable; and

e. incorporates a two-tone distress generator.

9.24.3 The radio-telephone shall be supplied complete with:

a. electronic noise blanker; and

b. interconnecting cabling; and

c. power supply.

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9.25 VHF COMMUNICATIONS

9.25.1 Marine Transceivers: These units are in addition to the Global Maritime Distress and Safety System (GMDSS) Digital Selective Calling (DSC) unit required as part of the GMDSS station.

9.25.2 Two (2) VHF/FM Marine radio transceivers shall be supplied and installed in the EER, each having associated remote units supplied and installed in the Bridge, and the Command Centre. One (1) VHF/FM Marine transceiver and associated antenna shall be supplied and installed, at a location aft on the MSPV. The antennae shall be the Coast Guard version of Sinclair Model 225M, centre cut to 156.8 MHz.

9.25.3 All transceivers shall have as a minimum the following features:

a. fully synthesized operation, covering all US and International private and weather channels which are used in the VHF band; and

b. programmed for all fifty-five (55) international maritime VHF channels with an additional capability to program a further twenty (20) private channels; and

c. sea watch operation with at least two (2) channels and including priority operation on Ch 16; and

d. One (1) button selection for Ch 16; and

e. One (1) Watt and twenty-five (25) Watt power output; and

f. Full function remote operation, with lock-out of remote at master control; and

g. Capable of transmitting in the frequency range of 155.4 MHz to 158 MHz, at channel separations of 25 kHz; and

h. Capable of receiving in the same frequency range and 160.0 MHz - 162.6 MHz; and

i. A sensitivity of 0.3 micro-volts for 12 db sinad, single channel operation.

9.26 AIR/GROUND TRANSCEIVER

9.26.1 One (1) VHF/AM radiotelephone shall be supplied and installed in the Bridge. The antenna shall be a Sinclair SRL-238M.

9.26.2 Features shall include:

a. 760 channel selection at 25 kHz spacing between 118 MHz and 136 MHz; and

b. 16 Watts nominal RF power output; and

c. side tone capability, adjustable up to 100 mW into 500 ohms; and

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d. single channel store and recall memory; and

e. speaker and headphone outputs.

9.27 WIDEBAND ENCRYPTION TRANSCEIVER

9.27.1 One (1) Mobile VHF-FM Wideband Radiotelephone complete with dual remote control heads, dual speakers, antenna and power supply shall be supplied and installed. The transceiver shall operate in a frequency range from 136 MHz to 174 MHz at a RF power level of 10 to 50 watts. Channel spacing shall be variable/programmable and Primary Operation and System Type shall be programmable. Feature Level shall be the Standard Package. The Transceiver unit shall be supplied and installed in the EER.

9.27.2 One (1) remote unit complete with limited keypad and display shall be supplied and installed in the Bridge and a second shall be supplied and installed in the Command Centre. Both units shall be supplied with encryption modules and all software required for programming of the transceiver and the encryption modules.

9.27.3 The antenna shall be Sinclair SRL-233 centre cut to 156.8 MHz. The antenna shall be supplied and installed in accordance with the accepted antenna arrangement. Each remote unit shall be equipped with an external speaker.

9.27.4 The Radiotelephone shall be a Motorola Astro XTL 5000 Digital Mobile Radio.

9.28 PORTABLES

9.28.1 Five (5) VHF/FM portable radio telephones, each fitted with a battery charger shall be supplied and installed in the Bridge. Three (3) of these shall be GMDSS TCMS approved units, Skanti VHF 9110, and two (2) shall be Icom M72 with Built-in UT112 voice scrambler. Units shall be supplied with carrying case and strap.

9.28.2 Two (2) Ultra High Frequency (UHF) FM portable radio telephones, each fitted with a battery charger shall be supplied and installed in the Bridge. Units shall be intrinsically safe Motorola MT1500 units capable of operating on 467 MHz. Units shall be supplied with intrinsically safe remote microphones, carrying case and strap.

9.29 GLOBAL MARITIME DISTRESS AND SAFETY SYSTEM STATION

9.29.1 One (1) Global Maritime Distress and Safety System (GMDSS) station meeting Canadian domestic carriage requirements shall be supplied and installed in the Bridge at a location agreed to by Canada. All operator interface components of the GMDSS station, with the exception of VHF Digital Selective Calling (DSC) radios, GMDSS portables, Emergency Position Indicating Radio Beacon (EPIRB), and Search and Rescue Radar Transponders (SART), shall be physically located in a deck standing console. The console shall meet the requirements of the Canadian Radio Inspection Certificate for A3 configuration. The station shall be supplied and installed complete with cables, batteries, connectors, antenna, display terminals, printers and all other items required

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for equipment set-to-work in conformance with the above requirements. The equipment shall be type-approved to IMO and IEC GMDSS performance standards.

9.29.2 Reserve battery or batteries shall be supplied and installed and all shall have as a minimum the capacity to power necessary equipment to satisfy the regulatory requirements. A battery-charging unit shall be supplied and installed.

9.29.3 The INMARSAT Standard C terminal, with Enhanced Group Call shall comply with the latest of INMARSAT performance standards. It shall also comply with the latest IEC regulations. The Standard C terminal shall be comprised of an integrated transceiver with monitor display and disc drive. A keyboard, printer, and remote distress control unit are also required. The Standard C terminal shall have a built-in GPS receiver that will allow automatic updating of the ship position every five (5) minutes in the event of a distress. The GPS antenna supplied shall be integral to the Standard C antenna radome.

9.29.4 The Medium Frequency / High Frequency Digital Selective Calling (MF/HF DSC) shall be a solid-state MF/HF DSC transceiver which shall have a power output of not less than 200 Watts PEP. The transceiver shall have a tuning range covering from 1.7 MHz to 28 MHz. The transceiver shall be tuneable on all International Telecommunication Union (ITU) marine channels, ITU Radio Regulations Appendix 18 refers, plus shall be capable of providing one hundred (100) programmable channels. The transceiver shall consist of three separate units – controller/remote, transceiver and automatic tuner unit (ATU). These three (3) units shall be capable of functioning with connecting cables. The controller shall include a NMEA 0183 interface for navigational devices such as a GPS receiver.

9.29.5 The Narrow Band Direct Printing Equipment, and the Search and Rescue Radar Transponder (SART) shall be compliant with the latest IEC requirements.

9.30 UHF COMMUNICATIONS

9.30.1 Space for one (1) multi-band transceiver (115 MHz -138 MHz, 136 MHz-174 MHz and 225 MHz -400 MHz bands) with scanning and fixed frequency operation in both AM and FM capability to communicate with Department of National Defence (DND) UHF/VHF AM/FM multi-band transceivers and ancillaries shall be allocated. This space shall be 5RU and allocated in the communications rack in the Command Centre to temporarily mount this transceiver.

9.30.2 A means to securely fasten this equipment shall be supplied. Antenna(e) to support this transceiver shall be supplied and permanently installed on the Bridge top or mast.

9.31 LOUDHAILERS

9.31.1 Two (2) weatherproof horn type loudhailers shall be supplied and installed on the searchlights.

9.31.2 The loudhailers shall be controlled from the BCS.

9.31.3 The loudhailers are part of the internal communication system and shall be integrated with the Talkback and Public Address (PA) systems.

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9.32 RACK(S) OR SHELVE(S)

9.32.1 19" Communications Rack(s) of welded steel construction as per 70-000-000-EU-JA-001, with a minimum of 65.4 cm useable depth and shelves shall be supplied and installed in the Command Centre to house radio transceivers that will be required by other Government Agencies during joint operations. If one (1) rack cannot accommodate all of the equipments listed below, a second rack with shelves shall be supplied and installed.

9.32.2 The rack(s) and shelves shall be designed, built and installed to allow quick and easy installation of the required radio transceivers. All power, interconnect and antenna cables shall allow for quick connect and disconnect.

9.32.3 A secure means of temporarily mounting the equipment shall be supplied and installed.

9.32.4 Antennae supporting the equipment noted below in 9.31.5 shall be supplied and permanently installed in accordance with the accepted antenna arrangement.

9.32.5 The rack(s) with shelves and 1RU vent panels separating each equipment shall have as a minimum the space to allow for the following equipment to be installed:

a. Motorola PDR 3500; and

b. VHF/UHF Transceiver; and

c. Motorola UHF Quantar Station/Repeater with duplexer; and

d. Motorola VHF Quantar Station/Repeater with duplexer; and

e. Ontario Provincial Police Transceiver – approximately 21 cm L x 8 cm D x 8 cm H; and

f. Quebec Provincial Police Transceiver – approximately 21 cm L x 8 cm D x 8 cm H; and

g. Kenwood TK980 Trunk Radio Transceiver; and

h. Motorola Astro XTL 5000.

9.33 CELLULAR PHONE

9.33.1 One (1) digital cellular phone capable of transmitting at a minimum power of three (3) Watts shall be supplied and installed in the Command Centre.

9.33.2 The antenna shall be supplied and installed in accordance with the accepted antenna arrangement.

9.33.3 The cellular phone shall be connected to the Integrated Internal Communications System (IICS) to allow authorized telephone access to this system.

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9.34 NAVTEX RECEIVER

9.34.1 One (1) Navtex receiver system shall be supplied and installed in the Command Centre and shall be connected to its antenna.

9.34.2 The antenna shall be located in accordance with the accepted antenna arrangement.

9.35 EMERGENCY POSITION INDICATING RADIO BEACON (EPIRB)

9.35.1 One (1) Class I TCMS approved EPIRB shall be supplied and installed on the Bridge top, clear of masts and antennae and mounted in a float free bracket.

9.36 RCMP TRANSCEIVERS

9.36.1 Space for one (1) Royal Canadian Mounted Police (RCMP) transceiver, a Motorola PDR 3500, TransPortable Digital Repeater (PDR)/TransPortable Base Station, one (1) Motorola Quantar (UHF) Station/Repeater and, associated duplexers shall be allocated in the communications rack(s) in the Command Centre to temporarily mount these units.

9.36.2 A means to securely fasten this equipment when installed shall be supplied.

9.36.3 The antennae to support these transceivers shall be supplied and permanently mounted in accordance with the accepted antenna arrangement.

9.36.4 Two (2) Sinclair SC320 collinear omni antennae shall be fitted in accordance with the accepted antenna arrangement and connected to the above transceivers utilizing LMR 600 FR coaxial cables.

9.36.5 The transmit frequency for the Motorola PDR unit shall be 426 MHz and the receive frequency shall be 421 MHz. The frequencies for the Motorola Quantar will be provided later.

9.37 OTHER GOVERNMENT AGENCIES

9.37.1 Two (2) spare runs of RG-214 coaxial cable and two (2) spare runs of LMR 600 FR coaxial cable shall be run from the communication rack(s) in the Command Centre to the Bridge Top to facilitate the installation of associated antennae for these transceivers in accordance with the accepted antenna arrangement.

9.38 CLOSED CIRCUIT TELEVISION SYSTEM (CCTV)

9.38.1 A CCTV system with a digital recording capability shall be supplied and installed on the MSPV and distributed over the administrative LAN.

9.38.2 The master monitor shall be supplied and installed in the Bridge.

9.38.3 Fixed cameras shall be supplied and installed throughout the MSPV in such a manner so as to allow complete monitoring of the entire upper deck area, all working deck areas, the gangway, and all machinery spaces.

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9.39 INTERIOR DATA TRANSMISSION

9.39.1 An internal data transmission system shall be supplied and installed. It shall be comprised of the following networks:

a. NMEA 0183 data network for Navigational and Communication Equipments; and

b. Ethernet 1 Gigabit per second (Gbps) for the administrative and operational LANs; and

c. International Processing Standards for Computers Communications Link for the Machinery Control Link.

9.39.2 The routing of cables and the grounding and bonding of electronic equipment shall meet the requirements of CCGS 70-000-000-EU-JA-001, General Specification for the Shipboard Installation of Electronic Equipment.

9.40 NAVIGATION AND COMMUNICATION SYSTEMS

9.40.1 Navigation and selected communication equipment shall be interfaced utilizing the NMEA 0183 data bus. This is also referred to as the IEC61162 standard.

9.41 LOCAL AREA NETWORKS (LAN)

9.41.1 Two (2) separate fibre-optic Ethernet-based Computer LANs shall be supplied as per STA 46-000-000-ES-TE-001. One (1) network will be used for operational purposes and the other will be used for administrative purposes. Each drop shall be fed by three (3) fibre optic pairs in a single tube. Each end of the fibres should be terminated by ST type connectors. The third fibre optic pair shall be connected to a fibre optic to Ethernet (RJ-45) converter. Converters shall be supplied and installed in the bulkhead and shall be powered. A maintenance access shall be supplied.

9.41.2 Computer connection capability shall be supplied to the administrative LAN, to allow information access and a means to communicate to all areas of the MSPV specified herein.

9.41.3 Operational LAN drops shall be supplied and installed in the following areas:

a. Three (3) in the Command Centre; and

b. One (1) in the Program Officer's/Incident Commander's cabin.

9.41.4 Administrative LAN drops shall be supplied and installed in the following areas:

a. Four (4) in the Command Centre (for a total of 7 LAN drops: 3 operational, 4 administrative); and

b. Three (3) on the Bridge; and

c. One (1) in the MCR; and

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d. One (1) per single cabin; and

e. Two (2) per double cabin; and

f. One (1) in the mess.

9.41.5 A 2.4 GHz 9db Omni antenna shall be supplied and installed. The antenna shall be routed to the LAN equipment rack in the EER by LMR600FR cable. An additional 2 m of cable is to be left coiled in base of rack to allow for future connectivity anywhere in the rack.

9.41.6 19" 40 RU rack of welded steel construction as per 70-000-000-EU-JA-001, with a minimum of 77.5 cm useable depth shall be provided in the EER to house the LAN equipment. Fibre optic cabling shall be terminated in patch panel(s) at the top section of this rack. Remaining vacant space shall be reserved for LAN hardware.

9.41.7 The MSPV shall be fitted-for-but-not-with computer workstations in the following locations:

a. The Bridge; and

b. MCR; and

c. Commanding Officer's Cabin; and

d. Chief Engineer's Cabin; and

e. The Mess.

9.42 TELEPHONE AND INTERCOM SYSTEMS

9.42.1 One (1) IICS shall be supplied and installed. It shall consist of:

a. telephone system with telephones in all cabins, workspaces, mess and workshops; and

b. talk-back system; and

c. PA system; and

d. shoreline connections; and

e. ship's recreational equipment; and

f. loudhailers.

9.42.2 The IICS shall be a Hose McCann (United Marine) Integrated Communication Platform product. System design shall dictate if more than one node (Equipment Cabinet) is required for all endpoint connectivity. One node shall be fitted in the EER and include the UPS, Power Supplies, EPIC, PBX, Main and Standby PA controllers. Cabinet fittings including shock mounts, thermostatically controlled cooling fan to provide positive air pressure, General Alarm override

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relay and, locking cabinet door shall be supplied and installed. Field wiring termination points shall be supplied directly in the rear of the cabinet, eliminating the need for additional cross-connect or junction panel hardware. Also incorporated within this cabinet shall be the control circuitry for the automatic fog signalling electric whistle system. All Fog Tone generators shall be monitored for failure.

9.42.3 All IICS speaker runs shall be monitored and controlled in such a way that if an open circuit, short circuit or a ground were to occur on either side of the speaker run, then a trouble indication appears on the Control Head, and the speaker run is automatically disconnected.

9.42.4 Functional integration in the Bridge and MCR shall be through the use a Control Head device incorporating access to all PA, Talkback/intercom, loudhailer, system alarm and key telephone system functions. The Control Head device is a single, flush-mount unit, providing distributed single-keystroke access to key IC functions at strategic locations throughout the Bridge and MCR consoles. By means of connections to the IICS, direct access to resources such as cellular and satellite phones shall be supplied through use of pre-programmed codes.

9.42.5 The PBX shall be able to handle voice and data transmissions simultaneously in all configuration of trunks, telephone and data devices. For this application, the exchange shall have a minimum of thirty (30) lines and twelve (12) analog trunks. This PBX shall be fully compatible with shore Central Office equipment.

9.42.6 The Talkback portion of the IICS shall use a telephone circuit for the call-back portion of all Talkback stations allowing Dual Telephone access to the PBX or Talkback function and giving private telephone communication along with the Talkback speaker.

9.42.7 The IICS shall be interfaced to the satellite transceivers and cell phones.

9.42.8 Four (4) analog trunk lines with lightning protection shall be supplied from the ship's IICS to shore.

9.43 AUTOMATIC TELEPHONES

9.43.1 Telephone stations shall be supplied and installed in all work areas and cabins. Each telephone shall be able to dial all other telephones onboard and access the shore trunks and communication systems if so programmed. Push-button dial telephone stations shall be equipped with special marine handset retainers, suitable for bulkhead or desk mount, and be either of regular inside, drip-proof or waterproof type depending on location. In machinery spaces auxiliary visual signalling strobe blue lens lights shall be supplied and installed to indicate an incoming call.

9.43.2 The Captain's Cabin and Bridge telephones shall be supplied with override and all-call paging facilities.

9.44 TALKBACK COMPONENT

9.44.1 The Bridge Talkback system shall be supplied and installed to provide point-to-point voice communication between the BCS and the following outlying stations:

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a. Captain's Cabin; and

b. Lifeboat Station; and

c. RHIB Stations; and

d. Aft Line Handling Position; and

e. Fwd Line Handling Position; and

f. Fuelling Station(s); and

g. Fuel Transfer Pumps;

h. MMR; and

i. If fitted, AMR; and

j. MCR; and

k. Loudhailers; and

l. Steering Gear Compartment.

9.44.2 The MCR Talkback system shall be supplied and installed to provide point-to-point voice communications between the MCR and the following outlying stations:

a. Bridge; and

b. Fuelling Station(s); and

c. Fuel Transfer Pumps; and

d. Steering Gear Compartment; and

e. MMR; and

f. If fitted, AMR; and

g. Sewage Treatment Room; and

h. Emergency Diesel Generator Compartment.

9.44.3 Communications between the Control Head and the outlying stations shall be by the use of the Control Head handset and dedicated station selection push-buttons. Reply from the outlying stations shall be hands free via the Talk-back loudspeaker, environmental and noise conditions permitting and all fixed and portable telephone headset and handset stations.

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9.44.4 All Talkback locations shall be equipped with individual call-in push-button to signal the group Control Heads. The talkback loudspeaker units shall also be connected to the PA system.

9.45 INTERCOM COMPONENT

9.45.1 An intercom system shall be supplied and installed to provide point-to-point voice communications between the Command Centre and the following stations:

a. Bridge; and

b. Captain's Cabin; and

c. Program Officer/Incident Commander's Cabin; and

d. Mess; and

e. Aft working deck.

9.46 PUBLIC ADDRESS COMPONENT

9.46.1 A PA component shall be supplied and installed to provide routine or emergency broadcast PA facilities to select or all areas of the ship via strategically located loudspeaker units throughout the MSPV. The PA system master control shall be located in the Bridge in a dedicated panel. The Bridge shall have priority over the communication system. Activation of this function shall override the general alarm signal.

9.46.2 Initiation of a PA message shall be from the Control Head station by use of the handset and dedicated selection push-buttons or by specifically programmed telephone stations (all-call only). The PA system shall be consolidated into selectable loudspeaker groups as follows:

a. Group 1 "work stations group"; and

b. Group 2 "common areas group"; and

c. Group 3 "cabin group"; and

d. Group 4 "machinery spaces group"; and

e. Group 5 "exterior deck group"; and

f. All-call (Groups 1, 2, 3, 4 and 5).

9.46.3 PA loudspeaker units shall also have dual functions: operating as public address/loudhail and Talk-back loudspeakers. However, there shall not be any switching devices located in the loudhailers and loudspeaker units to accomplish the additional functions described.

9.46.4 Loudhailers shall be supplied and installed and interconnected as detailed in Section 9.31 of the TSOR.

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9.47 SOUND POWERED TELEPHONES

9.47.1 A sound powered telephone system shall be supplied and installed as a backup for emergency communications between operational stations as follows:

a. Bridge; and

b. MMR; and

c. If fitted, AMR; and

d. Steering Gear Compartment; and

e. MCR; and

f. Aft working deck; and

g. Fuelling station(s).

9.48 SHIP'S ENTERTAINMENT SYSTEMS EQUIPMENT

9.48.1 The ships' entertainment systems equipment shall be fed from the communal entertainment antenna/distribution system.

9.49 TELEVISION AND BROADCAST SYSTEMS

9.49.1 A communal entertainment antenna/distribution system, including all cabling and fittings, shall be supplied and installed. An input for an external cable television shore connection shall be supplied. The shore connection shall be located adjacent to the shore power and shore telephone connections.

9.49.2 The system shall distribute high definition TV and AM/FM radio broadcasts.

9.49.3 The system shall utilize low-loss coaxial distribution cable and separate outlets in each space, where installed.

9.49.4 The TV and AM/FM distribution system shall be designed in such a manner as to provide a nominal level of 0 dbmv +/- 2 db on CATV channel 13 at each cabin outlet. Independent automatic gain control shall be supplied for each channel of the system.

9.49.5 Each antenna outlet shall be connected directly to a trunk-line directional tap-off. Isolation between outlets shall be not less than 25 db on VHF and 18 db on UHF. Trunk line directional tap-offs shall be easily accessible and preferably installed in Store Rooms or Locker Rooms. Where tap-offs are mounted behind bulkhead or deckhead linings, access shall be supplied by a dedicated removable access panel, labelled with appropriate identification.

9.49.6 An antenna system shall be supplied and installed and be comprised of a single omni-directional wide band antenna. Antenna shall be equipped with a preamplifier and shall be

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connected using low-loss coaxial cable. An antenna control position shall be supplied and installed in the EER. Antenna amplifier shall be supplied and installed near this control station.

9.49.7 The signal distribution system shall distribute TV and AM/FM radio signals to bulkhead-mounted outlets in:

a. the Bridge; and

b. all cabins; and

c. the Command Centre; and

d. the Mess.

9.50 ELECTRONIC EQUIPMENT ROOM

9.50.1 A dedicated EER shall be designed, built and installed in the MSPV, preferably on the main deck. This room shall contain the following equipment:

a. telephone/Talkback equipment; and

b. television and AM/FM radio distribution system, antenna control position and associated amplifiers; and

c. LAN equipment rack including fibre-optic cable termination patch panel(s); and

d. fitted-for-but-not-with two (2) Computer servers; and

e. communications equipment (e.g. FM wideband radio-telephone) with remotes in the Bridge and Command Centre; and

f. fibre optic gyro compass; and

g. E-mail-at-sea equipment rack.

9.50.2 Space shall be allocated in the EER for the installation of one (1) Motorola Quantar VHF repeater and duplexer, and the installation of a second transceiver of similar size. Spare coaxial cables shall be supplied and run from this location to locations in accordance with the accepted antenna arrangement.

9.50.3 Depending on the location of the EER, it may also house the radar transceiver units, which could be bulkhead mounted. A sufficient number of approximately 48.3 cm equipment racks, with adequate space in front of them, shall be supplied and installed so that the equipment can be installed or removed. There shall be approximately 45 cm clear space behind the racks. The racks shall be supplied and installed with removable doors at both the front and the back. The preferred location is near the Bridge and Command Centre.

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9.51 CENTRALIZED CONTROL, ALARM AND MONITORING SYSTEM (CCAMS)

9.51.1 The MSPV CCAMS, employing commercial-off-the-shelf (COTS) hardware and software, shall be supplied and installed.

9.51.2 The CCAMS shall have the main MCS located in the MCR. The MCS shall have remote and automatic machinery control to meet Class UMS requirements and other requirements as stated elsewhere in this document. The CCAMS shall provide an automatic data logging function. CCAMS shall log all alarms and shall have the capability to be configured to log user defined events. A log viewer shall be supplied to review the captured data complete with applicable units of measurement. A dedicated colour printer shall be supplied and installed at the MCS to print logs, active alarm lists and machinery control mimic pages.

9.51.3 The CCAMS shall have a BCS located on the Bridge. The BCS shall have two functions. First, the BCS shall have remote and automatic machinery control to meet Class UMS requirements and other requirements as stated elsewhere in this document. Second, the BCS shall be the human machine interface to provide operator control of propulsion and steering at the BCS over the complete range of vessel operation.

9.51.4 The CCAMS shall have permanent Bridge wing consoles. The wing consoles shall be capable of controlling steering and propulsion. The wing consoles shall be watertight to NEMA 4X, if exposed to environmental elements.

9.51.5 There shall be a CCAMS remote display unit in the Chief Engineer's cabin and in the 2nd engineer's cabin capable of displaying logs, active alarm lists and machinery control mimic pages. The remote display unit in both cabins shall also provide audible and visual alerts for all CCAMS alarms. These shall be able to be acknowledged without removing the alarm condition from the remote display units, the MCS and the BCS.

9.51.6 A ship alert system as per Marine Transportation Security Regulations shall be supplied and installed onboard.

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10 ACCOMMODATION OUTFITTING

10.1 PLUMBING FIXTURES AND ACCESSORIES

10.1.1 All trim pieces for fixtures and all accessories shall be chrome plated cast, forged brass or stainless steel and shall be of matching design for uniformity.

10.1.2 Grab rods shall be supplied and installed at all showers and toilets.

10.1.3 Isolation valves shall be supplied and installed as described at paragraph 7.12.8.

WASHBASINS

10.1.4 Washbasins, showers and service sinks shall be supplied and installed with hot and cold potable water.

10.1.5 Washbasins shall be stainless steel and shall be supplied and installed with self-closing and washerless faucets.

10.1.6 Washbasins, unless otherwise specified, shall be supplied and installed with the following accessories:

a. toiletries cabinet; and

b. soap dish; and

c. soap dispenser; and

d. towel hook/bar/ring.

SHOWERS

10.1.7 The showers shall be supplied and installed with:

a. a low-flow shower head (max 9.0 l/min); and

b. a non-scald mixing valve; and

c. a push button or level-operated control valve; and

d. the following shower accessories: soap dish, shower curtain and grab rail.

DEEP SERVICE SINKS

10.1.8 Each sink or set of double sinks shall be stainless steel and shall be supplied and installed with self-closing and washerless faucets and a soap dish.

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10.1.9 A service sink shall be supplied and installed in cleaning gear lockers if such facilities are not readily available in adjacent sanitary spaces.

TOILETS

10.1.10 Vitreous china toilets (vacuum type) shall be supplied and installed.

10.1.11 A toilet paper holder and grab rail shall be supplied and installed in each toilet enclosure.

10.1.12 A toilet seat, open front type, shall be supplied and installed for each toilet.

10.2 LOCKS, KEYS, KEYBOARDS AND KEY CABINETS

10.2.1 Locks shall be supplied and installed for all doors, hatches, manholes and scuttles. Cabin doors shall be able to be opened from the inside without a key. Identical keys shall be used for all furniture in cabins, different keys shall be used for furniture assigned to each person and four (4) key sets plus one (1) blank shall be furnished. Locks for desks, key cabinets and bookcases in cabins shall be the same as locks for the furniture in the corresponding cabins.

10.2.2 A lockable Key Cabinet shall be supplied and permanently mounted on the Bridge and shall contain one copy of all keys, complete with labels, supplied with the MSPV.

10.2.3 All locks on the MSPV, including locks for access doors, storerooms and lockers, shall be supplied and installed. They are to be keyed alike and shall be capable of being opened by a master key as well as their specific key. The only exceptions to this are the keys and locks for the firearms lockers which shall each be unique.

10.2.4 A lockable Duplicate Key Cabinet shall be supplied and permanently mounted in the Captain's Cabin. It shall contain three (3) labelled copies plus one (1) blank of all keys supplied with the MSPV.

10.3 HABITABILITY

FURNISHINGS

10.3.1 Bulkhead linings and false deckheads shall be supplied and installed in all cabins, Command Centre, mess, accommodation passageways, and Bridge. Bulkhead linings and false deckheads shall be supplied and installed in the galley and sanitary spaces. The outer face of joiner bulkhead panels fitted in the galley shall be stainless steel satin finish. Where necessary for frequent access, inspection, or troubleshooting, deckheads and linings shall be supplied and installed with portable or hinged access panels with easily removable fastenings.

10.3.2 All furniture supplied shall be of commercial design and modular construction, suited for the marine environment shipboard use. All furniture shall be free of sharp edges and burrs. Large articles of furniture shall be mounted on sub-bases and secured at the top and sides. Furniture shall not be rigidly attached to non-structural or joiner bulkheads. Maximum use of durable, low maintenance, lightweight materials and finishes for ease of cleaning shall be incorporated into all accommodation furnishings.

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10.3.3 All berths, drawer units, lockers, sideboards and dining table supports shall be constructed from TCMS approved fire retardant materials with standard marine fit and finish. Accommodation upholstery shall have a woven fabric and shall be fire retardant, washable and fastened to the frame with non-corrosive attachments. Vinyl upholstery shall not be used.

BERTHS

10.3.4 Berths shall be single- or double-tier and shall be installed in the fore and aft plane with the head position forward. Each berth shall accommodate a mattress having dimensions of at least 1980 mm long, 800 mm wide and 150 mm thick. The underside of the bottom tier pan shall be a minimum of 300 mm above the deck. The vertical clearance above the top of each mattress shall not be less than 910 mm.

10.3.5 Each berth shall be supplied and installed with:

a. one (1) reading light; and

b. one (1) stowage space for an Emergency Escape Breathing Device (EEBD) (approx 130 mm x 260 mm x 270 mm); and

c. one (1) a stowage space for reading material (approx 300 mm L x 75 mm D x 300 mm H); and

d. one (1) 150 mm thick spring filled mattress with latex coated spring coils, boxed border, cotton tufting, corded handles and vents and zipped cotton duck covering.

10.3.6 Double-tier berths shall be fitted with separate opaque privacy curtains with tie-backs.

KIT LOCKERS

10.3.7 One (1) kit locker per occupant shall be supplied and installed within each cabin as a minimum. The kit lockers shall be, approximately 500 mm L x 530 mm D x 1830 mm H. The lockers shall provide the following types of stowage:

a. minimum of three (3) drawers; and

b. minimum of five (5) shelves; and

c. one (1) cap stowage (for one RCMP or C&P Officer's Forage Cap); and

d. one (1) boot and shoe stowage; and

e. one (1) hanging bar for uniforms and civilian clothes; and

f. one (1) outside towel rail; and

g. two (2) clothes hooks; and

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h. Drawers and lockers shall be supplied and installed with cylinder locks keyed alike. Four (4) sets of keys per locker shall be supplied. Lockers shall be designed, built and installed so that they permit free air circulation within the locker and free unobstructed access within the compartments that they are situated in. Drawers and lockers shall not freely open due to the MSPV's motion.

DESKS, WRITING TABLES

10.3.8 Desks of a single pedestal type and appropriately surfaced to reduce husbandry shall be supplied and installed.

CHAIRS

10.3.9 Cabin chairs of a lightweight design with an upholstered seat on a light metal frame shall be supplied and installed.

TOILETRY CABINETS

10.3.10 Cabinets of metal construction and equipped with stainless steel shelves with edge rails and a mirror on doors shall be supplied and installed above each washbasin. Doors shall have secure catches. Cabinets shall be installed so that the centre of the mirror is approximately 1.6 m above the deck.

SINGLE CABINS

10.3.11 Single berths shall be supplied and installed in all single cabins. Each cabin shall be supplied and fitted with a desk with drawers and desk light, combination safe, desk chair, at least one (1) but up to two (2) kit lockers, a stainless steel washbasin complete with a compact mixer faucet and hot and cold shut-off valves, a toiletry cabinet, a single shelf bookshelf storage (1.5 m L and a minimum of 25 cm D), two (2) clothes hooks, waste bin, internal communications station, one (1) administrative LAN outlet, one (1) telephone outlet and, two (2) television and radio reception outlets fed from the communal entertainment antenna distribution system.

10.3.12 One (1) small-arms secure storage locker for a 9 mm individual pistol shall be supplied and installed in the Program Officer/Incident Commander's cabin. The designated cabin shall be determined by Canada during the outfitting design of the cabins.

10.3.13 One (1) small refrigerator (approximately 0.12 m^3) shall be supplied and installed in both the Captain's and Chief Engineer's Cabins.

10.3.14 The Commanding Officer's, Chief Engineer's and Program Officer/Incident Commander's cabins shall be each be supplied and installed with one (1) 40 watt stereo with two (2) speakers, one (1) CD player, one (1) twenty (20) inch flat screen HD LCD television and one (1) Blu-ray/DVD player.

10.3.15 Allocated storage shall be supplied and installed for one (1) immersion suit and one (1) lifejacket.

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DOUBLE CABINS

10.3.16 A double-tier berth, with a Pullman berth (or equivalent) as the top tier, shall be supplied and installed in each double cabin. Each double cabin shall also be supplied and fitted with a single pedestal desk with drawers, desk light, desk chair and at least two (2) but up to four (4) kit lockers. Each cabin shall be supplied and fitted with a stainless steel wash hand basin complete with a compact mixer faucet and hot and cold shut-off valves, a toiletry cabinet, a single bookshelf (1.5 m L and a minimum of 25 cm D), four (4) clothes hooks, waste bin, internal communications station, two (2) administrative LAN outlets, one (1) telephone outlet, and two (2) television and radio reception outlets fed from the communal entertainment antenna distribution system.

10.3.17 Two (2) separate, secure storage lockers each accommodating a 9 mm individual pistol, or equivalent, and one (1) long rifle shall be fitted in each double cabin.

10.3.18 Allocated storage shall be supplied and installed for two (2) immersion suits and two (2) lifejackets.

WASHROOMS

10.3.19 Four (4) washroom facilities shall be supplied and installed. One (1), located on the main deck in proximity to the Command Centre, shall be fitted with one (1) toilet and one (1) wash basin with all necessary fittings including hot and cold water, water isolating valves, self-closing and washerless faucets, toilet roll holder, grab rails, paper towel dispenser/disposal unit and coat hook. Three (3) washroom facilities shall be fitted with one (1) toilet enclosure with door, one (1) wash hand basin in a vanity type installation with toiletry cabinet and one (1) shower enclosure with curtain. The washroom shall be outfitted with all necessary fittings including hot and cold water, water isolating valves, self-closing and washerless faucets, toilet roll holder, towel rail, grab rails, paper towel dispenser/disposal unit, and coat hook. All facilities shall be supplied and fitted with a sanitary napkin depository and dispenser.

10.3.20 One (1) of the four (4) washroom facilities, complete with shower, shall be supplied and installed adjacent to the Captain's and Chief Engineer's Cabins for their shared use.

MESS

10.3.21 A large mess shall be supplied and built for the crew. The mess shall be cafeteria style with a service opening adjacent to the galley. The mess area shall be adaptable such that it will accommodate ten (10) persons for briefings and interviews.

10.3.22 The mess shall be fitted with moveable chairs and tables having a seating capacity for ten (10). The seating arrangement in the mess shall be configured so that each person has access to his or her place without disturbing another crewmember when everyone is seated. Individuals shall also be able to leave their seat without having to ask someone to move. For this seating arrangement, the tables shall be equipped with a mechanism that will allow them to be temporarily secured to the deck. Furthermore, the furniture in the mess shall have the capability of being struck down and stowed in the mess in order to leave a large, clear deck-space, which may be used for temporary (overnight) accommodations.

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10.3.23 The mess shall be fitted with a pass-through so that the crew can receive their meals and return their dirty dishes to the galley.

10.3.24 The mess shall have a counter with cupboards beneath supplied and installed close to the pass-through. The following items shall be supplied and installed:

a. a stainless steel counter that shall be outfitted with a bar style sink complete with a compact mixer faucet, hot and cold shut-off valves and with space for:

i) one (1) industrial stainless steel four (4) slice toaster to accept regular and oversize items (bagels); and

ii) one (1) electric coffee maker, maximum power of 1200 Watts, water tank size of not less than 2.0 l; and.

iii) one (1) electric soup and food warmer heater with 120 V / 800 Watts, non-stick surface and not less than 12.0 l capacity; and

iv) one (1) microwave oven in stainless steel with inverter turbo defrosts, 34.0 litre minimum capacity and 1200.0 Watts.

b. one (1) cabinet, counter-depth stainless steel refrigerator and freezer with a minimum combined capacity of approximately 563 litres and complete with French doors, glide-out freezer drawer, through the door ice and water dispenser, an easily accessible isolation valve on the refrigerator potable water supply; and

c. one (1) water dispenser column model, approximately 32 cm L x 30 cm D x 102 cm H. It shall be secured to the bulkhead and shall be compatible with approximately 18.5 l bottled water containers. A means of securing the water containers to the bulkhead shall be supplied and installed. Dispensed cold water temperature shall be between 4.0°and 10.0°C; and

d. food preparation area; and

e. one (1) garbage container in plastic complete with a hinged lid. It shall have a minimum capacity of 49.0 l; and

f. stainless steel cupboards to store dry food such as cereal and bread plus cupboards to store glasses, coffee mugs, plates and bowls as detailed at Appendix 4 of the TSOR; and

g. a stainless steel drawer for the stowage of cutlery, utensils and linen as detailed at Appendix 4 of the TSOR.

10.3.25 The mess shall also serve as the crew's recreation space. It shall be designed and built with an area for lounging and shall be supplied and installed with a comfortable upholstered sofa made of leather or other durable material. This area shall also be supplied and installed with an entertainment system cabinet outfitted with:

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a. a forty (40) watt AM/FM stereo; and

b. a multiple disc Compact Disc (CD) player; and

c. a forty (40) inch flat screen Liquid Crystal Display (LCD) High Definition (HD) television, with provision to provide suitable viewing for the whole mess area; and

d. a Blu-ray/Digital Video Device (DVD) player; and

e. eight (8) speakers, including two extension speakers to the galley.

10.3.26 The mess area shall contain:

a. a computer workstation space; and

b. an administrative LAN drop; and

c. a cork notice board (1.5 m L x 1.0 m H); and

d. a bookcase, two (2) linear metres of shelving at least 25 cm D; and

e. a clock; and

f. curtains made of opaque materials so as not to pass light, complete with tie backs; and

g. dimmable lighting; and

h. television and radio reception points fed from the communal entertainment antenna distribution system.

GALLEY

10.3.27 The galley shall be designed, built and equipped to allow for a single cook to prepare meals, generally composed of two choices of entrée, for a complement of fourteen (14) personnel when the MSPV is operating in conditions as described in Table 1 – Environmental Conditions. Ergonomics, efficiency and galley lay-out shall be optimized when planning the galley design. The galley should be free of overhead trunking and obstructions. Deck areas shall be designed to eliminate cross traffic and bottlenecks, yet retain specific areas designated for specific tasks. The galley shall provide storage spaces for a food locker and for items as detailed at Appendix 5 of the TSOR, meat and vegetable preparation spaces, a pastry and bread making section, cooking spaces, dishwashing spaces and garbage stowage space. The galley shall be supplied and outfitted with the following:

a. one (1) flash-steam combination oven and steamer, including operational modes for steam, convection and a combination of steam and convection heat. Features shall include automatic steam venting and a self-adjusting, flush-mounted rotary door handle with a steam venting safety stop. Controls shall include a 2-speed fan and a cool-down function. The oven shall be constructed of 18 gauge stainless steel, include an attached spray hose with backflow preventer, and an automatic cleaning function. The oven cavity is to

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accommodate up to six (6) half-size sheet pans, include a removable door gasket for easy replacement, appropriate door hinging, removable quick-connect internal product temperature probe in the oven interior, programming capability and cold water inlet(s); and

b. one (1) stainless steel range exhaust hood shall be fitted above the induction ranges. It shall be fitted with a grease trap, removable and cleanable filters and lights. The range hood shall be connected to the galley exhaust system; and

c. one (1) vertical, upright, stainless steel, marine type refrigerator of 595 l minimum capacity. It shall be fitted with five (5) adjustable shelves, a door latch and interior lighting; and

d. one (1) commercial, stainless steel exterior, combination convection and microwave oven of 34.0 litre capacity minimum. It shall provide up to and including 246.1°C (475°F) of convection cooking with 1400 Watts minimum of microwave heating and shall have an easy to clean interior; and

e. one (1) industrial dishwasher with a heat booster, which shall wash at a temperature of not less than 66.0°C and rinse at a temperature of not less than 82.0°C. The dishwasher shall have two (2) extra racks for cutlery and glasses and top and side panels; and

f. two (2) heavy-duty, stainless steel, commercial, dual hob, vitro ceramic countertop induction ranges with at least 2.5 kW per hob. The ranges shall accommodate two (2) pans each with a maximum diameter of 30.5 cm. The ranges shall be easy to clean; and

g. one (1) stainless steel, industrial, counter electric griddle at least 38 cm x 61 cm x 35 cm. The deep grease drawer shall be concealed behind a front cover door. The griddle shall be easy to clean and have safety features to prevent grease spills; and

h. one (1) stainless steel exterior industrial four (4) slice toaster to accept regular and oversize items (bagels); and

i. one (1) bulkhead-mounted, heavy-duty manual can opener capable of opening a 35 cm diameter can; and

j. one (1) garbage container in plastic with a minimum capacity of 80.0 l with a snap-fit or swinging lid; and

k. one (1) preparation table with a stainless steel base and a wooden "butcher block" counter top, located near the cooking section; and

l. one (1) stainless steel counter beneath the pass-through; and

m. one (1) plate dispenser fitted to one side of the stainless steel counter beneath the pass-through; and

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n. the pass-through shall be large enough to allow the crew to be served from the galley and to allow crew members to return dirty dishes to the galley concurrently; and

o. one (1) three (3) sink unit, with a single lever mixing valve faucet and spray nozzle attachment on a flexible hose; and

p. one (1) separate sink for hand washing fitted close to the preparation table, with a fixed soap and paper towel dispenser; and

q. one (1) food processor (KitchenAid TM 16 cup food processor KPFP850PM or equivalent); and

r. one (1) scale - portion (Bakers) 1-10 lb (Electronic scale); and

s. one (1) mixer (Hobart N50 Mixer or equivalent); and

t. galley items storage as detailed at Appendix 5 of the TSOR.

10.3.28 The main cooking section shall be close to the point of service.

10.3.29 The sink counter shall be of all stainless steel construction with 150mm backsplash. A three (3) compartment sink unit shall be made of stainless steel with radius corners throughout. Each side sink shall be approximately 50 cm L x 50 cm D x 50 cm H with 60 cm L x 50 cm D drain boards. Two (2) sinks shall each be fitted with a spin waste strainer. The rinsing sink shall be fitted with one (1) industrial-grade garborator of at least 0.75 kW. The garborator shall be totally enclosed to protect against ingress of outside moisture, it shall have a built-in thermal overload protection and it shall be designed for reverse action grinding. The garborator shall be all stainless steel and shall discharge all galley wastes that may contain grease through grease traps to a retaining box prior to discharge into the grey water system. A standard single lever, mixing valve faucet and spray nozzle attachment on a flexible hose shall serve the sink unit.

10.3.30 Equipment abutting other pieces of equipment or furnishings such as table tops, countertops and bulkheads shall have seals installed to avoid grease or soil catching crevices. Panels of quilted stainless steel shall only cover bulkheads behind heat producing equipment. Other bulkheads shall be made of fire retardant material other than stainless steel. The space between the heat producing equipment and the bulkhead shall be sealed against the entry of vermin, cooking ingredients or other extraneous matter.

10.3.31 All sinks, countertops and cupboards shall be constructed of stainless steel. Stainless steel cupboards and tables shall be reinforced, if required, to prevent warping or buckling of surfaces. Unless otherwise specified, they shall be of welded construction. All welds shall be sound, non-porous and free from imperfections. The deposited colour metal shall be corrosion resistant and matched to parent materials. All welds shall be ground and polished to a smooth finish.

10.3.32 Deck coverings shall be evenly laid and well sealed to prevent lifting through continuous use of water and they shall be made of durable and easy to clean material.

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10.3.33 Tables, counters and cupboards shall be supplied and installed to the maximum practical extent. Normal depth of counters accessible from one side shall be approximately 50 cm. Cupboards shall be of stainless steel construction, bulkhead mounted with adjustable shelving, and shall have hinged doors with latches and locking arrangements. Cupboards above the dishwashing area counter shall have dividers sized for dishes. Stowage for pots and pans shall be deep cupboards and drawers with spaces sized for utensils, located as near as possible to the oven and under the stainless steel counter beneath the pass through.

10.3.34 To accommodate the operational and stowage realities of the shipboard environment, the following are required:

a. counter tops and sink units shall be supplied and installed with inverted "V" edges; and

b. splash backs shall be supplied and installed for sinks and counters when sinks are installed against a bulkhead; and

c. all shelving shall be supplied and installed with raised edges; and

d. the front lip of refrigeration racks shall be raised; and

e. large overhead cupboards shall be supplied and installed with retaining bars; and

f. shelves shall be supplied and installed with lips for packaged and canned supplies; and

g. racks shall be supplied and installed for pot lids; and

h. drawers shall be supplied and installed with stainless steel bin inserts for sugar, flour, bread, etc.; and

i. cutlery and tool drawers shall be supplied and installed with internal sectioning and shall be fitted with latches; and

j. shelves and drawers shall be supplied and installed to be removable for easy cleaning. Drawers shall be supplied and installed with stops and latches; and

k. drainage shall be supplied and installed under all plumbed equipment; and

l. electrical outlets shall be installed and installed with waterproof covers. Wiring shall be sealed and encased in waterproof jackets; and

m. light fixtures shall be supplied and installed complete with waterproof seals and safety glass; and

n. grease trays shall be supplied and installed on main cooking equipment; and

o. all doors shall be supplied and installed with strong hooks to secure them when they are open; and

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p. cupboards and drawers shall be supplied and installed with storage for all the items as detailed at Appendix 5 of the TSOR.

10.3.35 The galley shall be fitted with a small ready use storage space for brooms, mops, buckets and cleaning materials.

COMMAND CENTRE

10.3.36 The Command Centre shall consist of stationary material storage spaces, Program/Incident presentation space, three Program/Incident staff working, writing and operational & administrative LAN spaces, spaces for communications and other electronics equipment and, a briefing area for seven personnel. Its furnishing shall consist of desks and shelving. The Command Control Centre shall be located aft of the Bridge and shall be supplied and installed with the following:

a. a working surface with a minimum size of 1270 mm L x 890 mm D and 910 mm above the deck; and

b. seating for four (4); and

c. one (1) whiteboard cabinet of minimum size 1200 mm W x 900 mm H, mounted 910 mm above the deck; and

d. inside cabinet features with hinged doors and cork bulletin board on the inside of each hinged door; and

e. a space for Program/Incident Commander's workstation with a desktop computer integrated with a supplied and installed digital projector; and

f. two (2), thirty-two (32) inch flat screen HD LCD televisions, two (2) Video Cassette Recorders (VCRs), and one (1) Blu-Ray/DVD players. Remote operation is required for all listed electronic devices; and

g. operational and administrative LANs; and

h. one (1) water dispenser column model, approximately 32 cm L x 30 cm D x 102 cm H. It shall be secured to the bulkhead and shall be compatible with approximately 18.5 litre bottled water containers. A means of securing the water containers to the bulkhead shall be supplied and installed. Dispensed cold water temperature shall be between 4.0°C and 10.0°C; and

i. one (1), four (4) drawer, lockable, heavy duty filing cabinet to hold up to and including SECRET documents as per Government Security Policy; and

j. door access to the Bridge with lock; and

k. a second door, with a thumb-turn lock and a non-opening window, giving access to the outside deck area. Fixed windows shall be supplied and installed to view port, starboard

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and astern, and shall be arranged so there is sufficient bulkhead space for the whiteboard, workstations and storage. Black out curtains on all Command Centre windows shall be supplied and installed.

BRIDGE

10.3.37 The size and layout of the Bridge shall accommodate both normal operations and Incident/Program Commander operations.

10.3.38 The Bridge shall be supplied and outfitted with navigational aids, communications and electronic equipment as per Section 9 and the following:

a. one (1) chart table with the top at least 1270 mm L x 890 mm D, 910 mm above the deck and with drawers and lockers underneath the table top; and

b. one (1) chart table lamp secured to bulkhead; and

c. three (3) administrative LAN connections not co-located; and

d. one (1) Flag locker; and

e. one (1) bookshelf, at least two (2) m L and 25 cm D; and

f. one (1) BCS to accommodate steering, navigation, communication, alarm, machinery controls and indicators, and auxiliary machinery monitors and controls; and

g. chairs for all consoles. They shall be Admiral Helm, or equivalent, adjustable type seats and a minimum of two (2) in total shall be supplied and installed. A fixed Captain's chair of the same type shall be supplied and installed for the master, positioned on the starboard side, as far forward as possible. It should be of a height to permit the master to see the upper edge of the bow while seated; and

h. one (1) each clock, barometer and barograph; and

i. one (1) inclinometer, the Chaney Instrument Co. Model MK IV or equivalent, shall be supplied and installed; and

j. one (1) magnetic compass shall be supplied and installed on the centreline; and

k. one (1) medical cabinet, including first aid kit shall be supplied and installed; and

l. stowage spaces for sextant, shapes, binocular boxes and lead lines shall be supplied and installed adjacent to the Helmsman's position; and

m. stowage space for binoculars shall be supplied and installed adjacent to the Captain's chair; and

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n. allocated storage space shall be supplied and installed for two (2) immersion suits and two (2) lifejackets; and

o. storm rails under all windows and at all consoles and control positions.

10.3.39 All navigational and electronic components shall be positioned so that they are readily visible from the BCS and do not obstruct general visibility from any other control position within the space. All navigation equipment and communication equipment that calls for continued use, such as gyro read-out, auto pilot, electronic charts, radar(s), echo sounder, etc., shall be favourably orientated for Bridge operations, and shall have dimmers.

10.3.40 Consoles shall be ergonomically designed and located for efficient and convenient visibility of, and access to, all equipment. Components on the display area of the console shall be logically grouped according to function and operational priorities.

10.3.41 The Bridge Wings shall extend to the ship's sides.

RAT PROOFING

10.3.42 Subject to the configuration of the bulwarks at the fairleads, rat proofing shall be accomplished by the nature of the construction rather than the use of additional fittings, plates and screens. In addition, enclosed inaccessible spaces shall be protected by permanent means. Inaccessible void spaces shall be rat proofed.

10.3.43 Circular openings shall not exceed 25 mm diameter and the side dimensions of square openings shall not exceed 25 mm. Openings in louvers and parallel-sided openings such as around doors and expanded metal bulkheads shall not exceed 10 mm in width. Deck gratings and portable flats in storerooms shall be constructed and fitted so that no openings are wider than 10 mm. Ventilation openings requiring rat proofing shall be fitted with rat proof screens.

10.4 STOREROOMS AND STOWAGE SPACES

GENERAL STORAGE SPACES OUTFIT

10.4.1 Storerooms and stowage spaces including lockers, cupboards and drawers shall be supplied and installed to provide stowage facilities for the ship's provisions, equipment or gear associated with the MSPV's functions. Lockers may be arranged in a common stowage space to afford convenience and economy of space. All storerooms and stowage spaces shall be fitted with locking arrangements. Shelving and stowage bins shall be supplied and installed in the stowage spaces. Stowage spaces shall be supplied and allocated for:

a. two (2) type B First Aid Kits, as per the Canadian Coast Guard Fleet Logistics Standard 400.00.07, metal construction and bulkhead mounted. The first kit shall be installed next to the medical equipment & SAR locker and the other shall be installed as designated by the TA; and

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b. a medical equipment & SAR locker at least 1.5 m L, 1.5 m D and 2.0 m H with shelves and a door shall be fitted; and

c. a Hazardous Medical Waste Receptacle, approximately 80 l, shall be stored in the medical equipment & SAR locker until proper disposal is later possible; and

d. a main Refrigerator (cool room) for provisions for 14 people for 14 days with adjustable shelves and interior lighting, easy to clean and situated on the same deck as the galley; and

e. a main Freezer (cold room) for provisions for 14 people for 14 days with adjustable shelves and interior lighting and easy to clean and situated on the same deck as the galley; and

f. a Dry Food Store sized to hold dry provisions for 14 people for 14 days situated on the same deck as the galley; and

g. a Central Storeroom sized to hold all items as detailed at Appendix 6 of the TSOR; and

h. a Linen Locker sized to hold all items as detailed at Appendix 7 of the TSOR; and

i. the laundry area shall be supplied and installed with the following:

i) two (2) sets of commercial quality, stackable front-loaded washer and dryers in stainless steel of at least 0.25 m3 each, with extra-large doors and drum openings and with no requirement to use money or debit card to operate. The dryer units shall be vented through a dedicated exhaust system to the MSPV exterior with suitable standpipe and weather tight closure; and

ii) one (1) single, stainless steel compartment sink mounted to the wall, with approximate dimensions 60 cm L x 36 D cm x 60 H cm. It shall drain to the grey water system; and

iii) one (1) heavy duty stainless steel faucet with at least two (2) m stainless steel hose and spray head, to reach and fill buckets on deck; and

iv) one (1) soap and one (1) paper towel dispenser; and

v) stainless steel cupboards and shelves for the stowage of soap, detergent, etc.; and

vi) one (1) folding ironing board fixed to the bulkhead for ironing and folding clothes; and

vii) one (1) closet rod 60 cm L for hanging clothes.

j. Cleaning Gear and Steward's Locker(s) sized to hold all items as detailed at Appendix 8 of the TSOR; and

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k. one (1) separate lockable Scientific Evidence Freezer (0.8 m^3) with tamper-proof hinges, located inside away from the elements; and

l. an Engineer's Spare Part Store approximately 10.0m^3 for the storage of maintenance gear, rag bins, small parts, fasteners and special instruments and tools; and

m. a minimum of three (3), approximately equally sized, lockers for Deck Stores (a minimum of 7.0 m^3 total) with stowage racks for the stowage of mooring and towing hawsers and other ropes, spare mooring gear, reels, fenders, scramble net, Jacob's Ladders, and two (2) long handled boat hooks and the SAR Equipment as required by Annex E of CCG Fleet Order 207.00 and identified for storage in this space by the CCG Fleet Order; and

n. a small after deck store approximately 1.0 m^3 for towing equipment as required in CCG Fleet Order 207.00 Annex E; and

o. a Paint Locker on the main deck with a separate ventilation system with the appropriate shelving and cabinets for ten (10) x 4.4 litre cans of paint and supplies; and

p. a Wet Gear Storeroom approximately 6.0 m^3 shall be located for direct access from the weather deck. It shall be vented to the outside, in accordance with paragraph 7.11.18, and heated, in accordance with paragraph 7.11.7, and shall be designed and built for direct access from the exposed main deck. It shall drain to the main deck. Racks shall be installed to facilitate the hanging-to-dry of fourteen (14) sets of wet weather gear in a manner that will allow easy potable water wash-down in accordance with paragraph 7.12.6n and drain off. The wet gear will consist of the following:

i) cold weather suit (floater) and work vests; and

ii) rain gear and work vests; and

iii) boots.

q. a Fire Fighting Equipment approximately 2.5 m^3 locker that opens to the weather deck for the firefighting equipment required by the regulations plus the firefighting equipment required by Annex E of CCG Fleet Order 207.00; and

r. a Fuel Oil Spill Control Locker approximately 1.5m^3 for oil-absorbent materials shall be located for direct access from the weather deck; and

s. a Hazardous Material (HAZMAT) locker approximately 1 m^3 accessible from the weather deck; and

t. a small locker approximately 1m x 0.7m x 0.7m on the Bridge for the miscellaneous equipment identified for storage in this space and required by Annex E of CCG Fleet Order 207.00 and pyrotechnics and other Bridge equipment required by Transport Canada; and

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u. Solid Waste Storage in the Garbage Handling Room, capable of storing four (4) 240 litre wheeled cart containers, and ventilated with weather deck access.

10.4.2 The Steering Gear Compartment may also be used as stowage spaces. All loose material stowed in the Steering Gear Compartment shall be contained in bins or lockers and properly secured to prevent it fouling the steering equipment. Passage between the stowage bins, lockers and steering equipment shall be no less than 610 mm wide and provide adequate maintenance envelope for the equipment installed in the compartment.

FENDERS

10.4.3 Six (6) portable fenders with suitable storage shall be supplied and installed onboard. The fenders supplied shall be approximately 66 cm in diameter and 100 cm H and therefore hold the MSPV approximately 50 cm off of the wharf in up to and including Sea State 2 as detailed at Appendix 3 of the TSOR.

WORKSHOP AND WORK AREA

10.4.4 A deck workshop and work area shall be supplied and installed and furnished with a workbench with the top work area approximately 1200 mm L x 760 mm D, approximately 940 mm above the deck.

10.4.5 One (1) washbasin shall be located close to the workbench.

GARBAGE AND TRASH STOWAGE

10.4.6 The MSPV shall have a well ventilated Garbage Handling Room as defined in TSOR paragraph 7.11.18, with weather deck access, for containers and bins to collect sorted garbage, recyclable material and regular waste, in accordance with CSA Garbage Pollution Prevention Regulations. All garbage stowage areas shall meet the requirements of the Canadian Labour Code Marine Occupational Safety and Health Regulations.

10.4.7 The Garbage Handling Room and trash compactor shall not be located adjacent to or within any messing area. Ventilation shall be fitted to the Garbage Handling Room to prevent accelerated decomposition of stored solid waste and exhaust ventilation shall be located to prevent short-circuiting into the MSPV's air intakes.

10.4.8 Space for four (4) waste containers, each having an internal volume of approximately 227 litres, shall be provided as follows:

a. food waste;

b. paper, books, fine cardboard, newspapers, magazine, corrugated cardboard;

c. metal cans and glass; and

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d. plastic.

10.4.9 Provisions shall be made on the MSPV to store sorted garbage for the maximum continuous duration of fourteen (14) days for fourteen (14) personnel based on the solid waste generation rate shown in Table 4 below.

Solid Waste Category	Generation Rate by Weight (kg/person-day)	Generation Rate Volume (litres/person-day)
Food	0.55	0.85
Paper and Cardboard	0.50	5.38
Metal and Glass	0.25	1.42
Plastic	0.10	4.25
Textiles	0.06	0.28
Daily Totals	1.46	12.48

TABLE 4 - ESTIMATED WASTE PRODUCTION

MAIN MACHINERY ROOM

10.4.10 A workbench shall be supplied and installed in the MMR with tool cabinet and tool box, with storage supplied and installed for special tools.

10.4.11 The MCR shall be located adjacent to the MMR and shall accommodate the CCAMS MCS. A chair and a steel desk with a durable marine grade laminate top shall be supplied and fitted. The desk dimensions shall be no less than 1.5 m L, 0.6m D, and 0.7 m H. The desk shall be supplied and installed with three (3) full depth drawers located at one end, one drawer shall be able to hang legal size folders. The desk shall be supplied and installed with an under mount, adjustable, retractable computer keyboard tray. The desk shall be well lit, with two (2) spare 115 V power outlets over and above the power supplies for necessary equipment.

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A.1 RIGID HULL INFLATABLE BOAT (RHIB) MARINE SECURITY VARIANT

The following are the required additional features to the base model of the Zodiac Hurricane H753 SAR Version.

ITEM	DESCRIPTION
Environmental Conditions	• Shall be capable of day and night operations in the following conditions: o Ambient air temperature range: -20.0°C to 35.0°C o Ambient water temperature range: -1.8°C to 30.0°C o Sea State 6 as detailed at Appendix 3 of the TSOR o Freezing spray or freezing rain with accumulations of up to 6.0mm while maintaining stability to allow for safe transit in Sea State 4 as detailed at Appendix 3 of the TSOR
Performance	• When fully loaded, range shall be at least 100.0 nm at 25.0 kts with 10% fuel reserve remaining • Shall be capable of maintaining maximum speed for up to and including 2 hours
Hull	• Shall be grey in colour • Deck covering shall be SKYDEX • The Kevlar© fibreglass beaching shoe that comes as standard equipment shall be grey in colour
Collar	• Shall be grey in colour • Shall be the foam-filled Durarib upgrade option • Shall have full-length anti-abrasion rubber strips fitted to both sides • The bottom of the collar and all wetted surfaces of the tube shall be fitted with a protective layer of material (EPDM or equivalent)
Seating	• Seating shall be in a 2 X 2 layout, 2 forward of the lifting arch, 2 aft • On the starboard side, a jockey style shock-absorbing type helm seat with control console shall be fitted side-by-side with another jockey style shock-absorbing seat with a combined Communications/Navigation console • The forward set of seats and consoles shall be a sufficient distance forward of the lifting arch and quick-release apparatus such that operators do not impact that arch while seated and underway in any sea conditions • The aft set of non-folding, jockey style shock-absorbing type seats with enclosed, lockable storage shall be fitted side by side immediately behind the forward set of seats and shall be similarly distanced from the lifting arch and quick-release apparatus such that the riders are not in danger of impacting those items in any sea conditions • Each seat shall have foldable foot rests • Hand bar(s) shall be fitted for each rider • Each seat shall have waterproof ballistic nylon seat covering or material of equivalent durability and waterproofing
Consoles	• Each console face shall be at an angle that maximizes console control operability, comfort and visibility when rider is in both a standing or sitting position

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	• Communication and navigational equipment shall be flush mounted into the consoles whenever possible, shall be weatherproof and, shall be supplied with protective coverings that are easily removable and lockable • Shall be manufactured from marine grade aluminum or fibreglass • One (1) additional accessory plug with screw on watertight cap shall be installed in the Helm console
Engines, Propellers & Steering Rams	• Each RHIB shall be fitted with twin 200 HP 4-stroke gasoline outboard engines of a type currently supported within Canada • Each outboard engine shall meet US EPA regulations for the control of emissions for marine spark ignition engines • There shall be an engine shut down, kill switch, mounted on the helm console • The propellers shall be stainless steel and of a pitch and diameter sufficient to achieve a speed of at least 45 kts in calm salt water, zero wind, when fully fuelled and, when carrying maximum payload of 500.0 kg including four (4) personnel and equipment • If not already supplied as standard equipment, there shall be individual propulsion leg trim controls and a SYNCRO trim switch to integrate the two (2) drive leg trim controls on one (1) switch • If not already supplied as standard equipment, the following instrumentation shall be supplied and installed on the driver's console: o Tachometer for each engine o Water pressure gauge for each engine o Hour meter for each engine o Ignition harness (mounted so that the ignition system cannot collect water) o Trim gauge o Fuel tank gauge(s) • RHIB draft with engines lowered shall be a maximum of one (1) metre • RHIB draft with engines raised shall be a maximum of 0.6 metres • Steering system rams shall have replaceable seals on the rams
Fasteners	• All fasteners shall be metric
Launch & Recovery Arrangements	• When fully fuelled (504 litres) and carrying maximum payload of 500.0 kg including four (4) personnel and equipment, the RHIB itself and all its launch/recovery arrangements and components shall be structurally capable of safely launching and recovering RHIBs in up to and including Sea State 5 at a vessel speed of up to five (5.0) kts • Shall be fully compatible with the MSPV's RHIB launch & recovery system • Shall be fully compatible with the MSPV's RHIB stowage arrangement
Antennas	• Three (3) shall be supplied and fitted to the righting arch o VHF for marine radio to comply with TCMS o UHF for RCMP radio o UHF for local law enforcement agency radio • Contractor shall supply and install all cabling and connectors from righting arch to communications console
Communications	• Contractor shall supply and install one (1) RayMarine model 215 DSC Marine

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	VHF radio, or equivalent • Contractor shall supply and install one (1) RayMarine model 430 Loud Hailer, or equivalent • Contractor shall supply and install one (1) DSM300 Digital Sound Module, or equivalent that interfaces with a Garmin integrated navigation package • Contractor will be later advised with respect to dimensional and power requirements for Contractor installation in the communications console of two (2) Government UHF radios
Navigation	• Contractor shall supply and install a four (4) kW Garmin radar and enclosed dome mounted on or above the righting arch • Contractor shall supply and install the Garmin radar display in the Navigation console and it shall be fully integrated to the radar, chart plotter and sonar through a Garmin integrated navigation package • Contractor shall supply and install a GPS antenna and receiver that is interfaced with the Garmin navigation package
Operations	• Contractor shall supply and install one (1) AIS 250 automatic identifier receiver • Contractor shall supply and install on the righting arch one (1) additional blue law enforcement high intensity strobe light • Contractor shall ensure that the supplied searchlight fitted to the righting arm is at least 1,000,000 candela and that the searchlight is remotely controllable • The remote control(s) for the searchlight shall be positioned such that the searchlight is operable by both the driver and the navigator from their seated positions • The two (2) Contractor-supplied handheld searchlights shall be 12V and at least 1,000,000 candela each • Additional deck floodlights shall be supplied and installed such that there are two (2) each for forward, aft, port & starboard for eight (8) in total
Miscellaneous	• The fuel filling inlets shall be fitted at the bow locker location onboard and shall be lockable • Fuel shutoff valves shall be installed at fuel tank outlets and must be readily accessible by vessel operators • The Contractor shall ensure the electromagnetic compatibility of all fitted navigation, communication, operations equipment and associated components • Retro-reflective tape shall not be affixed to any part of the RHIB • All electrical wiring shall be protected and all connections shall be waterproof • The Contractor-supplied electric bilge pumps shall be capable of pumping at least 4500 litres per hour and shall be installed one (1) per hull compartment • The electric bilge pump control switch shall be fitted to the driver's console with settings for 'on', 'off' and 'automatic operation'. There shall be an automatic float switch control fitted such that the electric bilge pump operates whenever the pump control switch is set to auto and there is water in the bilge • There shall be means fitted such that it is possible to drain both the forward and after hull compartments when the RHIB is out of the water • The RHIB shall be supplied and fitted with one (1) 2.5 m retractable type boat hook and two (2) paddles with securing holders

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	• In addition to the supplied fire extinguisher, two (2) Class 1 BC, marine type fire extinguishers and two (2) associated stowage holders shall be supplied and installed

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A.2 MISSION PERCENTAGES, PROFILES AND VESSEL UTILISATION

Primary Mission 75%: Fisheries Conservation and Protection Duties

Profile 1 – Day operation (a single 24 hour operation and return to port)	**Duration hrs**	**Speed kts**
Transit from Port to operating area	6	20.0
Loiter in operating area	8	2.0
Inter-area transit (economical speed)	4	14.0
Transit to Port from operating area	6	20.0

Profile 2 – Week operation (7 days away from port)	**Duration hrs**	**Speed kts**
Transit from Port to operating area	6	20.0
Inter-area transit (economical speed)	34	14.0
Loiter in operating area	24	2.0
Anchor in operating area	72	0
Berthed in port (away from home port)	24	0
Transit to Port from operating area	8	20.0

Profile 3 – 14 day operation	**Duration hrs**	**Speed kts**
Transit from Port to operating area	6	20.0
Inter-area transit (economical speed)	72	14.0
Loiter in operating area	94	2.0
Anchor in operating area	84	0
Berthed in port (away from home port)	72	0
Transit to Port from operating area	8	20.0

Secondary Mission 25%: Search and Rescue

Profile 4 – 4 day operation from home port	**Duration hrs**	**Speed kts**
Transit from Port to Rescue area	24	25.0
Rescue area search	62	4.0
Transit to nearest Port from rescue area	10	14.0

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Vessel Utilisation

At Sea:

Profile	Missions	Total days/ year
1	25	25
2	12	84
3	10	140
4	10	40
Other (same as profile 1)	20	20
Totals	77	309

Out of service:

Maintenance/refit: 35 days per year

Out of Service means that the vessel is not available for sea service and the vessel can be docked. Major equipment can be overhauled without expecting recall to service within the advised notice for service.

In Harbour:

Holidays, crew change, training, etc.: 21 days per year

It is considered that when the vessel is in harbour, it is available for sea service on not more than 60 minutes notice for departure. This means that the vessel is fully fuelled and stocked with provisions and mechanically available.

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A.3 SEA STATE TABLE

From "Sea Loads on Ships and Offshore Structures"
O.M. Faltinsen – Professor, Department of Marine Technology
Norwegian Institute of Technology

Table 2.3. Annual sea state occurrences in the North Atlantic and North Pacific (Lee et al., 1985)

Sea state no.	Significant wave height (m)		Sustained wind speed (knots)[a]		North Atlantic			North Pacific		
					Percentage probability of sea state	Modal wave period (s)		Percentage probability of sea state	Modal wave period (s)	
	Range	Mean	Range	Mean		Range[b]	Most probable[c]		Range[b]	Most probable[c]
0–1	0–0.1	0.05	0–6	3	0.70	—	—	1.30	—	—
2	0.1–0.5	0.3	7–10	8.5	6.80	3.3–12.8	7.5	6.40	5.1–14.9	6.3
3	0.5–1.25	0.88	11–16	13.5	23.70	5.0–14.8	7.5	15.50	5.3–16.1	7.5
4	1.25–2.5	1.88	17–21	19	27.80	6.1–15.2	8.8	31.60	6.1–17.2	8.8
5	2.5–4	3.25	22–27	24.5	20.64	8.3–15.5	9.7	20.94	7.7–17.8	9.7
6	4–6	5	28–47	37.5	13.15	9.8–16.2	12.4	15.03	10.0–18.7	12.4
7	6–9	7.5	48–55	51.5	6.05	11.8–18.5	15.0	7.00	11.7–19.8	15.0
8	9–14	11.5	56–63	59.5	1.11	14.2–18.6	16.4	1.56	14.5–21.5	16.4
>8	>14	>14	>63	>63	0.05	18.0–23.7	20.0	0.07	16.4–22.5	20.0

[a] Ambient wind sustained at 19.5 m above surface to generate fully-developed seas. To convert to another altitude, H_2, apply $V_2 = V_1(H_2/19.5)^{\frac{1}{7}}$.
[b] Minimum is 5 percentile and maximum is 95 percentile for periods given wave height range.
[c] Based on periods associated with central frequencies included in Hindcast Climatology.

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A.4 MESS ITEMS

DRAWERS shall be supplied and installed in the Mess pantry for all listed items of cutlery, utensils and linen.		**CUPBOARDS** shall be supplied and installed in the Mess pantry for ready-use dry food such as cereal, bread, peanut butter/jam, snacks and all listed items of crockery & glassware.	
Item	**Quantity**	**Item**	**Quantity**
Salad forks	36	Soup/stew bowls	18
Table forks	36	Cereal bowls	18
Steak knives	24	Salad bowls	18
Table knives	36	Breadbaskets 26.4 cm x 21 cm x 8.5 cm	4
Dessert spoons	36	Egg cups	28
Table spoons	36	Coffee cups	28
Dish towels 41 cm x 71 cm	12	Sundae dishes	18
Dish cloths 30 cm x 29 cm	12	Dessert dishes	8
Utility drawer insert	1	Sugar dispensers	3
		Glass goblet 10 oz	24
		Glass goblet 12 oz	24
		Dessert plates	24
		Dinner plates	36
		Salt shakers	4
		Pepper shakers	4
		Stainless steel salt shakers	2
		Stainless steel pepper shakers	2
		Plastic butter servers	4

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A.5 GALLEY ITEMS

Cupboards and drawers shall be supplied and installed in the Galley to provide stowage for all listed items of equipment and utensils.

Item	Quantity	Item	Quantity
Decorative icing bag		sauce 10 qt with SS	2
Canvas 12" bag	1	sauce 1qt with SS lid	2
Canvas 18" bag	1	sauté 12 "	1
Bag Icing – Tips (set) Sizes 1-8	1 kit	Potato Paring knife/Peeler	2
Melon ball cutter	1	Can piercer / bottle opener	2
Cutting board (Plastic boards) - 1 Large : 18''x12''x1'' and 1 Small : 14''x11''x1''	2	Rolling pin 15"	2
Bowl-Stainless Steel (SS)		Pitcher	
Mixing SS 1½ qt.	2	SS 2 qt open lip	6
Mixing SS 3 qt.	2	Plate	
Mixing SS 4 qt.	2	Pie SSl 10"	6
Mixing SS 8 qt.	2	Pie pizza 14"	6
Mixing SS 13 qt.	2	Pot	
Brush - Pastry	2	Cooking 9 qt SS	1
Brush-Nail and Hand	2	Cooking 12 qt SS with cover	1
Colander		Press – Garlic SS	1
SS 4w Base 13 quarts	1	Ladle	
SS Small	1	SS 1 oz.	1
Corer - Apple	1	SS 2 oz.	2
Corkscrew	1	SS 4 oz.	1
Cup		SS 6 oz	1
Measuring Alum. 8 oz.	1	Rack – Cake – Mesh 16 ¼ x 10 ¼	2
Measuring SS 16 oz.	1	Scale - Portion (Bakers) 1-10 lb (Electronic scale)	1
Measuring 4L	1	Scissors – 12"	2
Cutter	1	Scoop	
Cookie (Set)	1	Ice Cream 2 ¼ »	1
Doughnut	1	(Pan) Grocers Alum. 4"	1
Dredge		Grocers SS 6"	1
Flour	1	Scrapper	
Food processor (KitchenAid ™ 16 cup food processor KPFP850PM or equivalent)	1	Grill top	1
Mixer for soup (commercial model)	1	Bakers-SS	3
Shaker (commercial model)	1	Bowl-plastic	2
Funnel (medium, 13 oz)	1	Sieve-Flour	1
Grater / Shredder SS (4 sided)	1	Skewer (poultry) - 12/set	2
Juicer – Lemon	1	Skimmer-SS 6 ½"	1

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Knife		Slicer-Egg	1
Boning 6"	1	Spatula	
Bread 8"	2	Large Rubber	1
Chef-French 12"	1	Small Rubber	2
Chinese 8"	1	Bakers – SS 10 " x 1-5/8"	2
Cleaver 7"	1	Food Turner – SS 3" x 8"	1
Ham Slicing 12"	1	Off Set 3" x 8"	1
Paring 4"	2	Spoon	
Pie	2	Wooden 12 "	2
Pizza Wheel	1	Wooden 15''	2
Spreader 3 ½ "	2	Wooden 18 ''	2
Mixer (Hobart N50 Mixer or equivalent)	1	Serving Slotted SS 13''	2
Oven Mitts (commercial)	4 pairs	Serving Perforated SS 13"	2
Opener		Serving Solid 13"	2
Can (heavy blade)	2	Butchers 14''	1
Pan		Stone-Oil	1
Angel Food 9"	2	Strainer	
Bread: (2lb. loaf)- (4 pans per unit)	1	China-Cap-Large	1
Bun steel clad aluminum 18" x 26" x 1"	1	Thin Sieve	1
Bun steel clad aluminum 12" x 18" x 1"	2	Wire-Heavy Duty 10 ½"	1
Pan		Thermometer-Meat (Dial Type)	1
Cake rectangular 15" x 10" x 2"	2	Timer-Minute "Lux"	2
Cake round 10" x 2"	2	Tongs-Flat Spring	
Frying non stick steel clad	1	Steel 9"	2
aluminum omelet 7"	1	Steel 12"	2
Frying- cast iron 13"	1	Tongs-Spaghetti	1
Frying- non stick steel clad aluminum 15"	1	Tray-SS 16" x 20" Medium Gauge	4
Jelly roll 15" x 10" x ½"	1	Whip	
Muffin 13" x 10"	2	French SS 12"	1
Roasting 11 1/8" x 20"	2	French SS 14"	1
sauce 2 qt with SS lid	2	Piano SS 12"	1
		Potato hand whipper	1
sauce 5 qt with SS lid	2	Mandoline metal vegetable slicer	1

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A.6 CENTRAL STOREROOM

Central Storeroom space, complete with supplied and installed lockers, storage racks and shelves, shall be allocated within the MSPV to provide stowage for all listed items of protective clothing.

Protective Clothing Description	Quantity
Aprons - Food Handlers, White	6
Boots - Safety, Rubber, Hip	6
- Safety, Rubber, Knee	6
Cap - Food Handler	1 box of paper hats
Coveralls – Blue: 2 of each size (36 reg, 36 long, 40 short, 40 reg, 40 long, 44 short, 44 reg, 44 long, 48 short, 48 reg, 48 long)	22
Gloves:	
Cloth, Work	12
Leather, Work	12
Rubber, Small	3
Rubber, Medium	3
Rubber, Large	3
Helmet:	
Safety, White	3
Safety, Yellow	3
Strap - Chin, Safety Helmet	6
Liner - Safety Helmet	6
Overalls - Wet Weather: 1 of each size (36 reg, 36 long, 40 short, 40 reg, 40 long, 44 short, 44 reg, 44 long, 48 short, 48 reg, 48 long	11
Jacket Rain: 1 of each size (36 reg, 36 long, 40 short, 40 reg, 40 long, 44 short, 44 reg, 44 long, 48 short, 48 reg, 48 long)	11
Vest - Work , Floatation: (2 x size 36, 5 x size 40, 5 x size 44, 2 x size 48)	14
Cold Weather Suit (Floater): (2 x size 36, 5 x size 40, 5 x size 44, 2 x size 48)	14
Potable water bottles for water coolers (18.5 litres/bottle)	11

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A.7 LINEN LOCKER

Linen Locker shall be supplied and installed, complete with storage racks and shelves, to provide stowage for all listed items. The preferred locker location is in the vicinity of the Accommodation areas.

Description	**Quantity**
Heavy Quilted Bedspreads	16
Mattress covers	16
3 types of contour sheets: 22 cotton, 10 flannel, 10 micro fibre	42
3 types of flat sheets: 22 cotton, 10 flannel, 10 micro fibre	42
2 types of blankets: 6 wool and 8 polar	14
Pillows	4
Pillow covers	16
Pillow cases	16
Bath towels	32
Hand Towels	16
Face cloths	16
Bath mats	4
Laundry bags	16
Shower curtains	2
Shower curtain rings	20
Curtains for windows and portlights	4 spare curtains for windows and portlights
Curtains for the cabin doors	2 spare door curtains

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A.8 CLEANING GEAR AND STEWARD'S LOCKER(S)

CLEANING SUPPLIES and STEWARD'S LOCKER(S)
Locker(s), complete with racks and shelves, shall be supplied and installed to provide stowage for all listed items. The preferred locker location(s) is in the vicinity of the Galley or the Accommodation area.

Cleaning Supplies	Quantity		Steward's Stores	Quantity
Bag – Garbage, green	150		Batteries Flashlight, D cell	12
Bleach – Javex ™, 3.0 l, bottles	10		Flashlights (1 per berth)	14
Cleaning Compound			Broom	
Oven (liquid foam), cans	7		Corn, Whisk	2
Glass, Liquid, 1.0 l, bottles	7		Corn	2
Detergent			Push 14''	3
General purpose, liquid, 1.0 l, bottles	14		Push Broom	3
Laundry, powder, kgs	8		Brush	
Dishwashing Compound			Bannister	2
Liquid, 1.0 l, bottles	10		Toilet brush c/w holder	1 per washroom
Machine, powder, kgs	4		Scrub 6 ''	6
Disinfectant			Scrub 10''	4
Germicidal and Fungicidal	1 gallon		Turkshead 5'' c/w handle	6
Hand Cleaner			Bucket	
Abrasive, 1.0 l, bottles	6		Oval Mop c/w wheels	3
Waterless, 1.0 l, bottles	6		Wringer for Oval Bucket	1
Napkins, Paper	1 case		Mop	
Paper			Wet Spring Type	2
Toilet, 2-ply	72 rolls		Wet, Head Cotton	4
Wax, HD 18'' x 100'	1 roll		Dry, Dust 14 ''	2
Towel - Paper	1 case		Yacht, Cotton	4
Polish			Padlocks	6
Metal , Brass, 0.5 l, cans	2		Pail - Plastic , 8-10 qt.	6
Metal , Silver, 0.5 l, cans	2		Pans - Dust	4
Stainless Steel (Aerosol)	1 litre		Plunger, Toilet	4
Soap			Rags, Wiping	1 case
Toilet, White, bars	72		Scissors, 12''	1 per desk
Wrap			Scrubber - Deck c/w Rubber Squeeze and Handle.	4
Aluminum Foil, 18'' x 450'	1 roll		J-cloths	24 packs
Cellophane, 18" x 1000'	1 roll		Sponge, synthetic	12
			Pot Scrubbers, Metal Brass	12

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Cleaning Supplies	Quantity		Steward's Stores	Quantity
			Squeegee - Glass 10 '' c/w handle	2
			Vacuum Cleaner - Wet/ Dry type c/w attachments	2 (one 5 and one 8 gallons)

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RULES FOR CLASSIFICATION OF

High Speed, Light Craft and Naval Surface Craft

PART 0 CHAPTER 6

INTRODUCTION

IMO High Speed Craft Code

JANUARY 2011

This chapter has been amended since the main revision (January 2011), most recently in July 2011.
See "Changes" on page 3.

The electronic pdf version of this document found through http://www.dnv.com is the officially binding version

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FOREWORD

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The Rules lay down technical and procedural requirements related to obtaining and retaining a Class Certificate. It is used as a contractual document and includes both requirements and acceptance criteria.

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CHANGES

General

As of October 2010 all DNV service documents are primarily published electronically.

In order to ensure a practical transition from the "print" scheme to the "electronic" scheme, all rule chapters having incorporated amendments and corrections more recent than the date of the latest printed issue, have been given the date January 2011.

An overview of DNV service documents, their update status and historical "amendments and corrections" may be found through http://www.dnv.com/resources/rules_standards/.

Amendments July 2011

- **General**

— The restricted use legal clause found in Pt.1 Ch.1 Sec.4 has been added also on the front page.

Main changes

Since the previous edition (July 2008), this chapter has been amended, most recently in January 2009. All changes previously found in Pt.0 Ch.1 Sec.3 have been incorporated and a new date (January 2011) has been given as explained under "General".

In addition, the layout has been changed to one column in order to improve electronic readability.

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SECTION 1
PRINCIPLES OF APPLICATION OF THE HSC CODE

A. General

A 100 HSLC rules

101 The HSLC rules are applicable to a variety of craft, some under international conventions, some under domestic legislation only and others under no regulations other than voluntary classification rules. This section states the principles of application of the HSLC rules and relation to the HSC Code.

102 The basic requirements of the rules given by the class notation **1A1** as specified by Part 2, 3 and 4 are valid for all craft regardless of the safety certificate to be issued.

103 The type and service notations **Passenger, Cargo, Patrol** etc. specify the general requirements to the craft in addition to the **1A1** requirements.

104 The additional equipment requirements **E0, NAUT** etc. specify extra voluntary requirements to any HSLC.

A 200 DSC Code

201 The Code of Safety for Dynamically Supported Craft (DSC Code) has been the basis for the HSLC rules in the period from the 1985 edition to the 1996 edition of the rules.

202 This DSC Code does not apply to any craft the keel of which is laid or which is subject to repairs, alterations or modifications of a major character, on or after 96.01.01.

203 For craft constructed and in service under the DSC Code, this Code is still valid standard although guidance in the interpretation of the DSC Code may be obtained from the HSC Code.

A 300 HSC Code

301 The International Code of Safety for High Speed Craft (HSC Code) replaces the DSC Code as basis for HSLC under international legislation.

302 The HSC Code applies from 1 July 1996 to the notations **Passenger, Car Ferry** and **Cargo** in international trade for the distance from safe harbour in accordance with the Code.

303 The HSC Code does not apply to the full extent to the notations **Crew, Yacht** and **Patrol** although many of the requirements are equivalent.

304 The present HSLC rules reflect the basic philosophy of the HSC Code and the requirements are applied in the various Parts and Chapters of the rules to the extent found applicable by the Society.

305 Text quoted from the International Code of Safety for High Speed Craft is printed in *italics*.

B. Application

B 100 Non-convention craft

101 Craft with the type and service notations **Patrol, Yacht** and **Crew** may be given a letter of compliance on those parts of the HSC Code which may have been applied for the actual craft.

B 200 Domestic trade

201 HSLC with the notations **Passenger, Car Ferry** or **Cargo** in domestic trade and service restriction **R3, R4** or **R5** may be classed based on compliance with domestic legislation as far as this is found equivalent to the standard of the HSC Code by the flag state.

202 Such equivalent requirements shall be referred to in the appendix of the class certificate and the corresponding requirements of the rules which they replace and it is to be specified that the craft is built for domestic trade.

B 300 International trade

301 For international trade compliance with the HSC Code shall be provided. Full compliance with the technical part of the HSC Code covered by the class is provided for craft with service restrictions **R0, R1** and **R2**.

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Guidance note:
Additional requirements given by other Codes and Conventions than SOLAS such as ILLC and MARPOL may be applicable to the craft as decided by the flag state.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

C. IMO Regulations

C 100 Chapter X of SOLAS

101 The HSC Code becomes a mandatory part of SOLAS by chapter X, of which the relevant part is quoted below:

SAFETY MEASURES FOR HIGH SPEED CRAFT

Regulation 1 - Definitions

For the purpose of this chapter:

1 *'High Speed Craft Code (HSC Code)' means the International Code of Safety for High Speed Craft adopted by the Maritime Safety Committee of the Organization by resolution MSC.36(63), as may be amended by the Organization, provided that such amendments are adopted, brought into force and take effect in accordance with the provisions of article VIII of the present Convention concerning the amendment procedures applicable to the Annex other than chapter I.*

2 *'High speed craft' is a craft capable of maximum speed equal to or exceeding:*

$$3.7\ \nabla^{0.1667} \quad \text{(m/s)}$$

where:

∇ = *displacement corresponding to the design waterline (m^3).*

3 *The expression 'craft constructed' means a craft the keel of which is laid or which is at a similar stage of construction.*

4 *The term 'similar stage of construction' means a stage at which:*

.1 *construction identifiable with a specific craft begins; and*

.2 *assembly of that craft has commenced comprising at least 50 tonnes or 1% of the estimated mass of a/ / structural material, whichever is less.*

Regulation 2 - Application

1 *This chapter applies to high speed craft constructed on or after 1 January 1996 which are engaged in international voyages.*

C 200 Preamble of the HSC Code

1 *The international conventions ratified in respect of conventional ships and the regulations applied as a consequence of such conventions have largely been developed having in mind the manner in which conventional ships are constructed and operated. Traditionally, ships have been built of steel and with the minimum of operational controls. The requirements for ships engaged on long international voyages are therefore framed in such a way that, providing the ship is presented for survey and a ship safety certificate is issued, the ship may go anywhere in the world without any operational restrictions being imposed. Providing the ship is not involved in a casualty, all that is needed is that it is made available to the Administration for the purpose of a satisfactory resurvey before the ship safety certificate expires and the certificate will be reissued.*

2 *The traditional method of regulating ships should not be accepted as being the only possible way of providing an appropriate level of safety. Nor should it be assumed that another approach, using different criteria, could not be applied. Over a long period of years, numerous new designs of marine vehicles have been developed and have been in service. While these do not fully comply with the provisions of the international conventions relating to conventional ships built of steel, they have demonstrated an ability to operate at an equivalent level of safety when engaged on restricted voyages under restricted operational weather conditions and with approved maintenance and supervision schedules.*

3 *This Code has been derived from the previous Code of Safety for Dynamically Supported Craft (DSC) adopted by IMO in 1977. The Code recognized that safety levels can be significantly enhanced by the infrastructure associated with regular service on a particular route, whereas the conventional ship safety philosophy relies on the ship being self-sustaining with all necessary emergency equipment being carried on board. This revised Code has been prepared in recognition of the growth in size and types of high speed craft now existing and is intended to facilitate future research and development of fast sea transportation in order that they may be accepted internationally.*

4 *The safety philosophy of this Code is based on the management and reduction of risk as well as the traditional*

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philosophy of passive protection in the event of an accident. Management of risk through accommodation arrangement, active safety systems, restricted operation, quality management and human factors engineering should be considered in evaluating safety equivalent to current conventions. Application of mathematical analysis should be encouraged to assess risk and determine the validity of safety measures.

5 *The Code takes into account that a high speed craft is of a fight displacement compared with a conventional ship. This displacement aspect is the essential parameter to obtain fast and competitive sea transportation and consequently this Code allows for use of non-conventional shipbuilding materials, provided that a safety standard at least equivalent to conventional ships is achieved.*

6 *To clearly distinguish such craft, criteria based on speed and volumetric Froude number have been used to delineate those craft to which this Code applies from other, more conventional, craft.*

7 *The Code requirements also reflect the additional hazards which may be caused by the high speed compared with conventional ship transportation. Thus, in addition to the normal requirements including life-saving appliances, evacuation facilities, etc., provided in case of an accident occurring, further emphasis is placed on reducing the risk of hazardous situations arising. Some advantages result from the high speed craft concept, i.e. the light displacement provides a large reserve buoyancy in relation to displacement, reducing the hazards addressed by the International Load Line Convention. The consequences of other hazards such as of collision at high speed are balanced by more stringent navigational and operational requirements and specially developed accommodation provisions.*

8 *The above-mentioned safety concepts were originally reflected in the Code of Safety for Dynamically Supported Craft. The development of novel types and sizes of craft has led to the development of pressures within the maritime industry for craft which are not dynamically supported cargo craft, passenger craft carrying larger numbers of passengers or operating further afield than permitted by that Code to be certified according to those concepts. Additionally, improvements of maritime safety standards since 1977 were required to be reflected in the revisions of the Code to maintain safety equivalence with conventional ships.*

9 *Accordingly, two differing principles of protection and rescue were developed.*

10 *The first of these recognizes the craft which were originally foreseen at the time of development of the DSC Code. Where rescue assistance is readily available and the total number of passengers is limited, a reduction in passive and active protection may be permitted. Such craft are called "assisted craft" and form the basis for "category A passenger craft" of this Code.*

11 *The second concept recognizes the further development of high speed craft into larger craft. Where rescue assistance is not readily available or the number of passengers is unlimited, additional passive and active safety precautions are required. These additional requirements provide for an area of safe refuge on board, redundancy of vital systems, increased watertight and structural integrity and full fire-extinguishing capability. Such craft are called "unassisted craft" and form the basis for "cargo craft" and "category B passenger craft" of this Code.*

12 *These two concepts of the Code have been developed as a unified document on the basis that an equivalent level of safety to that normally expected on ships complying with the International Convention for the Safety of Life at Sea is achieved. Where the application of new technology or design indicates an equivalent safety level to the strict application of the Code, the Administration is permitted to formally recognize such equivalence.*

13 *It is important that an Administration, in considering the suitability of a high speed craft under this Code, should apply all sections of the Code because non-compliance with any part of the Code could result in an imbalance which would adversely affect the safety of the craft, passengers and crew. For a similar reason, modifications to existing craft, which may have an effect on safety, should be approved by the Administration.*

14 *In developing the Code, it has been considered desirable to ensure that high speed craft do not impose unreasonable demands on existing users of the environment or conversely suffer unnecessarily through lack of reasonable accommodation by existing users. Whatever burden of compatibility there is, it should not necessarily be laid wholly on the high speed craft.*

C 300 Chapter 1 of the HSC Code: "General comments and requirements"

301 The following text is quoted from Chapter 1 of the HSC Code:

1.1 General comments

This Code should be applied as a complete set of comprehensive requirements. It contains requirements for the design and construction of high speed craft engaged on international voyages, the equipment which should be provided and the conditions for their operation and maintenance. The basic aim of the Code is to set levels of safety which are equivalent to those of conventional ships required by the International Convention for the Safety of Life at Sea, 1974, as amended, (SOLAS Convention) and International Convention on Load Lines, 1966 (Load Line Convention) by the application of constructional and equipment standards in conjunction with strict operational controls.

These rules contain additional requirements compared to the HSC Code to fulfil the expressed aim of the HSC Code to be a complete alternative to both the SOLAS Convention and the Load Line Convention. The additional requirements are related to the main watertight bulkheads including collision bulkhead, watertight

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and weathertight closing appliances such as doors and hatches, window glass thicknesses and the amount of reserve buoyancy provided by the freeboard as required by the previous Code of Safety for Dynamically Supported Craft (the DSC Code), adopted as IMO res. A.373(X).

The HSC Code does not aim to cover requirements related to pollution prevention, and the MARPOL Convention has to be dealt with separately.

1.2 General requirements

The application of the provisions of this Code is subject to the following general requirements that:

.1 *the Code will be applied in its entirety:*

.2 *the management of the company operating the craft exercises strict control over its operation and maintenance by a quality management system *;*

.3 *the management ensures that only persons qualified to operate the specific type of craft used on the intended route are employed;*

.4 *the distances covered and the worst intended conditions in which operations are permitted will be restricted by the imposition of operational limits;*

.5 *the craft will at all times be in reasonable proximity to a place of refuge;*

.6 *adequate communications facilities, weather forecasts and maintenance facilities are available within the area of operation;*

.7 *in the intended area of operation there will be suitable rescue facilities readily available;*

.8 *areas of high fire risk such as machinery spaces and special category spaces are protected with fire-resistant materials and fire-extinguishing systems to ensure, as far as is practicable, containment and rapid extinguishing of fire;*

.9 *efficient facilities are provided for the rapid and safe evacuation of all persons into survival craft;*

.10 *that all passengers and crew are provided with seats;*

.11 *that no enclosed sleeping berths for passengers are provided;*

.12 *where the Administration has made a comprehensive review of the adequacy of the fire safety measures and evacuation procedures for the crew accommodation, sleeping berths for crew may be permitted.*

* *Refer to the International Safety Management (ISM) Code adopted by the Organization (IMO) by resolution A.741(18)*

1.3 Application

1.3.1 *This Code applies to high speed craft which are engaged in international voyages.*

1.3.2 *This Code applies to:*

.1 *passenger craft which do not proceed in the course of their voyage more than 4 h at operational speed from a place of refuge when fully laden; and*

.2 *cargo craft of 500 tons gross tonnage and over which do not proceed in the course of their voyage more than 8 h at operational speed from a place of refuge when fully laden.*

1.3.3 *This Code, unless expressly provided otherwise, does not apply to:*

.1 *craft of war and troopcraft;*

.2 *craft not propelled by mechanical means;*

.3 *wooden craft of primitive built;*

.4 *pleasure craft not engaged in trade; and*

.5 *fishing craft.*

1.3.4 *This Code does not apply to craft solely navigating the Great Lakes of North America and the River St. Lawrence as far east as a straight line drawn from Cap des Rosiers to West Point, Anticosti Island and, on the north side of Anticosti Island, the 63rd meridian.*

1.3.5 *The application of this Code should be verified by the Administration and be acceptable to the Governments of the States to which the craft will be operating.*

1.4 Definitions

For the purpose of this Code, unless expressly provided otherwise, the terms used therein have the meanings defined in the following paragraphs. Additional definitions are given in the general parts of the various chapters.

1.4.1 *"Administration" means the Government of the State whose flag the craft is entitled to fly.*

1.4.2 *"Air-cushion vehicle" (ACV) is a craft such that the whole or a significant part of its weight can be supported, whether at rest or in motion, by a continuously generated cushion of air dependent for its effectiveness on the proximity of the surface over which the craft operates.*

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1.4.3 *"Auxiliary machinery spaces" are spaces containing internal combustion engines of power output up to and including 110 kW driving generators, sprinkler, drencher or fire pumps, bilge pumps, etc., oil filling stations, switchboards of aggregate capacity exceeding 800 kW, similar spaces and trunks to such spaces.*

1.4.4 *"Auxiliary machinery spaces having little or no fire risk" are spaces such as refrigerating, stabilizing, ventilation and air conditioning machinery, switchboards of aggregate capacity 800 kW or less, similar spaces and trunks to such spaces.*

1.4.5 *"Base port" is a specific port identified in the route operational manual and provided with:*

.1 *appropriate facilities providing continuous radio communications with the craft at all times while in ports and at sea;*

.2 *means for obtaining a reliable weather forecast for the corresponding region and its due transmission to all craft in operation;*

.3 *for a category A craft, access to facilities provided with appropriate rescue and survival equipment; and*

.4 *access to craft maintenance services with appropriate equipment.*

1.4.6 *"Base port State" means the State in which the base port is located.*

1.4.7 *"Breadth (B) means breadth of the broadest part of the moulded watertight envelope of the rigid hull, excluding appendages, at or below the design waterline in the displacement mode with no lift or propulsion machinery active.*

1.4.8 *"Cargo craft" is any high speed craft other than passenger craft, and which is capable of maintaining the main functions and safety systems of unaffected spaces, after damage in any one compartment on board.*

1.4.9 *"Cargo spaces" are all spaces other than special category spaces used for cargo and trunks to such spaces.*

1.4.10 *"Category A craft" is any high speed passenger craft:*

.1 *operating on a route where it has been demonstrated to the satisfaction of the flag and port States that there is a high probability that in the event of an evacuation at any point of the route, all passengers and crew can be rescued safely within the least of:*

- *the time to prevent persons in survival craft from exposure causing hypothermia in the worst intended conditions,*
- *the time appropriate with respect to environmental conditions and geographical features of the route, or*
- *4 h; and*

.2 *carrying not more than 450 passengers.*

1.4.11 *"Category B craft" is any high speed passenger craft, other than a category A craft, with machinery and safety systems arranged such that, in the event of damage disabling any essential machinery and safety systems in one compartment, the craft retains the capability to navigate safely.*

1.4.12 *"Continuously manned control station" is a control station which is continuously manned by a responsible member of the crew while the craft is in normal service.*

1.4.13 *"Control stations" are those spaces in which the craft's radio or navigating equipment or the emergency source of power and emergency switchboard are located, or where the fire recording or fire control equipment is centralized, or where other functions essential to the safe operation of the craft such as propulsion control, public address, stabilization systems, etc., are located.*

1.4.14 *"Convention" means the International Convention for the Safety of Life at Sea, 1974, as amended.*

1.4.15 *"Crew accommodation" are those spaces allocated for the use of the crew, and include cabins, sick bays, offices, lavatories, lounges and similar spaces.*

1.4.16 *"Critical design conditions" means the limiting specified conditions chosen for design purposes, which the craft should keep in displacement mode. Such conditions should be more severe than the worst intended conditions by a suitable margin to provide for adequate safety in survival condition.*

1.4.17 *"Design waterline" means the waterline corresponding to the maximum operational weight of the craft with no lift or propulsion machinery active and is limited by the requirements of chapters 2* (Pt.3 Ch.6 Sec.1) *and 3* (Ch.4 Sec.4).

1.4.18 *"Displacement mode" means the regime, whether at rest or in motion, where the weight of the craft is fully or predominantly supported by hydrostatic forces.*

1.4.19 *"Failure mode and effect analysis (FMEA)" is an examination, in accordance with annex 4 (*Ch.4 Sec.2*), of the craft's systems and equipment to determine whether any reasonably probable failure or improper operation can result in a hazardous or catastrophic effect.*

1.4.20 *"Flap" means an element formed as integrated part of, or an extension of, a foil, used to adjust the hydro- or aerodynamic lift of the foil.*

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1.4.21 *"Flashpoint" means a flashpoint determined by a test using the closed cup apparatus referenced in the International Maritime Dangerous Goods (IMDG) Code.*

1.4.22 *"Foil" means a profiled plate or three dimensional construction at which hydrodynamic lift is generated when the craft is under way.*

1.4.23 *"Fully submerged foil" means a foil having no lift components piercing the surface of the water in the foilborne mode.*

1.4.24 *"High speed craft" is a craft capable of maximum speed equal to or exceeding:*

$$3.7\,\nabla^{0.1667} \quad \text{(m/s)}$$

where:

∇ = *displacement corresponding to the design waterline (m3).*

1.4.25 *"Hydrofoil boat" is a craft which is supported above the water surface in non-displacement mode by hydrodynamic forces generated on foils.*

1.4.26 *"Length (L)" means the overall length of the underwater watertight envelope of the rigid hull, excluding appendages, at or below the design waterline in the displacement mode with no lift or propulsion machinery active.*

1.4.27 *"Lightweight" is the displacement of the craft in tonnes without cargo, fuel, lubricating oil, ballast water, fresh water and feedwater in tanks, consumable stores, passengers and crew and their effects.*

1.4.28 *"Machinery spaces" are spaces containing internal combustion engines with aggregate total power output of more than 110 kW, generators, oil fuel units, propulsion machinery, major electrical machinery and similar spaces and trunks to such spaces.*

1.4.29 *"Maximum operational weight" means the overall weight up to which operation in the intended mode is permitted by the Administration.*

1.4.30 *"Maximum speed" is the speed achieved at the maximum continuous propulsion power for which the craft is certified at maximum operational weight and in smooth water.*

1.4.31 *"Muster station" is an area where passengers can be gathered in the event of an emergency, given instructions and prepared to abandon the craft, if necessary. The passenger spaces may serve as muster stations if all passengers can be instructed there and prepared to abandon the craft.*

1.4.32 *"Non-displacement mode" means the normal operational regime of a craft when non-hydrostatic forces substantially or predominantly support the weight of the craft.*

1.4.33 *"Oil fuel unit" is the equipment used for the preparation of oil fuel for delivery to an oil-fired boiler, or equipment used for the preparation for delivery of heated oil to an internal combustion engine, and includes any oil pressure pumps, filters and heaters dealing with oil at a pressure of more than 0.18 N/mm^2.*

1.4.34 *"Open vehicle spaces" are spaces:*

.1 *to which any passengers carried have access;*

.2 *intended for carriage of motor vehicles with fuel in their tanks for their own propulsion; and*

.3 *either open at both ends, or open at one end and provided with adequate natural ventilation effective over their entire length through permanent openings in the side plating or deckhead or from above.*

1.4.35 *"Operating compartment" means the enclosed area from which the navigation and control of the craft is exorcized.*

1.4.36 *"Operating station " means a confined area of the operating compartment equipped with necessary means for navigation, manoeuvring and communication, and from where the functions of navigating, manoeuvring, communication, commanding, conning and lockout are carried out.*

1.4.37 *"Operational speed" is 90% of the maximum speed.*

1.4.38 *"Organization" means the International Maritime Organization.*

1.4.39 *"Passenger" is every person other than:*

.1 *the master and members of the crew or other persons employed or engaged in any capacity on board a craft on the business of that craft; and*

.2 *a child under one year of age.*

1.4.40 *"Passenger craft" is a craft which carries more than twelve passengers.*

1.4.41 *"Place of refuge" is any naturally or artificially sheltered area which may be used as a shelter by a craft under conditions likely to endanger its safety.*

1.4.42 *"Public spaces" are those spaces allocated for the passengers and include bars, kiosks, smoke rooms, main seating areas, lounges, dining rooms, recreation rooms, lobbies, lavatories and similar permanently enclosed spaces allocated for passengers.*

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1.4.43 *"Service spaces" are those enclosed spaces used for pantries containing food warming equipment but no cooking facilities with exposed heating surfaces, lockers, sales shops, store-rooms and enclosed baggage rooms.*

1.4.44 *"Significant wave height" is the average height of the one third highest observed wave heights over a given period.*

1.4.45 *"Special category spaces" are those enclosed spaces intended for the carriage of motor vehicles with fuel in their tanks for their own propulsion, into and from which such vehicles can be driven and to which passengers have access, including spaces intended for the carriage of cargo vehicles.*

1.4.46 *Surface effect ship" (SES) is an air-cushion vehicle whose cushion is totally or partially retained by permanently immersed hard structures.*

1.4.47 *"Transitional mode" means the regime between displacement and non-displacement modes.*

1.4.48 *"Worst intended conditions" means the specified environmental conditions within which the intentional operation of the craft is provided for in the certification of the craft. This should take into account parameters such as the worst conditions of wind force allowable, significant wave height (including unfavourable combinations of length and direction of waves), minimum air temperature, visibility and depth of water for safe operation and such other parameters as the Administration may require in considering the type of craft in the area of operation.*

1.5 Surveys

1.5.1 *Each craft should be subject to the surveys specified below:*

.1 *an initial survey before the craft is put in service or before the certificate is issued for the first time;*

.2 *a renewal survey at intervals specified by the Administration but not exceeding 5 years except where 1.8.5 or 1.8.10 is applicable;*

.3 *a periodical survey within three months before or after each anniversary date of the certificate; and*

.4 *an additional survey as the occasion arises.*

1.5.2 *The surveys referred to in 1.5.1 should be carried out as follows:*

.1 *the initial survey should include:*

.1.1 *an appraisal of the assumptions made and limitations proposed in relation to loadings, environment, speed and manoeuvrability;*

.1.2 *an appraisal of the data supporting the safety of the design obtained as appropriate from calculations, tests and trials;*

.1.3 *a failure mode and effect analysis as required by this Code;*

.1.4 *an investigation into the adequacy of the various manuals to be supplied to the craft; and*

.1.5 *a complete inspection of the structure, safety equipment, radio installations and other equipment. fittings, arrangements and materials to ensure that they comply with the requirements of the Code, are in satisfactory condition and are fit for the service for which the craft is intended;*

.2 *the renewal and periodical surveys should include a complete inspection of the structure, including the outside of the craft's bottom and related items, safety equipment, radio installations and other equipment as referred to in 1.5.2.1 to ensure that they comply with the requirements of the Code, are in satisfactory condition and are fit for the service for which the craft is intended. The inspection of the craft's bottom should be conducted with the craft out of the water under suitable conditions for close-up examination of any damaged or problem areas; and*

.3 *an additional survey, either general or partial according to the circumstances, should be made after a repair resulting from investigations prescribed in 1.7.3, or wherever any important repairs or renewals are made. The survey should be such as to ensure that the necessary repairs or renewals have been effectively made, that the material and workmanship of such repairs or renewals are in all respects satisfactory, and that the craft complies in all respects with the requirements of the Code.*

1.5.3 *The periodical surveys referred to in 1.5.1.3 should be endorsed on the High Speed Craft Safety Certificate.*

1.5.4 *The inspection and survey of the craft, so far as regards the enforcement of the provisions of the Code, should be carried out by officers of the Administration. The Administration may, however, entrust the inspections and surveys either to surveyors nominated for the purpose or to organizations recognized by it.*

1.5.5 *An Administration nominating surveyors or recognizing organizations to conduct inspections and surveys as set forth in 1.5.4 should, as a minimum, empower any nominated surveyor or recognized organization to:*

.1 *require repairs to a craft; and*

.2 *carry out inspections and surveys if requested by the appropriate authorities of a port State.*

The Administration should notify the Organization of the specific responsibilities and conditions of the authority delegated to nominated surveyors or recognized organizations.

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1.5.6 *When a nominated surveyor or recognized organization determines that the condition of the craft or its equipment does not correspond substantially with the particulars of the certificate or is such that the craft is not fit to operate without danger to the craft or persons on board, such surveyor or organization should immediately ensure that corrective action is taken and should, in due course, notify the Administration. If such corrective action is not taken the certificate should be withdrawn and the Administration should be notified immediately; and, if the craft is in an area under the jurisdiction of another Government, the appropriate authorities of the port State should be notified immediately. When an officer of the Administration, a nominated surveyor or recognized organization has notified the appropriate authorities of the port State, the Government of the port State concerned should give such officer, surveyor or organization any necessary assistance to carry out their obligations under this section. When applicable, the Government of the port State concerned should ensure that the craft should not continue to operate until it can do so without danger to the craft or the persons on board.*

1.5.7 *In every case, the Administration should fully guarantee the completeness and efficiency of the inspection and survey, and should undertake to ensure the necessary arrangements to satisfy this obligation.*

1.6 Approvals

The owner of a craft should accept the obligation to supply sufficient information to enable the Administration to fully assess the features of the design. It is strongly recommended that the owner and Administration and, where appropriate, the port State or States, commence discussions at the earliest possible stage so that the Administration may fully evaluate the design in determining what additional or alternative requirements should be applied to the craft to achieve the required level of safety.

1.7 Maintenance of conditions after survey

1.7.1 *The condition of the craft and its equipment should be maintained to conform with the provisions of this Code to ensure that the craft in all respects will remain fit to operate without danger to the craft or the persons on board.*

1.7.2 *After any survey of the craft under 1.5 has been completed, no change should be made to structure, equipment, fittings, arrangements and materials covered by the survey, without the sanction of the Administration.*

1.7.3 *Whenever an accident occurs to a craft or a defect is discovered, either of which affects the safety of the craft or the efficiency or completeness of structure, equipment, fittings, arrangements and materials, the person in charge or owner of the craft should report at the earliest opportunity to the Administration, the nominated surveyor or recognized organization responsible, who should cause investigations to be initiated to determine whether a survey, as required by 1.5, is necessary. If the craft is in an area under the jurisdiction of another Government, the person in charge or the owner should also report immediately to the appropriate authorities of the port State and the nominated surveyor or recognized organization should ascertain that such a report has been made.*

1.8 High Speed Craft Safety Certificate

1.8.1 *A certificate called a High Speed Craft Safety Certificate is issued after completion of an initial or renewal survey to a craft which complies with the requirements of the Code. The certificate should be issued or endorsed either by the Administration or by any person or organization recognized by it. In every case, that Administration assumes full responsibility for the certificate.*

1.8.2 *A Contracting Government to the Convention may, at the request of the Administration, cause a craft to be surveyed and, if satisfied that the requirements of the Code are complied with, should issue or authorize the issue of a certificate to the craft and, where appropriate, endorse or authorize the endorsement of a certificate on the craft in accordance with the Code. Any certificate so issued should contain a statement to the effect that it has been issued at the request of the Government of the State the flag of which the craft is entitled to fly, and it should have the same force and receive the same recognition as a certificate issued under 1.8.1.*

1.8.3 *The certificate should be that of the model given in annex 1 to the Code. If the language used is neither English nor French, the text should include a translation into one of these languages.*

Guidance note:
Annex 1 of the HSC Code is not included in the HSLC Rules.

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1.8.4 *The High Speed Craft Safety Certificate should be issued for a period specified by the Administration which should not exceed five years.*

1.8.5 *Notwithstanding the requirements of 1.8.4, when the renewal survey is completed within three months before the expiry date of the existing certificate, the new certificate should be valid from the date of completion of the renewal survey to a date not exceeding five years from the date of expiry of the existing certificate.*

1.8.6 *When the renewal survey is completed after the expiry date of the existing certificate, the new certificate should be valid from the date of completion of the renewal survey to a date not exceeding five years from the date of expiry of the existing certificate.*

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1.8.7 *When the renewal survey is completed more than three months before the expiry date of the existing certificate, the new certificate should be valid from the date of completion of the renewal survey to a date not exceeding five years from the date of completion of the renewal survey.*

1.8.8 *If a certificate is issued for a period of less than five years, the Administration may extend the validity of the certificate beyond the expiry date to the maximum period specified in 1.8.4, provided that the surveys when a certificate is issued for a period of five years are carried out.*

1.8.9 *If a renewal survey has been completed and a new certificate cannot be issued or placed on board the craft before the expiry date of the existing certificate, the person or organization authorized by the Administration may endorse the existing certificate and such a certificate should be accepted as valid for a further period which should not exceed 5 months from the expiry date.*

1.8.10 *If a craft at the time when a certificate expires is not in the place in which it is to be surveyed, the Administration may extend the period of validity of the certificate but this extension should be granted only for the purpose of allowing the craft to proceed to the place in which it is to be surveyed, and then only in cases where it appears proper and reasonable to do so. No certificate should be extended for a period longer than one month, and a craft to which an extension is granted should not, on its arrival in the place in which it is to be surveyed, be entitled by virtue of such extension to leave that place without having a new certificate. When the renewal survey is completed, the new certificate should be valid to a date not exceeding five years from the date of expiry of the existing certificate before the extension was granted.*

1.8.11 *In special circumstances, as determined by the Administration, a new certificate need not be dated from the date of expiry of the existing certificate as required by 1.8.6 or 1.8.10. In these circumstances, the new certificate should be valid to a date not exceeding five years from the date of completion of the renewal survey.*

1.8.12 *If a periodical survey is completed before the period specified in 1.5, then:*

.1 *the anniversary date shown on the relevant certificate should be amended by endorsement to a date which should not be more than three months later than the date on which the survey was completed;*

.2 *the subsequent periodical survey required by 1.5 should be completed at the intervals prescribed by 1.5 using the new anniversary date; and*

.3 *the expiry date may remain unchanged provided one or more periodical surveys are carried out so that the maximum intervals between the surveys prescribed by 1.5.1.3 are not exceeded.*

1.8.13 *A certificate issued under 1.8.1 or 1.8.2 should cease to be valid in any of the following cases:*

.1 *if the relevant surveys are not completed within the periods specified in 7.5.1;*

.2 *if the certificate is not endorsed in accordance with 1.5.3; or*

.3 *upon transfer of the craft to the flag of another State. A new certificate should only be issued when the Government issuing the new certificate is fully satisfied that the craft is in compliance with the requirements of 1.7.1 and 1.7.2. In the case of a transfer between Governments that are Contracting Governments to the Convention, if requested within three months after the transfer has taken place, the Government of the State whose flag the craft was formerly entitled to fly should, as soon as possible, transmit to the Administration a copy of the certificate carried by the craft before the transfer and, if available, copies of the relevant survey reports.*

1.8.14 *The privileges of the Code may not be claimed in favour of any craft unless it holds a valid certificate.*

1.9 Permit to Operate High Speed Craft

1.9.1 *The craft should not operate commercially unless a Permit to Operate High Speed Craft is issued and valid in addition to the High Speed Craft Safety Certificate. Transit voyage without passengers or cargo may be undertaken without the Permit to Operate High Speed Craft.*

1.9.2 *The Permit to Operate High Speed Craft should be issued by the Administration to certify compliance with 1.2.2 to 1.2.7 and stipulate conditions of the operation of the craft and drawn up on the basis of the information contained in the route operational manual specified in chapter 18 of this Code.*

Guidance note:

Chapter 18 covers operational requirements, which is currently not included in the HSLC rules.

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1.9.3 *Before issuing the Permit to Operate, the Administration should consult with each port State to obtain details of any operational conditions associated with operation of the craft in that State. Any such conditions imposed should be shown by the Administration on the Permit to Operate and included in the route operational manual.*

1.9.4 *A port State may inspect the craft and audit its documentation for the sole purpose of verifying its compliance with the matters certified by and conditions associated with the Permit to Operate. Where deficiencies are shown by such an audit, the Permit to Operate ceases to be valid until such deficiencies are corrected or otherwise resolved.*

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1.9.5 *The provisions of 1.8 should apply to the issue and the period of validity of the Permit to Operate High Speed Craft.*

1.9.6 *The Permit to Operate High Speed Craft should be that of the model given in annex 2 to this Code. If the language used is neither English nor French, the text should include a translation into one of these languages.*

Guidance note:
Annex 2 of the HSC Code is not included in the HSLC rules.

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1.10 Control

The provisions of regulation I/19 of the Convention should be applied to include the Permit to Operate High Speed Craft in addition to the certificate issued under 1.8.

1.11 Equivalents

1.11.1 *Where this Code requires that a particular fitting, material, appliance or apparatus, or type thereof, should be fitted or carried in a craft, or that any particular provision should be made, the Administration may allow any other fitting, material, appliance or apparatus, or type thereof, to be fitted or carried, or any other provision to be made in that craft, if it is satisfied by trial thereof or otherwise that such fitting, material, appliance or apparatus, or type thereof, or provision, is at least as effective as that required by this Code.*

1.11.2 *Where compliance with any of the requirements of this Code would be impractical for the particular designs of the craft, the Administration may substitute those with alternative requirements provided that equivalent safety is achieved. The Administration which allows any such substitution should communicate to the Organization particulars of these substitutions and the reasons therefor, which the Organization should circulate to its Member Governments for their information.*

1.12 Information to be made available

1.12.1 *The Administration should ensure that the management of the company operating the craft has provided the craft with adequate information and guidance in the form of manuals to enable the craft to be operated and maintained safely. These manuals should include a route operational manual, craft operating manual, maintenance manual and servicing schedule. Such information should be updated as necessary.*

1.12.2 *The manuals should contain at least the information specified in chapter 18 and should be in a language understood by the crew. Where this language is not English, a translation into English should be provided of at least the route operational manual and the craft operating manual.*

Guidance note:
Chapter 18 covers operational requirements, which is currently not included in the HSLC rules.

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1.13 Further developments

1.13.1 *It is recognized that there is much ongoing research and development in the design of high speed craft and that new types may emerge which have different geometry to that envisaged during the formulation of this Code. It is important that this Code does not restrict this progress and the development of new designs.*

1.13.2 *A design may be produced which cannot comply with the provisions of this Code. In such a case the Administration should determine the extent to which the provisions of the Code are applicable to the design and, if necessary, develop additional or alternative requirements to provide an equivalent level of safety for the craft.*

1.13.3 *The foregoing should be considered by the Administration when assessing the granting of equivalents under the Code.*

1.14 Circulation of safety information

1.14.1 *In the event that an Administration has cause to investigate an accident involving a craft to which this Code applies, that Administration should provide a copy of the official report to the Organization, which will invite Member States to note the existence of the report and to obtain a copy.*

1.14.2 *In the event that operational experience reveals structural or equipment failures affecting the safety of a design, craft owners should inform the Administration.*

1.15 Review of the Code

1.15.1 *The Code should be reviewed by the Organization at intervals preferably not exceeding four years to consider revision of existing requirements to take account of new developments in design and technology.*

1.15.2 *Where a new development in design and technology has been found acceptable to an Administration, that Administration may submit particulars of such development to the Organization for consideration for incorporation into the Code during periodical review.*

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SECTION 2
CROSS REFERENCES TO THE RULES AND HSC CODE

A. General

A 100 Cross references

101 The International Code of Safety for High Speed Craft code (HSC Code) corresponds to the HSLC rules in accordance with Table A1.

Table A1 Cross reference table

HSC Code reference		*Introduction*	*Main Class* **1A1**	*Service and type notations*	*Equipment notations*
Ch.1 General comments and requirements		**P.0 Ch.6 Sec.1**			
1.1	General comments	C300			
1.2	General requirements				
1.3	Application				
1.4	Definitions				
1.5	Surveys				
1.6	Approvals				
1.7	Maintenance of condition of the survey				
1.8	High Speed Craft Safety Certificates				
1.9	Permit to Operate High Speed Craft				
1.10	Control				
1.11	Equivalents				
1.12	Information to be made available				
1.13	Further developments				
1.14	Circulation of safety information				
1.15	Review of the code				
Ch.2 Buoyancy, Stability and Subdivision					
PART A - GENERAL			**Pt.3 Ch.6 Sec.1**		
2.1	General		A100/A200		
2.2	Intact buoyancy		B100		
2.3	Intact stability in the displacement mode		B200		
2.4	Intact stability in the non-displacement mode				
2.5	Intact stability in the transient mode				
2.6	Buoyancy and stability in the displacement mode			**Pt.5 Ch.1 Sec.3** B400	
2.7	Inclining and stability information				
2.8	Loading and stability assessment				
2.9	Marking and recording of the design waterline				
PART B - REQUIREMENTS FOR PASSENGER CRAFT				**Pt.5 Ch.1 Sec.3**	
2.10	General			B200	
2.11	Intact stability in the displacement mode			B200	
2.12	Intact stability in the non-displacement mode			B300	
2.13	Buoyancy and stability in the displacement mode following damage			B400	
2.14	Inclining and stability information			B900	
PART C - REQUIREMENTS FOR CARGO CRAFT				**Pt.5 Ch.3 Sec.3**	
2.15	Buoyancy and stability in the displacement mode following damage			B200	
2.16	Inclining			B500	

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Table A1 Cross reference table (Continued)

HSC Code reference		*Introduction*	*Main Class* **1A1**	*Service and type notations*	*Equipment notations*
Ch.3 Structures		**Pt.0 Ch.4 Sec.4**			
3.1	General	A200			
3.2	Materials				
3.3	Structural strength				
3.4	Cyclic loads				
3.5	Design criteria				
3.6	Trials				
Ch.4 Accommodation and escape measures			**Pt.3 Ch.7 Sec.1**		
4.1	General		B100		
4.2	Public address and information system		B200		
4.3	Design acceleration levels		B300		
4.4	Accommodation design		B400		
4.5	Seating construction		B500		
4.6	Safety belts		B600		
4.7	Exits and means of escape		C100		
4.8	Evacuation time		C200		
4.9	Baggage, stores and cargo compartments		D100		
4.10	Noise levels		E100		
Ch.5 Directional control system			**Pt.4 Ch.13**		
5.1	General		Sec.1 B200/ D700 Sec.4 A100		
5.2	Reliability		Sec.1 C300, Sec.4 A200		
5.3	Demonstrations		Sec.1 D700		
5.4	Control Position		Sec.4 A300		
Ch.6 Anchoring, towing and berthing			**Pt.3 Ch.5 Sec.3**		
6.1	General		A100		
6.2	Anchoring		B100		
6.3	Towing		A300		
6.4	Berthing		A400		
Ch.7 Fire safety					
PART A - GENERAL			**Pt.4 Ch.10**		
7.1	General requirements		Sec.1 B		
7.2	Definitions		Sec.1 C		
7.3	Classification of space use		Sec.2 A		
7.4	Structural fire protection		Sec.2 B, Sec.3 A and Sec.3 B		
7.5.1-2 Fuel and other flammable fluid tanks and systems			Sec.3 C		
7.5.3-6 Fuel and other flammable fluid tanks and systems			(Not included)		
7.6	Ventilation		**Pt.4 Ch.10 Sec.4 A**		
7.7	Fire detection and extinguishing systems		Sec.5 A, Sec.6 A and 6 B, Sec.7 A		
7.8	Protection of special category spaces			**Pt.5 Ch.2 Sec.4 B**	
7.9	Miscellaneous		Sec.8 A and 8 B		
7.10	Fireman's outfits		Sec.8 C		
PART B - ADDITIONAL REQUIREMENTS FOR PASSENGER CRAFT				**Pt.5 Ch.1 Sec.4**	
7.11	Arrangement			B100	
7.12	Ventilation			B200	

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Table A1 Cross reference table (Continued)

HSC Code reference		*Introduction*	*Main Class* **1A1**	*Service and type notations*	*Equipment notations*
7.13	Fixed sprinkler system			B300	
PART C - ADDITIONAL REQUIREMENTS FOR CARGO CRAFT				**Pt.5 Ch.3 Sec.4**	
7.14	Control station			B100	
7.15	Cargo spaces			B200	
Ch.8 Lifesaving appliances and arrangements			**Pt.3 Ch.8 Sec.1**		
8.1	General and definitions		B100/B200/ B300		
8.2	Communications		C100/C200		
8.3	Personal lifesaving appliances		C300		
8.4	Muster list, emergency instructions and manuals		D100		
8.5	Operating instruction		D200		
8.6	Survival craft stowage		E100/E200		
8.7	Survival craft and rescue boat embarkation and recovery arrangements		E300		
8.8	Line-throwing appliance		C400		
8.9	Operational readiness, maintenance and inspections		F		
8.10	Additional requirements		E400		
Ch.9 Machinery			**Pt.4**		
PART A - GENERAL			Ch.1		
9.1	General		Ch.1 Sec.1		
9.2	Engine (General)		Ch.3 Sec.1		
9.3	Gas Turbines		Ch.3 Sec.3		
9.4	Diesel engines for main propulsion and essential auxiliaries		Ch.3 Sec.1		
9.5	Transmissions		Ch.4 Sec.2		
9.6	Propulsion and lift devices		Ch.4 Sec.4		
PART B - REQUIREMENTS FOR PASSENGER CRAFT				**Pt.5 Ch.1 Sec.6**	
9.7	Independent means of propulsion for category B craft			A100	
9.8	Means for return to a port of refuge for category B craft			A200	
PART C - REQUIREMENTS FOR CARGO CRAFT				**Pt.5 Ch.3 Sec.4**	
9.9	Essential machinery and control			C100	
Ch.10 Auxiliary systems					
PART A - GENERAL			**Pt.4**		
10.1	General		Ch.1 Sec.1 A300		
10.2	Arrangement of oil fuel, lubricating oil and other flammable oil		Ch.6 Sec.5		
10.3	Bilge pumping and drainage systems		Ch.6 Sec.4 A100		
10.4	Ballast systems		Ch.6 Sec.5 B100		
10.5	Cooling systems		Ch.6 Sec.5 B200		
10.6	Engine air intake systems		Ch.6 Sec.5 B500		
10.7	Ventilation systems		Ch.6 Sec.5 B600		
10.8	Exhaust systems		Ch.6 Sec.5 B400		

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Table A1 Cross reference table (Continued)

HSC Code reference		*Introduction*	*Main Class* **1A1**	*Service and type notations*	*Equipment notations*
PART B - REQUIREMENTS FOR PASSENGER CRAFT				**Pt.5 Ch.1 Sec.6**	
10.9	Bilge pumping and drainage systems			B100	
PART C - REQUIREMENTS FOR CARGO CRAFT				**Pt.5 Ch.3 Sec.4**	
10.10	Bilge pumping systems			C200	
Ch.11 Remote control alarm and safety systems			**Pt.4 Ch.13**		
11.1	Definitions		Sec.1 B100		
11.2	General		Sec.2 A100/ E100		
11.3	Emergency controls		Sec.2 E201		
11.4	Alarm systems		Sec.2 F, Pt.4 Ch.11 Sec.3 A300		
11.5	Safety systems		Sec.2 B100		
Ch.12 Electrical equipment					
PART A - GENERAL			**Pt.4 Ch.8**		
12.1	General		Sec.1 B100		
12.2	Main source of electrical power		Sec.3 B100		
12.3	Emergency source of electrical power		Sec.3 C100		
12.4	Starting arrangements for emergency generating sets		Sec.3 C200		
12.5	Steering and stabilization		Pt.4 Ch.8		
12.6	Precautions against shock, fire and other hazards of electrical origin		Sec.2/Sec.3/ Sec.9		
PART B - REQUIREMENTS FOR PASSENGER CRAFT				**Pt.5 Ch.1**	
12.7	General			Sec.5 A	
PART C - CARGO CRAFT				**Pt.5 Ch.3**	
12.8	General			Sec.4 D	
Ch.13 Navigational equipment			**Pt.4 Ch.11 Sec.2**		
13.1	Navigation (General)		A100		
13.2	Compasses		A200		
13.3	Speed and distance measurement		A300		
13.4	Echo-sounding device		A400		
13.5	Radar installations		A500		
13.6	Electronic positioning systems		A600		
13.7	Rate-of-turn indicator and rudder angle indicator		A700		
13.8	Other navigational aids		A900		
13.9	Searchlight		A1000		
13.10	Night vision equipment		A1100		
13.11	Steering arrangement and propulsion indicators		A1200		
13.12	Automatic steering aid (automatic pilot equipment)		A1300		
13.13	Performance standards		A1400		
Ch.14 Radiocommunications			**Pt.4 Ch.12**		
14.1	Application		Sec.1 A100		
14.2	Terms of definitions		Sec.1 B100		
14.3	Exemptions		Sec.1 A500		
14.4	Functional requirements		Sec.2 A100		
14.5	Radio installations		Sec.2 B100		
14.6	Radio equipment - General		Sec.2 C100		
14.7	Radio equipment - Sea area A1		Sec.2 C200		

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Table A1 Cross reference table (Continued)

HSC Code reference		*Introduction*	*Main Class* **1A1**	*Service and type notations*	*Equipment notations*
14.8	Radio equipment - Sea areas A1 and A2		Sec.2 C300		
14.9	Radio equipment - Sea areas A1, A2 and A3		Sec.2 C400		
14.10	Radio equipment - Sea areas A1, A2, A3 and A4		Sec.2 C500		
14.11	Watches		Sec.2 C600		
14.12	Sources of energy		Sec.2 C700		
14.13	Performance standards		Sec.2 C800		
14.14	Maintenance requirements		Sec.2 C900		
14.15	Radio personnel		Sec.1 C100		
14.16	Radio records		Sec.1 D100		
Ch.15 Operating compartment layout			**Pt.4 Ch.11**		
15.1	Definitions		Sec.1 B100		
15.2	General		Sec.3 A100		
15.3	Field of vision from the operating compartment		Sec.3 A200		
15.4	Operating compartment		Sec.3 A300		
15.5	Instruments and chart table		Sec.3 A400		
15.6	Lighting		Sec.3 A500		
15.7	Windows		Sec.3 A600		
15.8	Communication facilities		Sec.3 A700		
15.9	Temperature and ventilation		Sec.3 A800		
15.10	Colours		Sec.3 A900		
15.11	Safety measures		Sec.3 A1000		
Ch.16 Stabilization systems			**Pt.4 Ch.13**		
16.1	Definitions		Sec.1 B300		
16.2	General requirements		Sec.5 A100		
16.3	Lateral and height control systems		Sec.5 A200		
16.4	Demonstrations		Sec.1 D800		
Ch.17 Handling, controllability and performance			**Pt.4 Ch.11**		
17.1	General		Sec.1 E200		
17.2	Proof of compliance		Sec.4 A100		
17.3	Weight and centre of gravity		Sec.4 A200		
17.4	Effect of failures		Sec.4 A300		
17.5	Controllability and manoeuvrability		Sec.1 B200 Sec.4 A400		
17.6	Change of operating surface and mode		Sec.4 A500		
17.7	Surface irregularities		Sec.4 A600		
17.8	Acceleration and deceleration		Sec.4 A700		
17.9	Speeds		Sec.4 A800		
17.10	Minimum depth of water		Sec.4 A900		
17.11	Hard structure clearance		Sec.4 A1000		
17.12	Night operation		Sec.4 A1100		
Ch.18 Operational requirements					
PART A - GENERAL		(Not included)			
PART B - REQUIREMENTS FOR PASSENGER CRAFT		(Not included)			
PART C - REQUIREMENTS FOR CARGO CRAFT		(Not included)			
Ch.19 Inspection and maintenance requirements		**Pt.0 Ch.4 Sec.5**			
Annex 1 - Form of High-Speed Craft Safety Certificate		(Not included)			
Annex 2 - Form of Permit to Operate High-Speed Craft		(Not included)			
Annex 3 - Use of probability concept		**Pt.0 Ch.4 Sec.3**			

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Table A1 Cross reference table (Continued)				
HSC Code reference	*Introduction*	*Main Class* **1A1**	*Service and type notations*	*Equipment notations*
Annex 4 - Procedures for failure mode and effect analysis (FMEA)	**Pt.0 Ch.4 Sec.2**			
Annex 5 - Ice accretion applicable to all types of craft		**Pt.3 Ch.6 Sec.1**		
Annex 6 - Methods relating to the intact stability investigation of hydrofoil craft		**Pt.3 Ch.6**		
Annex 7 - Stability of multihull craft		**Pt.3 Ch.6 Sec.1**	**Pt.5 Ch.1 Sec.3**	
Annex 8 - Definitions, requirements and compliance criteria related to operational and safety performance	**Pt.0 Ch.4 Sec.1**			
Annex 9 - Criteria for testing and evaluation of revenue and crew seats		**Pt.3 Ch.7 Sec.2**		
Annex 10 - Open reversible liferafts		**Pt.3 Ch.8 Sec.2**		

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SECTION 3
FLAG ADMINISTRATION REQUIREMENTS

A. General

A 100 IMO HSC Code - General

101 The IMO HSC Code has a number of requirements which are left to the Flag State Administration to decide upon with respect to the specific interpretation of the requirement. The Code text often uses the expression that the requirement should be "to the satisfaction of the Administration".

102 The goal for international regulations is to have as uniform requirements as possible. Most requirements which contain the expression "to the satisfaction of the Administration" have been removed from IMO documents as far as practicable.

103 Those requirements which are dependant on local or domestic conditions are still up to the Administration to decide.

104 DNV aims at a uniform set of requirements both to be as transparent as possible and also to be specific in contractual and statutory matters. Consequently, a number of the "up to the Administration" requirements of the HSC Code has been interpreted by DNV.

105 The cross references between the HSC Code and the DNV rules refer to all requirements in the HSC Code where the Flag or Port State is mentioned in connection with a requirement.

106 The HSC Code paragraphs left to the Administration to decide, and the corresponding DNV paragraph with comments are given in the following. HSC Code paragraphs are given by x.x.x and DNV paragraphs by Pt.y Ch.y Sec.y.

A 200 HSC Code chapter 1

201

1.2.12 concerning evacuation procedures required for crew sleeping berths, see Sec.1 C300 for information. Specific requirements are to be developed in each case.

1.4.10.1 concerning criteria for maximum rescue time for category A craft, see Sec.1 C300 for information. This is an operational condition and has to be agreed between Flag and Port State(s) of the route in question.

1.4.29 concerning maximum operational weight in the intended mode, see Sec.1 C300 for information. Unless otherwise defined, this definition should correspond to the maximum displacement as defined in Pt.3 Ch. 1 Sec. 1 D101.

1.4.48 concerning parameters for worst intended condition, see Sec.1 C300 for information. Unless otherwise defined, this definition should correspond to the restrictions given by design accelerations in Pt.3 Ch.1 Sec.2 B200, and given in the appendix to the class certificate, see Pt.3 Ch.1 Sec.2 A105.

1.5.1.2 concerning renewal survey intervals, see Sec.1 C300 for information. Pt.7 Ch.2 Sec.1 A100 specify 5 years for main class notation **1A1 HSLC** and 3 years for **1A2 HSLC** See also Pt.1 Ch.1 Sec.2 B302 for the notation **1A2 HSLC**.

1.5.4 concerning recognised organisations, see Sec.1 C300 for information. DNV is a recognised classification society.

1.5.5 concerning recognised organisation, see 1.5.4.

1.5.6 concerning recognised organisation, see 1.5.4.

1.5.7 concerning Administrations' responsibility for completeness of inspections and surveys carried out by recognised organisations, see 1.5.4 and Pt.1 Ch.1 Sec.1 B602 with respect to information to the Flag Administration of the craft.

1.6 concerning approvals, see 1.5.4 to 1.5.7 above, and Pt.1 Ch.1 Sec. 3 A500 for plan approval.

1.7.2 concerning changes after initial survey, see Sec.1 C300 for information and Pt.1 Ch.1 Sec.3 B for retention of class.

1.8.1 concerning issue of High Speed Craft Safety Certificate, see Sec.1 C300 for information. This certificate is issued when DNV acts on behalf of a Flag Administration on basis of delegated authority.

1.8.11 concerning circumstances for issue of certificate, see Sec.1 C300 for information and Pt.1 Ch.1 Sec.3 B800 for issuance and validity of certificates.

1.11.1 concerning acceptance of equivalents, see Sec.1 C300 for information and Pt.1 Ch.1 Sec.1 B306 and B307 with respect to equivalent alternatives.

1.11.2 concerning alternative requirements, see 1.11.1. The Society does not have the possibility of applying

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alternative requirements which are not found to be equivalent, unless such alternative requirements are accepted by Flag State for own domestic service or reported by Flag State to IMO for craft intended for international service.

1.12.1 concerning sufficient manuals, see Sec.1 C300 for information. HSC Code chapter 18 is not included in the Rules for HSLC. This chapter covers the Permit to Operate «certificate», which is not covered by the class certificate.

1.13.2 concerning provisions for craft outside the Code, see Sec.1 C300 for information. This paragraph of the HSC Code is in conflict with paragraph 1.2.1 of the same Code, and equivalent solutions should be established. See comment under 1.11.1.

1.13.3 concerning equivalents for craft outside the Code, see 1.13.2.

1.14.2 concerning craft owner's obligation to inform the administration, see Sec.1 C300 for information, and Pt.1 Ch.1 Sec.3 B101 with respect to the owners duty to inform the class.

A 300 HSC Code chapter 2

301

2.3.4 concerning equivalent intact stability, see Pt.3 Ch.6 Sec.1 B501. Equivalent requirements are to be established in each case.

2.6.4 concerning the use of low-density foam for buoyancy, see Pt.5 Ch.1 Sec.3 B404 (without interpretation).

2.7.2 concerning addition and amendments to stability information, see Pt.3 Ch.6 Sec.1 A405 (without interpretation).

2.8 concerning electronic loading and stability calculation, see Pt.3 Ch.6 Sec.1 A501. Loading computers are subject to approval on basis of Rules for Classification of Ships.

2.16 concerning lightweight survey instead of inclining test, see Pt.3 Ch.6 Sec.1 A400, Guidance note with interpretation.

3.5 concerning design criteria, Ch.4 Sec.4 A200 gives information. Criteria are established by Pt.3 and Pt.4.

3.6 concerning full scale trials, see Ch.4 Sec.4 A200 for information. Requirements for functional and structural testing are given in Pt.1 Ch.1 Sec.3 A700.

A 400 HSC Code chapter 4

401

4.8.2 concerning evacuation procedure, see Pt.3 Ch.7 Sec.1 C202 (without interpretation).

4.8.3 concerning verification of evacuation time, see Pt.3 Ch.7 Sec.1 C203 (without interpretation).

4.8.6 concerning partial evacuation demonstration, see Pt.3 Ch.7 Sec.1 C206 (without interpretation).

A 500 HSC Code chapter 5

501

5.2.3 concerning manual secondary means of control, see Pt.4 Ch.14 (without interpretation).

5.2.4 concerning time to establish secondary control, see Pt.4 Ch.13 Sec.3 A202 (without interpretation). Backup on electrical system from auxiliary and emergency diesel generators is covered by separate requirements in Pt.4 Ch.8, with interpretation of HSC Code 12.3.6.

A 600 HSC Code chapter 7

601

7.2.4 concerning criteria for non-combustible material, see Pt.4 Ch.10 Sec.1 C401. The IMO Res. A.472(XII) applies.

7.5.6.2 concerning discharge of fuel with flash point below 43 °C, see Pt.4 Ch.6 Sec.5 A501 (without interpretation).

Guidance note:
The following text under HSC Code chapter 7 is taken from SOLAS and will be amended by IMO.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

7.7.2.1.8 concerning maximum number of enclosed spaces with fire detection, see Pt.4 Ch.10 Sec.5 A201 (without interpretation).

7.7.2.1.9 concerning fire detection of spaces without remote identification, see Pt.4 Ch.10 Sec.5 A201 (without interpretation).

7.7.2.1.11 concerning alternative fire detectors, see Pt.4 Ch.10 Sec.5 A201 (without interpretation).

7.7.2.2.5 concerning alternative spacing of fire detectors, see Pt.4 Ch.10 Sec.5 A202 (without interpretation).

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7.7.2.3.2 concerning alternative sensitivity of smoke-detectors, see Pt.4 Ch.10 Sec.5 A203 (without interpretation).

7.7.2.3.4 concerning increased setting of heat detectors, see Pt.4 Ch.10 Sec.5 A203 (without interpretation).

7.7.6.1.1 concerning use of fire extinguishing medium, see Pt.4 Ch.10 Sec.6 A201 (without interpretation).

7.7.6.1.5 concerning additional fire fighting medium where added air, see Pt.4 Ch.10 Sec.6 A201 (without interpretation)

7.7.6.1.12 concerning pressure vessels on fire fighting systems, see Pt.4 Ch.10 Sec.6 A201. The pressure vessel is to be certified by the Society.

7.7.8.5 concerning maximum length of fire hoses, see Pt.4 Ch.10 Sec.7 A101 (without interpretation).

7.10.1.3 concerning additional personal breathing apparatus, see Pt.4 Ch.10 Sec.8 C104 (without interpretation).

7.10.3.2.1 concerning self-contained breathing apparatus, see Pt.4 Ch.10 Sec.8 C201, with interpretation in Guidance note.

A 700 HSC Code chapter 8

701

8.1.2 concerning approval of lifesaving appliances, see Pt.3 Ch.8 Sec.1 B102 (without interpretation).

8.1.3 concerning approval of life-saving appliances, see 8.1.2. The IMO res. A.689(17) applies.

8.1.4 concerning approval of novel life-saving appliances, see 8.1.2. The IMO res. A.520(13) applies.

8.1.5 concerning acceptance of life-saving appliances, see 8.1.2.

8.1.6 concerning requirements outside Ch. III of the Convention, see 8.1.2.

8.1.7 concerning production tests, see 8.1.2.

8.1.8 concerning approval conditions, see 8.1.2.

8.1.9 concerning period of acceptability, see 8.1.2.

8.3.8 concerning relaxed requirement for suits in warm climates, see Pt.3 Ch.8 Sec.1 C308 (without interpretation).

8.6.1 concerning adjustable bowsing lines, see Pt.3 Ch.8 Sec.1 E101 (without interpretation).

8.7.5 concerning acceptance of direct boarding into survival craft, see Pt.3 Ch.8 Sec.1 E305. The rules apply 1,5 m as maximum without interpretation by Flag Administration.

8.9.2.2 concerning special shipboard maintenance program, see Pt.3 Ch.8 Sec.1 F202 (without interpretation).

8.10.1.6.2 concerning rescue boat for pair of liferafts, see Pt.3 Ch.8 Sec.1 E401 (without interpretation).

8.10.2 concerning the use of open reversible liferafts, see Pt.3 Ch.8 Sec.1 E402 (without interpretation).

A 800 HSC Code chapter 9

801

9.1.9 concerning equivalent safety level for machinery, see Pt.4 Ch.1 Sec.1 A210 (without interpretation).

9.1.12 concerning alternative design angles for machinery, see Pt.4 Ch.1 Sec.1 A213 (without interpretation).

A 900 HSC Code chapter 10

901

10.2.4.7.2 concerning permit to use oil level gauge of glass on cargo ships has been omitted from the rules as the arrangement is not relevant for high speed craft.

10.3.7 concerning internal diameter of bilge, see Pt.4 Ch.6 Sec. 4 A107 (without interpretation).

A 1000 HSC Code chapter 11

1001

12.2.9 concerning equivalent main bus-bar arrangement, see Pt.4 Ch.8 (without interpretation).

12.6.1.2 concerning additional requirements for portable electrical equipment, see Pt.4 Ch.8 (without interpretation).

12.6.2 concerning maximum voltage on switchboard front, see Pt.4 Ch.8 (without interpretation).

12.6.3 concerning automatic continuous checking of insulation level, see Pt.4 Ch.8, which exceeds the requirements of the Code text. Manual checking is not accepted.

12.6.4.1 concerning non-continuous metal sheets and armour, see Pt.4 Ch.8 which exceeds the requirements of the Code text. Exceptions not accepted.

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12.6.4.2 concerning use of non-flame-retardant cables, see Pt.4 Ch.8, which exceeds the requirements of the Code text.

12.6.4.4 concerning cables in hazardous areas, see Pt.4 Ch.8, which exceeds the requirements of the Code text.

12.6.5.1 concerning use of non-protected circuits, see Pt.4 Ch.8, which exceeds the requirements of the Code text.

12.6.9 concerning use of electrical equipment in spaces with flammable mixtures, see Pt.4 Ch.8, which exceeds the requirements of the Code text.

12.6.10 concerning use of higher voltage for propulsion purposes is not covered by any DNV rule text. This is to be specially considered in each individual case.

12.7.4.4.1 concerning reduced emergency power for navigational equipment, see Pt.5 Ch.1 Sec.5 A203 (without interpretation).

12.7.9.1 concerning alternative emergency lightening, see Pt.5 Ch.1 Sec.5 A208 (without interpretation).

12.8.2.2.4.1 concerning reduced emergency power for navigational equipment, see Pt.5 Ch.3 Sec.4 D202 (without interpretation).

A 1100 HSC Code chapter 13

1101

13.1.1. concerning equivalent navigational equipment, see Pt.4 Ch.11 Sec.2 A101 with interpretation in 102 and 103.

13.1.2 concerning satisfactory navigational equipment, see Pt.4 Ch.11 Sec.2 A104 (without interpretation).

A 1200 HSC Code chapter 14

1201

14.3.1 concerning exemptions from radio equipment, see Pt.4 Ch.12 Sec.1 A500 (without interpretation).

14.3.3 concerning exemptions to be reported, see 14.3.1.

14.6.4 concerning exemptions after 970201, see 14.3.1.

14.8.4 concerning exemptions before 970201, see 14.3.1.

14.9.4 concerning exemptions before 970201, see 14.3.1.

14.10.2 concerning exemptions before 970201, see 14.3.1.

14.14.5 concerning maintenance of radio equipment, see Pt.4 Ch.12 Sec.2 C905, (without interpretation).

14.14.6 concerning radio equipment for restricted service, see 14.3.1.

14.14.7. see 14.3.1.

14.14.8. see 14.3.1.

14.15 concerning qualification of radio personnel, see Pt.4 Ch.12 Sec.1 C101 (without interpretation).

A 1300 HSC Code chapter 15

1301

15.3.1 concerning layout of navigation workstation, see Pt.4 Ch.11 Sec. 3 A201 (without interpretation).

15.3.4 concerning astern field of vision, see Pt.4 Ch.11 Sec.3 A204 (without interpretation).

15.4.10 concerning the use of safety belts for operating crew, see Pt.4 Ch.11 Sec. 3 A312 (without interpretation).

15.5.8. concerning suitable table for chart, see Pt.4 Ch.11 Sec. 3 A408 (should be a part of integrated work-station).

15.7.2. concerning clear view from the bridge, see Pt.4 Ch.11 Sec. 3 A602. Wipers, water spray and de-icing may be required.

A 1400 HSC Code chapter 17

1401

17.5.4.1 concerning safety in respect of handling, controllability and performance, see Pt.4 Ch.11 Sec.1 B200 and Pt.4 Ch.11 Sec.4 A400, with interpretation in Pt.5 Ch.1 Sec.1 B201.

17.8 concerning the worst likely acceleration or deceleration, see Pt.4 Ch.11 Sec.4 A700, with interpretation in Pt.3 Ch.1 Sec.2 B and Pt.5 Ch.1 Sec.2 B300.

A 1500 HSC Code chapter 18

1501

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Chapter 18 of the HSC Code concerning:

— maintenance manual to be carried onboard
— permit to operate
— operational training for crew
— practical test over the relevant route
— procedure for re-validation of type rating certificate
— crew standard of physical fitness
— training, experience and qualification of the master and crew
— person in charge of liferaft

is not included in the rules. However, regarding 18.1.4 concerning maximum allowable distance from a base port or place of refuge, see Pt.1 Ch.1 Sec.2 B400, with interpretations in 402 and 404.

A 1600 HSC Code chapter 19

1601

19.1 concerning operator's organisation. This is not included in the rules.

19.2 concerning maintenance of craft and equipment, see Pt.1 Ch.1 Sec.3 B (with interpretation).

19.3 concerning maintenance of all life-saving appliances, see Pt.3 Ch.8 Sec.1 F (without interpretation).

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General Information for the Rules and Regulations for the Classification of Special Service Craft

July 2011

Lloyd's Register

LIFE MATTERS

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General Information

1. The 2011 edition of the Rules and Regulations for the Classification of Special Service Craft is a complete reprint of the 2010 edition, consisting of 8 books.

Volume 1, Part 1	Regulations
Rules for the Manufacture, Testing and Certification of Materials	
Volume 3, Part 3	General Requirements and Constructional Arrangement
Volume 3, Part 4	Additional Requirements for Yachts
Volume 3, Part 5	Design and Load Criteria
Volume 4, Part 6	Hull Construction in Steel
Volume 5, Part 7	Hull Construction in Aluminium
Volume 6, Part 8	Hull Construction in Composite
Volume 7, Part 9	General Requirements for Machinery
Volume 7, Part 10	Prime Movers
Volume 7, Part 11	Transmission Systems
Volume 7, Part 12	Propulsion Devices
Volume 7, Part 13	Shaft Vibration and Alignment
Volume 7, Part 14	Steering Systems
Volume 7, Part 15	Piping Systems and Pressure Plant
Volume 7, Part 16	Control and Electrical Engineering
Volume 8, Part 17	Fire Protection, Detection and Extinction

2. A decimal notation system has been adopted throughout. Five sets of digits cover the divisions, i.e. Part, Chapter, Section, sub-Section and paragraph. The textual cross-referencing within the text is as follows, although the right-hand digits may be added or omitted depending on the degree of precision required:
   (a) In same Chapter, e.g. *see* 2.1.3 (i.e. down to paragraph).
   (b) In same Part but different Chapter, e.g. *see* Ch 3,2.1 (i.e. down to sub-Section).
   (c) In another Part, e.g. *see* Pt 5, Ch 1,3 (i.e. down to Section).

   The cross-referencing for Figures and Tables is as follows:
   (a) In same Chapter, e.g. as shown in Fig. 2.3.5 (i.e. Chapter, Section and Figure Number).
   (b) In same Part but different Chapter, e.g. as shown in Fig. 2.3.5 in Chapter 2.
   (c) In another Part, e.g. *see* Table 2.7.1 in Pt 3, Ch 2.

3. The primary changes from the 2010 edition of the Rules are identified in the Guide Book. The effective dates of the indicated changes are 1 January 2011, 1 February 2011 & 1 July 2011.

4. Until the next edition of the Rules and Regulations for the Classification of Special Service Craft is published, Rule change Notices and/or Corrigenda, as necessary, will be published on the LR Webstore — www.webstore.lr.org/ – and will be available for downloading free of charge. It is not intended at this time to publish hard copies of future Rule Notices to Existing Rules.

5. In this publication, a shortened version of the Notice has been reproduced listing all the paragraphs that have been altered since the last edition of the Rules. It is followed by a comprehensive Contents list of all books in the set, showing all the titles down to Section level.

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Notice – Summary of Changes

Summary of Changes from the 2010 Rules

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 1					**Effective Date 1 January 2011**
2	4	4.4.3	Surveys - General	New paragraph added	1
2	4	4.4.3 to 4.4.7	Surveys - General	Existing paragraphs renumbered	1

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 1					**Effective Date 1 February 2011**
2	1	1.1.13	Conditions for classification	Paragraph deleted	3
2	1	1.1.13	Conditions for classification	New paragraph added	3
2	1	1.1.14	Conditions for classification	Paragraph deleted	3
2	1	1.1.14	Conditions for classification	New paragraph added	3
2	1	1.1.15	Conditions for classification	New paragraph added	3

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 1					**Effective Date 1 July 2011**
2	4	4.5.16	Surveys - General	Paragraph amended	6
3	2	2.2.16	Annual Surveys - Hull and machinery requirements	New paragraph added	7
3	2	2.2.16 & 2.2.17	Annual Surveys - Hull and machinery requirements	Existing paragraphs renumbered	7

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Rules for the Manufacture, Testing and Certification of Materials					**Effective Date 1 July 2011**
1	3	3.1.4	Certification of materials	Paragraph amended	1
1	5	5.4.1	Non-destructive examination	Paragraph amended	1
1	6	Whole Section	References	New Section added	1
2	2	2.1.15	Tensile tests	Paragraph amended	1
3	5	5.1.2	Steels for machinery fabrications	Paragraph amended	1
3	5	Table 3.5.1	Steels for machinery fabrications	Table amended	1
3	9	9.1.1	Bars for welded chain cables	Paragraph amended	1
3	9	9.1.3	Bars for welded chain cables	Paragraph amended	1
3	9	9.2.1	Bars for welded chain cables	Paragraph amended	1
3	9	9.2.3	Bars for welded chain cables	New paragraph added	1
3	9	9.3.2	Bars for welded chain cables	Paragraph amended	1
3	9	9.3.3	Bars for welded chain cables	Paragraph amended	1
3	9	9.3.4	Bars for welded chain cables	New paragraph added	1
3	9	9.4.2	Bars for welded chain cables	Paragraph amended	1
3	9	9.4.3	Bars for welded chain cables	Paragraph amended	1
3	9	9.5.1	Bars for welded chain cables	Paragraph amended	1
3	9	9.5.2	Bars for welded chain cables	Paragraph amended	1
3	9	9.6.1	Bars for welded chain cables	Paragraph amended	1
3	9	Fig. 3.9.1	Bars for welded chain cables	New Figure added	1
3	9	9.6.2	Bars for welded chain cables	Paragraph amended	1
3	9	9.6.4	Bars for welded chain cables	New paragraph added	1
3	9	9.7	Bars for welded chain cables	New sub-Section added	1
3	9	9.7	Bars for welded chain cables	Existing sub-Section renumbered	1
3	9	9.8	Bars for welded chain cables	Existing sub-Section renumbered	1
3	9	9.8.1	Bars for welded chain cables	Existing paragraph renumbered & amended	1
3	9	9.9.2 to 9.9.4	Bars for welded chain cables	New paragraphs added	1
3	9	9.8.2	Bars for welded chain cables	Existing paragraph renumbered	1
3	9	Table 3.9.2	Bars for welded chain cables	Table amended	1
3	9	Table 3.9.3	Bars for welded chain cables	Table amended	1
3	9	9.9 & 9.10	Bars for welded chain cables	Existing sub-Sections renumbered	1
3	9	9.10.1	Bars for welded chain cables	Existing paragraph renumbered & amended	1

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Notice – Summary of Changes

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Rules for the Manufacture, Testing and Certification of Materials (cont'd)					**Effective Date 1 July 2011**
5	3	3.4.12	Forgings for shafting and machinery	Paragraph amended	1
9	1	Table 9.1.1	Castings for propellers	Table amended	1
9	1	1.8.10	Castings for propellers	Paragraph amended	1
9	1	1.8.12	Castings for propellers	Paragraph amended	1
9	1	1.8.18	Castings for propellers	Paragraph amended	1
9	1	1.10.4	Castings for propellers	Paragraph amended	1
9	1	Fig. 9.1.2	Castings for propellers	Figure amended	1
9	1	1.11.1	Castings for propellers	Paragraph amended	1
9	2	Table 9.2.2	Castings for valves, liners and bushes	Table amended	1
9	2	2.8.2	Castings for valves, liners and bushes	Paragraph amended	1
9	2	Table 9.2.5	Castings for valves, liners and bushes	New Table added	1
9	2	2.8.3	Castings for valves, liners and bushes	Paragraph amended	1
9	3	3.9.4	Tubes	Paragraph amended	1
9	3	3.10.5	Tubes	Paragraph amended	1
10	1	1.1.2	Anchors	New paragraph added	1
10	1	1.1.2	Anchors	Existing paragraph renumbered	1
10	1	1.3.2	Anchors	Existing paragraph deleted	1
10	1	1.3.3	Anchors	Existing paragraph renumbered	1
10	1	1.3.4	Anchors	Existing paragraph renumbered & amended	1
10	1	1.3.5 & 1.3.6	Anchors	Existing paragraphs renumbered	1
10	1	1.3.6	Anchors	New paragraph added	1
10	1	1.5.2	Anchors	Existing paragraph deleted	1
10	1	1.5.2	Anchors	New paragraph added	1
10	1	1.6.5	Anchors	New paragraph added	1
10	1	1.7	Anchors	Sub-Section deleted	1
10	1	1.7	Anchors	New sub-Section added	1
10	1	1.9.2	Anchors	Paragraph deleted	1
10	1	1.9.2	Anchors	New paragraph added	1
10	1	1.9.8 & 1.9.9	Anchors	New paragraphs added	1
10	1	Table 10.1.2	Anchors	New Table added	1
10	1	Table 10.1.3	Anchors	New Table added	1
10	1	1.9.10 to 1.9.14	Anchors	New paragraphs added	1
10	1	1.10	Anchors	Sub-Section deleted	1
10	1	1.11	Anchors	Existing sub-Section renumbered	1
10	1	1.10.6	Anchors	New paragraph added	1
10	1	1.12	Anchors	Existing sub-Section renumbered	1
10	1	1.12.1	Anchors	Paragraph deleted	1
10	1	1.11.1	Anchors	New paragraph added	1
10	1	1.12.2	Anchors	Existing paragraph renumbered & amended	1
10	1	1.13	Anchors	Existing sub-Section renumbered	1
10	1	1.13.1	Anchors	Existing paragraph renumbered & amended	1
10	1	1.13.3	Anchors	Existing paragraph renumbered & amended	1
10	2	2.5.3	Stud link chain cables for ships	Paragraph amended	1
10	2	2.7.2	Stud link chain cables for ships	Paragraph amended	1
10	2	2.7.3	Stud link chain cables for ships	Paragraph amended	1
10	2	2.7.4	Stud link chain cables for ships	Paragraph amended	1
10	2	2.7.5	Stud link chain cables for ships	Paragraph amended	1
10	2	2.7.6	Stud link chain cables for ships	New paragraph added	1
10	2	2.10.2	Stud link chain cables for ships	Paragraph deleted	1
10	2	2.10.3 to 2.10.5	Stud link chain cables for ships	Existing paragraphs renumbered	1
10	2	2.12.1	Stud link chain cables for ships	Paragraph amended	1
10	2	2.12.3	Stud link chain cables for ships	Paragraph amended	1
10	2	2.12.8 to 2.12.10	Stud link chain cables for ships	New paragraphs added	1
10	2	2.13.3	Stud link chain cables for ships	Paragraph amended	1
10	2	2.13.8	Stud link chain cables for ships	Paragraph amended	1
10	2	2.15.1	Stud link chain cables for ships	Paragraph amended	1
10	2	Fig. 10.2.1	Stud link chain cables for ships	Figure deleted	1

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Notice – Summary of Changes

Ch	Section	Para	Section Title	Status	Notice
Rules for the Manufacture, Testing and Certification of Materials (cont'd)					**Effective Date 1 July 2011**
10	2	Fig. 10.2.1	Stud link chain cables for ships	New Figure added	1
10	2	2.15.3	Stud link chain cables for ships	Paragraph deleted	1
10	2	2.15.3 & 2.15.4	Stud link chain cables for ships	New paragraphs added	1
10	2	2.15.4 to 2.15.6	Stud link chain cables for ships	Existing paragraphs renumbered	1
10	2	2.15.7	Stud link chain cables for ships	Existing paragraph renumbered & amended	1
10	2	2.15.8 to 2.15.10	Stud link chain cables for ships	Existing paragraphs renumbered	1
10	2	Fig.10.2.2 to 10.2.7	Stud link chain cables for ships	Figures deleted	1
10	2	Fig.10.2.2 to 10.2.7	Stud link chain cables for ships	New Figures added	1
10	2	2.16.1	Stud link chain cables for ships	Paragraph amended	1
10	2	2.17.1	Stud link chain cables for ships	Paragraph amended	1
10	2	2.17.2	Stud link chain cables for ships	Paragraph amended	1
10	3	3.1.1	Stud link mooring chain cables	Paragraph amended	1
10	3	3.2.4	Stud link mooring chain cables	Paragraph deleted	1
10	3	3.2.5 to 3.2.7	Stud link mooring chain cables	Existing paragraphs renumbered	1
10	3	3.2.8	Stud link mooring chain cables	Existing paragraph renumbered & amended	1
10	3	3.2.9 & 3.2.10	Stud link mooring chain cables	Existing paragraphs renumbered	1
10	3	3.2.11	Stud link mooring chain cables	Paragraph deleted	1
10	3	3.3	Stud link mooring chain cables	New sub-Section added	1
10	3	3.3	Stud link mooring chain cables	Existing sub-Section renumbered	1
10	3	3.3.2 & 3.3.3	Stud link mooring chain cables	Existing paragraphs renumbered & amended	1
10	3	3.3.5	Stud link mooring chain cables	Existing paragraph renumbered & amended	1
10	3	Fig.10.3.2 & 10.3.3	Stud link mooring chain cables	New Figures added	1
10	3	3.4	Stud link mooring chain cables	Existing sub-Section renumbered	1
10	3	3.4.3	Stud link mooring chain cables	Existing paragraph renumbered & amended	1
10	3	3.5	Stud link mooring chain cables	Existing sub-Section renumbered	1
10	3	3.6.1	Stud link mooring chain cables	New paragraph added	1
10	3	3.5.1 & 3.5.2	Stud link mooring chain cables	Existing paragraphs renumbered	1
10	3	3.5.3	Stud link mooring chain cables	Existing paragraph renumbered & amended	1
10	3	3.5.4	Stud link mooring chain cables	Existing paragraph renumbered	1
10	3	3.5.5	Stud link mooring chain cables	Existing paragraph renumbered & amended	1
10	3	3.5.6 & 3.5.7	Stud link mooring chain cables	Existing paragraphs renumbered	1
10	3	3.6.9 & 3.6.10	Stud link mooring chain cables	New paragraphs added	1
10	3	3.5.8	Stud link mooring chain cables	Existing paragraph renumbered & amended	1
10	3	3.5.9	Stud link mooring chain cables	Existing paragraph renumbered	1
10	3	3.5.10	Stud link mooring chain cables	Existing paragraph renumbered & amended	1
10	3	3.6.14	Stud link mooring chain cables	New paragraph added	1
10	3	3.5.11	Stud link mooring chain cables	Existing paragraph renumbered	1
10	3	3.5.12 & 3.5.13	Stud link mooring chain cables	Existing paragraphs renumbered & amended	1
10	3	3.5.14 & 3.5.15	Stud link mooring chain cables	Existing paragraphs renumbered	1
10	3	3.5.16 & 3.6.17	Stud link mooring chain cables	Existing paragraphs renumbered & amended	1
10	3	3.5.18 to 3.5.20	Stud link mooring chain cables	Existing paragraphs renumbered	1
10	3	3.5.21	Stud link mooring chain cables	Existing paragraph renumbered & amended	1
10	3	3.5.22 to 3.5.25	Stud link mooring chain cables	Existing paragraphs renumbered	1
10	3	3.6.30	Stud link mooring chain cables	New paragraph added	1
10	3	Table 10.3.1	Stud link mooring chain cables	Table deleted	1
10	3	Table 10.3.1	Stud link mooring chain cables	New Table added	1
10	3	Table 10.3.2	Stud link mooring chain cables	Table amended	1
10	3	Table 10.3.3	Stud link mooring chain cables	Table amended	1
10	3	Fig. 10.3.4	Stud link mooring chain cables	New Figure added	1
10	3	Table 10.3.4	Stud link mooring chain cables	New Table added	1
10	3	3.6	Stud link mooring chain cables	Existing sub-Section renumbered	1
10	3	3.6.7 to 3.6.9	Stud link mooring chain cables	Existing paragraphs renumbered & amended	1
10	3	3.7	Stud link mooring chain cables	Existing sub-Section renumbered	1
10	3	3.7.1 to 3.7.2	Stud link mooring chain cables	Existing paragraphs renumbered & amended	1
10	3	3.8.3 to 3.8.7	Stud link mooring chain cables	New paragraphs added	1
10	3	3.7.3	Stud link mooring chain cables	Existing paragraph renumbered & amended	1
10	3	3.8.9 to 3.8.15	Stud link mooring chain cables	New paragraphs added	1
10	3	Fig.10.3.5 & 10.3.6	Stud link mooring chain cables	New Figures added	1
10	3	3.7.4 & 3.7.5	Stud link mooring chain cables	Existing paragraphs renumbered	1
10	3	3.7.6	Stud link mooring chain cables	Paragraph deleted	1
10	3	3.7.7 to 3.7.9	Stud link mooring chain cables	Existing paragraphs renumbered & amended	1

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Notice – Summary of Changes

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Rules for the Manufacture, Testing and Certification of Materials (cont'd)					**Effective Date 1 July 2011**
10	3	3.7.10	Stud link mooring chain cables	Existing paragraph renumbered	1
10	3	3.8.22	Stud link mooring chain cables	New paragraph added	1
10	3	3.7.11	Stud link mooring chain cables	Existing paragraph renumbered & amended	1
10	3	3.7.12	Stud link mooring chain cables	Paragraph deleted	1
10	3	3.7.13	Stud link mooring chain cables	Existing paragraph renumbered & amended	1
10	3	3.8.25	Stud link mooring chain cables	New paragraph added	1
10	3	3.8	Stud link mooring chain cables	Existing sub-Section renumbered	1
10	3	3.9 & 3.10	Stud link mooring chain cables	Sub-Sections deleted	1
10	3	3.10 & 3.11	Stud link mooring chain cables	New sub-Sections added	1
10	4	4.1.1	Studless mooring chain cables	Paragraph amended	1
10	4	4.1.3	Studless mooring chain cables	Paragraph amended	1
10	4	4.4.1	Studless mooring chain cables	Paragraph amended	1
10	4	4.5.1	Studless mooring chain cables	Paragraph amended	1
10	4	4.6.1	Studless mooring chain cables	New paragraph added	1
10	4	4.6.1	Studless mooring chain cables	Existing paragraph renumbered	1
10	4	4.6.2 to 4.6.7	Studless mooring chain cables	Existing paragraphs renumbered & amended	1
10	4	4.6.9	Studless mooring chain cables	New paragraph added	1
10	4	4.7.1	Studless mooring chain cables	Paragraph amended	1
10	4	4.8.1	Studless mooring chain cables	Paragraph amended	1
10	4	4.9.1	Studless mooring chain cables	Paragraph amended	1
10	4	4.11.1	Studless mooring chain cables	Paragraph amended	1
10	5	5.1.2	Short link chain cables	Paragraph amended	1
10	5	5.4.1	Short link chain cables	Paragraph amended	1
10	5	5.6.1	Short link chain cables	Paragraph amended	1
10	5	Table 10.5.1	Short link chain cables	Table deleted	1
10	5	Table 10.5.1	Short link chain cables	New Table added	1
10	5	5.7.2	Short link chain cables	Paragraph amended	1
10	5	Fig. 10.5.1	Short link chain cables	Figure deleted	1
10	5	Fig. 10.5.1	Short link chain cables	New Figure added	1
10	6	6.7.1	Steel wire ropes	Paragraph deleted	1
10	6	6.7.1	Steel wire ropes	New paragraph added	1
10	7	7.4.1	Fibre ropes	Paragraph deleted	1
10	7	7.4.1 & 7.4.2	Fibre ropes	New paragraphs added	1
11	1	1.8	General	New sub-Section added	1
11	3	3.10	Electrodes for manual and gravity welding	Sub-Section deleted	1
11	3	3.11	Electrodes for manual and gravity welding	Existing sub-Section renumbered	1
11	8	8.5.1	Consumables for welding austenitic and duplex stainless steels	Paragraph amended	1
12	2	2.5.5	Welding Procedure Qualification Tests for Steels	Paragraph amended	1
12	2	2.15.10	Welding Procedure Qualification Tests for Steels	Paragraph amended	1
12	4	4.1.2	Welding procedure tests for non-ferrous alloys	Paragraph amended	1
12	4	Table 12.4.1	Welding procedure tests for non-ferrous alloys	Table deleted	1
12	4	Table 12.4.1	Welding procedure tests for non-ferrous alloys	New Table added	1
12	4	Table 12.4.2	Welding procedure tests for non-ferrous alloys	New Table added	1
12	4	Tables 12.4.2 to 12.4.9	Welding procedure tests for non-ferrous alloys	Existing Tables renumbered	1
13	1	1.11.1	General welding requirements	Paragraph amended	1
13	2	2.12.5	Specific requirements for ship hull structure and machinery	Paragraph amended	1
13	2	Table 13.2.4	Specific requirements for ship hull structure and machinery	Table amended	1
13	2	Table 13.2.6	Specific requirements for ship hull structure and machinery	Table amended	1

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Notice – Summary of Changes

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Rules for the Manufacture, Testing and Certification of Materials (cont'd)					**Effective Date 1 July 2011**
13	4	4.13.5	Specific requirements for fusion welded pressure vessels	New paragraph added	1
13	4	4.14.4	Specific requirements for fusion welded pressure vessels	Paragraph amended	1
13	8	Whole Section	Specific requirements for welded aluminium	New Section added	1
14	1	1.1.2	General requirements	Paragraph amended	1
14	1	1.1.7	General requirements	Paragraph deleted	1
14	1	1.1.7 & 1.1.8	General requirements	New paragraphs added	1
14	1	1.3.4	General requirements	New paragraph added	1

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 3					**Effective Date 1 July 2011**
5	8	8.2	Windlass design and testing	Sub-Section title amended	5
5	8	8.2.1	Windlass design and testing	Paragraph amended	5
5	8	8.2.3 to 8.2.9	Windlass design and testing	New paragraphs added	5
5	8	8.2.3 & 8.2.4	Windlass design and testing	Existing paragraphs renumbered	5
5	8	8.3 to 8.6	Windlass design and testing	New sub-Sections added	5
5	8	8.3 & 8.4	Windlass design and testing	Existing sub-Sections renumbered	5

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 4					**Effective Date 1 February 2011**
2	8	Whole Section	Intact stability	Section deleted	3
2	9	Whole Section	Damage stability	Section deleted	3
2	10	Whole Section	Navigation in first year ice conditions	Existing Section renumbered	3
3	10	Whole Section	Intact stability	Section deleted	3

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 8					**Effective Date 1 July 2011**
3	1	1.13.1	General	Paragraph amended	4
3	1	1.13.9	General	Paragraph amended	4
7	3	3.2.2	Stress control	New paragraph added	4
7	3	3.5.1	Stress control	Paragraph deleted	4
7	3	3.5.1 to 3.5.3	Stress control	New paragraphs added	4
7	3	Table 7.3.3	Stress control	New Table added	4

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 9					**Effective Date 1 July 2011**
1	1	1.1.1	General requirements	Paragraph amended	5
1	1	1.1.3	General requirements	Paragraph amended	5
1	3	3.1.2	Certification of materials	Paragraph amended	5
2	2	2.4.3	Diesel engines	New paragraph added	7
2	2	2.4.3 to 2.4.5	Diesel engines	Existing paragraphs renumbered	7

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 10					**Effective Date 1 July 2011**
1	1	1.5.1	General requirements	Paragraph amended	7
1	2	2.1.1	Particulars to be submitted	Paragraph amended	7
1	2	2.1.6	Particulars to be submitted	Paragraph deleted	7
1	2	2.1.4 & 2.1.5	Particulars to be submitted	Existing paragraphs renumbered	7
1	2	2.1.7 & 2.1.8	Particulars to be submitted	Existing paragraphs renumbered	7

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Notice – Summary of Changes

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 10 (cont'd)					**Effective Date 1 July 2011**
1	7	7.5.4	Starting arrangements	Paragraph amended	7
1	7	7.6.6	Starting arrangements	Paragraph amended	7
1	7	7.7	Starting arrangements	New sub-Section added	7
1	11	11.2.2	Mass produced engines	Paragraph amended	7
1	11	11.2.5	Mass produced engines	Paragraph amended	7
1	11	11.4.2	Mass produced engines	New paragraph added	7
1	11	11.5.3	Mass produced engines	New paragraph added	7
1	11	11.5.3 to 11.5.11	Mass produced engines	Existing paragraphs renumbered	7
1	11	11.5.10	Mass produced engines	Existing paragraph renumbered & amended	7
1	13	13.1.1 to 13.1.5	Electronically controlled engines	Paragraphs amended	7
1	13	13.1.6	Electronically controlled engines	New paragraph added	7
1	13	13.2.1 & 13.2.2	Electronically controlled engines	Paragraphs amended	7
1	13	13.3	Electronically controlled engines	New sub-Section added	7
1	13	13.3	Electronically controlled engines	Existing sub-Section renumbered	7
1	13	13.4 & 13.5	Electronically controlled engines	Sub-Sections deleted	7
1	13	13.5 & 13.6	Electronically controlled engines	New sub-Sections added	7
1	14	14.1.2	Program for trials of diesel engines to assess operational capability	Paragraph amended	7
1	14	14.2	Program for trials of diesel engines to assess operational capability	Sub-Section title amended	7
1	14	14.2.1 & 14.2.2	Program for trials of diesel engines to assess operational capability	Paragraphs amended	7
1	14	14.2.4 & 14.2.5	Program for trials of diesel engines to assess operational capability	New paragraphs added	7
1	14	14.2.4 & 14.2.5	Program for trials of diesel engines to assess operational capability	Existing paragraphs renumbered	7
1	14	Table 1.14.2	Program for trials of diesel engines to assess operational capability	Table amended	5
1	14	Table 1.14.2	Program for trials of diesel engines to assess operational capability	Table amended	7

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 12					**Effective Date 1 July 2011**
2	—	Whole Chapter	Water Jet Systems	Chapter deleted	5
2	—	Whole Chapter	Waterjet Systems	New Chapter added	5

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 14					**Effective Date 1 July 2011**
1	6	6.2.4	Control, monitoring and electrical equipment	New paragraph added	5
1	6	Table 1.6.1	Control, monitoring and electrical equipment	Table amended	5
1	7	7.1.1 & 7.1.2	Requirements for craft which are not required to comply with the HSC Code	Paragraphs deleted	5
1	7	7.1.1	Requirements for craft which are not required to comply with the HSC Code	New paragraph added	5
1	7	7.2.1 & 7.2.2	Requirements for craft which are not required to comply with the HSC Code	New paragraphs added	5
1	7	7.2.1 to 7.2.6	Requirements for craft which are not required to comply with the HSC Code	Existing paragraphs renumbered	5

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Notice – Summary of Changes

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 15					**Effective Date 1 July 2011**
1	2	2.1.3	Details to be submitted	Paragraph amended	5
1	9	—	Stainless steel	Section title amended	5
1	9	Table 1.9.1	Stainless steel	Table deleted	5
1	9	Table 1.9.1	Stainless steel	New Table added	5
2	11	11.4.4 to 11.4.14	Air, overflow and sounding pipes	New paragraphs added	5
2	15	15.1.1	Requirements for yachts and service craft of 24m or greater in length, which are not required to comply with the HSC Code	Paragraph amended	5
2	15	15.2	Requirements for yachts and service craft of 24m or greater in length, which are not required to comply with the HSC Code	Sub-Section title amended	5
2	15	15.2.1	Requirements for yachts and service craft of 24m or greater in length, which are not required to comply with the HSC Code	Paragraph deleted	5
2	15	15.2.1 & 15.2.2	Requirements for yachts and service craft of 24m or greater in length, which are not required to comply with the HSC Code	New paragraphs added	5
3	4	4.6.1	Oil fuel systems	Paragraph amended	5
3	6	6.2	Lubricating/hydraulic oil systems	Sub-Section title amended	5
3	6	6.2.1	Lubricating/hydraulic oil systems	Paragraph deleted	5
3	6	6.2.1 & 6.2.2	Lubricating/hydraulic oil systems	New paragraphs added	5

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 16					**Effective Date 1 January 2011**
2	16	16.1.1	Fire safety systems	Paragraph deleted	2
2	16	16.1.1 to 16.1.4	Fire safety systems	New paragraphs added	2
2	16	16.1.2 to 16.1.17	Fire safety systems	Existing paragraphs renumbered	2
2	16	16.6.8	Fire safety systems	Paragraph amended	2

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 16					**Effective Date 1 July 2011**
1	1	1.2.2	General requirements	Paragraph amended	5
1	1	1.2.5	General requirements	Paragraph amended	5
1	1	1.2.6	General requirements	New paragraph added	5
1	1	1.2.6 to 1.2.9	General requirements	Existing paragraphs renumbered	5
1	2	2.8.7	Essential features for control, alarm and safety systems	Paragraph amended	5
1	2	2.10.20	Essential features for control, alarm and safety systems	Paragraph amended	5
1	2	2.11.3	Essential features for control, alarm and safety systems	Paragraph amended	5
1	2	2.11.7	Essential features for control, alarm and safety systems	New paragraph added	5
1	2	2.11.7 to 2.11.10	Essential features for control, alarm and safety systems	Existing paragraphs renunbered	5
1	2	2.12	Essential features for control, alarm and safety systems	New sub-Section added	5
1	2	2.12 & 2.13	Essential features for control, alarm and safety systems	Existing sub-Sections renumbered	5
1	6	6.1.4	Trials	New paragraph added	5
2	2	2.3.2	Main source of electrical power	Paragraph amended	5
2	5	5.3.5	Supply and distribution	New paragraph added	5
2	5	5.3.5 to 5.3.7	Supply and distribution	Existing paragraphs renumbered	5

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Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 16 (cont'd)					**Effective Date 1 July 2011**
2	10	Table 2.10.2	Electrical cables and busbar trunking systems (busways)	Table deleted	5
2	10	Table 2.10.2	Electrical cables and busbar trunking systems (busways)	New Table added	5
2	10	10.5.3	Electrical cables and busbar trunking systems (busways)	Paragraph amended	5
2	10	Table 2.10.3	Electrical cables and busbar trunking systems (busways)	Table deleted	5
2	10	Table 2.10.3	Electrical cables and busbar trunking systems (busways)	New Table added	5
2	10	Table 2.10.4	Electrical cables and busbar trunking systems (busways)	Table deleted	5
2	10	Table 2.10.4	Electrical cables and busbar trunking systems (busways)	New Table added	5
2	10	Table 2.10.5	Electrical cables and busbar trunking systems (busways)	Table deleted	5
2	10	Table 2.10.5	Electrical cables and busbar trunking systems (busways)	New Table added	5
2	10	10.8.10	Electrical cables and busbar trunking systems (busways)	New paragraph added	5
2	10	10.8.10 to 10.8.17	Electrical cables and busbar trunking systems (busways)	Existing paragraphs renumbered	5
2	10	10.8.19 to 10.8.22	Electrical cables and busbar trunking systems (busways)	New paragraphs added	5
2	10	10.9.1	Electrical cables and busbar trunking systems (busways)	Paragraph amended	5
2	10	10.16.3	Electrical cables and busbar trunking systems (busways)	New paragraph added	5
2	11	11.5.1	Batteries	Paragraph amended	5
2	11	11.5.2	Batteries	New paragraph added	5
2	11	11.5.2 to 11.5.10	Batteries	Existing paragraphs renumbered	5
2	18	18.1.2	Craft safety systems	Paragraph deleted	5
2	18	18.1.3 to 18.1.12	Craft safety systems	Existing paragraphs renumbered	5
2	20	20.2.4	Testing and trials	Paragraph amended	5
2	20	20.2.5	Testing and trials	Paragraph amended	5

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 17					**Effective Date 1 July 2011**
1	1	1.1.2	General requirements	Paragraph amended	4
1	1	1.2.5	General requirements	New paragraph added	4

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2	3	3.9.1	Character classification of class and class notations	Reference amended	6
2	4	4.5.15	Surveys - General	References amended	7
2	4	4.9.5	Surveys - General	Reference amended	1
2	4	4.9.6	Surveys - General	Reference amended	1
4	11	11.1.2	Surveys of unclassed machinery in existing classed yachts	Reference amended	1
5	1	1.3.2	General	Reference amended	1

Ch	Section	Para	Section Title	Status	Notice
Rules for the Manufacture, Testing and Certification of Materials					
10	3	3.6.9	Stud link mooring chain cables	Reference amended	1
10	4	4.2.1	Studless mooring chain cables	Reference deleted	1
10	4	4.6.2	Studless mooring chain cables	References amended	1
10	4	4.6.3	Studless mooring chain cables	Reference amended	1
10	4	4.6.4	Studless mooring chain cables	Reference deleted	1
10	4	4.6.5	Studless mooring chain cables	References amended	1
10	4	4.6.6	Studless mooring chain cables	Reference amended	1
10	4	4.6.7	Studless mooring chain cables	References amended	1
10	4	4.7.1	Studless mooring chain cables	Reference amended	1
10	4	4.8.1	Studless mooring chain cables	Reference amended	1
10	4	4.9.1	Studless mooring chain cables	References amended	1
10	4	4.10.1	Studless mooring chain cables	Reference amended	1
11	3	3.11.3	Electrodes for manual and gravity welding	References amended	1
11	3	3.11.5	Electrodes for manual and gravity welding	References amended	1
12	4	4.1.3	Welding procedure tests for non-ferrous alloys	Reference amended	1
12	4	4.1.6	Welding procedure tests for non-ferrous alloys	References amended	1
12	4	4.2.4	Welding procedure tests for non-ferrous alloys	Reference amended	1
12	4	4.2.5	Welding procedure tests for non-ferrous alloys	Reference amended	1
12	4	4.2.6	Welding procedure tests for non-ferrous alloys	Reference amended	1

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Part 4					
2	8	8.1.4	Intact stability	Reference amended	3

Ch	Section	Para	Section Title	Status	Notice
Part 5					
2	7	7.1.1	Component design loads	Paragraph amended	6

Ch	Section	Para	Section Title	Status	Notice
Part 6					
7	4	Table 7.4.3	Buckling control	Table amended	6

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7	4	Table 7.4.3	Buckling control	Table amended	6

Ch	Section	Para	Section Title	Status	Notice
Part 8					
3	5	5.3.6	Single bottom structure and appendages	Reference amended	6
3	10	10.10.5	Pillars and pillar bulkheads	Paragraph amended	6

Ch	Section	Para	Section Title	Status	Notice
Part 10					
1	10	10.2.2	Requirements for craft which are not required to comply with the HSC Code	Reference amended	7
1	11	11.5.4	Mass produced engines	References amended	7
1	11	11.5.5	Mass produced engines	Reference amended	7
1	11	11.5.8	Mass produced engines	Reference amended	7
1	13	13.2.2(m)	Electronically controlled engines	Reference deleted	7
1	13	13.5.1	Electronically controlled engines	References amended	5

Ch	Section	Para	Section Title	Status	Notice
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1	7	7.2.6	Requirements for craft which are not required to comply with the HSC Code	Reference deleted	5

Ch	Section	Para	Section Title	Status	Notice
Part 16					
1	1	1.2.5	General requirements	Reference amended	5
1	2	2.5.11	Essential features for control, alarm and safety systems	Reference amended	5
1	2	2.6.7	Essential features for control, alarm and safety systems	Reference amended	6
1	2	2.10.1	Essential features for control, alarm and safety systems	References amended	5
1	2	2.10.2	Essential features for control, alarm and safety systems	Reference amended	5
1	2	2.10.5	Essential features for control, alarm and safety systems	Reference amended	5
1	2	2.10.6	Essential features for control, alarm and safety systems	References amended	5
1	2	2.10.9	Essential features for control, alarm and safety systems	Reference amended	5
1	2	2.12.1	Essential features for control, alarm and safety systems	References amended	5
1	2	2.13.1	Essential features for control, alarm and safety systems	References amended	5
2	5	5.3.6	Supply and distribution	Reference amended	5
2	10	10.13.1	Electrical cables and busbar trunking systems (busways)	Reference amended	5
2	16	16.1.3	Fire safety systems	References amended	2
2	16	16.1.9	Fire safety systems	Reference amended	2

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Notice – Summary of Changes

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 16 (cont'd)					
2	19	19.1.3	Cargo craft, patrol and pilot craft, workboats and other similar craft of less than 500 tons gross tonnage for operation in Service Groups 1 to 3, and yachts less than 500 gt	Reference amended	6
2	19	19.9.1(b)	Cargo craft, patrol and pilot craft, workboats and other similar craft of less than 500 tons gross tonnage for operation in Service Groups 1 to 3, and yachts less than 500 gt	Paragraph amended	6

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Rules and Regulations for the Classification of Special Service Craft

Volume 1
Part 1
Regulations
July 2011

Lloyd's Register
LIFE MATTERS

000560

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A guide to the Rules

and published requirements

Rules and Regulations for the Classification of Special Service Craft

Introduction

The Rules are published as a complete set; individual Parts are, however, available on request. A comprehensive List of Contents is placed at the beginning of each Part.

Numbering and Cross-References

A decimal notation system has been adopted throughout. Five sets of digits cover the divisions, i.e. Part, Chapter, Section, sub-Section and paragraph. The textual cross-referencing within the text is as follows, although the right hand digits may be added or omitted depending on the degree of precision required:

(a) In same Chapter, e.g. *see* 2.1.3 (i.e. down to paragraph).
(b) In same Part but different Chapter, e.g. *see* Ch 3,2.1 (i.e. down to sub-Section).
(c) In another Part, e.g. *see* Pt 5, Ch 1,3 (i.e. down to Section).

The cross-referencing for Figures and Tables is as follows:

(a) In same Chapter, e.g. as shown in Fig. 2.3.5 (i.e. Chapter, Section and Figure Number).
(b) In same Part but different Chapter, e.g. as shown in Fig. 2.3.5 in Chapter 2.
(c) In another Part, e.g. *see* Table 2.7.1 in Pt 3, Ch 2.

Rules updating

The Rules are generally published annually and changed through a system of Notices. Subscribers are forwarded copies of such Notices when the Rules change.

Current changes to Rules that appeared in Notices are shown with a black rule alongside the amended paragraph on the left hand side. A solid black rule indicates amendments and a dotted black rule indicates corrigenda.

Rules programs

LR has developed a suite of Calculation Software that evaluates Requirements for Ship Rules, Special Service Craft Rules and Naval Ship Rules. For details of this software please contact LR.

Direct calculations

The Rules require direct calculations to be submitted for specific parts of the ship structure or arrangements and these will be assessed in relation to LR's own direct calculation procedures. They may also be required for ships of unusual form, proportion or speed, where intended for the carriage of special cargoes or for special restricted service and as supporting documentation for arrangements or scantlings alternative to those required by the Rules.

July 2011

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Lloyd's Register, its affiliates and subsidiaries and their respective officers, employees or agents are, individually and collectively, referred to in this clause as the 'Lloyd's Register Group'. The Lloyd's Register Group assumes no responsibility and shall not be liable to any person for any loss, damage or expense caused by reliance on the information or advice in this document or howsoever provided, unless that person has signed a contract with the relevant Lloyd's Register Group entity for the provision of this information or advice and in that case any responsibility or liability is exclusively on the terms and conditions set out in that contract.

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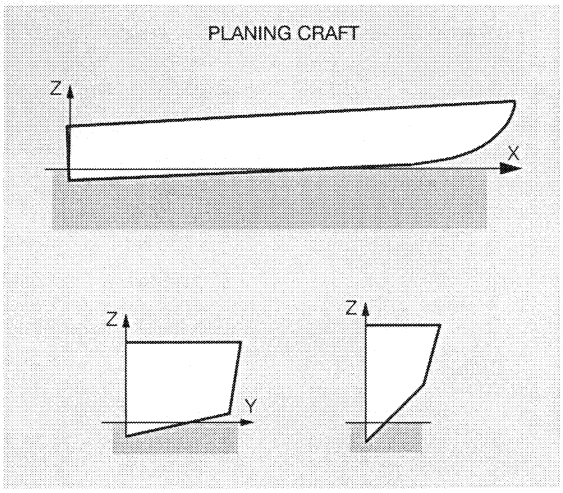
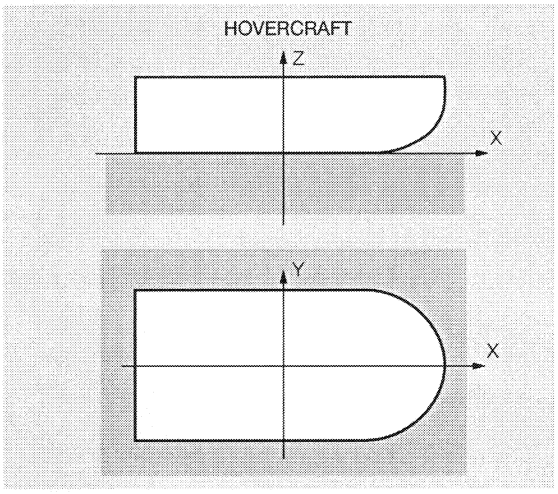
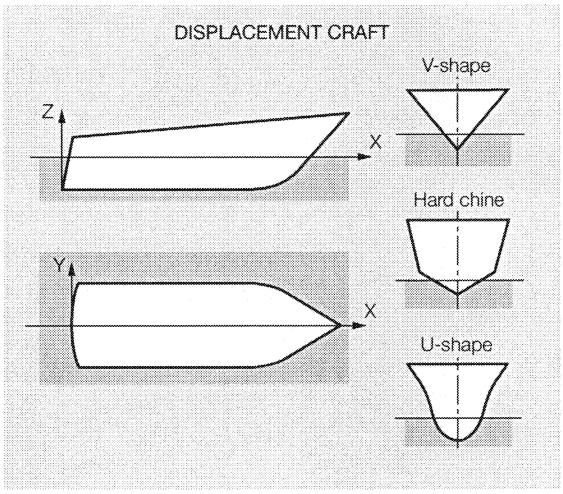
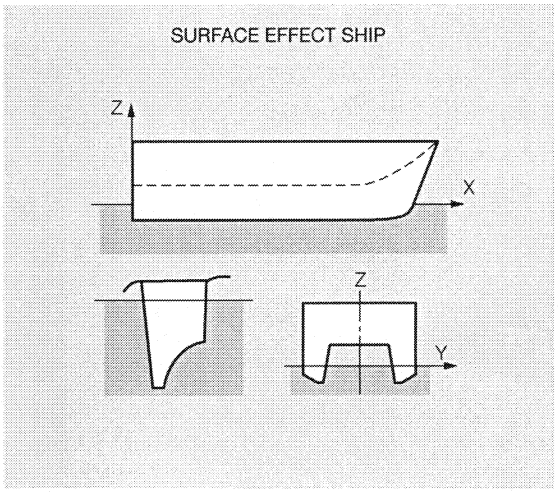
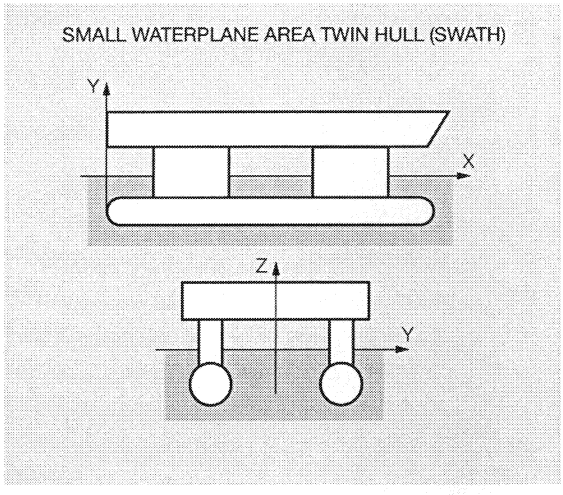
DIFFERENT TYPES OF HULL FORMS COVERED BY THE SPECIAL SERVICE CRAFT RULES

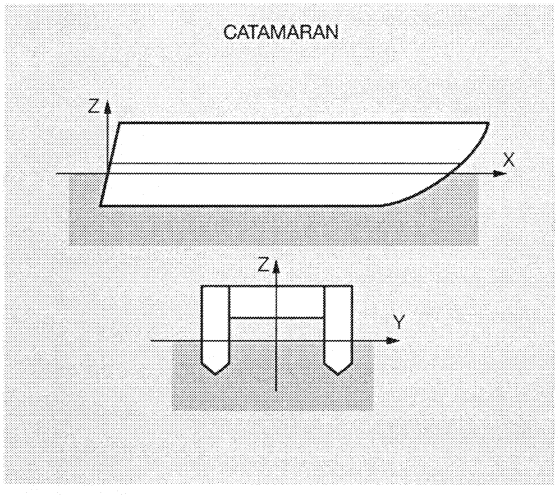












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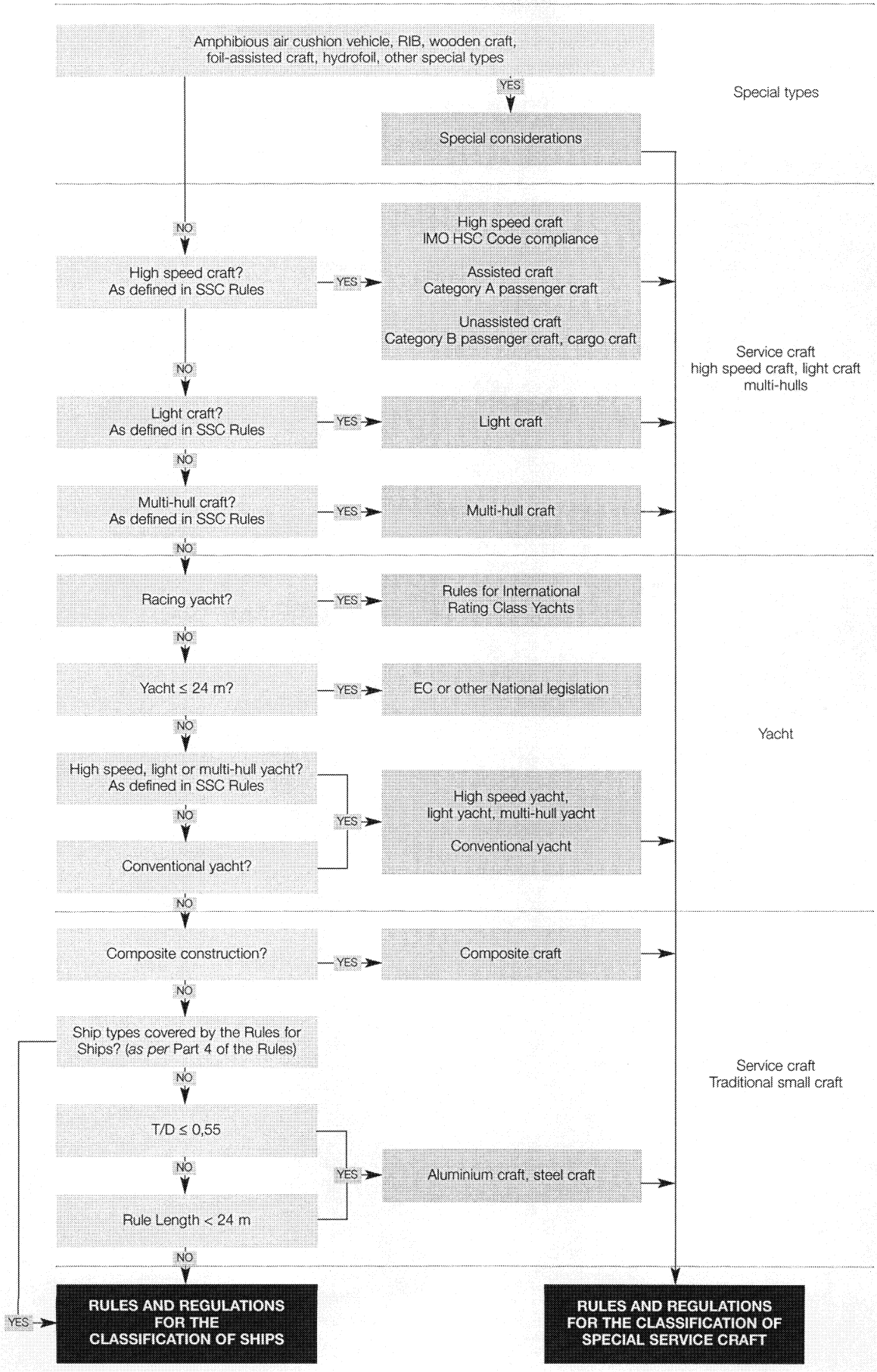
DIFFERENT TYPES OF CRAFT COVERED BY THE SPECIAL SERVICE CRAFT RULES



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■ *Section 1*

1.1 Lloyd's Register (hereinafter referred to as 'LR'), which is recognised under the laws of the United Kingdom as a corporate body and a charity established for the benefit of the community, was founded in 1760. It was established for the purpose of producing a faithful and accurate classification of merchant shipping. It now primarily produces classification Rules.

1.2 Classification services are delivered to clients by a number of other members of the Lloyd's Register Group, including: Lloyd's Register EMEA, Lloyd's Register Asia, Lloyd's Register North America, Inc., and Lloyd's Register Central and South America Limited.

1.3 The Lloyd's Register Group (hereinafter referred to as 'the LR Group') comprises charities, other forms of organisation and non-charitable companies, with the latter supporting the charities in their main goal of enhancing the safety of life and property, at sea, on land and in the air, for the benefit of the public and the environment.

■ *Section 2*

2.1 LR remains the sole classification society in the LR Group. LR is managed by a Board of Trustees (hereinafter referred to as 'the Board').

The Board has:

appointed a Classification Committee and determined its powers and functions and authorised it to delegate certain of its powers to a Classification Executive and Devolved Classification Executives;
appointed Technical Committees and determined their powers, functions and duties.

2.2 The LR Group has established National and Area Committees in the following:

Countries:
Australia (via Lloyd's Register Asia)
Canada (via Lloyd's Register North America, Inc.)
China (via Lloyd's Register Asia)
Egypt (via Lloyd's Register EMEA)
Federal Republic of Germany
(via Lloyd's Register EMEA)
France (via Lloyd's Register EMEA)
Italy (via Lloyd's Register EMEA)
Japan (via Lloyd's Register)
New Zealand (via Lloyd's Register Asia)
Poland (via Lloyd's Register (Polska) Sp zoo)
Spain (via Lloyd's Register EMEA)
United States of America (via Lloyd's Register North America, Inc.)

Areas:
Benelux (via Lloyd's Register EMEA)
Central America (via Lloyd's Register Central and South America Ltd)
Nordic Countries (via Lloyd's Register EMEA)
South Asia (via Lloyd's Register Asia)
Asian Shipowners (via Lloyd's Register Asia)
Greece (via Lloyd's Register EMEA)

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■ *Section 3*

3.1 LR's Technical Committee is at present composed of a maximum of 80 members which includes:

Ex officio members:

- Chairman and Chief Executive Officer of LR .....
- Chairman of the Classification Committee of LR .....

Members Nominated by:

- Technical Committee .....
- Royal Institution of Naval Architects 2
- Institution of Engineers and Shipbuilders in Scotland 2
- Institute of Marine, Engineering, Science and Technology 2
- Institute of Materials, Minerals and Mining 1
- Honourable Company of Master Mariners 2
- Institution of Engineering and Technology 1
- Institute of Refrigeration 1
- Welding Institute 1
- Shipbuilders' and Shiprepairers' Association 2
- The Society of Consulting Marine Engineers and Ship Surveyors .....
- Community of European Shipyards Associations 1
- Society of Maritime Industries 2
- European Marine Equipment Council 1
- Chamber of Shipping 1
- Greek Shipping Co-operation Committee 1
- International Association of Oil and Gas Producers 1

3.2 In addition to the foregoing:

(a) Each National or Area Committee may appoint a representative to attend meetings of the Technical Committee.

(b) A maximum of five representatives from National Administrations may be co-opted to serve on the Technical Committee. Representatives from National Administrations may also be elected as members of the Technical Committee under one of the categories identified in 3.1.

(c) Further persons may be co-opted to serve on the Technical Committee by the Technical Committee.

3.3 All elections are subject to confirmation by the Board.

3.4 The function of the Technical Committee is to consider:

(a) any technical issues connected with LR's marine business;

(b) any proposed alterations in the existing Rules;

(c) any new Rules for classification;

Where changes to the Rules are necessitated by mandatory implementation of International Conventions, Codes or Unified Requirements adopted by the International Association of Classification Societies these may be implemented by LR without consideration by the Technical Committee.

3.5 The term of office of the Chairman and of all members of the Technical Committee is five years. Members may be re-elected to serve an additional term of office with the approval of the Board. The term of office of the Chairman may be extended with the approval of the Board.

3.6 In the case of continuous non-attendance of a member, the Technical Committee may withdraw membership.

3.7 Meetings of the Technical Committee are convened as often and at such times and places as is necessary, but there is to be at least one meeting in each year. Urgent matters may be considered by the Technical Committee by correspondence.

3.8 Any proposal involving any alteration in, or addition to, Part 1, Chapter 1 of Rules for Classification is subject to approval of the Board. All other proposals for additions to or alterations to the Rules for Classification other than Part 1, Chapter 1, will following consideration and approval by the Technical Committee either at a meeting of the Technical Committee or by correspondence, be recommended to the Board for adoption.

3.9 The Technical Committee is empowered to:

(a) appoint sub-Committees or panels; and

(b) co-opt to the Technical Committee, or to its sub-Committees or panels, representatives of any organisation or industry or private individuals for the purpose of considering any particular problem.

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■ *Section 4*

4.1 LR's Naval Ship Technical Committee is at present composed of a maximum of 50 members and includes:

Ex officio members

- Chairman and Chief Executive Officer of LR

Member nominated by:

- Naval Ship Technical Committee;
- The Royal Navy and the UK Ministry of Defence;
- UK Shipbuilders, Ship Repairers and Defence Industry;
- Overseas Navies, Governments and Governmental Agencies;
- Overseas Shipbuilders, Ship Repairers and Defence Industries;

4.2 All elections are subject to confirmation by the Board.

4.3 All members of the Naval Ship Technical Committee are to hold security clearance from their National Authority for the equivalent of NATO CONFIDENTIAL. All material is to be handled in accordance with NATO Regulations or, for non-NATO countries, an approved equivalent. No classified material shall be disclosed to any third party without the consent of the originator.

4.4 The term of office of the Naval Ship Technical Committee Chairman and of all members of the Naval Ship Technical Committee Chairman is five years. Members may be re-elected to serve an additional term of office with the approval of the Board. The term of the Chairman may be extended with the approval of the Board.

4.5 In the case of continuous non-attendance of a member, the Naval Ship Technical Committee may withdraw membership.

4.6 The function of the Naval Ship Technical Committee is to consider technical issues connected with Naval Ship matters and to approve proposals for new Naval Ship Rules, or amendments to existing Naval Ship Rules.

4.7 Meetings of the Naval Ship Technical Committee are convened as necessary but there will be at least one meeting per year. Urgent matters may be considered by the Naval Ship Technical Committee by correspondence.

4.8 Any proposal involving any alteration in, or addition to, Part 1, Chapter 1 of Rules for Classification of Naval Ships is subject to approval of the Board. All other proposals for additions to or alterations to the Rules for Classification of Naval Ships, other than Part 1, Chapter 1, will following consideration and approval by the Naval Ship Technical Committee, either at a meeting of the Naval Ship Technical Committee or by correspondence, be recommended to the Board for adoption.

4.9 The Naval Ship Technical Committee is empowered to:

(a) appoint sub-Committees or panels; and

(b) co-opt to the Naval Ship Technical Committee, or to its sub-Committees or panels, representatives of any organisation or industry or private individuals for the purpose of considering any particular problem.

■ *Section 5*

5.1 LR has the power to adopt, and publish as deemed necessary, Rules relating to classification and has (in relation thereto) provided the following:

(a) Except in the case of a special directive by the Board, no new Regulation or alteration to any existing Regulation relating to classification or to class notations is to be applied to existing ships.

(b) Except in the case of a special directive by the Board, or where changes necessitated by mandatory implementation of International Conventions, Codes or Unified Requirements adopted by the International Association of Classification Societies are concerned, no new Rule or alteration in any existing Rule is to be applied compulsorily after the date on which the contract between the ship builder and shipowner for construction of the ship has been signed, nor within six months of its adoption. The date of 'contract for construction' of a ship is the date on which the contract to build the ship is signed between the prospective shipowner and the ship builder. This date and the construction number (i.e. hull numbers) of all the vessels included in the contract are to be declared by the party applying for the assignment of class to a newbuilding. The date of 'contract for construction' of a series of sister ships, including specified optional ships for which the option is ultimately exercised, is the date on which the contract to build the series is signed between the prospective shipowner and the ship builder. In this section a 'series of sister ships' is a series of ships built to the same approved plans for classification purposes, under a single contract for construction. The optional ships will be considered part of the same series of sister ships if the option is exercised not later than 1 year after the contract to build the series was signed. If a contract for construction is later amended to include additional ships or additional options, the date of 'contract for construction' for such ships is the date

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on which the amendment to the contract is signed between the prospective shipowner and the ship builder. The amendment to the contract is to be considered as a 'new contract'. If a contract for construction is amended to change the ship type, the date of 'contract for construction' of this modified vessel, or vessels, is the date on which the revised contract or new contract is signed between the Owner, or Owners, and the shipbuilder. Where it is desired to use existing approved ship or machinery plans for a new contract, written application is to be made to LR. Sister ships may have minor design alterations provided that such alterations do not affect matters related to classification, classification, or if the alterations are subject to classification requirements, these alterations are to comply with the classification requirements in effect on the date on which the alterations are contracted between the prospective owner and the ship builder or, in the absence of the alteration contract, comply with the classification requirements in effect on the date on which the alterations are submitted to LR for approval.

(c) All reports of survey are to be made by surveyors authorised by members of the LR Group to survey and report (hereinafter referred to as 'the Surveyors') according to the form prescribed, and submitted for the consideration of the Classification Committee.

(d) Information contained in the reports of classification and statutory surveys will be made available to the relevant owner, National Administration, Port State Administration, P&I Club, hull underwriter and, if authorised in writing by that owner, to any other person or organisation.

(e) Notwithstanding the general duty of confidentiality owed by LR to its client in accordance with the LR Rules, LR clients hereby accept that, LR will participate in the IACS Early Warning System which requires each IACS member to provide its fellow IACS members and Associates with relevant technical information on serious hull structural and engineering systems failures, as defined in the IACS Early Warning System (but not including any drawings relating to the ship which may be the specific property of another party), to enable such useful information to be shared and utilised to facilitate the proper working of the IACS Early Warning System LR will provide its client with written details of such information upon sending the same to IACS Members and Associates.

(f) Information relating to the status of classification and statutory surveys and suspensions/withdrawals of class together with any associated conditions of class will be made available as required by applicable legislation or court order.

(g) A Classification Executive consisting of senior members of LR's Classification Department staff shall carry out whatever duties that may be within the function of the Classification Committee that the Classification Committee assigns to it.

■ *Section 6*

6.1 No LR Group employee is permitted under any circumstances, to accept, directly or indirectly, from any person, firm or company, with whom the work of the employee brings the employee into contact, any present, bonus, entertainment or honorarium of any sort whatsoever which is of more than nominal value or which might be construed to exceed customary courtesy extended in accordance with accepted ethical business standards.

■ *Section 7*

7.1 LR has the power to withhold or, if already granted, to suspend or withdraw any ship from class (or to withhold any certificate or report in any other case), in the event of non-payment of any fee to any member of the LR Group.

■ *Section 8*

8.1 When providing services LR does not assess compliance with any standard other than the applicable LR Rules, international conventions and other standards agreed in writing.

8.2 In providing services, information or advice, the LR Group does not warrant the accuracy of any information or advice supplied. Except as set out herein, LR will not be liable for any loss, damage or expense sustained by any person and caused by any act, omission, error, negligence or strict liability of any of the LR Group or caused by any inaccuracy in any information or advice given in any way by or on behalf of the LR Group even if held to amount to a breach of warranty. Nevertheless, if the Client uses LR's services or relies on any information or advice given by or on behalf of the LR Group and as a result suffers loss, damage or expense that is proved to have been caused by any negligent act, omission or error of the LR Group or any negligent inaccuracy in information or advice given by or on behalf of the LR Group, then a member of the LR Group will pay compensation to the client for its proved loss up to but not exceeding the amount of the fee (if any) charged for that particular service, information or advice.

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8.3 Notwithstanding the previous clause, the LR Group will not be liable for any loss of profit, loss of contract, loss of use or any indirect or consequential loss, damage or expense sustained by any person caused by any act, omission or error or caused by any inaccuracy in any information or advice given in any way by or on behalf of the LR Group even if held to amount to a breach of warranty.

8.4 Any dispute about LR's services is subject to the exclusive jurisdiction of the English courts and will be governed by English law.

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Section

1 **Conditions for classification**

2 **Scope of the Rules**

3 **Character of classification and class notations**

4 **Surveys – General**

5 **IACS QSCS Audits**

6 **Type Approval/Type testing/ Quality control system**

7 **Classification of machinery for craft/yachts with [⊠] LMC or MCH notation**

■ *Section 1* Conditions for classification

1.1 General

1.1.1 The *Rules and Regulations for the Classification of Special Service Craft* (hereinafter referred to as the Rules for Special Service Craft), are applicable to those types of craft which are defined in 2.1. Where the word craft is used in the text of the Rules, it is to be taken as being applicable to yachts and other craft as stated herein unless specifically indicated otherwise.

1.1.2 The Rules are framed on the understanding:

(a) that the craft will at all times be properly loaded. They do not, unless stated or implied in the class notation, provide for special distributions or concentrations of loading associated with the operation of the craft. Lloyd's Register (hereinafter referred to 'LR') may require additional strengthening to be fitted in any craft, which, in their opinion, would otherwise be subjected to severe stresses due to particular features in the design or operation, or where it is desired to make provision for exceptional loading conditions. In such cases particulars and details of the required loadings are to be submitted for consideration,

(b) that the craft will at all times be properly handled, with particular reference to the placing on board of persons and equipment and the reduction of speed in heavy weather,

(c) that compliance with the Rules does not relieve the designer of his responsibilities to his client for compliance with the specification and the requirements for the overall design and in service performance of the craft,

(d) that the craft will not be operated outside of the para-meters specified in any operational envelope which may have been assigned, without the prior agreement of LR.

1.1.3 New craft built in accordance with the Rules, or in accordance with requirements equivalent thereto, will be assigned a class in the appropriate *Register Book* and will continue to be classed so long as they are found, upon examination at the prescribed surveys, to be maintained in accordance with the requirements of the Rules. Classification will be conditional upon compliance with LR's requirements for both hull and machinery.

1.1.4 The class notations of yachts will be recorded on the ClassDirect Live website. The class notations of other craft will be recorded on the ClassDirect Live website in the *Register of Ships*.

1.1.5 LR, in addition to requiring compliance with the Rules, will, in general, require to be satisfied that craft are suitable for the geographical or other limits or conditions of the service contemplated.

1.1.6 Loading conditions and any other preparations required to permit a craft with a notation specifying some service limitation to undertake a sea-going voyage, either from port of building to service area or from one service area to another, are to be in accordance with arrangements agreed by LR prior to the voyage.

1.1.7 Any damage, defect, breakdown or grounding, which could invalidate the conditions for which a class has been assigned, is to be reported to LR without delay. Any detention or arrest is also to be reported to LR without delay.

1.1.8 Where the provision of loading or stress monitoring equipment has been required by LR as the result of local, longitudinal or transverse strength calculations and the imposition of operating limitations, the necessary loading guidance information and operating instructions are to be incorporated in the relevant manuals supplied to the Master.

1.1.9 Where an onboard computer system having longitudinal strength computation capability, which is required by the Rules, is provided on a new craft, or newly installed on an existing craft, then the system is to be certified in respect of longitudinal strength use in accordance with LR's document entitled *Approval of Longitudinal Strength and Stability Calculation Programs.*

1.1.10 Where an onboard computer system having stability computation capability is provided on a new craft, then the system is to be certified in respect of stability aspects in accordance with LR's document entitled, *Approval of Longitudinal Strength and Stability Calculation Programs*. When provided, an onboard computer system having stability computation capability is to carry out the calculations and checks necessary to assess compliance with all the stability requirements applicable to the craft on which it is installed.

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1.1.11 For craft, the arrangements and equipment of which are required to comply with the requirements of the:

- *International Convention on Load Lines, 1966*:
- *International Convention for the Safety of Life at Sea, 1974* and its protocol of 1978, which includes the *International Code of Safety for High Speed Craft*:
- *International Convention for the Prevention of Pollution from ships, 1974*, as modified by the Protocol of 1978 relating thereto:

and applicable Amendments thereto, the Committee requires the applicable Convention Certificates to be issued by a National Administration, or by LR, or by an IACS Member when so authorised. Safety Management Certificates in accordance with the provisions of the *International Safety Management Code* (ISM Code) may be issued by an organisation complying with IMO Resolution A.739(18) and authorised by the National Authority with which the craft is registered. Cargo Ship Radio Certificates may be issued by an organisation authorised by the National Authority with which the craft is registered.

1.1.12 In the case of dual classed craft, Convention certificates may be issued by the other classification society with which the craft is classed provided this is recognised in a formal Dual Class Agreement with LR and provided the other classification society is also authorised by the National Authority.

1.1.13 Yachts with a load line length, of 24m and over, having a service type notation of **Yacht**, will be assigned class only after it has been demonstrated that the stability of the yacht complies with the stability requirements of the UK MCA's Large Commercial Yacht Code, or the requirements of the National Administration, provided these are as a minimum equivalent to the requirements of the UK MCA LY Code (as amended).

1.1.14 Yachts with a load line length between 24 m and 85 m and with a gross tonnage less than 3000 will be assigned a service type notation **Yacht(S)** only after it has been demonstrated that the intact stability complies with the UK MCA LY2 Code for multi hulls and sailing vessels and the IMO IS 2008 Code for mono hull motor vessels (as amended) Damage stability is to be in compliance with the UK MCA LY2 Code (as amended). Alternative requirements may be acceptable, subject to acceptance by LR.

1.1.15 Yachts with a load line length of 85 m and above or with a gross tonnage of 3000 and above will be assigned a service type notation **Yacht(S)** only after it has been demonstrated that the intact stability complies with the UK MCA LY2 Code for multi hulls and sailing vessels (as amended). Damage stability is to be in compliance with the SOLAS requirements for passenger vessels (as amended). Alternative requirements may be acceptable, subject to acceptance by LR.

1.2 Application

1.2.1 Except in the case of a special directive by the Committee, no new Regulation or alteration to any existing Regulation relating to character of classification or to class notations is to be applied to existing craft.

1.3 Interpretation of the Rules

1.3.1 The interpretation of the Rules is the sole responsibility, and at the sole discretion, of LR.

1.4 Scope of classification

1.4.1 Classification covers the structural design, watertight integrity and standard of construction of the hull and construction, installation and testing of the propulsion machinery, essential auxiliary machinery, essential piping and electrical systems to the extent indicated within these Rules.

1.4.2 Outfit, other than that covered by 1.4.1, general finish, noise levels, vibration (other than shaft vibration where applicable), trim, design speed and stability, except as mentioned in 1.1.11, 1.1.13 and 1.1.14 are outside the scope of classification.

1.4.3 Where a craft is to be fitted with sails, the masts, rigging and sail arrangements are left to the judgment and experience of the Owner, the Builders and the designers, and LR does not accept responsibility for them. However, for classification purposes the attending Surveyor must be satisfied that they are being maintained in a satisfactory condition.

1.4.4 Where a craft is so badly damaged that class has to be suspended, LR is prepared to assist the Owner with advice if requested.

1.4.5 The attention of Owners and Builders is drawn to statutory requirements which may be imposed by the relevant National Administration and which may not be within the scope of classification.

1.5 Client's responsibilities

1.5.1 The Client is to give LR's Surveyors every facility and necessary access to carry out their survey duties. The Client should familiarise himself with the relevant LR Rules and, where appropriate, arrange that all sub-contractors, suppliers of components, materials or equipment do the same.

1.5.2 The survey procedures undertaken by LR when providing services are on the basis of periodical visits involving both monitoring and direct survey, and LR's Surveyors will not be in continual attendance at LR's Client's premises. As construction and outfitting are continuous processes, the Builder has the overall responsibility to his client to ensure and document that the requirements of the Rules, approved drawings and any agreed amendments made by the attending LR Surveyors have been complied with.

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Section 2
Scope of the Rules

2.1 Applicable craft types

2.1.1 The Rules are applicable to the following craft types constructed from steel, aluminium alloy, composite materials or combinations of these materials:

(a) High speed craft.
(b) Light displacement craft.
(c) Multi-hull craft.
(d) Yachts of overall length, L_{OA}, 24 m or greater.
(e) Craft with draught to depth ratio less than or equal to 0,55.

2.1.2 The following craft types will be considered upon request on the basis of the Rules:

(a) Amphibious air cushion vehicles.
(b) Rigid inflatable boats.
(c) Hydrofoil craft.
(d) Foil assisted craft.
(e) Craft as defined 2.1.1(a) to (e) constructed from wood or wood/composite combinations.
(f) Other craft constructed from composite materials.
(g) Craft with a Rule length, L_R, less than 24 m and draught to depth ratio greater than 0,55.

2.1.3 Existing yachts, regardless of length, are subject to the survey requirements defined in Chapter 4.

2.1.4 The Rules incorporate those requirements of the *International Convention for the Safety of Life at Sea, 1974* as amended (SOLAS 74) Chapter X – Safety Measures for High Speed Craft (*International Code of Safety for High Speed Craft*) hereinafter referred to as the HSC code, as applicable to the classification of such craft.

2.1.5 At the discretion of LR craft types which are specifically covered by LR's *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships) or other LR Rules and Regulations for Classification may be considered for classification in accordance with these Rules and Regulations.

2.1.6 Where any aspect of the design or construction is not covered by the Rules, the relevant requirements of the Rules for Ships or the *Rules and Regulations for the Classification of Naval Ships* (hereinafter referred to as the Rules for Naval Ships) will be applied as considered necessary.

2.2 Definitions

2.2.1 For the purpose of the Rules, the definitions given in 2.2.2 to 2.2.29 will apply.

2.2.2 **Air Cushion Vehicle.** An Air Cushion Vehicle (ACV) is a craft such that the whole or a significant part of its weight can be supported, whether at rest or in motion, by a continuously generated cushion of air dependent for its effectiveness on the proximity of the surface over which the craft operates.

2.2.3 **Assisted craft.** An assisted craft is any craft operating on a route where it has been demonstrated to the satisfaction of the Administrations concerned that there is a high probability that in the event of an evacuation at any point of the route, all passengers and crew can be rescued safely within the time specified in the HSC Code.

2.2.4 **Catamaran.** A catamaran is a craft with twin-hulls linked by a bridging structure.

2.2.5 **Composite materials.** Composite materials are those construction materials consisting principally of fibre reinforced plastics.

2.2.6 **Design waterline** is the waterline corresponding to the maximum operational weight of the craft with no lift or propulsion machinery active.

2.2.7 **Foil assisted craft.** A foil assisted craft is a craft designed such that a significant part of its weight, whilst in motion, is supported by hydrodynamic lift generated by foils.

2.2.8 **High speed craft.** A high speed craft is a craft capable of maximum speed, V, *see* 2.2.11, not less than:

$$V = 7{,}19\,\nabla^{1/6} \text{ knots}$$

where

∇ = moulded displacement, in m^3, of the craft corresponding to the design waterline.

2.2.9 **Hydrofoil craft.** A hydrofoil craft is a craft which is supported above the water surface in non-displacement mode by hydrodynamic forces generated by foils.

2.2.10 **Light displacement craft.** A light displacement craft is a craft with a displacement not exceeding:

$$\Delta = 0{,}04(L_R B)^{1,5} \text{ tonnes}$$

where

L_R and B are defined in Pt 3, Ch 1.

2.2.11 **Maximum speed.** Maximum speed is the speed, in knots, achieved at the maximum continuous power for which the craft is certified at maximum operational weight and in smooth water.

2.2.12 **Mono-hull craft.** A mono-hull craft is a craft whose single hull may be of displacement form or of a semi-planing or planing form subject to some support by hydrodynamic lift.

2.2.13 **Multi-hull craft.** A multi-hull craft is a craft with two or more hulls linked by a bridging structure which may be of displacement form or of a semi-planing or planing form subject to some support by hydrodynamic lift.

2.2.14 **Operational speed.** Operational speed is the speed, in knots, corresponding to that permitted by the operational envelope. For High Speed Craft it is not more than 90 per cent of the maximum speed.

2.2.15 **Operational envelope.** The operational envelope defines the craft's service in terms of operational speeds, wave heights, displacements, service area and time required to seek refuge.

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2.2.16 **Passenger.** A passenger is every person other than:

(a) The Master and the members of the crew or other persons employed or engaged in any capacity on board a craft on the business of that craft, and

(b) a child under one year of age.

2.2.17 **Passenger craft.** A passenger craft is a craft which carries more than twelve passengers.

2.2.18 **Patrol craft.** A patrol craft is a craft which may be operated by the harbour, police, customs, military authorities, search and rescue or similar organisations.

2.2.19 **Pilot launch.** A pilot launch is a craft designed to come alongside ships whilst at sea to embark or disembark pilots.

2.2.20 **Place of refuge.** A place of refuge is any naturally or artificially sheltered area which may be used as a shelter by a craft under conditions likely to endanger its safety.

2.2.21 **Range to refuge.** Range to refuge is the maximum allowable distance in nautical miles, measured along the shortest safe navigational track from any point on the intended voyage route of the craft to the nearest accessible harbour or place of refuge.

2.2.22 **Reasonable weather.** Reasonable weather is defined as wind strengths of force six or less on the Beaufort scale, associated with:

(a) Sea states within the operational envelope which are sufficiently moderate to ensure that green water is taken on board at infrequent intervals only or not at all.

(b) Motions such as do not impair the efficient operation of the craft and do not significantly reduce passenger comfort or safety or impose any undue loads on any cargo carried.

2.2.23 **Rigid Inflatable Boat.** A Rigid Inflatable Boat (RIB) is a craft combining a rigid hull enclosed by a watertight self-draining deck situated above the deepest operational load waterline and provided with a gas, air or foam-filled flotation collar/fender at the edge of the deck above the hull to improve the stability and to augment the reserve of buoyancy and sea-keeping ability of the rigid hull.

2.2.24 **Service craft.** Service craft is any craft within the scope of the Rules other than a yacht or an amphibious air cushion vehicle.

2.2.25 **Small Waterplane Area Twin Hull Ship.** A Small Waterplane Area Twin Hull Ship (SWATH) is a twin-hulled craft characterised by bulbous lower hulls (torpedoes) and relatively narrow struts connecting them to the haunches and deck structure.

2.2.26 **Surface Effect Ship.** A Surface Effect Ship (SES) is an air-cushion vehicle whose cushion is totally or partially retained by permanently immersed rigid structures.

2.2.27 **Unassisted craft.** An unassisted craft is any craft other than an assisted craft, with machinery and safety systems arranged such that, in the event of damage disabling any essential machinery and safety systems in one compartment, the craft retains the capability to navigate safely as defined in the HSC Code.

2.2.28 **Wave piercer.** A wave piercer is a particular type of catamaran with lower hulls of a displacement or semi-displacement form that provide a positive freeboard when at rest in smooth water but which are expected to become partially submerged when advancing in waves.

2.2.29 **Yacht.** A yacht is a recreational craft used for sport or pleasure and may be propelled mechanically, by sail or by a combination of both.

2.2.30 **Workboat.** A workboat is a general purpose service craft which may be adapted for duties such as line handling, towing, tender, survey, fishing, oil spill recovery, or diving support.

Section 3
Character of classification and class notations

3.1 General

3.1.1 This Section details the character symbols and notations which comprise the class assigned to special service craft.

3.1.2 The operational envelope assigned to craft built and classed in accordance with the Rules will be included in the operational manual of the craft where such a manual is required by the Rules. A reference to the operational envelope will be made in the Classification Certificate.

3.1.3 Craft built and classed in accordance with the Rules for restricted service but which are not assigned an operational envelope will have their geographical limits included in the Classification Certificate.

3.2 Character symbols

3.2.1 All craft, when classed, will be assigned a character of classification comprising one or more character symbols as applicable, e.g. **✠100A1 SSC.**

3.2.2 A full list of character symbols for which craft may be eligible is as follows:

✠ This distinguishing mark will be assigned, at the time of classing, to new craft constructed under LR's Special Survey, in compliance with the Rules, and to the satisfaction of the Committee.

$\overline{✠}$ This distinguishing mark will be assigned, at the time of classing, to new craft constructed under LR's Special Survey in accordance with plans approved by another recognised classification society.

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100 This character figure will be assigned to all craft considered suitable for sea-going service except those in Service Group 1, *see* 3.5.5.

A This character letter will be assigned to all craft which have been built or accepted into class in accordance with LR's Rules and Regulations, and which are maintained in good and efficient condition.

1 This character figure will be assigned to:
(a) Craft having on board, in good and efficient condition, anchoring and/or mooring equipment in accordance with the Rules.
(b) Craft classed for a specific service, having on board, in good and efficient condition, anchoring and/or mooring equipment approved by the Committee as suitable and sufficient for the particular service.

N This character letter will be assigned to craft on which the Committee has agreed that anchoring and mooring equipment need not be fitted in view of their particular service.

T This character letter will be assigned to ships which are intended to perform their primary designed service function only while they are anchored, moored, towed or linked, and which have, in good and efficient condition, adequately attached anchoring, mooring, towing or linking equipment which has been approved by the Committee as suitable and sufficient for the intended service.

SSC These character letters will be assigned to craft indicating that the craft has been constructed or accepted into class on the basis of the Rules.

3.2.3 For classification purposes the character figure **1** or the character letter **N** is to be assigned.

3.2.4 In cases where the anchoring and/or mooring equipment is found to be seriously deficient in quality or quantity, the class of the craft will be liable to be withheld.

3.3 Class notations (hull)

3.3.1 When considered necessary by the Committee, or when requested by an Owner and agreed by the Committee, a class notation will be appended to the character of classification assigned to the craft. The class notation will consist of one of, or a combination of:
(a) a high speed craft notation;
(b) a light displacement craft notation;
(c) a service area restriction notation;
(d) a service type notation; and
(e) a craft type notation;
(f) other hull notations;
e.g.
✠100A1 SSC Passenger (A) Catamaran
HSC G3 'service area'
✠100A1 SSC Yacht Catamaran
LDC G5.

3.3.2 A list of class notations (hull) for which a craft may be eligible is given in 3.4 to 3.10.

3.4 High speed craft and light displacement craft notations

3.4.1 **HSC – High speed craft notation.** This class notation will be assigned to high speed craft as defined in 2.2.8.

3.4.2 **LDC – Light displacement craft notation.** This class notation will be assigned to light displacement craft as defined in 2.2.10.

3.5 Service area restriction notations

3.5.1 All craft classed under the Rules will be assigned a service area restriction notation **G** followed by a number e.g. **G1.** Craft classed under the Rules for service groups **G1** to **G5** are not suitable for unrestricted service except as noted in the service area restriction notation, *see* 3.5.5.

3.5.2 Service area restriction notations, given in 3.5.5, are expressed in terms of range to refuge in nautical miles as defined in 2.2.20.

3.5.3 Where craft are required to satisfy limitations in respect of the maximum duration of time to a place of refuge from any point during the voyage, this time is to be determined by dividing the range to refuge by the permitted operational speed of the craft (when fully laden) in the prevailing conditions as imposed by the operational envelope.

3.5.4 For craft that are designed in accordance with an operational envelope, typically **HSC** or **LDC** craft as defined in 3.4:
- these craft are to be operated at reduced speeds and are to seek calmer waters or refuge when the weather conditions deteriorate or are predicted to deteriorate such that the limits of the operational envelope are exceeded.

For craft that are not assigned an operational envelope:
- these craft are to be operated at reduced speeds and are to seek calmer waters or refuge when the weather conditions deteriorate or are predicted to deteriorate.

All craft are to be aware of the weather forecast for the proposed and current areas of operation and area of refuge.

3.5.5 The service area restriction notations defined below describe the service area restriction for which the craft has been approved and constructed.

G1 **Service Group 1** covers craft intended for service in sheltered waters adjacent to sandbanks, estuaries, reefs, breakwaters or other coastal features and in similarly sheltered waters between islands in reasonable weather where the range to refuge is, in general, five nautical miles or less. The geographical limits of the intended service are to be identified by the Builder and agreed with LR. Craft in this group are not eligible for the assignment of the character figure **100.**

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G2 **Service Group 2** covers craft intended for service in reasonable weather, in waters where the range to refuge is 20 nautical miles or less. This group will usually cover craft intended for service in coastal waters, for which geographical limits are to be identified by the Builder and agreed with LR.

G3 **Service Group 3** covers craft intended for service in waters where the range to refuge is 150 nautical miles or less. The geographical limits of the intended service are to be reported to LR.

G4 **Service Group 4** covers craft intended for service in waters where the range to refuge is 250 nautical miles or less. The geographical limits of the intended service are to be reported to LR.

G5 **Service Group 5** covers craft intended for service in waters where the range to refuge is 350 nautical miles or less. The geographical limits of the intended service are to be reported to LR.

G6 **Service Group 6** covers yachts and steel patrol craft having unrestricted service.

3.5.6 Consideration may be given to requests for an increase in the permissible range to refuge subject to:

(a) The specific geographic limits and the period over which the extended service is to be operated being defined.
(b) Satisfactory statistical data in respect of wave height, being provided to demonstrate that the craft will be suitable for the extended service.
(c) Equipment consistent with that required for the extended service being provided onboard during the period of operation.
(d) Any maximum duration of voyage limitations imposed by 3.5.3 not being exceeded during the extended service.

3.6 Service type notations

3.6.1 The service type notation will be recorded in the appropriate *Register Book* indicating the primary purpose for which the craft has been designed and constructed.

3.6.2 A list of service type notations for which craft may be eligible is given below:

Cargo (A) This notation will be assigned to cargo craft other than Cargo (B) craft.

Cargo (B) This notation will be assigned to unassisted high speed cargo craft of 500 gross tons and over which do not proceed in the course of their voyage more than eight hours at operational speed from a place of refuge when fully laden. These craft correspond to 'Cargo Craft' as defined in the HSC Code.

Passenger This notation will be assigned to passenger craft other than **Passenger (A)** or **Passenger (B)** craft.

Passenger (A) This notation will be assigned to assisted high speed craft carrying not more than 450 passengers on board and which do not proceed in the course of their voyage more than four hours at operational speed from a place of refuge when fully laden. These craft correspond to 'Category A Craft' as defined in the HSC Code.

Passenger (B) This notation will be assigned to unassisted high speed craft which may carry more than 450 passengers on board and which do not proceed in the course of their voyage more than four hours at operational speed from a place of refuge when fully laden. These craft correspond to 'Category B Craft' as defined in the HSC Code.

Patrol This notation will be assigned to patrol craft complying with the relevant requirements of the Rules.

Pilot This notation will be assigned to pilot launches complying with the relevant requirements of the Rules.

Yacht This notation will be assigned to all yachts.

Workboat This notation will be assigned to workboats complying with the relevant requirements of the Rules.

3.7 Craft type notations

3.7.1 The craft type notation will be recorded in the appropriate *Register Book* indicating the type of hull form and mode of operation for which the craft has been designed and constructed.

3.7.2 A list of craft type notations for which craft may be eligible is given below:

ACV This notation will be assigned to amphibious air cushion vehicles.

Catamaran This notation will be assigned to catamarans including wave piercers.

Hydrofoil This notation will be assigned to hydrofoil craft.

Mono This notation will be assigned to mono-hull craft other than amphibious air cushion vehicles, hydrofoils and rigid inflatable boats.

Multi This notation will be assigned to multi-hull craft other than catamarans, swaths and surface effect ships.

RIB This notation will be assigned to rigid inflatable boats.

SES This notation will be assigned to surface effect ships.

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Swath This notation will be assigned to small water-plane area twin hull ships.

3.7.3 Where craft indicated in 3.7.2 are foil assisted the letters (FA) may be appended to the Craft Type Notation.

3.8 Other hull notations

3.8.1 **Ice class notation.** A class notation for navigation in first year ice conditions will be specially considered.

3.8.2 ***IWS.** This notation (In-water Survey) may be assigned to a craft where the applicable requirements of LR's Rules and Regulations are complied with. (*See* Ch 3,4.3 and Ch 4,3.3, *see also* Pt 3, Ch 3,2.37).

3.8.3 **Special features notation.** A notation indicating that the craft incorporates special features which significantly affect the design, e.g. movable decks.

3.8.4 **LI.** This notation will be assigned where an approved loading instrument has been installed as a classification requirement.

3.9 Class notations (machinery)

3.9.1 The following class notations may be assigned as considered appropriate by the Committee:

✠LMC This notation will be assigned when the propelling and essential auxiliary machinery has been constructed, installed and tested under LR's Special Survey and in accordance with LR's Rules and Regulations.

$\overline{✠}$ LMC This notation will be assigned when the propelling and essential auxiliary machinery has been constructed under the survey of a recognised authority in accordance with the Rules and Regulations equivalent to those of LR. In addition, the whole of the machinery will be required to have been installed and tested under LR's Special Survey in accordance with LR's Rules and Regulations.

[✠]LMC This notation will be assigned when the propelling arrangements, steering systems, pressure vessels and the electrical equipment for essential systems have been constructed, installed and tested under LR's Special Survey and are in accordance with LR's Rules and Regulations. Other items of machinery for propulsion and electrical power generation including propulsion gearing arrangements and other auxiliary machinery for essential services that are in compliance with LR Rules and supplied with the manufacturer's certificate will be acceptable under this notation. The system arrangements of propelling and essential auxiliary machinery are required to be appraised by LR, and found to be acceptable to LR. *See* 3.10.2.

LMC This notation (without ✠) will be assigned when the propelling and essential auxiliary machinery has neither been constructed nor installed under LR's Special Survey but the existing machinery, its installation and arrangement, has been tested and found to be acceptable to LR. This notation is assigned to existing craft in service accepted or transferring into LR class.

MCH This notation will be assigned when the propelling and essential auxiliary machinery has been installed and tested under LR's survey requirements and found to be acceptable to LR. Items of machinery and equipment for propelling and auxiliary machinery for essential services supplied with the manufacturer's certificate will be acceptable under this class notation. The system arrangements of propelling and essential auxiliary machinery are required to be appraised by LR, and found to be acceptable to LR. *See* 3.10.1.

UMS This notation may be assigned when the control engineering equipment has been arranged, installed and tested in accordance with LR's Rules, or is equivalent thereto and the arrangements are such that the craft can be operated with the machinery spaces unattended.

CCS This notation may be assigned when the arrangements are such that the machinery may be operated with continuous supervision from a centralised control station. It denotes that the control engineering equipment has been arranged, installed and tested in accordance with LR's Rules, or is equivalent thereto.

3.9.2 Machinery class notations will not be assigned to craft the hulls of which are not classed or intended to be classed with LR.

3.9.3 The notation **✠LMC**, **$\overline{✠}$ LMC**, **[✠]LMC**, **LMC** (without ✠) and **MCH** will in general not be assigned to non-propelled craft, but individual cases will be considered on their merits.

3.10 Application notes

3.10.1 Propelling and essential auxiliary machinery includes machinery, equipment and systems installed for the craft/yacht to be under seagoing conditions and that are necessary for the following:

(a) Maintaining the watertight and weathertight integrity of the hull and spaces within the hull.
(b) The safety of the craft/yacht, machinery and personnel on board.
(c) The functioning and dependability of propulsion, steering and electrical systems.
(d) The operation and functioning of control engineering systems for the monitoring and safety of propulsion, steering and electrical power systems.
(e) The operation and functioning of emergency machinery and equipment.

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3.10.2 **Manufacturer's certificate** for assignment of the **[⊕]LMC** notation. Acceptance of the manufacturer's certificate for items of machinery for propulsion (including propulsion gearing with single input/output arrangements) and for electrical power generation and for other auxiliary machinery for essential services is subject to the following:

(a) For a craft: The craft is intended for the carriage of cargo (not passengers), is less than 500 gross tonnage or is of 500 gross tonnage or greater and is not required to comply with international conventions applicable to a craft with unrestricted service.

(b) For a yacht: The yacht has a gross tonnage of less than 500, or has a gross tonnage of 500 or more and is not required to comply with international conventions applicable to a yacht with unrestricted service.

(c) Propulsion power is provided by oil engines or gas turbines which have been type approved to LR requirements for marine application.

(d) Electrical power is provided by generators driven by oil engines or gas turbines which have been type approved to LR requirements for marine application.

(e) The design and manufacturing standards for all machinery and associated systems are the applicable LR Rules.

(f) The machinery and equipment is manufactured under a recognised quality control system.

(g) Propellers, propulsion shafting and multiple input/output gearboxes are not included within the scope of propulsion arrangements for acceptance of a manufacturer's certificate.

3.10.3 **Manufacturer's certificate** for assignment of the **MCH** notation. Acceptance of the manufacturer's certificate for propelling and essential auxiliary machinery is subject to the following:

(a) For a craft: The craft is intended for the carriage of cargo (not passengers), is less than 500 gross tonnage or is of 500 gross tonnage or greater and is not required to comply with international conventions applicable to a craft with unrestricted service.

(b) For a yacht: The yacht is less than 500 gross tonnage or is of 500 gross tonnage or more and is not required to comply with international conventions applicable to a yacht with unrestricted service.

(c) Propulsion power is provided by oil engines or gas turbines which have been type approved to LR requirements for marine application.

(d) Electrical power is provided by generators driven by oil engines or gas turbines which have been type approved to LR requirements for marine application.

(e) The power of any engine or gas turbine is less than 2,250 kW and the cylinder bore of any diesel engine is not greater than 300 mm.

(f) The design and manufacturing standards for machinery and associated systems are the applicable LR Rules or other marine standards acceptable to LR.

(g) The machinery and equipment is manufactured under a recognised quality control system.

3.11 Class notations (Environmental Protection)

3.11.1 The following class notations are associated with the design and operation of a Special Service Craft and may be assigned as considered appropriate by the Committee, on application from the Owners:

EP This notation may be assigned when the design and operation of a Special Service Craft are in accordance with the relevant requirements in Pt 7, Ch 11 of the Rules.

$\overline{\text{EP}}$ This notation may be assigned when the environmental protection provisions of the Special Service Craft are in accordance with the requirements of another recognised classification society and are broadly equivalent to the requirements in Pt 7, Ch 11 of the Rules. Prior to assignment of the notation, an audit, in accordance with the requirements in 4.1.3 and 4.1.4 of Pt 7, Ch 11 of the Rules, is to be undertaken by LR to confirm that the necessary Environmental Protection procedures are in place and implemented effectively.

3.12 Descriptive notes

3.12.1 In addition to any class notations, an appropriate descriptive note may be entered in column 6 of the appropriate *Register Book* indicating the type of craft in greater detail than is contained in the class notation, and/or providing additional information about the craft's design and construction. This descriptive note is not a LR classification notation and is provided solely for the information of users of the *Register Book*.

3.12.2 The descriptive note **SCM** (Screwshaft Condition Monitoring) may be assigned when oil lubricated screwshaft arrangements with approved oil glands are fitted and the requirements of Ch 3,11.3 or Ch 4,10.3 are complied with.

■ *Section 4*
Surveys – General

4.1 Statutory surveys

4.1.1 The Committee will act, when authorised on behalf of Governments, in respect of National and International statutory safety and other requirements.

4.1.2 The Committee will also act, when authorised, in respect of National safety and other requirements relating to craft used for offshore mineral exploration and exploitation.

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4.2 New construction surveys

4.2.1 When it is intended to build a craft for classification with LR, constructional plans and all particulars relevant to the hull, equipment and machinery, as detailed in the Rules, are to be submitted for the approval of the Committee before the work is commenced. Any subsequent modifications or additions to the scantlings, arrangements or equipment shown on the approved plans are also to be submitted for approval.

4.2.2 Where the proposed construction of any part of the hull or machinery is of novel design, or involves the use of unusual material, or where experience, in the opinion of the Committee, has not sufficiently justified the principle or mode of application involved, special tests or examinations before and during service may be required. In such cases a suitable notation may be entered in the appropriate *Register Book*.

4.2.3 The materials used in the construction of hulls and machinery intended for classification are to be of good quality and free from defects and are to comply with the requirements of the Rules.

4.2.4 The Surveyor is to be satisfied that the capability, organisation and facilities of the Builder are such that acceptable standards can be obtained both for the construction of the craft and the installation of machinery, electrical and control equipment.

4.2.5 In addition to 4.2.4, the hull construction of craft manufactured from composite materials is to be controlled by a documented quality control system covering the Builder's management, organisation and relevant construction processes and inspection procedures, *see* Pt 8, Ch 2.

4.2.6 New craft intended for classification are to be built under LR's Special Survey. The Surveyors are to be satisfied that the materials, workmanship and arrangements are in accordance with the Rules. Any items found not to be in accordance with the Rules or the approved plans, or any material, workmanship or arrangements found to be so, are to be rectified.

4.2.7 For compliance with 4.2.6 LR is prepared to consider methods of survey and inspection for hull construction which formally include procedures involving the shipyard management, organisation and quality systems as defined in Chapter 2 of Parts 6, 7 and 8 for steel, aluminium alloy and composite construction respectively.

4.2.8 Copies of approved plans (showing the craft as built), essential certificates and records, required loading and other instruction manuals are to be readily available for use when required by LR's Surveyors and may be required to be kept on board.

4.2.9 After completion, the craft is to be examined afloat, and trials are to be conducted as specified in the Rules.

4.2.10 When the machinery is constructed under LR's Special Survey, this survey is to relate to the period from the commencement of the work until the final test under working conditions. Any items found not to be in accordance with the Rules or the approved plans, or any material, workmanship or arrangements found to be unsatisfactory, are to be rectified.

4.2.11 When arrangements are such that essential machinery can be operated by remote and/or automatic control equipment, the control equipment is to be arranged, installed and tested in accordance with the Rules, as applicable.

4.2.12 The date of completion of the Special Survey during construction of craft built under LR's inspection will normally be taken as the date of build to be entered in the appropriate *Register Book*. If the period between launching and commissioning is, for any reason, unduly prolonged, the dates of launching and completion or commissioning may be separately indicated in the appropriate *Register Book*.

4.2.13 When a craft, upon completion, is not immediately commissioned but is laid-up for a period, the Committee, upon application by the Owner, prior to the craft proceeding to sea, will direct an examination to be made by LR's Surveyors which may include a survey in dry-dock. If, as the result of such survey, the hull and machinery be reported in all respects free from deterioration, the subsequent Special Survey and Complete Survey of the machinery will date from the time of such examination.

4.3 Existing craft

4.3.1 **Classification of craft not built under survey.** The requirements of the Committee for the classification of craft which have not been built under LR's Survey are indicated in Ch 3,12 or Ch 4,12 as applicable. Special consideration will be given to craft transferring class to LR from another recognised Classification Society.

4.3.2 **Reclassification.** When reclassification or class reinstatement is desired for a craft for which the class previously assigned by LR has been withdrawn or suspended, the Committee will direct that a survey, appropriate to the age of the craft and the circumstances of the case, be carried out by LR's Surveyors. If, at such survey, the craft be found or placed in a good and efficient condition in accordance with the requirements of the Rules, the Committee will be prepared to consider reinstatement of the original class or the assignment of such other class as may be deemed necessary.

4.3.3 In the case of existing yachts over 15 years of age, the requirements for classification of craft not built under survey or for reclassification will be specially considered.

4.3.4 The Committee reserves the right to decline an application for classification or reclassification where the prior history or condition of the craft indicates this to be appropriate.

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4.4 Damages, repairs and alterations

4.4.1 All repairs to hull, equipment and machinery which may be required in order that a craft may retain her class, *see* 1.1.7, are to be carried out to the satisfaction of LR's Surveyors. When repairs are effected at a port, terminal or location where the services of a Surveyor to LR are not available, the repairs are to be surveyed by one of LR's Surveyors at the earliest opportunity thereafter.

4.4.2 When at any survey the Surveyors consider repairs to be immediately necessary, either as a result of damage, or wear and tear, they are to communicate their recommendations at once to the Owner, or his representative. When such recommendations are not complied with, immediate notification is to be given to the Committee by the Surveyors.

4.4.3 Where repairs are to be carried out by a riding crew during a voyage then these must be planned in advance. A complete repair procedure, including the extent of proposed repair and the need for Surveyor's attendance during the voyage, is to be submitted reasonably in advance to the Surveyor for agreement. Failure to notify LR in advance of the repairs may result in the class of the ship being specially considered by the Classification Committee. Where emergency repairs are effected immediately due to an emergency circumstance, the repairs should be documented in the ship's log and submitted thereafter to LR for use in determining further survey requirements.

4.4.4 When at any survey it is found that any damage, defect, or breakdown (*see* 1.1.7) is of such a nature that it does not require immediate permanent repair, but is sufficiently serious to require rectification by a prescribed date in order to maintain class, a suitable condition of class is to be imposed by the Surveyors and recommended to the Committee for consideration.

4.4.5 If a craft which is classed with LR is to leave harbour limits or protected waters under tow, the Owner is to advise LR of the circumstances prior to her departure.

4.4.6 If a craft which is classed with LR is taken in tow whilst at sea, the Owner is to advise LR of the circumstances at the first practicable opportunity.

4.4.7 Plans and particulars of any proposed alterations to the approved scantlings and arrangements of hull, equipment, or machinery are to be submitted for approval by Owners or Builders or their representatives and such alterations are to be carried out to the satisfaction of LR's Surveyors.

4.4.8 The Owners should notify LR whenever a craft can be examined in dry-dock or on a slipway.

4.5 Existing service craft and yachts – Periodical Surveys

4.5.1 Service craft are to be submitted to the periodical survey requirements as defined in Chapter 3.

4.5.2 Yachts are to be submitted to the periodical survey requirements defined in Chapter 4, except in the case where LR issues Statutory Loadline SAFCON certification or Certificate of Compliance to 'Code of Practice' as a requirement of the National Authority of the country in which the yacht is registered. In these cases they are to be submitted to the periodical survey requirements as defined in Chapter 3.

4.5.3 Annual Surveys are to be held on all craft other than yachts within three months, before or after each anniversary of the completion, commissioning or Special Survey. The date of the last Annual Survey will be recorded on the ClassDirect Live website.

4.5.4 Intermediate Surveys are to be held on all craft other than yachts instead of the second or third Annual Survey after completion, commissioning or Special Survey. The date of the last Intermediate Survey will be recorded on the ClassDirect Live website.

4.5.5 Intermediate Surveys are to be held on yachts between the second and third anniversary after completion, commissioning or Special Survey.

4.5.6 The Owner should notify the Surveyors whenever a craft can be examined in dry-dock or on a slipway. A minimum of two Docking Surveys are to be held in each five-year Special Survey period and the maximum interval between successive Docking Surveys is not to exceed three years. One of the two Docking Surveys required in each five year period is to coincide with the Special Survey. Consideration may be given at the discretion of the Committee to any special circumstances justifying an extension of this interval and the Committee may accept an In-water Survey in lieu of the intermediate docking between Special Surveys, *see* Ch 3,4.3 and Ch 4,3.3. A Docking Survey is considered to coincide with the Special Survey when held within the 15 months prior to the due date of the Special Survey.

4.5.7 The interval between dry-dockings for craft operating in fresh water and for certain non self-propelled craft may at the discretion of the Committee, be greater than that given in 4.5.6.

4.5.8 Attention is to be given to any relevant statutory requirements of the National Authority of the country in which the craft is registered.

4.5.9 The date of the last examination in dry-dock or on a slipway will be recorded on the ClassDirect Live website.

4.5.10 Survey requirements for In-water Surveys are given in Ch 3,4.3 and Ch 4,3.3 as appropriate. The date of the last In-water Survey will be recorded on the ClassDirect Live website.

4.5.11 All craft classed with LR are also to be subjected to Special Surveys. These Surveys become due at five-yearly intervals, the first one five years from the date of build or date of Special Survey for Classification as recorded in the appropriate *Register Book*, and thereafter five years from the date recorded for the previous Special Survey. Consideration can be given at the discretion of the Committee to any exceptional circumstances justifying an extension of the hull

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classification to a maximum of three months beyond the fifth year. If an extension is agreed the next period of hull classification will start from the due date of the Special Survey before the extension was granted.

4.5.12 Special surveys may be commenced at the fourth Annual Survey or fourth anniversary, as appropriate, after completion, commissioning, or previous Special Survey, and be progressed during the succeeding year with a view to completion by the due date of the Special Survey.

4.5.13 Special Surveys which are commenced prior to their due date are not to extend over a period greater than 15 months, except with the prior approval of the Committee.

4.5.14 Craft which have satisfactorily passed a Special Survey will have a record entered indicating the date. Where the Special Survey is completed more than three months before the due date, the new record of Special Survey will be the final date of survey. In all other cases the date recorded will be the fifth anniversary. In the case of yachts this information will be recorded on the ClassDirect Live website.

4.5.15 At the request of an Owner, the Committee may agree that the Special Survey of the hull be carried out on the Continuous Survey basis, all compartments of the hull being opened for survey and testing, in rotation, with an interval of five years between consecutive examinations of each part. In general, approximately one fifth of the Special Survey is to be completed each year and all the requirements of the particular hull Special Survey must be completed at the end of the five year cycle. If the examination during Continuous Survey reveals any defects, further parts are to be opened up and examined as considered necessary by the Surveyor. For examination of items listed in Ch 3,2.2.17, 2.2.18, 3.2.2, 3.2.3, 3.2.4 or Ch 4,2.2.11, 2.2.12, 2.2.13 as applicable, the intervals for inspection will require to be specially agreed. Craft which have satisfactorily completed the cycle will have a record entered in the *Register Book* indicating the date of completion which will not be later than five years from the last assigned date of Complete Survey of the hull. The agreement for surveys to be carried out on Continuous Survey basis may be withdrawn at the discretion of the Committee.

4.5.16 Complete Surveys of machinery become due at five yearly intervals, the first one five years from the date of build or date of first classification as recorded in the appropriate *Register Book*, and thereafter five years from the date recorded for the previous Complete Survey. Consideration can be given at the discretion of the Committee to any exceptional circumstances justifying an extension of machinery class to a maximum of three months beyond the fifth year. If an extension is agreed to, the next period of machinery class will start from the due date of Complete Survey of machinery before extension was granted. Surveys which are commenced prior to their due date are not to extend over a period greater than 15 months, except with the prior approval of the Committee. Where the complete survey is completed more than three months before the due date, the recorded date of completion will be the final date of survey. In all other cases the date recorded will be the fifth anniversary.

4.5.17 Upon application by an Owner, the Committee may agree to the extension of the survey requirements for main engines, which, by the nature of the craft's normal service, do not attain the number of running hours recommended by the engines' manufacturer for major overhauls within the survey periods given in 4.5.16.

4.5.18 If it is found desirable that any part of the machinery should be examined again before the due date of the next survey, a certificate for a limited period will be granted in accordance with the nature of the case.

4.5.19 When, at the request of an Owner, it has been agreed by the Committee that the Complete Survey of the machinery may be carried out on the Continuous Survey basis, the various items of machinery are to be opened for survey in rotation, so far as is practicable, to ensure that the interval between consecutive examinations of each item will not exceed five years. In general, approximately one-fifth of the machinery is to be examined each year.

4.5.20 If any examination during Continuous Survey reveals defects, further parts are to be opened up and examined as considered necessary by the Surveyor, and the defects are to be made good to his satisfaction.

4.5.21 Upon application by an Owner, The Committee may agree to an arrangement whereby, subject to certain conditions, some items of machinery may be examined by the Chief Engineer of the craft at ports where LR is not represented, or, where practicable, at sea, followed by a limited confirmatory survey carried out at the next port of call where an Exclusive Surveyor is available. Particulars of this arrangement may be obtained from LR's Headquarters.

4.5.22 Where an approved planned maintenance scheme is in operation the confirmatory surveys of machinery as required by 4.5.21 may be held at annual intervals, at which time the records will be checked and the operation of the scheme verified. Particulars of this arrangement may be obtained from any of LR's Offices.

4.5.23 Where condition monitoring equipment is fitted, the Committee, upon application by the Owner, will be prepared to amend applicable Periodical Survey requirements where details of the equipment are submitted and found satisfactory. Where machinery installations are accepted for this method of survey, it will be a requirement that an Annual Survey be held, at which time monitored records will be analysed and the machinery examined under working conditions. An acceptable lubricating oil trend analysis programme may be required as part of the condition monitoring procedures.

4.5.24 Screwshaft and Waterjet Unit Surveys are to be carried out as stated in Ch 3,11 for service craft and Ch 4,10 for yachts.

4.5.25 Boiler surveys and steam pipe surveys, where applicable are to be carried out as stated in accordance with Pt 1, Ch 3,15 and 16 of the Rules for Ships.

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4.5.26 Craft of unusual design, type or arrangement may be subject to exceptional survey requirements. Such survey requirements will be detailed at the assignment of classification.

4.5.27 Where the Committee has agreed to an Owner's request to assign the notation 'laid-up', the vessel may be retained in class provided a satisfactory general examination of the hull and machinery is carried out at the Annual Survey/Intermediate Survey due date and in addition an Underwater Examination (UWE) is carried out at the Special Survey due date. The general examination may be carried out within three months before or after the Annual Survey due date.

4.6 Existing amphibious air cushion vehicles – Periodical Surveys

4.6.1 Amphibious Air Cushion Vehicles are to be submitted to the periodical survey requirements as defined in Chapter 5.

4.7 Certificates

4.7.1 When the required reports, on completion of the survey of new or existing craft which have been submitted for classification, have been received from the Surveyors and approved by the Committee, a certificate of First Entry of Classification, signed by the Chairman, or the Deputy Chairman and Chairman of the Sub-Committee of Classification, will be issued to Builders or Owners.

4.7.2 A Certificate of Class valid for five years subject to endorsement for Annual and/or Intermediate Surveys, as appropriate, will also be issued to the Owners.

4.7.3 LR's Surveyors are permitted to issue provisional (interim) certificates to enable a craft classed with LR to proceed on her voyage provided that in their opinion it is in a fit and efficient condition. Such certificates will embody the Surveyors' recommendations for continuance of class, but in all cases are subject to confirmation by the Committee.

4.8 Notice of surveys

4.8.1 It is the responsibility of the Owners to ensure that all surveys necessary for the maintenance of class are carried out at the proper time and in accordance with the instructions of the Committee. Information is available to Owners on the ClassDirect Live website.

4.8.2 LR will give timely notice to an Owner about forthcoming surveys by means of a letter or a computer print-out of a craft's *Quarterly Listing of Surveys, Conditions of Class and Memoranda*. The omission of such notice, however, does not absolve the Owner from his responsibility to comply with LR's survey requirements for maintenance of class, all of which are available to Owners on the ClassDirect Live website.

4.9 Withdrawal/Suspension of class

4.9.1 When the class of a craft, for which the Regulation as regards surveys on hull, equipment and machinery have been complied with, is withdrawn by the Committee in consequence of a request from the Owner the notation 'Class withdrawn at Owner's request' (with date) will be assigned.

4.9.2 When the Regulations as regards surveys on the hull, equipment or machinery have not been complied with and the craft is thereby not entitled to retain class, the class will be suspended or withdrawn, at the discretion of the Committee, and a corresponding notation will be assigned.

4.9.3 Class will be automatically suspended and the Certificate of Class will become invalid if the Annual or Intermediate Survey, as appropriate, is not completed within three months of the due date of the survey.

4.9.4 Class will be automatically suspended from the expiry date of the Certificate of Class in the event that the Special Survey has not been completed by the due date and an extension has not been agreed (*see* 4.5.11), or is not under attendance by the Surveyors with a view to completion prior to resuming trading.

4.9.5 When in accordance with 4.4.4 a condition of class is imposed, this will be assigned a due date for completion and the craft's class will be subject to a suspension procedure if the condition of class is not dealt with, or postponed by agreement, by the due date.

4.9.6 When it is found, from the reported condition of the hull or equipment or machinery of a craft, that an Owner has failed to comply with Regulations 1.1.7, 1.1.11, 4.4.1 or 4.4.6 above, the class will be liable to be suspended or withdrawn, at the discretion of the Committee, and a corresponding notation assigned. When it is considered that an Owner's failure to comply with these requirements is sufficiently serious the suspension or withdrawal of class may be extended to include other craft controlled by the same Owner, at the discretion of the Committee.

4.9.7 When any craft proceeds to sea with less freeboard than that approved by the Committee, or when the freeboard marks are placed higher on the sides of the craft than the position assigned or approved by the Committee, or, in cases of craft where freeboards are not assigned, the draught is greater than that approved by the Committee, the class will be liable to be withdrawn or suspended.

4.9.8 When it is found that a craft is being operated in a manner contrary to that agreed at the time of classification, i.e. out with the parameters of the operational envelope, the class will be liable to be automatically withdrawn or suspended.

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4.9.9 In all instances of class withdrawal or suspension, the assigned notation, with date of application, will appear in the *Register Book*. In cases where class has been suspended by the Committee and it becomes apparent that the Owners are no longer interested in retaining LR's class, the notation will be amended to withdrawn status. After class withdrawn status has been established in the appropriate *Register Book* for one year, it will be automatically amended to 'classed LR until' (with date). In the case of yachts this information will be recorded on the ClassDirect Live website.

4.9.10 For reclassification and reinstatement of class, *see* 4.3.2 and 4.3.3.

4.10 Survey of craft out of commission

4.10.1 The classification requirements for laid up vessels will be specially considered. Surveys for continuation of class may be required at the discretion of the Committee.

4.11 Appeal from Surveyors' recommendations

4.11.1 If the recommendations of LR's Surveyors are considered in any case to be unnecessary or unreasonable, appeal may be made to the Committee, who may direct a Special Examination to be held.

■ *Section 5* IACS QSCS Audits

5.1 Audit of Surveys

5.1.1 The surveys required by the Regulations may be subject to audit in accordance with the requirements of the International Association of Classification Societies Quality System Certification Scheme.

■ *Section 6* Type Approval/Type testing/ Quality control system

6.1 LR Type Approval – Marine Applications

6.1.1 LR Type Approval is an impartial certification system that provides independent third-party Type Approval Certificates attesting to a product's conformity with specific standards or specifications. It is based on design review and type testing or where testing is not appropriate, a design analysis.

6.1.2 The LR Type Approval System is a process whereby a product is assessed in accordance with a specification, standard or code to check that it meets the stated requirements and through selective testing demonstrates compliance with specific performance requirements. The testing is carried out on a prototype or randomly selected product(s) which are representative of the manufactured product under approval. Thereafter, the producer is required to use Quality Control procedures and processes to ensure that each item delivered is in conformity with that which has been Type Tested.

6.1.3 The selective testing required by 6.1.2 is to include environmental testing applicable to the product's installation on board a craft or yacht classed or intended to be classed with LR.

6.1.4 LR Type Approval does not remove the requirements for inspection and survey procedures required by the Rules for equipment to be installed in craft/yachts classed or intended to be classed with LR. Also, LR Type Approval does not remove the requirement for plan appraisal of a system that incorporates Type Approved equipment where required by the Rules.

6.1.5 LR Type Approval is subject to the understanding that the producer's recommendations and instructions for the product and any relevant requirements of the Rules for the Classification of Special Service Craft are fulfilled.

6.1.6 The producer supplying equipment or components under Quality Control procedures and processes is to have a recognised quality management system certified by an IACS member or Notified Body. The Quality Control procedures and processes are to address the production of the product consistent with 6.3.

6.1.7 Where equipment or components have been Type Approved in accordance with specifications and procedures other than LR's, details of the product, certification and testing are to be submitted for consideration where appropriate.

6.2 Type testing

6.2.1 Type testing is an impartial process that provides independent third-party verification that an item of machinery or equipment has satisfactorily undergone a functional type test.

6.2.2 Type testing is carried out against defined performance and test standards for a defined period of time with test conditions varying between minimum and maximum declared design conditions.

6.2.3 Type testing is carried out on a prototype or randomly selected product(s) which are representative of the manufactured product under assessment.

6.2.4 After type testing, mechanical equipment is to be opened out and inspected for damage or excessive wear.

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6.2.5 On application from the manufacturer, type tests may be waived for equipment and machinery that has been proven to be reliable in marine service and where compliance with the current applicable standards can be demonstrated. Equipment and machinery that has been previously type tested with satisfactory testing evidence and certification need not have the type tests repeated where previous testing is in compliance with the current testing standards.

6.2.6 The acceptance of type testing certification is subject to the understanding that the manufacturer's recommendations and instructions for the product and any relevant requirements of the applicable Rules are fulfilled.

6.3 Quality control system

6.3.1 A quality control system for the purposes of LR acceptance of materials and machinery refers to a scheme that covers the operational techniques and activities that is used to demonstrate that the quality requirements for a product are in accordance with declared standards.

6.3.2 The quality control system for a particular product extends to all parties involved in the supply chain from manufacture and testing through to delivery of the product.

6.3.3 LR acceptance of machinery and equipment manufactured under a quality control scheme is dependent on the scheme being maintained through a traceable process involving planned audits and spot inspections at the discretion of LR Surveyors. The purpose of the audits and spot inspections is to ensure that the procedures for manufacture and quality control are being maintained in a satisfactory manner.

6.3.4 The use of a quality control system does not remove the requirements for inspection processes that may be required by the Rules applicable to the equipment being supplied with a manufacturer's certificate. Also the use of a quality control system does not remove the requirement for plan appraisal of equipment or systems where required by the Rules.

■ *Section 7*
Classification of machinery for craft/yachts with [✠]LMC or MCH notation

7.1 General

7.1.1 After delivery of machinery and equipment with the manufacturer's certificate to the build yard, Survey at the build yard and Periodical Surveys are to be in accordance with the requirements for craft/yacht built or accepted into class with the ✠**LMC** notation.

7.2 Appraisal and records

7.2.1 To facilitate survey and compilation of classification records, plans and information required for a craft/yacht being accepted into class with the ✠**LMC** notation are to be submitted for appraisal and information. Plans are not required where machinery and equipment has previously been type approved; in these cases it is only necessary to submit details of the machinery and equipment together with details of the previous approval.

7.3 Survey and inspection

7.3.1 The manufacturer's certificate for acceptance of machinery and equipment for assignment of the **[✠]LMC** or **MCH** notation is to be in the English language and include the following information:

(a) Design and manufacturing standard(s) used.
(b) Materials used for construction of key components and their sources.
(c) Details of the quality control system applied during design, manufacture and testing and any software maintenance.
(d) Details of any type approval or type testing.
(e) Details of installation and testing recommendations for the machinery or equipment.

The manufacturer is to have a recognised quality management system certified by an IACS member or a Notified Body.

7.3.2 The installation and testing of machinery and equipment at the build yard which has been supplied with a manufacturer's certificate is to be in accordance with the requirements applicable to a craft/yacht having the ✠**LMC** notation.

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Section

1 **General**

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4 **Docking Surveys and In-water Surveys – Hull and machinery requirements**

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8 **Gas turbines – Detailed requirements**

9 **Oil engines – Detailed requirements**

10 **Electrical equipment**

11 **Screwshafts, tube shafts, propellers and water jet units**

12 **Classification of craft not built under survey**

Section 1 General

1.1 Frequency of surveys

1.1.1 The requirements of this Chapter are applicable to the Periodical Surveys set out in Ch 2,4.5. Except as amended at the discretion of the Committee, the periods between such surveys are as follows:

(a) Annual Surveys, as required by Ch 2,4.5.3.
(b) Intermediate Surveys as required by Ch 2,4.5.4.
(c) Docking Surveys as required by Ch 2,4.5.6 and 4.5.7.
(d) Special Surveys at five-yearly intervals, *see* Ch 2,4.5.11. For alternative arrangements, *see also* Ch 2,4.5.12, 4.5.13 and 4.5.15.
(e) Complete Surveys of machinery at five-yearly intervals, *see* Ch 2,4.5.16. For alternative arrangements, *see also* Ch 2,4.5.17, 4.5.19, 4.5.21, 4.5.22 and 4.5.23.

1.1.2 For vessels assigned the notation 'laid-up', in order to maintain the vessel in class a general examination of the hull and machinery is to be carried out in lieu of the Annual Survey/Intermediate Survey and in addition an Underwater Examination (UWE) is to be carried out in lieu of the Special Survey, *see* 2.1.3, 5.1.4 and 7.1.3.

1.1.3 When it has been agreed that the complete survey of the hull and machinery may be carried out on the Continuous Survey basis, all compartments of the hull and all items of machinery are to opened for survey in rotation to ensure that the interval between consecutive examinations of each part will not exceed five years, *see* Ch 2,4.5.15 and 4.5.19.

1.1.4 For the frequency of surveys of screwshafts, tube shafts propellers and water jet units, *see* Section 11.

1.2 Surveys for damage or alterations

1.2.1 At any time when a craft is undergoing alterations or damage repairs, any exposed parts of the structure normally difficult to access are to be specially examined, e.g. if any part of the main or auxiliary machinery is removed for any reason, the hull structure in way is to be carefully examined by the Surveyor, or when cement in the bottom or sheathing on decks is removed, the structure in way is to be examined before the cement or sheathing is relaid.

1.3 Unscheduled surveys

1.3.1 In the event that Lloyd's Register (hereinafter referred to 'LR') has cause to believe that its Rules and Regulations are not being complied with, LR reserves the right to perform unscheduled surveys of the hull or machinery.

1.3.2 In the event of significant damage or defect affecting any craft, LR reserves the right to perform unscheduled surveys of the hull or machinery of other similar craft classed by LR and deemed to be vulnerable.

1.4 Surveys for the issue of Convention certificates

1.4.1 Surveys are to be held by LR when so appointed, or by the Exclusive Surveyors to a National Administration or by an IACS Member when so authorised by the National Authority, or, in the case of Cargo Ship Safety Radio Certificates or Safety Management Certificates, by any organisation authorised by the National Authority. In the case of dual classed craft, Convention Certificates may be issued by the other Society with which the craft is classed provided this is recognised in a formal Dual Class Agreement with LR and provided the other Society is also authorised by the National Authority.

1.5 Definitions

1.5.1 **A Ballast tank** is a tank which is used solely for salt water ballast. A tank which is used for both cargo and salt water ballast will be treated as a salt water ballast tank when substantial corrosion has been found in that tank.

1.5.2 **Spaces** are separate hull compartments including integral tanks.

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1.5.3 **Suspect areas** are locations within the hull structure vulnerable to increased likelihood of structural deterioration and may include:

(a) For steel hulls, areas of substantial corrosion and/or fatigue cracking.
(b) For aluminium alloy hulls, areas of fatigue cracking and areas in the vicinity of bimetallic connections.
(c) For composite hulls, areas subject to impact damage.
(d) For high speed craft (as defined in Ch 2,2.2.7), areas of the bottom structure forward prone to slamming damage.

1.5.4 **Substantial corrosion** is wastage of individual steel or aluminium plates and stiffeners in excess of 75 per cent of allowable margins, but within acceptable limits.

1.5.5 **Protective coatings** for steel craft should usually be hard coatings. Other coating systems (e.g. soft coating) may be considered acceptable as alternatives provided they are applied and properly maintained in compliance with the manufacturer's specification.

1.5.6 **Coating condition** for steel craft is defined as follows:

GOOD condition with only minor spot rusting affecting not more than 20 per cent of areas under consideration.

Section 2
Annual Surveys – Hull and machinery requirements

2.1 General

2.1.1 Annual Surveys are to be held concurrently with any relevant statutory annual or other statutory surveys, wherever practicable.

2.1.2 At Annual Surveys, the Surveyor is to examine the hull and machinery, so far as necessary and practicable, in order to be satisfied as to their general condition.

2.1.3 For vessels assigned the notation 'laid-up', in lieu of the normal Annual Survey requirements a general examination of the hull and machinery is to be carried out.

2.2 Annual Surveys

2.2.1 The Surveyor is to be satisfied regarding:

(a) The efficient condition of hatchways on freeboard and superstructure decks, weather deck plating, ventilator coamings and air pipes, exposed casings, skylights, flush deck scuttles, deckhouses and companionways, superstructure bulkheads, side, bow and stern doors, windows and storm shutters, side scuttles and dead-lights, chutes and other openings, together with all closing appliances and flame screens.
(b) The efficient operating condition of mechanically operated hatch covers including stowage, fit, securing, locking, sealing and operational testing of hydraulic power components, wires, chains, etc.
(c) The efficient condition of scuppers and sanitary discharges (so far as is practicable); valves on discharge lines (so far as is practicable) and their controls; guard rails and bulwarks; freeing ports, gangways and life-lines; fittings and appliances for timber deck cargoes.
(d) The efficient condition of bilge level detection and alarm systems on craft assigned a **UMS** notation.

2.2.2 Any cargo hatch covers and coamings together with any cargo doors or ramps which form part of the watertight integrity of the hull are to be examined to ensure that no alterations have been made to the approved arrangements.

(a) Mechanically operated cargo hatch covers or doors are to be tested for tightness and to confirm the satisfactory condition of securing and sealing arrangements; drainage channels; operating mechanisms; tracks and wheels.
(b) Cargo hatch covers of the portable type are to be examined to confirm that the covers and closing appliances are in a satisfactory condition.

2.2.3 The anchoring and mooring equipment including anchor warps or wire ropes is to be examined so far as is practicable.

2.2.4 The watertight doors in watertight bulkheads, their indicators and alarms are to be examined and operationally tested locally and where applicable remotely. Other watertight bulkhead penetrations, are to be examined so far as is practicable.

2.2.5 The Surveyor is to examine and test in operation all main and auxiliary steering arrangements including their associated equipment and control systems, and verify that log book entries have been made in accordance with statutory requirements where applicable.

2.2.6 Where applicable, the Surveyor is to be satisfied regarding the freeboard marks on the craft's side.

2.2.7 The Surveyor is to generally inspect the machinery spaces with particular attention being given to the propulsion system, auxiliary machinery and to the existence of any fire and explosion hazards. Where applicable, emergency escape routes are to be checked to ensure that they are free of obstruction.

2.2.8 The means of communication between the navigating bridge and the machinery control positions, as well as the bridge and the alternative steering position, if fitted, are to be tested.

2.2.9 The bilge pumping systems and bilge wells, including operation of extended spindles, self closing drain cocks and level alarms, where fitted, are to be examined so far as is practicable. Satisfactory operation of the bilge pumps, including any hand pumps, is to be proven.

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2.2.10 The boilers, other pressure vessels and their appurtenances, including foundations, controls, high pressure and waste steam piping, and insulation and gauges, are to be generally examined. Surveyors should confirm that Periodical Surveys of boilers and other pressure vessels have been carried out as required by the Rules.

2.2.11 For boilers, the safety devices are to be tested, and the safety valves are to be operated using the relieving devices. For exhaust gas heated economisers/boilers, the safety valves are to be tested at sea by the Chief Engineer and details recorded in the log book.

2.2.12 The operation and maintenance records, repair history and feed water chemistry records of boilers are to be examined.

2.2.13 For other pressure vessels, the safety devices are to be examined.

2.2.14 The electrical equipment and cabling forming the main and emergency electrical installations are to be generally examined under operating conditions so far as is practicable. The satisfactory operation of the main and emergency sources of power and electrical services essential for safety in an emergency is to be verified; where the sources of power are automatically controlled they should be tested in the automatic mode. Bonding straps for the control of static electricity and earthing arrangements are to be examined where fitted.

2.2.15 For main propulsion, essential auxiliary and emergency machinery control engineering systems, a general examination of the equipment and arrangements is to be carried out. Records of modifications are to be made available for review by the attending Surveyor. The documentation required by Pt 6, Ch 1, including configuration management, are to be reviewed following system modifications. Satisfactory operation of the safety devices and control systems is to be verified. For craft having **UMS** or **CCS** notation, a general examination of the control engineering equipment required for these notations is also to be carried out.

2.2.16 For craft fitted with an electronically controlled engine for main propulsion, essential auxiliary or emergency power purposes, the following is to be carried out to the satisfaction of the Surveyor:

(a) Verification of evidence of satisfactory operation of the engine and, where possible, this is to include a running test under load;
(b) Verification of satisfactory operation of the safety devices and control, alarm and monitoring systems; and
(c) Verification that any changes to the software or control, alarm, monitoring and safety systems that affect the operation of the engine have been assessed by LR and are under configuration management control.

2.2.17 For craft to which Pt 17, Ch 1 applies, the arrangements for fire protection, detection and extinction are to be examined and are to include the following items, as required to be fitted in accordance with the Rules:

(a) Verification, so far as is practicable, that no significant changes have been made to the arrangement of structural fire protection.
(b) Verification of the operation of manual and/or automatic doors where fitted.
(c) Verification that fire control plans are properly posted;
(d) Examination, so far as is possible, and testing as feasible, of the fire and/or smoke detection and alarm system(s).
(e) Examination of fire main system, and confirmation that each fire pump, including the emergency fire pump can be operated separately so that the required jets of water can be produced simultaneously from different hydrants.
(f) Verification that fire-hoses, nozzles, applicators and spanners are in good working condition and situated at their respective locations.
(g) Examination of fixed fire-fighting systems controls, piping, instructions and marking, checking for evidence of proper maintenance and servicing, including date of last systems tests.
(h) Verification that all portable and semi-portable fire-extinguishers are in their stowed positions, checking for evidence of proper maintenance and servicing, conducting random checks for evidence of discharged containers.
(j) Verification, so far as is practicable, that the remote control for stopping fans and machinery and shutting off fuel supplies in machinery spaces and, where fitted, the remote controls for stopping fans in accommodation spaces and the means of cutting off power to the galley are in good working order.
(k) Examination of the closing arrangements of ventilators, skylights and doorways where applicable.
(l) Verification that the fireman's outfits are complete and in good condition.
(m) Verification that gas installations for domestic purposes comply with the relevant statutory requirements.

2.2.18 For steel craft, the requirements of 3.2.2 and 5.4.2 regarding the survey of water ballast spaces, integral sanitary tanks and bilges are also to be complied with as applicable.

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Section 3
Intermediate Surveys – Hull and machinery requirements

3.1 General

3.1.1 Intermediate Surveys are to be held concurrently with statutory annual or other relevant statutory surveys wherever practicable.

3.2 Intermediate Surveys

3.2.1 The requirements of Section 2 are to be complied with so far as applicable.

3.2.2 For steel craft a general examination of salt water ballast tanks, integral sanitary tanks and bilges is to be carried out as required below. If such inspections reveal no visible structural defects then the examination may be limited to a verification that the protective coating remains in GOOD condition as defined in 1.5.6. When considered necessary by the Surveyor thickness measurement of the structure is to be carried out. Where the protective coating is found to be other than in GOOD condition, and it has not been repaired, maintenance of class will be subject to the spaces in question being internally examined and gauged as necessary at Annual Surveys.

(a) For all craft over five years of age and up to 10 years of age, representative salt water ballast tanks, integral sanitary tanks and bilges are to be generally examined. Where the protective coating is found to be other than in GOOD condition, as defined in 1.5.6, or other defects are found, the examination is to be extended to other spaces of the same type.

(b) For steel craft over 10 years of age all salt water ballast tanks, integral sanitary tanks and bilges are to be generally examined.

3.2.3 For all craft over 10 years of age the anchors are to be partially lowered and raised using the windlass.

3.2.4 The electrical generating sets are to be examined under working conditions.

3.2.5 Representative internal spaces including fore and aft peak spaces, machinery spaces, bilges, etc., are to be generally examined. These spaces should include all suspect areas, *see* 1.5.3.

Section 4
Docking Surveys and In-water Surveys – Hull and machinery requirements

4.1 General

4.1.1 At Docking Surveys or In-water Surveys the Surveyor is to examine the craft and machinery, so far as necessary and practicable, in order to be satisfied as to the general condition.

4.2 Docking Surveys

4.2.1 Where a craft is in dry-dock or on a slipway it is to be placed on blocks of sufficient height and proper staging is to be erected as may be necessary, for the examination of the outside of the hull, rudder(s) and underwater fittings. The outside surface of the hull is to be cleaned as may be required by the Surveyor.

4.2.2 Attention is to be given to parts of the external hull structure particularly liable to structural deterioration from causes such as high stresses, chafing and lying on the ground, and to areas of structural discontinuity.

4.2.3 The following parts of the external hull structure are to be specially examined:

(a) For steel hulls attention is to be given to parts of the structure particularly liable to excessive corrosion and to any undue unfairness of the plating of the bottom. The coating system is to be examined and made good as necessary.

(b) For aluminium alloy hulls attention is to be given to areas adjacent to any bimetallic connections at skin fittings, etc.

(c) For composite hulls the gelcoat or other protective finish is to be examined for surface cracking, blistering or other damage which may impair the efficiency of the protection to the underlying laminate.

4.2.4 Where required by the Rules, the satisfactory condition of the cathodic protection is to be confirmed.

4.2.5 The clearances in the rudder bearings and pintles are to be measured. Where considered necessary by the Surveyor rudders are to be lifted for examination of the stock. The securing of rudder couplings and/or pintle fastenings is to be confirmed.

4.2.6 The sea connections and overboard discharge valves, their attachments to the hull and the gratings at the sea inlets are to be examined.

4.2.7 The propeller and fastenings are to be examined. The sternbush is to be examined as far as is practicable.

4.2.8 The clearance in the sternbush or the efficiency of the oil glands is to be ascertained. The clearance of any shaft bracket bearings is to be ascertained.

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4.2.9 The inboard shaft seals or glands are to be examined. Where flexible sternglands are fitted, the satisfactory condition of the rubber hose and securing clips is to be confirmed.

4.2.10 Special attention is to be given to the hull in way of underwater fittings such as transverse thrusters, stabilisers, etc.

4.2.11 Where applicable, attention is to be given to the connection and/or intersection of the cross-deck structure to the hulls of multi hull craft.

4.2.12 Where water jet units are fitted, the impeller, hull ducting, grating, nozzle steering and reversing arrangements are to be examined as far as is practicable.

4.2.13 Where transom mounted propulsion units are fitted, the steering arrangements and any flexible transom seals are to be examined.

4.2.14 When chain cables are ranged, the anchors and cables are to be examined by the Surveyor, *see also* 5.3.7 and Table 3.5.1.

4.2.15 For SES craft any flexible skirts together with their attachment are to be examined.

4.2.16 For hydrofoil or foil assisted craft the attachment of foils is to be examined.

4.3 In-water Surveys

4.3.1 The Committee will accept an In-water Survey in lieu of the intermediate docking between Special Surveys required in a five year period on craft where an ***IWS** notation is assigned, *see* Ch 2,3.8.2.

4.3.2 The Committee may accept an In-water Survey in lieu of the intermediate docking between Special Surveys required in a five year period on craft where suitable protection is applied to the underwater portion of the hull. If requested, an ***IWS** class notation may be assigned on satisfactory completion of the survey, provided that the applicable requirements of the Rules are complied with, *see also* Ch 2,3.8.2.

4.3.3 The In-water Survey is to provide the information normally obtained from the Docking Survey, so far as is practicable.

4.3.4 Proposals for In-water Surveys are to be submitted in advance of the survey being required so that satisfactory arrangements can be agreed with LR.

4.3.5 The In-water Survey is to be carried out at agreed geographical locations under the surveillance of a Surveyor to LR, with the craft in sheltered waters; the in-water visibility is to be good and the hull below the waterline is to be clean. The Surveyor is to be satisfied that the method of pictorial presentation is satisfactory. There is to be good two-way communication between the Surveyor and the diver.

4.3.6 Diving and In-water Survey operations are to be carried out by firms recognised by the Committee. Continued recognition by the Committee will be dependent on the standard of workmanship by the firm being maintained to the satisfaction of LR's Surveyors.

4.3.7 If the In-water Survey reveals damage or deterioration that requires early attention, the Surveyor may require that the craft be dry-docked in order that a fuller survey can be undertaken and the necessary work carried out.

4.3.8 Where a vessel has an ***IWS** notation, the condition of the high resistant paint is to be confirmed at each dry-docking in order that the ***IWS** notation can be maintained.

4.3.9 Some National Administrations may have requirements additional to those of 4.3.1 to 4.3.8.

■ *Section 5* Special Survey – General – Hull requirements

5.1 General

5.1.1 The survey is to be of sufficient extent to ensure that the hull and related equipment is in satisfactory condition and is fit for its intended purpose, subject to proper maintenance and operation and to Periodical Surveys being carried out as required by the Regulations.

5.1.2 The requirements of Section 2 are to be complied with so far as applicable.

5.1.3 A Docking Survey in accordance with the requirements of 4.2 is to be carried out as part of the Special Survey.

5.1.4 For vessels assigned the notation 'laid-up', an Underwater Examination (UWE) and general examination of hull and machinery is to be carried out in lieu of the normal Special Survey requirements.

5.2 Preparation

5.2.1 The craft is to be prepared for survey in accordance with the requirements of Table 3.5.1. The preparation should be of sufficient extent to facilitate an examination to ascertain any excessive corrosion, erosion, deformation, fractures, damages and other structural deterioration.

5.2.2 Where, in accordance with Table 3.5.1, the craft is opened out by removal of linings, ceilings, cabin sole, etc., and defects are found, further opening out will be required in order that the Surveyor can confirm the full extent of the defects.

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Table 3.5.1 Survey preparation

Special Survey I (Craft 5 years old)	Special Survey II (Craft 10 years old)	Special Survey III (Craft 15 years old) and subsequent special surveys
(1) The interior of the craft is to be sufficiently opened out by the removal of lining, ceiling/cabin sole, portable tanks and ballast, etc as required in order that the Surveyor may be satisfied as to the condition of suspect areas of the structure, *see* 1.5.3. A record is to be made of those areas where lining, ceiling/cabin sole etc., were opened out and where equipment was removed during the survey. This record is to be retained for reference during subsequent surveys. (2) Machinery compartments, fore and aft peaks and other spaces as directed by the Surveyor, are to be cleared and cleaned as necessary, and the bilges and limbers all fore and aft are to be cleaned and prepared for examination. Platform plates in engine spaces are to be lifted as may be necessary for the examination of the structure below. Where necessary, pipework may be required to be removed for examination of the structure. (3) In way of the single and/or double bottom areas, a sufficient amount of ceiling/cabin sole is to be lifted to permit examination of the bilges and/or tanktops below. (4) All integral tanks are to be cleaned as necessary to permit examination. (For steel craft, *see* Table 3.5.2).	In addition to the requirements for Special Survey I, the following are to be complied with: (1) The chain locker is to be cleared and cleaned internally for examination of the structure and examination of the cable securing arrangements. The chain cables/anchor warps, as applicable, are to be ranged for inspection. The anchors are to be cleaned and placed in an accessible position for inspection. (2) The rudder is to be unshipped for examination of the rudder stock and trunk at the discretion of the Surveyor.	In addition to the requirements for Special Survey II the following are to be complied with: (1) Linings, ceiling/cabin soles, etc are to be removed as required in order that the Surveyor may be satisfied as to the condition of the structure. For steel craft: (2) Portions of wood sheathing, or other covering, on steel decks are to be removed, as considered necessary by the Surveyor, in order to ascertain the condition of the plating. (3) Where spaces are insulated, sufficient insulation is to be removed in each space to enable the Surveyors to be satisfied with the condition of the structure. (4) Linings are to be removed in way of shell plating immediately above tank top connections to the side shell, in way of galleys/washrooms and beneath portlights and windows.

Table 3.5.2 *Tank internal examination requirements for steel craft*

Tank	Special Survey I (Craft 5 years old)	Special Survey II (Craft 10 years old)	Special Survey III (Craft 15 years old)	Special Survey IV (Craft 20 years old)	All Subsequent Special Surveys
Peaks	All tanks	All tanks	All tanks	All tanks	All tanks
Salt water ballast	All tanks	All tanks	All tanks	All tanks	All tanks
Lubricating oil	None	None	*See* Note 2	*See* Note 3	All tanks
Fresh water	None	*See* Note 1	*See* Note 2	*See* Note 3	All tanks
Oil fuel	None	*See* Note 1	*See* Note 2	*See* Note 3	All tanks
Sanitary	All tanks	All tanks	All tanks	All tanks	All tanks

NOTES
1. Tanks (excluding peak tanks) used exclusively for oil fuel or fresh water need not all be examined internally provided that the Surveyor is satisfied with the condition, after both external examination and testing and from an internal examination of the after end of one forward double bottom tank, and of one selected deep tank.
2. Tanks (excluding peak tanks) used exclusively for oil fuel, oil fuel and fresh water ballast, or lubricating oil, need not all be examined internally provided that the Surveyor is satisfied with the condition, after both external examination and testing and from an internal examination of one double bottom tank forward and one aft and one deep tank.
3. Tanks (excluding peak tanks) used exclusively for oil fuel, oil fuel and fresh water ballast, or lubricating oil, need not all be examined internally provided that the Surveyor is satisfied with the condition, after both external examination and testing and from internal examination of a least one double bottom tank amidships, one forward and one aft and one deep tank.
4. When examining tanks internally the Surveyor is to verify that striking plates or other additional reinforcement is fitted under sounding pipes. In the case of tanks fitted only with remote gauging facilities, the satisfactory operation of the gauges is to be confirmed.

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5.3 Examination and testing – General

5.3.1 All spaces within the hull and superstructure including integral tanks are to be examined (*see also* 5.4.1 for tank examinations on steel craft). Special attention is to be paid to any suspect areas, *see* 1.5.3.

5.3.2 Double bottom compartments, peak tanks and all other integral tanks are to be tested by a head sufficient to give the maximum pressure that can be experienced in service. Tanks may be tested afloat provided that their internal examination is also carried out afloat.

5.3.3 Where repairs are effected to the hull shell or bulkheads, any integral tanks in way are to be tested to the Surveyor's satisfaction on completion of these repairs.

5.3.4 All decks, casings and superstructures are to be examined.

5.3.5 The satisfactory attachment of any wood or other deck sheathing is to be confirmed, *see also* 5.4.4.

5.3.6 Attention is to be given to the corners of openings and other discontinuities in the hull structure.

5.3.7 The anchors are to be examined. If the chain cables are ranged they are to be examined together with the chain locker, *see* Table 3.5.1. If any length of chain cable is found to be reduced in mean diameter at its most worn part by 12 per cent or more from its nominal diameter, it is to be renewed. The windlass is to be examined.

5.3.8 The Surveyor is to be satisfied that there are suitable towlines and mooring ropes when these are a Rule requirement.

5.3.9 Representative structural fastenings, e.g. bolts in way of resiliently mounted deckhouses, are to be tested to ascertain their soundness and may require to be drawn for examination at the discretion of the Surveyor.

5.3.10 For craft to which Pt 17, Ch 1 applies, the Surveyor is to be satisfied as to the efficient condition of the means of escape from crew and passenger spaces, and spaces in which crew are normally employed.

5.4 Examination and testing – Additional items for steel craft

5.4.1 All integral tanks are generally to be internally examined. However, in certain circumstances the internal examination of lubricating oil, fresh water and oil fuel tanks may be waived. For the minimum extent of tank internal examination, *see* Table 3.5.2.

5.4.2 In salt water ballast spaces, integral sanitary tanks and bilges where the protective coating is found to be other than in GOOD condition as defined in 1.5.6 and it has not been repaired, maintenance of class will be subject to the spaces in question being internally examined and gauged as necessary at Annual Surveys.

5.4.3 The protection of steelwork, other than as referred to in 5.4.2 should be examined and made good where necessary on satisfactory completion of the survey. In areas where the inner surface of the bottom plating is covered with cement, asphalt or other composition, the removal of this covering may be dispensed with, provided that it is found sound and adhering satisfactorily to the steel.

5.4.4 Wood deck sheathing is to be examined and the caulking is to be tested and recaulked as necessary. If decay or rot is found, or the wood is excessively worn, the wood is to be renewed. Attention is to be given to the condition of the plating under wood deck sheathing or other deck covering. If it is found that such coverings are broken, or are not adhering closely to the plating, sections are to be removed as necessary to ascertain the condition of the plating. *See also* 1.2.1.

5.4.5 The structure in way of bimetallic connections, e.g. to aluminium alloy deckhouses is to be examined.

5.4.6 The Surveyors may require to measure the thickness of the material in any portion of the structure where signs of wastage are evident or wastage is normally found. Any parts of the structure which are found defective or excessively reduced in scantlings are to be made good by materials of the approved scantlings and quality. The minimum requirements for thickness measurements are given in Section 6.

5.5 Examination and testing – Additional items for aluminium alloy craft

5.5.1 The structure in way of any bimetallic connections is to be examined and the efficiency of the insulation arrangements confirmed.

5.5.2 The Surveyor may require to measure the thickness of the material in any portion of the structure where signs of deterioration are evident or may normally be found. Any parts of the structure which are found defective or excessively reduced in scantlings are to be made good by materials of the approved scantlings and quality.

5.6 Examination and testing – Additional items for composite craft

5.6.1 The bonded attachments of frames, floors, bulkheads, structural joinery, engine bearers, sterntubes, rudder tubes, and integral tank boundaries are to be examined.

5.6.2 The hull to deck joint together with any joints between the deck and deckhouses or superstructures are to be examined.

5.6.3 The structure in way of the bolted attachment of fittings including guardrail stanchions, windlass, shaft brackets, fendering, mooring bitts, etc. is to be examined.

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Section 6
Special Survey – Thickness measurement requirements for steel craft

6.1 General

6.1.1 Thickness measurements, as required by Section 5 are to be carried out in accordance with the following requirements.

6.1.2 Thickness measurements are to be taken at the forward and aft areas of all plates. In all cases the measurements are to represent the average of the multiple measurements taken on each plate. The extent of local substantial corrosion of plates is to be established by intensive measurement in the affected areas. Where measured plates are renewed, the thicknesses of adjacent plates in the same strake are to be reported.

6.1.3 Thickness measurements are normally to be by means of ultrasonic test equipment and are to be carried out by a firm qualified as Grade 1 or Grade 2 according to LR Approval for Thickness Measurement of Hull Structures or by the Surveyor.

6.1.4 The degree of supervision or check testing by the Surveyor is dependent upon the grade of approval extended to the firm carrying out the thickness measurements.

(a) The work of firms having Grade 1 approval is subject to check testing by the Surveyor.

(b) Thickness measurements by firms having Grade 2 approval is to be carried out with the Surveyor substantially in attendance.

6.1.5 Thickness measurements may be carried out in association with the fourth Annual Survey.

6.1.6 The minimum requirements for thickness measurement are indicated in Table 3.6.1.

6.1.7 The Surveyor may extend the scope of thickness measurement if deemed necessary.

Table 3.6.1 Thickness measurement of steel craft

Special Survey I (Craft 5 years old)	Special Survey II (Craft 10 years old)	Special Survey III (Craft 15 years old) (Craft 20 years old and over)	Special Survey IV and subsequent
Suspect areas, as required by the Surveyor and may include areas where the coatings are *found to be other than in GOOD condition, see* Note 1.	Suspect areas, as required by the Surveyor and may include areas where the coatings are *found to be other than in GOOD condition, see* Note 1.	(1) Any exposed plating throughout the Main Deck. (2) Shell plating in way of the waterline throughout the length of the craft. (3) Suspect areas, as required by the Surveyor and may include areas where the coatings are found to be other than in GOOD condition, *see* Note 1.	(1) All Main Deck plating outside deckhouses or superstructures and including plating in way of wood deck planking or sheathing. (2) Shell plating in way of, and below, the waterline throughout the length of the craft. (3) 2 transverse sections of deck and shell plating within 0,5*L* amidships. (4) Suspect areas, as required by the Surveyor and to include as applicable: (a) Areas where the coatings are found to be other than in GOOD condition. (b) Shell and tanktop plating immediately adjacent to tank top margins. (c) Bottom shell in way of any cement, asphalt or other composition. (d) Shell plating below portlights and windows. (e) Tanktop plating below ceiling or cabin soles. (f) Deck plating and side shell plating in way of galleys, washrooms and refrigerated store spaces. (g) Structure in way of integral sanitary tanks.

NOTES
1. Suspect areas are locations within the hull structure vulnerable to increased likelihood of structural deterioration and may include, for steel hulls, areas of substantial corrosion and/or fatigue cracking, *see also* 1.5.3 and 5.4.6.
2. Coating condition for steel craft is defined in 1.5.6.

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6.2 Thickness measurement reporting

6.2.1 A report is to be prepared by the approved firm carrying out the thickness measurement. The report is to give the location of measurement, the thickness measured as well as the corresponding original thickness. The report is to give the date when the measurement was carried out, the type of measuring equipment, names of personnel and their qualifications and is to be signed by the operator and supervisor.

6.2.2 The thickness measurement report is to be verified and signed by the Surveyor.

■ *Section 7*
Machinery surveys – General requirements

7.1 Annual, Intermediate and Docking Surveys

7.1.1 For Annual, Intermediate and Docking Surveys, *see* Sections 2, 3 and 4.

7.1.2 For craft where an Approved Planned Maintenance Scheme is in operation an Annual Survey of the machinery is to be carried out together with an audit of the maintenance and monitoring records.

7.1.3 For vessels assigned the notation 'laid-up', a general examination of the machinery is to be carried out in lieu of the normal Annual Survey/Intermediate Survey requirements.

7.2 Complete Surveys

7.2.1 While the craft is in dry-dock, all openings to the sea in the machinery spaces and pump-rooms, together with the valves, cocks and the fastenings with which these are connected to the hull, are to be examined.

7.2.2 Athwartships thrust propellers are to be generally examined so far as is possible in dry dock and tested under working conditions afloat for satisfactory operation.

7.2.3 All shafts (except screwshafts and tube shafts, for which special arrangements are detailed in Section 11), thrust block and all bearings are to be examined. The lower halves of bearings need not be exposed if alignment and wear are found to be acceptable.

7.2.4 An examination is to be made as far as practicable of all propulsion gears complete with all wheels, pinions, shafts, bearings and gear teeth, thrust bearings and incorporated clutch arrangements.

7.2.5 The following auxiliaries and components are also to be examined:

(a) Auxiliary engines, auxiliary air compressors with their intercoolers, filters and/or oil separators and safety devices, and all pumps and components used for essential services.
(b) Steering machinery.
(c) Windlass and associated driving equipment, where fitted.
(d) The holding down bolts, chocks or resilient mounts of main and auxiliary engines, gearcases, thrust blocks and intermediate shaft bearings.

7.2.6 All air receivers for essential services, together with their mountings, valves and safety devices, are to be cleaned internally and examined internally and externally. If internal examination of the air receivers is not practicable, they are to be tested hydraulically to 1,3 times the working pressure.

7.2.7 The valves, cocks and strainers of the bilge system including bilge injection, are to be opened up as considered necessary by the Surveyor and together with pipes, are to be examined and tested under working conditions. The oil fuel, feed, lubricating oil and cooling water systems also any ballast connections together with all pressure filters, heaters and coolers used for essential services, are to be opened up and examined or tested, as considered necessary by the Surveyor. All safety devices for the foregoing items are to be examined.

7.2.8 Fuel tanks which do not form part of the craft's structure are to be examined, and if considered necessary by the Surveyor, they are to be tested to the pressure specified for new tanks. The tanks need not be examined internally at the first survey if they are found satisfactory on external inspection. The mountings, fittings and remote controls of all oil fuel tanks are to be examined, so far as is practicable.

7.2.9 Where remote and/or automatic controls are fitted for essential machinery, they are to be tested to demonstrate that they are in good working order.

7.2.10 In addition to the above, detailed requirements for gas turbines and oil engines and electrical installations are given in Sections 8, 9 and 10 respectively. In certain instances, upon application by the Owner or where indicated by the maker's servicing recommendations, the Committee will give consideration to the circumstances where deviation from these detailed requirements is warranted, taking account of design, appropriate indicating equipment (e.g. vibration indicators) and operational records, *see* Ch 2,4.5.17 and 4.5.23.

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Section 8
Gas turbines – Detailed requirements

8.1 Complete Surveys

8.1.1 The requirements of Section 7 are to be complied with. *See* 7.2.10 regarding any deviation from the following.

8.1.2 The following parts are to be opened out and examined:

- Compressor including impellers or blading, rotors and casing.
- Combustion chambers, burners, intercoolers and heat exchangers.
- Gas, air and fuel piping and fittings.
- Gas generator turbine and power turbine blading, rotors and casing.
- Rotors to include couplings, clutches, bearings and tie bolts.
- Auxiliary mounted fuel, L.O. and cooling water pumps, their drive transmissions and fittings.
- Starting system (for starting air pipes, *see* 9.1.3).
- All safety devices and local controls.
- Mountings and support frame.

8.1.3 The compressor/turbine units are to be operated and maintained in accordance with the manufacturer's instructions. Overhauls, including the prescribed replacement of limited life components, are to be undertaken at the specified intervals. Full service records are to be available for review by the Surveyor.

8.1.4 The manoeuvring of the propulsion system is to be tested under working conditions.

Section 9
Oil engines – Detailed requirements

9.1 Complete Surveys

9.1.1 The requirements of Section 7 are to be complied with. *See* 7.2.10 regarding any deviation from the following.

9.1.2 The following parts are to be opened out and examined:

- Cylinders and covers.
- Valves and valve gear.
- Pistons and connecting rods.
- Crankshafts and all bearings.
- Crankcases and entablatures.
- Crankcase door fastenings and explosion relief devices.
- Turbo-chargers and their associated coolers.
- Air compressors and their intercoolers.
- Filters and/or separators and safety devices.
- Fuel pumps and fittings.
- Camshaft drives and balancer units.
- Vibration dampers or detuners.
- Flexible couplings and clutches.
- Reverse gears.
- Attached pumps and cooling arrangements.

9.1.3 Selected pipes in the starting air system, if fitted, are to be removed for internal examination and are to be hammer tested. If any appreciable amount of lubricating oil is found in the pipes, the starting air system is to be thoroughly cleaned internally by steaming out, or other suitable means. Some of the pipes selected are to be those adjacent to the starting air valves at the cylinders and to the discharges from the air compressors.

9.1.4 The electric ignition system, if fitted, is to be examined and tested.

9.1.5 The manoeuvring of engines is to be tested under working conditions. Initial starting arrangements are to be tested.

Section 10
Electrical equipment

10.1 Annual and Intermediate Surveys

10.1.1 The requirements of 2.2.14 and 3.2.4 are to be complied with as far as applicable.

10.2 Complete Surveys

10.2.1 An electrical insulation resistance test is to be made on the electrical equipment and cables. The installation may be sub-divided, or equipment which may be damaged disconnected, for the purpose of this test.

10.2.2 The fittings on the main and emergency switchboards, section boards and distribution boards are to be examined and over-current protective devices and fuses inspected to verify that they provide suitable protection for their respective circuits.

10.2.3 Generator circuit-breakers are to be tested, so far as is practicable, to verify that protective devices including preference tripping relays, if fitted, operate satisfactorily.

10.2.4 The electric cables and their securing arrangements are to be examined, so far as is practicable, without undue disturbance of fixtures or casings unless opening up is considered necessary as a result of observation or of the tests required by 10.2.1.

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10.2.5 The generator prime movers are to be surveyed as required by Sections 8 and 9 and the governing of the engines tested. The motors concerned with essential services together with associated control and switch gear are to be examined and if considered necessary, are to be operated, so far as is practicable, under working conditions. All generators and steering gear motors are to be examined and are to be operated under working conditions, though not necessarily under full load or simultaneously.

10.2.6 Where transformers or electrical apparatus associated with supplies to essential services are liquid filled or cooled by a liquid in direct contact with current carrying parts, the owner is to arrange for samples of the liquid to be taken and tested, by a competent authority, in accordance with the equipment manufacturer's requirements, and a certificate giving the test results is to be furnished to the Surveyor.

10.2.7 Navigation light indicators are to be tried under working conditions, and correct operation on the failure of supply or failure of navigation lights verified.

10.2.8 The emergency sources of electrical power, where fitted, together with their automatic arrangements and associated circuits are to be tested.

10.2.9 Emergency lighting, transitional emergency lighting, supplementary emergency lighting, general emergency alarm and public address systems are to be tested as far as practicable.

10.2.10 Where the craft is electrically propelled, the propulsion motors, generators, cables and all ancillary electrical gear, exciters and ventilating plant (including coolers) associated therewith are to be examined, and the insulation resistance to earth is to be tested. Special attention is to be given to windings, commutators and slip-rings. The operation of protective gear and alarm devices is to be checked, so far as is practicable. Liquids for filling and cooling, if used, are to be tested in accordance with 10.2.6. Interlocks intended to prevent unsafe operations or unauthorised access are to be checked to verify that they are functioning correctly. Emergency overspeed governors are to be tested.

10.2.11 Where batteries provide the source of power for any essential services, their installation, including charging and ventilation arrangements, is to be examined.

Section 11
Screwshafts, tube shafts, propellers and water jet units

11.1 Frequency of surveys

11.1.1 Shafts with keyed propeller attachments and fitted with continuous liners or approved oil glands, or made of approved corrosion resistant materials, are to be surveyed at intervals of five years when the keyway complies fully with the present Rules.

11.1.2 Shafts having keyless type propeller attachments are to be surveyed at intervals of five years provided they are fitted with approved oil glands or are made of approved corrosion resistant materials.

11.1.3 Shafts having solid coupling flanges at the after end are to be surveyed at intervals of five years provided they are fitted with approved oil glands or are made of approved corrosion resistant materials.

11.1.4 All other shafts not covered by 11.1.1 to 11.1.3 are to be surveyed at intervals of $2^1/_2$ years.

11.1.5 Controllable pitch propellers for main propulsion purposes are to be surveyed at the same intervals as the screwshaft.

11.1.6 Directional propeller units for main propulsion purposes are to be surveyed at intervals not exceeding five years.

11.1.7 Water jet units for main propulsion purposes are to be surveyed at intervals not exceeding five years provided the impeller shafts are made of approved corrosion resistant material or have approved equivalent arrangements.

11.1.8 Athwartship thrust propellers and shaftings are to be surveyed at intervals not exceeding five years, *see* 7.2.2.

11.2 Normal surveys

11.2.1 All screwshafts are to be withdrawn for examination by LR's Surveyors at the intervals prescribed in 11.1.1 to 11.1.4. The after end of the cylindrical part of the shaft and forward one third of the shaft cone, or fillet of the flange, is to be examined by a magnetic particle crack detection method. In the case of a keyed propeller attachment at least the forward one third of the shaft cone is to be examined with the key removed. Weardown is to be measured and the sterntube bearings, oil glands, propellers and fastenings are to be examined. Controllable pitch propellers where fitted are to be opened up and the working parts examined, together with the control gear.

11.2.2 Directional propeller units are to be dismantled for examination of the propellers, shafts, gearing and control gear.

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11.2.3 Water Jet Units are to be dismantled for examination of the impeller, casing, shaft, shaft seal, shaft bearing, inlet and outlets channels, steering nozzle, reversing arrangements, and control gear.

11.3 Screwshaft Condition Monitoring (SCM)

11.3.1 Where oil lubricated shafts with approved oil glands are fitted, and the Owner has complied with the following requirements, the descriptive note **SCM** (Screwshaft Condition Monitoring) may be entered in column 6 of the *Register Book*:

(a) Lubricating oil analysis to be carried out regularly at intervals not exceeding six months. The lubricating oil analysis documentation is to be available on board. Each analysis is to include the following minimum parameters:
- water content
- chloride content
- bearing material and metal particles content
- oil ageing (resistance to oxidation).

(b) Oil samples are to be taken under service conditions and are to be representative of the oil within the sterntube.

(c) Oil consumption is to be recorded.

(d) Bearing temperatures are to be recorded (two temperature sensors or other approved arrangements are to be provided).

(e) Facilities are to be provided for measurement of bearing weardown.

(f) Oil glands are to be capable of being replaced without withdrawal of the screwshaft.

11.3.2 For maintenance of the descriptive note **SCM**, the records of analyses, consumption and temperatures, together with weardown readings, are to be retained on board and audited annually.

11.3.3 Where the requirements for the descriptive note **SCM** have been complied with, the screwshaft need not be withdrawn at surveys as required by 11.2.1 provided all condition monitoring data is found to be within permissible limits and all exposed areas of the shaft are examined by a magnetic particle crack detection method. The remaining requirements of 11.2.1 are to be complied with. Where the Surveyor considers that the data presented is not entirely to his satisfaction the shaft will be required to be withdrawn in accordance with 11.2.1.

11.4 Modified Survey

11.4.1 A Modified Survey may be accepted at alternate five-yearly surveys for shafts described in 11.1.1 provided they are fitted with oil lubricated bearings and approved oil glands, and also for those in 11.1.2 and 11.1.3.

11.4.2 The Modified Survey is to consist of the partial withdrawal of the shaft, sufficient to ascertain the condition of the stern bearing and shaft in way. For keyless propellers or shafts with a solid flange connection to the propeller a visual examination to confirm the good condition of the sealing arrangements is to be made. The oil glands are to be capable of being replaced without removal of the propeller. The forward bearing and all accessible parts including the propeller connection to the shaft are to be examined as far as possible. Wear down is to be measured and found satisfactory. Where a controllable pitch propeller is fitted, at least one of the blades is to be dismantled complete for examination of the working parts and the control gear.

11.4.3 For keyed propellers, the after end of the cylindrical part of the shaft and forward one third of the shaft cone is to be examined by a magnetic particle crack detection method, for which dismantling of the propeller and removal of the key will be required.

11.4.4 Where the descriptive note **SCM** has been assigned as described in 11.3.1 and all data is found to be within permissible limits, partial withdrawal of the shaft may not be required. Where doubt exists regarding any of the above findings the shaft is to be withdrawn to permit an entire examination.

11.5 Partial Survey

11.5.1 For shafts where the Modified Survey is applicable, upon application by the Owner, the Committee will be prepared to give consideration to postponement of the survey for a maximum period of half the specified cycle provided a Partial Survey is held.

11.5.2 The Partial Survey is to consist of the propeller being backed off in any keyed shaft and the top half of the cone examined by an efficient crack detection method for which removal of the key will be required. Oil gland and seals are to be examined and dealt with as necessary. Weardown is to be measured and found satisfactory. Propeller and fastenings are to be examined.

11.5.3 The Committee will be prepared to give consideration to the circumstances of any special case upon application by the Owner.

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Section 12
Classification of craft not built under survey

12.1 General

12.1.1 When classification is desired for a craft not built under the supervision of LR's Surveyors, application should be made to the Committee in writing.

12.1.2 Periodical Surveys of such craft, when classed, are subsequently to be held as in the case of craft built under survey.

12.1.3 Where classification is desired for a craft which is classed by another recognised Society, special consideration will be given to the scope of the survey.

12.2 Hull and equipment

12.2.1 Plans showing the main scantlings and arrangements of the actual craft together with any proposed alterations are to be submitted for approval.These should comprise plans of the midship section, longitudinal section and decks, and such other plans as may be requested. If plans cannot be obtained or prepared by the Owner, facilities are to be given for LR's Surveyor to obtain the necessary information from the craft.

12.2.2 Particulars of the process of manufacture and the testing of the material of construction are to be supplied. The requirements for composite craft will be specially considered.

12.2.3 The full requirements of Sections 5 and 6 are to be carried out as applicable. Craft of recent construction will receive special consideration.

12.2.4 During the survey, the Surveyors are to satisfy themselves regarding the workmanship and verify the approved scantlings and arrangements. For this purpose, and also in order to ascertain the amount of any deterioration of steel craft, parts of the structure will require to be gauged as necessary. Full particulars of the anchors, chain cables and equipment are to be submitted. For craft to which Pt 15, Ch 1 applies, fire protection, detection and extinction are to be in accordance with the Rules.

12.2.5 When the full survey requirements indicated in 12.2.3 and 12.2.4 cannot be completed at one time, the Committee may consider granting an interim record for a limited period. The conditions regarding the completion of the survey will depend on the merits of each particular case, which should be submitted for consideration.

12.3 Machinery

12.3.1 To facilitate the survey, the following plans and particulars (plans of piping are to be diagrammatic), together with the particulars of the materials used in the construction of any boilers, air receivers and important forgings are to be submitted:

- Name of manufacturer of engine and gearbox including the manufacturer's type designation of engine and gearbox, together with the continuous shaft power of the engine at the crankshaft coupling with the revolutions per minute of crankshaft and propeller.
- General pumping arrangements, including air and sounding pipes (Builder's plan).
- Bilge, ballast and oil fuel pumping arrangements including the capacities of the pumps on bilge service.
- Arrangement and dimensions of any steam pipes.
- Arrangement of oil fuel pipes and fittings at settling and service tanks.
- Arrangement of oil fuel piping in connection with oil burning installations.
- Oil fuel overflow systems, where these are fitted.
- Arrangement of boiler feed systems.
- Oil fuel settling, service and other oil fuel tanks not forming part of the craft's structure.
- Boilers and economisers.
- Air receivers.
- Crank, thrust, intermediate and screw shafting.
- Details of water jet or directional propeller units, if fitted.
- Clutch and reversing gear with methods of control.
- Reduction gearing.
- Propeller (including spare propeller if supplied) where the diameter exceeds 1 m.
- Electrical circuits.
- Arrangement of compressed air systems for main and auxiliary services.
- Arrangement of lubricating oil, other flammable liquids and cooling water systems for main and auxiliary services.
- Steering gear including control arrangement.
- Arrangement of exhaust system indicating materials, method of cooling, and if water spray injected, the method of draining.

12.3.2 Plans additional to those detailed in 12.3.1 are not to be submitted unless the machinery is of a novel or special character affecting classification.

12.3.3 Where remote and/or automatic controls are fitted to propulsion machinery and essential auxiliaries, a description of the scheme is to be submitted.

12.3.4 For new craft and craft which have been in service less than two years, calculations of the torsional vibration characteristics of the propelling machinery are to be submitted for consideration, as required for craft constructed under Special Survey. For older craft the circumstances will be specially considered in relation to their service record and type of machinery installed. Where calculations are not submitted, the Committee may require that the machinery certificate be endorsed to this effect. When desired by the Owner, the calculations and investigation of the torsional vibration characteristics of the machinery may be carried out by LR upon special request.

12.3.5 The main and auxiliary machinery, feed pipes, compressed air pipes and boilers are to be examined as required at Complete Surveys. Working pressures are to be determined from the actual scantlings in accordance with the Rules.

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12.3.6 The screwshaft is to be drawn and examined.

12.3.7 Any steam pipes or oil burning installations are to be examined and tested as required by Pt 1, Ch 3,15 or Ch 3,16 of the *Rules and Regulations for the Classification of Ships*.

12.3.8 The bilge, ballast and oil fuel pumping arrangements are to be examined and amended, as necessary, to comply with the Rules.

12.3.9 The electrical equipment is to be examined as required at Complete Surveys.

12.3.10 The whole of the machinery, including essential controls, is to be tried under working conditions to the Surveyor's satisfaction.

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Section

1 **General**

2 **Intermediate Surveys – Hull and machinery requirements**

3 **Docking Surveys and In-water Surveys – Hull and machinery requirements**

4 **Special Survey – General – Hull requirements**

5 **Special Survey – Thickness measurement requirements for steel yachts**

6 **Machinery surveys – General requirements**

7 **Gas turbines – Detailed requirements**

8 **Oil engines – Detailed requirements**

9 **Electrical equipment**

10 **Screwshafts, tube shafts, propellers and water jet units**

11 **Surveys of unclassed machinery in existing classed yachts**

12 **Classification of yachts not built under survey**

Section 1 General

1.1 Frequency of surveys

1.1.1 The requirements of this Chapter are applicable to the Periodical Surveys set out in Ch 2,4.5. Except as amended at the discretion of the Committee, the periods between such surveys are as follows:

(a) Intermediate Surveys as required by Ch 2,4.5.5.
(b) Docking Surveys as required by Ch 2,4.5.6 and 4.5.7.
(c) Special Surveys at five-yearly intervals, *see* Ch 2,4.5.11. For alternative arrangements, *see also* Ch 2,4.5.12, 4.5.13 and 4.5.15.
(d) Complete Surveys of machinery at five-yearly intervals, *see* Ch 2,4.5.16. For alternative arrangements, *see also* Ch 2,4.5.17, 4.5.19, 4.5.21, 4.5.22 and 4.5.23.

1.1.2 When it has been agreed that the Complete Survey of the hull and machinery may be carried out on the Continuous Survey basis, all compartments of the hull and all items of machinery are to be opened for survey in rotation to ensure that the interval between consecutive examinations of each part will not exceed five years, *see* Ch 2,4.5.15 and 4.5.19.

1.1.3 For the frequency of surveys of screwshafts, tube shafts, propellers and water jet units, *see* Section 10.

1.2 Surveys for damage or alterations

1.2.1 At any time when a yacht is undergoing alterations or damage repairs, any exposed parts of the structure normally difficult to access are to be specially examined, e.g. if any part of the main or auxiliary machinery is removed for any reason, the hull structure in way is to be carefully examined by the Surveyor, or when cement in the bottom or sheathing on decks is removed the structure in way is to be examined before the cement or sheathing is relaid.

1.3 Unscheduled surveys

1.3.1 In the event that Lloyd's Register (hereinafter referred to as 'LR') has cause to believe that its Rules and Regulations are not being complied with, LR reserves the right to perform unscheduled surveys of the hull or machinery.

1.3.2 In the event of significant damage or defect affecting any yacht, LR reserves the right to perform unscheduled surveys of the hull or machinery of other similar yachts classed by LR and deemed to be vulnerable.

1.4 Surveys for the issue of Convention certificates

1.4.1 Surveys are to be held by LR when so appointed, or by the Exclusive Surveyors to a National Administration or by an IACS Member when so authorised by the National Authority, or, in the case of Cargo Ship Safety Radio Certificates or Safety Management Certificates, by any organisation authorised by the National Authority. In the case of dual classed yachts, Convention Certificates may be issued by the other Society with which the yacht is classed provided this is recognised in a formal Dual Class Agreement with LR and provided the other Society is also authorised by the National Authority.

1.5 Definitions

1.5.1 A **Ballast tank** is a tank which is used primarily for salt water ballast.

1.5.2 **Spaces** are separate hull compartments including integral tanks.

1.5.3 **Suspect areas** are locations within the hull structure vulnerable to increased likelihood of structural deterioration and may include:

(a) For steel hulls, areas of substantial corrosion and/or fatigue cracking.
(b) For aluminium alloy hulls, areas of fatigue cracking and areas in the vicinity of bimetallic connections.
(c) For composite hulls, areas subject to impact damage.
(d) For wood hulls, areas subject to decay as a result of fresh water ingress or poor ventilation.
(e) For high speed craft (as defined in Ch 2,2.2.7), areas of the bottom structure forward prone to slamming damage.
(f) For sailing craft, areas subject to high local stresses due to rigging loads and ballast keel attachments.

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1.5.4 **Substantial corrosion** is wastage of individual steel or aluminium plates and stiffeners in excess of 75 per cent of allowable margins, but within acceptable limits.

1.5.5 **Protective coatings** for steel craft should usually be hard coatings. Other coating systems (e.g. soft coating) may be considered acceptable as alternatives provided they are applied and maintained in compliance with the manufacturer's specification.

1.5.6 **Coating condition** for steel yacht is defined as follows:

GOOD condition with only minor spot rusting affecting not more than 20 per cent of areas under consideration.

Section 2
Intermediate Surveys – Hull and machinery requirements

2.1 General

2.1.1 At Intermediate Surveys, the Surveyor is to examine the hull and machinery, so far as necessary and practicable, in order to be satisfied as to their general condition.

2.2 Intermediate Surveys

2.2.1 The Surveyor is to be satisfied regarding:

(a) The efficient condition of hatchways on freeboard and superstructure decks, weather deck plating, ventilator coamings and air pipes, exposed casings, skylights, flush deck scuttles, deckhouses and companionways, superstructure bulkheads, side, bow and stern doors, windows and storm shutters, side scuttles and deadlights, chutes and other openings, together with all closing appliances and flame screens.

(b) The efficient condition of scuppers and sanitary discharges (so far as is practicable); valves on discharge lines (so far as is practicable) and their controls; guard rails and bulwarks; freeing ports, gangways and life-lines.

(c) The efficient condition of bilge level detection and alarm systems on yachts assigned a **UMS** notation.

2.2.2 The anchoring and mooring equipment including anchor warps or wire ropes is to be examined so far as is practicable. For all yachts over 10 years of age the anchors are to be partially lowered and raised using the windlass.

2.2.3 The watertight doors in watertight bulkheads are to be examined and operationally tested locally and where applicable remotely. Other watertight bulkhead penetrations, are to be examined so far as is practicable.

2.2.4 The Surveyor is to examine and test in operation all main and auxiliary steering arrangements including their associated equipment and control systems.

2.2.5 The Surveyor is to generally inspect the machinery spaces with particular attention being given to the propulsion system, auxiliary machinery and to the existence of any fire and explosion hazards. Where applicable, emergency escape routes are to be checked to ensure that they are free of obstruction.

2.2.6 The means of communication between the navigating bridge and the machinery control positions, as well as the bridge and the alternative steering position, if fitted, are to be tested.

2.2.7 The bilge pumping systems and bilge wells, including operation of extended spindles, self closing drain cocks and level alarms, where fitted, are to be examined so far as is practicable. Satisfactory operation of the bilge pumps, including any hand pumps, is to be proven.

2.2.8 Any pressure vessels including safety devices, foundations, controls, relieving gear, associated piping systems, insulation and gauges, are to be generally examined. Surveyors should confirm that Periodical Surveys of pressure vessels have been carried out as required by the Rules and that the safety devices have been tested.

2.2.9 The electrical equipment and cabling forming the main and emergency electrical installations are to be generally examined under operating conditions so far as is practicable. The satisfactory operation of the main and emergency sources of power and electrical services essential for safety in an emergency is to be verified; where the sources of power are automatically controlled they should be tested in the automatic mode. Bonding straps for the control of static electricity and earthing arrangements are to be examined where fitted.

2.2.10 The electrical generating sets are to be examined under working conditions.

2.2.11 For yachts having **UMS** or **CCS** notation, a General Examination of automation equipment is to be carried out. Satisfactory operation of safety devices and control systems is to be verified.

2.2.12 For yachts to which Pt 17, Ch 1 applies, the arrangements for fire protection, detection and extinction are to be examined and are to include the following items, as required to be fitted in accordance with the Rules:

(a) Verification, so far as is practicable, that no significant changes have been made to the arrangement of structural fire protection.

(b) Verification of the operation of manual and/or automatic doors where fitted.

(c) Verification that fire control plans are properly posted.

(d) Examination, so far as is possible, and testing as feasible, of the fire and/or smoke detection and alarm system(s).

(e) Examination of fire main system, and confirmation that each fire pump, including the emergency fire pump can be operated separately so that the required jets of water can be produced simultaneously from different hydrants.

(f) Verification that fire-hoses, nozzles, applicators and spanners are in good working condition and situated at their respective locations.

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(g) Examination of fixed fire-fighting systems controls, piping, instructions and marking, checking for evidence of proper maintenance and servicing, including date of last systems tests.
(h) Verification that all portable and semi-portable fire-extinguishers are in their stowed positions, checking for evidence of proper maintenance and servicing, conducting random checks for evidence of discharged containers.
(j) Verification, so far as is practicable, that the remote control for stopping fans and machinery and shutting off fuel supplies in machinery spaces and, where fitted, the remote controls for stopping fans in accommodation spaces and the means of cutting off power to the galley are in good working order.
(k) Examination of the closing arrangements of ventilators, skylights and doorways where applicable.
(l) Verification that the fireman's outfits are complete and in good condition.
(m) Verification that gas installations for domestic purposes comply with the relevant statutory requirements.

2.2.13 For steel yachts a general examination of salt-water ballast tanks, integral sanitary tanks and bilges is to be carried out as required below. If such inspections reveal no visible structural defects then the examination may be limited to a verification that the protective coating remains in GOOD condition as defined in 1.5.6. When considered necessary by the Surveyor thickness measurement of the structure is to be carried out. Where the protective coating is found to be other than in GOOD condition, and it has not been repaired, maintenance of class will be subject to the spaces in question being internally examined and gauged as necessary annually.
(a) For all yachts over five years of age and up to 10 years of age, representative salt water ballast tanks, integral sanitary tanks and bilges are to be generally examined. Where the protective coating is found to be other than in GOOD condition, as defined in 1.5.6, or other defects are found, the examination is to be extended to other spaces of the same type.
(b) For steel yachts over 10 years of age all salt water ballast tanks, integral sanitary tanks and bilges are to be generally examined.

2.2.14 Representative internal spaces including fore and aft peak spaces, machinery spaces, bilges, etc are to be generally examined. These spaces should include all suspect areas, *see* 1.5.3.

2.2.15 In sailing and auxiliary yachts, the mast(s), mast steps, spars, standing and running rigging, rigging screws, chainplates and sails are to be examined so far as is practicable.

Section 3
Docking Surveys and In-water Surveys – Hull and machinery requirements

3.1 General

3.1.1 At Docking Surveys or In-water Surveys the Surveyor is to examine the yacht and machinery, so far as necessary and practicable, in order to be satisfied as to the general condition.

3.2 Docking Surveys

3.2.1 Where a yacht is in dry-dock or on a slipway it is to be placed on blocks of sufficient height and proper staging is to be erected as may be necessary, for the examination of the outside of the hull, rudder(s) and underwater fittings. The outside surface of the hull is to be cleaned as may be required by the Surveyor.

3.2.2 Attention is to be given to parts of the external hull structure particularly liable to structural deterioration from causes such as high stresses, chafing and lying on the ground, and to areas of structural discontinuity.

3.2.3 The following parts of the external hull structure are to be specially examined:
(a) For steel hulls attention is to be given to parts of the structure particularly liable to excessive corrosion and to any undue unfairness of the plating of the bottom. The coating system is to be examined and made good as necessary.
(b) For aluminium alloy hulls attention is to be given to areas adjacent to any bimetallic connections at skin fittings, etc.
(c) For composite hulls the gelcoat or other protective finish is to be examined for surface cracking, blistering or other damage which may impair the efficiency of the protection to the underlying laminate.
(d) For wood hulls the condition of any caulking or sheathing is to be examined as applicable. The condition of external fastenings may require to be confirmed by removal at the discretion of the Surveyor.
(e) For sailing or auxiliary yachts fitted with external ballast, the attachment of bilge or centreline ballast keels is to be examined.

3.2.4 Where required by the Rules, the satisfactory condition of the cathodic protection is to be confirmed.

3.2.5 The clearances in the rudder bearings and pintles are to be measured. Where considered necessary by the Surveyor rudders are to be lifted for examination of the stock. The securing of rudder couplings and/or pintle fastenings is to be confirmed.

3.2.6 The sea connections and overboard discharge valves, their attachments to the hull and the gratings at the sea inlets are to be examined.

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3.2.7 The propeller and fastenings are to be examined. The sternbush is to be examined as far as is practicable.

3.2.8 The clearance in the sternbush or the efficiency of the oil gland is to be ascertained. The clearance of any shaft bracket bearings is to be ascertained.

3.2.9 The inboard shaft seals or glands are to be examined. Where flexible sternglands are fitted, the satisfactory condition of the rubber hose and securing clips is to be confirmed.

3.2.10 Special attention is to be given to the hull in way of underwater fittings such as transverse thrusters, stabilisers, etc.

3.2.11 Where applicable, attention is to be given to the connection and/or intersection of the cross-deck structure to the hulls of multi hull craft.

3.2.12 Where water jet units are fitted, the impeller, hull ducting, grating, nozzle steering and reversing arrangements are to be examined as far as is practicable.

3.2.13 Where transom mounted propulsion units are fitted, the steering arrangements and any flexible transom seals are to be examined.

3.2.14 When chain cables are ranged, the anchors and cables are to be examined by the Surveyor, *see also* 4.3.7 and Table 4.4.1.

3.3 In-water Surveys

3.3.1 The Committee will accept an In-water Survey in lieu of the intermediate docking between Special Surveys required in a five year period on yachts where an ***IWS** notation is assigned, *see* Ch 2,3.8.2.

3.3.2 The Committee may accept an In-water Survey in lieu of the intermediate docking between Special Surveys required in a five year period on yachts where suitable protection is applied to the underwater portion of the hull. If requested, an ***IWS** class notation may be assigned on satisfactory completion of the Survey, provided that the applicable requirements of the Rules are complied with, *see also* Ch 2,3.8.2.

3.3.3 The In-water Survey is to provide the information normally obtained from the Docking Survey, so far as is practicable.

3.3.4 Proposals for In-water Surveys are to be submitted in advance of the survey being required so that satisfactory arrangements can be agreed with LR.

3.3.5 The In-water Survey is to be carried out at agreed geographical locations under the surveillance of a Surveyor to LR, with the yacht in sheltered waters; the in-water visibility is to be good and the hull below the waterline is to be clean. The Surveyor is to be satisfied that the method of pictorial presentation is satisfactory. There is to be good two-way communication between the Surveyor and the diver.

3.3.6 Diving and In-water Survey operations are to be carried out by firms recognised by the Committee. Continued recognition by the Committee will be dependent on the standard of workmanship by the firm being maintained to the satisfaction of LR's Surveyors.

3.3.7 If the In-water Survey reveals damage or deterioration that requires early attention, the Surveyor may require that the yacht be dry-docked in order that a fuller survey can be undertaken and the necessary work carried out.

3.3.8 Where a yacht has an ***IWS** notation, the condition of the high resistant paint is to be confirmed at each dry-docking in order that the ***IWS** notation can be maintained.

3.3.9 Some National Administrations may have requirements additional to those of 3.3.1 to 3.3.8.

■ *Section 4* Special Survey – General – Hull requirements

4.1 General

4.1.1 The survey is to be of sufficient extent to ensure that the hull and related equipment is in satisfactory condition and is fit for its intended purpose, subject to proper maintenance and operation and to Periodical Surveys being carried out as required by the Regulations.

4.1.2 The requirements of Section 2 are to be complied with so far as applicable.

4.1.3 A Docking Survey in accordance with the requirements of 3.2 is to be carried out as part of the Special Survey.

4.1.4 For sailing and auxiliary yachts fitted with unclassed machinery installations the requirements of 11.3.1 are to be complied with.

4.2 Preparation

4.2.1 The yacht is to be prepared for survey in accordance with the requirements of Table 4.4.1. The preparation should be of sufficient extent to facilitate an examination to ascertain any excessive corrosion, erosion, deformation, fractures, damages and other structural deterioration.

4.2.2 Where, in accordance with Table 4.4.1, the yacht is opened out by removal of linings, cabin sole, etc., and defects are found, further opening out will be required in order that the Surveyor can confirm the full extent of the defects.

4.3 Examination and testing – General

4.3.1 All spaces within the hull and superstructure including integral tanks are to be examined (*see also* 4.4.1 for tank examinations on steel craft). Special attention is to be paid to any suspect areas, *see* 1.5.3.

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Table 4.4.1 Survey preparation

Special Survey I (Yachts 5 years old)	Special Survey II (Yachts 10 years old)	Special Survey III (Yachts 15 years old) and subsequent special surveys
(1) The interior of the yacht is to be sufficiently opened out by the removal of lining, ceiling/cabin sole, portable tanks and ballast, etc as required in order that the Surveyor may be satisfied as to the condition of suspect areas of the structure (*see* 1.5.3). A record is to be made of those areas where lining, cabin sole, etc., were opened out and where equipment was removed during the survey. This record is to be retained for reference during subsequent surveys. (2) Machinery compartments, fore and aft peaks and other spaces as directed by the Surveyor, are to be cleared and cleaned as necessary, and the bilges and limbers all fore and aft are to be cleaned and prepared for examination. Platform plates in engine spaces are to be lifted as may be necessary for the examination of the structure below. Where necessary, pipework may be required to be removed for examination of the structure. (3) In way of the single and/or double bottom areas, a sufficient amount of cabin sole is to be lifted to permit examination of the bilges and/or tanktops below. (4) All integral tanks are to be cleaned as necessary to permit examination. (For steel yachts, *see* Table 4.4.2). (5) In sailing and auxiliary yachts the sails are to be laid out so that they can be properly examined.	In addition to the requirements for Special Survey I, the following are to be complied with: (1) The chain locker is to be cleared and cleaned internally for examination of the structure and examination of the cable securing arrangements. The chain cables/anchor warps, as applicable, are to be ranged for inspection. The anchors are to be cleaned and placed in an accessible position for inspection. (2) The rudder is to be unshipped for examination of the rudder stock and trunk at the discretion of the Surveyor. For sailing or auxiliary yachts: (3) On yachts fitted with an external ballast keel, fastenings are to be drawn for examination as may be required by the Surveyor. (4) On yachts fitted with a centreplate or lifting keel, the pivot bolts and lifting arrangements are to be dismantled for examination as required by the Surveyor. For wood yachts: (5) Where the hull is sheathed with metal, such sheathing as will permit an examination of the stem, wood keel, garboards, plank ends and sternpost is to be removed as required by the Surveyor. (6) Fastenings are to be drawn as may be required by the Surveyor. (7) The outside surface of the planking is to be scraped bright at the discretion of the Surveyor.	In addition to the requirements for Special Survey II the following are to be complied with: (1) Linings, ceiling/cabin soles, etc. are to be removed as required in order that the Surveyor may be satisfied as to the condition of the structure. For steel yachts: (2) Portions of wood sheathing, or other covering, on steel decks are to be removed, as considered necessary by the Surveyor, in order to ascertain the condition of the plating. (3) Where spaces are insulated, sufficient insulation is to be removed in each space to enable the Surveyors to be satisfied with the condition of the structure. (4) Linings are to be removed in way of shell plating immediately above tank top connections to the side shell, in way of galleys/washrooms and beneath portlights and windows. For sailing or auxiliary yachts: (5) The masts are to be unshipped for survey. The whole of the standing rigging, including rigging screws, bolts, pins and fittings, is to be dismantled as considered necessary by the Surveyor. NOTE This requirement may be waived at alternate Special Surveys provided the masts and rigging are thoroughly examined *in situ*. (6) On yachts fitted with an external ballast keel, a minimum of 50% of the total number of ballast keel fastenings are to be drawn for examination as required by the Surveyor. If defects are found the remaining fastenings should be drawn for sexamination. For wood yachts: (7) Where iron or mild steel fastenings are used, as a minimum requirement the following are to be drawn for examination where applicable: • 6 floor arm fastenings each side. • 4 hanging knee fastenings each side. • 4 chain plate fastenings each side at each mast. • 18 frame to plank fastenings each side. • 12 garboard and 12 plank end fastenings each side.

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4.3.2 Double bottom compartments, peak tanks and all other integral tanks are to be tested by a head sufficient to give the maximum pressure that can be experienced in service. Tanks may be tested afloat provided that their internal examination is also carried out afloat.

4.3.3 Where repairs are effected to the hull shell or bulkheads, any integral tanks in way are to be tested to the Surveyor's satisfaction on completion of these repairs.

4.3.4 All decks, casings and superstructures are to be examined.

4.3.5 The satisfactory attachment of any wood or other deck sheathing is to be confirmed, *see also* 4.4.4.

4.3.6 Attention is to be given to the corners of openings and other discontinuities in the hull structure.

4.3.7 The anchors are to be examined. If the chain cables are ranged they are to be examined together with the chain locker, *see* Table 4.4.1. If any length of chain cable is found to be reduced in mean diameter at its most worn part by 12 per cent or more from its nominal diameter, it is to be renewed. The windlass is to be examined.

4.3.8 The Surveyor is to be satisfied that there are suitable towlines and mooring ropes when these are a Rule requirement.

4.3.9 Representative structural fastenings, are to be tested to ascertain their soundness and may require to be drawn for examination at the discretion of the Surveyor.

4.3.10 For yachts to which Pt 17, Ch 1 applies, the Surveyor is to be satisfied as to the efficient condition of the means of escape from crew and passenger spaces, and spaces in which crew are normally employed.

4.4 Examination and testing – Additional items for steel yachts

4.4.1 All integral tanks are generally to be internally examined. However, in certain circumstances the internal examination of lubricating oil, fresh water and oil fuel tanks may be waived. For the minimum extent of tank internal examination, *see* Table 4.4.2.

4.4.2 In salt water ballast spaces, integral sanitary tanks and bilges, where the protective coating is found to be other than in GOOD condition as defined in 1.5.6 and it has not been repaired, maintenance of class will be subject to the spaces in question being internally examined and gauged as necessary annually.

4.4.3 The protection of steelwork, other than as referred to in 4.4.2 should be examined and made good where necessary on satisfactory completion of the survey. In areas where the inner surface of the bottom plating is covered with cement, asphalt or other composition, the removal of this covering may be dispensed with, provided that it is found sound and adhering satisfactorily to the steel.

4.4.4 Wood decks or sheathing are to be examined and the caulking is to be tested and recaulked as necessary. If decay or rot is found, or the wood is excessively worn, the wood is to be renewed. When a wood deck, laid on stringers and ties, has worn by 20 per cent or more in thickness, it is to be renewed. Attention is to be given to the condition of the plating under wood deck sheathing or other deck covering. If it is found that such coverings are broken, or are not adhering closely to the plating, sections are to be removed as necessary to ascertain the condition of the plating, *see also* 1.2.1.

4.4.5 The structure in way of bimetallic connections, e.g. to aluminium alloy deckhouses is to be examined.

Table 4.4.2 Tank internal examination requirements for steel yachts

Tank	Special Survey I (Yachts 5 years old)	Special Survey II (Yachts 10 years old)	Special Survey III (Yachts 15 years old)	Special Survey IV (Yachts 20 years old)	All Subsequent Special Surveys
Peaks	All tanks	All tanks	All tanks	All tanks	All tanks
Salt water ballast	All tanks	All tanks	All tanks	All tanks	All tanks
Lubricating oil	None	None	*See* Note 2	*See* Note 3	All tanks
Fresh water	None	*See* Note 1	*See* Note 2	*See* Note 3	All tanks
Oil fuel	None	*See* Note 1	*See* Note 2	*See* Note 3	All tanks
Sanitary	All tanks	All tanks	All tanks	All tanks	All tanks

NOTES
1. Tanks (excluding peak tanks) used exclusively for oil fuel or fresh water need not all be examined internally provided that the Surveyor is satisfied with the condition, after both external examination and testing and from an internal examination of the after end of one forward double bottom tank, and of one selected deep tank.
2. Tanks (excluding peak tanks) used exclusively for oil fuel, oil fuel and fresh water ballast, or lubricating oil, need not all be examined internally provided that the Surveyor is satisfied with the condition, after both external examination and testing and from an internal examination of one double bottom tank forward and one aft and one deep tank.
3. Tanks (excluding peak tanks) used exclusively for oil fuel, oil fuel and fresh water ballast, or lubricating oil, need not all be examined internally provided that the Surveyor is satisfied with the condition, after both external examination and testing and from internal examination of a least one double bottom tank amidships, one forward and one aft and one deep tank.
4. When examining tanks internally the Surveyor is to verify that striking plates or other additional reinforcement is fitted under sounding pipes. In the case of tanks fitted only with remote gauging facilities, the satisfactory operation of the gauges is to be confirmed.

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4.4.6 The Surveyors may require to measure the thickness of the material in any portion of the structure where signs of wastage are evident or wastage is normally found. Any parts of the structure which are found defective or excessively reduced in scantlings are to be made good by materials of the approved scantlings and quality. The minimum requirements for thickness measurements are given in Section 5.

4.5 Examination and testing – Additional items for aluminium alloy yachts

4.5.1 The structure in way of any bimetallic connections is to be examined and the efficiency of the insulation arrangements confirmed.

4.5.2 The Surveyor may require to measure the thickness of the material in any portion of the structure where signs of deterioration are evident or may normally be found. Any parts of the structure which are found defective or excessively reduced in scantlings are to be made good by materials of the approved scantlings and quality.

4.6 Examination and testing – Additional items for composite yachts

4.6.1 The bonded attachments of frames, floors, bulkheads, structural joinery, engine bearers, sterntubes, rudder tubes, and integral tank boundaries are to be examined.

4.6.2 The hull to deck joint together with any joints between the deck and deckhouses or superstructures are to be examined.

4.6.3 The structure in way of the bolted attachment of fittings including guardrail stanchions, windlass, shaft brackets, fendering, mooring bitts, mast steps, rigging chainplates, etc., is to be examined.

4.7 Examination and testing – Additional items for wood yachts

4.7.1 Where hulls are provided with metal sheathing, the condition of the structure in way of any sheathing is to be confirmed. For the extent of removal of metal sheathing *see* Table 4.4.1. The satisfactory adhesion of any glass/nylon reinforced plastic sheathing is also to be confirmed.

4.7.2 Wood decks or sheathing are to be examined and the caulking is to be tested and re-caulked as necessary. If decay or rot is found or the wood has worn by 20 per cent or more in thickness, the wood is to be renewed. Attention is to be given to the condition of the structure under wood decks, and to fabric deck coverings. If it is found that such coverings are damaged or are not adhering closely to the deck, sections are to be removed as necessary to ascertain the condition of the deck under.

4.7.3 Fastenings as may be required by the Surveyor are to be drawn for examination, see Table 4.4.1.

4.8 Examination and testing – Additional items for sailing and auxiliary yachts

4.8.1 The mast(s), mast steps, spars, standing and running rigging, rigging screws, chainplates and sails are to be examined, *see* Table 4.4.1.

4.8.2 The structure in way of the attachment of bilge or centreline ballast keels is to be examined. Ballast keel bolts are to be tested to ascertain their soundness and may require to be drawn for examination, *see* Table 4.4.1.

4.8.3 On yachts fitted with a centreplate or lifting keel, the pivot bolt and lifting arrangements are to be examined as far as is practicable.

■ *Section 5*
Special Survey – Thickness measurement requirements for steel yachts

5.1 General

5.1.1 Thickness measurements, as required by Section 4 are to be carried out in accordance with the following requirements.

5.1.2 Thickness measurements are to be taken at the forward and aft areas of all plates. In all cases the measurements are to represent the average of the multiple measurements taken on each plate. The extent of local substantial corrosion of plates is to be established by intensive measurement in the affected areas. Where measured plates are renewed, the thicknesses of adjacent plates in the same strake are to be reported.

5.1.3 Thickness measurements are normally to be by means of ultrasonic test equipment and are to be carried out by a firm qualified as Grade 1 or Grade 2 according to LR's *Approval for Thickness Measurement of Hull Structures* or by the Surveyor.

5.1.4 The degree of supervision or check testing by the Surveyor is dependent upon the grade of approval extended to the firm carrying out the thickness measurements:

(a) The work of firms having Grade 1 approval is subject to check testing by the Surveyor.

(b) Thickness measurements by firms having Grade 2 approval is to be carried out with the Surveyor substantially in attendance.

5.1.5 Thickness measurements may be carried out in association with the fourth Annual Survey.

5.1.6 The minimum requirements for thickness measurement are indicated in Table 4.5.1.

5.1.7 The Surveyor may extend the scope of thickness measurement if deemed necessary.

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Table 4.5.1 Thickness measurement of steel yachts

Special Survey I (Yachts 5 years old)	Special Survey II (Yachts 10 years old)	Special Survey III (Yachts 15 years old)	Special Survey IV and subsequent (Yachts 20 years old and over)
Suspect areas, as required by the Surveyor and may include areas where the coatings are found to be other than in GOOD condition, *see* Note 1.	Suspect areas, as required by the Surveyor and may include areas where the coatings are found to be other than in GOOD condition, *see* Note 1.	(1) Any exposed plating throughout the Main Deck. (2) Shell plating in way of the waterline throughout the length of the craft. (3) Suspect areas, as required by the Surveyor may include areas where the coatings are found to be other than in GOOD condition, *see* Note 1.	(1) All Main Deck plating outside deckhouses or superstructures and including plating in way of wood deck planking or sheathing. (2) Shell plating in way of, and below, the waterline throughout the length of the craft. (3) 2 transverse sections of deck and shell plating within 0,5*L* amidships. (4) Suspect areas, as required by the Surveyor and to include as applicable: (a) Areas where the coatings are found to be other than in GOOD condition. (b) Shell and tanktop plating immediately adjacent to tank top margins. (c) Bottom shell in way of any cement, asphalt or other composition. (d) Shell plating below portlights and windows. (e) Tanktop plating below ceiling or cabin soles. (f) Deck plating and side shell plating in way of galleys, washrooms and refrigerated store spaces. (g) Structure in way of integral sanitary tanks.

NOTES
1. Suspect areas are locations within the hull structure vulnerable to increased likelihood of structural deterioration and may include, for steel hulls, areas of substantial corrosion and/or fatigue cracking, *see also* 1.5.3 and 4.4.6.
2. Coating condition for steel craft is defined in 1.5.6.

5.2 Thickness measurement reporting

5.2.1 A report is to be prepared by the approved firm carrying out the thickness measurement. The report is to give the location of measurement, the thickness measured as well as the corresponding original thickness. The report is to give the date when the measurement was carried out, the type of measuring equipment, names of personnel and their qualifications and is to be signed by the operator and supervisor.

5.2.2 The thickness measurement report is to be verified and signed by the Surveyor.

■ *Section 6* Machinery surveys – General requirements

6.1 Intermediate and Docking Surveys

6.1.1 For Intermediate and Docking Surveys, *see* Sections 2 and 3.

6.1.2 For yachts where an Approved Planned Maintenance Scheme is in operation an Annual Survey of the machinery is to be carried out together with an audit of the maintenance and monitoring records.

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6.2 Complete Surveys

6.2.1 While the yacht is in dry-dock, all openings to the sea in the machinery spaces and pump-rooms, together with the valves, cocks and the fastenings with which these are connected to the hull, are to be examined. For athwartships thrust propellers, *see* 10.1.8.

6.2.2 Athwartships thrust propellers are to be generally examined as far as is possible in dry dock and tested under working conditions afloat for satisfactory operation.

6.2.3 All shafts (except screwshafts and tube shafts, for which special arrangements are detailed in Section 10), thrust block and all bearings are to be examined. The lower halves of bearings need not be exposed if alignment and wear are found to be acceptable.

6.2.4 An examination is to be made as far as practicable of all propulsion gears complete with all wheels, pinions, shafts, bearings and gear teeth, thrust bearings and incorporated clutch arrangements.

6.2.5 The following auxiliaries and components are also to be examined:

(a) Auxiliary engines, auxiliary air compressors with their intercoolers, filters and/or oil separators and safety devices, and all pumps and components used for essential services.
(b) Steering machinery.
(c) Windlass and associated driving equipment, where fitted.
(d) The holding down bolts, chocks or resilient mounts of main and auxiliary engines, gearcases, thrust blocks and intermediate shaft bearings.

6.2.6 All air receivers for essential services, together with their mountings, valves and safety devices, are to be cleaned internally and examined internally and externally. If internal examination of the air receivers is not practicable, they are to be tested hydraulically to 1,3 times the working pressure.

6.2.7 The valves, cocks and strainers of the bilge system including bilge injection, are to be opened up as considered necessary by the Surveyor and together with pipes, are to be examined and tested under working conditions. The oil fuel, feed, lubricating oil and cooling water systems also any ballast connections together with all pressure filters, heaters and coolers used for essential services, are to be opened up and examined or tested, as considered necessary by the Surveyor. All safety devices for the foregoing items are to be examined.

6.2.8 Fuel tanks which do not form part of the yacht's structure are to be examined, and if considered necessary by the Surveyor, they are to be tested to the pressure specified for new tanks. The tanks need not be examined internally at the first survey if they are found satisfactory on external inspection. The mountings, fittings and remote controls of all oil fuel tanks are to be examined, so far as is practicable.

6.2.9 Where remote and/or automatic controls are fitted for essential machinery, they are to be tested to demonstrate that they are in good working order.

6.2.10 In addition to the above, detailed requirements for gas turbines and oil engines and electrical installations are given in Sections 7, 8 and 9 respectively. In certain instances, upon application by the Owner or where indicated by the maker's servicing recommendations, the Committee will give consideration to the circumstances where deviation from these detailed requirements is warranted, taking account of design, appropriate indicating equipment (e.g. vibration indicators) and operational records, *see* Ch 2,4.5.17 and 4.5.23.

■ *Section 7*
Gas turbines – Detailed requirements

7.1 Complete Surveys

7.1.1 The requirements of Section 6 are to be complied with. *See* 6.2.10 regarding any deviation from the following.

7.1.2 The following parts are to be opened out and examined:

- Compressor including impellers or blading, rotors and casing.
- Combustion chambers, burners, intercoolers and heat exchangers.
- Gas, air and fuel piping and fittings.
- Gas generator turbine and power turbine blading, rotors and casing.
- Rotors to include couplings, clutches, bearings and tie bolts.
- Auxiliary mounted fuel, L.O. and cooling water pumps, their drive transmissions and fittings.
- Starting system (for starting air pipes, *see* 8.1.3).
- All safety devices and local controls.
- Mountings and support frame.

7.1.3 The compressor/turbine units are to be operated and maintained in accordance with the manufacturer's instructions. Overhauls, including the prescribed replacement of limited life components, are to be undertaken at the specified intervals. Full service records are to be available for review by the Surveyor.

7.1.4 The manoeuvring of the propulsion system is to be tested under working conditions.

■ *Section 8*
Oil engines – Detailed requirements

8.1 Complete Surveys

8.1.1 The requirements of Section 6 are to be complied with. *See* 6.2.10 regarding any deviation from the following.

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8.1.2 The following parts are to be opened out and examined:

- Cylinders and covers.
- Valves and valve gear.
- Pistons and connecting rods.
- Crankshafts and all bearings
- Crankcases and entablatures.
- Crankcase door fastenings and explosion relief devices.
- Turbo-chargers and their associated coolers.
- Air compressors and their intercoolers.
- Filters and/or separators and safety devices.
- Fuel pumps and fittings.
- Camshaft drives and balancer units.
- Vibration dampers or detuners.
- Flexible couplings and clutches.
- Reverse gears.
- Attached pumps and cooling arrangements.

8.1.3 Selected pipes in the starting air system, if fitted, are to be removed for internal examination and are to be hammer tested. If any appreciable amount of lubricating oil is found in the pipes, the starting air system is to be thoroughly cleaned internally by steaming out, or other suitable means. Some of the pipes selected are to be those adjacent to the starting air valves at the cylinders and to the discharges from the air compressors.

8.1.4 The electric ignition system, if fitted, is to be examined and tested.

8.1.5 The manoeuvring of engines is to be tested under working conditions. Initial starting arrangements are to be tested.

■ *Section 9*
Electrical equipment

9.1 Intermediate Surveys

9.1.1 The requirements of 2.2.9 and 2.2.13 are to be complied with as far as applicable.

9.2 Complete Surveys

9.2.1 An electrical insulation resistance test is to be made on the electrical equipment and cables. The installation may be sub-divided or equipment, which may be damaged, disconnected for the purpose of this test.

9.2.2 The fittings on the main and emergency switch-boards, section boards and distribution boards are to be examined and over-current protective devices and fuses inspected to verify that they provide suitable protection for their respective circuits.

9.2.3 Generator circuit-breakers are to be tested, so far as is practicable, to verify that protective devices including preference tripping relays, if fitted, operate satisfactorily.

9.2.4 The electric cables and their securing arrangements are to be examined, so far as is practicable, without undue disturbance of fixtures or casings unless opening up is considered necessary as a result of observation or of the tests required by 9.2.1.

9.2.5 The generator prime movers are to be surveyed as required by Sections 7 and 8 and the governing of the engines tested. The motors concerned with essential services together with associated control and switch gear are to be examined and if considered necessary, are to be operated, so far as is practicable, under working conditions. All generators and steering gear motors are to be examined and are to be operated under working conditions, though not necessarily under full load or simultaneously.

9.2.6 Where transformers or electrical apparatus associated with supplies to essential services are liquid filled or cooled by a liquid in direct contact with current carrying parts, the owner is to arrange for samples of the liquid to be taken and tested, by a competent authority, in accordance with the equipment manufacturer's requirements, and a certificate giving the test results is to be furnished to the Surveyor.

9.2.7 Navigation light indicators are to be tried under working conditions, and correct operation on the failure of supply or failure of navigation lights verified.

9.2.8 The emergency sources of electrical power, where fitted, together with their automatic arrangements and associated circuits are to be tested.

9.2.9 Emergency lighting, transitional emergency lighting, supplementary emergency lighting, general emergency alarm and public address systems are to be tested as far as practicable.

9.2.10 Where the yacht is electrically propelled, the propulsion motors, generators, cables and all ancillary electrical gear, exciters and ventilating plant (including coolers) associated therewith are to be examined, and the insulation resistance to earth is to be tested. Special attention is to be given to windings, commutators and slip-rings. The operation of protective gear and alarm devices is to be checked, so far as is practicable. Liquids for filling and cooling, if used, are to be tested in accordance with 9.2.6. Interlocks intended to prevent unsafe operations or unauthorised access are to be checked to verify that they are functioning correctly. Emergency overspeed governors are to be tested.

9.2.11 Where batteries provide the source of power for any essential services, their installation, including charging and ventilation, is to be examined.

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Section 10
Screwshafts, tube shafts, propellers and water jet units

10.1 Frequency of surveys

10.1.1 Shafts with keyed propeller attachments and fitted with continuous liners or approved oil glands, or made of approved corrosion resistant materials, are to be surveyed at intervals of five years when the keyway complies fully with the present Rules.

10.1.2 Shafts having keyless type propeller attachments are to be surveyed at intervals of five years provided they are fitted with approved oil glands or are made of approved corrosion resistant materials.

10.1.3 Shafts having solid coupling flanges at the after end are to be surveyed at intervals of five years provided they are fitted with approved oil glands or are made of approved corrosion resistant materials.

10.1.4 All other shafts not covered by 10.1.1 to 10.1.3 are to be surveyed at intervals of $2^1/_2$ years.

10.1.5 Controllable pitch propellers for main propulsion purposes are to be surveyed at the same intervals as the screwshaft.

10.1.6 Directional propeller units for main propulsion purposes are to be surveyed at intervals not exceeding five years.

10.1.7 Water jet units for main propulsion purposes are to be surveyed at intervals not exceeding five years provided the impeller shafts are made of approved corrosion resistant material or have approved equivalent arrangements.

10.1.8 Athwartship thrust propellers and shaftings are to be surveyed at intervals not exceeding five years, *see* 6.2.2.

10.2 Normal surveys

10.2.1 All screwshafts are to be withdrawn for examination by LR's Surveyors at the intervals prescribed in 10.1.1 to 10.1.4. The after end of the cylindrical part of the shaft and forward one third of the shaft cone, or fillet of the flange, is to be examined by a magnetic particle crack detection method. In the case of a keyed propeller attachment at least the forward one third of the shaft cone is to be examined with the key removed. Weardown is to be measured and the sterntube bearings, oil glands, propellers and fastenings are to be examined. Controllable pitch propellers where fitted are to be opened up and the working parts examined, together with the control gear.

10.2.2 Directional propeller units are to be dismantled for examination of the propellers, shafts, gearing and control gear.

10.2.3 Water jet units are to be dismantled for examination of the impeller, casing, shaft, shaft seal, shaft bearing, inlet and outlets channels, steering nozzle, reversing arrangements, and control gear.

10.3 Screwshaft Condition Monitoring (SCM)

10.3.1 Where oil lubricated shafts with approved oil glands are fitted, and the Owner has complied with the following requirements, the descriptive note **SCM** (Screwshaft Condition Monitoring) may be assigned:

(a) Lubricating oil analysis to be carried out regularly at intervals not exceeding six months. The lubricating oil analysis documentation is to be available on board. Each analysis is to include the following minimum parameters:
- water content
- chloride content
- bearing material and metal particles content
- oil ageing (resistance to oxidation).

(b) Oil samples are to be taken under service conditions and are to be representative of the oil within the sterntube.

(c) Oil consumption is to be recorded.

(d) Bearing temperatures are to be recorded, (two temperature sensors or other approved arrangements are to be provided).

(e) Facilities are to be provided for measurement of bearing weardown.

(f) Oil glands are to be capable of being replaced without withdrawal of the screwshaft.

10.3.2 For maintenance of the descriptive note **SCM**, the records of analyses, consumption and temperatures, together with weardown readings are to be retained on board and audited annually.

10.3.3 Where the requirements for the descriptive note **SCM** have been complied with, the screwshaft need not be withdrawn at surveys as required by 10.2.1 provided all condition monitoring data is found to be within permissible limits and all exposed areas of the shaft are examined by a magnetic particle crack detection method. The remaining requirements of 10.2.1 are to be complied with. Where the Surveyor considers that the data presented is not entirely to his satisfaction the shaft will be required to be withdrawn in accordance with 10.2.1.

10.4 Modified Survey

10.4.1 A Modified Survey may be accepted at alternate five-yearly surveys for shafts described in 10.1.1 provided they are fitted with oil lubricated bearings and approved oil glands, and also for those in 10.1.2 and 10.1.3.

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10.4.2 The Modified Survey is to consist of the partial withdrawal of the shaft, sufficient to ascertain the condition of the stern bearing and shaft in way. For keyless propellers or shafts with a solid flange connection to the propeller a visual examination to confirm the good condition of the sealing arrangements is to be made. The oil glands are to be capable of being replaced without removal of the propeller. The forward bearing and all accessible parts including the propeller connection to the shaft are to be examined as far as possible.

Wear-down is to be measured and found satisfactory. Where a controllable pitch propeller is fitted, at least one of the blades is to be dismantled complete for examination of the working parts and the control gear.

10.4.3 For keyed propellers, the after end of the cylindrical part of the shaft and forward one third of the shaft cone is to be examined by a magnetic particle crack detection method, for which dismantling of the propeller and removal of the key will be required.

10.4.4 Where the descriptive note **SCM** has been assigned as described in 10.3.1 and all data is found to be within permissible limits, partial withdrawal of the shaft may not be required. Where doubt exists regarding any of the above findings the shaft is to be withdrawn to permit an entire examination.

10.5 Partial Survey

10.5.1 For shafts where the Modified Survey is applicable, upon application by the Owner, the Committee will be prepared to give consideration to postponement of the survey for a maximum period of half the specified cycle provided a Partial Survey is held.

10.5.2 The Partial Survey is to consist of the propeller being backed off in any keyed shaft and the top half of the cone examined by an efficient crack detection method for which removal of the key will be required. Oil gland and seals are to be examined and dealt with as necessary. Weardown is to be measured and found satisfactory. Propeller and fastenings are to be examined.

10.5.3 The Committee will be prepared to give consideration to the circumstances of any special case upon application by the Owner.

■ *Section 11*
Surveys of unclassed machinery in existing classed yachts

11.1 General

11.1.1 The requirements of this survey are considered necessary in order to establish, so far as practicable, that the unclassed machinery installation does not constitute a hazard to the classed hull. The survey is applicable only to existing sailing yachts fitted with unclassed auxiliary propulsion engines not exceeding 37 kW.

11.1.2 At any time when unclassed machinery in an existing classed yacht is undergoing alteration and/or replacement, the requirements of Ch 2,4.4.6 are to be complied with.

11.2 Intermediate and Docking Surveys

11.2.1 For Intermediate and Docking Surveys, *see* Sections 2 and 3.

11.3 Complete Surveys

11.3.1 At each Special Survey of the hull the requirements of 11.2.1 and the following are to be complied with:

(a) The bilge pumping system is to be examined and tested under working conditions.
(b) A general examination is to be made of the fuel tanks and fuel system with their valves, pipes and fittings, and of the engine exhaust system, piping and fittings.
(c) A general examination of the electrical equipment is to be made and, if considered necessary, a test of the insulation resistance is to be carried out in accordance with 9.2.1.
(d) The starting arrangements are to be examined.
(e) The screwshafts and tube shafts are to be withdrawn for examination.
(f) The main and essential auxiliary machinery is to be examined under full working conditions in accordance with 8.1.4.

■ *Section 12*
Classification of yachts not built under survey

12.1 General

12.1.1 When classification is desired for a yacht not built under the supervision of LR's Surveyors, application should be made to the Committee in writing.

12.1.2 Periodical Surveys of such yachts, when classed, are subsequently to be held as in the case of yachts built under survey.

12.1.3 Where classification is desired for a yacht which is classed by another recognised Society, special consideration will be given to the scope of the survey.

12.2 Hull and equipment

12.2.1 Plans showing the main scantlings and arrangements of the actual yacht together with any proposed alterations are to be submitted for approval.These should comprise plans of the midship section, longitudinal section and decks, and such other plans as may be requested. If plans cannot be obtained or prepared by the Owner, facilities are to be given for LR's Surveyor to obtain the necessary information from the yacht.

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12.2.2 Particulars of the process of manufacture and the testing of the material of construction are to be supplied. The requirements for composite yachts will be specially considered.

12.2.3 The full requirements of Sections 4 and 5 are to be carried out as applicable. Yachts of recent construction will receive special consideration.

12.2.4 During the survey, the Surveyors are to satisfy themselves regarding the workmanship and verify the approved scantlings and arrangements. For this purpose, and also in order to ascertain the amount of any deterioration of steel yachts, parts of the structure will require to be gauged as necessary. Full particulars of the anchors, chain cables and equipment are to be submitted. For yachts to which Pt 17, Ch 1 applies, fire protection, detection and extinction are to be in accordance with the Rules.

12.2.5 When the full survey requirements indicated in 12.2.3 and 12.2.4 cannot be completed at one time, the Committee may consider granting an interim record for a limited period. The conditions regarding the completion of the survey will depend on the merits of each particular case, which should be submitted for consideration.

12.3 Machinery

12.3.1 To facilitate the survey, the following plans and particulars (plans of piping are to be diagrammatic), together with the particulars of the materials used in the construction of any boilers, air receivers and important forgings are to be submitted:

- Name of manufacturer of engine and gearbox including the manufacturer's type designation of engine and gearbox, together with the continuous shaft power of the engine at the crankshaft coupling with the revolutions per minute of crankshaft and propeller.
- General pumping arrangements, including air and sounding pipes (Builder's plan).
- Bilge, ballast and oil fuel pumping arrangements including the capacities of the pumps on bilge service.
- Arrangement and dimensions of any steam pipes.
- Arrangement of oil fuel pipes and fittings at settling and service tanks.
- Arrangement of oil fuel piping in connection with oil burning installations.
- Oil fuel overflow systems, where these are fitted.
- Arrangement of boiler feed systems.
- Oil fuel settling, service and other oil fuel tanks not forming part of the craft's structure.
- Boilers and economisers.
- Air receivers.
- Crank, thrust, intermediate and screw shafting.
- Details of water jet or directional propeller units, if fitted.
- Clutch and reversing gear with methods of control.
- Reduction gearing.
- Propeller (including spare propeller if supplied) where the diameter exceeds 1m.
- Electrical circuits.
- Arrangement of compressed air systems for main and auxiliary services.
- Arrangement of lubricating oil, other flammable liquids and cooling water systems for main and auxiliary services.
- Steering gear including control arrangement.
- Arrangement of exhaust system indicating materials, method of cooling, and if water spray injected, the method of draining.

12.3.2 Plans additional to those detailed in 12.3.1 are not to be submitted unless the machinery is of a novel or special character affecting classification.

12.3.3 Where remote and/or automatic controls are fitted to propulsion machinery and essential auxiliaries, a description of the scheme is to be submitted.

12.3.4 For new yachts and yachts which have been in service less than two years, calculations of the torsional vibration characteristics of the propelling machinery are to be submitted for consideration, as required for yachts constructed under Special Survey. For older yachts the circumstances will be specially considered in relation to their service record and type of machinery installed. Where calculations are not submitted, the Committee may require that the machinery certificate be endorsed to this effect. When desired by the Owner, the calculations and investigation of the torsional vibration characteristics of the machinery may be carried out by LR upon special request.

12.3.5 The main and auxiliary machinery, feed pipes, compressed air pipes and boilers are to be examined as required at Complete Surveys. Working pressures are to be determined from the actual scantlings in accordance with the Rules.

12.3.6 The screwshaft is to be drawn and examined.

12.3.7 Any steam pipes or oil burning installations are to be examined and tested as required by Pt 1, Ch 3,15 or Ch 3,16 of the *Rules and Regulations for the Classification of Ships*.

12.3.8 The bilge, ballast and oil fuel pumping arrangements are to be examined and amended, as necessary, to comply with the Rules.

12.3.9 The electrical equipment is to be examined as required at Complete Surveys.

12.3.10 The whole of the machinery, including essential controls, is to be tried under working conditions to the Surveyor's satisfaction.

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Periodical Survey Regulations for Amphibious Air Cushion Vehicles (ACV)

Section

1 **General**

2 **Annual Surveys – Hull and machinery requirements**

3 **Intermediate Surveys – Hull and machinery requirements**

4 **Special Surveys (Hull and machinery)**

5 **Classification of ACVs not built under survey**

■ *Section 1* General

1.1 Frequency of surveys

1.1.1 Except as amended at the discretion of the Committee, the periods between surveys are as follows:

(a) Annual Surveys are to be held within three months before or after each anniversary of the completion, commissioning or Special Survey.

(b) Intermediate Surveys are to be held instead of the second or third Annual Survey after completion, commissioning or Special Survey.

(c) Special Surveys (hull and machinery) are to be held at the fifth anniversary after completion, commissioning or previous Special Survey.

1.2 Machinery surveys

1.2.1 The manufacturer's approved operating and service instructions for the main and auxiliary power units, transmission systems, propellers and lift fans are to be incorporated into an approved planned maintenance scheme for the ACV.

1.2.2 Maintenance, overhaul or replacement will then normally be determined by the specified condition/performance monitoring limits and running hours.

1.2.3 It is a requirement of this arrangement that any significant defect, damage repair or alteration be reported to Lloyd's Register (hereinafter referred to 'LR') without delay, *see also* Ch 2,1.1.7.

1.3 Surveys for damage, repairs or alterations

1.3.1 At any time when an ACV is undergoing alterations or damage repairs, any exposed parts of the structure normally difficult to access are to be specially examined, e.g. if any part of the main or auxiliary machinery is removed for any reasons, the hull structure in way is to be carefully examined by the Surveyor.

1.3.2 All significant repairs, alterations, approved modifications and replacements are to be recorded in the ACV's Log Books in a manner that will enable their later identification by the Surveyors, *see also* Ch 2,4.4.1 and 4.4.6.

1.3.3 Trials are to be made on any craft which have been significantly modified, overhauled or repaired, prior to returning to service, to ensure to the Surveyor's satisfaction that the ACV has been returned in a satisfactory condition for its intended service.

1.4 Unscheduled surveys

1.4.1 In the event that LR has cause to believe that its Rules and Regulations are not being complied with, LR reserves the right to perform unscheduled surveys of the hull or machinery.

1.5 Surveys for the issue of Convention Certificates

1.5.1 Surveys are to be held either by LR when so appointed or by the Exclusive Surveyors of a National Administration when so delegated by a Flag State.

■ *Section 2* Annual Surveys – Hull and machinery requirements

2.1 General

2.1.1 Annual Surveys are to be held concurrently with any relevant statutory annual or other statutory surveys, wherever practicable.

2.1.2 The Surveyor is to audit the approved planned maintenance scheme. The records will be checked and the satisfactory operation of the scheme verified. Condition monitoring data will be reviewed and trends analysed.

2.1.3 The Surveyor is to examine the Log Book to verify that a proper record has been kept in respect of servicing, maintenance and overhaul requirements for those aspects not covered by the approved planned maintenance scheme.

2.1.4 Certification for replacement units/parts will be required.

2.2 Preparation

2.2.1 The ACV is to be slung or jacked up to permit a thorough inspection of all underside parts, fittings and attachments.

2.2.2 Panelling, floor coverings, etc. need not be removed at these surveys, unless they are of portable type or unless the Surveyor has reason to suspect they may conceal significant damage.

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2.3 Hull items

2.3.1 The Surveyor is to be satisfied as to the efficient condition of the following items:

(a) Bottom and side plating, any external stiffeners, and side walls or skirts, including flexible keels, if any.
(b) Weather doors, ventilators, windows and emergency or other hatches.
(c) Weather decks, houses, etc.
(d) Machinery casings and seats.
(e) Anchoring and mooring equipment when required by the Rules.
(f) Fire equipment including fire detection, alarm systems and means of escape , where the survey of such items is not covered by statutory certification.
(g) Where applicable, passenger seat foundations and cargo tie down points.
(h) Skirt attachment and operating mechanisms.
(j) Air propeller shroud structures.
(k) Side body attachments and supports (when fitted).
(l) Operation of ramps, and their closing and locking arrangements.
(m) The structural attachment and retention arrangements for external fuel tanks (when fitted).

2.4 Machinery items

2.4.1 The Surveyor is to be satisfied as to the efficient condition of the following items:

(a) Fuel tanks and associated fuel system with pumps, filters, etc.
(b) Lubricating oil tanks and associated lubricating system with coolers, pumps, filters, etc.
(c) The bilge pumping system.
(d) Machinery alarm arrangements.
(e) The electrical machinery, the switchgear and other electrical equipment are to be generally examined under operating conditions so far as practicable. The satisfactory operation of the emergency source of power, including the automatic controls as fitted, is to be verified.
(f) Hydraulic, electrical and pneumatic control systems, including steering, are to be examined under operating conditions.
(g) Engine starting arrangements.
(h) All drive belts, associated running surfaces and tension adjustment (where fitted).
(j) Air propellers, including (where fitted) hub assemblies, servos and actuating equipment of controllable pitch propellers.
(k) The overall operation of the machinery including propulsion and lift machinery. A machinery proving trial of short duration is to demonstrate to the Surveyor the satisfactory operation of the machinery.

■ *Section 3*
Intermediate Surveys – Hull and machinery requirements

3.1 General

3.1.1 The requirements of Section 2 are to be complied with.

3.2 Preparation

3.2.1 A sufficient amount of panelling, floor covering, insulation and paint etc., is to be removed to enable the Surveyors to satisfy themselves that all major structural items are in a satisfactory condition.

3.3 Examination and testing

3.3.1 Representative integral tanks and buoyancy spaces are to be examined as necessary to ensure that they continue to be in a satisfactory condition.

3.3.2 At the discretion of the Surveyor, tanks or buoyancy spaces may require to be tested to ensure that they continue to be tight.

■ *Section 4*
Special Surveys (Hull and machinery)

4.1 General

4.1.1 The requirements of Sections 2 and 3 are to be complied with.

4.2 Hull Surveys

4.2.1 All integral tanks and buoyancy spaces are to be examined and tested to ensure that they continue to be tight and in a satisfactory condition.

4.2.2 All other hull compartments are to be examined.

4.2.3 The anchoring and mooring equipment, when required by the Rules, is to be examined to ensure its efficiency, accessibility and readiness for use. Anchor cables or warps are to be ranged for examination.

4.3 Machinery Surveys

4.3.1 The main and essential auxiliary machinery is to be generally examined with particular attention given to safety devices, fastening arrangements and resilient mountings. A limited opening up, e.g. removal of inspection covers, should be undertaken in order that the Surveyor can confirm the satisfactory condition of these items.

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4.3.2 Where not carried out as a regular monitoring procedure, lubricating oil analysis may be required.

4.3.3 Items that have not been overhauled as part of the approved planned maintenance scheme since installation, commissioning or the previous Special Survey may require to be opened up for examination.

4.3.4 The insulation resistance of the electrical equipment and connections is to be tested.

■ *Section 5* Classification of ACVs not built under survey

5.1 General

5.1.1 The requirements for classification of an ACV not built under the supervision of LR's Surveyors are to be in accordance with the applicable sub-Sections of Pt 1, Ch 3,12.

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Rules for the Manufacture, Testing and Certification of Materials

July 2011

Lloyd's Register

LIFE MATTERS

000621

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A guide to the Rules

and published requirements

Rules for the Manufacture, Testing and Certification of Materials

Introduction

The Rules are published as a complete set; individual Parts are, however, available on request. A comprehensive List of Contents is placed at the beginning of each Part.

Numbering and Cross-References

A decimal notation system has been adopted throughout. Five sets of digits cover the divisions, i.e. Part, Chapter, Section, sub-Section and paragraph. The textual cross-referencing within the text is as follows, although the right hand digits may be added or omitted depending on the degree of precision required:

(a) In same Chapter, e.g. *see* 2.1.3 (i.e. down to paragraph).

(b) In another set of Lloyd's Register Rules, e.g. *see* Pt 5, Ch 3,2.1 of the Rules and Regulations for the Classification of Ships.

The cross-referencing for Figures and Tables is as follows:

(a) In same Chapter, e.g. as shown in Fig. 2.3.5 (i.e. Chapter, Section and Figure Number).

(b) In another set of Lloyd's Register Rules, e.g. *see* Table 2.7.1 in Pt 3, Ch 2 of the Rules and Regulations for the Classification of Special Service Craft.

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RULES FOR THE MANUFACTURE, TESTING AND CERTIFICATION OF MATERIALS

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General Requirements

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■ *Section 1* Scope

1.1 General

1.1.1 Materials used for the construction, conversion, modification or repair of ships, other marine structures and associated machinery which are classed or are intended for classification by Lloyd's Register (hereinafter refered to as LR), are to be manufactured, tested and inspected in accordance with these Rules.

1.1.2 Wrought, cast and extruded materials are to comply with the requirements of Chapters 1 and 2, and the appropriate specific requirements of Chapters 3 to 9 of these Rules. Mooring and anchoring equipment is to comply with the requirements of Chapters 1 and 2, and the appropriate specific requirements of Chapter 10. Manufacturers of these materials must be approved by LR according to the requirements in Sections 2 or 3. Only those materials within a manufacturer's scope of approval may be used.

1.1.3 Welding consumables are to comply with the requirements of Chapter 11 of these Rules.

1.1.4 Where welding is used for the construction, conversion, modification or repair of ships, other marine structures and associated machinery which are classed or are intended for classification by LR, welding qualifications and tests shall be performed according to Chapter 12 of these Rules. All welding shall be performed according to Chapter 13 of these Rules.

1.1.5 Plastics materials are to comply with the requirements of Chapter 14 of these Rules.

1.1.6 The materials and components which are to comply with these requirements for the purposes of classification are defined in the relevant Rules dealing with design and construction.

■ *Section 2* Approval and survey requirements

2.1 Approval and survey requirements – General

2.1.1 Marine materials manufactured in accordance with Chapters 3 to 10 of these Rules are to be made at works which have been approved by LR for the type and grade of product being supplied.

2.1.2 Materials manufactured in accordance with Chapters 3 to 10 of these Rules are to be manufactured, tested and inspected under Survey according to the requirements of one of the following two schemes:
(a) The Materials Survey Scheme, *see* 2.3.
(b) The Materials Quality Scheme, *see* 2.4.

2.1.3 For the purposes of survey, LR Surveyors are to be allowed access to all relevant parts of the works, and are to be provided with the necessary facilities and information to enable them to verify that the manufacture is being carried out in accordance with the approved procedures. Facilities are also to be provided for the selection of test material, the witnessing of mechanical tests and the examination of materials, as required by these Rules.

2.1.4 Where a production process, testing or examination of materials is sub-contracted, this must be with the approval of LR. Surveyors are to be allowed access to the sub-contractor's premises in order to conduct Surveys according to the requirements of these Rules.

2.1.5 Products manufactured in accordance with Chapters 11 and 14 are to be approved in accordance with the requirements therein. For these materials, approval is given for a specific product on a type approval basis, rather than the approved manufacturer/survey arrangements applied to materials covered by Chapters 3 to 10.

2.2 LR Approval – General

2.2.1 Unless specifically stated in other Chapters of these Rules, all LR approvals apply to materials used in applications intended for marine service, as described in 1.1.

2.2.2 The procedures for application for approval of manufacturers and products, the details of the information to be supplied by the manufacturer, and the test programme to be conducted on the products are given in the appropriate book of LR's *Materials and Qualification Procedures for Ships* (MQPS). This is published in the CD Live section of LR's web site at http://www.lr.org.

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2.2.3 LR publishes lists of approved manufacturers and approved products. The lists are published in the CD Live section of LR's website, http://www.lr.org.
The lists are as follows:

- *List of Approved Manufacturers of Materials*.
- *Approved Welding Consumables for Use in Ship Construction*.
- *Lists of Paints, Resins, Reinforcements and Associated Materials*.
- *Lists of Approved Anchors*.

2.2.4 For initial LR approval as an Approved Manufacturer for a particular material, the manufacturer is required to demonstrate to the satisfaction of LR that the necessary manufacturing and testing facilities are available, and are supervised by suitably qualified personnel. A specified programme of tests is to be carried out under the supervision of LR Surveyors, and the results are to be to the satisfaction of LR.

2.2.5 If the results of the initial assessment of the manufacturer, and the test programme are considered satisfactory, the manufacturer will be added to the list of approved manufacturers of materials, and a certificate of approval will be issued to the manufacturer by LR, showing the scope of materials and grades covered by the approval. Initial approval will generally be under the Materials Survey Scheme, *see* 2.3.

2.2.6 Approved manufacturers who meet the entry requirements may apply for approval under the Materials Quality Scheme, *see* 2.4.

2.2.7 When a manufacturer has more than one works, the manufacturer's approval shall only be valid for the works where the test programme was conducted.

2.2.8 It is the manufacturer's responsibility to advise LR of all changes to the manufacturing process parameters that may affect the application of the material, prior to the adoption of the changes in production. Additional approval tests may be required to maintain the approval.

2.2.9 Maintenance of approval is dependent on the manufacturer continuing to meet the requirements of the applicable sections of these Rules.

2.2.10 Where it is considered that an approved manufacturer is not maintaining its responsibilities to comply with these Rules, the approval may be suspended by LR until such time that agreed corrective and preventive actions are considered to have been satisfactorily carried out. If considered necessary, LR may require that the normal level of testing and inspection is increased.

2.2.11 In all instances, LR will reduce the scope of, or withdraw approval from, a manufacturer where it becomes apparent that the manufacturer is unable to maintain compliance with these Rules or the scope of approval.

2.2.12 Where a manufacturer disagrees with any decisions made with regard to LR approval, they may appeal in writing to LR.

2.2.13 Any documents, data or other information received as part of the approval process will be treated as strictly confidential, and will not be disclosed to any third party, without the manufacturer's prior written consent.

2.3 Materials Survey Scheme

2.3.1 Materials according to Chapters 3 to 10 of these Rules and produced under the Materials Survey Scheme will be subject to Direct Survey by an LR Surveyor. The scheme requires the Surveyor to survey and certify all materials according to the requirements of these Rules.

2.3.2 Approved manufacturers are to request a survey of the material by an LR Surveyor, when required. Manufacturers must provide the Surveyor with details of the order, specification and any special conditions additional to the requirements of these Rules.

2.3.3 All mechanical tests required by these Rules are to be witnessed. The Surveyor may allow part of this task to be carried out by a member of the works staff by prior written agreement.

2.3.4 Before final acceptance, all materials are to be submitted to the specified tests and examinations under conditions acceptable to the Surveyor. The results are to comply with the Rules, and all materials are to be to the satisfaction of the Surveyor.

2.3.5 The specified tests and examinations are to be carried out prior to the despatch of finished materials from the manufacturer's works. Where materials are supplied in the rough or unfinished condition, as many as possible of the specified tests are to be carried out by the manufacturer, and any tests or examinations that are not completed are to be carried out under survey at a subsequent stage of manufacture.

2.3.6 In the event of any material proving unsatisfactory during subsequent working, machining or fabrication, such material is to be rejected, notwithstanding any previous certification.

2.3.7 In addition to witnessing test results, the Surveyor is responsible for ensuring that the manufacturing process, inspection, testing, identification and certification are properly conducted. As part of the Materials Survey Scheme, regular visits will be made to all relevant parts of the works to check for compliance against the requirements of these Rules, and to ensure that the manufacturer is maintaining the capability to consistently produce approved materials.

2.3.8 The Surveyor, when satisfied that the material fully meets the requirements of these Rules, will certify the material in accordance with Section 3 and the appropriate Chapter of these Rules.

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2.3.9 For a manufacturer to maintain approval under this scheme, the works will be subject to a periodic inspection of all relevant parts of the works, at intervals not exceeding three years. The procedure for this periodic inspection is given in Book B of LR's *Materials and Qualification Procedures for Ships* (MQPS). This periodic inspection is in addition to the regular visits made according to 2.3.7.

2.4 Materials Quality Scheme

2.4.1 The manufacturer may apply to be approved under the Materials Quality Scheme where the following requirements are met:

(a) The manufacturer has been approved by LR for a minimum of three years; and

(b) The manufacturer has a quality management system, which has been certified as meeting the requirements of ISO 9001 by a certification body recognised by LR, which is one accredited by a member of the International Accreditation Forum; and

(c) The manufacturer has a satisfactory history of quality performance in the manufacture and supply of LR approved materials.

2.4.2 Special consideration may be given to manufacturers who have not been approved under the Materials Survey Scheme, and may be considered onto the Materials Quality Scheme providing:

(a) They have a quality management system which has been certified as meeting the requirements of ISO 9001 by a certification body recognised by LR, which is one accredited by a member of the International Accreditation Forum.

(b) They can demonstrate a history of satisfactory supply of materials which LR deems to be equivalent to those for which approval under the Materials Quality Scheme is requested.

In this case, the initial assessment of the manufacturer will include the product testing regime, as required for initial approval under the Materials Survey Scheme, *see* 2.2.4.

2.4.3 The Scheme is based on a Scheme Certification Schedule, made between LR and each individual manufacturer. The schedule will stipulate:

(a) The scope of approved products covered by the approval.

(b) The process route applied by the manufacturer for each approved product.

(c) The arrangements for LR scheme, audits, including scope, frequency, schedule, etc.

(d) Agreed procedures for certification of approved materials.

(e) Information to be supplied periodically to LR by the manufacturer.

(f) Procedures for the use of the scheme mark.

2.4.4 The contents of the Scheme Certification Schedule are to remain confidential between LR and the manufacturer.

2.4.5 The Materials Quality Scheme is based on a technical audit approach, and is designed to complement the quality management systems audits performed to ISO 9001. The role of the Surveyor in scheme audits is to:

(a) Verify that the quality management system is being maintained and audited to the requirements of ISO 9001.

(b) Verify that the requirements of these Rules are being implemented.

(c) Verify that the requirements of this Scheme are being implemented.

(d) Perform Scheme audits, which focus on the technical aspects of the product realisation process, particularly with regard to Rule requirements.

(e) Perform witness testing as required.

(f) Verify the data supplied to LR periodically by the manufacturer as part of the Scheme requirements.

2.4.6 The Materials Quality Scheme may be applied to any approved manufacturer who meets the eligibility requirements, and who applies to be approved under the scheme. If approved under the scheme, the manufacturer's name will appear on the List of Approved Manufacturers published by LR, with an indication that they are approved under this scheme.

2.4.7 The scheme is available to manufacturers producing approved materials according to Chapters 3 to 10 of these Rules.

2.4.8 The procedures for application for approval for the Materials Quality Scheme are given in Book M of LR's *Materials and Qualification Procedures for Ships* (MQPS).

2.4.9 Where LR is satisfied that the manufacturer meets all of the requirements of the Scheme, and that it is appropriate for the products being manufactured, a Scheme Certification Schedule will be issued, which must be signed by an authorised representative of the manufacturer.

2.4.10 Once the Scheme Certification Schedule has been signed by both parties, LR will issue the manufacturer with a certificate of approval according to the Materials Quality Scheme.

2.4.11 Maintenance of approval will be according to the Scheme Certification Schedule agreed between LR and the manufacturer, and these Rules.

2.4.12 It is the responsibility of the attending Surveyor to perform regular Scheme audits at the manufacturer's works in accordance with the Scheme Certification Schedule, and the requirements of these Rules.

2.4.13 It is not the intention to repeat the audit according to ISO 9001 conducted by the recognised certification body. The Surveyor is, however, to be satisfied that these audits are being conducted effectively. Where appropriate, the Surveyor may conduct a partial audit to ISO 9001 to verify this.

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2.4.14 Witness tests may be conducted as part of the Scheme audit. This will involve the selection of material, and the witness of sampling and testing according to the requirements of the appropriate chapter of these Rules. Such witness testing may be on LR grades, or materials which the Surveyor deems to be equivalent (for the purposes of audit testing only).

2.4.15 Once every three years, a full assessment of scheme compliance will be conducted by a Surveyor who is not the regular attending Surveyor.

2.4.16 In the event of any change which means that the manufacturer no longer meets the requirements for the Materials Quality Scheme (for example the loss of ISO 9001 approval), the Scheme certificate of approval will be revoked. The manufacturer will revert to the Materials Survey Scheme, and will be subject to survey according to that scheme.

■ *Section 3* Certification of materials

3.1 General

3.1.1 All materials subject to these Rules are to be supplied with appropriate certification, as required by the relevant requirements of these Rules. This will normally be an LR certificate or a manufacturer's certificate validated by LR, although a manufacturer's certificate may be accepted where allowed by the relevant requirements of these Rules.

3.1.2 Manufacturers approved under the Materials Quality Scheme are licensed to apply the scheme mark to manufacturer's certificates according to the requirements of the scheme, *see* 2.4.

3.1.3 The following certificate types are to be used, (a) and (b) for the Materials Survey Scheme, and (d) for the Materials Quality Scheme:

(a) **LR Certificate**
This type of certificate is issued by LR based on the results of testing and inspection being satisfactorily carried out in accordance with the requirements of these Rules.

(b) **Manufacturer's certificate validated by LR**
A manufacturer's certificate, validated by LR on the basis of inspection and testing carried out on the delivered product in accordance with the requirements of these Rules may be accepted. In this case, the certificate will include the following statement:
"We hereby certify that the material has been made by an approved process and satisfactorily tested in accordance with the Rules of Lloyd's Register."

(c) **Manufacturer's certificate**
This type of certificate is issued by the manufacturer based on the results of testing and inspection being satisfactorily carried out in accordance with the requirements of these Rules or the applicable National or International standard. The certificate is to be validated by the manufacturer's authorised representative, independent of the manufacturing department. The certificate will contain a declaration that the products are in compliance with the requirements of these Rules or the applicable National or International standard.

(d) **Manufacturer's certificate issued under the Materials Quality Scheme**
Where a manufacturer is approved according to the Materials Quality Scheme, they will issue manufacturer's certificates bearing the scheme mark. The certificates must also bear the following statement:
"This certificate is issued under the arrangements authorised by Lloyd's Register (operating group) in accordance with the requirements of the Materials Quality Scheme and certificate number MQS ....."

3.1.4 Where these Rules allow for the issue of a manufacturer's certificate for materials, either validated by an LR Surveyor, or bearing the Materials Quality Scheme mark, the manufacturer is to ensure that a copy of the certificate is supplied to LR.

3.2 Materials Survey Scheme

3.2.1 The requirements for certification of materials according to the Materials Survey Scheme are established by the relevant requirements of these Rules.

3.2.2 The manufacturer is to supply the surveyor with any additional customer order requirements that are in addition to the requirements of these Rules, when the request for the issue or validation of the certificate is made.

3.3 Materials Quality Scheme

3.3.1 Part of the certification schedule will include an agreement for the manufacturer to apply the scheme mark to manufacturer's certificates relating to approved products within the scope of approval of the manufacturer.

3.3.2 The use of the scheme mark is governed by the following:

(a) The use of the scheme mark is not transferable. It is only to be used in conjunction with the manufacturer and works name and location shown on the certificate of approval.

(b) The scheme mark must be applied to all manufacturers' certificates relating to approved materials produced under the Scheme.

(c) In no circumstances is the scheme mark to be applied to test certificates relating to non-approved products.

(d) The scheme mark is not to be used in any way which may imply approval for products which are not covered within the manufacturer's scope of approval.

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(e) Where a manufacturer is removed or suspended from the scheme, use of the scheme mark must cease immediately.

3.3.3 The certificate as given in 3.1.3(d) is to be validated by an authorised representative of the manufacturer. The size and position of the scheme mark and statement on the manufacturer's certificate must be agreed by LR.

3.3.4 Where manufacturers are approved under this scheme, the manufacturer's certificate issued according to these requirements fully meets the materials certification requirements of these Rules.

3.4 Electronic certification

3.4.1 Where these Rules allow the issue of manufacturers' test certificates, under either the Materials Survey Scheme or the Materials Quality Scheme, these may be issued in electronic format provided that:

(a) All tests and inspections have been satisfactorily completed according to the requirements of these Rules.
(b) Procedures are in place to ensure that electronic certificates are only issued according to the requirements of these Rules.
(c) The certification system is subject to regular inspection by the attending Surveyor.
(d) A copy of the electronic certificate is supplied to LR. This copy will be deemed to be the original of the test certificate.

3.4.2 In addition to the requirements of 3.4.1, for items certified under the Materials Survey Scheme, the LR office stamp and Surveyor's name may be applied electronically. This is only allowed where the Surveyor has access to the results of the relevant tests and inspections, and is able to authorise by access to the electronic system, the application of the LR office stamp and Surveyor's name on the test certificate. The name of the authorising Surveyor is to be the name included on the certificate. The authorisation may be conducted electronically either at the manufacturers' works, or remotely by the Surveyor.

3.4.3 If the LR office stamp and name are being applied electronically according to 3.4.2, then the manufacturer is to ensure that the Surveyor is provided with all relevant information regarding the customer order, when the request for authorisation is made.

Section 4
General requirements for manufacture

4.1 General

4.1.1 The following definitions are applicable to these Rules:

Item: A single forging, casting, plate, tube or other rolled product as delivered.
Piece: The rolled product from a single slab or billet or from a single ingot if this is rolled directly into plates, strip, sections or bars.
Batch: A number of similar items or pieces presented as a group for acceptance testing.

4.1.2 Where a manufacturer purchases semi-finished products (e.g. slabs) for the purpose of re-processing (e.g. rolling), the manufacturer is to ensure that the materials are from an LR approved manufacturer, and manufactured within the scope of approval of that manufacturer. The aim of chemical analysis, dimensions, surface and internal quality checks are to be agreed between the manufacturer and purchaser. The semi-finished materials must be supplied with appropriate certification, according to these Rules.

4.1.3 It is the responsibility of the manufacturer to ensure compliance with all relevant aspects of these Rules. All deviations are to be recorded as non-compliances, and brought to the attention of the Surveyor, along with corrective actions taken. Failure to do this is considered to render the material as not complying with these Rules.

4.1.4 The manufacturer is to maintain all test and inspection records required by these Rules for at least seven years. Records are to be made available to LR on request.

4.1.5 Where material is produced which does not meet all aspects of these Rules, the manufacturer may apply to LR for a concession to certify the material as approved. LR will consider each application on a case-by-case basis, although concession will only normally be granted in exceptional circumstances. If the concession is granted, a formal written numbered concession will be issued to the manufacturer. The concession number must be applied to the approval certificate, whether it is an LR certificate or a validated manufacturer's certificate.

4.2 Chemical composition

4.2.1 The ladle analysis used for certification purposes is to be determined after all alloying elements have been added and sufficient time allowed for such additions to equalise throughout the ladle.

4.2.2 The method of taking samples is to ensure that the reported analysis is representative of the cast. In addition, the manufacturer must determine and certify the chemical composition of every heat of material.

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4.2.3 Where more than one sample is taken, the method of averaging for the final certificate result and the determination of acceptable variations in composition are to be agreed with the Surveyor.

4.2.4 The chemical composition of ladle samples is to be determined by the manufacturer in an adequately equipped and competently staffed laboratory. The manufacturer's analysis will be accepted, but may be subject to occasional independent checks if required by the Surveyor.

4.2.5 The analysis is to include the content of all the elements detailed in the relevant Sections of the Rules and, where appropriate, the National or International Standard applied.

4.2.6 At the discretion of the Surveyors, a check chemical analysis of suitable samples from products may also be required. These samples are to be taken from the material used for mechanical tests but, where this is not practicable, an alternative procedure for obtaining a representative sample is to be agreed with the manufacturer. For product samples, the permissible limits of deviation from the specified ladle analysis are to be in accordance with an appropriate International or National Standard specification.

4.3 Heat treatment

4.3.1 Materials are to be supplied in the condition specified in, or permitted by, the relevant Chapters of these Rules.

4.3.2 Heat treatment is to be carried out in properly constructed furnaces which are efficiently maintained and have adequate means for control and recording of temperature. The furnace dimensions are to be such as to allow the whole item to be uniformly heated to the necessary temperature. In the case of very large components which require heat treatment, alternative methods will be specially considered.

4.3.3 The manufacturer is to maintain the records, including the temperature charts of all heat treatments for at least seven years.

4.4 Test material

4.4.1 Sufficient test material is to be provided for the preparation of the test specimen detailed in the specific requirements. It is, however, in the interests of manufacturers to provide additional material for any re-tests which may be necessary, as insufficient or unacceptable test material may be a cause for rejection.

4.4.2 The test material is to be representative of the item or batch and is not to be separated until all the specified heat treatment has been completed, except where provision for an alternative procedure is made in subsequent Chapters of these Rules.

4.4.3 All test material is to be selected by the Surveyor or an authorised deputy and identified by suitable markings which are to be maintained during the preparation of the test specimens.

4.5 Mechanical tests

4.5.1 The dimensions, number and direction of test specimens are to be in accordance with the requirements of Chapter 2 and the specific requirements for the product.

4.5.2 Where Charpy impact tests are required, a set of three test specimens is to be prepared and the average energy value is to comply with the requirements of subsequent Chapters. One individual value may be less than the required average value provided that it is not less than 70 per cent of that value.

4.5.3 In the Rules, mechanical properties are specified in SI units, but alternative units may be used for acceptance testing. In such cases, the specified values are to be converted in accordance with the appropriate conversions given in Table 1.4.1. It is preferred that test results be reported in SI units, but alternative units may be used provided that the test certificate gives, in the same units, the equivalent specification values.

Table 1.4.1 Conversions from SI units to metric and Imperial units

1 N/mm^2 or MPa	=	0,102 kgf/mm^2
1 N/mm^2 or MPa	=	0,0647 $tonf/in^2$
1 N/mm^2 or MPa	=	0,145 x 10^3 lbf/in^2
1J	=	0,102 kgf m
1J	=	0,738 ft lbs
1 kgf/mm^2	=	9,81 N/mm^2 or MPa
1 $tonf/in^2$	=	15,4 N/mm^2 or MPa
1 lbf/in^2	=	6,89 x 10^{-3} N/mm^2 or MPa
1 kgf m	=	9,81 J
1 ft lbf	=	1,36 J

4.6 Re-test procedures

4.6.1 Re-test procedures are to be in accordance with the requirements of Ch 2,1.4.

4.7 Rectification of defective material

4.7.1 Small surface imperfections may be removed by mechanical means provided that, after such treatment, the dimensions are acceptable, the area is proved free from defects and the rectification has been completed in accordance with any applicable requirements of subsequent Chapters of these Rules and to the satisfaction of the Surveyor.

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4.7.2 The repair of defects by welding can be accepted only when permitted by the appropriate specific requirements and provided that the agreement of the Surveyor is obtained before the work is commenced. When a repair has been agreed, it is necessary in all cases to prove by suitable methods of non-destructive examination that the defects have been completely removed before welding is commenced. Welding procedures and inspection on completion of the repair are to be in accordance with the appropriate specific requirements and are to be to the satisfaction of the Surveyor.

4.7.3 Manufacturers wishing to carry out welding work must have at their disposal the necessary workshops, lifting gear, welding equipment, pre-heating, and where necessary annealing facilities and testing devices, as well as certified welders and supervisors to enable them to perform the work properly. Proof shall be furnished to the Surveyor that these conditions are satisfied before welding work begins.

4.8 Identification of materials

4.8.1 The manufacturer is to adopt a system of identification which will enable all finished materials to be traced to the original cast, and the Surveyors are to be given full facilities for tracing the material when required. When any item has been identified by the personal mark of a Surveyor, or his deputy, this is not to be removed until an acceptable new identification mark has been made by a Surveyor. Failure to comply with this condition will render the item liable to rejection.

4.8.2 Before any item is finally accepted it is to be clearly marked by the manufacturer in at least one place with the particulars detailed in the appropriate specific requirements.

4.8.3 Where hard stamps such as the LR brand stamp are issued to manufacturers to carry out the stamping on behalf of LR, the procedure for issue, maintenance and use of stamps is to be agreed in writing.

4.8.4 Hard stamping is to be used except where this may be detrimental to the material, in which case stencilling, painting or electric etching is to be used. Paints used to identify alloy steels are to be free from lead, copper, zinc or tin, i.e. the dried film is not to contain any of these elements in quantities of more than 250 ppm.

4.8.5 Where a number of identical items are securely fastened together in bundles, the manufacturer need only brand the top item of each bundle. Alternatively, a durable label giving the required particulars may be attached to each bundle.

■ *Section 5* Non-destructive examination

5.1 General NDE requirements

5.1.1 Prior to the final acceptance of materials, surface inspection and verification of dimensions, non-destructive examination is to be carried out in accordance with the requirements detailed in this Section and subsequent Chapters of these Rules.

5.1.2 It is the manufacturer's responsibility for maintaining the required tolerances and making the necessary measurements. Periodic surveys by the Surveyor do not absolve the manufacturer from this responsibility.

5.1.3 When there is visible evidence to doubt the soundness of any material or component, such as flaws in test specimens or suspicious surface marks, the manufacturer is expected to prove the quality of the material by a suitable method.

5.1.4 Acceptance criteria are detailed in subsequent Chapters of these Rules. Alternative specifications may be submitted for consideration, provided they demonstrate equivalence to these Rules.

5.2 Personnel qualifications

5.2.1 The shipyard, fabricator or manufacturer is to ensure that personnel carrying out non-destructive examination or interpreting the results of non-destructive examination are qualified to the appropriate level of a nationally recognised scheme such as ISO 9712, EN 473, PCN, ACCP or SNT-TC-1A. Level 1 personnel are not permitted to interpret results to Codes or Standards.

5.2.2 When certification of personnel is made on an in-house basis under a scheme such as SNT-TC-1A, practical examinations are to be relevant to material, product type, joint configuration, material thickness and acceptance criteria of items inspected for Classification purposes.

5.2.3 Personnel qualifications of NDE operators are to be randomly checked by the Surveyor.

5.3 Non-destructive examination methods

5.3.1 Non-destructive examination methods are to comply with the relevant requirements of these Rules.

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5.4 Non-destructive examination procedures

5.4.1 All non-destructive examinations are to be carried out to a procedure that is representative of the item under inspection. As a minimum the procedures are to be in accordance with the following:

(a) Procedures are to identify the component to be examined, the NDE method, equipment to be used and the full extent of the examinations including any test restrictions.
(b) Procedures are to specify the qualification and certification requirements of the inspection personnel to be employed.
(c) Procedures are to state the degree of surface preparation required and the methods of preparation to be used before the examinations are made.
(d) Procedures are to state the reference standards for testing and the acceptance criteria to be applied to the results of the inspections.
(e) Procedures are to include the requirement for components to be positively identified and for a datum system or marking system to be applied to ensure repeatability of inspections.
(f) Procedures are to identify any requirements for increasing the extent of applied NDE where defects have been found during spot examination.
(g) Procedures are to identify reporting requirements.
(h) Procedures are to be reviewed by the Surveyor to ensure they are appropriate for the product type.
(j) Procedures for radiography are to specify the acceptable optical density within the area of interest on the radiograph.
(k) The minimum optical density within the area of interest on a radiograph is to be equal to or greater than 2,0 for gamma ray and 1,8 for X-ray. A maximum density of 4,0 is acceptable.
(l) Procedures are to include the method and requirements for equipment calibrations and functional checks.
(m) Procedures are to be approved by an operator qualified to a minimum of Level III in accordance with a recognised standard.
(n) The Surveyor will review procedures for compliance with this Section.

5.4.2 The shipyard, fabricator or manufacturer may submit other Codes or Standards for consideration by LR, providing they meet the requirements of these Rules.

5.5 Non-destructive examination reports

5.5.1 NDE reports are to include all information required to identify how the examination was executed and are to include the following information where appropriate:

(a) Date of test.
(b) Name and qualification of operator with signatures of the operator.
(c) Details of the component identification, description of test location and volume examined.
(d) Heat treatment status.
(e) Weld type, procedure and configuration.
(f) Surface condition.
(g) Test procedure.
(h) Equipment used.
(j) Test results with a map or record of any defects, giving location, dimensions and defect nature.
(k) Reference to acceptance criteria and evaluation in accordance to these criteria.
(l) Material type and thickness.
(m) Calibration.

Section 6 References

6.1 General

6.1.1 The locations of National and International Standards referenced in these Rules are shown in Table 1.6.1.

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Table 1.6.1 List of National and International Standards

Rule reference	Standard
Chapter 1 – General Requirements	ISO 9001: 2008
Chapter 2 – Testing Procedures for Metallic Materials	ISO 6892-1: 2009 ISO 185: 2005 ISO 2566-1: 1999 ISO 148-1: 2009 ISO 7500-1: 2004 EN 10045-1: 1990 ASTM E23-07
Chapter 3 – Rolled Steel Plates, Strip, Sections and Bars	EN 10160: 1999 ASTM A578-07 ASTM E112-96 (2004)e2 ASTM E381-01 (2006) ASTM A255-07 (e1)
Chapter 4 – Steel Castings	ISO 1161: 1984/Amendment 1: 2007
Chapter 5 – Steel Forgings	ASTM E112-96 (2004)e2
Chapter 8 – Aluminium Alloys	ASTM G66-99 (2005)e1 ASTM G67-04
Chapter 9 – Copper Alloys	ASTM E272-99 (2004)
Chapter 10 – Equipment for Mooring and Anchoring	ISO 1704: 2008 ISO 1834: 1999 ISO 4565: 1986 ASTM E112-96 (2004)e2 ASTM E381-01 (2006) ASTM A255-07 (e1)
Chapter 11 – Approval of Welding Consumables	ISO 3690: 2000 ISO 10042: 2005 ASTM G48-03 (2009)
Chapter 12 – Welding Qualifications	ISO 6947: 1997 ISO 5817: 2007 ISO 6520-1: 2007 ISO 6507-1: 2005 ISO 10042: 2005
Chapter 13 – Requirements for Welded Construction	ISO 9712/Cor1: 2006 EN 473: 2008 ISO 6520-1: 2007 SNT-TC-1A: 2006 ISO 10042: 2005
Chapter 14 – Plastics Materials	ISO 527-2: 1993 ISO 178: 2001 ISO 62: 2008 ISO 75-2: 2004 ISO 604: 2002 ISO 527-4: 1997 ISO 14125: 1998 ISO 14130: 1997 ISO 1172: 1996 ISO 1922- 2001 ASTM C273/C273M-07[a] ASTM C393/C393M-06 ISO 845- 2006 ASTM C297/C297M-04 ISO 844-2007 ISO 1922-2001 ISO 180-2000 DIN EN59 ISO 175: 1999

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Testing Procedures for Metallic Materials

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Section 1
General requirements for testing

1.1 Preparation of test specimens

1.1.1 The requirements specified below detail all the tests that may be applied to metallic materials. The specific tests and the test specimen types required for each material type, grade and product type are detailed in the subsequent Chapter of these Rules.

1.1.2 Where test material is cut from products by shearing or flame cutting, a reasonable margin is required to allow sufficient material to be removed from the cut edges during machining of the test specimens.

1.1.3 Test specimens are to be prepared in such a manner that they are not subjected to any significant work hardening, cold straining or heating during straightening or machining.

1.1.4 Test samples are not to be removed from the material they represent until heat treatment is complete. For castings in cases where test samples are separately cast, the castings and samples are to be heat treated together.

1.1.5 Dimensional tolerances are to comply with a relevant ISO specification.

1.2 Testing machines

1.2.1 All tests are to be carried out by competent personnel. Testing machines are to be maintained in a satisfactory and accurate condition and are to be recalibrated at approximately annual intervals. This calibration is to be carried out by organisations of standing that have been approved or recognised by a National Authority and are to be to the satisfaction of the Surveyor. A record of all calibrations is to be kept available in the test house.

1.2.2 Tensile testing machine load cells are to be calibrated with an accuracy of ± one per cent in accordance with ISO 7500-1 or another recognised National Standard.

1.2.3 Impact tests are to be carried out on Charpy V-notch machines calibrated to ISO 148, EN 10045 or ASTM E23 dependent on the testing machine type. The testing machines are to be calibrated using either a direct or indirect method. Other National Standards equivalent to ISO 148 may be considered.

1.3 Discarding of test specimens

1.3.1 If a test specimen fails because of faulty preparation or incorrect operation of the testing machine it may be discarded and replaced by a new test specimen prepared from material adjacent to the original test.

1.3.2 In addition to the discarding of test specimens as indicated in 1.3.1, a tensile test specimen may also be discarded when the specified minimum elongation is not obtained and the distance between the fracture and the nearest gauge mark is less than one-quarter of the gauge length.

1.4 Re-testing procedures

1.4.1 Where the result of any test, other than an impact test, does not comply with the requirements, two additional tests of the same type are to be made from the same test sample, or if sufficient material is not available, a further representative sample taken from the item under test. For acceptance of the material, satisfactory results are to be obtained from both of these additional tests.

1.4.2 Where the result of any test taken from a weld procedure approval test, other than an impact test, does not comply with the requirements, two additional tests of the same type are to be made from the same weld test assembly. Where insufficient original welded assembly is available, a new assembly is to be prepared using the same conditions as the original test weld. For acceptance, satisfactory results are to be obtained from both of these additional tests.

1.4.3 Where the result of any test taken from a welding consumable approval test, other than an impact test, does not comply with the requirements, two additional tests of the same type are to be made from the same weld test assembly. Where insufficient original welded assembly is available, a new assembly is to be prepared using welding consumables from the same batch. If the new assembly is made with the same procedure (particularly the same number of runs) as the original assembly, only the duplicate re-test specimens need be prepared and tested. For acceptance of a weld consumable batch, satisfactory results are to be obtained from both of these additional tests.

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1.4.4 Where the results from a set of three impact test specimens do not comply with the requirements, an additional set of three impact test specimens may be tested provided that, of the original set tested, not more than two individual values are less than the required average value and, of these, not more than one is less than 70 per cent of this average value. The results obtained are to be combined with the original results to form a new average which, for acceptance, is to be not less than the required average value. Additionally, for these combined results, not more than two individual values are to be less than the required average value and, of these, not more than one is to be less than 70 per cent of this average value.

1.4.5 The additional tests detailed in 1.4.1 and 1.4.2 are, where possible, to be made on material adjacent to the original samples. For castings, where insufficient material remains in the original test samples, the additional test may be made on other test samples representative of the castings. *See also* 1.3 for discarding of test specimens.

1.4.6 When unsatisfactory results are obtained from tests representative of a batch of material, the item or piece from which the tests were taken is to be rejected. The remainder of the material in the batch may be accepted provided that two further items or pieces are selected and tested with satisfactory results. If the tests from one or both or these additional items or pieces give unsatisfactory results, the batch is to be rejected.

1.4.7 When a batch of material is rejected, the remaining items or pieces in the batch may be resubmitted individually for test, and those which give satisfactory results may be accepted.

1.4.8 At the option of the manufacturer, rejected material may be resubmitted as another grade and may then be accepted, provided that the test results comply with the appropriate requirements.

1.4.9 When material which is intended to be supplied in the 'as-rolled' or 'hot-finished' condition fails test, it may be suitably heat treated and resubmitted for test. Similarly, materials supplied in the heat treated condition may be reheat treated and resubmitted for test. Unless otherwise agreed by the Surveyor, such reheat treatment is to be limited to one repeat of the final heat treatment cycle.

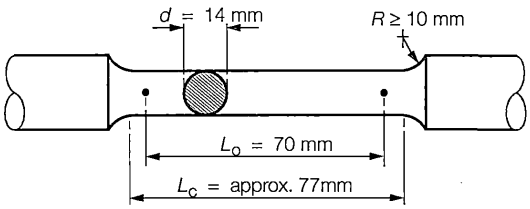
■ *Section 2*
Tensile tests

2.1 Dimensions of test specimens

2.1.1 Proportional test specimens with a gauge length L_o of $5{,}65\sqrt{S_o}$ or $5d$, where S_o is the cross-sectional area, d the diameter and L_c the parallel test length, have been adopted as the standard form of test specimen, and in subsequent Chapters in these Rules the minimum percentage elongation values are given for test specimens of these proportions.

2.1.2 The gauge length is to be greater than 20 mm and may be rounded off to the nearest 5 mm provided that the difference between the adjusted gauge length and the calculated one is less than 10 per cent of the calculated gauge length.

2.1.3 For forgings and castings (excluding those in grey cast iron) proportional test specimens of circular cross-section are to be machined to the dimensions shown in Fig. 2.2.1.

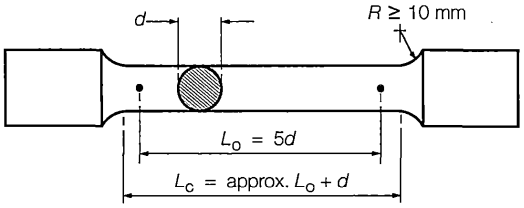


NOTE: For nodular cast iron and materials with a specified elongation less than 10%, $R \geq 20$ mm

Fig. 2.2.1
Test specimen dimensions for forgings and castings – I

2.1.4 For hot rolled bars and similar products, the test specimens are to be as in Fig. 2.2.1, except that for small sizes they may consist of a suitable length of bar or other product tested in the full cross-section.

2.1.5 As an alternative to 2.1.3 and 2.1.4, proportional or non-proportional test specimens of other dimensions may be used, subject to any requirements for minimum cross-sectional area given in subsequent Chapters of these Rules. Where the size of proportional test specimens is other than as shown in Fig. 2.2.1, the general dimensions are to conform with Fig. 2.2.2.



NOTE: For nodular cast iron and materials with a specified elongation less than 10%, $R \geq 1{,}5d$

Fig. 2.2.2
Test specimen dimensions for forgings and castings – II and aluminium alloys

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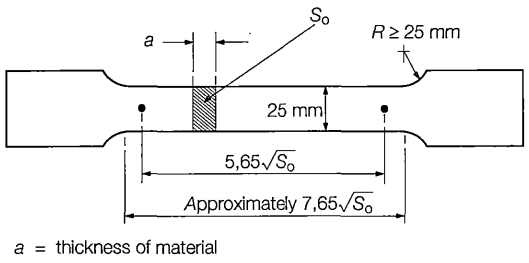
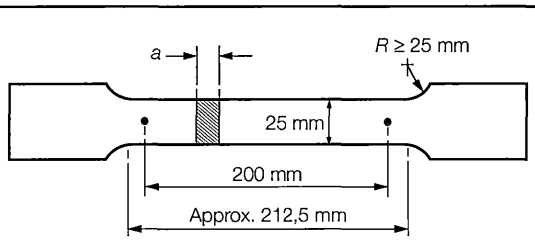
2.1.6 For plates, strip and sections, the test specimens are to be machined to the dimensions shown in Fig. 2.2.3 or Fig. 2.2.4. Where the capacity of the available testing machine is insufficient to allow the use of a test specimen of full thickness, this may be reduced by machining one of the rolled surfaces. Alternatively, for materials over 40 mm thick, test specimens of circular cross-section machined to the dimensions shown in Fig. 2.2.1 may be used. The axes of these test specimens are to be located at approximately one quarter of the thickness from one of the rolled surfaces.



a = thickness of material

Fig. 2.2.3
Test specimen dimensions for plates, strip and sections – I and aluminium alloys



a = thickness of material

Fig. 2.2.4
Test specimen dimensions for plates, strip and sections – II

2.1.7 As an alternative to 2.1.6, test specimens with a width of other than 25 mm may be used subject to any requirements for minimum cross-sectional area given in subsequent Chapters of these Rules. A ratio of width/thickness of 8:1 should not be exceeded.

2.1.8 For pipes and tubes, the test specimens may consist of a suitable length tested in full cross-section with the ends plugged. The gauge length is to be 5,65 $\sqrt{S_o}$ or 50 mm, and the length of the test specimen between the grips or plugs, whichever is the smaller, is to be not less than the gauge length plus D, where D is the external diameter. Alternatively, test specimens may be prepared from strips cut longitudinally and machined to the dimensions shown in Fig. 2.2.5 or Fig. 2.2.6. The parallel test length is not to be flattened, but the enlarged ends may be flattened for gripping in the testing machine. The cross-sectional area of this type of test specimen is to be calculated from:

$S_o = ab$

where

S_o = cross-sectional area
a = average radial thickness
b = average width

Test specimens of circular cross-section may also be used provided that the wall thickness is sufficient to allow the machining of such specimens to the dimensions shown in Fig. 2.2.1, with their axes located at the mid-wall thickness.

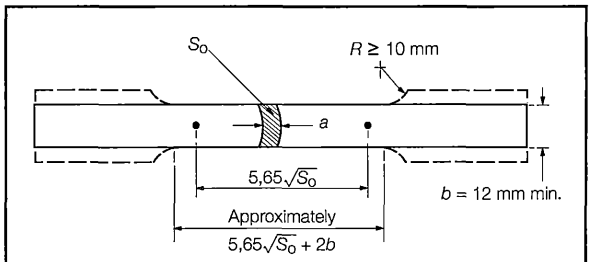


Fig. 2.2.5
Test specimen dimensions for pipes and tubes – I

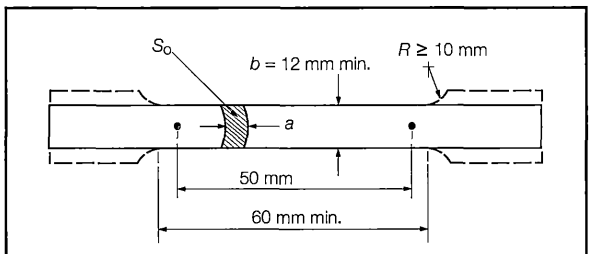


Fig. 2.2.6
Test specimen dimensions for pipes and tubes – II

2.1.9 For wire, the test specimen may consist of a suitable length tested in full cross-section. The gauge length is to be 200 mm and the parallel test length 250 mm.

2.1.10 For grey iron castings, the test specimens are to be machined to the dimensions shown in Fig. 2.2.7 or Fig. 2.2.8.

2.1.11 For aluminium alloy plates and sections of thickness, a, less than or equal to 12,5 mm; the dimensions of rectangular cross-sectioned test specimens are to be as shown in Fig. 2.2.3. The rectangular cross-sectioned test specimen surfaces should remain as rolled/extruded. Where the thickness, a, is greater than 12,5 mm the test specimens are to be of round type as shown in Fig. 2.2.2.

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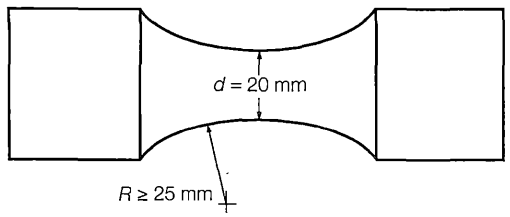

Fig. 2.2.7
Test specimen dimensions for grey iron castings – I

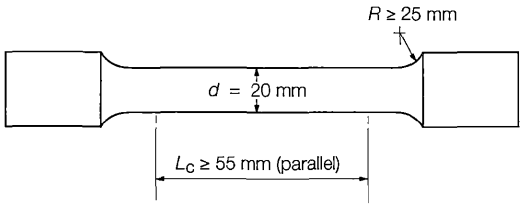

Fig. 2.2.8
Test specimen dimensions for grey iron castings – II

2.1.12 Deposited weld metal tensile test specimens are to be machined to the dimensions shown in Fig. 2.2.9, and may be heated to a temperature not exceeding 250°C for a period not exceeding 16 hours for hydrogen removal, prior to testing.

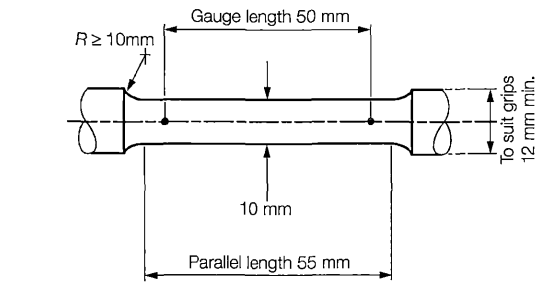

Fig. 2.2.9
Test specimen for deposited weld metal tensile

2.1.13 Butt weld tensile test specimens are to be machined to the dimensions shown in Fig. 2.2.10. For thicknesses of more than 2 mm, the test width is to be 25 mm. For thicknesses less than 2 mm, the test width is to be reduced to 12 mm. The upper and lower surfaces of the weld are to be filed, ground or machined flush with the surface of the plate.

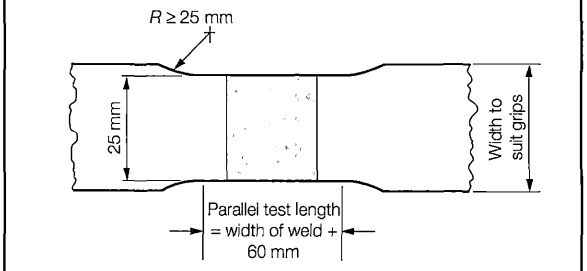

Fig. 2.2.10 Test specimen for butt weld

2.1.14 Through-thickness tensile test specimens may be, at the option of the steelmaker, either plain test specimens or test specimens with welded extensions in accordance with a Recognised Standard. The extension pieces are to be of steel with a tensile strength exceeding that of the plate to be tested and may be attached to the plate surfaces by manual, resistance or friction welding carried out in such a way as to ensure a minimal heat affected zone.

2.1.15 Tolerances on tensile specimen dimensions are to be in accordance with ISO 6892-1 or another Recognised Standard as appropriate.

2.2 Definition of yield stress for steel

2.2.1 The yield phenomenon is not exhibited by all the steels detailed in these Rules but, except for austenitic and duplex stainless steels, the term 'yield stress' is used throughout when requirements are specified for acceptance testing at ambient temperature. For the purposes of the Rules, the terms 'yield stress' and 'yield strength' are to be regarded as synonymous.

2.2.2 Where reference is made to 'yield stress' in the requirements for carbon, carbon-manganese and alloy steel products and in the requirements for the approval of welding consumables, either the upper yield stress or, where this is not clearly exhibited, the 0,2 per cent proof stress or the 0,5 per cent proof stress under load is to be determined. In cases of dispute, the 0,2 per cent proof stress is to be determined.

2.2.3 For austenitic and duplex stainless steel products and welding consumables, both the 0,2 and the 1,0 per cent proof stresses are to be determined.

2.3 Procedure for testing at ambient temperature

2.3.1 Except as provided in 2.3.5, the elastic stress rate for the determination of the upper yield for steels and copper alloys is to be between 6 and 60 N/mm^2 per second and between 2 and 20 N/mm^2 per second for aluminium. After reaching the yield or proof load, the straining rate may be increased to a maximum of $0{,}008s^{-1}$ for the determination of the tensile strength.

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2.3.2 For steel, the upper yield stress is to be calculated from:

(a) the value of stress measured at the commencement of plastic deformation, or

(b) on a load/extension diagram using the value of stress measured at the first peak obtained during yielding even when the peak is equal to or less than any subsequent peaks observed during plastic deformation at yield.

2.3.3 When a well defined yield point cannot be obtained, the 0,2 or 1,0 per cent proof stress (non-proportional elongation) is to be determined from an accurate load/extension diagram by drawing a line parallel to the straight elastic portion and a distance from it where the amount represents 0,2 or 1,0 per cent of the extensometer gauge length. The point of intersection of this line with the plastic portion of the diagram represents the proof load, from which the 0,2 or 1,0 per cent proof stress can be calculated.

2.3.4 For stainless steels the 1,0 per cent proof stress and/or 0,2 per cent proof stress is specified as required by the relevant Chapters in these Rules.

2.3.5 For the determination of the tensile strength of flake graphite cast iron, the stress rate is not to exceed 10 N/mm^2 per second.

2.3.6 A measured elongation value is to be regarded as valid only if the fracture occurs within the gauge length and at least the following distances from the gauge marks:

Round test specimen: 1,25*d*

Flat test specimen: *a* plus width of specimen

The measurement is valid irrespective of the position of the fracture, if the percentage elongation after fracture reaches at least the specified value, and this is to be stated in the test report.

2.4 Equivalent elongations

2.4.1 When a gauge length other than $5,65\sqrt{S_o}$ is used, the equivalent percentage elongation value is to be calculated using the following formula:

$$A = \frac{A_R}{2}\left(\frac{L_o}{\sqrt{S_o}}\right)^{0,40}$$

where

A_R = actual measured percentage elongation of test specimen

S_o = actual cross-sectional area of test specimen

L_o = actual gauge length of test piece

A = equivalent percentage elongation for a test specimen with a gauge length of $5,65\sqrt{S_o}$

2.4.2 Alternatively, where a number of test specimens of similar material and dimensions are involved, the actual percentage elongation values may be recorded, provided that the equivalent specified minimum elongation value appropriate for the test specimen dimensions is calculated from the formula in 2.4.1 and is recorded on the test certificate.

2.4.3 For proportional test specimens having a gauge length other than $5,65\sqrt{S_o}$, the equivalent elongation may be calculated using the following factors (*d* is the diameter of the test specimen):

Actual gauge length	Factor for equivalent elongation on $5,65\sqrt{S_o}$
$4\sqrt{S_o}$	x 0,870
$8,16\sqrt{S_o}$	x 1,158
$11,3\sqrt{S_o}$	x 1,317
4*d*	x 0,916
8*d*	x 1,207

2.4.4 For non-proportional test specimens with gauge lengths of 50 mm and 200 mm, the equivalent elongation values tabulated in ISO 2566 are to apply.

2.4.5 The above conversions are reliable only for carbon, carbon-manganese and low alloy steels with a tensile strength not exceeding 700 N/mm^2 in the hot rolled, annealed, normalised, or normalised and tempered condition.

2.4.6 For alloy steels in the quenched and tempered condition, the following conversions may be used for proportional test specimens with a gauge length of $4\sqrt{S_o}$:

Actual percentage elongation on $4\sqrt{S_o}$	Equivalent elongation on $5,65\sqrt{S_o}$
22	17
20	15
18	13
17	12
16	12
15	11
14	10
12	8
10	7
8	5

2.4.7 Any proposals to use conversion factors for equivalent elongation values for the following materials are to be agreed with the Surveyors:

(a) Carbon, carbon-manganese and alloy steels in the normalised or normalised and tempered condition with a tensile strength exceeding 700 N/mm^2.

(b) Cold-worked steels.

(c) Austenitic stainless steels.

(d) Non-ferrous alloys.

2.5 Procedure for testing at elevated temperatures

2.5.1 The test specimens used for the determination of lower yield or 0,2 per cent proof stress at elevated temperatures are to have an extensometer gauge length of not less than 50 mm and a cross-sectional area of not less than 65 mm^2. Where, however, this is precluded by the dimensions of the product or by the test equipment available, the test specimen is to be of the largest practicable dimensions.

2.5.2 The heating apparatus is to be such that the temperature of the specimen during testing does not deviate from that specified by more than ±5°C.

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2.5.3 The straining rate when approaching the lower yield or proof load is to be controlled within the range 0,1 to 0,3 per cent of the extensometer gauge length per minute.

2.5.4 The time intervals used for estimation of strain rate from measurements of strain are not to exceed 6 seconds.

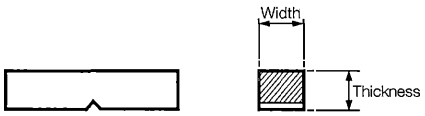
■ *Section 3* Impact tests

3.1 Dimensions of test specimens

3.1.1 Impact tests are to be of the Charpy V-notch type. The test specimens are to be machined to the dimensions and tolerances given in Table 2.3.1 and are to be carefully checked for dimensional accuracy.

Table 2.3.1 Dimensions and tolerances for Charpy V-notch impact test specimens

Dimension	Nominal	Tolerance
Length, mm	55	±0,60
Width, mm– standard specimen	10	±0,11
– standard subsidiary specimen	7,5	±0,11
– standard subsidiary specimen	5	±0,06
Thickness, mm	10	±0,06
Angle of notch	45°	±2°
Depth below notch, mm	8	±0,06
Root radius, mm	0,25	±0,025
Distance of notch from end of test specimen, mm	27,5	±0,42
Angle between plane of symmetry of notch and longitudinal axis of test specimen	90°	±2°



3.1.2 For material under 10 mm in thickness, the largest possible size of standard subsidiary Charpy V-notch test specimen is to be prepared with the notch cut on the narrow face. Generally, impact tests are not required when the thickness of the material is less than 6 mm.

3.2 Testing procedures

3.2.1 All impact tests are to be carried out on Charpy machines approved by Lloyd's Register (hereinafter referred as LR) and having a striking energy of not less than 150 J.

3.2.2 Charpy V-notch impact tests may be carried out at ambient or lower temperatures in accordance with the specific requirements given in subsequent Chapters of these Rules. Where the test temperature is other than ambient, the temperature of the test specimen is to be controlled to within ±2°C for sufficient time to ensure uniformity throughout the cross-section of the test specimen, and suitable precautions are to be taken to prevent any significant change in temperature during the actual test. In cases of dispute, ambient temperature is to be considered as 18°C to 25°C.

3.2.3 For acceptance, the average energy value for a set of three impact tests must be equal to or greater than the appropriate specified minimum average value. Additionally, only one individual value may be less than the required average value but not less than 70 per cent of this average value.

3.2.4 Where standard subsidiary Charpy V-notch test specimens are necessary, the minimum energy values required are to be reduced as follows:

Specimen 10 x 7,5 mm: 5/6 of tabulated energy.

Specimen 10 x 5 mm: 2/3 of tabulated energy.

3.2.5 When reporting results, the specimen dimensions and the units used for expressing the energy absorbed (Joules) and the testing temperature are to be clearly stated.

■ *Section 4* Ductility tests for pipes and tubes

4.1 Bend tests

4.1.1 The test specimens are to be cut as circumferential strips of full wall thickness and with a width of not less than 40 mm. For thick walled pipes, the thickness of the test specimens may be reduced to 20 mm by machining. The edges of the specimens may be rounded to a radius of 1,6 mm.

4.1.2 Testing is to be carried out at ambient temperature, and the specimens are to be doubled over a former whose diameter is to be in accordance with the specific requirements for the material. For submerged arc welded tube the test piece is to be bent with the root of the weld in tension. For other tubes, the test piece is to be bent in the original direction of curvature. In all cases, the welds are to be in the middle of the test specimen. The test is considered to be satisfactory if, after bending, the specimens are free from cracks and laminations. Small cracks at the edges of the test specimens are to be disregarded.

4.2 Flattening tests

4.2.1 Ring test specimens are to be cut with the ends perpendicular to the axis of the pipe or tube. The length of the specimen is to be equal to 1,5 times the external diameter of the pipe or tube, but is to be not less than 10 mm or greater than 100 mm. Alternatively, the length of the test specimen may be 40 mm irrespective of the external diameter.

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4.2.2 Testing is to be carried out at ambient temperature and is to consist of flattening the specimens in a direction perpendicular to the longitudinal axis of the pipe. Flattening is to be carried out between two plain parallel and rigid platens which extend over both the full length and the width after flattening of the test specimen. Flattening is to be continued until the distance between the platens, measured under load, is not greater than the value given by the formula:

$$H = \frac{t(1+C)}{C+\frac{t}{D}}$$

where

H = distance between plates, in mm
t = specified thickness of the pipe, in mm
D = specified outside diameter, in mm
C = a constant dependent on the steel type and detailed in the specific requirements

After flattening, the specimens are to be free from cracks or other flaws. Small cracks at the ends of the test specimens may be disregarded.

4.2.3 For welded pipes or tubes, the weld is to be placed at 90° to the direction of flattening.

4.3 Drift expanding tests

4.3.1 The test specimens are to be cut with the ends perpendicular to the axis of the tube. The edges of the end to be tested may be rounded by filing.

4.3.2 For metallic tubes, the length of the specimen is to be at least 1,5 times the external diameter of the tube except when a mandrel with an included angle of 30° is used, in which case the length of the specimen is to be twice the external diameter of the tube. In all cases the length of section remaining cylindrical after test is not be less than 0,5 times the external diameter.

4.3.3 Testing is to be carried out at ambient temperature and is to consist of expanding the end of the tube symmetrically by means of a hardened conical steel mandrel having a total included angle of 30°, 45° or 60°, *see* Fig. 2.4.1. The mandrel is to be forced into the test specimen at a rate not exceeding 50 mm/min until the percentage increase in the outside diameter of the end of the test specimen is not less than the value given in the specific requirements for boiler and superheater tubes, *see* Chapter 6. The mandrel is to be lubricated, but there is to be no rotation of the tube or mandrel during the test. The expanded portion of the tube is to be free from cracks or other flaws.

4.4 Flanging tests

4.4.1 The test specimens are to be cut with the ends perpendicular to the axis of the tube. The length of the specimens is to be at least equal to the external diameter of the tube and such that after testing the portion that remains cylindrical is not less than half the external diameter. The edges of the end to be tested may be rounded by filing.

4.4.2 Testing is to be carried out at ambient temperature and is to consist of flanging the end of the tube symmetrically by means of hardened conical steel mandrels. The rate of flanging is not to exceed 50 mm/min.

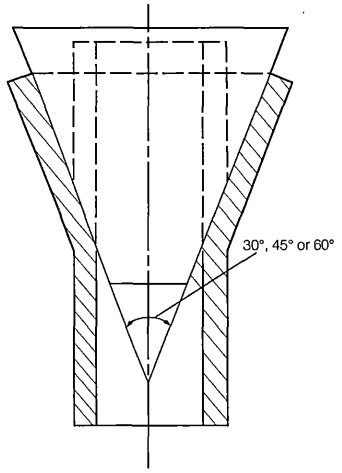

Fig. 2.4.1 Drift expanding test

4.4.3 The first stage of flanging is to be carried out with a conical angled mandrel having an included angle of approximately 90°, *see* Fig. 2.4.2(a). The completion of the test is achieved with a second forming tool as shown in Fig. 2.4.2(b). The mandrels are to be lubricated and there is to be no rotation of the tube or mandrels during the test. The test is to continue until the drifted portion has formed a flange perpendicular to the axis of the test specimens. The percentage increase in the external diameter of the end of the specimens is to be not less than the value given in the specific requirements for boiler and superheater tubes, *see* Chapter 6. The cylindrical and flanged portion of the tube is to be free from cracks or other flaws.

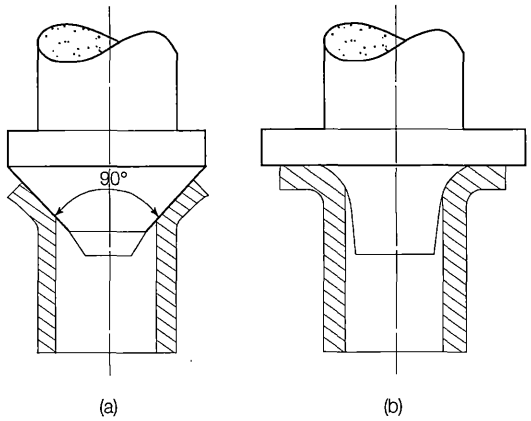

Fig. 2.4.2 Flanging test

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■ *Section 5* Embrittlement tests

5.1 Temper embrittlement tests

5.1.1 The test material is to be heat treated in accordance with the specification except that after tempering:

(a) half the material is to be water quenched;

(b) the other half is to be cooled from the tempering temperature to 300°C at a rate not exceeding 10°C per minute.

5.1.2 Impact tests in accordance with Section 3 are to be made on the material in each condition at temperatures over a range wide enough to establish the upper and lower shelf energies and temperatures, tests being made at no less than three intermediate temperatures.

5.1.3 A set of three specimens is to be tested at each temperature. The results are to be plotted separately for each condition, in the form illustrated in Fig. 2.5.1. In addition, the test temperatures, proportions of crystallinity and absorbed energies for all the specimens tested are to be reported.

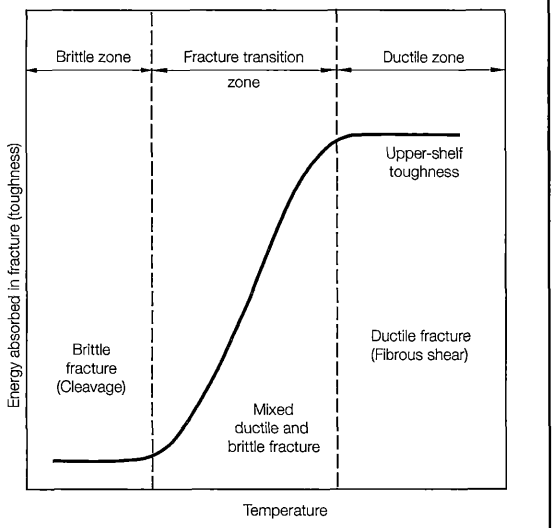

Fig. 2.5.1 Idealised transition curve

5.1.4 The transition temperature for each condition is to be taken as the mid-temperature of the fracture transition zone. The difference between the two transition temperatures is to be reported.

5.2 Strain age embrittlement tests

5.2.1 The test material is to be heat treated in accordance with the specification and then subjected to five per cent strain. Half of the test material is then to be heated to 250°C and held for one hour.

5.2.2 Impact tests in accordance with 5.1.2 are to be made in both the strained and unstrained conditions.

5.2.3 The tests are to comply with 5.1.3.

5.2.4 The test results are treated in accordance with 5.1.4.

5.3 Hydrogen embrittlement tests

5.3.1 Two specimens are to be tested. The specimens are to be of a diameter of 20 mm. Where this is not practicable a diameter of 14 mm may be accepted.

5.3.2 One specimen is to be tested within a maximum of 3 hours after machining. Where the specimen diameter is 14 mm, the time limit is 1,5 hours. Alternatively, the specimen may be cooled to –60°C immediately after machining and kept at that temperature for a maximum period of 5 days before being tested.

5.3.3 The other specimen is to be tested after baking at 250°C for 4 hours. Where the specimen diameter is 14 mm the baking time is to be 2 hours.

5.3.4 A strain rate not exceeding $0{,}0003s^{-1}$ is to be used during the entire test, until fracture occurs.

5.3.5 Tensile strength, elongation and reduction of area are to be reported.

5.3.6 The ratio Z_1/Z_2 is to be reported, where Z_1 is the reduction in area without baking and Z_2 the reduction in area after baking.

■ *Section 6* Crack tip opening displacement tests

6.1 Dimensions of test specimens

6.1.1 Unless agreed otherwise, tests are to be made on specimens of the full section thickness and which conform to a nationally agreed standard.

6.1.2 Normally the specimens are to be rectangular with the main dimensions as indicated in Fig. 2.6.1 and are to be tested in three point bending.

6.1.3 A subsidiary specimen as in Fig. 2.6.2 may be used by agreement.

6.1.4 In each case the notch is to be positioned at the centre of the loading span; its root radius is not to exceed 0,10 mm. The notch is to be extended by the generation of a fatigue crack to give an effective crack length of the dimension *a*. For this purpose, the fatigue stress ratio, R_1, is to be within the range 0 to 0,1 and the fatigue intensity is not to exceed $0{,}63\sigma_y B^{1/2}$ where σ_y is the 0,2 per cent proof stress at the test temperature.

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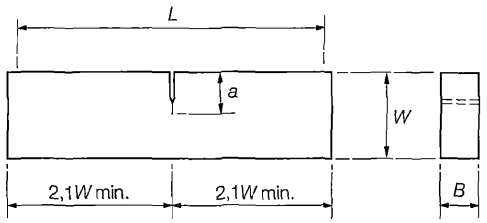
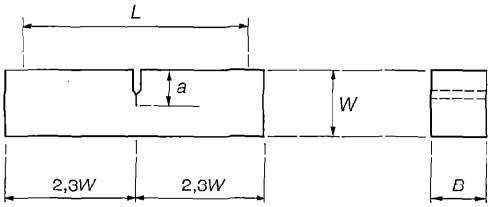


B = thickness
W = width = $2B$
a = effective crack length = $0{,}45W$ to $0{,}55W$
L = loading span = $4W$

Fig. 2.6.1
Outline dimensions of the preferred specimen



B = thickness
W = width = B
a = effective crack length (to be agreed between the purchaser and manufacturer)
L = loading span = $4W$

Fig. 2.6.2
Outline dimensions of the subsidiary specimen

6.2 Test equipment

6.2.1 Whenever possible, tests are to be made using machines operating under displacement control. The type of control is to be recorded.

6.2.2 The test equipment is to be calibrated annually.

6.2.3 The crack opening displacement gauge is to have an accuracy of at least one per cent. It is to be calibrated at least once every day of testing and at intervals of no more than 10 tests. It should be demonstrated that the calibration is satisfactory for the test conditions.

6.3 Testing procedures

6.3.1 Tests are to be made in a recognised test house in accordance with a nationally accepted standard.

6.3.2 Unless otherwise agreed, all tests on unwelded wrought material are to be made on specimens taken transverse to the principal working direction and are to be through-thickness notched.

6.3.3 Where tests are made on weld material, the fatigue crack should be arranged to sample the maximum amount of unrefined weld metal.

6.3.4 Where tests are made on the Heat Affected Zone (H.A.Z.) of a weld, a K or single bevel weld preparation is recommended. The region of lowest fracture toughness in the Heat Affected Zone should be identified for the particular steel and weld procedure by means of preliminary tests. The fatigue crack is to be accurately positioned to sample as high a proportion of this critical region as possible and after testing has been completed, the specimen is to be sectioned to check that this has been achieved. Sufficient tests should be made to ensure that the critical region has been sampled in at least three specimens.

6.3.5 At least three valid tests are to be made for each material condition. Invalid tests are to be disregarded and the tests repeated.

6.3.6 Local pre-compression of the test specimen ahead of the notch is acceptable in order to provide an acceptably even fatigue crack front.

6.3.7 The temperature of the test piece is to be measured to within ±2°C over the range minus 196°C to +200°C and to within ±5°C outside this range. The temperature should be measured at a point on the specimen not farther than 2 mm away from the crack tip.

6.4 Validity requirements

6.4.1 The test is to be regarded as invalid if:

(a) the fatigue crack front is not in a single plane;
(b) any part of the fatigue crack surface lies in a plane whose angle with the plane of the notch exceeds 10°;
(c) the length of any part of the fatigue crack is less than $0{,}025W$ or 1,25 mm, whichever is the greater;
(d) the difference between the maximum and minimum lengths of the fatigue crack exceeds $0{,}1W$;
(e) the difference between any two of the lengths of the fatigue crack at $0{,}25B$, $0{,}5B$ and $0{,}75B$ exceeds $0{,}05W$.

6.4.2 In addition, for tests on welds and Heat Affected Zones (H.A.Z.), the following criteria are to be complied with:

(a) Weld metal. The fatigue crack front shall not extend outside the weld metal deposit and 80 per cent should be within 2 mm of the fusion line.
(b) Grain coarsened H.A.Z.. The fatigue crack should be within 0,5 mm of the fusion line and should sample all of the grain coarsened H.A.Z. present. However, if fusion line irregularities prevent this, a sample including as much grain coarsened H.A.Z. as possible may be accepted.
(c) Subcritical/intercritical H.A.Z. boundary. The fatigue crack is to sample the boundary between the subcritical and intercritical regions of the H.A.Z. However, if fusion line irregularities prevent this, a sample including as much relevant microstructure as possible may be accepted.

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6.5 Test reports

6.5.1 The test report is to include:

(a) details of the material, its condition and size;
(b) the thickness and width of the test specimen;
(c) the fatigue pre-cracking conditions;
(d) the test temperature and environment;
(e) the test machine control system and rate of change of displacement or load;
(f) crack length measurements;
(g) force/displacement records, preferably in the form of an autographic record;
(h) the critical crack opening displacement;
(j) a photograph of the fracture;
(k) any observation on the fracture surface.

■ *Section 7* Bend tests

7.1 Dimensions of test specimens

7.1.1 Flat bend test specimens are to be of rectangular cross-section with dimensions as defined in Fig. 2.7.1.

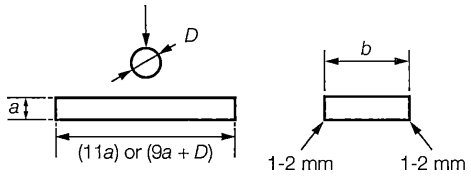

Fig. 2.7.1 Bend test specimen

7.1.2 For plates, sections and strip the dimensions shall be full thickness and width 30 mm. Where the rolled thickness exceeds 25 mm the compression face may be reduced to 25 mm.

7.1.3 For forgings, castings and semi-finished products the thickness shall be 20 mm and width 25 mm.

7.1.4 Butt weld face and root bend test specimens are to be 30 mm in width and of the full plate thickness. Where the thickness exceeds 25 mm, two side bend test specimens may be tested in place of the face and root specimens specified. The side bend specimens should be 10 mm minimum thickness. The upper and lower surfaces of the weld are to be filed, ground or machined flush with the surface of the plate.

7.1.5 The edges on the tension side of bend samples are to be rounded to a radius of 1 to 2 mm.

7.2 Testing procedures

7.2.1 The bend sample is plastically deformed by plunging a mandrel between two fixed points as shown in Fig. 2.7.2.

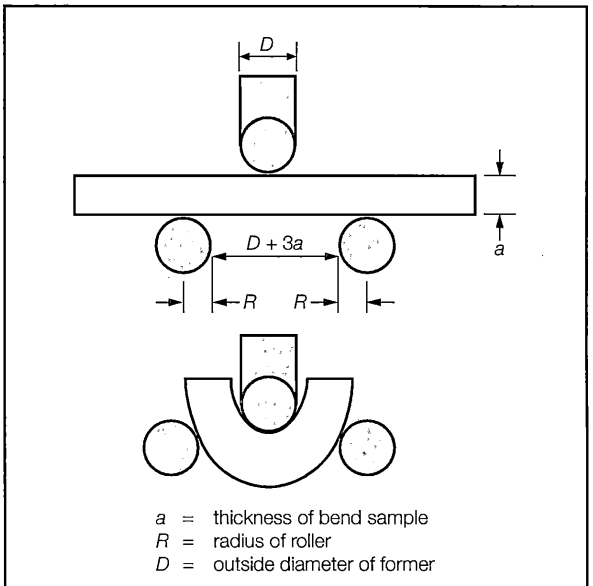

Fig. 2.7.2 Bend test

7.2.2 For aluminium welds a guided bend is required to ensure even deformation as shown in Fig. 2.7.3.

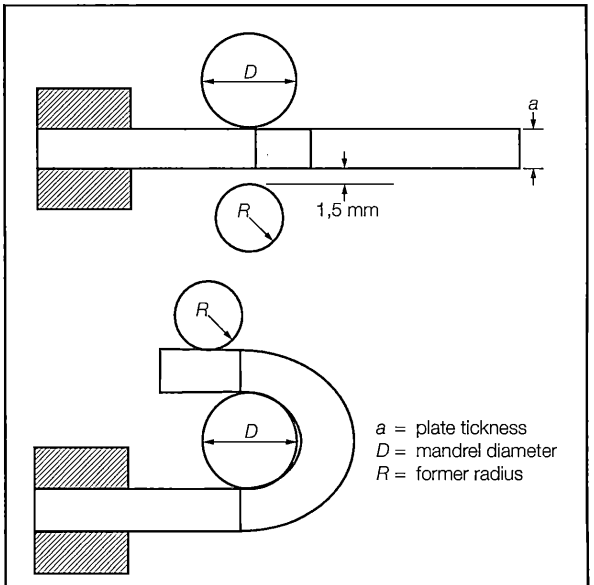

Fig. 2.7.3 Guide bend test for aluminium

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7.2.3 Bend tests are to be conducted at ambient temperature at the highest convenient rate of bending (but not impact).

Section 8
Corrosion tests

8.1 Intergranular corrosion test

8.1.1 For all products other than pipes, the material for the test specimens is to be taken adjacent to that for the tensile test and is to be machined to suitable dimensions for either a round or rectangular section bend test. The diameter or thickness is to be not more than 12 mm, and the total surface area is to be between 1500 mm^2 and 3500 mm^2.

8.1.2 For pipes with an outside diameter not exceeding 40 mm, the test specimens are to consist of a full cross-section. For larger pipes, the test specimens are to be cut as circumferential strips of full wall thickness and having a width of not less than 12,5 mm. In both cases the total surface area is to be between 1500 mm^2 and 3500 mm^2.

8.1.3 Specimens are to be heated to a temperature of 700 ± 10°C for 30 minutes, followed by rapid cooling in water. They are then to be placed on a bed of copper turnings (50 g per litre of test solution) and immersed for 15 to 24 hours in a boiling solution of the following composition:

- 100 g of hydrated copper sulphate granules ($CuSO_4 \cdot 5H_2O$)
- 184 g (100 ml) sulphuric acid (density 1,84 g/ml) added dropwise to distilled water to make 1 litre of solution.

Precautions are to be taken during boiling to prevent concentration of the solution by evaporation.

8.1.4 After immersion, the full cross-section test specimens from pipes are to be subjected to a flattening test in accordance with Ch 2,4.2. All other test specimens are to be bent, at ambient temperature, through 90° over a former with a diameter equal to twice the diameter or thickness of the test specimen.

8.1.5 After flattening or bending, the test specimens are to be free from cracks on the outer, convex surface.

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Rolled Steel Plates, Strip, Sections and Bars

Section

1 **General requirements**

2 **Normal strength steels for ship and other structural applications**

3 **Higher strength steels for ship and other *structural applications***

4 **Steels for boilers and pressure vessels**

5 **Steels for *machinery fabrications***

6 **Ferritic steels for low temperature service**

7 **Austenitic and duplex stainless steels**

8 **Plates with specified through thickness properties**

9 **Bars for welded chain cables**

10 **High strength quenched and tempered steels for welded structures**

Section 1 General requirements

1.1 Scope

1.1.1 This Section gives the general requirements for hot rolled plates and sections intended for use in the construction of ships, other marine structures, machinery, boilers and pressure vessels.

1.1.2 This Chapter is not applicable to hot rolled bars intended for the manufacture of bolts, plain shafts, etc., by machining operations only. Where used for this purpose, hot rolled bars are to comply with the requirements of Chapter 5.

1.1.3 Plate and strip which is hot coiled after rolling and subsequently uncoiled, cold flattened and cut to the required dimensions are also subject to the appropriate requirements of this Chapter.

1.1.4 Plates, strip, sections and bars are to be manufactured and tested in accordance with the requirements of Chapters 1 and 2, the general requirements of this Section and the appropriate specific requirements given in Sections 2 to 10.

1.1.5 As an alternative to 1.1.4, materials which comply with National or proprietary specifications may be accepted, provided that these specifications give equivalence to the requirements of this Chapter or are approved for a specific application. Particular attention is to be taken of the minimum required under thickness tolerance, *see* 1.5. Generally, survey and certification of such materials are to be carried out in accordance with the requirements of Chapter 1.

1.1.6 Steels intended for high heat input welding above 50 kJ/cm are to be specially approved. Approval will be indicated on the manufacturer's approval certificate by adding a high heat input welding notation to the grade approved e.g. EH36-W300, *indicating approval up to 300 kJ/cm.*

1.2 Steel with guaranteed through thickness *properties – 'Z' grade steel*

1.2.1 When plate material, intended for welded construction, will be subject to significant strains in a direction perpendicular to the rolled surfaces, it is recommended that consideration be given to the use of special plate material with specified through thickness properties, 'Z' grade steel. These strains are usually associated with thermal contraction and restraint during welding, particularly for full penetration 'T'-butt welds, but may also be associated with loads applied in service or during construction. Where these strains are of sufficient magnitude, lamellar tearing may occur. Requirements for 'Z' grade plate material are detailed in Section 8. It is the responsibility of the fabricator to make provision for the use of this material.

1.2.2 Steels intended to have guaranteed through thickness properties will include the supplementary suffix Z25 or Z35 in the designation, for example: LR DH36 Z35.

1.3 Manufacture

1.3.1 All materials are to be manufactured at works which have been approved by LR for the type and grade of steel which is being supplied and for the relevant steelmaking and processing route.

1.3.2 Steel is to be cast in metal ingot moulds or by the continuous casting process. The size of the ingot, billet or slab is to be proportional to the dimensions of the final product such that the reduction ratio is normally to be at least 3 to 1. Sufficient discard is to be taken to ensure soundness in the portion used for further processing.

1.3.3 The cast analysis to be used for certification purposes is to be determined after all alloying additions have been carried out and sufficient time allowed for such an addition to homogenise.

1.3.4 Material may be supplied either as-rolled, normalised, normalising rolled, or thermomechanically controlled rolled. The following definitions apply:

(a) As-rolled (AR) refers to rolling of steel at high temperature followed by air cooling. The rolling and finishing temperatures are typically in the austenite recrystallisation region and above the normalising temperature. The strength and toughness properties of steel produced by this process are generally less than those of steel heat treated after rolling or steel produced by advanced processes.

(b) Normalising (N) refers to an additional heating cycle of rolled steel above the critical temperature, A_{c3}, and in the lower end of the austenite recrystallisation region followed by air cooling. The process improves the mechanical properties of as-rolled steel by refining the grain size.

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(c) Normalising rolling (NR), also known as controlled rolling, is a rolling procedure in which the final deformation is carried out in the normalising temperature range, resulting in a material condition generally equivalent to that obtained by normalising.

(d) Thermomechanically controlled rolling (TM) is a procedure which involves the strict control of both the steel temperature and the rolling reduction. Generally a high proportion of the rolling reduction is carried out close to the A_{r3} temperature and may involve the rolling in the dual phase temperature region. Unlike normalising rolling the properties conferred by TM (TMCP) cannot be reproduced by subsequent normalising or other heat treatment. The use of accelerated cooling on completion of TM may also be accepted subject to the special approval by LR.

(e) Accelerated Cooling, (AcC) is a process which aims to improve mechanical properties by controlled cooling with rates higher than air cooling immediately after the final TM operation. Direct quenching is excluded from accelerated cooling. The material properties conferred by TM and AcC cannot be reproduced by subsequent normalising or other austenitising heat treatment.

(f) Quenching and Tempering (QT),is a heat treatment process in which steel is heated to an appropriate temperature above the A_{c3} and then cooled with an appropriate coolant for the purpose of hardening the microstructure, followed by tempering, a process in which the steel is re-heated to an appropriate temperature, not higher than the A_{c1} to restore the toughness properties by improving the microstructure.

1.3.5 Where material is being produced by a normalising rolling or a thermomechanically controlled process (T.M.) an additional program of tests for approval is to be carried out under the supervision of the Surveyors and the results are to be to the satisfaction of Lloyd's Register (hereinafter referred to as 'LR').

1.3.6 Weldable high strength steels may be supplied in the quenched and tempered condition for other marine structures, *see* Section 10.

1.4 Quality of materials

1.4.1 Surface and internal imperfections not prejudicial to the proper application of the steel are not, except by special agreement, to be grounds for rejection. Where necessary, suitable methods of non-destructive examination may be used for the detection of harmful surface and internal defects. The extent of this examination, together with an appropriate acceptance standard, is to be agreed between the purchaser, steelmaker and Surveyor and is to be included in the manufacturing specification.

1.5 Dimensional tolerances

1.5.1 For materials intended for hull structural purposes as detailed in Sections 2, 3 and 10, the under thickness tolerance of plates, strip and wide flats is not to exceed 0,3 mm.

1.5.2 The minus tolerance on sections (except for wide flats) is to be in accordance with the requirements of a recognised National or International Standard.

1.5.3 The attention of Shipbuilders and Owners is to be drawn to the fact that when thickness gauging is carried out during the ship's life, estimation of the diminution of hull plating and structure will be based on the nominal thickness, this being the original approved thickness for the item of structure under consideration.

1.5.4 The under thickness tolerance acceptable for classification is to be considered as the lower limit of a range of thickness tolerance which could be found in the normal production of a conventional rolling mill manufacturing material, on average, to the nominal thickness.

1.5.5 The Shipbuilder and Owner may agree in individual cases whether they wish to specify a more stringent under thickness tolerance than that given in 1.5.1.

1.5.6 The minus tolerances for plates and wide flats intended for machinery structures are given in Section 5.

1.5.7 For materials intended for applications as detailed in Sections 4 and 6, no minus tolerance is permitted in the thickness of plates and strip. The minus tolerances on sections are to comply with the requirements of a recognised National or International Standard.

1.5.8 For the materials detailed in Section 7, the under thickness tolerance of material intended for use in the construction of cargo tanks is not to exceed 0,3 mm. For other applications, no minus tolerance is permitted in the thickness of plates and strip.

1.5.9 Dimensional tolerances for material detailed in Section 9 are given in Table 3.9.3.

1.5.10 The thickness of plates and strip is to be measured at random locations whose distance from a longitudinal edge is to be at least 10 mm. Local surface depressions resulting from imperfections and ground areas resulting from the elimination of defects may be disregarded provided that they are in accordance with the requirements of a recognised National or International Standard.

1.5.11 Tolerances relating to length, width, flatness and over thickness are to comply with a National or International Standard.

1.5.12 The responsibility for maintaining the required tolerances and making the necessary measurements rests with the manufacturer. Occasional checking by the Surveyor does not absolve the manufacturer from this responsibility.

1.6 Heat treatment

1.6.1 Acceptable conditions of supply are specified in subsequent Sections of this Chapter.

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1.6.2 The manufacturer is to carry out any heat treatment which may be necessary to prevent hydrogen cracking or to make the material in a safe condition for transit. The Surveyor is to be advised of any heat treatment proposed.

1.6.3 Where material is manufactured using a thermo-mechanically controlled process consideration must be given to the possibility of consequent reduction in mechanical properties if it is subjected to heating for forming or stress relieving or is welded using a high heat input.

1.7 Test material and mechanical tests

1.7.1 Depending on the type of product, provision is made in subsequent Sections of this Chapter for the testing of individual items or for batch testing. Where the latter is permitted, all materials in a batch presented for acceptance tests are to be of the same product form, (e.g. plates, flats, sections, etc.), from the same cast and in the same condition of supply.

1.7.2 The test samples are to be fully representative of the material and, where appropriate, are not to be cut from the material until heat treatment has been completed. The test specimens are not to be separately heat treated in any way.

1.7.3 The test material is to be taken from the thickest piece in each batch, *see* Ch 1, 4.1.

1.7.4 Test material is to be taken from the following positions:

(a) At the square cut end of plates and flats greater than 600 mm wide, approximately one-quarter width from an edge, *see* Fig. 3.1.1(a).

(b) For flats 600 mm or less in width, bulb flats and other solid sections, at approximately one-third of the width from an edge, *see* Fig. 3.1.1(b), (c) and (d). Alternatively, in the case of channels, beams or bulb angles, at approximately one-quarter of the width from the centreline of the web, *see* Fig. 3.1.1(c).

(c) For rectangular hollow sections, at approximately the centre of any side, *see* Fig. 3.1.1(e). For circular hollow sections, at any position on the periphery.

(d) For bars intended for purposes as detailed in Sections 2, 3, 5 and 9, at approximately one-third of the radius or half-diagonal from the outer surface, *see* Fig. 3.1.1(f). For smaller bars, the position of the test material is to be as close as is possible to the above.

(e) For bars intended for the applications detailed in Sections 4, 6 and 7 at approximately 12,5 mm below the surface. For bars up to 25 mm diameter, the test specimens may be machined coaxially.

(f) For plates and flats with thicknesses in excess of 40 mm, full thickness specimens may be prepared, but when instead a machined round specimen is used then the axis is to be located at a position lying one-quarter of the product thickness from the surface as shown in Fig. 3.1.1(g).

1.7.5 Tensile test specimens and impact test specimens, where required for the type and grade of product being supplied, are to be prepared from each item or batch of material submitted for acceptance.

1.7.6 Where the finished width of plates and flats is greater than 600 mm, the tensile test specimens are to be cut with their principal axes perpendicular to the final direction of rolling. For all other rolled products, the principal axes are to be parallel to the final direction of rolling.

1.7.7 The tensile test specimens are to be machined to the dimensions detailed in Ch 2,2.1.6 and 2.1.7.

1.7.8 Impact test specimens are to be cut with their principal axes either parallel (longitudinal test) or perpendicular (transverse test) to the final direction of rolling, as required by subsequent Sections of this Chapter. Where both longitudinal and transverse impact properties are shown for a particular grade, only the longitudinal test is required to be carried out, unless otherwise specified by the purchase order or subsequent Sections of this Chapter. However, for plates and wide flats, by certifying that the product meets the requirements of the Rules, the manufacturer guarantees that the acceptance values will be met if tested in the transverse direction. The Surveyor may request testing in this direction to confirm conformity.

1.7.9 Impact test specimens are to be of the Charpy V-notch type, machined to the dimensions detailed in Chapter 2. They are to be taken from a position within 2 mm of one of the rolled surfaces, except that for plates and sections over 40 mm thick, the axes of the test specimens are to be at one-quarter of the thickness from one of the rolled surfaces. For bars and other similar products the axes of the test specimens are to be as specified in 1.7.4(d).

1.7.10 Standard test specimens 10 mm square are to be used, except where the thickness of the material does not allow this size of test specimen to be prepared. In such cases the largest possible size of subsidiary test specimen, in accordance with Table 2.3.1 is to be prepared, with the notch cut on the narrow face. Alternatively, for material of suitable thickness, the rolled surfaces may be retained so that the test specimen width will be the full thickness of the material. In such cases the tolerances for width given in Table 2.3.1 in Chapter 2 are not applicable. The notch is to be cut in a face of the test specimen which was originally perpendicular to the rolled surface. The position of the notch is to be not nearer than 25 mm to a flame-cut or sheared edge.

1.7.11 Impact tests are not required when the nominal material thickness is less than 6 mm.

1.7.12 The test procedures used for all tensile and impact tests are to be in accordance with the requirements of Chapter 2.

1.8 *Visual and non-destructive examination*

1.8.1 Surface inspection and verification of dimensions are the responsibility of the steelmaker and are to be carried out on all material prior to despatch. Acceptance by the Surveyors of material later found to be defective shall not absolve the steelmaker from this responsibility.

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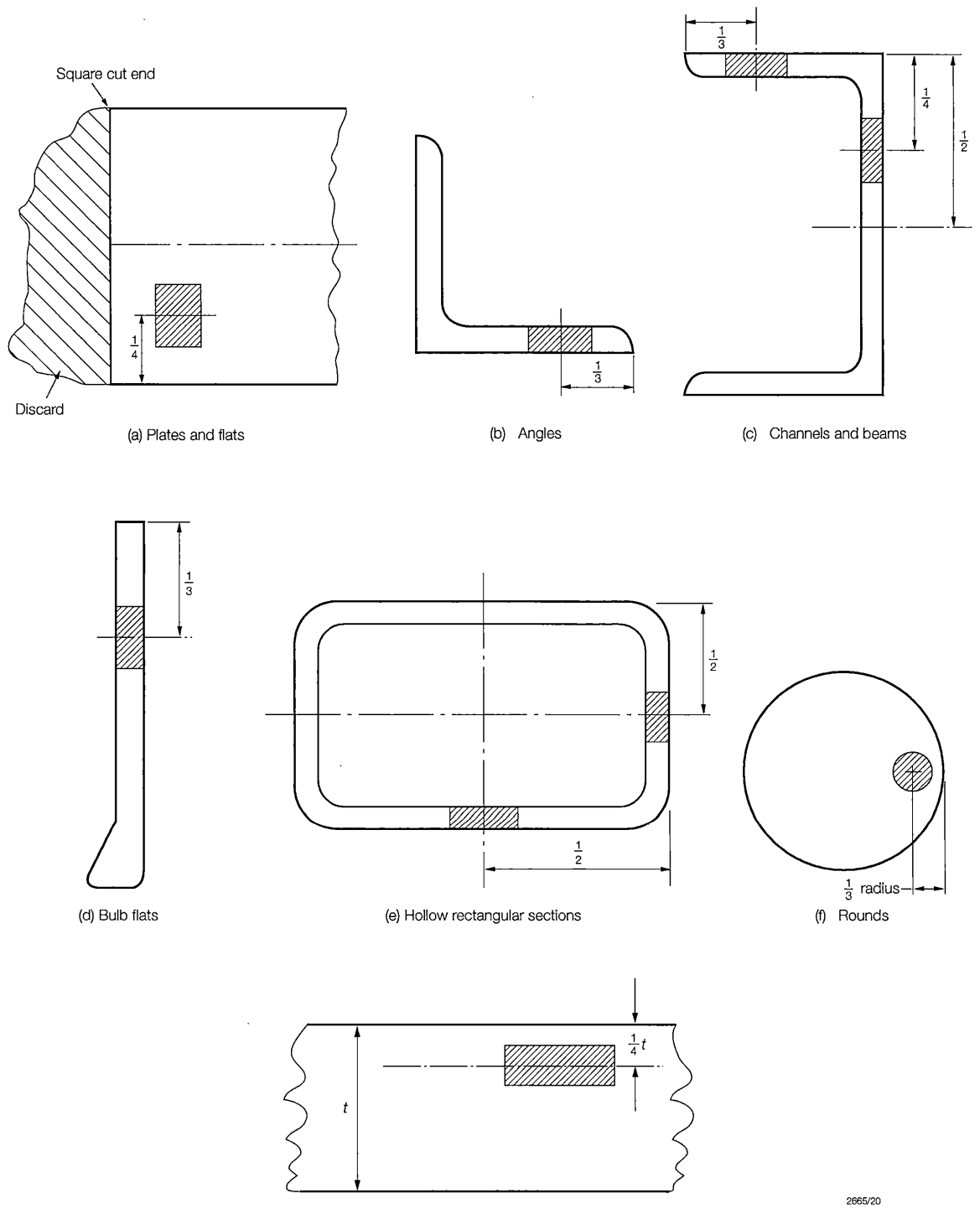

Fig. 3.1.1 Position of test material

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1.8.2 With the exception of 'Z' grade plate material (*see* Section 8) and bars for offshore mooring cable (*see* Section 9), the non-destructive examination of materials is not required for acceptance purposes, *see also* 1.4.1. However, manufacturers are expected to employ suitable methods of non-destructive examination for the general maintenance of quality standards.

1.9 Rectification of defects

1.9.1 For materials intended for structural purposes as detailed in Sections 2, 3 and 5, surface defects may be removed by local grinding provided that:

(a) the thickness is in no place reduced to less than 93 per cent of the nominal thickness, but in no case by more than 3 mm,
(b) each single ground area does not exceed 0,25 m^2,
(c) the total area of local grinding does not exceed two per cent of the total surface,
(d) the ground areas have smooth transitions to the surrounding surface.

Where necessary, the entire surface may be ground to a maximum depth as given by the underthickness tolerances of the product. The extent of such rectification is to be agreed in each case with the Surveyors and is to be carried out under their supervision, unless otherwise agreed. They may request that complete removal of the defect is proven by suitable non-destructive examination of the affected area.

1.9.2 Surface defects which cannot be dealt with as in 1.9.1 may be repaired by chipping or grinding followed by welding, subject to the Surveyor's consent and under his supervision, provided that:

(a) after removal of the defect and before welding, the thickness of the item is in no place reduced by more than 20 per cent,
(b) each single weld does not exceed 0,125 m^2,
(c) the total area of welding does not exceed two per cent of the surface of the side involved,
(d) the distance between any two welds is not less than their average width,
(e) the welds are of reasonable size and made with an excess layer of beads which is then ground smooth to the surface level,
(f) elimination of the defect is proven by suitable non-destructive examination of the affected area,
(g) welding is carried out by an approved procedure and by competent operators using approved electrodes and the repaired area is ground smooth to the correct nominal thickness,
(h) when requested by the Surveyor, the item is normalised or otherwise suitably heat treated after welding and grinding, and
(j) at the discretion of the Surveyor, the repaired area is proven free from defects by suitable non-destructive examination.

1.9.3 For materials intended for applications as detailed in Sections 4, 6 and 7, surface defects may be removed by grinding in accordance with 1.9.1, except that when the thickness is reduced below that given in the approved plans, acceptance will be subject to special consideration. Weld repairs may also be carried out generally in accordance with 1.9.2, except that in all cases suitable heat treatment after welding and non-destructive testing of the repaired areas is required. The fabricator is to be advised regarding the position and extent of all repairs.

1.9.4 For plates which have been produced by a T.M. process or by normalising rolling, repair by welding will be approved by the Surveyor only after procedure tests have shown that the mechanical properties have not been impaired.

1.9.5 Cracks, shells, sand patches and sharp edged seams are always considered defects which would impair the end use of the product and which require rejection or repair irrespective of their size and number. The same applies to other imperfections exceeding the acceptable limits.

1.10 Identification of materials

1.10.1 Every finished item is to be clearly marked by the manufacturer in at least one place with LR's brand ℛ and the following particulars:

(a) The manufacturer's name or trade mark.
(b) The grade of steel. The designations given in subsequent Sections of this Chapter may be preceded by the letters 'LR' in order to fully describe the grade, e.g. LR A, LR 490FG. LR LT-FH40, LR 316L, etc.
(c) When the material complies with the requirements of Section 8, the grade is to include the suffix Z25 or Z35, e.g. LR AH36 Z35.
(d) Identification number and/or initials which will enable the full history of the item to be traced.
(e) If required by the purchaser, his order number or other identification mark.

The above particulars, but excluding the manufacturer's name or trade mark where this is embossed on finished products, are to be encircled with paint or otherwise marked so as to be easily recognisable.

1.10.2 Where a number of light materials are securely fastened together in bundles, the manufacturer may brand only the top piece of each bundle or, alternatively, a firmly fastened durable label containing the identification may be attached to each bundle.

1.10.3 In the event of any material bearing LR's brand failing to comply with the test requirements, the brand is to be unmistakably defaced, *see also* Ch 1,4.8.

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1.11 Certification of materials

1.11.1 Unless a LR certificate is specified in other parts of the Rules, a manufacturer's certificate validated by LR is to be issued (*see* Ch 1,3.1) and is to include the following particulars:

(a) Purchaser's name and order number.
(b) If known, the contract number for which the material is intended.
(c) Address to which material is dispatched.
(d) Name of steelworks.
(e) Description and dimensions of the material.
(f) Specification or grade of the steel.
(g) Identification number of piece, including test specimen number where appropriate.
(h) Cast number and chemical composition of ladle samples.
(j) Mechanical test results (not required on shipping statements).
(k) Condition of supply.

1.11.2 Before the test certificates are signed by the Surveyor, the steelmaker is required to provide a written declaration stating that the material has been made by an approved process, and that it has been subjected to and has withstood satisfactorily the required tests in the presence of the Surveyor, or an authorised deputy. The following form of declaration will be accepted if stamped or printed on each test certificate with the name of the steelworks and signed by an authorised representative of the manufacturer:

'We hereby certify that the material has been made by an approved process and satisfactorily tested in accordance with the Rules of Lloyd's Register'.

1.11.3 When steel is not produced at the works at which it is rolled, a certificate is to be supplied by the steelmaker stating the process of manufacture, the cast number and the chemical composition of ladle samples. The works at which the steel was produced must be approved by LR.

1.11.4 The manufacturer of coiled plate is required to issue a certificate which clearly identifies the material as coil. The certificate issued should include the words; 'Coils covered by this certificate require further processing at a works approved by Lloyd's Register before being certified as plate in accordance with the Rules of Lloyd's Register' in addition to the requirements of 1.11.2.

1.11.5 The supplier of plate cut from coil is required to issue a certificate which clearly identifies the product as finished plate meeting the requirements of the Rules in accordance with 1.11.2.

1.11.6 The form of certificates produced by computer systems is to be agreed with the Surveyor.

Section 2
Normal strength steels for ship and other structural applications

2.1 Scope

2.1.1 The requirements of this Section are primarily intended to apply to steel plates and wide flats not exceeding 100 mm in thickness and sections and bars not exceeding 50 mm in thickness in Grades A, B, D and E. For greater thicknesses, variations in the requirements may be permitted or required for particular applications.

2.1.2 Additional approval tests may be required to verify the suitability for forming and welding of Grade E plate exceeding 50 mm in thickness.

2.2 Manufacture and chemical composition

2.2.1 The method of deoxidation and the chemical composition of ladle samples are to comply with the requirements given in Table 3.2.1.

2.2.2 Small variations from the chemical compositions given in Table 3.2.1 may be allowed for Grade E steel in thicknesses exceeding 50 mm or when any Grade of steel is supplied in a thermo-mechanically controlled processed condition, provided that these variations are documented and approved in advance.

2.2.3 The manufacturer's declared analysis will be accepted subject to occasional checks if required by the Surveyors.

2.2.4 For plate supplied from coil, the chemical analysis can be transposed from the certificate of the coil manufacture onto the re-processor's certificate.

2.3 Condition of supply

2.3.1 All materials are to be supplied in a condition complying with the requirements given in Table 3.2.2. Where alternative conditions are permitted these are at the option of the steelmaker, unless otherwise expressly stated in the order for the material, but a steelmaker is to supply materials only in those conditions for which he has been approved by LR.

2.3.2 Where normalising rolling and thermomechanically controlled rolling (T.M.) processes are used, it is the manufacturer's responsibility to ensure that the programmed rolling schedules are adhered to. Where deviation from the programmed rolling schedule occurs, the manufacturer must ensure that each affected piece is tested and that the local Surveyor is informed.

2.3.3 If a steel product supplied in the T.M. condition is to be subjected to heating for forming or stress relieving or is to be welded by a high energy input process, consideration must be given to the possibility of a consequent reduction in mechanical properties.

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Table 3.2.1 Chemical composition and deoxidation practice

Grade	A	B	D	E
Deoxidation	For $t \leq 50$ mm: Any method (for rimmed steel, *see* Note 1)	For $t \leq 50$ mm: Any method except rimmed steel	For $t \leq 25$ mm: Killed	Killed and fine grain treated with aluminium
	For $t > 50$ mm: Killed	For $t > 50$ mm: Killed	For $t > 25$ mm: Killed and fine grain treated with aluminium	
Chemical composition % (*see* Note 5)				
Carbon	0,21 max. (*see* Note 2)	0,21 max.	0,21 max.	0,18 max.
Manganese	2,5 x C% min.	0,80 min. (*see* Note 3)	0,60 min.	0,70 min.
Silicon	0,50 max.	0,35 max.	0,10 – 0,35	0,10 – 0,35
Sulphur	0,035 max.	0,035 max.	0,035 max.	0,035 max.
Phosphorus	0,035 max.	0,035 max.	0,035 max.	0,035 max.
Aluminium (acid soluble)	—	—	0,015 min. (*see* Note 4)	0,015 min. (*see* Note 4)
	Carbon + $^1/_6$ of the manganese content is not to exceed 0,40%			

NOTES
1. For Grade A, rimmed steel may only be accepted for sections up to a maximum thickness of 12,5 mm, provided that it is stated on the test certificates or shipping statements to be rimmed steel.
2. The maximum carbon content for Grade A steel may be increased to 0,23% for sections.
3. Where Grade B is impact tested the minimum manganese content may be reduced to 0,60%.
4. The total aluminium content may be determined instead of the acid soluble content. In such cases the total aluminium content is to be not less than 0,020%.
5. Where additions of any other elements are made as part of the steelmaking practice, the content is to be recorded.

Table 3.2.2 Condition of supply

Grade	Thickness, mm	Conditions of supply			
A and B	≤50	Any			(*see* Note 1)
	>50 ≤100	N	NR	TM	(*see* Note 2)
D	≤35	Any			(*see* Note 1)
	>35 ≤100	N	NR	TM	(*see* Note 3)
E	≤100	N		TM	(*see* Note 4)

N = normalised
NR = normalising rolled
TM = thermomechanically controlled-rolled

NOTES
1. 'Any' includes as-rolled, normalised, normalising rolled and thermomechanically controlled-rolled.
2. Plates, wide flats, sections and bars may be supplied in the as-rolled condition, subject to special approval from LR.
3. Sections in Grade D steel may be supplied in thicknesses greater than 35 mm in the as-rolled condition provided that satisfactory results are consistently obtained from Charpy V-notch impact tests.
4. Sections in Grade E steel may be supplied in the as-rolled and normalising rolled conditions provided that satisfactory results are consistently obtained from Charpy V-notch impact tests.

2.4 Mechanical tests

2.4.1 The results of all tensile tests and the average energy value from each set of three impact tests are to comply with the appropriate requirements given in Table 3.2.3 except where enhanced by the requirements of this Section.

2.4.2 With the exception given in 2.4.4, one tensile test is to be made for each batch presented unless the mass of finished material is greater than 50 tonnes, in which case one test is to be made from a different piece from each 50 tonnes or fraction thereof. Additional tests are to be made for every variation of 10 mm in the thickness or diameter of products from the same cast. For sections, the thickness to be considered is the thickness of the product at the point at which samples are taken for mechanical tests. A piece is to be regarded as the rolled product from a single slab or billet, or from a single ingot if this is rolled directly into plates, strip, sections or bars.

2.4.3 For Grades A and B where plate is supplied from coil, results of the tensile test can be transposed from the certificate of the coil manufacture onto the certificate issued by the re-processor. If the coil mass exceeds 50 tonnes, testing will additionally be required from two locations representing the start and end of the coil. For Grades D and E, the mechanical properties must be sampled from the de-coiled plate in accordance with the frequency specified in the Rules.

2.4.4 For plates of thickness exceeding 50 mm in Grade E steel, one tensile test is to be made on each piece.

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Table 3.2.3 Mechanical properties for acceptance purposes

Grade	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation on $5{,}65\sqrt{S_o}$ % minimum	Charpy V-notch impact test (*see* Notes 3, 4, 5, 6 and 7)		
				Thickness mm	Average energy J minimum	
					Longitudinal	Transverse (*see* Note 3)
A	235	400 – 520 (*see* Note 1)	22 (*see* Note 2)	≤50	27	20
B				>50 ≤70	34	24
D				>70 ≤100	41	27
E						

Impact tests are to be made on the various grades at the following temperatures:

A grade	not required
B grade	0°C
D grade	–20°C
E grade	–40°C

NOTES

1. For sections in Grade A, the upper limit of the tensile strength range may be exceeded at the discretion of the Surveyor.
2. For full thickness tensile test specimens with a width of 25 mm and a gauge length of 200 mm (*see* Fig. 2.2.4 in Chapter 2), the minimum elongation is to be:

Thickness mm	≤5	>5 ≤10	>10 ≤15	>15 ≤20	>20 ≤25	>25 ≤30	>30 ≤35	>35 ≤50
Elongation %	14	16	17	18	19	20	21	22

3. Tests are to be taken in the longitudinal direction. Normally, transverse test specimens are not required. Transverse test results for plates and wide flats are to be garenteed by the supplier.
4. *See* 2.4.5 and 2.4.6.
5. *See* 2.4.7.
6. *See* 1.7.11.
7. *See* 2.4.14.

2.4.5 For Grade A steel, Charpy V-notch impact tests are not required when the thickness does not exceed 50 mm, or up to 100 mm thick if the material is supplied in either the normalised or thermo-mechanically controlled-rolled condition and has been fine grain treated. However, the manufacturer should confirm, by way of regular in-house checks, that the material will meet a requirement of 27 J at +20°C. The results of these checks shall be reported to the Surveyor. The frequency of these checks should as a minimum be every 250 tonnes.

2.4.6 When Grade A steel is supplied in a thickness greater than 50 mm and either, in the normalising rolled condition, or when special approval has been given to supply in the as-rolled condition, a set of three impact test specimens is to be tested from each batch of 50 tonnes or fraction thereof.

2.4.7 Impact tests are not required for Grade B steel of 25 mm or less in thickness. However, the manufacturer is to confirm, by way of regular in-house tests, and on occasional material selected by the Surveyor, that the material meets the requirement in Table 3.2.3. The results of the tests are to be reported to the Surveyor. The frequency of the in-house checks are to be, as a minimum, one set of three impact test specimens for every 250 tonnes.

2.4.8 For Grade B steels of thicknesses above 25 mm, supplied in the as-rolled or normalising rolled condition, one set of three impact test specimens is to be made from the thickest item in each batch presented. If the mass of finished material is greater than 25 tonnes, one extra set of tests is to be made from a different piece from each 25 tonnes or fraction thereof.

2.4.9 For Grade B steels of thicknesses above 25 mm, supplied in the furnace normalised or thermomechanically controlled-rolled condition, one set of three impact test specimens is to be made from the thickest item in each batch presented. If the mass of finished material is greater than 50 tonnes, one extra set of tests is to be made from a different piece from each 50 tonnes or fraction thereof.

2.4.10 For Grade D steels supplied in the as-rolled or normalising rolled condition, one set of three impact test specimens is to be made from the thickest item in each batch presented. If the mass of finished material is greater than 25 tonnes, one extra set of tests is to be made from a different piece from each 25 tonnes or fraction thereof.

2.4.11 For Grade D steels, supplied in the furnace normalised or thermomechanically controlled-rolled condition, one set of three impact test specimens is to be made from the thickest item in each batch presented. If the mass of finished material is greater than 50 tonnes, one extra set of tests is to be made from a different piece from each 50 tonnes or fraction thereof.

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2.4.12 For plates in Grade E steel, one set of three impact test specimens is to be made from each piece. For bars and sections in Grade E steel, one set of three test specimens is to be made from each 25 tonnes or fraction thereof. When, subject to the special approval of LR, sections are supplied in the as-rolled or normalising rolled conditions, one set of impact tests is to be taken from each batch of 15 tonnes or fraction thereof.

2.4.13 The results of all tensile tests and the average energy values from each set of three impact tests are to comply with the appropriate requirements given in Table 3.2.3. For impact tests, one individual value may be less than the required average value provided that it is not less than 70 per cent of this average value. *See* Ch 1,4.6 for re-test procedures.

2.4.14 For batch tested Grade B and D steel plates supplied in a condition other than furnace normalised, with a thickness equal to, or greater than 25 mm and 12 mm respectively, and where the average value of one set of tests is less than 40 J, two further items from the same batch are to be selected and tested. If these fail to achieve an average of 40 J on either set, each individual piece of the heat is to be tested. The plates are acceptable provided they meet the requirements of Table 3.2.3. Additional testing is not required where the manufacturer can demonstrate to the satisfaction of the Surveyor that the plate was rolled outside the limits of the programmed rolling schedule. In this instance the plate should be rejected, *see also* 2.3.2.

2.4.15 Where standard subsidiary Charpy V-notch test specimens are necessary, *see* Ch 2,3.2.4.

2.5 Identification of materials

2.5.1 The particulars detailed in 1.10 are to be marked on all materials which have been accepted. Where a number of light materials are bundled, the bundle is to be identified in accordance with 1.10.2.

2.6 Certification of materials

2.6.1 At least two copies of each test certificate are to be provided. They are to be of the type and give the information detailed in 1.11 and, additionally, are to indicate if sections in Grade A steel of rimming quality have been supplied. As a minimum, the chemical composition is to include the contents of any grain refining elements used and the residual elements, as detailed in Table 3.2.1.

■ *Section 3*
Higher strength steels for ship and other structural applications

3.1 Scope

3.1.1 Provision is made for material to be supplied in four strength levels, 27S, 32, 36 and 40.

3.1.2 The required notch toughness is designated by subdividing the strength levels into Grades AH, DH, EH and FH.

3.1.3 For the designation to fully identify a steel and its properties the appropriate grade letters should precede the strength level number, e.g. AH32 or FH40.

3.1.4 The requirements of this Section are primarily intended to apply to plates, wide flats, sections and bars not exceeding the thickness limits given in Table 3.3.1. For greater thicknesses, variations in the requirements may be permitted or required for particular applications but a reduction of the required impact energy is not allowed.

Table 3.3.1 Maximum thickness limits

Steel designation				Maximum thickness mm	
				Plates and wide flats	Sections and bars
AH 27S AH 32 AH 36 AH 40	DH 27S DH 32 DH 36 DH 40	EH 27S EH 32 EH 36 EH40	FH27S FH32 FH36 FH40	100	50

3.1.5 It should be noted that the fatigue strength of weldments in steels of high strength levels may not be greater than those of steels of lower strength levels.

3.2 Alternative specifications

3.2.1 Steels differing from the requirements of this Section in respect of chemical composition, deoxidation practice, condition of supply or mechanical properties may be accepted subject to special approval by LR. Such steels are to be given a special designation, *see* 3.7.2.

3.3 Manufacture

3.3.1 All the grades of steel are to be in the killed and fine grain treated condition.

3.4 Chemical composition

3.4.1 The chemical compositions of ladle samples for all grades of steel are to comply with the requirements given in Table 3.3.2.

3.4.2 The carbon equivalent is to be calculated from the ladle analysis using the formula given below and is not to exceed the maximum value agreed between the fabricator and the steelmaker when the steel is ordered.

$$\text{Carbon equivalent} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

For TM steels, the agreed carbon equivalent is not to exceed the values given in Table 3.3.3.

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Table 3.3.2 Chemical composition

Grades	AH, DH, EH	FH
Carbon % max.	0,18	0,16
Manganese %	0,9 – 1,60 (*see* Note 1)	0,9 – 1,60
Silicon % max.	0,50	0,50
Phosphorus % max.	0,035	0,025
Sulphur % max.	0,035	0,025
Grain refining elements (*see* Note 2)		
Aluminium (acid soluble) %	0,015 min. (*see* Note 3)	
Niobium %	0,02 – 0,05	
Vanadium %	0,05 – 0,10	
Titanium %	0,02 max.	
Total (Nb + V + Ti) % (*see* Note 5)	0,12 max.	
Residual elements		
Nickel % max.	0,40	0,80
Copper % max.	0,35	0,35
Chromium % max.	0,20	0,20
Molybdenum % max.	0,08	0,08
Nitrogen % max.		0,009 (0,012 max. if Al is present)

NOTES
1. For AH grade steels in all strength levels and thicknesses up to 12,5 mm, the specified minimum manganese content is 0,70%.
2. The steel is to contain aluminium, niobium, vanadium or other suitable grain refining elements, either singly or in any combination. When used singly, the steel is to contain the specified minimum content of the grain refining element. When used in combination, the specified minimum content of each element is not applicable.
3. The total aluminium content may be determined instead of the acid soluble content. In such cases the total aluminium content is to be not less than 0,020%.
4. Alloying elements other than those listed above are to be included in the approved manufacturing specification.
5. The grain refining elements are to be in accordance with the approved specification.

Table 3.3.3 Carbon equivalent requirements for higher tensile strength steels up to 100 mm in thickness when supplied in the TM condition

Grade	Carbon Equivalent, max. (%)	
	$t \leq 50$	$50 < t \leq 100$
AH 27S DH 27S EH 27S FH 27S	0,36	0,38
AH 32 DH 32 EH 32 FH 32	0,36	0,38
AH 36 DH 36 EH 36 FH 36	0,38	0,40
AH 40 DH 40 EH 40 FH 40	0,40	0,42

NOTE
t = thickness, in mm.

3.4.3 The cold cracking susceptibility, P_{cm}, may be used instead of the carbon equivalent for evaluating weldability, in which case the following formula is to be used for calculating the P_{cm} from the ladle analysis:

$$P_{cm} = C + \frac{Si}{30} + \frac{Mn + Cr + Cu}{20} + \frac{Ni}{60} + \frac{Mo}{15} + \frac{V}{10} + 5B$$

The maximum allowable P_{cm} is to be agreed with LR and is to be included in the manufacturing specification and reported on the certificate.

3.4.4 Small deviations in chemical composition from that given in Table 3.3.2 for plates exceeding 50 mm in thickness in Grades EH36, EH40, FH36 and FH40 may be approved provided that these deviations are documented and approved in advance.

3.4.5 Where the grain refining elements Niobium, Titanium and Vanadium are used either singly or in combination, the chemical composition is to be specifically approved for each Grade in combination with the rolling procedure to be used.

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3.4.6 When any grade is supplied in an approved thermomechanically controlled processed condition, variations in the specified chemical composition may be considered, provided that these variations are documented and approved in advance.

3.4.7 For plate supplied from coil, the chemical analysis can be transposed from the certificate of the coil manufacture onto the re-processor's certificate.

3.5 Condition of supply

3.5.1 All materials are to be supplied in a condition complying with the requirements given in Table 3.3.4 or Table 3.3.5. Where alternative conditions are permitted, these are at the option of the steelmaker, unless otherwise expressly stated in the order for the material.

3.5.2 Where normalising rolling and thermomechanically controlled rolling (T.M.) processes are used, it is the manufacturer's responsibility to ensure that the programmed rolling schedules are adhered to. Where deviation from the programmed rolling schedule occurs, the manufacturer must ensure that each affected piece is tested and that the local Surveyor is informed.

3.5.3 The use of precipitation hardening steels is not acceptable, except where such hardening is incidental to the use of grain refining elements.

3.6 Mechanical tests

3.6.1 The results of all tensile tests and the average energy value from each set of three Charpy V-notch impact tests are to comply with the appropriate requirements given in Table 3.3.6 except where enhanced by the requirements of this Section.

Table 3.3.4 Conditions of supply for plates and wide flats

Grade	Grain refining practice (*see* Note 1)	Thickness range mm	Conditions of supply (*see* Note 2)				
AH 27S AH 32 AH 36	Al or Al + Ti	≤20	AR	N	NR	TM	
		>20 ≤100	–	N	NR	TM	(*see* Note 3)
	Nb or V or Al + (Nb or V) or Al + (Ti) + (Nb or V)	≤12,5	AR	N	NR	TM	
		>12,5 ≤100	–	N	NR	TM	
AH 40	Any practice	≤12,5	AR	N	NR	TM	
		>12,5 ≤50	–	N	NR	TM	
		>50 ≤100	–	N	–	TM	QT
DH 27S DH 32 DH 36	Al or Al + Ti	≤20	AR	N	NR	TM	
		>20 ≤100	–	N	NR	TM	(*see* Note 4)
	Nb or V or Al + (Nb or V) or Al + (Ti) + (Nb or V)	≤12,5	AR	N	NR	TM	
		>12,5 ≤100	–	N	NR	TM	
DH 40	Any practice	≤50	–	N	NR	TM	
		>50 ≤100	–	N	–	TM	QT
EH 27S EH 32 EH 36	Any practice	≤100	–	N	–	TM	
EH 40	Any practice	≤100	–	N	–	TM	QT
FH 27S FH 32 FH 36 FH 40	Any practice	≤100	–	N	–	TM	QT

NOTES
1. Grain refining elements used singly or in any combination, require specific approval from Materials and NDE Department, London office.
2. AR = as-rolled N = furnace normalised NR = normalising rolled
   TM = *thermomechanically controlled-rolled* QT = *quenched and tempered*
3. Material up to 35 mm thick may be supplied in the as-rolled condition provided that prior approval has been obtained from LR.
4. Material up to 25 mm thick may be supplied in the as-rolled condition provided that prior approval has been obtained from LR.

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Table 3.3.5 Conditions of supply for sections and bars

Grade	Grain refining practice (*see* Note 1)	Thickness range mm	Conditions of supply (*see* Note 2)			
AH 27S AH 32 AH 36	Al or Al + Ti	≤20	Any			
		>20 ≤50	N	NR	TM	(*see* Note 3)
	Nb or V or Al + Nb or Al + V or Al + (Ti) + (Nb or V)	≤12,5	Any			
		>12,5 ≤50	N	NR	TM	(*see* Note 3)
AH 40	Any practice	≤12,5	Any			
		>12,5 ≤50	N	NR	TM	
DH 27S DH 32 DH 36	Al or Al + Ti	≤20	Any			
		>20 ≤50	N	NR	TM	(*see* Note 3)
	Nb or V or Al + Nb or Al + V or Al + (Ti) + (Nb or V)	≤12,5	Any			
		>12,5 ≤50	N	NR	TM	(*see* Note 3)
DH 40	Any practice	≤50	N	NR	TM	
EH 27S EH 32 EH 36	Any practice	≤50	N	TM		(*see* Notes 3 and 4)
EH 40	Any practice	≤50	N	TM	QT	
FH 27S FH 32 FH 36 FH 40	Any practice	≤50	N	TM	QT	(*see* Note 4)

NOTES
1. Grain refining elements used singly or in any combination require specific approval from Materials and NDE Department, London Office.
2. N = furnace normalised NR = normalising rolled
   TM = thermomechanically controlled-rolled QT = quenched and tempered
3. Subject to the special approval of LR, sections may be supplied in the as-rolled condition provided satisfactory results are consistently obtained from Charpy V-notch impact tests.
4. Subject to the special approval of LR, sections may be supplied in the NR condition.

3.6.2 For steels in the as-rolled, normalised, normalising rolled or T.M. conditions, one tensile test is to be made for each batch of 50 tonnes or fraction thereof. Additional tests are to be made for every variation of 10 mm in the thickness or diameter of products from the same cast.

3.6.3 Where plate is supplied from coil, both the tensile tests and the Charpy V-notch tests are to be taken from the de-coiled plate in accordance with the frequency specified for the Grade as required by this Section.

3.6.4 For steels in the quenched and tempered condition a tensile test is to be made on each plate as heat treated. For continuously heat treated plates, one tensile test is to be made for each 50 tonnes or fraction thereof from a single cast. Additional tests are to be made for every variation of 10 mm in the thickness of the products from a single cast. The tensile test specimens are to be taken with their axes transverse to the main direction of rolling.

3.6.5 For products in the AH and DH grades, at least one set of three impact tests is to be made on the thickest piece in each batch of 50 tonnes when supplied in either the normalised or thermomechanically controlled condition. When the products are supplied in the as-rolled or normalising rolled conditions a set of impact test specimens is to be taken from a different piece from each 25 tonnes or fraction thereof. When supplied in the quenched and tempered condition, a set of impact tests is to be made on each length as heat treated. Test specimens from the quenched and tempered plates are to have their axes transverse to the main rolling direction.

3.6.6 For plates and wide flats in the EH and FH grades supplied in the normalised or thermomechanically controlled conditions, one set of impact tests is to be made on each piece. For plates supplied in the quenched and tempered condition a set of impact tests is to be made on each length as heat treated. Test specimens from the quenched and tempered plates are to have their axes transverse to the main rolling direction.

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Table 3.3.6 Mechanical properties for acceptance purposes (*see* Note 1)

Grades (*see* Note 3)	Yield Stress N/mm^2 min.	Tensile Strength N/mm^2	Elongation on $5{,}65\sqrt{S_o}$ % min. (*see* Note 2)	Charpy V-notch impact tests (*see* Notes 3, 4 and 5) Average energy J minimum					
				$t \leq 50$ mm		$50 < t \leq 70$ mm		$70 < t \leq 100$ mm	
				Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse
AH 27S DH 27S EH 27S FH 27S	265	400 – 530	22	27	20	34	24	41	27
AH 32 DH 32 EH 32 FH 32	315	440 – 570	22	31	22	38	26	46	31
AH 36 DH 36 EH 36 FH 36	355	490 – 630	21	34	24	41	27	50	34
AH 40 DH 40 EH 40 FH 40	390	510 – 650	20	39	26	46	31	55	37

Impact tests are to be made on the various grades at the following temperatures:

AH grades 0°C
DH grades –20°C
EH grades –40°C
FH grades –60°C

NOTES

1. The requirements for products thicker than those detailed in the table are subject to agreement, *see* 3.1.4.
2. For full thickness tensile test specimens with a width of 25 mm and a gauge length of 200 mm, *see* Fig. 2.2.4 in Chapter 2, the minimum elongation is to be:

Thickness mm		≤5	>5 ≤10	>10 ≤15	>15 ≤20	>20 ≤25	>25 ≤30	>30 ≤40	>40 ≤50	>50
Elongation %	Strength levels 27S, 32	14	16	17	18	19	20	21	22	To be specially agreed
	Strength level 36	13	15	16	17	18	19	20	21	
	Strength level 40	12	14	15	16	17	18	19	20	

3. Subject to special approval by LR, the minimum tensile strength may be reduced to 470 N/mm^2, for grades AH36, DH36, EH36 and FH36, in the TM condition when micro-alloying elements Nb, Ti or V are used singly and not in combination and provided the yield to tensile strength ratio does not exceed 0,89. For plates with a thickness ≤12 mm, the yield to tensile strength ratio is to be specially considered.
4. Tests are to be taken in the longitudinal direction. Normally, transverse test specimens are not required. Transverse test results for plates and wide flats are to be guaranteed by the supplier.
5. *See* 1.7.11
6. *See* 3.6.8.

3.6.7 For sections and bars in the EH and FH grades supplied in the normalised or thermomechanically controlled conditions, one set of impact tests is to be made on the thickest piece in a batch not exceeding 25 tonnes. For sections supplied in the as-rolled or normalising rolled conditions the batch size is not to exceed 15 tonnes.

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3.6.8 For batch tested plates in a condition other than furnace normalised, with a thickness equal to 12 mm or greater, and where the average value of one set of tests is less than 50 J, two further items from the same batch are to be selected and tested. If these fail to achieve an average of 50 J on either set, each individual piece of the heat is to be tested. The plates are acceptable provided they meet the requirements of Table 3.3.6. Additional testing is not required where the manufacturer can demonstrate to the satisfaction of the Surveyor that the plate was rolled outside the limits of the programmed rolling schedule. In this instance the plate should be rejected, *see also* 3.5.2.

3.6.9 Where standard subsidiary impact specimens are necessary, *see* Ch 2,3.2.4.

3.7 Identification of materials

3.7.1 The particulars detailed in 1.10 are to be marked on all materials which have been accepted and, for ease of recognition, are to be encircled or otherwise marked with paint. Where a number of light products are bundled, the bundle is to be identified in accordance with 1.10.2.

3.7.2 Steels which have been specially approved and which differ from the requirements of this Section are to have the letter 'S' after the agreed identification mark.

3.8 Certification of materials

3.8.1 At least two copies of each test certificate are to be provided. They are to be of the type and give the information detailed in 1.11 and, additionally, are to state the specified maximum carbon equivalent. As a minimum, the chemical composition is to include the contents of any grain refining elements used and of the residual elements.

3.8.2 For steels which have been specially approved, the agreed identification mark, the specified minimum yield stress and, if applicable, the contents of alloying elements are additionally to be stated on the test certificate or shipping statement.

3.8.3 The steelmaker is to provide the Surveyor with a written declaration as detailed in 1.11.2.

■ *Section 4*
Steels for boilers and pressure vessels

4.1 Scope

4.1.1 Provision is made in this Section for carbon, carbon-manganese and alloy steels intended for use in the construction of boilers and pressure vessels. In addition to specifying mechanical properties at ambient temperature for the purposes of acceptance testing, these requirements also give details of appropriate mechanical properties at elevated temperatures which may be used for design purposes.

4.1.2 Where it is proposed to use a carbon or carbon-manganese steel with a specified minimum tensile strength intermediate to those given in this Section, corresponding minimum values for the yield stress, elongation and mechanical properties at elevated temperatures may be obtained by interpolation.

4.1.3 Carbon and carbon-manganese steels with a specified minimum tensile strength of greater than 490 N/mm^2 but not exceeding 520 N/mm^2 may be accepted, provided that details of the proposed specification are submitted for approval.

4.1.4 Where it is proposed to use alloy steels other than as given in this Section, details of the specification are to be submitted for approval. In such cases the specified minimum tensile strength is not to exceed 600 N/mm^2.

4.1.5 Materials intended for use in the construction of the cargo tanks and process pressure vessels storage tanks for liquefied gases and for other low temperature applications are to comply with the requirements of Section 6 or 7, as appropriate.

4.2 Manufacture and chemical composition

4.2.1 The method of deoxidation and the chemical composition of ladle samples are to comply with the appropriate requirements of Table 3.4.1.

4.2.2 For plate supplied from coil, the chemical analysis may be transposed from the certificate of the coil manufacture onto the re-processor's certificate.

4.3 Heat treatment

4.3.1 All materials are to be supplied in a condition complying with the requirements given in Table 3.4.2 except that, when agreed, material intended for hot forming may be supplied in the as-rolled condition.

4.4 Mechanical tests

4.4.1 For plates, a tensile test specimen is to be taken from one end of each piece when the mass does not exceed 5 tonnes and the length does not exceed 15 m. When either of these limits is exceeded, tensile test specimens are to be taken from both ends of each piece. A piece is to be regarded as the rolled product from a single slab or from a single ingot if this is rolled directly into plates.

4.4.2 For strip, tensile test specimens are to be taken from both ends of each coil.

4.4.3 Sections and bars are to be presented for acceptance test in batches containing not more than 50 lengths, as supplied. The material in each batch is to be of the same section size, from the same cast and in the same condition of supply. One tensile test specimen is to be taken from material representative of each batch, except that additional tests are to be taken when the mass of a batch exceeds 10 tonnes.

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Table 3.4.1 Chemical composition and deoxidation practice

Grade of steel	Deoxidation	Chemical composition %						
Carbon and carbon-manganese steels		C max.	Si	Mn	P	S	Al	Residual elements
360 AR	Any method except rimmed steel	0,18	0,50 max.	0,40 – 1,20	0,040 max.		–	Cr 0,25 max. Cu 0,30 max. Mo 0,10 max. Ni 0,30 max. Total 0,70 max.
410 AR		0,21		0,40 – 1,30			–	
460 AR		0,23		0,80 – 1,50			–	
360	Any method except rimmed steel	0,17	0,35 max.	0,40 – 1,20	0,035 max.		–	
410		0,20		0,50 – 1,30			–	
460		0,20 (*see* Note 1)	0,40 max.	0,80 – 1,40			–	
490	Killed		0,10 – 0,50	0,90 – 1,60			–	
360 FG	Killed fine grained	0,17	0,35 max.	0,40 – 1,20	0,035 max.		(*see* Note 2)	
410 FG		0,20		0,50 – 1,30				
460 FG		0,20 (*see* Note 1)	0,40 max.	0,80 – 1,50				
490 FG			0,10 – 0,50	0,90 – 1,60				
510 FG		0,22						

Alloy steel		C	Si	Mn	P S	Al	Cr	Mo	Residual elements
13Cr Mo 45	Killed	0,10–0,18	0,15–0,35	0,4–0,8	0,035 max.	(*see* Note 3)	0,70–1,30	0,40–0,60	Cu 0,30 max.
11Cr Mo 910		0,08–0,18	0,15–0,50				2,00–2,50	0,90–1,10	Ni 0,30 max.

NOTES
1. For thicknesses greater than 30 mm, carbon 0,22% max.
2. Aluminium (acid soluble) 0,015% min. or
   Aluminium (total) 0,018% min.
   Niobium, vanadium or other suitable grain refining elements may be used either in place of or in addition to aluminium.
3. Aluminium (acid soluble or total) 0,020% max.

Table 3.4.2 Condition of supply

Grade of steel	Condition of supply
Carbon and carbon-manganese 360 AR to 460 AR	As-rolled Maximum thickness or diameter is 40 mm
Carbon and carbon-manganese 360 to 490	Normalised or normalised rolled
Carbon and carbon-manganese 360 FG to 510 FG	Normalised or normalised rolled
13Cr Mo 45	Normalised and tempered
11Cr Mo 910	Normalised and tempered

4.4.4 Where plates are required for hot forming and it has been agreed that the heat treatment will be carried out by the fabricator, the tests at the steelworks are to be made on material which has been cut from the plates and given a normalising and tempering heat treatment in a manner simulating the treatment which will be applied to the plates.

4.4.5 If required by the Surveyors or by the fabricator, test material may be given a simulated stress relieving heat treatment prior to the preparation of the test specimens. This has to be stated on the order together with agreed details of the simulated heat treatment and the mechanical properties which can be accepted.

4.4.6 The results of all tensile tests are to comply with the appropriate requirements given in Tables 3.4.3 to 3.4.5.

4.4.7 Where plate is supplied from coil, the tensile tests are to be taken from the de-coiled plate in accordance with the frequency specified for the Grade as required by this Section.

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Table 3.4.3 Mechanical properties for acceptance purposes: carbon and carbon-manganese steels – As-rolled

Grade of steel	Thickness mm	Yield stress N/mm² minimum	Tensile strength N/mm²	Elongation on $5{,}65\sqrt{S_o}$ % minimum
360 AR	≤ 40	190	360–480	24
410 AR	≤ 40	215	410–530	22
460 AR	≤ 40	240	460–580	21

Table 3.4.4 Mechanical properties for acceptance purposes: carbon and carbon-manganese steels – Normalised or normalised rolled

Grade of steel	Thickness mm (*see* Note)	Yield stress N/mm² minimum	Tensile strength N/mm²	Elongation on $5{,}65\sqrt{S_o}$ % minimum
360	>3 ≤16	205	360 – 480	26
	>16 ≤40	195		26
	>40 ≤63	185		25
410	>3 ≤16	235	410 – 530	24
	>16 ≤40	225		24
	>40 ≤63	215		23
460	>3 ≤16	285	460 – 580	22
	>16 ≤40	255		22
	>40 ≤63	245		21
490	>3 ≤16	305	490 – 610	21
	>16 ≤40	275		21
	>40 ≤63	265		20
360 FG	>3 ≤16	235	360 – 480	26
	>16 ≤40	215		26
	>40 ≤63	195		25
410 FG	>3 ≤16	265	410 – 530	24
	>16 ≤40	245		24
	>40 ≤63	235		23
460 FG	>3 ≤16	295	460 – 580	22
	>16 ≤40	285		22
	>40 ≤63	275		21
490 FG	>3 ≤16	315	490 – 610	21
	>16 ≤40	315		21
	>40 ≤63	305		21
510 FG	>3 ≤16	355	510 – 650	21
	>16 ≤40	345		
	>40 ≤63	335		

NOTE
For thicknesses greater than 63 mm, the minimum values for yield stress may be reduced by 1% for each 5 mm increment in thickness over 63 mm. The minimum elongation values may also be reduced one unit, for all thicknesses over 63 mm. For thicknesses over 100 mm, the above values are to be agreed.

Table 3.4.5 Mechanical properties for acceptance purposes: alloy steels – Normalised and tempered

Grade of steel	Thickness mm (see Note)	Yield stress N/mm² minimum	Tensile strength N/mm²	Elongation on $5{,}65\sqrt{S_o}$ % minimum
13Cr Mo45	≤63	305	470–620	20
11Cr Mo910	≤16	275	480–630	18
	>16 ≤63	265		

NOTE
For thicknesses greater than 63 mm, the minimum values for yield stress may be reduced by 1% for each 5 mm increment in thickness over 63 mm. The minimum elongation values may also be reduced one unit, e.g. for all thicknesses over 63 mm. For thicknesses over 100 mm, the above values are to be agreed.

4.4.8 All test specimens are to be taken in the transverse direction unless otherwise agreed.

4.4.9 When material will be subject to strains in a through thickness direction, it is recommended that it should have specified through thickness properties in accordance with the requirements of Section 8.

4.5 Identification of materials

4.5.1 The particulars detailed in 1.10 are to be marked on all materials which have been accepted.

4.6 Certification of materials

4.6.1 At least two copies of each test certificate are to be provided. They are to be of the type and to give the information detailed in 1.11 and, additionally, are to state the specified maximum carbon equivalent. As a minimum, chemical composition is to include the content of any grain refining elements used and of the residual elements, as detailed in Table 3.4.1.

4.7 Mechanical properties for design purposes

4.7.1 Nominal values for the minimum lower yield or 0,2 per cent proof stress at temperatures of 50°C and higher are given in Tables 3.4.6 to 3.4.8.

4.7.2 These values are intended for design purposes only, and verification is not required except for materials complying with National or proprietary specifications where the elevated temperature properties used for design purposes are higher than given in Tables 3.4.6 to 3.4.8.

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Table 3.4.6 Mechanical properties for design purposes (*see* 4.7.1) **: carbon and carbon-manganese steels – As-rolled**

Grade of steel	Thickness mm	Design temperature °C (*see* Note)						
		50	100	150	200	250	300	350
		Nominal minimum lower yield or 0,2% proof stress N/mm^2						
360 AR	≤ 40	154	153	152	145	128	108	102
410 AR	≤ 40	186	183	181	174	155	134	127
460 AR	≤ 40	218	213	210	203	182	161	153

NOTE
Maximum permissible design temperature is 350°C.

4.7.3 In such cases, at least one tensile test at the proposed design or other agreed temperature is to be made on material from each cast. Where materials of more than one thickness are supplied from one cast, the thickest material is to be tested. The test specimens are to be prepared from material adjacent to that used for tests at ambient temperature. The axis of the test specimens is to be between mid and quarter thickness of the material and the test specimens are to be machined to dimensions in accordance with the requirements of Chapter 2. The test procedure is also to be as detailed in Chapter 2, and the results are to comply with the requirements of the National or proprietary specifications.

4.7.4 As an alternative to 4.7.3, a manufacturer may carry out an agreed comprehensive test program for a stated grade of steel to demonstrate that the specified minimum mechanical properties at elevated temperatures can be consistently obtained. This test program is to be carried out under supervision of the Surveyors, and the results submitted for assessment and approval. When a manufacturer is approved on this basis, tensile tests at elevated temperatures are not required for acceptance purposes but, at the discretion of the Surveyors, occasional check tests of this type may be requested.

Table 3.4.7 Mechanical properties for design purposes (*see* 4.7.1)**: carbon and carbon-manganese steels – Normalised or controlled-rolled**

Grade of steel	Thickness mm (*see* Note)	Design temperature °C								
		50	100	150	200	250	300	350	400	450
		Nominal minimum lower yield or 0,2% proof stress N/mm^2								
360	>3 ≤16	183	175	172	168	150	124	117	115	113
	>16 ≤40	173	171	169	162	144	124	117	115	113
	>40 ≤63	166	162	158	152	141	124	117	115	113
410	>3 ≤16	220	211	208	201	180	150	142	138	136
	>16 ≤40	204	201	198	191	171	150	142	138	136
	>40 ≤63	196	192	188	181	168	150	142	138	136
460	>3 ≤16	260	248	243	235	210	176	168	162	158
	>16 ≤40	235	230	227	220	198	176	168	162	158
	>40 ≤63	227	222	218	210	194	176	168	162	158
490	>3 ≤16	280	270	264	255	228	192	183	177	172
	>16 ≤40	255	248	245	237	214	192	183	177	172
	>40 ≤63	245	240	236	227	210	192	183	177	172
360 FG	>3 ≤16	214	204	185	165	145	127	116	110	106
	>16 ≤40	200	196	183	164	145	127	116	110	106
	>40 ≤63	183	179	172	159	145	127	116	110	106
410 FG	>3 ≤16	248	235	216	194	171	152	141	134	130
	>16 ≤40	235	228	213	192	171	152	141	134	130
	>40 ≤63	222	215	204	188	171	152	141	134	130
460 FG	>3 ≤16	276	262	247	223	198	177	167	158	153
	>16 ≤40	271	260	242	220	198	177	167	158	153
	>40 ≤63	262	251	235	217	198	177	167	158	153
490 FG	>3 ≤16	297	284	265	240	213	192	182	173	168
	>16 ≤40	293	279	260	237	213	192	182	173	168
	>40 ≤63	286	272	256	234	213	192	182	173	168
510 FG	>3 ≤63	313	290	270	255	235	215	200	180	—

NOTE
For thicknesses greater than 63 mm, the values for lower yield or 0,2% proof stress are to be reduced by 1% for each 5 mm increment in thickness up to 100 mm. For thicknesses over 100 mm, the values are to be agreed and verified by test.

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Table 3.4.8 Mechanical properties for design purposes (*see* 4.7.1)**: alloy steels – Normalised and tempered**

Grade of steel	Thickness mm (see Note)	Design temperature °C									
		50	100	200	300	350	400	450	500	550	600
		Nominal minimum lower yield or 0,2% proof stress N/mm^2									
13CrMo 45	>3 ≤63	284	270	248	216	203	199	194	188	181	174
11CrMo 910	>3 ≤63	255	249	233	219	212	207	194	180	160	137

NOTE
For thicknesses greater than 63 mm, the values for lower yield or 0,2% proof stress are to be reduced by 1% for each 5 mm increment in thickness up to 100 mm. For thicknesses over 100 mm, the values are to be agreed and verified by test.

4.7.5 Values for the estimated average stress to rupture in 100 000 hours are given in Table 3.4.9 and may be used for design purposes.

Table 3.4.9 Mechanical properties for design purposes (*see* 4.7.5)**: estimated average values for stress to rupture in 100 000 hours (units N/mm^2)**

Temperature °C	Grades of steel				
	Carbon and carbon-manganese			Low alloy	
	360FG 410FG 460FG	360 410 460	490 490FG 510FG	13CrMo 45	11CrMo 910
380	171	219	227	—	—
390	155	196	203	—	—
400	141	173	179	—	—
410	127	151	157	—	—
420	114	129	136	—	—
430	102	109	117	—	—
440	90	92	100	—	—
450	78	78	85	290	—
460	67	67	73	262	—
470	57	57	63	235	210
480	47	48	55	208	186
490	36	—	47	181	165
500	—	—	—	155	145
510	—	—	—	129	128
520	—	—	—	103	112
530	—	—	—	80	98
540	—	—	—	62	84
550	—	—	—	49	72
560	—	—	—	42	61
570	—	—	—	36	51
580	—	—	—	—	44

Section 5
Steels for machinery fabrications

5.1 General

5.1.1 Steel plates, sections or bars intended for use in the construction of major components of welded machinery structures, such as bedplates, crankcases, frames and entablatures, are to comply with one of the following alternatives:

(a) Any grade of normal strength structural steel as detailed in Section 2.

(b) Any grade of higher tensile structural steel as detailed in Section 3.

(c) Any grade of carbon-manganese boiler or pressure vessel steel as detailed in Section 4, except that for this application batch testing is acceptable. The size of a batch and the number of tensile tests are to be as detailed in Section 2.

5.1.2 The minus tolerances for products for machinery structures are to be in accordance with Table 3.5.1.

Table 3.5.1 Under thickness tolerances

Nominal thickness, t (mm)	Minus tolerance (mm)
$5 \leq t < 8$	–0,4
$8 \leq t < 15$	–0,5
$15 \leq t < 25$	–0,6
$25 \leq t < 40$	–0,8
$t \geq 40$	–1,0

5.2 Certification of materials

5.2.1 At least two copies of each test certificate are to be provided. They are to be of the type and give the information detailed in 1.11 and, additionally, are to state the specified maximum carbon equivalent. As a minimum, chemical composition is to include the contents of any grain refining elements used and of the residual elements.

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Section 6
Ferritic steels for low temperature service

6.1 Scope

6.1.1 This Section gives specific requirements for carbon-manganese and nickel alloy steels intended for use in the construction of cargo tanks, storage tanks and process pressure vessels for liquefied gases.

6.1.2 The requirements of this Section are also applicable for other types of pressure vessels where the use of steels with guaranteed impact properties at low temperatures is required.

6.1.3 Provision is made for plates and sections up to 40 mm thick.

6.1.4 Steels with alternative chemical compositions or mechanical properties or in a different supply condition may be given special consideration.

6.2 Manufacture and chemical composition

6.2.1 All steels are to be in the killed and fine grain treated condition.

6.2.2 The chemical compositions of carbon-manganese steels are to comply with the appropriate requirements for Grades AH, DH, EH and FH strength levels 27S, 32, 36 and 40, *see* Table 3.3.2. For the uses defined in 6.1.1 and 6.1.2, however, these grades are to be designated LT–AH, LT–DH, LT–EH and LT–FH respectively.

6.2.3 The chemical compositions of nickel alloy steels are to comply with the appropriate requirements of Table 3.6.1.

6.2.4 For plate supplied from coil, the chemical analysis may be transposed from the certificate of the coil manufacture onto the re-processor's certificate.

6.3 Heat treatment

6.3.1 All materials are to be supplied in a condition complying with the requirements given in Table 3.6.2.

Table 3.6.2 Supply conditions

Grade	Plates	Sections and bars
LT – AH	N TM	Any
LT – DH		
LT – EH	Normalised (*see* Note) T.M.C.P.	
LT – FH	Quenched and tempered	N TM
1 1/2 Ni 3 1/2 Ni 5Ni	Normalised (*see* Note) Normalised and tempered Quenched and tempered	
9Ni	Double normalised and tempered Quenched and tempered	
NOTE Where the term 'Normalised' is used it does not include normalising rolling.		

6.4 Mechanical tests

6.4.1 For plates, a tensile test specimen is to be taken from one end of each piece when the mass does not exceed 5 tonnes and the length does not exceed 15 m. When either of these limits is exceeded, tensile test specimens are to be taken from both ends of each piece. A piece is to be regarded as the rolled product from a single slab or from a single ingot if this is rolled directly into plates.

6.4.2 For strips, tensile test specimens are to be taken from both ends of each coil.

6.4.3 Sections and bars are to be presented for acceptance test in batches containing not more than 50 lengths, as supplied. The material in each batch is to be of the same section size, from the same cast and in the same condition of supply. One tensile test specimen is to be taken from material representative of each batch, except that additional tests are to be taken when the mass of a batch exceeds 10 tonnes.

6.4.4 One set of three Charpy V-notch impact test specimens is to be taken for each tensile test specimen required.

Table 3.6.1 Chemical compositions of nickel alloy steels

Grade of steel	C	Si	Mn	Ni	P	S	Residual elements	Aluminium
1 1/2 Ni	0,18 max.	0,10 – 0,35	0,30 – 1,50	1,30 – 1,70	0,025 max.	0,020 max.	Cr 0,25 max. Cu 0,35 max. Mo 0,08 max. Total 0,60 max.	Total 0,020% min. Acid soluble 0,015% min.
3 1/2 Ni	0,15 max.		0,30 – 0,90	3,20 – 3,80				
5Ni	0,12 max.			4,70 – 5,30				
9Ni	0,10 max.			8,50 – 10,0				

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6.4.5 For plates, these impact test specimens are to be cut with the principal axis perpendicular to the final direction of rolling. For sections, the impact test specimens are to be taken longitudinally.

6.4.6 The results of all tensile tests are to comply with the appropriate requirements given in Table 3.6.3. The ratio between the yield stress and the tensile strength is not to exceed 0,9 for normalised and TM steels and 0,94 for QT steels.

6.4.7 The average value for the three impact tests is to comply with the appropriate requirements given in Table 3.6.3. One individual value may be less than the required value provided that it is not less than 70 per cent of this average value. *See* Ch 2,1.4 for re-test procedures.

6.4.8 Where standard subsidiary impact specimens are necessary, *see* Ch 2,3.2.4.

6.4.9 Where plate is supplied from coil, both the tensile tests and the Charpy V-notch tests are to be taken from the de-coiled plate in accordance with the frequency specified for the Grade as required by this Section.

6.5 Identification of materials

6.5.1 The particulars detailed in 1.10 are to be marked on all materials which have been accepted.

6.6 Certification of materials

6.6.1 At least two copies of each test certificate are to be provided. They are to be of the type and give the information detailed in 1.11 together with general details of the heat treatment. As a minimum, chemical composition is to include the contents of any grain refining elements used and of the residual elements as detailed in Tables 3.3.2 or 3.6.1.

Table 3.6.3 Mechanical properties for acceptance purposes (*see* Note 1)

Grade of steel	Yield stress N/mm^2 min.	Tensile strength N/mm^2	Elongation on $5{,}65\sqrt{S_o}$ % min.	Charpy V-notch impact tests (*see* Note 3)	
				Test temp. °C	Impact energy
27S	265	400 – 530	22		
32	315	440 – 590	22		
LT – AH 36	355	490 – 620	21	0	
40	390	510 – 650	20		
27S	265	400 – 530	22		
32	315	440 – 590	22		
LT – DH 36	355	490 – 620	21	–20	Plates – transverse tests
40	390	510 – 650	20		
27S	265	400 – 530	22		Average energy 27 J min
32	315	440 – 590	22		
LT – EH 36	355	490 – 620	21	–40	
40	390	510 – 650	20		
27S	265	400 – 530	22		Sections and bars – longitudinal tests
32	315	440 – 590	22		
LT – FH 36	355	490 – 620	21	–60	
40	390	510 – 650	20		Average energy 41 J min
$1\frac{1}{2}$ Ni	275	490 – 640	22	–65	
$3\frac{1}{2}$ Ni	285	450 – 610	21	–95	
5Ni	390	540 – 740	21	–110	
9Ni	490	640 – 790	18	–196	

NOTES
1. These requirements are applicable to products not exceeding 40 mm in thickness. The requirements for thicker products are subject to agreement.
2. The minimum design temperatures at which plates of different thicknesses in the above grades may be used are given in Fig. 3.6.1 and Fig. 3.6.2. Consideration will be given to the use of thicknesses greater than those in the Tables or to the use of design temperatures below –165°C.
3. Impact tests are not required on thicknesses less than 6 mm.

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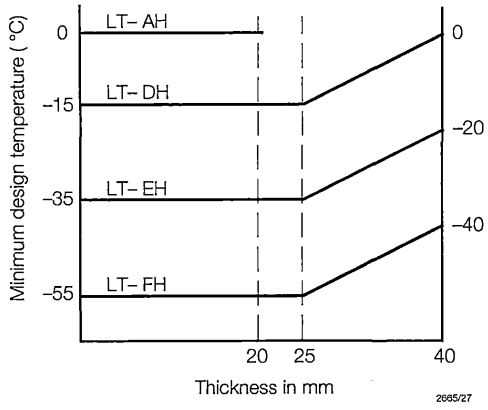

Fig. 3.6.1
Minimum design temperatures for carbon-manganese grades

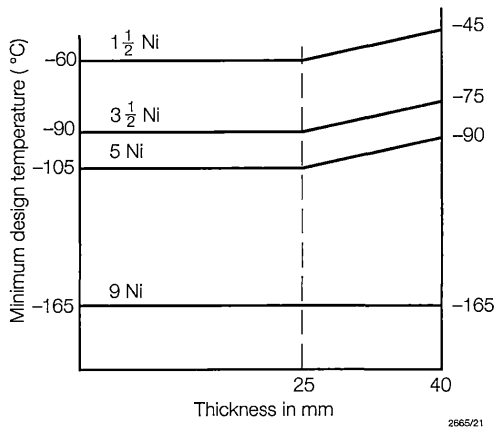

Fig. 3.6.2
Minimum design temperatures for nickel grades

Section 7
Austenitic and duplex stainless steels

7.1 Scope

7.1.1 Provision is made in this Section for rolled products in austenitic and duplex (austenite plus ferrite) stainless steels intended for use in the construction of cargo tanks, storage tanks and process pressure vessels for chemicals and liquefied gases.

7.1.2 Austenitic stainless steels are suitable for applications where the lowest design temperature is not lower than –165°C.

7.1.3 Austenitic stainless steels are also suitable for service at elevated temperatures, and for such applications the proposed specification should contain, in addition to the requirements of 7.1.6, minimum values for 0,2 and 1,0 per cent proof stresses at the design temperature.

7.1.4 Duplex stainless steels are suitable for applications where the lowest design temperature is above 0°C. Any requirement to use duplex stainless steels below 0°C will be subject to special consideration.

7.1.5 Duplex stainless steels are also suitable for service at temperatures up to 300°C, and for such applications the proposed specification should include, in addition to the requirements of 7.1.6, a minimum value for 0,2 per cent proof stress at the design temperature.

7.1.6 A specification giving details of the chemical composition, heat treatment and mechanical properties, including, for the austenitic grades, both the 0,2 and 1,0 per cent proof stresses, is to be submitted for consideration and approval.

7.2 Chemical composition

7.2.1 The chemical composition of ladle samples is to comply with the requirements given in Table 3.7.1.

7.2.2 Consideration will be given to the use of steels whose compositions are outside the scope of Table 3.7.1.

7.3 Heat treatment

7.3.1 All materials are to be supplied in the solution treated condition.

7.4 Mechanical tests

7.4.1 Tensile test specimens are to be taken in accordance with the appropriate requirements of 4.4 and 6.4.1.

7.4.2 For the duplex grades, one set of three Charpy V-notch impact test specimens machined from the longitudinal direction for each tensile test is to be tested at –20°C. The average energy value of the three specimens is to be not less than 41 Joules.

7.4.3 Unless otherwise agreed, impact tests are not required from the austenitic grades of steel given in this Section.

7.4.4 Where standard subsidiary Charpy V-notch test specimens are necessary, *see* Ch 2,3.2.4.

7.4.5 The results of all tensile tests are to comply with the requirements of Table 3.7.2 or the approved specification.

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Table 3.7.1 Chemical composition

Type and grade of steel	Chemical composition % (*see* Note)									
	C	Si	Mn	P	S	Cr	Ni	Mo	N	Other
Austenitic										
304 L						17,0—20,0	8,0—13,0	—	0,10	—
304 LN						17,0—20,0	8,0—12,0	—	0,10—0,22	—
316 L	0,03					16,0—18,5	10,0—15,0	2,0—3,0	0,10	—
316 LN		1,0	2,0	0,045	0,03	16,0—18,5	10,0—14,5	2,0—3,0	0,10—0,22	—
317 L						18,0—20,0	11,0—15,0	3,0—4,0	0,10	—
317 LN						18,0—20,0	12,5—15,0	3,0—4,0	0,10—0,22	—
321	0,08					17,0—19,0	9,0—12,0	—	0,10	$5 \times C \leq Ti \leq 0,7$
347	0,08					17,0—19,0	9,0—13,0	—	0,10	$10 \times C \leq Nb \leq 1,0$
Duplex										
UNS S 31803	0,03	1,0	2,0	0,03	0,02	21,0—23,0	4,5—6,5	2,5—3,5	0,08—0,20	—
UNS S 32750	0,03	0,80	1,2	0,035	0,02	24,0—26,0	6,0—8,0	3,0—5,0	0,24—0,32	Cu 0,50 max.

NOTE
All figures are a maximum value except where a range is shown.

Table 3.7.2 Mechanical properties for acceptance purposes

Type and grade of steel	0,2% Proof stress (N/mm^2) minimum	1% Proof stress (N/mm^2) minimum	Tensile strength (N/mm^2) minimum	Elongation on $5,65\sqrt{S_o}$ % minimum
Austenitic				
304L	170	210	485	40
304LN	205	245	515	40
316L	170	210	485	40
316LN	205	245	515	40
317L	205	245	515	40
317LN	240	280	550	40
321	205	245	515	40
347	205	245	515	40
Duplex				
UNS S 31803	450	—	620	25
UNS S 32750	550	—	795	15

7.5 Through thickness tests

7.5.1 Where material will be strained in a through thickness direction during welding or in service, through thickness tests are required on plates over 10 mm thick in all the grades of steels listed in Table 3.7.1, apart from Grades 304L, 304 LN, 321 and 347.

7.5.2 Testing is to conform with the requirements of Section 8, with the exception given in 7.5.3.

7.5.3 When the reduction in area is less than 35 per cent, metallographic or other evidence is required to show that no significant amount of any detrimental phase, such as sigma, is present.

7.6 Intergranular corrosion tests

7.6.1 For certain specific applications such as storage tanks for chemicals, it may be necessary to demonstrate that the material used is not susceptible to intergranular corrosion resulting from grain boundary precipitation of chromium-rich carbides.

7.6.2 When required, one test of this type is to be carried out for each tensile test. The material for the test is to be taken adjacent to that for the tensile test.

7.6.3 Unless otherwise agreed or required for a particular chemical cargo, the testing procedure is to be as given in 7.6.4, *see* Ch 2,8.

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7.6.4 Wherever practical, exposed cut edges should be avoided. However, where any such edges are to remain after fabrication is completed it is to be shown by an appropriate test that the corrosion resistance is adequate for the cargoes expected to be encountered.

7.7 Clad plates

7.7.1 Carbon or carbon-manganese steel plates, clad on one or both surfaces with a suitable grade of austenitic or duplex stainless steel, may be used for the construction of cargo or storage tanks for chemicals.

7.7.2 The carbon or carbon-manganese steel base plates are to comply with the requirements of Section 4, and the austenitic cladding material generally with the requirements of this Section.

7.7.3 The process of manufacture is to be specially approved and may be either by roll cladding or by explosive bonding.

7.7.4 Where the use of clad materials is proposed, the material specification is to be submitted for consideration, together with details of the extent, and the acceptance standards for non-destructive examination.

7.8 Identification of materials

7.8.1 The particulars detailed in 1.10 are to be marked on all materials which have been accepted.

7.9 Certification of materials

7.9.1 At least two copies of each test certificate are to be provided. They are to be of the type and give the information detailed in 1.11 and, where applicable, the results obtained from intercrystalline corrosion tests, and, additionally, are to state the specified maximum carbon equivalent. As a minimum, chemical composition is to include the contents of any grain refining elements used and of the residual elements, as detailed in Table 3.7.1.

■ *Section 8*
Plates with specified through thickness properties

8.1 Scope

8.1.1 Provision is made in this Section for 'Z' grade plate and wide flat material with improved ductility in the through thickness or 'Z' direction, *see* Fig. 3.8.1. The use of this material is recommended for certain types of welded structures (*see* 1.2) in order to minimise the possibility of lamellar tearing either during fabrication or erection.

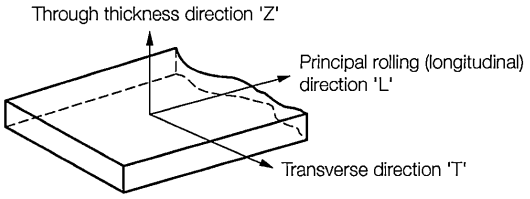

Fig. 3.8.1 Schematic of testing directions

8.1.2 Through thickness properties are characterised by specified values for reduction of area in a through thickness tensile test.

8.1.3 Provision is made for two grades Z25 and Z35. For normal ship applications the Z25 grade is applicable, whilst the Z35 grade is for more severe applications.

8.1.4 This 'Z' grade material is to comply with the requirements of Sections 2, 3, 4, 5 and 6 as appropriate, and the additional requirements of this Section.

8.1.5 The test procedure detailed in this Section may also be used to demonstrate that no unacceptable amount of banding of any detrimental phase, such as sigma is present, *see* 7.5.

8.2 Manufacture

8.2.1 All plates and wide flats are to be manufactured at works which have been approved by LR for this quality of material.

8.2.2 It is recommended that the steel should be efficiently vacuum de-gassed. The sulphur content is not to exceed 0,008 per cent.

8.2.3 Consideration will be given to proposals for alternative methods of improving through thickness properties.

8.3 Test material

8.3.1 Unless otherwise agreed, through thickness tensile tests are only required for plate materials where the thickness exceeds 15 mm for carbon and alloy steels or 10 mm in the case of austenitic and duplex stainless steels.

8.3.2 For plates and wide flats, one test sample is to be taken close to the longitudinal centreline from one end of each rolled piece representing the batch, *see* Table 3.8.1 and Fig. 3.8.2. The test sample must be large enough to accommodate the preparation of 6 specimens. 3 test specimens are to be prepared while the rest of the sample remains for possible retest.

8.3.3 The dimensions of the test specimens are to be in accordance with Ch 2,2.1.12.

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Table 3.8.1 Batch size dependent on product and sulphur content

Product	$S > 0{,}005\%$	$S \leq 0{,}005\%$
Plates	Each piece (parent plate)	Maximum 50 t of products of the same cast, thickness and heat treatment
Wide flats of nominal thickness ≤ 25 mm	Maximum 10 t of products of the same cast, thickness and heat treatment	Maximum 50 t of products of the same cast, thickness and heat treatment
Wide flats of nominal thickness > 25 mm	Maximum 20 t of products of the same cast, thickness and heat treatment	Maximum 50 t of products of the same cast, thickness and heat treatment

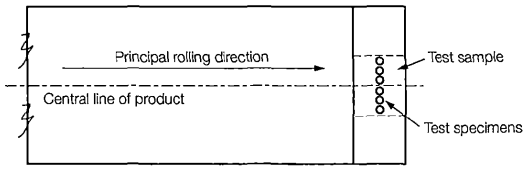

Fig. 3.8.2
Plate and wide flat sampling position

8.3.4 Alternatively, test sampling may be carried out in accordance with an accepted National or International Standard.

8.4 Mechanical tests

8.4.1 The three through thickness tensile test specimens are to be tested at ambient temperature and for acceptance are to give a minimum average reduction of area value of not less than that shown in Table 3.8.2. Only one individual value may be below the minimum average, but should not be less than the minimum individual value shown for the appropriate grade.

Table 3.8.2 Reduction of area acceptance values

Grade	Z25	Z35
Minimum average	25%	35%
Minimum individual	15%	25%

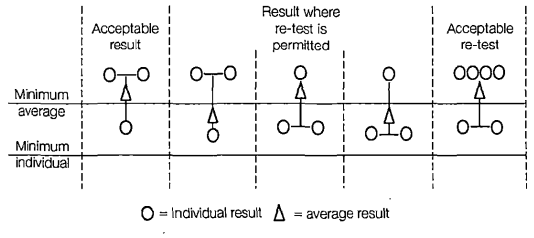

Fig. 3.8.3
Diagram showing acceptance/rejection and re-test criteria

8.4.2 If the average value fails to comply with 8.4.1, three additional tests may be made on specimens from the same test sample. The results of these tests are to be added to those previously obtained to form a new average, which for acceptance is to be not less than 25 per cent for grade Z25 or 35 per cent for grade Z35. No individual results in the re-test shall be below 25 per cent for grade Z25 or 35 per cent for grade Z35, *see* Fig. 3.8.3.

8.4.3 Where batch testing is permitted, and failure after re-test occurs, the tested piece is to be rejected. Each remaining piece in the batch may be individually tested and accepted based on satisfactory results.

8.4.4 If the fracture of a test specimen occurs in the weld or in the heat affected zone the test is to be regarded as invalid and is to be repeated on a new test specimen.

8.5 Non-destructive examination

8.5.1 All 'Z' grade plates are to be ultrasonically tested in the final supply condition with a probe frequency of 3-5 MHz. The testing is to be performed in accordance with and in compliance with either EN 10160 Level S1/E1 or ASTM A 578 Level C.

8.6 Identification of materials

8.6.1 Products which comply with the requirements of this Section are to have the notation Z25 or Z35 added to the steel grade designation.

8.7 Certification of materials

8.7.1 The following information is required to be included on the certificate in addition to the appropriate steel grade requirements:

(a) Through thickness reduction in area (%), individual results and average.

(b) Steel grade with Z25 or Z35 notation.

8.7.2 Steel grade requirements are to comply with Sections 1 to 7.

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■ *Section 9*
Bars for welded chain cables

9.1 Scope

9.1.1 Provision is made in this Section for rolled steel bars intended for the manufacture of three Grades (U1, U2 and U3) of stud link chain cable for the anchoring and mooring of ships and five Grades (R3, R3S, R4, R4S and R5) of offshore mooring cable.

9.1.2 For the ship grades, U1, U2 and U3, approval will permit the supply of bars of the appropriate grades and size to any chain cable manufacturer.

9.1.3 For the offshore grades, R3, R3S, R4, R4S and R5, approval is confined to bar to be supplied to a nominated chain manufacturer and will be given only after successful testing of a completed chain. Separate approvals are required if bar is to be supplied to more than one cable manufacturer. Approval of a higher grade does not cover approval of a lower grade, as all grades must be individually approved.

9.1.4 For all grades, approval is normally given for diameters of bars no greater than those of the bars used in procedure tests.

9.2 Manufacture

9.2.1 All grades of bar material are to be made from killed steel, and all grades of bar material except for Grade U1 chain cables are to be fine grained. For Grades R4S and R5 the austenite grain size is to be 6 or finer, in accordance with ASTM E112.

9.2.2 The bars are to be made to a specification approved by LR which should include the manufacturing procedure, deoxidation practice, heat treatment and mechanical properties.

9.2.3 The rolling reduction ratio of bars for Grades R3, R3S, R4, R4S and R5 must be at least 5:1.

9.3 Chemical composition

9.3.1 For Grades U1, U2 and U3 the chemical composition should be generally within the limits given in Table 3.9.1.

9.3.2 For Grades R3, R3S, R4, R4S and R5 the chemical composition is to comply with an approved specification, *see* 9.2.2.

9.3.3 For Grades R4, R4S and R5 chain cable the steel should contain a minimum of 0,2 per cent molybdenum. The reported composition is to include the contents of antimony, arsenic, tin, copper, nitrogen, aluminium and titanium.

9.3.4 For Grades R4S and R5 the steel used must be vacuum degassed.

9.4 Heat treatment

9.4.1 Unless stipulated otherwise, the bars are to be supplied in the as-rolled condition, but the supplier is to be advised by the chain manufacturer of the heat treatment to be used for the completed chain in order that the mechanical test specimens may be tested in the condition of heat treatment used for the chain.

9.4.2 For Grades U1 and U2, the samples selected from each batch may be tested either in the as-rolled condition, or after heat treatment where the chain is to be used in the heat treated condition, in full cross-section and in a manner simulating the heat treatment applied to the finished cable.

9.4.3 For Grades U3, R3, R3S, R4, R4S and R5 the sample is to be tested after heat treatment as detailed in 9.4.2.

9.5 Embrittlement tests

9.5.1 For Grades R3, R3S, R4, R4S and R5 the bar manufacturer is to provide evidence that the material is not susceptible to strain ageing or to temper brittleness under the conditions of manufacture of the chain. The results of the relevant tests are to be reported to LR at the approval stage. Approval will be restricted to the specified steel composition and if later this is altered then re-approval will be required. Temper brittleness testing may be waived if the chain is to be quenched after tempering.

Table 3.9.1 Chemical composition of killed steel bars

Grade	Chemical composition %												
	C max.	Si	Mn	P max.	S max.	Al	Nb max.	V max.	N max.	Cr max.	Cu max.	Ni max.	Mo max.
U1	0,20	0,15–0,35	0,40 min.	0,04	0,04	–	–	–	–	–	–	–	–
U2	0,24	0,15–0,55	1,60 max.	0,035	0,035	0,02 min. *see* Note 1	–	–	–	–	–	–	–
U3	0,33	0,15–0,35	1,90 max.	0,04	0,04	0,065 max. *see* Note 2	0,05 *see* Note 2	0,10 *see* Note 2	0,015	0,25	0,35	0,40	0,08

NOTES
1. Aluminium may be partly replaced by other grain refining elements.
2. To obtain fine grain steel, at least one of these grain refining elements must be present in sufficient amount.

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9.5.2 Each heat of steel bars of grades R3S, R4, R4S and R5 is to be tested for hydrogen embrittlement (*see* Ch 2,5.3). In the case of continuous casting, test samples representing both the beginning and the end of the charge are to be taken. In the case of ingot casting, test samples representing two different ingots are to be taken.

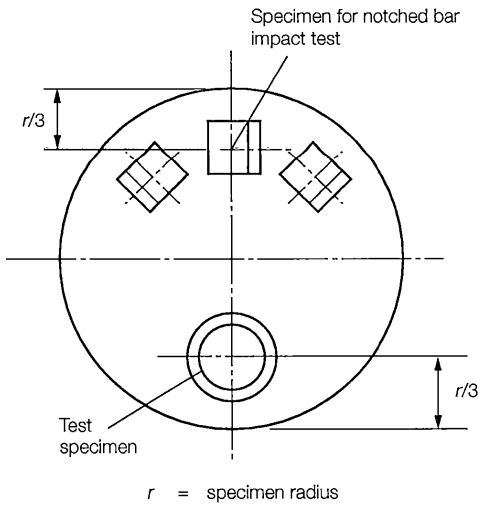
9.5.3 Each sample is to be heat treated in a manner simulating the heat treatment of the finished chain. From each sample two specimens are to be prepared from the mid-diameter of the bar and tested in accordance with Ch 2,5.3.

9.5.4 The ratio Z_1/Z_2 is to be greater than or equal to 0,85, where Z_1 is the reduction in area without baking and Z_2 the reduction in area after baking.

9.5.5 If the requirement is not met, the material is to be subjected to a hydrogen degassing treatment which is subject to approval by LR. Further tests are to be performed after degassing.

9.6 Mechanical tests

9.6.1 Bars of the same nominal diameter are to be presented for test in batches of 50 tonnes or fraction thereof from the same cast. A suitable length from one bar in each batch is to be selected for test purposes. Test pieces are to be taken from the positions as shown in Fig. 3.9.1.



r = specimen radius

Fig. 3.9.1 Sampling of steel bars

9.6.2 For all grades, one tensile test is to be taken from each sample length selected. Additionally, for Grades U3, R3, R3S, R4, R4S and R5 material, one set of three Charpy V-notch impact test specimens is to be prepared. Impact tests are also required for Grade U2 when the chain is to be supplied in as-welded condition.

9.6.3 The results of all tensile and, where applicable, impact tests are to be in accordance with the appropriate requirements of Table 3.9.2.

9.6.4 Failure to meet the requirements will result in the rejection of a batch of material, unless it is clearly attributed to improper simulated heat treatment. This is to be confirmed to be to the satisfaction of LR, and further heat treatment and testing will be required prior to acceptance.

9.7 Structure and hardenability tests

9.7.1 For Grades R4S and R5, the following tests are to be carried out on each heat:

(a) Assessment and quantification of the level of non-metallic micro inclusion. These must be acceptable for the final product.

(b) Macro etching on a representative sample, in accordance with ASTM E381 or equivalent. This must be free from any injurious segregation or porosity.

(c) Jominy hardenability tests in accordance with ASTM A255 or equivalent.

9.8 Dimensional tolerances

9.8.1 The tolerances on diameter and ovality of the bar are to be in accordance with Table 3.9.3.

9.9 Non-destructive examination

9.9.1 For the R3, R3S, R4, R4S and R5 grades all bars are to be inspected by a magnetic particle or eddy current method and are also to be subjected to ultrasonic examination.

9.9.2 All non-destructive examination is to be carried out in accordance with approved procedures, in accordance with Ch 1,5.

9.9.3 All non-destructive examination operators are to be qualified in the method of non-destructive examination to a minimum of Level II in accordance with a recognised standard.

9.9.4 The bars are to be free from pipes, cracks, flakes, and injurious surface defects such as seams, laps, and rolled-in mill scale. Longitudinal discontinuities may be removed by blending to a smooth contour provided that their depth is not greater than 1 per cent of the bar diameter, and that the required diameter tolerances are not compromised. The contour radiuses are to be a minimum of four times the excavation depth.

9.9.5 The frequency of non-destructive testing may be reduced at the discretion of LR, provided statistical evidence is available that the required quality is achieved consistently.

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Table 3.9.2 Mechanical properties

Grade	Yield stress N/mm² minimum	Tensile strength N/mm²	Elongation on 5,65 $\sqrt{S_o}$ % minimum	Reduction of area % minimum	Charpy V-notch impact tests		
					Test temperature °C	Average energy J minimum	Average energy flash weld J minimum
U1	–	370–490	25	—	—	—	—
U2	295	490–690	22	—	0 (*see* Note 1)	27	—
U3	410	690 minimum	17	40	0 –20 (*see* Note 2)	60 35	— —
R3	410 (*see* Note 3)	690 minimum (*see* Note 3)	17	50	0 –20 (*see* Note 2)	60 40	50 30
R3S	490 (*see* Note 3)	770 minimum (*see* Note 3)	15	50	0 –20 (*see* Note 2)	65 45	53 33
R4	580 (*see* Note 3)	860 minimum (*see* Note 3)	12	50	–20	50	36
Grade R4S (*see* Note 4)	700 (*see* Note 3)	960 minimum (*see* Note 3)	12	50	–20	56	40
Grade R5 (*see* Note 4)	760 (*see* Note 3)	1000 minimum (*see* Note 3)	12	50	–20	58	42

NOTES
1. Impact tests may be waived when the chain cable is to be supplied in one of the heat treated conditions given in Table 10.2.3.
2. Testing may be carried out at either 0°C or –20°C, at the option of LR.
3. The ratio of yield strength to tensile strength should not exceed 0,92.
4. The maximum hardness for R4S is to be HB330, and for R5 is to be HB340.

Table 3.9.3 Dimensional tolerance of bar stock

Nominal diameter mm	Tolerance on diameter mm	Tolerance on roundness ($d_{max} - d_{min}$) mm
≤20	–0/+5,0	0,60
>20 ≤25	–0/+1,0	0,60
>26 ≤35	–0/+1,2	0,80
>36 ≤50	–0/+1,6	1,10
>51 ≤80	–0/+2,0	1,50
>81 ≤100	–0/+2,6	1,95
>101 ≤120	–0/+3,0	2,25
>121 ≤160	–0/+4,0	3,00
>161 ≤210	–0/+5,0	4,00

9.10 Identification

9.10.1 Each bar is to be identified in accordance with 1.10 and, in addition, is to be marked with the appropriate grade of chain cable.

9.11 Certification of materials

9.11.1 Each consignment of bars is to be accompanied by a certificate of a type and in accordance with 1.11 but with the addition of the grade of chain cable, the rolling reduction ratio, the results of the micro inclusion, macro etch and hardenability tests, where required by each grade.

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■ *Section 10*
High strength quenched and tempered steels for welded structures

10.1 Scope

10.1.1 Provision is made in this Section for weldable high strength quenched and tempered steel plates and wide flats up to 70 mm thick. However, special consideration will be given to thicknesses up to 50 mm supplied in the TM rolled condition.

10.1.2 Plates and wide flats exceeding 70 mm in thickness as well as other product forms may also be supplied in accordance with the requirements of this Section provided that the prior agreement of LR is obtained.

10.1.3 The steels may be supplied in six strength levels with minimum yield stresses of 420, 460, 500, 550, 620 and 690 N/mm^2 respectively.

10.1.4 Each strength level is sub-divided into four grades AH, DH, EH and FH, differing essentially in the required levels of notch toughness.

10.1.5 For the designation to fully identify a steel and its properties, the appropriate grade letter should precede the strength level number, e.g. EH 42.

10.1.6 Steels differing in strength level, mechanical properties and chemical composition from those detailed in this Section may be supplied, subject to special approval from LR. Such steels are to have the letter 'S' after the agreed identification mark.

10.2 Manufacture and chemical composition

10.2.1 The steels are to be fully killed and fine grain treated.

10.2.2 The chemical composition is to comply with the requirements of the approved manufacturing specification and the limits set in Table 3.10.1.

10.2.3 The cold cracking susceptibility, P_{cm}, may be used as an alternative to the carbon equivalent for evaluating weldability. It is to be calculated from the ladle analysis using the following formula:

$$P_{cm} = C + \frac{Si}{30} + \frac{Mn + Cr + Cu}{20} + \frac{Ni}{60} + \frac{Mo}{15} + \frac{V}{10} + 5B$$

The maximum allowable P_{cm} is to be agreed with LR and is to be included in the approved manufacturing specification.

10.3 Mechanical properties

10.3.1 At least one tensile test piece and one set of three Charpy V-notch impact tests specimens are to be taken from each piece as heat treated.

Table 3.10.1 Chemical composition

Grade	AH	DH	EH	FH
Carbon % max	0,21	0,20		0,18
Manganese % max	1,70	1,70		1,60
Silicon % max	0,55	0,55		0,55
Phosphorus % max	0,035	0,030		0,025
Sulphur % max	0,035	0,030		0,025
Nitrogen % max	0,020	0,020		0,020
Grain refining elements (*see* Note 1)				
Aluminium (acid soluble) % min (*see* Note 2)	0,015			
Niobium %	0,02—0,05			
Vanadium %	0,03—0,10			
Titanium % max	0,02			
Total (Nb + V + Ti) % max	0,12			

NOTES
1. The steel is to contain aluminium, niobium, vanadium or other suitable grain refining elements, either singly or in any combination. When used singly, the content is to be within the limits given in the Table. When used in combination, these limits are not applicable but the proportions of the grain refining elements are to be in accordance with the approved manufacturing specification.
2. The total aluminium content may be determined instead of the acid soluble content. In such cases the total aluminium content is not to be less than 0,020%.
3. Alloying elements and residual elements other than those listed in the Table (e.g. Ni, Cr, Cu, Mo and B) are to be included in the approved manufacturing specification.

10.3.2 For continuously heat treated products, one tensile test piece and a set of three impact test specimens are to be taken from each plate as heat treated.

10.3.3 For plates and wide flats with widths exceeding 600 mm, the tensile and impact test specimens are to be taken with their axes transverse to the final direction of rolling. For other products, the impact test specimens are to be taken in the longitudinal direction but the tensile test specimens may be taken in either the longitudinal or transverse direction as agreed with LR.

10.3.4 The results of all tests are to comply with the appropriate requirements of Table 3.10.2.

10.3.5 Where standard subsidiary impact test specimens are necessary, *see* Ch 2,3.2.4.

10.4 Identification of materials

10.4.1 The particulars detailed in 1.10 are to be marked on each piece which has been accepted and, for ease of recognition, are to be encircled or otherwise marked with paint.

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Table 3.10.2 Mechanical properties for acceptance purposes

Grade	Yield stress N/mm² min. (*see* Note 1)	Tensile strength N/mm²	Elongation on $5{,}65\sqrt{S_o}$ % minimum (*see* Note 2)		Charpy V-notch impact tests (*see* Note 4)		
					Test temperature	Average energy J minimum	
			Transverse	Longitudinal	°C	Transverse	Longitudinal
AH 42 DH 42 EH 42 FH 42	420	530 – 680	18	20	0 –20 –40 –60	28	42
AH 46 DH 46 EH 46 FH 46	460	570 – 720	17	19	0 –20 –40 –60	31	46
AH 50 DH 50 EH 50 FH 50	500	610 – 770	16	18	0 –20 –40 –60	33	50
AH 55 DH 55 EH 55 FH 55	550	670 – 830	16	18	0 –20 –40 –60	37	55
AH 62 DH 62 EH 62 FH 62	620	720 – 890	15	17	0 –20 –40 –60	41	62
AH 69 DH 69 EH 69 FH 69	690	770 – 940	14	16	0 –20 –40 –60	46	69

NOTES

1. Where a distinct yield stress indication is not obtainable during tensile testing the 0,2% proof stress is applicable.
2. For full thickness tensile test specimens with a width of 25 mm and a gauge length of 200 mm (*see* Fig. 2.2.4 in Chapter 2) the minimum elongation is to be:

Thickness mm		≤10	>10 ≤15	>15 ≤20	>20 ≤25	>25 ≤40	>40 ≤50	>50 ≤70
Strength levels								
Elongation %	42	11	13	14	15	16	17	18
	46	11	12	13	14	15	16	17
	50 and 55	10	11	12	13	14	16	16
	62	9	11	12	12	13	14	15
	69	9	10	11	11	12	13	14

These values apply to transverse specimens. Where the use of longitudinal specimens has been agreed, the values are to be increased by 2%.

3. The ratio of yield strength to tensile strength should not exceed 0,94.
4. Impact tests are not required on thicknesses less than 6 mm.

10.5 Certification of materials

10.5.1 At least two copies of each test certificate are to be provided. They are to be of the type and give the information detailed in 1.11 and, additionally, are to state the specified maximum carbon equivalent. As a minimum, chemical composition is to include the contents of any grain refining elements used and of the residual elements as detailed in Table 3.10.1.

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Steel Castings

Chapter 4

Section 1

Section

1 **General requirements**

2 **Castings for ship and other structural applications**

3 **Castings for machinery construction**

4 **Castings for crankshafts**

5 **Castings for propellers**

6 **Castings for boilers, pressure vessels and piping systems**

7 **Ferritic steel castings for low temperature service**

8 **Stainless steel castings**

9 **Steel castings for container corner fittings**

■ *Section 1*
General requirements

1.1 Scope

1.1.1 This Section gives the general requirements for steel castings intended for use in the construction of ships, other marine structures, machinery, boilers, pressure vessels and piping systems.

1.1.2 Where required by the relevant Rules dealing with design and construction, castings are to be manufactured and tested in accordance with Chapters 1 and 2, together with the general requirements given in this Section and the appropriate specific requirements given in Sections 2 to 9.

1.1.3 As an alternative to 1.1.2, castings which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Chapter or alternatively are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

1.1.4 Where small castings are produced in large quantities, or where castings of the same type are produced in regular quantities, alternative survey procedures, in accordance with Ch 1,2.4 may be adopted.

1.2 Manufacture

1.2.1 Castings are to be made at foundries approved by LR. The steel used is to be manufactured by a process approved by Lloyd's Register (hereinafter referred to as 'LR').

1.2.2 All flame cutting, scarfing or arc-air gouging to remove surplus metal is to be undertaken in accordance with recognised good practice and is to be carried out before the final heat treatment. Preheating is to be employed where necessitated by the chemical composition and/or thickness of the casting. The affected areas are to be either machined or ground smooth for a depth of about 2 mm unless it has been shown that the material has not been damaged by the cutting process. Special examination will be required to find any cracking in way of the cut surfaces.

1.2.3 Where two or more castings are joined by welding to form a composite item, details of the proposed welding procedure are to be submitted for approval. Welding approval procedure tests will be required, *see also* the requirements of 1.9.

1.3 Quality of castings

1.3.1 All castings are to be free from surface or internal defects which would be prejudicial to their proper application in service. The surface finish is to be in accordance with good practice and any specific requirements of the approved specification.

1.3.2 The surfaces are not to be hammered, peened or treated in any way which may obscure defects.

1.3.3 The locations of all chaplets are to be noted and to be subject to close visual inspection (and when necessary ultrasonic examination) to ensure complete fusion.

1.4 Chemical composition

1.4.1 All castings are to be made from killed steel. The chemical composition of the ladle sample is to be within the limits given in the relevant Section of this Chapter. Where general overall limits are specified, the chemical composition is to be appropriate for the type of steel, dimensions and required mechanical properties of the castings.

1.4.2 Except where otherwise specified, suitable grain refining elements may be used at the discretion of the manufacturer. The content of such elements is to be reported in the ladle analysis.

1.5 Heat treatment

1.5.1 All castings are to be heat treated in accordance with the requirements given in the relevant Section of this Chapter.

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1.5.2 Heat treatment is to be carried out in a properly constructed furnace which is efficiently maintained and has adequate means of temperature control and is fitted with pyrometers which measure and record the temperature of the furnace charge. The furnace dimensions are to be such as to allow the whole furnace charge to be uniformly heated to the necessary temperature. Sufficient thermocouples are to be connected to the furnace charge to show that its temperature is adequately uniform and the temperatures are to be recorded throughout the heat treatment. Alternative procedures are to be approved by LR, Materials and NDE department. Copies of these records are to be presented to the Surveyor together with a sketch showing the positions at which the temperature measurements were carried out. The records are to identify the furnace that was used and give details of the charge, the heat treatment temperature and time at temperature and the date. The Surveyor is to examine the charts and confirm the details on the certificate. In the case of very large components which require heat treatment, alternative methods will be specially considered.

1.5.3 If a casting is locally reheated, or any straightening operation is performed after the final heat treatment, a subsequent stress relieving heat treatment may be required in order to avoid the possibility of harmful residual stresses.

1.6 Test material and test specimens

1.6.1 Test material sufficient for the tests specified in Sections 2 to 9 and for possible re-test purposes is to be provided for each casting. The test samples are to be either integrally cast or gated to the casting and are to have a thickness of not less than 30 mm.

1.6.2 The test samples are not to be detached from the casting until the heat treatment specified in 1.5.1 has been completed and they have been properly identified.

1.6.3 As an alternative to 1.6.1 and 1.6.2, where a number of small castings of about the same size, each of which is under 1000 kg in mass, are made from one cast and heat treated in the same furnace charge, a batch testing procedure may be adopted, using separately cast test samples of suitable dimensions. The test samples are to be properly identified and heat treated together with the castings which they represent. At least one test sample is to be provided for each batch of castings.

1.6.4 The test specimens are to be prepared in accordance with the requirements of Chapter 2. Tensile test specimens are to have a cross-sectional area of not less than 150 mm^2.

1.6.5 Re-test procedures are to be in accordance with Ch 2,1.4.

1.7 Visual and non-destructive examination

1.7.1 This Section gives the general requirements for non-destructive examination of steel castings. As an alternative, castings may be examined in accordance with a National Specification, provided it gives reasonable equivalence to these Rules.

1.7.2 All castings are to be cleaned and adequately prepared for inspection. Suitable methods include pickling, caustic cleaning, wire brushing, local grinding, shot or sand blasting.

1.7.3 The surfaces are not to be hammered, peened or treated in any way which may obscure defects.

1.7.4 Unless otherwise agreed, the accuracy and verification of dimensions are the responsibility of the manufacturer.

1.7.5 All castings are to be presented to the Surveyor for visual examination. Where applicable, this is to include the examination of internal surfaces. Castings are to be subject to magnetic particle examination or dye penetrant inspection (for austenitic stainless steel castings, *see* Section 8) in accordance with 1.7.9, unless more specific requirements for non-destrutive examination are included in subsequent Sections of this Chapter, other parts of the Rules or the agreed specification.

1.7.6 Where specified or required by the Rules non-destructive examination is to be carried out before acceptance. All tests are to be in accordance with the requirements of Ch 1,5.

1.7.7 The manufacturer is to provide the Surveyor with a signed report confirming that non-destructive examination has been carried out and that such inspection has not revealed any significant defects.

1.7.8 Where magnetic particle examination is specified or required, this is to be carried out using a suspension of magnetic particles in a suitable fluid. The dry powder method is not acceptable for the final inspection. Prods are not permitted on finished machined surfaces.

1.7.9 Where required, magnetic particle or dye penetrant testing is to be carried out by the manufacturer whenever appropriate and also when the castings are in the finished condition. The tests are to be made in the presence of the Surveyor unless otherwise specially agreed. The castings are to be examined in the following areas:

(a) At all accessible fillets and changes of section.
(b) At positions where surplus metal has been removed by flame cutting, scarfing or arc-air gouging.
(c) In way of fabrication weld preparations, for a distance not less than 50 mm form the edge.
(d) In way of welds.
(e) In way of chaplets.
(f) At other positions agreed with the Surveyor to include areas which may be subjected to high stress in service.

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1.7.10 Where required by subsequent Sections or by the agreed specification, ultrasonic examination is to be carried out by the manufacturer, but Surveyors may request to be present in order to verify that the examination is carried out in accordance with the agreed procedure. This examination is to be carried out in the following areas:

(a) At positions which may be subjected to high stresses in service, as agreed with the Surveyor.
(b) In way of fabrication weld preparations, for a distance not less than 50 mm form the edge.
(c) At positions where subsequent machining may expose filamentary shrinkage or other defects (e.g. bolt holes, bearing bores).
(d) In way of welding.
(e) In way of riser positions.
(f) At positions where experience shows that significant internal defects may occur: these are to be agreed between the manufacturer and the Surveyor.

1.7.11 Radiographic examination, where required, is to be carried out by the manufacturer in areas generally as indicated for ultrasonic examination in 1.7.10. All radiographs are to be submitted to the Surveyor for examination and acceptance. The radiographic technique and acceptance standards are to be to the satisfaction of the Surveyor and in accordance with any requirements of the approved specification.

1.7.12 In the event of any casting proving to be defective during subsequent machining or testing it is to be rejected notwithstanding any previous certification.

1.7.13 The general acceptance criteria given in 2.5.2 are to be applied where no specific acceptance criteria are stated in the subsequent Sections of this Chapter.

1.8 Pressure testing

1.8.1 Where required by the relevant Rules, castings are to be pressure tested in the final machined condition before final acceptance. These tests are to be carried out in the presence of the Surveyors and are to be to their satisfaction.

1.9 Rectification and dressing of castings

1.9.1 When unacceptable defects are found in a casting, these are to be removed by machining or chipping. Flame-scarfing or arc-air gouging may also be used provided that preheating is employed when necessary and that the surfaces of the resulting excavation are subsequently ground smooth. Complete elimination of the defective material is to be proven by adequate non-destructive examination. Shallow grooves or excavations resulting from the removal of defects may, at the discretion of the Surveyor, be accepted provided that they will cause no appreciable reduction in the strength of the castings and that they are suitably blended by grinding. Complete elimination of the defective material is to be verified by magnetic particle or dye penetrant testing.

1.9.2 Where flame scarfing or arc-air gouging is used, the requirements detailed in 1.2.2 are to apply.

1.9.3 Grinding wheels for use on austenitic stainless steels are to be of an iron-free type and shall have been used only on stainless steels.

1.9.4 All proposals to repair a defective casting by welding are to be submitted to the Surveyor before this work is commenced. The Surveyor is to satisfy himself that the number, position and size of the defects are such that the casting can be effectively repaired.

1.9.5 A statement and/or sketch detailing the extent and position of all welds is to be prepared by the manufacturer. Copies of these sketches are to be submitted to LR, and copies are to be attached to the certificates for the castings.

1.9.6 All welding is to be carried out by an approved welder and in accordance with an approved welding procedure which includes the features referred to in 1.9.6 to 1.9.13.

1.9.7 Where welding is required, a grain refining heat treatment is to be given to the whole casting prior to carrying out welding unless agreed otherwise with the Surveyor. Grain refining heat treatment requires heating above the upper critical temperature.

1.9.8 Any excavations are to be of suitable shape to allow good access for welding and, after final preparation for welding, are to be re-examined by suitable non-destructive testing methods to ensure that all defective material has been eliminated.

1.9.9 All castings in alloy steels other than austenitic and duplex stainless steels are to be suitably preheated prior to welding. Castings in carbon-manganese steels may also be required to be preheated, depending on their chemical composition, the dimensions, configuration and positions of the welds.

1.9.10 Welding is to be carried out under cover, in positions free from draughts and adverse weather conditions. As far as possible, all welding is to be carried out in the downhand (flat) position.

1.9.11 The welding consumables used are to be of an appropriate composition, giving a weld deposit with mechanical properties similar and in no way inferior to those of the parent castings. The use of low hydrogen type welding consumables is preferred. Welding procedure tests are to be carried out by the manufacturer to demonstrate that satisfactory mechanical properties can be obtained after heat treatment as detailed in 1.9.12, and the results of these tests are to be presented to the Surveyor.

1.9.12 After welding is completed, the castings are to be given the heat treatment specified in Sections 2 to 9, or a stress relieving heat treatment at a temperature of not less than 550°C. The type of heat treatment required will be dependent on the chemical composition of the casting and the dimensions, positions and nature of the repairs.

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1.9.13 Special consideration may be given to a local stress relieving heat treatment where both the welded area is small and machining of the casting has reached an advanced stage but prior agreement is to be obtained from LR in writing. The welding procedure is to be such that residual stresses are minimised.

1.9.14 On completion of heat treatment, all welds and adjacent material are to be ground smooth and examined by magnetic particle, or liquid penetrant testing, ultrasonic or radiographic examination. The Surveyor is to attend at these inspections, to witness the results of magnetic particle or liquid penetrant examination and to examine any radiographs. Satisfactory results are to be obtained from all forms of non-destructive examination used.The acceptance criteria for the NDE of welds are to be in accordance with subsequent Sections of this Chapter or where these do not exist, Tables 13.2.4 to 13.2.6 in Chapter 13, as appropriate.

1.9.15 Where no welding has been made on a casting, the manufacturer is to provide the Surveyor with a written statement that this is the case.

1.9.16 The foundry is to maintain full records detailing the weld procedure, heat treatment and the extent and location of all welds made to each casting. These records are to be available for review by the Surveyor, and copies of individual records are to be supplied to the Surveyor on request.

1.9.17 For rectification of defective steel castings for crankshafts, *see* 4.7.

1.10 Identification of castings

1.10.1 The manufacturer is to adopt a system of identification, which will enable all finished castings to be traced to the original cast, and the Surveyor is to be given full facilities to trace the castings when required.

1.10.2 Before acceptance, all castings which have been tested and inspected with satisfactory results are to be clearly marked by the manufacturer with the following particulars:

(a) Identification number, cast number or other marking which will enable the full history of the casting to be traced.
(b) Manufacturer's name or trade mark.
(c) LR or Lloyd's Register and the abbreviated name of LR's local office.
(d) Personal stamp of Surveyor responsible for inspection.
(e) Test pressure, where applicable.
(f) Date of final inspection.

1.10.3 Where small castings are manufactured in large numbers, modified arrangements for identification may be specially agreed with the Surveyor.

1.11 Certification of materials

1.11.1 A LR certificate is to be issued, *see* Ch 1,3.1.

1.11.2 The manufacturer is to provide the Surveyor with a written statement giving the following particulars for each casting or batch of castings which has been accepted:

(a) Purchaser's name and order number.
(b) Description of castings and steel grade.
(c) Identification number.
(d) Steel making process, cast number, chemical analysis of ladle samples and, in the case of the Special grade (*see* Section 2), the chemical analysis of the product or test bar.
(e) General details of heat treatment including the temperature and time at temperature.
(f) Results of mechanical tests.
(g) Test pressure, where applicable.

1.11.3 Where applicable, the manufacturer is to provide a signed report regarding non-destructive examination as required by 1.7.7 together with a statement and/or sketch detailing the extent and position of all weld repairs made to each casting as required by 1.9.5 or the statement detailed in 1.9.15.

■ *Section 2*
Castings for ship and other structural applications

2.1 Scope

2.1.1 The requirements for carbon-manganese steel castings, intended for ship and other structural applications where the design and acceptance tests are related to mechanical properties at ambient temperature, are given in this Section.

2.1.2 Provision is made for two quality grades, Normal and Special.

2.1.3 Where it is proposed to use carbon-manganese steels of higher specified minimum tensile strength than required by 2.4.3, or alloy steels, particulars of the chemical composition, mechanical properties and heat treatment are to be submitted for approval.

2.2 Chemical composition

2.2.1 The chemical composition of ladle samples is to comply with Table 4.2.1.

2.2.2 For the Special grade, the product of the aluminium and nitrogen contents is to comply with the following formula:

$$(\%\ Al_{acid\ sol} \times \%\ N)\ 10^5 \leq 60$$

2.2.3 For the Special grade, a check chemical analysis on the product or a test bar is mandatory. The check analysis on the product or test bar is to comply with the requirements of Table 4.2.1.

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Table 4.2.1 Chemical composition

Quality grade	Normal	Special (*see* Note 3)
Carbon	0,23% max.	0,23% max.
Silicon	0,60% max.	0,60% max.
Manganese	0,70–1,60%	0,70–1,60%
Sulphur	0,040% max.	0,035% max.
Phosphorus	0,040% max.	0,035% max.
Aluminium – (acid soluble)	–	0,015–0,080% (*see* Notes 1 and 2)
Residual elements:		
Copper	0,30% max.	0,30% max.
Chromium	0,30% max.	0,30% max.
Nickel	0,40% max.	0,40% max.
Molybdenum	0,15% max.	0,15% max.
Total	0,80% max.	0,80% max.

NOTES
1. The total aluminium content may be determined instead of the acid soluble content, in which case the total aluminium content is to be 0,020–0,10%.
2. Grain refining elements other than aluminium may be used subject to special agreement with LR.
3. For the Special grade, the nitrogen content is to be determined.

2.3 Heat treatment

2.3.1 Castings are to be supplied:
(a) fully annealed; or
(b) normalised; or
(c) normalised and tempered at a temperature of not less than 550°C; or
(d) quenched and tempered at a temperature of not less than 550°C.

2.3.2 For larger castings where a coarse of microstructure may be present in heavier thickness, a double austenising heat treatment may be required to ensure adequate grain refinement. A coarse microstructure will be indicated by an increased attenuation of approxiamtely 30 dB/m at 2 MHz during ultrasonic examination.

2.3.3 Following weld repair and or the attachment of handling brackets, all castings are to be subject to post weld heat treatment at a temperature of not less than 550°C before delivery.

2.4 Mechanical tests

2.4.1 At least one tensile test is to be made on material representing each casting or batch of castings.

2.4.2 Where the casting is of complex design, or where the finished mass exceeds 10 tonnes, two test samples are to be provided. Where large castings are made from two or more casts which are not mixed in a ladle prior to pouring, two or more test samples are required corresponding to the number of casts involved. These are to be integrally cast at locations as widely separated as possible.

2.4.3 The results of these tests are to comply with the following requirements:

Yield stress	200 N/mm^2 min.
Tensile strength	400 N/mm^2 min.
Elongation on $5{,}65\sqrt{S_o}$	25% min.
Reduction of area	40% min.

2.4.4 A set of three Charpy V-notch impact test specimens is to be provided with each casting in the Special grade. These may be taken from a small extension of the thickest part of the casting or from a block cast integrally with the casting and having dimensions representative of the largest section thickness of the casting. These are to be tested in accordance with Chapter 2 and are to have an average energy of not less than 27J at 0°C.

2.5 Non-destructive examination

2.5.1 Castings used in ship construction for the sternframe, rudder and propeller shaft supports are to be examined by ultrasonic and magnetic particle methods in accordance with 1.7. The type and extent of non-destructive examination of castings for other structural applications are to be specially agreed by the Surveyor.

2.5.2 The extent and methods of non-destructive examination to be applied to typical hull steel castings are shown in Figs. 4.2.1 to 4.2.6 in addition to the areas specified in 1.7.9 and 1.7.10.

2.5.3 Acceptance levels for Visual Inspection are to be taken as follows:
(a) No cracks or hot tears are permitted.
(b) Castings are to be free of other injurious indications to the satisfaction of the Surveyor.
(c) Additional magnetic particle, dye penetrant or ultrasonic testing may be required for a more detailed evaluation of surface irregularities at the request of the Surveyor. These examinations are in addition to those required by 2.6.

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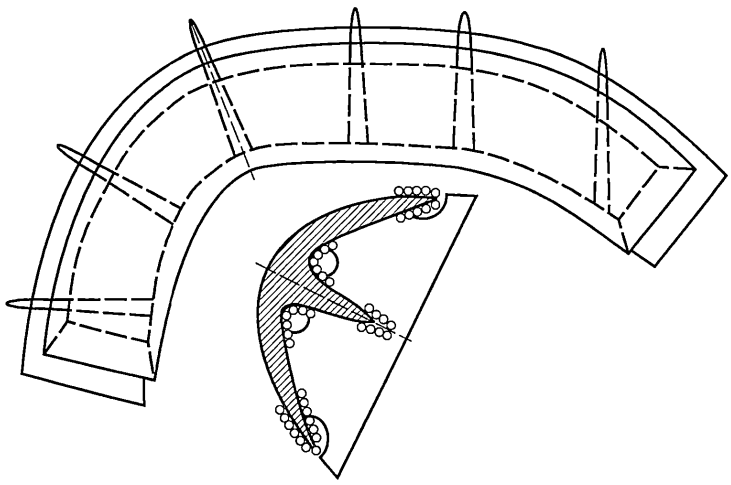
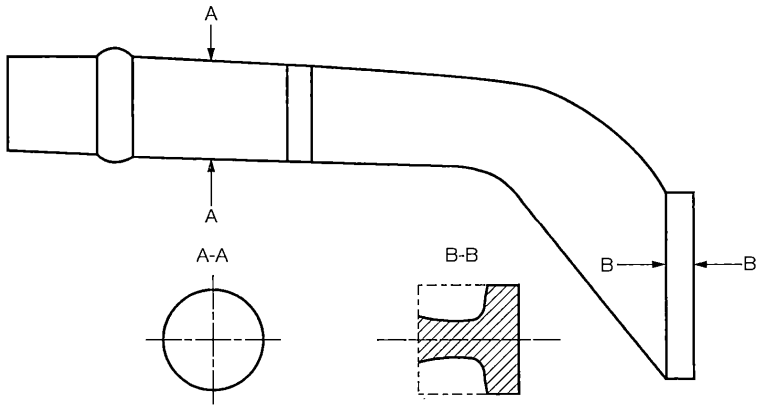


Location of non-destructive examination

1. All surfaces: Visual examination
2. Location indicated with (ooo): Magnetic particle and Ultrasonic testing

Fig. 4.2.1 Extent of non-destructive evaluation for stern frame castings



Location of non-destructive examination

All surfaces: Visual examination
Magnetic particle and ultrasonic testing

Fig. 4.2.2 Extent of non-destructive evaluation for rudder stock castings

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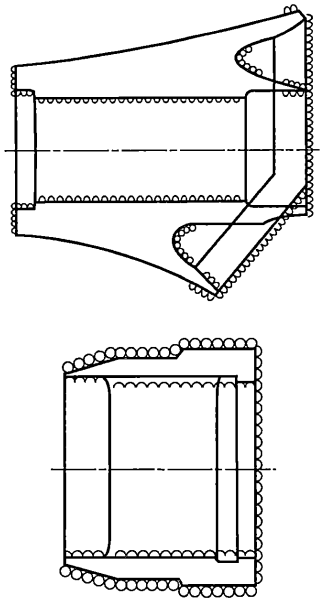
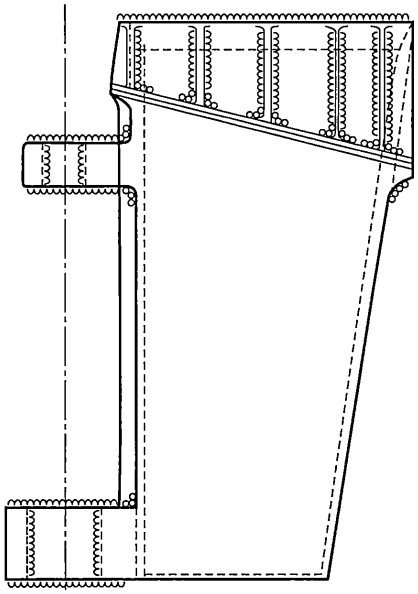


Location of non-destructive examination

1.	All surfaces:	Visual examination
2.	Location indicated with (ooo):	Magnetic particle and ultrasonic testing
3.	Location indicated with (⌒):	Ultrasonic testing

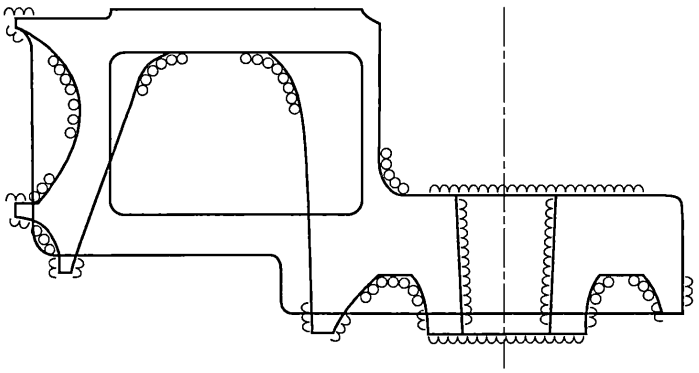
Fig. 4.2.3
Extent of non-destructive evaluation for stern boss castings



Location of non-destructive examination

1.	All surfaces:	Visual examination
2.	Location indicated with (ooo):	Magnetic particle and Ultrasonic testing
3.	Location indicated with (⌒):	Ultrasonic testing

Fig. 4.2.4
Extent of non-destructive evaluation for rudder hanging castings



Location of non-destructive examination

1.	All surfaces:	Visual examination
2.	Location indicated with (ooo):	Magnetic particle and Ultrasonic testing
3.	Location indicated with (⌒):	Ultrasonic testing

Fig. 4.2.5 Extent of non-destructive evaluation for rudder (upper part) castings

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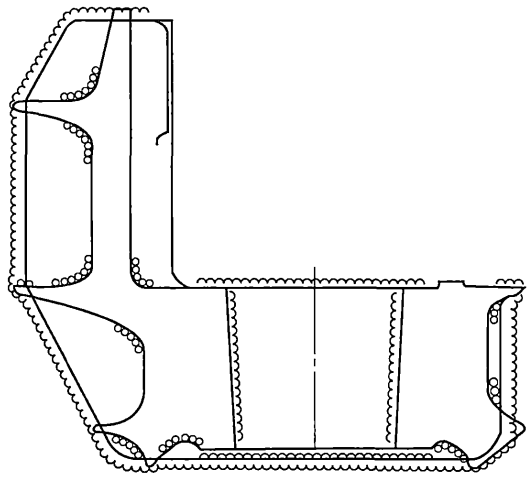

Location of non-destructive examination

1. All surfaces: Visual examination
2. Location indicated with (ooo): Magnetic particle and Ultrasonic testing
3. Location indicated with (ωω): Ultrasonic testing

Fig. 4.2.6
Extent of non-destructive evaluation for rudder (lower part) castings

2.6 Acceptance levels for surface crack detection

2.6.1 The following definitions apply to indications associated with magnetic particle and dye penetrant inspection:

(a) **Linear indication.** An indication in which the length is at least three times the width.

(b) **Non-linear indication.** An indication of circular or elliptical shape with a length less than three times the width.

(c) **Aligned indication.** Three or more indications in a line, separated by 2 mm or less edge-to-edge.

(d) **Open indication.** An indication visible after removal of the magnetic particles or that can be detected by the use of contrast dye penetrant.

(e) **Non-open indication.** An indication that is not visually detectable after removal of the magnetic particles or that cannot be detected by the use of contrast dye penetrant.

(f) **Relevant indication.** An indication that is caused by a condition or type of discontinuity that requires evaluation. Only indications which have any dimension greater than 1,5 mm are to be considered relevant.

2.6.2 For the purpose of evaluating indications, the surface is to be divided into reference band length of 150 mm for level MT1/PT1 and into reference areas of 225 cm^2 for level MT2/PT2. The band length and/or area is to be taken in the most unfavourable location relative to the indications being evaluated.

2.6.3 The following quality levels recommended for magnetic particle testing (MT) and/or dye penetrant testing (PT) are;

(a) Level MT1/PT1 – fabrication weld preparation areas.

(b) Level MT2/PT2 – other locations indicated on Figs. 4.2.1 to 4.2.6.

The acceptance criteria are shown in Table 4.2.2. Cracks and hot tears are not acceptable.

2.6.4 Acceptance criteria for ultrasonic testing are shown in Table 4.2.3 as UT1 and UT2. Discontinuities within the examined zones interpreted to be cracks or hot tears are not acceptable.

2.6.5 Level UT1 is applicable to the following:

(a) Fabrication weld preparations for a distance of 50 mm.

(b) 50 mm depth from the final machined surface including boltholes.

(c) Fillet radii to a depth of 50 mm and within a distance of 50 mm from the radius end.

(d) Castings subject to cyclic bending stresses, e.g. rudder horn, rudder castings and rudder stocks, the outer one third of thickness in the zones shown in Figs. 4.2.1 to 4.2.6

2.6.6 Level UT2 is applicable to the following:

(a) For locations which are not specified in 2.6.5, nominated for ultrasonic testing in Figs. 4.2.1 to 4.2.6 or on the inspection plan.

(b) Positions outside locations nominated for level UT1 examination where feeders and gates have been removed.

(c) Castings subject to cyclic bending stresses, at the central one third of thickness in the zones shown in Figs. 4.2.1 to 4.2.6.

Table 4.2.2 Acceptance criteria for surface inspection evaluation

Quality level	Maximum number of indication	Type of indication	Maximum number each type	Maximum dimension of single indication, mm^2
MT1/PT1	4 in 150 mm length	Non-linear Linear Aligned	4, *see* Note 1 4, *see* Note 1 4, *see* Note 1	5 3 3
MT2/PT2	20 in 22500 mm^2 area	Non-Linear Linear Aligned	10 6 6	7 5 5

NOTES
1. Minimum of 30 mm between relevant indications.
2. In weld repairs, the maximum dimension is 2 mm.

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Table 4.2.3 Ultrasonic acceptance criteria for marine steel castings

Quality level	Allowable disc shape according to the Distance-Gain Size (DGS), mm	Maximum number of indications to be registered, *see* Note 1	Allowable length of linear indications, mm, *see* Note 2
UT1	>6	0	0
UT2	12–15 >15	5 0	50 0

NOTES
1. Grouped in an area measuring 300 x 300 mm.
2. Measured on the scanning surface.

2.6.7 Ultrasonic acceptance criteria for casting areas not nominated in Figs. 4.2.1 to 4.2.6 will be subject to special consideration based on the anticipated stress levels and the type, size and position of the discontinuity.

2.6.8 *Parts which are welded are to be examined by the* same method as at the initial inspection as well as by additional methods as required by the Surveyor.

■ *Section 3* Castings for machinery construction

3.1 Scope

3.1.1 This Section gives the material requirements for carbon-manganese steel castings intenced for use in machinery construction and which are not within the scope of Sections 4 to 7.

3.1.2 Where it is proposed to use steels of higher carbon content than is indicated in 3.2.1, or alloy steels, particulars of the chemical composition, mechanical properties and heat treatment are to be submitted for approval.

3.1.3 The manufacture or repair of cast steel connecting rods is not permitted, except where the manufacturing and *quality control procedures have been approved by LR. For* approval purposes, tests are to be carried out at the place of manufacture using the proposed process to demonstrate that the castings are sound. Tests are to be carried out to confirm that the appropriate mechanical properties are attained within the casting, including areas where weld repairs have been performed. Any changes to manufacturing, repair and quality control procedures are to be submitted to LR for approval, *see also* Ch 1,2.2.

3.2 Chemical composition

3.2.1 The chemical composition of ladle samples is to comply with the following limits, except as specified in 3.2.2:

Carbon	0,40% max.
Silicon	*0,60% max.*
Manganese	0,50–1,60%
Sulphur	0,040% max.
Phosphorus	0,040% max.
Residual elements:	
Copper	0,30% max.
Chromium	0,30% max.
Nickel	0,40% max.
Molybdenum	0,15% max.
	Total 0,80% max.

3.2.2 Castings which are intended for parts of a welded fabrication are to be of weldable quality with a carbon content generally not exceeding 0,23 per cent.

3.2.3 Proposals to use steels with higher carbon content, or alloy steels, for welded construction will be subject to special consideration.

3.3 Heat treatment

3.3.1 Castings are to be supplied:
(a) fully annealed; or
(b) normalised; or
(c) normalised and tempered at a temperature of not less than 550°C; or
(d) quenched and tempered at a temperature of not less than 550°C.

3.3.2 Engine bedplate castings, turbine castings and any other castings where dimensional stability and freedom from internal stresses are important, are to be given a stress relief heat treatment. This is to be at a temperature not lower than 550°C, followed by furnace cooling to 300°C or lower. Alternatively, full annealing may be used provided that the castings are furnace cooled to 300°C or lower.

3.4 Mechanical tests

3.4.1 At least one tensile test is to be made on material representing each casting or batch of castings.

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3.4.2 Where the casting is of complex design, or where the finished mass exceeds 10 tonnes, two test samples are to be provided. Where large castings are made from two or more casts which are not mixed in a ladle prior to pouring, two or more test samples are required corresponding to the number of casts involved. The test samples are to be integrally cast at locations as widely separated as possible.

3.4.3 Table 4.3.1 gives the minimum requirements for yield stress, elongation and reduction of area corresponding to different strength levels, but it is not intended that these should necessarily be regarded as specific grades. Intermediate levels of minimum tensile strength may be specified, in which case minimum values for yield stress, elongation and reduction of area may be obtained by interpolation.

Table 4.3.1 Mechanical properties for acceptance purposes: carbon and carbon-manganese steel castings for machinery construction

Tensile strength N/mm^2	Yield stress N/mm^2 minimum	Elongation on $5{,}65\sqrt{S_0}$ % minimum	Reduction of area % minimum
400–550	200	25	40
440–590	220	22	30
480–630	240	20	27
520–670	260	18	25
560–710	300	15	20
600–750	320	13	20

3.4.4 Castings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Table 4.3.1.

3.4.5 The results of all tensile tests are to comply with the requirements of Table 4.3.1 appropriate to the specified minimum tensile strength.

3.4.6 For alloy steel castings and carbon-manganese steel castings containing more than 0,40 per cent carbon, the results of all mechanical tests are to comply with an approved specification.

3.4.7 When a casting, or a batch of castings, has failed to meet the mechanical test requirements, it may be re-heat treated and re-submitted for acceptance tests but this may not be carried out more than twice, *see* Ch 1,4.6.

3.5 Non-destructive examination

3.5.1 All piston crowns and cylinder covers are to be examined by ultrasonic testing. In addition, where these castings are intended for engines having a bore size larger than 400 mm, they are to be examined by magnetic particle or dye penetrant testing in accordance with 1.7.

3.5.2 Engine bedplate castings are to be examined by ultrasonic and magnetic particle or dye penetrant testing in accordance with 1.7.

3.5.3 Turbine castings are to be examined by magnetic particle or dye penetrant testing in accordance with 1.7. In addition, an ultrasonic or radiographic examination is to be made in way of fabrication weld preparations.

3.5.4 Other castings are to be examined by non-destructive methods where specified.

■ *Section 4* Castings for crankshafts

4.1 Scope

4.1.1 This Section gives the requirements for carbon and carbon-manganese steel castings for semi-built crankshafts.

4.1.2 Where it is proposed to use steels of higher carbon content than is indicated in 4.3.1, or alloy steels, particulars of the chemical composition, mechanical properties and heat treatment are to be submitted for approval. For alloy steels, the specified minimum tensile strength is not to exceed 700 N/mm^2.

4.2 Manufacture

4.2.1 The method of producing combined web and pin castings is to be approved. For this purpose, tests to demonstrate the soundness of the casting and the properties at important locations may be required.

4.3 Chemical composition

4.3.1 The chemical composition of ladle samples is to comply with the following limits:

Carbon	0,40% max. (*but see* 4.7.4(c))
Silicon	0,60% max.
Manganese	0,50–1,60%
Sulphur	0,040% max.
Phosphorus	0,040% max.
Residual elements:	
Copper	0,30% max.
Chromium	0,30% max.
Nickel	0,40% max.
Molybdenum	0,15% max.
	Total 0,80% max.

4.4 Heat treatment

4.4.1 Castings are to be supplied either:

(a) fully annealed and cooled in the furnace to a temperature of 300°C or lower; or

(b) normalised and tempered at a temperature of not less than 550°C, and cooled in the furnace to a temperature of 300°C or lower.

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4.5 Mechanical tests

4.5.1 Proposals for the number of tests and the location of test material on the casting are to be submitted by the manufacturer.

4.5.2 Not less than one tensile test and three impact tests are to be made on material representing each casting. The impact tests are to be carried out at ambient temperature.

4.5.3 Table 4.4.1 gives the minimum requirements for yield stress and elongation corresponding to different strength levels, and it is not intended that these should necessarily be regarded as specific grades. The strength levels have been given in multiples of 40 N/mm^2 to facilitate interpolation for intermediate values of specified minimum tensile strength.

Table 4.4.1 Mechanical properties for acceptance purposes: carbon-manganese steel castings for crankshafts

Tensile strength N/mm^2	Yield stress N/mm^2 minimum	Elongation on $5{,}65\sqrt{S_o}$ % minimum	Reduction of area % minimum	Charpy V-notch impact tests average energy J minimum (*see* Note)
400–550	200	28	45	32
440–590	220	26	45	28
480–630	240	24	40	25
520–670	260	22	40	20
550–700	275	20	35	18

NOTE
Impact tests are to be made at ambient temperature.

4.5.4 Castings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Table 4.4.1.

4.5.5 The results of all tests are to comply with the requirements of Table 4.4.1 appropriate to the specified minimum tensile strength. For the impact tests, one individual value may be less than the required average value provided that it is not less than 70 per cent of this average value. *See* Ch 1,4.6 for re-test procedures.

4.6 Non-destructive examination

4.6.1 Magnetic particle examination is to be carried out over all surfaces in accordance with Fig. 4.4.1.

4.6.2 Each casting is to be examined by ultrasonic testing, and the extent of examination and defect acceptance criteria, using the DGS (Distance Gain Size) technique, are to be as shown in Fig. 4.4.2. Alternative ultrasonic procedures may be submitted for approval.

4.7 Rectification of defective castings

4.7.1 The requirements of 1.9 apply, except where amended by this Section.

4.7.2 Where castings have shallow surface defects, consideration is first to be given to removing such defects by grinding and blending or by machining the surface where there is excess metal on the Rule dimension.

4.7.3 Subject to prior agreement and submission of the detailed welding procedure for approval by LR, welding may be carried out prior to the final austenitising heat treatment.

4.7.4 Approval for welding will not be given in the following circumstances:

(a) For the rectification of repetitive defects caused by improper foundry technique or practice.

(b) For the building up by welding of surfaces or large shallow depressions.

(c) Where the carbon content of the steel exceeds 0,30 per cent.

(d) Where the carbon equivalent of the steel, given by $C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$ exceeds 0,65 per cent.

4.7.5 Provided that the Surveyors are satisfied that welding is justified, they may also authorise welding to the surfaces of crankwebs, following the final austenitising heat treatment, within the following limits:

(a) In general, the volume of the largest groove which is to be welded is not to exceed $3{,}2t$ cm^3, where t is the web axial thickness, in cm. The total volume of all grooves which are to be welded is not to exceed $9{,}6t$ cm^3 per crankweb.

(b) The welds do not extend within the cross-hatched zones marked on Fig. 4.4.3 for semi-built crank throws.

(c) Larger welds on balance weights may be permitted at the discretion of the Surveyor, provided that such repairs are wholly contained within the balance weight and do not affect the strength of the crankweb.

4.7.6 Subsequent to the final austenitising heat treatment, welding may be authorised in the surface of the bore for the journal (or pin) within the following limits:

(a) In general, the welds are to be not less than 125 mm apart.

(b) The welds are not to be located within circumferential bands of $\frac{t}{5}$ from the edges of the bores, nor at any position within the inner 120° arc of the bores, as cross-hatched on Fig. 4.4.3.

(c) The volume of the largest weld is to be not more than $1{,}1t$ cm^3, where t is the web axial thickness at the bore, in cm, and not more than three welds are to be made in any one bore surface.

4.7.7 After all defective material has been removed from a region, and this has been proven in the presence of the Surveyor by magnetic particle inspection or other suitable method, the excavation is to be suitably shaped to allow good access for welding.

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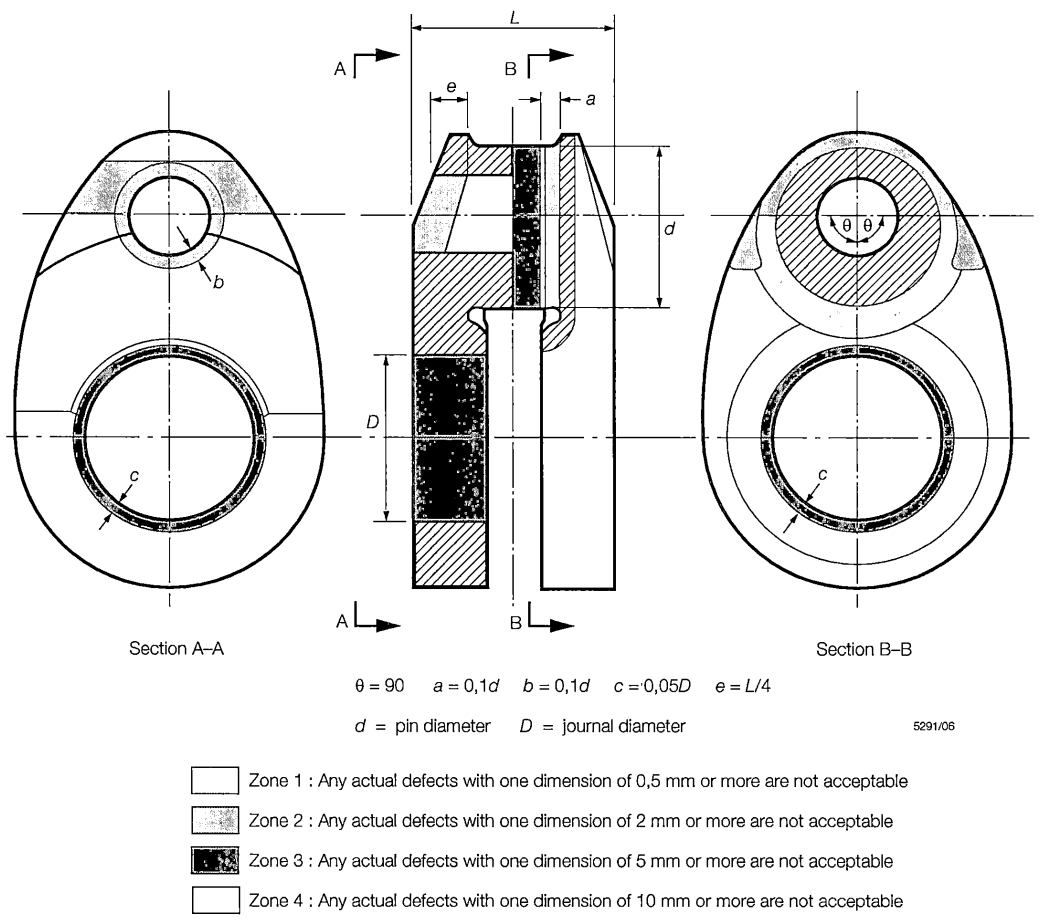

Fig. 4.4.1 Magnetic particle inspection acceptance levels

4.7.8 At the discretion of the Surveyor, the size of a groove may be increased beyond the limiting sizes given in 4.7.5 or 4.7.6, if the removal of further metal will facilitate welding.

4.7.9 Welding is to be carried out by approved welders using approved procedures. The welds are to be made by an electric arc process using low hydrogen type consumables which will produce a deposited metal that is not inferior in properties to the parent metal.

4.7.10 All castings are to be given a preliminary refining heat treatment prior to the commencement of welding. Before welding, the material is to be preheated in accordance with the qualified procedure. Where possible, preheating is to be carried out in a furnace. The preheat temperature is to be maintained until welding is completed, and preferably until the casting is charged to the furnace for post-weld heat treatment.

4.7.11 Where welding is carried out after the final austenitising heat treatments, a post-weld stress relieving heat treatment is to be applied at a temperature of not less than 600°C, *see also* 1.5.2.

4.7.12 Welds are to be dressed smooth by grinding. The surfaces of the welds and adjacent parent steel are to be proven by magnetic particle and, where appropriate, ultrasonic inspection, *see* 1.9.15 and 1.9.14.

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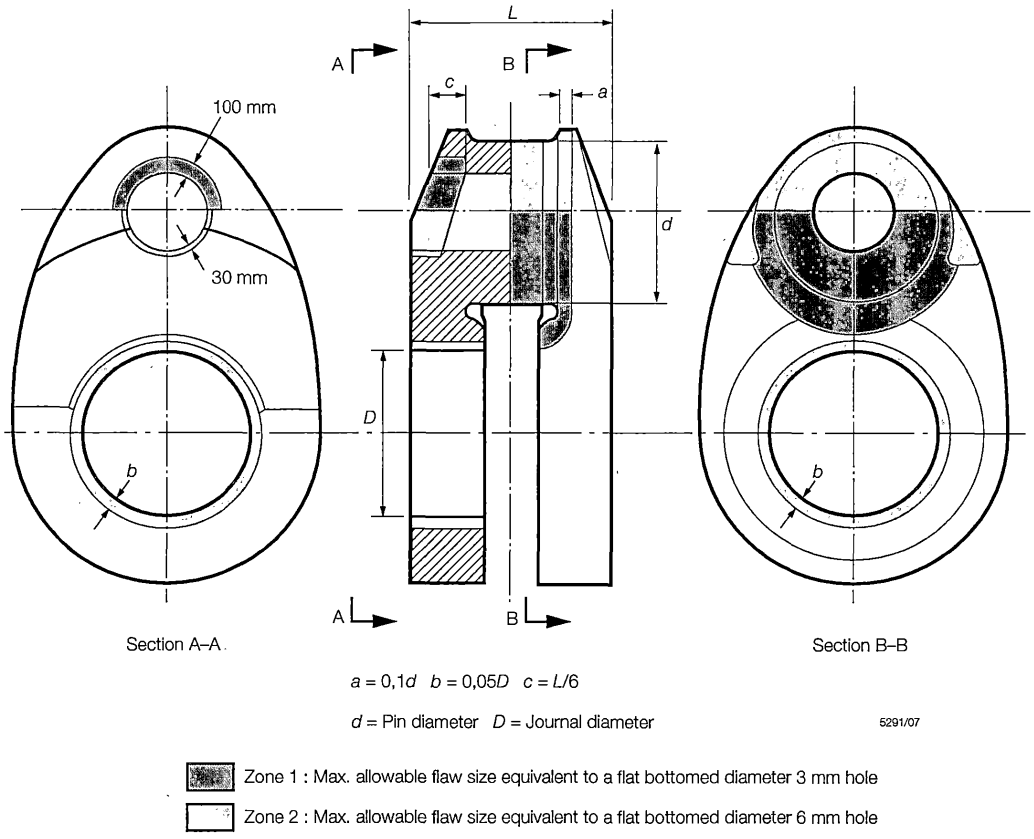

Fig. 4.4.2 Ultrasonic examination acceptance levels

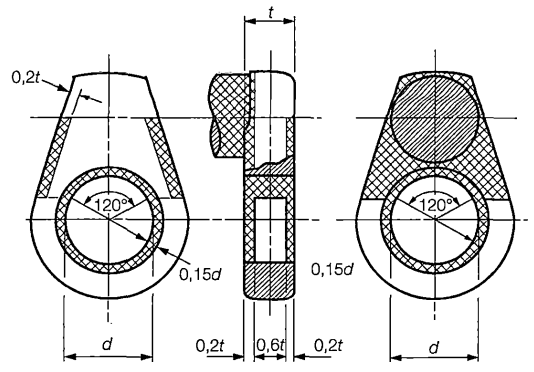

Fig. 4.4.3
Areas of semi-built crank throws to which weld *repairs are* not permitted

■ *Section 5*
Castings for propellers

5.1 Scope

5.1.1 This Section gives the requirements for steel castings for one-piece propellers and separately cast blades and hubs for fixed pitch and controllable pitch propellers (CPP). These include contra-rotating propellers, azipods and azimuth thrusters. The requirements for copper alloy propellers, blades and hubs are given in Ch 9,1.

5.1.2 These castings are to be manufactured and tested in accordance with the appropriate requirements of Chapters 1 and 2 and Ch 4,1 as well as the requirements of this Section.

5.1.3 Full details of the manufacturer's specification are to be submitted for approval. These should include the chemical composition, heat treatment, mechanical properties, microstructure and repair procedures.

5.1.4 Special requirements are given for castings which are intended for ice service in Table 4.5.2.

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5.2 Chemical composition

5.2.1 The chemical composition of ladle samples is to comply with the approved specification, *see* 5.1.3.

5.2.2 Typical cast steel propeller alloys are given in Table 4.5.1.

5.3 Heat treatment

5.3.1 Martensitic stainless steel castings are to be austenitised, quenched and tempered in accordance with the approved specification, *see* 5.1.3.

5.3.2 Austenitic stainless steel castings are to be solution treated in accordance with the approved specification, *see* 5.1.3.

5.4 Mechanical tests

5.4.1 The test material is to be cast integral with the boss of propeller castings, or with the flange of separately cast propeller blades. Alternatively, the test material may be attached on blades in an area between 0,5 and 0,6*R*, where *R* is the radius of the propeller.

5.4.2 The test material is not to be removed from the casting until final heat treatment has been carried out. Removal is to be by non-thermal procedures.

5.4.3 At least one tensile test and for the martensitic stainless steel grades one set of three Charpy V-notch impact tests are to be made on material representing each casting. The results are to comply with the requirements of Table 4.5.2 or the approved specification.

5.4.4 As an alternative to 5.4.3, where a number of small propeller castings of about the same size, and less than 1 m in diameter, are made from one cast and heat treated in the same furnace charge, a batch testing procedure may be adopted using separately cast test samples of suitable dimensions. At least one set of mechanical tests is to be provided for each multiple of five castings in the batch.

5.4.5 Separately cast test bars may be used subject to prior approval of the Surveyor. Test bars must be cast from the same heat, or heats, and must also be heat treated with castings they represent.

5.5 Non-destructive examination

5.5.1 On completion of machining and grinding, the whole surface of each casting is to be examined in accordance with Ch 9,1.8.

5.5.2 When appropriate, magnetic particle inspection may be used in lieu of liquid penetrant testing.

5.5.3 Castings are to be free from cracks and hot tears.

Table 4.5.1 Typical chemical composition for steel propeller castings

Alloy type	C Max. (%)	Mn Max. (%)	Cr (%)	Mo Max. (%) (*see* Note)	Ni (%)
Martensitic (12Cr 1Ni)	0,15	2,0	11,5–17,0	0,5	Max. 2,0
Martensitic (13Cr 4Ni)	0,06	2,0	11,5–17,0	1,0	3,5–5,0
Martensitic (16Cr 5Ni)	0,06	2,0	15,0–17,5	1,5	3,5–6,0
Austenitic (19Cr 11Ni)	0,12	1,6	16,0–21,0	4,0	8,0–13,0

NOTE
Minimum values are to be in accordance with the agreed specification or recognised National or International Standards.

Table 4.5.2 Typical mechanical properties for steel propeller castings

Alloy type	Yield stress or, 0,2% proof stress minimum, N/mm^2	Tensile strength minimum N/mm^2	Elongation on $5{,}65\sqrt{S_o}$ % minimum	Reduction of area % minimum	Charpy V-notch impact tests J minimum (*see* Notes 1 and 2)
Martensitic (12Cr 1Ni)	440	590	15	30	20
Martensitic (13Cr 4Ni)	550	750	15	35	30
Martensitic (16Cr 5Ni)	540	760	15	35	30
Austenitic (19Cr 11Ni)	180 (*see* Note 3)	440	30	40	—

NOTES
1. When a general service notation **Ice Class 1AS, 1A, 1B or 1C** is required, the tests are to be made at –10°C.
2. For general service or where the notation **Ice Class 1D** is required, the tests are to be made at 0°C.
3. $R_{p1,0}$ value is 205 N/mm^2.

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5.6 Rectification of defective castings

5.6.1 The rectification of defective castings is to be undertaken in accordance with 1.9 and the following paragraphs.

5.6.2 Removal of defective material is to be by mechanical means, e.g. by grinding, chipping or milling. The resultant grooves are to be blended into the surrounding surface so as to avoid any sharp contours.

5.6.3 Grinding in severity zone A may be carried out to an extent that maintains the blade thickness. Repair by welding is generally not permitted in zone A and will only be allowed after special consideration.

5.6.4 Defects in severity zone B that are not deeper than $t/40$ mm (t is the minimum local thickness according to the Rules) or 2 mm, whichever is the greater, are to be removed by grinding. Those defects that are deeper may be repaired by welding subject to prior approval of the Surveyor.

5.6.5 Repair welding is generally permitted in severity zone C.

5.6.6 Welds having an area of less than 5 cm^2 are to be avoided. The maximum surface area of repairs is to be in accordance with Table 9.1.4 in Chapter 9.

5.6.7 Welding is to be in accordance with the approved specification, *see* 5.1.3.

5.6.8 After weld repair, the propeller or blade is to be heat treated in such fashion as will minimise the residual stresses. For martensitic stainless steels, this will involve full heat treatment as specified in the approved specification.

5.6.9 LR reserves the right to restrict the amount of repair work accepted from a manufacturer when it appears that repetitive defects are the result of improper foundry techniques or practices.

5.6.10 All welds are to be inspected by the appropriate NDE method, *see* 1.7.

5.7 Identification

5.7.1 Castings are to be clearly marked by the manufacturer in accordance with the requirements of Chapter 1. The following details are to be shown on all castings which have been accepted:

(a) Identification mark which will enable the full history of the item to be traced.
(b) Type of steel, this should include or allow identification of the chromium and nickel contents.
(c) LR or Lloyd's Register and the abbreviated name of Lloyd's Register's local office.
(d) Personal stamp of Surveyor responsible for the final inspection.
(e) LR certificate number.
(f) Skew angle, if in excess of 25°.
(g) Ice class symbol, where applicable.
(h) Date of final inspection.

5.8 Certification of materials

5.8.1 In addition to the requirements in Ch 4,1.11, the manufacturer is to provide the Surveyor with a written statement giving the following particulars for each casting:

(a) Description of casting with drawing number.
(b) Diameter, number of blades, pitch, direction of turning.
(c) Skew angle, if in excess of 25°.
(d) Final mass.
(e) Vessel identification, where known.

■ *Section 6*
Castings for boilers, pressure vessels and piping systems

6.1 Scope

6.1.1 This Section gives the requirements for carbon-manganese and alloy steel castings for boilers, pressure vessels and piping systems for use at temperatures not lower than 0°C.

6.1.2 Where it is proposed to use alloy steels other than as given in this Section, details of the specification are to be submitted for approval. In such cases, the specified minimum tensile strength is not to exceed 600 N/mm^2.

6.1.3 Castings which comply with these requirements are acceptable for liquefied gas piping systems where the design temperature is not lower than 0°C. Where the design temperature is lower than 0°C, and for other applications where guaranteed impact properties at low temperatures are required, the castings are to comply with the requirements of Section 7 or 8.

6.2 Chemical composition

6.2.1 The chemical composition of ladle samples is to comply with the limits specified in Table 4.6.1.

6.3 Heat treatment

6.3.1 Castings are to be supplied:

(a) fully annealed; or
(b) normalised; or
(c) normalised and tempered; or
(d) quenched and tempered.

6.4 Mechanical tests

6.4.1 A tensile test is to be made on material representing each casting, unless a batch testing procedure has been agreed, *see* 1.6.

6.4.2 The tensile test is to be carried out at ambient temperature, and unless agreed otherwise with the Surveyor, the results are to comply with the requirements of Table 4.6.2.

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Table 4.6.1 Chemical composition of steel castings for boilers, pressure vessels and piping systems

Type of steel	Chemical composition %											
	C max.	Si max.	Mn	S max.	P max.	Residual elements						
Carbon-manganese	0,25	0,60	0,50-1,20	0,040	0,040	Cr 0,30 max. Mo 0,15 max. Cu 0,30 max. Ni 0,40 max. Total 0,80 max.						
						Cr	Mo	V	Residual elements Cr	Cu	Ni	
1/2 Mo	0,20	0,60	0,50–1,00	0,040	0,040	—	0,45-0,65	—	0,30 max.	0,30 max.	0,40 max.	
1 Cr 1/2 Mo	0,20	0,60	0,50-0,80	0,040	0,040	1,00-1,50	0,45-0,65	—	—	0,30 max.	0,40 max.	
2 1/4 Cr1 Mo	0,18	0,60	0,40-0,70	0,040	0,040	2,00-2,75	0,90-1,20	—	—	0,30 max.	0,40 max.	
1/2 Cr 1/2 Mo 1/4 V	0,10–0,15	0,45	0,40-0,70	0,030	0,030	0,30-0,50	0,40-0,60	0,22-0,30	—	0,30 max.	0,30 max.	

Table 4.6.2 Mechanical properties for acceptance purposes: steel castings for boilers, pressure vessels and piping systems

Type of steel	Yield stress minimum N/mm^2	Tensile strength N/mm^2	Elongation on $5{,}65\sqrt{S_o}$ % minimum	Reduction of area % minimum
Carbon-manganese	275	485-655	22	25
1/2Mo	260	460-590	18	30
1Cr1/2Mo	280	480-630	17	20
2 1/4 Cr1 Mo	325	540-630	17	20
1/2Cr1/2Mo1/4V	295	510-660	17	20

6.4.3 Where it is proposed to use a carbon-manganese steel with a specified minimum tensile strength intermediate to those given in this Section, corresponding minimum values for the yield stress, elongation and reduction of area may be obtained by interpolation.

6.4.4 Carbon-manganese steels with a specified minimum tensile strength of greater than 490 N/mm^2, but not exceeding 520 N/mm^2, may be accepted provided that details of the proposed specification are submitted for approval.

6.5 Non-destructive examination

6.5.1 The non-destructive examination of castings is to be carried out in accordance with the appropriate requirements of 1.7.7 to 1.7.11 and additionally as agreed between the manufacturer, purchaser and Surveyor.

6.6 Mechanical properties for design purposes

6.6.1 Nominal values for the minimum lower yield or 0,2 per cent proof stress at temperatures of 100°C and higher are given in Table 4.6.3. These values are intended for design purposes only, and verification is not required except for materials complying with National or proprietary specifications where the elevated temperature properties used for design purposes are higher than those given in Table 4.6.3.

6.6.2 In such cases, at least one tensile test at the proposed design or other agreed temperature is to be made on each casting or each batch of castings. The test specimen is to be taken from material adjacent to that used for tests at ambient temperature, and the test procedure is to be in accordance with the requirements of Chapter 2. The results of all tests are to comply with the requirements of the National or proprietary specification.

6.6.3 Values for the estimated average stress to rupture in 100 000 hours are given in Table 4.6.4 and may be used for design purposes.

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Table 4.6.3 Mechanical properties for design purposes (*see* 6.6.1)

Type of steel	Nominal minimum lower yield or 0,2% proof stress N/mm^2										
	Temperature °C										
	100	150	200	250	300	350	400	450	500	550	600
Carbon-manganese	225	214	201	186	163	156	152	—	—	—	—
1/2Mo	242	236	226	207	186	175	169	158	145	136	126
1Cr1/2Mo	240	—	212	—	196	—	184	—	160	—	117
2 1/4Cr1 Mo	323	312	305	296	290	280	273	258	240	211	180
1/2Cr1/2Mo1/4V	264	—	244	—	230	—	214	—	194	—	144

Table 4.6.4 Mechanical properties for design purposes (*see* 6.6.3)**: estimated average stresses to rupture in 100,000 hours (N/mm^2)**

Temperature °C	Type of steel			
	1/2Mo	1Cr1/2Mo	2 1/4Cr1Mo	1/2Cr1/2Mo1/4V
430	308	—	—	—
440	276	—	—	—
450	245	—	222	277
460	212	—	199	237
470	174	236	177	206
480	133	186	156	181
490	103	148	139	159
500	84	120	124	140
510	71	100	111	124
520	60	84	99	109
530	—	70	—	96
540	—	58	—	85
550	—	—	—	75
560	—	—	—	66

Section 7
Ferritic steel castings for low temperature service

7.1 Scope

7.1.1 This Section gives the requirements for castings in carbon-manganese and nickel alloy steels intended for use in liquefied gas piping systems where the design temperature is lower than 0°C, and for other applications where guaranteed impact properties at low temperatures are required.

7.1.2 Where it is proposed to use alternative steels, particulars of the specified chemical composition, mechanical properties and heat treatment are to be submitted for approval.

7.2 Chemical composition

7.2.1 The chemical composition of ladle samples is to comply with the limits specified in Table 4.7.1. Carbon-manganese steels are to be made by fine grain practice.

7.3 Heat treatment

7.3.1 Castings are to be supplied:
(a) normalised; or
(b) normalised and tempered; or
(c) quenched and tempered.

7.4 Mechanical tests

7.4.1 One tensile test and one set of three Charpy V-notch impact test specimens are to be prepared from material representing each casting or batch of castings.

7.4.2 The tensile test is to be carried out at ambient temperature, and the results are to comply with the appropriate requirements given in Table 4.7.2.

7.4.3 The average value for impact test specimens is to comply with the appropriate requirements given in Table 4.7.2. One individual value may be less than the required average value provided that it is not less than 70 per cent of this average value. *See* Ch 2,1.4 for re-test procedure.

7.5 Non-destructive examination

7.5.1 The non-destructive examination of castings is to be carried out in accordance with the appropriate requirements of 1.7.7 to 1.7.11 and additionally agreed between the manufacturer, purchaser and Surveyor.

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Table 4.7.1 Chemical composition of ferritic steel castings for low temperature service

Type of steel	Chemical composition %						
	C max.	Si max.	Mn	S max.	P max.	Ni	Residual elements max.
Carbon-manganese	0,25	0,60	0,70-1,60	0,030	0,030	0,80 max.	Cr 0,25 Cu 0,30 Mo 0,15 V 0,03 Total 0,60
2 1/4Ni	0,25	0,60	0,50-0,80	0,025	0,030	2,00-3,00	
3 1/2Ni	0,15	0,60	0,50-0,80	0,020	0,025	3,00-4,00	

Table 4.7.2 Mechanical properties for acceptance purposes: ferritic steel castings for low temperature service

Type of steel	Grade	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation on $5,65\sqrt{S_o}$ % minimum	Reduction or area % minimum	Charpy V-notch impact test	
						Test temperature °C	Average energy J minimum
Carbon-manganese	400 430 460	200 215 230	400-550 430-580 460-610	25 23 22	40 35 30	–60 (*see* Note)	27
2 1/4Ni	490	275	490-640	20	35	–70	34
3 1/2Ni	490	275	490-640	20	35	–95	34

NOTE
The test temperature for carbon-manganese steels may be 5°C below the design temperature if the latter is above –55°C, with a maximum test temperature of –20°C.

■ *Section 8*
Stainless steel castings

8.1 Scope

8.1.1 This Section gives the requirements for castings in austenitic and duplex stainless steels for machinery, marine structures, piping systems in ships for liquefied gases, and in bulk chemical tankers.

8.1.2 Austenitic stainless steels castings are suitable for applications where the lowest design temperature is not lower than –165°C.

8.1.3 Duplex stainless steels castings are suitable for applications where the lowest design temperature is above 0°C. Any requirement to use duplex stainless steels castings below 0°C will be subject to special consideration.

8.1.4 Where it is proposed to use alternative steels, particulars of the specified chemical composition, mechanical properties and heat treatment are to be submitted for approval.

8.2 Chemical composition

8.2.1 The chemical composition of ladle samples is to comply with the requirements given in Table 4.8.1.

8.3 Heat treatment

8.3.1 Austenitic stainless steel castings are to be solution treated at a temperature of not less than 1000°C and cooled rapidly in water.

8.3.2 Duplex stainless steels castings are to be solution treated at a temperature of not less that 1100°C and cooled rapidly in water.

8.4 Mechanical tests

8.4.1 One tensile test specimen is to be prepared from material representing each casting or batch of castings. In addition, where the castings are intended for liquefied gas applications, where the design temperature is lower than –55°C, one set of three Charpy V-notch impact test specimens is to be prepared.

8.4.2 The tensile test is to be carried out at ambient temperature, and the results are to comply with the requirements given in Table 4.8.2.

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Table 4.8.1 Chemical composition of stainless steel castings

Type of steel	Chemical composition %								
	C	Si	Mn	S	P	Cr	Mo	Ni	Others
Austenitic									
304L	0,03	0,20-1,5	0,50-2,0	0,040		17,0-21,0	—	8,0–12,0	—
304	0,08						—	8,0–12,0	—
316L	0,03						2,0–3,0	9,0–13,0	—
316	0,08						2,0–3,0	9,0–13,0	—
317	0,08						3,0–4,0	9,0–12,0	—
347 (*see* Note 1)	0,06						—	9,0–12,0	Nb ≥ 8 x C ≤ 0,90
Duplex									
UNS S 31803	0,03	1,00	2,00	0,025	0,035	21,0–23,0	2,5–3,5	4,5–6,5	N 0,08–0,20

NOTES
1. When guaranteed impact values at low temperature are not required, the maximum carbon content may be 0,08% and the maximum niobium may be 1,00%.
2. Where a single value is shown (and not a range of values), the value is to be taken as maximum.

Table 4.8.2 Mechanical properties for acceptance purposes: stainless steel castings

Type of steel	Tensile strength N/mm^2 minimum	1,0% proof stress N/mm^2 minimum	Elongation on $5,65\sqrt{S_o}$ % minimum	Reduction of area % minimum	Charpy V-notch impact tests	
					Test temperature °C	Average energy J minimum
Austenitic						
304L	430	215	26	40	–196	41
304	480	220				
316L	430	215	26	40	–196	41
316	480	220				
317	480	240				
347	480	215	22	35	–196	41
Duplex						
UNS S 31803	600	420	20	35	0	41

8.4.3 The average value for impact test specimens is to comply with the appropriate requirements given in Table 4.8.2. One individual value may be less than the required average value provided that it is not less than 70 per cent of this average value. *See* Ch 2,1.4 for re-test procedures.

8.5 Intergranular corrosion tests

8.5.1 Where corrosive conditions are anticipated in service, intergranular corrosion tests are required on castings in grades 304, 316, 317 and all duplex stainless steels. Such tests may not be required for grades 304L, 316L and 347.

8.5.2 Where an intergranular corrosion test is specified, it is to be carried out in accordance with the procedure given in Ch 2,8.1.

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8.6 Non-destructive examination

8.6.1 The non-destructive examination of castings is to be carried out in accordance with the appropriate requirements of 1.7.7 to 1.7.11 and additionally agreed between the manufacturer, purchaser and Surveyor.

■ *Section 9*
Steel castings for container corner fittings

9.1 General

9.1.1 This Section gives the requirements for cast steel corner fittings used in the fabrication of freight and tank containers. The fittings are also to comply with the requirements of the latest edition of International Standard ISO 1161.

9.1.2 The castings are to be made in foundries approved by LR. These foundries are also to be specially approved for the manufacture of container corner castings. In order to comply with these requirements, the manufacturer is required to verify that the casting soundness, mechanical properties, weldability and dimensional tolerances required by this Section and the manufacturing specification are met.

9.1.3 Castings may be released on the basis of an LR survey or, alternatively, the manufacturer may be approved by means of a Quality Assurance Scheme as detailed in Ch 1,2.

9.2 Chemical composition

9.2.1 Chemical analysis is to be carried out on each cast.

9.2.2 The chemical composition of the ladle samples is to comply with the limits given in Table 4.9.1.

9.2.3 The carbon equivalent:

$$C_{eq} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15} \ (\%)$$

must not exceed 0,45 per cent.

9.3 Heat treatment

9.3.1 Castings are to be supplied either:

(a) normalised; or

(b) water or oil quenched and tempered at a temperature of not less than 550°C.

9.4 Mechanical tests

9.4.1 At least one tensile test is to be made on each batch of castings, using separately cast test bars which are to be from the same cast and heat treatment lot as the castings they represent.

9.4.2 The results of the tensile tests are to comply with the following:

Yield stress	220 N/mm² min.
Tensile strength	430–600 N/mm²
Elongation on $\sqrt{S_o}$	25% min.
Reduction of area	40% min.

9.4.3 Impact tests are not required on all casts but may be required on a random basis at the discretion of the Surveyor.

9.4.4 When required, the impact test specimens are to be tested in accordance with Ch 1,4.5 and Ch 2,3.2. In general, tests are to be made at a temperature of –20°C and the minimum average energy obtained is to be 27J.

9.5 Non-destructive examination

9.5.1 Ultrasonic or radiographic testing is to be carried out, in accordance with 1.7.10 or 1.7.11 respectively, on at least one casting from each cast or from every 400 castings, whichever is the lesser.

9.6 Repair of defects

9.6.1 Minor defects may be removed by grinding provided that the allowable minus tolerance is not exceeded.

Table 4.9.1 Chemical composition of steel castings for container corner fittings

Chemical composition %										
C max.	Mn	Si max.	P max.	S max.	Cr max.	Ni max.	Cu max.	Mo max.	Al acid soluble min. (*See* Notes)	Cr + Ni + Cu + Mo max.
0,20	0,90 to 1,50	0,50	0,035	0,035	0,25	0,30	0,20	0,08	0,015	0,70

NOTES
1. The total aluminium content may be determined instead of the acid soluble content. In such cases, the total aluminium content is to be not less than 0,02%.
2. Aluminium may be replaced partly or totally by other grain refining elements as stated in the approved specification.

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9.6.2 Defects which exceed the allowable minus tolerance may be removed by grinding or chipping followed by welding, provided the weld depth does not exceed 40 per cent of the wall thickness and that the following requirements are met:

(a) welding is not to be carried out in the as-cast condition; the grain structure has to be refined by heat treatment,
(b) the casting is to be preheated to 80–100°C,
(c) welding is to be performed only by qualified welders in accordance with a qualified welding procedure,
(d) all welded castings are to be post-weld heat treated at a temperature not less than 550°C,
(e) the welded areas are to be ground or machined flush with the adjacent surface and inspected by magnetic particle or dye penetrant examination as appropriate.

9.7 Identification

9.7.1 Each casting is to be clearly marked by the manufacturer with at least the following:

(a) manufacturer's name or trade mark,
(b) cast number or identification number which will enable the full history of the casting to be traced.

9.7.2 Where the casting has been inspected and found acceptable it is to be marked with the Surveyor's personal stamp.

9.7.3 The markings may be stamped or cast on the inner surface of the casting.

9.8 Certification of materials

9.8.1 For each consignment a manufacturer's certificate is to be issued (*see* Ch 1,3.1), containing at least the following:

(a) Purchaser's name and order number.
(b) Grade of steel.
(c) Drawing and/or specification number.
(d) Cast number and chemical composition.
(e) Details of the heat treatment.
(f) Number and weight of the castings.
(g) Results of inspections and mechanical tests.

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Steel Forgings

Chapter 5

Section 1

Section

1 **General requirements**

2 **Forgings for ship and other structural applications**

3 **Forgings for shafting and machinery**

4 **Forgings for crankshafts**

5 **Forgings for gearing**

6 **Forgings for turbines**

7 **Forgings for boilers, pressure vessels and piping systems**

8 **Ferritic steel forgings for low temperature service**

9 **Austenitic stainless steel forgings**

Section 1
General requirements

1.1 Scope

1.1.1 This Section gives the general requirements for steel forgings intended for use in the construction of ships, other marine structures, machinery, boilers, pressure vessels and piping systems. These requirements are also applicable to rolled slabs and billets used as a substitute for forgings and to rolled bars used for the manufacture (by machining operations only) of shafts, bolts, studs and other components of similar shape.

1.1.2 When required by the relevant Rules dealing with design and construction, forgings are to be manufactured and tested in accordance with Chapters 1 and 2, together with the general requirements given in this Section and the appropriate specific requirements given in Sections 2 to 9.

1.1.3 As an alternative to 1.1.2, steel forgings which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Chapter or alternatively are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

1.1.4 Normalised forgings with mass up to 1000 kg each and quenched and tempered forgings with mass up to 500 kg each may be batch tested. A batch is to consist of forgings of similar shape and dimensions, made from the same heat of steel, heat treated in the same furnace charge and with a total mass not exceeding 6 tonnes for normalised forgings and 3 tonnes for quenched and tempered forgings, respectively.

1.1.5 A batch testing procedure may also be used for hot rolled bars, *see* 3.4.3.

1.1.6 Where small forgings are produced in large quantities, or where forgings of the same type are produced in regular quantities, alternative survey procedures in accordance with Ch 1,2.4 may be adopted.

1.2 Manufacture

1.2.1 Forgings are to be made at works which have been approved by Lloyd's Register (hereinafter referred to as LR). The steel used is to be manufactured in accordance with the requirements of Ch 3,1.3.

1.2.2 When forgings are made directly from ingots, or from blooms or billets forged from ingots, the ingots are to be cast in chill moulds with the larger cross-section uppermost and with efficient feeder heads.

1.2.3 Adequate top and bottom discards are to be made to ensure freedom from piping and harmful segregations in the finished forgings.

1.2.4 The forgings are to be gradually and uniformly hot worked and are to be formed as closely as possible to the finished shape and size. The plastic deformation is to be such as to ensure soundness, uniformity of structure and satisfactory mechanical properties after heat treatment.

1.2.5 For certain components, such as crankshafts, where grain flow is required in the most favourable direction having regard to the mode of stressing in service, the proposed method of manufacture may require special approval by LR. In such cases, tests may be required to demonstrate that a satisfactory structure and grain flow are obtained.

1.2.6 The reduction ratio (reduction of area expressed as a ratio) is to be calculated with reference to the average cross-sectional area of the ingot or continuously cast material, where appropriate. Where an ingot is initially upset, this reference area may be taken as the average cross-sectional area after this operation.

1.2.7 For components forged directly from ingots or from forged blooms or billets, and in which the fibre deformation is mainly longitudinal, the reduction ratio is not to be less than 3:1.

1.2.8 For forgings made from rolled billets, or where fibre deformation has taken place in more than one direction, the reduction ratio is not to be less than 4:1.

1.2.9 Where rolled bars are used as a substitute for forgings and the requirements of 1.2.2 are not complied with, the reduction ratio is to be not less than 6:1.

1.2.10 Where the length of any section of a shaft forging is less than its diameter (e.g. a collar), the reduction ratio is to be not less than half that given in 1.2.7, 1.2.8 or 1.2.9 respectively.

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1.2.11 Disc type forgings, such as gear wheels, are to be made by upsetting, and the thickness of any part of the disc is to be not more than one-half of the length of the billet from which it was formed, provided that this billet has received an initial forging reduction of not less than 1,5:1. Where the piece used has been cut directly from an ingot, or where the billet has received an initial reduction of less than 1,5:1, the thickness of any part of the disc is to be not more than one-third of the length of the original piece.

1.2.12 Rings and other types of hollow forgings are to be made from pieces cut from ingots or billets and which have been suitably punched, bored or trepanned prior to expanding or hollow forging. Alternatively, pieces from hollow cast ingots may be used. The wall thickness of the forging is to be not more than one-half of the thickness of the prepared hollow piece from which it was formed. Where this is not practicable, the forging procedure is to be such as to ensure that adequate work is given to the piece prior to punching, etc. This may be either longitudinal or upset working of not less than 2:1.

1.2.13 The shaping of forgings or rolled slabs and billets by flame cutting, scarfing or arc-air gouging is to be undertaken in accordance with recognised good practice and, unless otherwise approved, is to be carried out before the final heat treatment. Preheating is to be employed where necessitated by the composition and/or thickness of the steel. For certain components, subsequent machining of all flame cut surfaces may be required, *see* 4.2.4.

1.2.14 Where two or more forgings are joined by welding to form a composite component, details of the proposed welding procedure are to be submitted for approval. Welding approval procedure tests may be required.

1.3 Quality

1.3.1 All forgings are to be free from surface or internal defects which would be prejudicial to their proper application in service.

1.4 Chemical composition

1.4.1 All forgings are to be made from killed steels, and the chemical composition of ladle samples is to comply with the requirements detailed in subsequent Sections in this Chapter. Where general overall limits are specified, the chemical composition selected is to be appropriate for the type of steel, dimensions and required mechanical properties of the forgings being manufactured.

1.4.2 Except where otherwise specified, suitable grain refining elements such as aluminium, niobium or vanadium may be used at the discretion of the manufacturer. The content of such elements is to be reported in the ladle analysis.

1.4.3 For alloy steel forgings, the chemical composition of ladle samples is to generally comply with the following overall limits and the requirements of the approved specifications:

Carbon	0,45% max.
Silicon	0,45% max.
Manganese	0,30% min.
Sulphur	0,035% max.
Phosphorus	0,035% max.
Copper	0,30% max.

And at least one of the following elements is to comply with the minimum content:

Chromium	0,40% min.
Molybdenum	0,15% min.
Nickel	0,40% min.

The contents of all alloying elements and significant impurities detailed in the specification are to be reported.

1.5 Heat treatment

1.5.1 At an appropriate stage of manufacture, after completion of all hot working operations, forgings are to be suitably heat treated to refine the grain structure and to obtain the required mechanical properties. Acceptable heat treatment procedures are to be such as to avoid the formation of hair-line cracks and are detailed in Sections 2 to 9.

1.5.2 Heat treatment is to be carried out in properly constructed furnaces which are efficiently maintained and have adequate means for control and recording of temperature. The furnace dimensions are to be such as to allow the whole furnace charge to be uniformly heated to the necessary temperature. In the case of very large forgings, alternative methods of heat treatment will be specially considered. Sufficient thermocouples are to be connected to the furnace charge to measure and record that its temperature is adequately uniform. Alternative procedures are to be approved by LR, Materials and NDE Department.

1.5.3 Where forgings are to be quenched and tempered and cannot be hot worked close to size and shape, they are to be suitably rough machined or flame cut prior to being subjected to this treatment.

1.5.4 If for any reason a forging is subsequently heated for further hot working, the forging is to be reheat treated.

1.5.5 If any straightening operation is performed after the final heat treatment, consideration should be given to a subsequent stress relieving heat treatment in order to avoid the possibility of harmful residual stresses.

1.5.6 Where it is intended to surface harden forgings, full details of the proposed procedure and specification are to be submitted for approval. For the purposes of this approval, the manufacturer will be required to demonstrate by tests that the proposed procedure gives a uniform surface layer of the required hardness and depth and that it does not impair the soundness and properties of the steel.

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1.5.7 Where induction hardening or nitriding is to be carried out after machining, forgings are to be heat treated at an appropriate stage to a condition suitable for this subsequent surface hardening.

1.5.8 Where carburising is to be carried out after machining, forgings are to be heat treated at an appropriate stage (generally either by full annealing or by normalising and tempering) to a condition suitable for subsequent machining and carburising.

1.5.9 The forge is to maintain records of heat treatment identifying the furnace used, furnace charge, thermocouple location, date, temperature and time at temperature. The records are to be presented to the Surveyor on request.

1.6 Test material

1.6.1 Test material, sufficient for the required tests and for possible re-test purposes, is to be provided with a cross-sectional area of not less than that part of the forging which it represents. This test material is to be integral with each forging, except in the case of small forgings which are batch tested, *see* 1.6.4.

1.6.2 Where a forging is subsequently divided into a number of components, all of which are heat treated together in the same furnace charge, for test purposes this may be regarded as one forging and the number of tests required is to be related to the total length and mass of the original multiple forging, *see* 2.4.2.

1.6.3 Except for components which are to be carburised, test material is not to be cut from a forging until the heat treatment detailed in Sections 2 to 9 has been completed. The testing procedure for components which are to be carburised is to be in accordance with the details given in Section 5.

1.6.4 Where a number of small forgings of about the same size are made from one cast and heat treated in the same furnace charge, batch testing procedures (*see* 1.1.4) may be adopted using one of the forgings for test purposes, or alternatively using separately forged test samples. These test samples are to have a forging reduction similar to that used for the forgings which they represent. They are to be properly identified and heat treated together with the forgings.

1.7 Mechanical tests

1.7.1 Specimens for mechanical tests are to be prepared as required by Sections 2 to 9.

1.7.2 Test specimens are normally to be cut with their axes mainly parallel (longitudinal test) or mainly tangential (tangential test) to the principal axial direction of each product.

1.7.3 Unless otherwise agreed, the longitudinal axis of the test specimens is to be positioned as follows:

(a) for thickness or diameter ≤ 50 mm, the axis is to be at the mid-thickness or the centre of the cross-section;

(b) for thickness or diameter > 50 mm, the axis is to be at one quarter thickness (mid-radius) or 80 mm, whichever is less, below any heat treated surface;

Test pieces shall be taken in such a way that no part of the gauge length is machined from material closer than 12,5 mm to any heat treated surface. For impact testing, this requirement is to apply to the complete test piece.

1.7.4 Tensile test specimens are to be machined to the dimensions detailed in Chapter 2. Where this is precluded by the dimensions of the forging, the test specimen is to be of the largest practicable cross-sectional area.

1.7.5 Impact test specimens are to be prepared in accordance with the requirements of Chapter 2.

1.7.6 The procedures used for the tensile and impact tests are to be in accordance with the requirements of Chapter 2.

1.7.7 Hardness tests, preferably of the Brinell type, are to be carried out when specified in subsequent Sections in this Chapter.

1.8 Visual and non-destructive examination

1.8.1 Before acceptance, all forgings are to be presented to the Surveyor for visual examination. Where applicable, this is to include the examination of internal surfaces and bores.

1.8.2 Forgings are to be examined in the condition for final delivery. Surfaces are to be clean and free from dirt, grease, paint, etc. Black forgings are to be suitably descaled by either shotblasting or flame descaling methods.

1.8.3 All forgings are to be free of cracks, crack-like indications, laps, seams, folds, or other injurious indications. At the request of the Surveyor, additional magnetic particle, dye penetrant and ultrasonic testing may be required for a more detailed evaluation of surface irregularities.

1.8.4 When specified in subsequent Sections in this Chapter, or by an approved procedure for welding composite components, *see* 1.2.14, appropriate non-destructive examination is also to be carried out before acceptance. All tests are to be carried out in accordance with the requirements of Ch 1,5.

1.8.5 Magnetic particle and dye penetrant testing is to be carried out when the forgings are in the finished machined condition, *see also* Ch 1,2.3.5. For magnetic particle testing, attention is to be paid to the contact between the forging and the clamping devices of stationary magnetisation benches in order to avoid local overheating or burning damage on its surface. Prods are not permitted on finished machined items. Unless otherwise agreed, these tests are to be carried out in the presence of the Surveyor.

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1.8.6 The following definitions apply to indications associated with magnetic particle and dye penetrant inspection:

(a) **Linear indication.** An indication in which the length is at least three times the width.

(b) **Nonlinear indication.** An indication of circular or elliptical shape with a length less than three times the width.

(c) **Aligned indication.** Three or more indications in a line, separated by 2 mm or less edge-to-edge.

(d) **Open indication.** An indication visible after removal of the magnetic particles or that can be detected by the use of contrast dye penetrant.

(e) **Non-open indication.** An indication that is not visually detectable after removal of the magnetic particles or that cannot be detected by the use of contrast dye penetrant.

(f) **Relevant indication.** An indication that is caused by a condition or type of discontinuity that requires evaluation. Only indications which have any dimension greater than 1,5 mm are to be considered relevant.

1.8.7 Acceptance standards for defects found by visual or non destructive examinations are to be in accordance with any specific requirements of the approved plan, and with any additional requirements of this Chapter. In all cases they are to be to the satisfaction of the Surveyor.

1.8.8 Where required, ultrasonic examination is to be carried out after the forgings have been machined to a condition suitable for this type of examination and after the final heat treatment. Both radial and axial scanning are to be carried out where appropriate for the shape and the dimensions of the forgings being examined. Unless otherwise agreed, this examination is to be carried out by the manufacturer, although Surveyors may request to be present in order to verify that the examination is being carried out in accordance with the agreed procedure.

1.8.9 If the forging is supplied in the black condition for machining at a separate works, the manufacturer is to ensure that a suitable ultrasonic examination is carried out to verify the internal quality of the forging.

1.8.10 In the circumstance detailed in either 1.8.8 or 1.8.9, the manufacturer is to provide the Surveyor with a signed report confirming that ultrasonic examination has been carried out and that such inspection has not revealed any significant internal defects.

1.8.11 Unless otherwise agreed, the accuracy and verification of dimensions are the responsibility of the manufacturer.

1.8.12 In the event of any forging proving defective during subsequent machining or testing, it is to be rejected notwithstanding any previous certification.

1.8.13 When required by the conditions of approval for surface hardened forgings (*see* 1.5.6) additional test samples are to be processed at the same time as the forgings which they represent. These test samples are subsequently to be sectioned in order to determine the hardness, shape and depth of the locally hardened zone and which are to comply with the requirements of the approved specification.

1.9 Rectification of defects

1.9.1 Small surface imperfections may be removed by grinding or by chipping and grinding. Complete elimination of these imperfections is to be proved by magnetic particle or dye penetrant examination (as appropriate to the material). At the discretion of the Surveyor, the resulting shallow grooves or depressions can be accepted, provided that they are blended by grinding.

1.9.2 Repairs by welding are not generally permitted, but special consideration will be given to such repairs where they are of a minor nature and in areas of low working stresses. In such cases, full details of the proposed repair and subsequent inspection procedures are to be submitted for review by the Surveyors prior to the commencement of the proposed rectification. A report and/or sketch detailing the extent and location of all repairs, together with details of the post-weld heat treatment and non-destructive examination are to be provided for record purposes and are to be attached to the certificate.

1.9.3 Repair welding is not permitted for crankshafts or similar rotating components.

1.9.4 Where fabrication welding is involved, *see* 1.2.14, any repair of defects is to be carried out in accordance with the approved welding procedure.

1.9.5 The forging manufacturer is to maintain records of repairs and subsequent inspections traceable to each forging. The records are to be presented to the Surveyor on request.

1.9.6 Non-open indications evaluated as segregation are acceptable.

1.10 Identification

1.10.1 The manufacturer is to adopt a system of identification, which will enable all finished forgings to be traced to the original cast, forging process and heat treatment batch, and the Surveyor is to be given full facilities for so tracing the castings when required.

1.10.2 Forgings are to be clearly marked by the manufacturer in accordance with the requirements of Chapter 1. The following details are to be shown on all forgings which have been accepted:

(a) Identification number, cast number or other marking which will enable the full history of the forging to be traced.

(b) LR or Lloyd's Register and the abbreviated name of LR's local office.

(c) Personal stamp of Surveyor responsible for inspection.

(d) Test pressure, where applicable.

(e) Date of final inspection.

1.10.3 Modified arrangements for the identification of small forgings manufactured in large numbers, as with closed-die forgings may be agreed with the Surveyor.

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1.11 Certification of materials

1.11.1 A LR certificate is to be issued, *see* Ch 1,3.1.

1.11.2 The manufacturer is to provide the Surveyor with a written statement giving the following particulars for each forging or batch of forgings which has been accepted:
(a) Purchaser's name and order number.
(b) Description of forgings and steel quality.
(c) Identification number.
(d) Steelmaking process, cast number and chemical analysis of ladle samples.
(e) General details of heat treatment.
(f) Results of mechanical tests.
(g) Test pressure, where applicable.

1.11.3 As a minimum, the chemical composition of ladle samples is to include the content of all the elements detailed in the specific requirements.

1.11.4 Where applicable, the manufacturer is also to provide a signed report regarding ultrasonic examination as required by 1.8.8, a report of magnetic particle inspection and a statement and/or sketch detailing all repairs by welding as required by 1.9.2.

1.11.5 When steel is not produced at the works at which it is forged, a certificate is to be supplied by the steelmaker stating the process of manufacture, cast number and the chemical composition of ladle samples. The works at which the steel was produced is to have been approved by LR, *see* 1.4.3.

■ *Section 2*
Forgings for ship and other structural applications

2.1 Scope

2.1.1 This Section gives the specific requirements for carbon-manganese steel forgings intended for ship and other structural applications such as rudder stocks, pintles, etc.

2.1.2 Where it is proposed to use an alloy steel, particulars of the chemical composition, mechanical properties and heat treatment are to be submitted for approval, *see* 1.4.3.

2.2 Chemical composition

2.2.1 For forgings to which structural items are to be attached by welding or which are intended for parts of a fabricated component, or are to be weld cladded or may be subject to weld repair in service, the chemical composition of ladle samples is to comply with the following:

Carbon	0,23% max.
Silicon	0,45% max.
Manganese	0,30–1,50% but not less than 3 times the actual carbon content for components which are not given a post-weld heat treatment
Sulphur	0,035% max.
Phosphorus	0,035% max.
Residual elements:	
Copper	0,30% max.
Chromium	0,30% max.
Molybdenum	0,15% max.
Nickel	0,40% max.
Total	0,85% max.

For samples from forgings, the carbon content is not to exceed 0,26 per cent.

2.2.2 It is recommended that forgings for rudder stocks, pintles and rudder coupling bolts comply with 2.2.1 in order to obtain satisfactory weldability for any future repairs by welding in service.

2.2.3 For forgings not intended for welding the carbon content may be 0,65 per cent max., *see* 3.2.1.

2.3 Heat treatment

2.3.1 Carbon-manganese steel forgings are to be:
(a) fully annealed; or
(b) normalised; or
(c) normalised and tempered at a temperature of not less than 550°C.
(d) quenched and tempered.

2.3.2 Alloy steel forgings are to be quenched and then tempered at a temperature of not less than 550°C. Alternatively, they may be supplied in the normalised and tempered condition, in which case the specified mechanical properties are to be agreed by LR.

2.4 Mechanical tests

2.4.1 At least one tensile specimen is to be taken from each forging or batch of forgings.

2.4.2 Where a forging exceeds both 4 tonnes in mass and 3 m in length, tensile test specimens are to be taken from each end. These limits refer to the 'as forged' mass and length but exclude the test material.

2.4.3 Unless otherwise agreed between the manufacturer and the Surveyor, the test specimens are to be cut in a longitudinal direction.

2.4.4 The results of all tensile tests are to comply with the requirements given in Table 5.2.1 appropriate to the specified minimum tensile strength. Forgings may be supplied to any specified minimum tensile strength within the general limits given in Table 5.2.1, and intermediate values may be obtained by interpolation. *See* 2.4.6 for rudder stocks, pintles, and rudder coupling keys and bolts.

2.4.5 For large forgings, where tensile tests are taken from each end, the variation in tensile strength is not to exceed 70 N/mm^2.

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Table 5.2.1 Mechanical properties for ship and other structural applications

Steel type	Yield stress N/mm² minimum	Tensile strength N/mm²	Elongation on $5{,}65\sqrt{S_o}$ min.%		Reduction of area min. %	
			Long.	Tang.	Long.	Tang.
C and C-Mn	180	360-480	28	20	50	35
	200	400-520	26	19	50	35
	220	440-560	24	18	50	35
	235	470-590	23	17	45	35
	240	480-600	22	16	45	30
	260	520-640	21	15	45	30
	280	560-680	20	14	40	27
	300	600-750	18	13	40	27
	320	640-790	17	12	40	27
	340	680-830	16	12	35	24
	360	720-870	15	11	35	24
	380	760-910	14	10	35	24
Alloy	350	550-570	20	14	50	35
	400	600-750	18	13	50	35
	450	650-800	17	12	50	35

2.4.6 For rudder stocks, pintles, and rudder coupling keys and bolts, the minimum specified yield strength is not to be less than 200 N/mm², *see* Table 13.2.4 in Pt 3, Ch 13.

2.4.7 Impact tests are required for rudder stocks to be fitted to vessels which have an ice class notation. The tests are to be carried out at minus 10°C and the average energy value is to be not less than 27J.

2.5 Non-destructive examination

2.5.1 Surface inspections are to be carried out by visual examination and magnetic particle testing (or dye penetrant testing where appropriate).

2.5.2 Surface inspections are to be carried out in the zones I and II as indicated in Fig. 5.2.1.

2.5.3 For the purpose of evaluating indications, the surface is to be divided into reference areas of 225 cm². The area is to be taken in the most unfavourable location relative to the indication being evaluated.

2.5.4 The allowable number and size of indications in the reference area is given in Table 5.2.2.

2.5.5 Volumetric inspection is to be carried out by ultrasonic testing using the contact method.

2.5.6 Ultrasonic testing is to be carried out on rudder stocks having a finished diameter of 200 mm or greater.

2.5.7 Ultrasonic testing is to be carried out in the zones I to III as indicated in Fig. 5.2.2. Areas may be upgraded to a higher zone at the discretion of the Surveyors.

Table 5.2.2 Steel forgings surface inspection

Inspection zone	Maximum number of indications	Type of indication	Maximum number each type	Maximum dimension, mm
I	3	Linear Non-linear Aligned	0, *see* Note 3 0, *see* Note	— 3,0 —
II	10	Linear Non-linear Aligned	3, *see* Note 7 3, *see* Note	3,0 5,0 3,0

NOTE
Linear or aligned indications are not permitted on bolts, which receive a direct fluctuating load, e.g. main bearing bolts, connecting rod bolts, crosshead bearing bolts and cylinder cover bolts.

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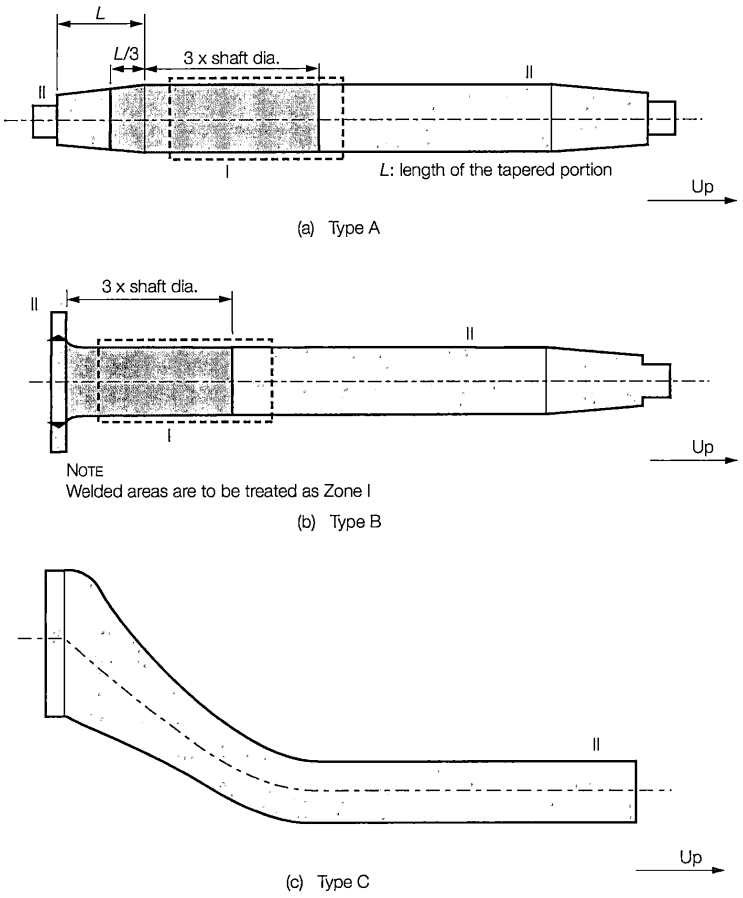

Fig. 5.2.1 Inspection zones for magnetic particle/dye penetrant testing on rudder stocks

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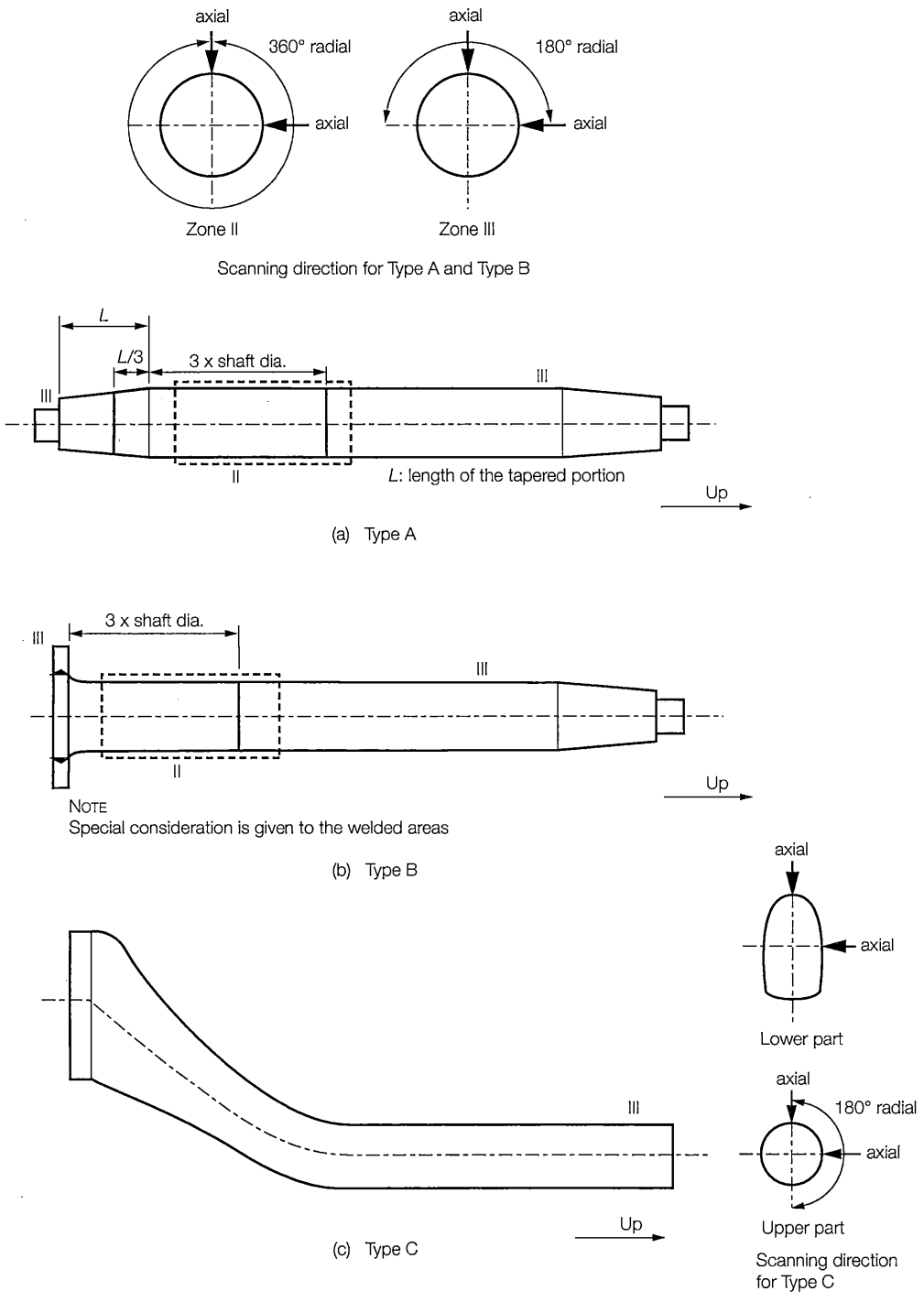

Fig. 5.2.2 Inspection zones for ultrasonic testing on rudder stocks

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Section 3
Forgings for shafting and machinery

3.1 Scope

3.1.1 Detailed in this Section are the requirements for carbon-manganese steel forgings for shafting and other items of machinery which are not within the scope of Sections 4 to 8.

3.1.2 Where it is proposed to use alloy steel forgings, particulars of the chemical composition, mechanical properties and heat treatment are to be submitted for approval. For main propulsion shafting in alloy steels, the specified minimum tensile strength is not to exceed 800 N/mm^2 (800–950 N/mm^2 acceptance range) and for other forgings is not to exceed 1100 N/mm^2 (1100–1300 N/mm^2 acceptance range).

3.2 Chemical composition

3.2.1 The chemical composition of ladle samples for carbon and carbon-manganese steels is to comply with the following overall limits:

Carbon	0,65% max.
Silicon	0,45% max.
Manganese	0,30–1,50%
Sulphur	0,035% max.
Phosphorus	0,035% max.
Residual elements:	
Copper	0,30% max.
Chromium	0,30% max.
Molybdenum	0,15% max.
Nickel	0,40% max.
Total	*0,85% max.*

3.2.2 For alloy steels, *see* 1.4.3.

3.2.3 For forgings to which structural items are to be attached by welding, or which are intended for parts of a fabricated component, are to be of weldable quality, *see* 2.2.1.

3.3 Heat treatment

3.3.1 Forgings are to be:
(a) fully annealed; or
(b) normalised; or
(c) normalised and tempered; or
(d) quenched and tempered.
The tempering temperature is to be not less than 550°C.

3.4 Mechanical tests

3.4.1 At least one tensile test is to be made on each forging, or each batch of forgings. Impact tests are not required except on screwshafts for ice service, *see* 3.4.12.

3.4.2 Where a forging exceeds both 4 tonnes in mass and 3 m in length, a tensile test is to be taken from each end. These limits refer to the 'as forged' mass and length but exclude the test material.

3.4.3 A batch testing procedure may be used for hot rolled bars not exceeding 250 mm diameter, which are intended for the manufacture (by machining operations only) of straight shafting, bolts, studs and other machinery components of similar shape. A batch is to consist of either:
(a) material from the same piece provided that where this is cut into individual lengths, these are all heat treated in the same furnace charge; or
(b) bars of the same diameter and cast, heat treated in the same furnace charge and with a total mass not exceeding 2,5 tonnes.

3.4.4 The test specimens are to be taken in the longitudinal direction but, at the discretion of the manufacturer and if agreed by the Surveyor, alternative directions or positions as shown in Figs. 5.3.1 to 5.3.3 may be used.

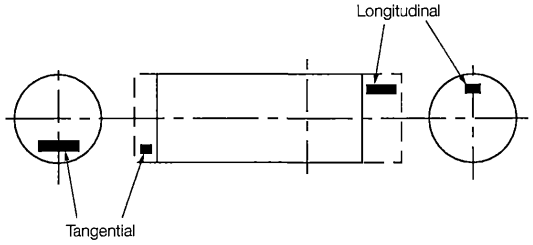

Fig. 5.3.1
Directions and positions of test specimens

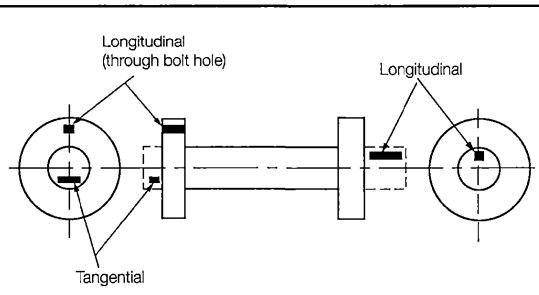

Fig. 5.3.2
Directions and positions of test specimens

3.4.5 For carbon-manganese steels, Table 5.3.1 gives the minimum requirements for yield stress, elongation and reduction of area, corresponding to different strength levels, but it is not intended that these should necessarily be regarded as specific grades. Intermediate values for other specified minimum tensile strengths should be calculated by interpolation.

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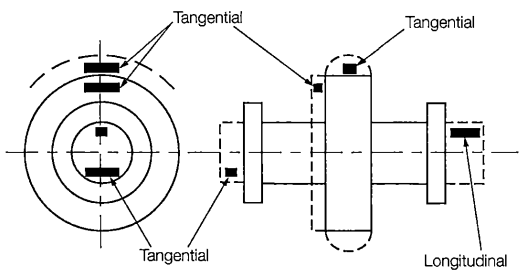

Fig. 5.3.3
Directions and positions of test specimens

3.4.6 Forgings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Table 5.3.1, except that for main propulsion shafting forgings the specified minimum tensile strength is to be not less than 400 N/mm^2 (400–520 N/mm^2 acceptance range) and not greater than 600 N/mm^2 (600–750 N/mm^2 acceptance range) *see* shaded area of Table 5.3.1.

3.4.7 The results of all tensile tests are to comply with the requirements given in Table 5.3.1 appropriate to the specified minimum tensile strength.

3.4.8 The minimum requirements for yield stress, elongation and reduction of area, corresponding to different strength levels in alloy steel forgings are given in Table 5.3.2.

Table 5.3.1 Mechanical properties for acceptance purposes: carbon and carbon-manganese steel forgings for machinery and shafting

Tensile strength N/mm^2	Yield stress N/mm^2	Elongation on $5{,}65\sqrt{S_o}$ min.%		Reduction of area min. %	
		Long.	Tang.	Long.	Tang.
360-480	180	28	20	50	35
400-520	200	26	19	50	35
440-560	220	24	18	50	35
470-590	235	23	17	45	35
480-600	240	22	16	45	30
520-640	260	21	15	45	30
560-680	280	20	14	40	27
600-750	300	18	13	40	27
640-790	320	17	12	40	27
680-830	340	16	12	35	24
700-850 [2]	350	15	11	35	24
720-870 [2]	360	15	11	35	24
760-910 [2]	380	14	10	35	24

NOTES
1. For main propulsion shafting forgings, the specified minimum tensile strength is to be between 400 and 600 N/mm^2 (shaded area of Table) *see* 3.4.6.
2. Where the specified minimum tensile strength exceeds 700 N/mm^2, forgings are to be supplied only in the quenched and tempered condition.

Table 5.3.2 Mechanical properties for acceptance purposes: alloy steel forgings for machinery and shafting

Tensile strength N/mm^2	Yield stress N/mm^2	Elongation on $5{,}65\sqrt{S_o}$ min.%		Reduction of area min. %	
		Long.	Tang.	Long.	Tang.
600-750	420	18	14	50	35
650-800	450	17	13	50	35
700-850	480	16	12	45	30
750-900	530	15	11	45	30
800 -950	580	14	10	40	27
850-1000	630	13	9	40	27
900-1100	690	13	9	40	27
950-1150	750	12	8	35	24
1000-1200	810	12	8	35	24
1050-1250	870	11	7	35	24
1100-1300	930	11	7	35	24

NOTE
For main propulsion shafting forgings, the minimum specified tensile strength is not to exceed 800 N/mm^2, *see* 3.4.9 (shaded area of Table).

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3.4.9 Forgings in alloy steels may be supplied to any specified minimum tensile strength selected within the general limits detailed in Table 5.3.2, and minimum yield stress, elongation and reduction of area, obtained by interpolation, except that for main propulsion shafting forgings the specified minimum tensile strength is not to exceed 800 N/mm^2 (800–950 N/mm^2 acceptance range) *see* shaded area of Table 5.3.2.

3.4.10 The results of all tensile tests are to comply with the requirements given in Table 5.3.2 appropriate to the specified minimum tensile strength.

3.4.11 Where more than one tensile test is taken from a forging, the variation in tensile strength is not to exceed the following:

Specified minimum tensile strength N/mm^2	Difference in tensile strength N/mm^2
<600	70
≥600 < 900	100
≥900	120

3.4.12 For screwshafts intended for ships with the notation **Ice Class 1AS** or **1A** and where the connection between the propeller and the screwshaft is by means of a key, a set of three Charpy V-notch impact tests (longitudinal test) is to be made on material from the propeller end of each shaft. The tests are to be carried out at –10°C and the average energy value is to be not less than 20 J.

3.5 Non-destructive examination

3.5.1 Magnetic particle or dye penetrant testing (where appropriate) is to be carried out on forgings for main propulsion shafting (including propeller shafts, intermediate shafts, and thrust shafts with minimum diameter not less than 100 mm), on all connecting rod, piston rod, and crosshead forgings and on the following components when they are intended for engines having a bore diameter larger than 400 mm:

- Cylinder covers
- Piston crowns
- Piston rods
- Tie rods
- Gear wheels for camshaft drives
- Bolts and studs for:
  - Cylinder covers
  - Crossheads
  - Main bearings
  - Connecting rod bearings
  - Propeller blade fastening bolts
  - Crankpin bolts
  - Tie rod bolts

  Additionally, bolts for engine bore diameters of less than 400 mm but having a minimum diameter 50 mm or greater (which are subjected to dynamic stress), are also to be subjected to surface examinations.

3.5.2 The areas to be tested by magnetic particle or dye penetrate testing are shown in Fig. 5.3.4 and Fig. 5.3.5. Areas of other components not shown in these figures are to be agreed with the Surveyor. For tie rods, only threaded portions and the adjacent material over a length equal to that of the thread need be tested.

3.5.3 Surface inspection acceptance criteria are to be in accordance with 2.5. Other acceptance criteria may be applied, providing they meet these minimum criteria, and are to the satisfaction of the Surveyor.

3.5.4 Ultrasonic testing is to be carried out in accordance with 2.5 on the following items:

(a) Shafts having a finished diameter of 200 mm or larger when intended for main propulsion or other essential services.
(b) All piston crowns and cylinder covers.
(c) Piston rods, connecting rods and crossheads for engines having a bore diameter greater than 200 mm.

The areas to be tested are shown in Fig. 5.3.6 and Fig. 5.3.7. Areas of other components not shown in these drawings are to be agreed with the Surveyor.

3.5.5 Ultrasonic acceptance criteria are shown in Table 5.3.4. Other acceptance criteria may be applied, providing they meet these minimum criteria, and are to the satisfaction of the Surveyor.

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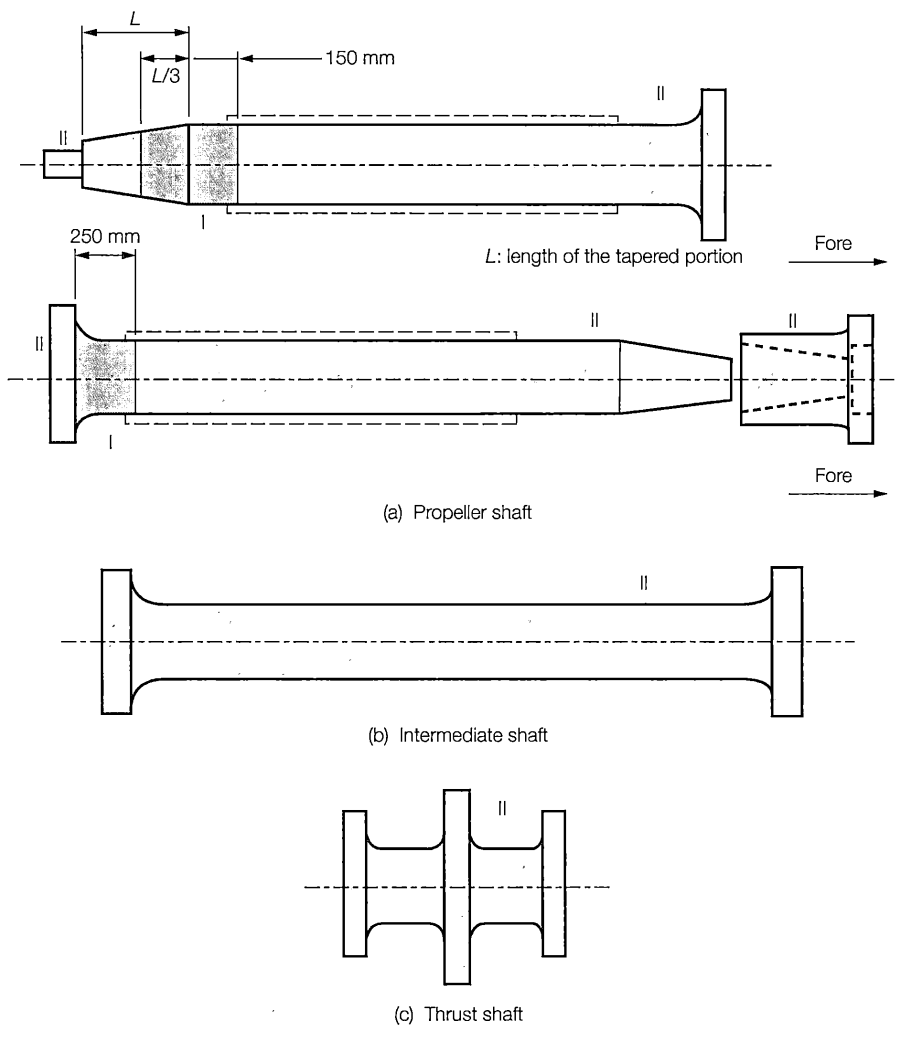

(a) Propeller shaft

(b) Intermediate shaft

(c) Thrust shaft

NOTE
For propeller shaft, intermediate shafts and thrust shafts, all areas with stress raisers such as radial holes, slots and key ways are to be treated as Zone I.

Fig. 5.3.4 Zones for magnetic particle/dye penetrant testing on machinery components

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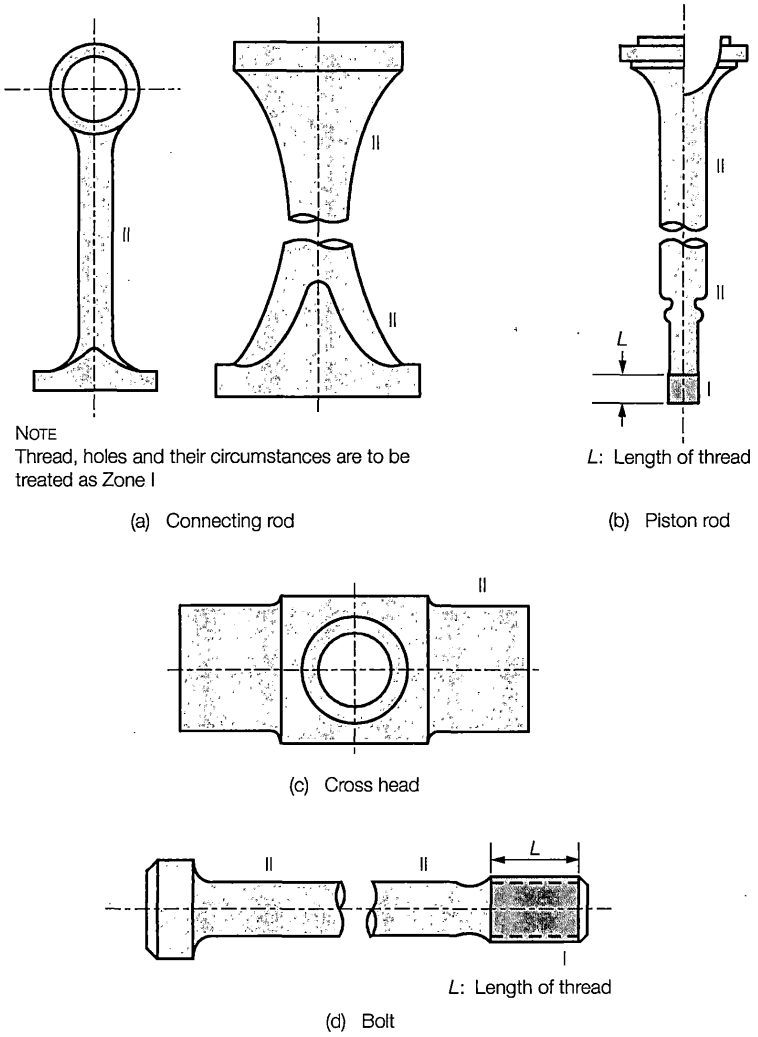

Fig. 5.3.5 *Zones for magnetic particle/dye penetrant testing on machinery components*

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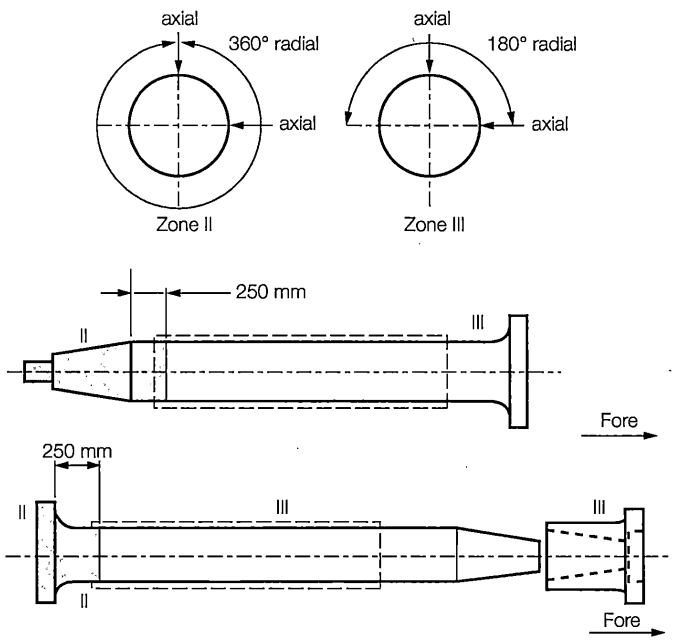
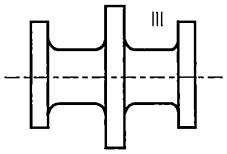


(a) Propeller shaft

(b) Intermediate shaft



(c) Thrust shaft

NOTES
1. For hollow shafts, 360° radial scanning applies to Zone III
2. Circumferences of the bolt holes in the flanges are to be treated as Zone II

Fig. 5.3.6 Zones for ultrasonic testing on shafts

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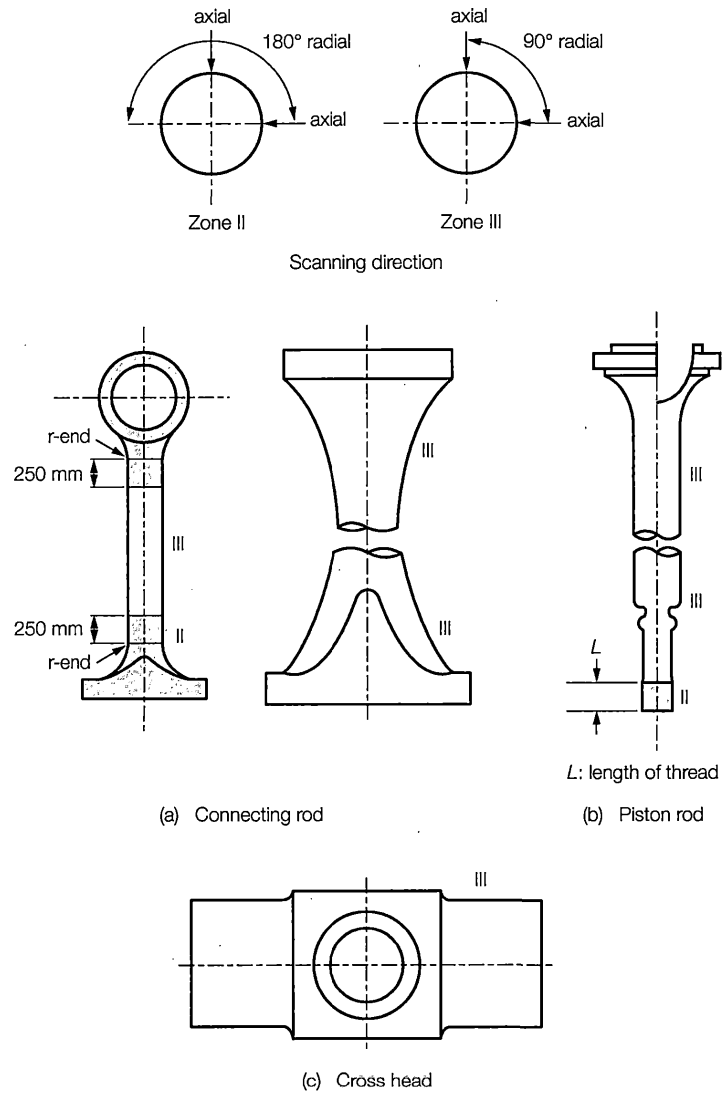

Fig. 5.3.7 Zones for ultrasonic testing on machinery components

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Table 5.3.4 Acceptance criteria for ultrasonic testing

Type of forging	Zone	Allowable disc shape according to Distance Gain Size (DGS), *see* Note 1, mm	Allowable length of indication, mm	Allowable distance between two indications, *see* Note 2, mm
Propeller shaft Intermediate shaft	II	Outer $d \leq 2$ Inner $d \leq 4$	≤10 ≤15	≥20 ≥20
Thrust shaft Rudder stock	III	Outer $d \leq 3$ Inner $d \leq 6$	≤10 ≤15	≥20 ≥20
Connecting rod Piston rod Crosshead	II	$d \leq 2$	≤10	≥20
	III	$d \leq 4$	≤10	≥20

NOTES
1. Outer part means the part beyond one third of the shaft radius from the centre. The inner part means the remaining core area.
2. For accumulations of two or more isolated indications which are subjected to registration, the minimum distance between two neighbouring indications is to be at least the length of the larger indication.

■ *Section 4*
Forgings for crankshafts

4.1 Scope

4.1.1 The specific requirements for solid forged crankshafts and forgings for use in the construction of fully built and semi-built crankshafts are detailed in this Section.

4.1.2 Where it is proposed to use alloy steel forgings, particulars of the chemical composition (*see* 1.4.3), heat treatment and mechanical properties are to be submitted for approval. The specified minimum tensile strength is not to exceed 1000 N/mm^2 (1000–1200 N/mm^2 acceptance range).

4.2 Manufacture

4.2.1 For closed die and continuous grain flow crankshafts forgings, where an allowance is given for design purposes, full details of the proposed method of manufacture are to be submitted for approval. In such cases, tests will be required to demonstrate that a satisfactory structure and grain flow are obtained. The number and positions of test specimens are to be agreed with LR.

4.2.2 For the manufacture of welded crankshafts, approval is required for the welding procedure.

4.2.3 For combined crankweb and pin forgings, the proposed method of forging is to be submitted for approval. It is recommended that these forgings be made by a folding method. Other methods which can be shown to produce sound forgings with satisfactory mechanical properties will be considered, but where the gapping method is used for cranks having a pin diameter exceeding 510 mm this will only be accepted provided that an upsetting operation is included in the manufacturing sequence. In general, the amount of work during the upsetting operation is to be such that the reduction in the original length of the ingot (after discard) or bloom is not less than 50 per cent.

4.2.4 Where crankwebs are flame cut from forged or rolled slabs, the procedure used is to be in accordance with 1.2.13, and additionally, unless specially agreed, a depth of at least 7,5 mm is to be removed by machining from all flame-cut surfaces.

4.3 Chemical composition

4.3.1 The chemical composition of ladle samples is to comply with 3.2.1 for carbon and carbon-manganese steels and 1.4.3 for alloy steels.

4.3.2 For alloy steel forgings which are to be nitrided, the phosphorus or sulphur contents are not to exceed 0,02 per cent.

4.4 Heat treatment

4.4.1 For forgings in all types of steels, heat treatment is to be either:
(a) normalising and tempering, or
(b) quenching and tempering.
The temperature used for tempering is to be not less than 550°C.

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4.4.2 Where it is proposed to surface harden crankshaft forgings by nitriding or induction hardening, full details of the proposed procedure are to be submitted as required by 1.5.6.

4.5 Mechanical tests

4.5.1 At least one tensile test specimen is to be taken from each forging.

4.5.2 For solid forged crankshafts, tests are to be taken in the longitudinal direction from the coupling end of each forging (test position A in Fig. 5.4.1). Where the mass, as heat treated but excluding test material, exceeds 3 tonnes, a second set of tests is to be taken from the end opposite the coupling, in addition (test position B in Fig. 5.4.1). Where the crankthrows are formed by machining or flame cutting, the second set of tests is to be taken in a tangential direction from material removed from the crankthrow at the end opposite the coupling (test position C in Fig. 5.4.1).For continuous grain flow (CGF) crankshaft forgings, where insufficient material exists for a second longitudinal test, the second set of tests may be taken in a tangential direction from the crankthrow (test position C in Fig. 5.4.2).

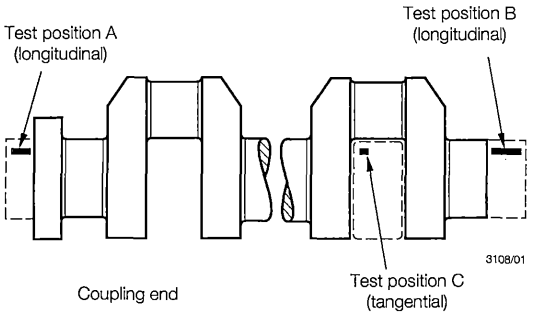

Fig. 5.4.1 Solid forged crankshaft

4.5.3 The number and position of test specimens from combined crankweb and pin forgings are to be in accordance with the requirements of the approved method of manufacture.

4.5.4 For other crankshaft forgings, tests are to be taken as detailed in Section 3, except that for crankwebs the test specimens are to be cut in a tangential direction.

4.5.5 As an alternative to 4.5.2, small solid forged crankshafts may be batch tested in accordance with 1.6.4, provided that, in addition, hardness tests are carried out on each forging.

4.5.6 Tables 5.4.1 to 5.4.3 give the minimum requirements for yield stress and elongation corresponding to different strength levels, but it is not intended that these should necessarily be regarded as specific grades. The strength levels have been given in multiples of 40 N/mm^2, or 50 N/mm^2 in the case of alloy steels, to facilitate interpolation for intermediate values of specified minimum tensile strength.

Table 5.4.1 Mechanical properties for acceptance purposes: carbon-manganese steel forgings for crankshafts

Tensile strength N/mm^2	Yield stress N/mm^2 minimum	Elongation on $5{,}65\sqrt{S_o}$ % minimum		Hardness Brinell
		Long.	Tang.	
400–520	200	26	19	110–150
440–560	220	24	18	125–160
480–600	240	22	16	135–175
520–640	260	21	15	150–185
560–680	280	20	14	160–200
600–750	300	18	13	175–215
640–790	320	17	12	185–230
680–830	340	16	12	200–240
720–870	350	15	11	210–250
760–910	380	14	18	225–265
Intermediate values may be obtained by interpolation.				

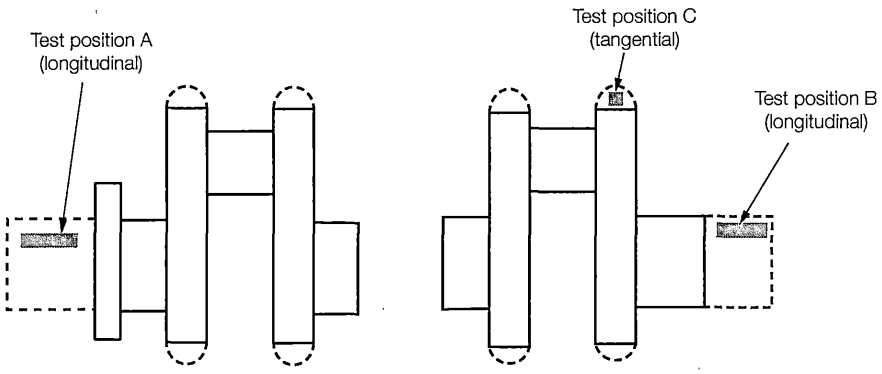

Fig. 5.4.2 CGF Crankshaft

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Table 5.4.2 Mechanical properties for acceptance purposes: alloy steel forgings for crankshafts – Normalised and tempered

Tensile strength N/mm²	Yield stress N/mm² minimum	Elongation on $5{,}65\sqrt{S_o}$ % minimum		Hardness Brinell
		Long.	Tang.	
600–750	330	18	14	175–215
650–800	355	17	13	190–235
700–850	380	16	12	205–245
750–900	405	15	11	215–260
800–950	430	14	10	235–275
Intermediate values may be obtained by interpolation.				

Table 5.4.3 Mechanical properties for acceptance purposes: alloy steel forgings for crankshafts – Quenched and tempered

Tensile strength N/mm²	Yield stress N/mm² minimum	Elongation on $5{,}65\sqrt{S_o}$ % minimum		Hardness Brinell
		Long.	Tang.	
600–750	420	18	14	175–215
650–800	450	17	13	190–235
700–850	380	16	12	205–245
750–900	530	15	11	215–260
800–950	590	14	10	235–275
850–1000	640	13	9	245–290
900–1100	690	13	9	260–320
950–1150	750	12	8	275–340
1000–1200	810	12	8	290–365
Intermediate values may be obtained by interpolation.				

4.5.7 Forgings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Tables 5.4.1 to 5.4.3.

4.5.8 The results of all tensile tests are to comply with the requirements of Table 5.4.1, 5.4.2 or 5.4.3 appropriate to the specified minimum tensile strength.

4.5.9 Where more than one tensile test is taken from a forging, the variation in tensile strength is not to exceed the following:

Specified minimum tensile strength N/mm²	Difference in tensile strength N/mm²
<600	70
≥600 <900	100
≥900	120

4.5.10 For small crankshaft forgings which have been batch tested, the hardness values are to be not less than those given in Tables 5.4.1 to 5.4.3, as appropriate. The variation in hardness in each batch is to comply with the following:

Specified minimum tensile strength (N/mm²)	Difference in hardness (Brinell number)
<600	not more than 25
≥600 <900	not more than 35
≥900	not more than 42

4.6 Non-destructive examination

4.6.1 Magnetic particle or dye penetrant testing as detailed in 1.8.5 and 2.5 is to be carried out on all forgings for crankshafts. Where applicable, this is to include all surfaces which have been flame-cut, but not subsequently machined during manufacture. Particular attention is to be given to the testing of the pins, journals and associated fillet radii of solid forged crankshafts and to the pins and fillet radii of combined web and pin forgings. The extent of testing is shown in Fig. 5.4.3.

4.6.2 The manufacturer is to carry out an ultrasonic examination of all forgings as detailed in 1.8.8 and 2.5, except that for closed-die forgings this examination may, subject to approval, be confined to the initial production and to subsequent occasional checks. The extent of ultrasonic testing is shown in Fig. 5.4.4.

4.6.3 Surface inspection acceptance criteria are to be in accordance with 2.5 and with Table 5.4.4. Other acceptance criteria may be applied, providing they meet these minimum criteria, and is to the satisfaction of the Surveyor.

4.6.4 Ultrasonic acceptance criteria are shown in Table 5.4.5. Other acceptance criteria may be applied, providing they meet these minimum criteria, and is to the satisfaction of the Surveyor.

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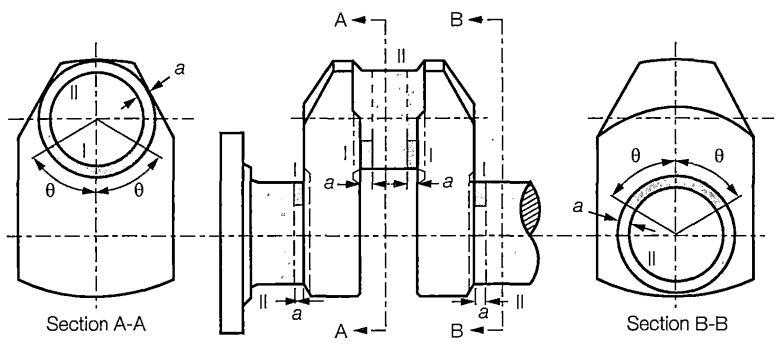
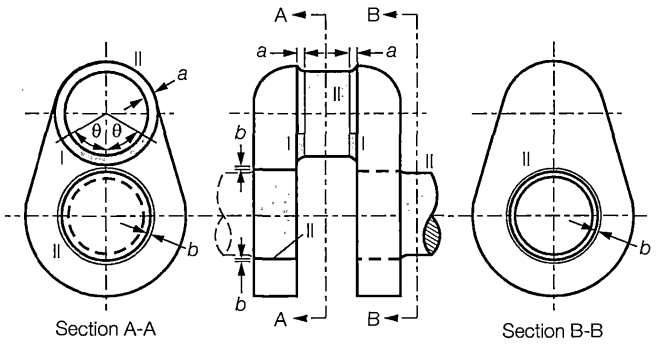


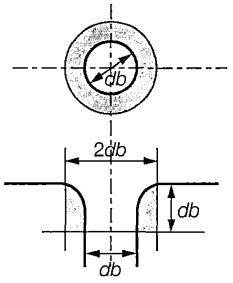
(a) Soild crankshaft



(b) Semi built-up crankshaft

NOTES

1. Where the crankpin or journal has oil holes, the circumferential surfaces of the oil are to be treated as Zone I, (*see* the figure on the right)
2. In the above figures:
   θ = 60°
   a = 1,5*r*
   b = 0,05*d* (: circumferential surfaces of shrinkage fit)
   where
   r : fillet radius
   d : journal diameter
3. Identification of the Zones:
   : Zone I
   : Zone II



db: Oil hole bore diameter

Fig. 5.4.3 Zones for magnetic particle/dye penetrant testing on crankshafts

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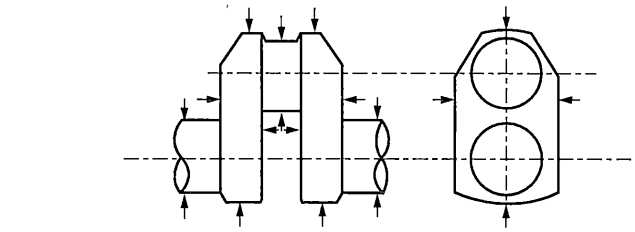
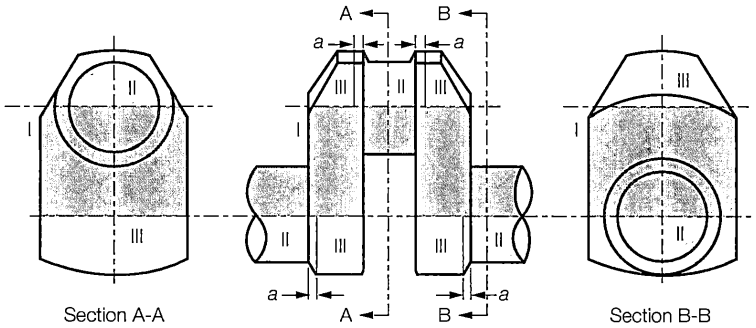
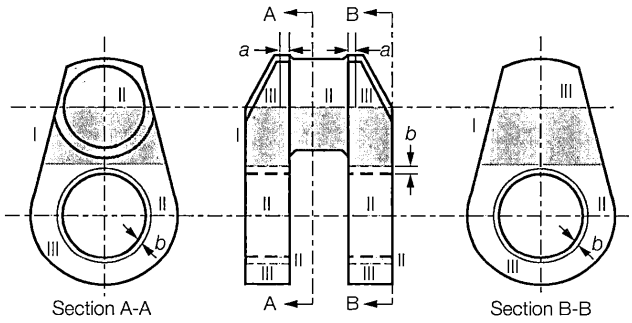




(a) Solid crankshaft



(b) Semi built-up crankshaft

NOTES

1. In the above figures:
   a = 0,1d or 25 mm, whichever is greater
   b = 0,05d or 25 mm, whichever is greater (: circumstances of shrinkage fit)
   where
   d : pin or journal diameter
2. The mid third area of crank pins and/or journals within a raduis of 0,25d between the webs may generally be coordinated to Zone II
3. Identification of the Zones:
   : Zone I
   : Zone II
   : Zone III

Fig. 5.4.4 Zones for ultrasonic testing on crankshafts

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Table 5.4.4 Surface inspection acceptance for crankshaft forgings – Allowable number and size of indications in a reference area of 225 cm²

Inspection zone	Maximum number of indication	Type of indication	Maximum number each type	Maximum dimension of single indication, mm
I Critical fillet area	0	Linear Non-linear Aligned	0 0 0	— — —
II Important fillet area	3	Linear Non-linear Aligned	0 3 0	— 3,0 —
III Journal surfaces	3	Linear Non-linear Aligned	0 3 0	— 5,0 —

Table 5.4.5 Ultrasonic acceptance criteria for crankshafts

Type of forging	Zone	Allowable disc shape according to Distance Gain Size (DGS), mm	Allowable length of indication, mm	Allowable distance between two indications, *see* Note, mm
Crank shaft	I II III	$d \leq 2,0$ $d \leq 3,0$ $d \leq 4,0$	— ≤10 ≤15	— ≥20 ≥20
NOTE For accumulations of two or more isolated indications which are subjected to registration, the minimum distance between two neighbouring indications is to be at least the length of the larger indication. This applies to the distance in axial direction as to the distance in depth. Isolated indications with less distance are to be determined as one single indication.				

■ *Section 5*
Forgings for gearing

5.1 Scope

5.1.1 Provision is made in this Section for carbon-manganese and alloy steel forgings intended for use in the construction of gearing for main propulsion and for driving electric generators.

5.1.2 Gear wheel and rim forgings with a specified minimum tensile strength not exceeding 760 N/mm² (760–910 N/mm² acceptance range) may be made in carbon-manganese steel. Gear wheel or rim forgings where the specified minimum tensile strength is in excess of 760 N/mm², and all pinion or pinion sleeve forgings, are to be made in a suitable alloy steel. Specifications for alloy steel components and for quill shafts, giving chemical composition, heat treatment and mechanical properties, are to be submitted for approval.

5.1.3 Forgings for flexible couplings, quill shafts and gear wheel shafts are to comply with the requirements of Section 3.

5.1.4 Manufacturers' test certificates for forgings may be accepted where the transmitted power does not exceed 220 kW (300 shp) for main propulsion and 100 kW (150 shp) for auxiliary drives.

5.2 Manufacture

5.2.1 All forgings are to be made with sufficient material to allow an adequate machining allowance on all surfaces for the removal of unsound or decarburised material.

5.2.2 The hardenability of the forged material is to be checked at random intervals using an end quench test complying with a National or International Standard.

5.2.3 The grain size is to be checked on a random basis in accordance with the testing and reporting procedures of ASTM E 112, or an equivalent National Standard, and is to be within the range 5 to 8.

5.2.4 The microstructure of the hardened case is to be mainly martensite, with a maximum content of 15 per cent of retained austenite.

5.3 Chemical composition

5.3.1 The chemical composition of ladle samples is to comply with 3.2.1. for carbon and carbon-manganese steels and 1.4.3 for alloy steels.

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5.4 Heat treatment

5.4.1 Except as provided in 5.4.4 and 5.4.5, forgings may be either normalised and tempered or quenched and tempered in accordance with the approved specification. The tempering temperature is to be not less than 550°C.

5.4.2 Where forgings are machined prior to heat treatment, the allowance left for final machining is to be sufficient to remove the decarburised surface material, taking into account any bending or distortion which may occur.

5.4.3 When the teeth of a pinion or gear wheel are to be surface hardened, i.e, carburised, nitrided or induction hardened, the proposed specification together with details of the process and practice are to be submitted for approval. For purposes of initial approval, the gear manufacturer is required to demonstrate by test that the surface hardening of the teeth is uniform and of the required depth and that it does not impair the soundness and quality of the steel.

5.4.4 Where induction hardening of nitriding is to be carried out after machining of the gear teeth, the forgings are to be heat treated at an appropriate stage to a condition suitable for this subsequent surface hardening.

5.4.5 Forgings for gears which are to be carburised after final machining are to be supplied in either the fully annealed or the normalised and tempered condition, suitable for subsequent machining and carburising.

5.5 Mechanical tests for through hardened, induction hardened or nitrided forgings

5.5.1 At least one tensile test specimen is to be taken from each forging in carbon or carbon-manganese steel, and at least one tensile test specimen from forgings in alloy steel. Sufficient test material is to be provided for this purpose and the test specimens are to be taken as follows:

(a) For pinion forgings where the finished diameter of the toothed portion exceeds 200 mm, tests are to be taken in a tangential direction and adjacent to the toothed portion (test position B in Fig. 5.5.1). Where the dimensions preclude the preparation of tests from this position, tests in a tangential direction are to be taken from the end of the journal (test position C in Fig. 5.5.1). If, however, the journal diameter is 200 mm or less, tests are to be taken in a longitudinal direction (test position A in Fig. 5.5.1). Where the finished length of the toothed portion exceeds 1250 mm, tests are to be taken from each end.

(b) For small pinion forgings where the finished diameter of the toothed portion is 200 mm or less, tests are to be taken in a longitudinal direction (test position A in Fig. 5.5.1).

(c) For gear wheel forgings, tests are to be taken in a tangential direction (from one of the test positions B in Fig. 5.5.2).

(d) For gear wheel rim forgings, tests are to be taken in a tangential direction (from one of the test positions A in Fig. 5.5.3). Where the finished diameter exceeds 2500 mm or the mass (as heat treated but excluding test material) exceeds 3 tonnes, tests are to be taken from two diametrically opposite positions (test positions A in Fig. 5.5.3).

(e) For pinion sleeve forgings, tests are to be taken in a tangential direction (from one of the test positions C in Fig. 5.5.4). Where the finished length exceeds 1250 mm, tests are to be taken from each end.

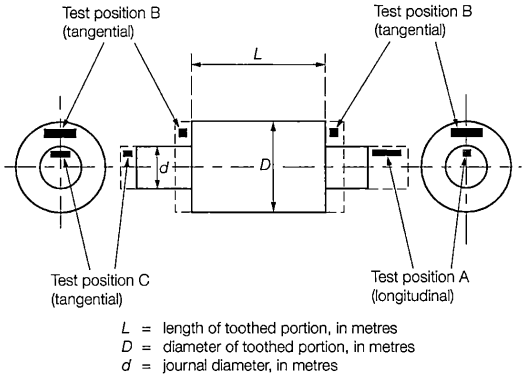

Fig. 5.5.1 Test positions for forgings for gearing

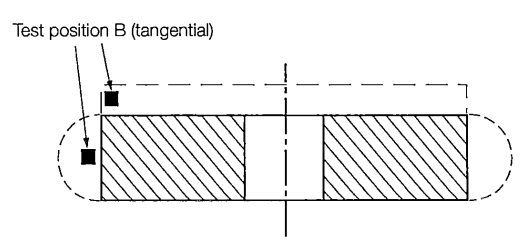

Fig. 5.5.2 Test position B

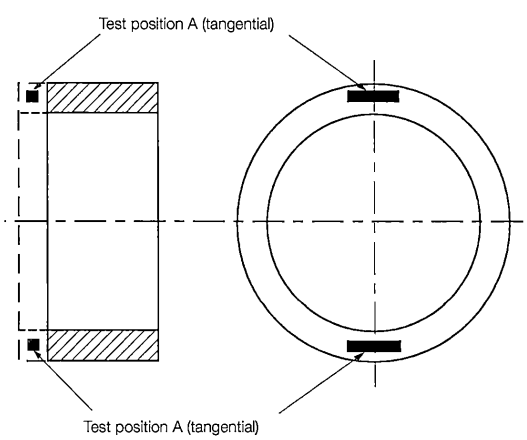

Fig. 5.5.3 Test position A

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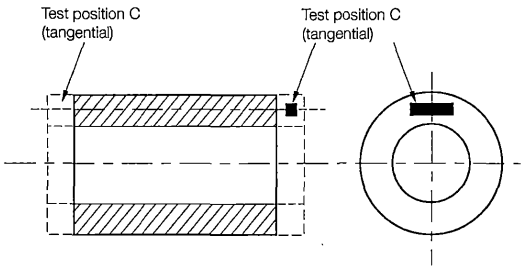

Fig. 5.5.4 Test position C

5.5.2 As an alternative to 5.5.1, small forgings may be batch tested in accordance with 1.6.4 provided that, in addition, hardness tests are carried out on each forging.

5.5.3 Tables 5.5.1 to 5.5.3 give the minimum requirements for yield stress and elongation corresponding to different strength levels, but it is not intended that these should necessarily be regarded as specific grades. The strength levels have been given in multiples of 40 N/mm^2, or 50 N/mm^2 in the case of alloy steels, to facilitate interpolation for intermediate values of specified minimum tensile strength.

Table 5.5.1 Mechanical properties for acceptance purposes: carbon-manganese steels for gear wheel and rim forgings

Tensile strength N/mm^2 (*see* Note)	Yield stress N/mm^2 minimum	Elongation on $5{,}65\sqrt{S_o}$ % minimum		Hardness Brinell
		Rims	Wheels	
400–520	200	26	22	110–150
440–560	220	24	21	125–160
480–600	240	22	19	135–175
520–640	260	21	18	150–185
560–680	280	20	17	160–200
600–750	300	18	15	175–215
640–790	320	17	14	185–230
680–830	340	16	14	200–240
720–870	360	15	13	210–250
760– 910	380	14	12	225–265
Intermediate values may be obtained by interpolation.				
NOTE When the specified minimum tensile strength exceeds 700 N/mm^2 forgings are to be supplied only in the quenched and tempered condition.				

5.5.4 Forgings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Tables 5.5.1 to 5.5.3.

5.5.5 The results of all tensile tests are to comply with the requirements of Table 5.5.1, 5.5.2 or 5.5.3, appropriate to the specified minimum tensile strength. Unless otherwise agreed, the specified minimum tensile strength is to be not less than 800 N/mm^2 (800–950 N/mm^2 acceptance range) for induction hardened or nitrided gear forgings.

Table 5.5.2 Mechanical properties for acceptance purposes: alloy steel gear wheel and rim forgings – Normalised and tempered

Tensile strength N/mm^2	Yield stress N/mm^2 minimum	Elongation on $5{,}65\sqrt{S_o}$ % minimum		Hardness Brinell
		Rims	Wheels	
600–750	330	18	16	175–215
650–800	355	17	15	190–235
700–850	380	16	14	205–245
750–900	405	15	13	215–260
800–950	430	14	12	235–275
850–1000	455	13	11	245–290
Intermediate values may be obtained by interpolation.				

Table 5.5.3 Mechanical properties for acceptance purposes: alloy steel gear forgings – Quenched and tempered

Tensile strength N/mm^2 (*see* Notes 1 and 2)	Yield stress N/mm^2 minimum (*see* Note 2)	Elongation on $5{,}65\sqrt{S_o}$ % minimum			Hardness Brinell
		A	B	C	
600–750	420	18	16	14	175–215
650–800	450	17	15	13	190–235
700–850	480	16	14	12	205–245
750–900	530	15	13	11	215–260
800–950	590	14	12	10	235–275
850–1000	640	13	11	9	245–290
900–1050	690	13	11	9	260–310
950–1100	750	12	10	8	275–330
1000–1150	810	12	10	8	290–340
1050–1200	870	11	9	7	310–365
Column A is applicable to tests from gear rims and to longitudinal tests from pinions. Column B is applicable to tests from gear wheels and to tangential tests from pinions. Column C is applicable to tests from pinion sleeves.					
Intermediate values may be obtained by interpolation.					
NOTES 1. For gear wheel and rim forgings the specified minimum tensile strength is not to exceed 850 N/mm^2. 2. *For carburised gear forgings the requirements for minimum* yield stress and maximum tensile strength are not applicable.					

5.5.6 Where more than one tensile test is taken from a forging, the variation in tensile strength is not to exceed the following:

Specified minimum tensile strength N/mm^2	Difference in tensile strength N/mm^2
<600	70
≥600 <900	100
≥900	120

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5.5.7 Hardness tests are to be carried out on all forgings after completion of heat treatment and prior to machining the gear teeth. The hardness is to be determined at four positions equally spaced around the circumference of the surface where teeth will subsequently be cut. Where the finished diameter of the toothed portion exceeds 2500 mm, the number of test positions is to be increased to eight. Where the width of a gear wheel rim forging exceeds 1250 mm, the hardness is to be determined at eight positions at each end of the forging.

5.5.8 For small gear forgings which are batch tested, at least one hardness test is to be carried out on each forging.

5.5.9 The results of all hardness tests are to comply with the appropriate requirements of Tables 5.5.1 to 5.5.3. The difference between the highest and lowest values on any one forging is not to exceed the following:

Specified minimum tensile strength (N/mm^2)	Difference in hardness (Brinell number)
<600	25
≥600 <900	35
≥900	42

5.5.10 On nitrided or induction hardened components, hardness tests are also to be made on the teeth when surface hardening and grinding have been completed. The results are to comply with the approved specification.

5.6 Mechanical tests for carburised forgings

5.6.1 Sufficient test material is to be provided for preliminary tests at the forge and for final tests after completion of carburising. For this purpose, duplicate sets of test material are to be taken from positions as detailed in 5.5.1, except that, irrespective of the dimensions or mass of the forging, tests are required from one position only, and in the case of forgings with integral journals are to be cut in a longitudinal direction. The test material which is to be used for measurements of case depth, hardness, grain size and residual austenite as well as mechanical properties is to be machined to a coupon of diameter of $\frac{D}{4}$ or 30 mm, whichever is less, where D is the finished diameter of the toothed portion.

5.6.2 For small forgings, where a system of batch testing is adopted, the test material may be prepared from surplus steel from the same cast provided that the forging reduction approximates to that of the actual gear forgings. The test samples are to be correctly identified and heat treated with the forgings they represent.

5.6.3 For preliminary tests at the forge, one set of test material is to be given a blank carburising and heat treatment cycle simulating that which will be subsequently applied to the forgings.

5.6.4 For final acceptance tests, the second set of test material is to be blank carburised and heat treated together with the forgings which it represents.

5.6.5 At the discretion of the forgemaster or gear manufacturer, test samples of larger cross-section than in 5.6.1 may be either carburised or blank carburised, but these are to be machined to the required diameter prior to the final quenching and stress relieving heat treatment.

5.6.6 At least one tensile specimen is to be prepared from each sample of test material.

5.6.7 Unless otherwise agreed, the specified minimum tensile strength is to be not less than 750 N/mm^2, and the results of all tensile tests are to comply with the requirements given in Table 5.5.3.

5.6.8 Where it is proposed to adopt alternatives to the requirements of 5.6.1 to 5.6.7, full details are to be submitted to the Surveyor for consideration.

5.7 Non-destructive examination

5.7.1 Magnetic particle or liquid penetrant testing is to be carried out on the teeth of all surface hardened forgings. This examination may also be requested on the finished machined teeth of through hardened gear forgings.

5.7.2 The manufacturer is to carry out an ultrasonic examination of all forgings where the finished diameter of the surfaces, where teeth will be cut, is in excess of 200 mm, and is to provide the Surveyor with a signed statement that such inspection has not revealed any significant internal defects.

5.7.3 On gear forgings where the teeth have been surface hardened, additional test pieces may be required to be processed with the forgings and subsequently sectioned to determine the depth of the hardened zone. These tests are to be carried out at the discretion of the Surveyor, and for induction or carburised gearing the depth of the hardened zone is to be in accordance with the approved specification. For nitrided gearing, the full depth of the hardened zone, (i.e. depth to core hardness), is to be not less than 0,5 mm and the hardness at a depth of 0,25 mm is to be not less than 500 HV.

■ *Section 6* Forgings for turbines

6.1 Scope

6.1.1 Provision is made in this Section for ferritic steel forgings for turbine rotors, discs and spindles, turbine-driven generator rotors and compressor rotors.

6.1.2 Plans for rotor forgings are to state whether the rotor is intended for propulsion or auxiliary machinery and the shaft power of auxiliary turbines. In the case of a rotor which is to be tested for thermal stability, the maximum operating temperature and the proposed test temperature are also to be stated.

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6.1.3 Specifications of alloy steel forgings giving the proposed chemical composition, heat treatment and mechanical properties are to be submitted for approval with the plans of the components.

6.1.4 Where it is proposed to use rotors of welded construction, the compositions of the steels for the forgings are to be submitted for special consideration, together with details of the proposed welding procedure. Welding procedure tests may be required.

6.2 Manufacture

6.2.1 Forgings are to be manufactured in accordance with the requirements of Section 1, except that for rotors the forging reduction is to be not less than 2,5 to 1. Where an upsetting operation is included in the manufacturing procedure, the above requirement applies to the cross-sectional area of the upset bloom and not to that of the ingot.

6.3 Chemical composition

6.3.1 The chemical composition of ladle samples is to comply with 3.2.1 for carbon and carbon-manganese steels and 1.4.3 for alloy steels.

6.4 Heat treatment

6.4.1 Forgings are to be supplied in the heat treated condition, and the thermal treatment at all stages is to be such as to avoid the formation of hair-line cracks. At a suitable stage of manufacture, the forgings are to be reheated above the upper critical point to refine the grain, cooled in an approved manner and then tempered to produce the desired mechanical properties.

6.4.2 Where forgings receive their main heat treatment before machining, they are to be stress relieved after rough machining. Forgings which are heat treated in the rough machined condition need not be stress relieved provided that they have been slowly cooled from the tempering temperature.

6.4.3 The tempering and stress relieving temperatures are to be not less than 550°C for carbon and carbon-manganese steels, and not less than 600°C for alloy steels. The holding times and subsequent cooling rates are to be such that the forging in its final condition is free from harmful residual stresses.

6.4.4 Details of the proposed heat treatment for rotors of welded construction are to be submitted for approval.

6.5 Mechanical tests

6.5.1 At least one tensile test specimen, cut in a longitudinal direction, is to be taken from each rotor forging. For forgings exceeding both 3 tonnes in mass and 2000 mm in length, tests are to be taken from each end.

6.5.2 For rotor forgings of all main propulsion machinery and of auxiliary turbines exceeding 1100 kW, tangential and, where the dimensions permit, radial tensile tests are to be taken from the end of the body corresponding to the top end of the ingot, *see* Fig. 5.6.1.

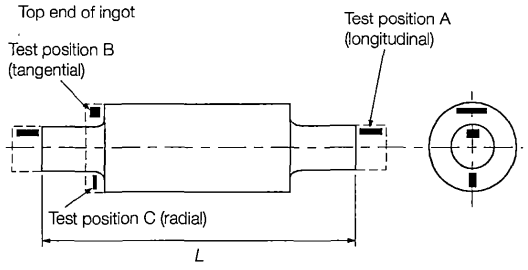

Fig. 5.6.1 Test positions for turbine rotor forgings

6.5.3 For each turbine disc, at least one tensile test specimen is to be cut in a tangential direction from material at the hub, *see* Fig. 5.6.2.

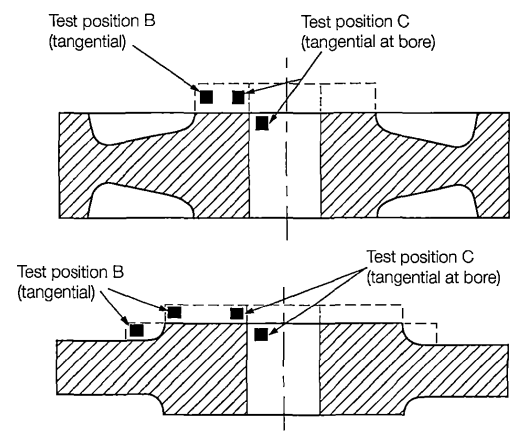

Fig. 5.6.2 Test positions for turbine disc forgings

6.5.4 For the tests required by 6.5.1 to 6.5.3, sufficient test material is to be left on each forging and is not to be removed until all heat treatment, including stress relieving, has been completed. In this connection, a thermal stability test does not form part of the heat treatment of a turbine forging. Any excess test material is not to be completely severed from a forging until all the mechanical tests have been completed with satisfactory results.

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6.5.5 Tables 5.6.1 and 5.6.2 give the minimum requirements for yield stress, elongation and reduction of area corresponding to different strength levels, but it is not intended that these should necessarily be regarded as specific grades. The strength levels have been given in multiples of 40 N/mm^2, or 50 N/mm^2 for alloy steels, to facilitate interpolation for intermediate values of specified minimum tensile strength.

Table 5.6.1 Mechanical properties for acceptance purposes: carbon-manganese steel forgings for turbines – Normalised and tempered

Tensile strength N/mm^2	Yield stress N/mm^2 minimum	Elongation $5{,}65\sqrt{S_o}$ % minimum			Reduction of area % minimum		
		A	B	C	A	B	C
400–520	200	26	22	18	50	40	35
440–560	220	24	21	17	50	40	35
480–600	240	22	19	15	45	35	30
520–640	260	21	18	14	45	35	30
560–680	280	20	17	13	40	30	25
600–720	300	18	15	12	40	30	25

NOTES
Columns A are applicable to longitudinal tests from rotor and spindle forgings.
Columns B are applicable to tangential tests from rotor forgings.
Columns C are applicable to radial tests from rotor forgings.
Intermediate values may be obtained by interpolation.

6.5.6 Forgings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Table 5.6.1 or Table 5.6.2.

6.5.7 The results of all tensile tests are to comply with the requirements of Table 5.6.1 or Table 5.6.2 appropriate to the specified minimum tensile strength. For monobloc rotor forgings, the specified minimum tensile strength is not to exceed 800 N/mm^2.

6.6 Non-destructive examination

6.6.1 The end faces of the body of rotor forgings and the end faces of the boss and the bore surface of each turbine disc are to be machined to a fine smooth finish for visual and magnetic particle examination.

6.6.2 The manufacturer is to carry out an ultrasonic examination of each forging and is to provide the Surveyor with a signed statement that such inspection has not revealed any significant internal defects.

6.6.3 Rotor forgings for propulsion machinery and for auxiliary turbines exceeding 1100 kW are to be hollow bored for internal examination. The surface of the bore is to have a fine smooth finish and is to be examined by means of an optical instrument of suitable magnification. Where the bore size permits, magnetic particle examination is also to be carried out. These examinations are to be confirmed by the Surveyor. Alternatively, an approved method of ultrasonic examination may be accepted instead of hollow boring. Details of the proposed method of ultrasonic examination are to be submitted for special consideration.

Table 5.6.2 Mechanical properties for acceptance purposes: alloy steel forgings for turbines – Quenched and tempered or normalised and tempered

Tensile strength N/mm^2 (*see* Note)	Yield stress N/mm^2 minimum Normalised and tempered	Yield stress N/mm^2 minimum Quenched and tempered	Elongation on $5{,}65\sqrt{S_o}$ % minimum			Reduction of area %minimum		
			A	B	C	A	B	C
500 – 650	275	—	22	20	18	50	40	35
550 – 700	300	—	20	18	16	50	40	35
600 – 750	330	410	18	16	14	50	40	35
650 – 800	355	450	17	15	13	50	40	35
700 – 850	385	490	16	14	12	45	35	30
750 – 900	—	530	15	13	11	45	35	30
800 – 950	—	590	14	12	10	45	35	30
850 – 1000	—	640	13	11	9	40	30	25
900 – 1050	—	690	13	11	9	40	30	25
950 – 1100	—	750	12	10	8	40	30	25
1000 – 1150	—	810	12	10	8	40	30	25

NOTES
Columns A are applicable to longitudinal tests from rotor and spindle forgings.
Columns B are applicable to tangential tests from rotor and spindle forgings, and to tangential tests from discs – test position B in Fig. 5.6.2.
Columns C are applicable to radial test from rotor forgings and to tangential tests from discs – test position C in Fig. 5.6.2.
Intermediate values may be obtained by interpolation.

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6.7 Thermal stability tests

6.7.1 Thermal stability tests after heat treatment and rough machining of the turbine rotors, referred to in the relevant Rules dealing with design and construction, are to be undertaken in properly constructed furnaces, using accurate and reliable measuring equipment. Each test is to be carried out in accordance with the following recommended procedure:

(a) Five bands are to be machined concentric with the axis of rotation. Two of these are to be reference bands and are to be positioned at or near the locations of the bearings. The remaining three bands are to be test bands located one as near as possible to the mid-length, and the other two near each end of the body. Where the length of a rotor is such that five bands cannot be provided, alternative proposals are to be submitted to the Surveyor for his approval.

(b) Four positions, 90° apart, are to be stamped A, B, C and D on the coupling end of the rotor.

(c) The whole of the body, and as much of the shaft at either end as will include the positions of the glands, is to be enclosed in the furnace. In the case of a rotor having an overhung astern wheel, the astern wheel is also to be enclosed in the furnace during the first test.

(d) The rotor is to be rotated at a uniform and very low speed.

(e) The deflections at all bands are to be recorded at the A, B, C and D positions. Initial cold readings are to be taken prior to heating.

(f) The rotor is to be heated uniformly and slowly. Temperatures are to be recorded continuously at the surface of the rotor and, if practicable, in the bore at the mid-length of the body. In no circumstances is the surface temperature to exceed the temperature at which the rotor was tempered. During heating, the rate of rise of temperature is to be such as to avoid excessive temperature gradients in the rotor.

(g) The maximum or holding temperature is to be not less than 28°C above the maximum operating temperature of the rotor. For the purposes of the test, the holding period is to start when the rotor has attained a uniform and specified temperature. The rotor is to be held under the specified temperature conditions until not less than three consecutive hourly readings of deflections show the radial eccentricity to be constant within 0,006 mm on all test bands.

(h) The turbine rotor is to be rotated during cooling until the temperature is not more than 100°C. The rate of cooling is to be such as to avoid excessive temperature gradients in the rotor.

(j) Final cold readings are to be taken.

6.7.2 The movements of the axis of the rotor in relation to the reference bands are to be determined from polar plots of the deflection readings. The radial movement of the shaft axis, as determined by the difference between the final hot and the final cold movements, is not to exceed 0,025 mm on any one band. As verification that test equipment and conditions are satisfactory, it is required that similar determinations of differences between initial cold and final cold movements do not exceed 0,025 mm on any one band.

6.7.3 If the results of the test on a rotor fail to meet either or both of the requirements in 6.7.2, the test may be repeated if requested by the maker and agreed by the Surveyor. In the case of a rotor failing to meet the requirements of a thermal stability test, the rotor is deemed unacceptable. Proposals for the rectification of thermal instability of a rough machined rotor are to be submitted for special consideration.

■ *Section 7*
Forgings for boilers, pressure vessels and piping systems

7.1 Scope

7.1.1 Provision is made in this Section for carbon-manganese and low alloy steel forgings intended for use in the construction of boilers, pressure vessels and piping systems where the design temperature is not lower than 0°C.

7.1.2 In addition to specifying mechanical properties at ambient temperature for the purposes of acceptance testing, these requirements give details of appropriate mechanical properties at elevated temperatures to be used for design purposes.

7.1.3 Forgings used in the construction of equipment for the containment of liquefied gases are to comply with the requirements of Section 8, except for those used in piping systems, where the design temperature is not lower than 0°C. Forgings for other pressure vessels and piping systems, where the use of steels with guaranteed impact properties at low temperatures is required, are also to comply with Section 8.

7.2 Chemical composition

7.2.1 The chemical composition of ladle samples is to comply with the appropriate requirements of Table 5.7.1.

7.3 Heat treatment

7.3.1 Carbon-manganese steel forgings are to be normalised, normalised and tempered or quenched and tempered.

7.3.2 Alloy steel forgings are to be normalised and tempered or quenched and tempered.

7.3.3 No forging is to be fully heat treated more than twice.

7.4 Mechanical tests

7.4.1 Except as provided in 7.4.2 and 7.4.4, at least one tensile test is to be taken from each forging and, where the dimensions and shape allow, the test specimen is to be cut in the longitudinal direction.

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Table 5.7.1 Chemical composition

Type of steel	Tensile strength N/mm²	Chemical composition of ladle samples %							
		C max.	Si	Mn	P max.	S max.	Al	Residual elements	
Carbon-manganese	410–530	0,20	0,10–0,40	0,50–1,20	0,030	0,025	(*See* Notes 1 and 3)	Ni 0,40 max. Cr 0,25 max. Mo 0,10 max. Cu 0,30 max. Total 0,80 max.	
	460–580	0,23		0,80–1,40					
	490–610	0,25		0,90–1,70					
								Cr	Mo
Alloy steel 1Cr½Mo	440–590	0,18	0,15–0,40	0,40–0,70	0,030	0,025	0,020 max. (*See* Note 2)	0,85–1,15	0,45–0,65
2¼ Cr1Mo	490–640	0,15						2,0–2,5	0,90–1,20

NOTES
1. Fine grained steels are to contain:
   aluminium (acid soluble) 0,015% min. or
   aluminium (total) 0,018% min.
2. For alloy steels, aluminium (acid soluble) 0,020% max.
   The determination of the aluminium (total) content is acceptable provided the above value is not exceeded.
3. Niobium may be used as a grain refiner in place of aluminium, in which case the content is to be in the range 0,01% to 0,06%.

7.4.2 On seamless drums and headers which are initially forged with open ends, test material is to be provided at each end of each forging. Where forged with one solid end, test material is to be provided at the open end only. Except where the ends are to be subsequently closed by forging, the test material is not to be removed until heat treatment has been completed. Where the ends are to be closed, rings of test material are to be cut off prior to the closing operation and are to be heat treated with the finished forging. In all cases, the test specimens are to be cut in the circumferential direction.

7.4.3 Unless otherwise agreed, tensile test specimens are to be taken with their axis at approximately 12,5 mm below the surface of the forging.

7.4.4 Small forgings may be batch tested in accordance with 1.6.4 provided that hardness tests are carried out on each forging. In such cases, the mass of each forging is not to exceed 1 tonne and that of the batch is not to exceed 10 tonnes and the hardness values are to accord with Table 5.7.2.

Table 5.7.2 Mechanical properties for acceptance purposes

Type of steel	Diameter or equivalent thickness mm	Yield stress N/mm²	Tensile strength N/mm²	Elongation on $5{,}65\sqrt{S_o}$ % minimum	Hardness Brinell
Carbon-manganese not specifically fine grained	≤100	215	410–530	20	110–155
	>100 ≤500	205			
	≤100	245	460–580	18	130–170
	>100	235			
	≤100	265	490–610	16	140–180
	>100	255			
Carbon-manganese, fine grained	≤100	235	410–530	20	110–155
	>100 ≤250	220			
	≤100	275	460–580	18	130–170
	>100 ≤250	255			
	≤100	305	490–610	16	140–180
	>100 ≤250	280			
Alloy steel 1Cr½Mo	–	275	440–590	19	110–160
2¼Cr1Mo	–	275	490–640	18	140–185

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7.4.5 If required by the Surveyors or by the Fabricators, test material may be given a simulated stress relieving heat treatment prior to the preparation of the test specimens. This has to be stated on the order, together with agreed details of the simulated heat treatment and the mechanical properties which can be expected.

7.4.6 Except as provided in 7.4.7, the results of all tensile tests are to comply with the requirements given in Table 5.7.2 appropriate to the specified minimum tensile strength.

7.4.7 Where tests are taken at a depth greater than 12,5 mm from the surface or where they are taken in a transverse direction, the mechanical properties which can be expected are to be agreed.

7.4.8 On seamless drums and headers where tests are taken from each end, the variation in tensile strength is not to exceed 70 N/mm^2.

7.4.9 For small batch-tested forgings, the hardness values are to comply with the requirements of Table 5.7.2 appropriate to the specified minimum tensile strength. If forgings of more than one thickness are to be supplied from one cast, then the test is to be made on the thickest forging.

7.5 Non-destructive examination

7.5.1 Non-destructive testing is to be carried out in accordance with the requirements of the approved forging drawing and specification, or as otherwise agreed between the manufacturer, purchaser and Surveyor.

7.6 Pressure tests

7.6.1 Where applicable, pressure tests are to be carried out in accordance with the requirements of the relevant Rules.

7.7 Mechanical properties for design purposes

7.7.1 Nominal values for the minimum lower yield or 0,2 per cent proof stress at temperatures of 50°C and higher are given in Table 5.7.3. These values are intended for design purposes only, and verification is not required except for materials complying with National or proprietary specifications where the elevated temperature properties used for design purposes are higher than those given in Table 5.7.3.

Table 5.7.3 Mechanical properties for design purposes

Type of steel	Diameter or equivalent thickness mm	Tensile strength N/mm^2	Nominal minimum lower yield or 0,2% proof stress N/mm^2											
			Temperature °C											
			50	100	150	200	250	300	350	400	450	500	550	600
Carbon-manganese not specifically fine grained	≤100	410–530	196	192	188	181	168	150	142	138	136	–	–	–
	>100		183	178	175	170	162	150	142	138	136	–	–	–
	≤100	460–580	227	222	218	210	194	176	168	162	158	–	–	–
	>100		212	206	203	197	188	176	168	162	158	–	–	–
	≤100	490–610	245	240	236	227	210	192	183	177	172	–	–	–
	>100		229	222	219	212	203	192	183	177	172	–	–	–
Carbon-manganese fine grained	≤100	410–530	222	215	204	188	171	152	141	134	130	–	–	–
	>100		207	200	190	175	164	152	141	134	130	–	–	–
	≤100	460–580	262	251	236	217	198	177	167	158	153	–	–	–
	>100		244	233	220	202	190	177	167	158	153	–	–	–
	≤100	490–610	286	272	256	234	213	192	182	173	168	–	–	–
	>100		266	253	238	218	205	192	182	173	168	–	–	–
Alloy steel 1Cr^1/$_2$Mo	–	410–560	254	241	224	213	197	184	170	162	157	151	146	145
2^1/$_4$Cr1Mo	–	490–640	268	261	253	245	236	230	224	218	205	189	167	145

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7.7.2 Where verification is required, at least one tensile test at the proposed design or other agreed temperature is to be made on each forging or each batch of forgings. The test specimen is to be taken from material adjacent to that used for tests at ambient temperature, and the test procedure is to be in accordance with the requirements of Chapter 2. The results of all tests are to comply with the requirements of the National or proprietary specification.

7.7.3 Values for the estimated average stress to rupture in 100 000 hours are given in Table 5.7.4 and may be used for design purposes.

Table 5.7.4 Mechanical properties for design purposes: estimated average values for stress to rupture in 100 000 hours (units N/mm²)

Temperature °C	Grades of steel		
	Carbon-manganese	1 Cr ½ Mo	2¼ Cr 1Mo
380	227	—	—
390	203	—	—
400	179	—	—
410	157	—	—
420	136	—	—
430	117	—	—
440	100	—	—
450	85	290	—
460	73	262	—
470	63	235	210
480	55	208	186
490	—	181	165
500	—	155	145
510	—	129	128
520	—	103	112
530	—	80	98
540	—	62	84
550	—	49	72
560	—	42	61
570	—	36	49
580	—	32	—
590	—	29	—

Section 8
Ferritic steel forgings for low temperature service

8.1 Scope

8.1.1 The requirements for carbon-manganese and nickel steels suitable for low temperature service are detailed in this Section. They are applicable to all forgings used for the construction of cargo tanks, storage tanks and process pressure vessels for liquefied gases and, where the design temperature is less than 0°C, to forgings for the piping systems.

8.1.2 The requirements are also applicable to forgings for other pressure vessels and pressure piping systems where the use of steels with guaranteed impact properties at low temperatures is required.

8.1.3 In all cases, details of the proposed chemical composition, heat treatment and mechanical properties are to be submitted for approval.

8.1.4 In addition to the steels in this Section, the austenitic stainless steels detailed in Section 9 may also be used for low temperature applications.

8.2 Chemical composition

8.2.1 The chemical composition of ladle samples is, in general, to comply with the requirements given in Table 5.8.1.

8.3 Heat treatment

8.3.1 Forgings are to be normalised, normalised and tempered or quenched and tempered in accordance with the approved specification.

8.4 Mechanical tests

8.4.1 At least one tensile and three Charpy V-notch impact test specimens are to be taken from each forging or each batch of forgings. Where the dimensions and shape allow, the test specimens are to be cut in a longitudinal direction.

8.4.2 The impact tests are to be carried out at a temperature appropriate to the type of steel and for the proposed application. Where forgings are intended for ships for liquefied gases, the test temperature is to be in accordance with the requirements given in Table 3.6.3 in Chapter 3.

8.4.3 The results of all tensile tests are to comply with the approved specification.

8.4.4 The average energy values for impact tests are also to comply with the approved specification and generally with the requirements of Ch 3,6. One individual value may be less than the required average value provided that it is not less than 70 per cent of this value. *See* Ch 2,1.4 for re-test procedures.

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Table 5.8.1 Chemical composition of ferritic steel forgings

Grade of steel	C %	Si %	Mn %	Ni %	P %	S %	Residual elements %	Grain refiners % Al	Grain refiners % Other
LT–AH (AH40) LT–DH (DH40) LT–EH (EH40)	0,18 max.	0,50 max.	0,90–1,60	0,40 max.	0,035 max.	0,030 max.	Cu 0,35 max. Cr 0,20 max. Mo 0,08 max. Total 0,60 max.		(*See* Note) Nb 0,02 – 0,05 V 0,03 – 0,10 Ti 0,02 max.
LT–FH (FH40)	0,16 max.			0,80 max.		0,025 max.			
1½Ni	0,18 max.	0,10 – 0,35	0,30–1,50	1,30–1,70	0,025 max.	0,020 max.	Cu 0,35 max. Cr 0,25 max. Mo 0,08 max. Total 0,60 max.	Total 0,020 min. Acid soluble 0,015 min.	
3½Ni	0,15 max.		0,30–0,90	3,20–3,80					
5Ni	0,12 max.			4,70–5,30					
9 Ni	0,10 max.			8,50–10,0					

NOTE
The steel is to contain aluminium, niobium, vanadium or other suitable grain refining elements, either singly or in any combination. When used singly, the steel is to contain the specified minimum content of the grain refining element. When used in combination, the specified minimum content of each element is not applicable.

8.5 Non-destructive examination

8.5.1 Non-destructive testing is to be carried out in accordance with the requirements of the approved forging drawing and specification, or as otherwise agreed between the manufacturer, purchaser and Surveyor.

8.6 Pressure tests

8.6.1 When applicable, pressure tests are to be carried out in accordance with the requirements of the relevant Rules.

■ *Section 9*
Austenitic stainless steel forgings

9.1 General

9.1.1 Forgings in austenitic stainless steels are acceptable for use in the construction of cargo tanks, storage tanks and piping systems for chemicals and liquefied gases. They may also be accepted for elevated temperature service in boilers.

9.1.2 Where it is proposed to use forgings in these types of steels, details of the chemical composition, heat treatment and mechanical properties are to be submitted for approval. These are to comply, in general, with the requirements of Ch 3,7 for austenitic steel plates.

9.1.3 Unless otherwise agreed, impact tests are not required for acceptance purposes. Where they are required, tests are to be made on longitudinal specimens at minus 196°C and the minimum average energy requirement is to be 41J.

9.2 Mechanical properties for design purposes

9.2.1 Where austenitic stainless steel forgings are intended for service at elevated temperatures, the nominal values for the minimum one per cent proof stress at temperatures of 100°C and higher given in Table 5.9.1 may be used for design purposes. Verification of these values is not required except for material complying with a National or proprietary specification in which the elevated temperature properties proposed for design purposes are higher than those given in Table 5.9.1.

9.3 Non-destructive examination

9.3.1 Non-destructive examination is to be carried out in accordance with the requirements of the approved forging drawing and specification or as otherwise agreed between the manufacturer, purchaser and Surveyor.

9.4 Intergranular corrosion tests

9.4.1 Where corrosive conditions are anticipated in service, intergranular corrosion tests are required on forgings in Grades 304, 316 and 317. Such tests may not be required for Grades 304L, 316L, 321 and 347.

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Table 5.9.1 Mechanical properties for design purposes: austenitic stainless steels

Grade	Nominal 1% proof stress (N/mm^2) at a temperature of												
	100°C	150°C	200°C	250°C	300°C	350°C	400°C	450°C	500°C	550°C	600°C	650°C	700°C
304L	168	150	137	128	122	116	110	108	106	102	100	96	93
316L	177	161	149	139	133	127	123	119	115	112	110	107	105
316LN	238	208	192	180	172	166	161	157	152	149	144	142	138
321	192	180	172	164	158	152	148	144	140	138	135	130	124
347	204	192	182	172	166	162	159	157	155	153	151	—	—

9.4.2 When an intergranular corrosion test is specified, it is to be carried out in accordance with the procedure given in Ch 2,8.1.

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Steel Pipes and Tubes

Section

1 **General requirements**

2 **Seamless pressure pipes**

3 **Welded pressure pipes**

4 **Ferritic steel pressure pipes for low temperature service**

5 **Austenitic stainless steel pressure pipes**

6 **Boiler and superheater tubes**

■ *Section 1* General requirements

1.1 Scope

1.1.1 This Section gives the general requirements for boiler tubes, superheater tubes and pipes intended for use in the construction of boilers, pressure vessels and pressure piping systems.

1.1.2 In addition to specifying mechanical properties for the purpose of acceptance testing, these requirements give details of appropriate mechanical properties at elevated temperatures to be used for design purposes.

1.1.3 Except for pipes for Class III pressure systems (as defined in the relevant Rules), all pipes and tubes are to be manufactured and tested in accordance with the requirements of Chapters 1 and 2, the general requirements of this Section and the appropriate specific requirements given in Sections 2, 3, 4, 5 and 6.

1.1.4 Steels intended for the piping systems for liquefied gases where the design temperature is less than 0°C are to comply with the specific requirements of Section 4 or 5.

1.1.5 As an alternative to 1.1.3 and 1.1.4, pipes or tubes which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Chapter or alternatively are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

1.1.6 At the discretion of the Surveyor, a modified testing procedure may be adopted for small quantities of materials. In such cases, these may be accepted on the manufacturer's declared chemical composition and hardness tests or other evidence of satisfactory properties.

1.1.7 Pipes for Class III pressure systems are to be manufactured and tested in accordance with the requirements of an acceptable National specification. The manufacturer's test certificate will be acceptable and is to be provided for each consignment of material. Forge butt welded pipes are not acceptable for oil fuel systems, heating coils in oil tanks, primary refrigerant systems and other applications where the pressure exceeds 4,0 bar (4,1 kgf/cm^2).

1.2 Manufacture

1.2.1 Pipes for Class I and II pressure systems, boiler and superheater tubes are to be manufactured at works approved by Lloyd's Register (hereinafter referred to as 'LR'). The steel used is to be manufactured and cast in ingot moulds or by an approved continuous casting process as detailed in Ch 3,1.3.

1.2.2 Unless a particular method is requested by the purchaser, pipes and tubes may be manufactured by any of the following methods:

- Hot finished seamless.
- Cold finished seamless.
- Electric resistance or induction welded.
- Cold finished electric resistance or induction welded.
- Electric fusion welded.

1.2.3 Care is to be taken during manufacture that the pipe or tube surfaces coming in contact with any non-ferrous metals or their compounds are not contaminated to such an extent as could prove harmful during subsequent fabrication and operation.

1.3 Quality

1.3.1 All pipes and tubes are to have a workmanlike finish and are to be clean and free from such surface and internal defects as can be established by the specified tests.

1.3.2 All pipes and tubes are to be reasonably straight. The ends are to be cut nominally square with the axis of the pipe or tube, and are to be free from excessive burrs.

1.4 Dimensional tolerances

1.4.1 The tolerances on the wall thickness and diameter of pipes and tubes are to be in accordance with an acceptable National specification.

1.5 Chemical composition

1.5.1 The requirements for the chemical composition of ladle samples and acceptable methods of deoxidation are detailed in subsequent Sections in this Chapter.

1.6 Heat treatment

1.6.1 All pipes and tubes are to be supplied in the condition detailed in the relevant specific requirements.

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1.7 Test material

1.7.1 Pipes and tubes are to be presented for test in batches. The size of a batch and the number of tests to be performed are dependent on the application.

1.7.2 Where heat treatment has been carried out, a batch is to consist of pipes or tubes of the same size, manufactured from the same types of steel and subjected to the same finishing treatment in a continuous furnace, or heat treated in the same furnace charge in a batch type furnace.

1.7.3 Where no heat treatment has been carried out, a batch is to consist of pipes or tubes of the same size manufactured by the same method from material of the same type of steel.

1.7.4 For pipes for Class I pressure systems and boiler and superheater tubes, at least two per cent of the number of lengths in each batch is to be selected at random for the preparation of tests at ambient temperature.

1.7.5 For pipes for Class II pressure systems, each batch is to contain not more than the number of lengths given in Table 6.1.1. Tests are to be carried out on at least one pipe selected at random from each batch or part thereof.

Table 6.1.1 Batch sizes for pipes for Class II pressure systems

Outside diameter mm	Number in batch
≤323,9	200 pipes as made
>323,9	100 pipes as made

1.8 Dimensions of test specimens and test procedures

1.8.1 The procedures for mechanical tests and the dimensions of the test specimens are to be in accordance with Chapter 2.

1.9 Visual and non-destructive testing

1.9.1 All pipes for Class I and II pressure systems, boiler and superheater tubes, are to be presented for visual examination and verification of dimensions. The manufacturer is to provide adequate lighting conditions to enable an internal and external examination of the pipes and tubes to be carried out.

1.9.2 For welded pipes and tubes, the manufacturer is to employ suitable non-destructive methods for the quality control of the welds. It is preferred that this examination is carried out on a continuous basis.

1.10 Hydraulic test

1.10.1 Each pipe and tube is to be subjected to a hydraulic test at the manufacturer's works.

1.10.2 The hydraulic test pressure is to be determined from the following formula, except that the maximum test pressure need not exceed 140 bar (143 kgf/cm^2):

$$P = \frac{20st}{D} \left(P = \frac{200st}{D}\right)$$

where

P = test pressure, in bar (kgf/cm^2)
D = nominal outside diameter, in mm
t = nominal wall thickness, in mm
s = 80 per cent of the specified minimum yield stress, in N/mm^2 (kgf/mm^2), for ferritic steels and 70 per cent of the specified minimum, 1,0 per cent proof stress, in N/mm^2 (kgf/mm^2), for austenitic steels. These relate to the values specified for acceptance testing at ambient temperature.

1.10.3 The test pressure is to be maintained for sufficient time to permit proof and inspection. Unless otherwise agreed, the manufacturer's certificate of satisfactory hydraulic test will be accepted. Where it is proposed to adopt a test pressure other than that determined as in 1.10.2, the proposal will be subject to special consideration.

1.10.4 Subject to special approval, either an ultrasonic or eddy current test can be accepted in lieu of the hydraulic test.

1.11 Rectification of defects

1.11.1 Surface imperfections may be removed by grinding provided that the thickness of the pipe or tube after dressing is not less than the required minimum thickness. The dressed area is to be blended into the contour of the tube.

1.11.2 By agreement with the Surveyor, the repair of minor defects by welding can be accepted, subject to welding procedure tests which demonstrate acceptable properties appropriate for the grade of pipe to be repaired. Weld procedure tests are to be subjected to the same heat treatment as will be applied to the actual pipes after weld repair.

1.11.3 The repaired area is to be tested by magnetic particle examination, or, for austenitic steels, by liquid penetrant examination on completion of welding, heat treatment and surface grinding.

1.12 Identification

1.12.1 Pipes and tubes are to be clearly marked by the manufacturer in accordance with the requirements of Chapter 1. The following details are to be shown on all materials which have been accepted:

(a) LR or Lloyd's Register.
(b) Manufacturer's name or trade mark.
(c) Identification mark for the specification or grade of steel.
(d) Identification number and/or initials which will enable the full history of the item to be traced.
(e) The personal stamp of the Surveyor responsible for the final inspection.

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1.12.2 It is recommended that hard stamping be restricted to the end face, but it may be accepted in other positions in accordance with National Standards and practices.

1.13 Certification of materials

1.13.1 Unless a LR certificate is specified in other parts of the Rules, a manufacturer's certificate validated by LR is to be issued, *see* Ch 1,3.1.

1.13.2 The manufacturer is to provide LR with the following information:

(a) Purchaser's name and order number.
(b) If known, the contract number for which the material is intended.
(c) Address to which material is despatched.
(d) Specification or the grade of material.
(e) Description and dimensions.
(f) Identification number and/or initials.
(g) Cast number and chemical composition of ladle samples.
(h) Mechanical test results, and results of the intercrystalline corrosion tests where applicable.
(j) Condition of supply.

1.13.3 As a minimum, the chemical composition stated on the certificate is to include the content of all the elements detailed in the specific requirements. Where rimming steel is supplied, this is to be stated on the certificate.

1.13.4 When steel is not produced at the pipe or tube mill, a certificate is to be supplied by the steelmaker stating the process of manufacture, the cast number and the ladle analysis.

1.13.5 The steel manufacturer's works is to be approved by LR.

■ *Section 2*
Seamless pressure pipes

2.1 Scope

2.1.1 Provision is made in this Section for seamless pressure pipes in carbon, carbon-manganese and low alloy steels.

2.1.2 Where pipes are used for the manufacture of pressure vessel shells and headers, the requirements for forgings in Ch 5,7 are applicable where the wall thickness exceeds 40 mm.

2.2 Manufacture and chemical composition

2.2.1 Pipes are to be manufactured by a seamless process and may be hot or cold finished.

2.2.2 The method of deoxidation and the chemical composition of ladle samples are to comply with the appropriate requirements given in Table 6.2.1.

Table 6.2.1 Chemical composition of seamless pressure pipes

Type of steel	Grade	Method of deoxidation	Chemical composition of ladle samples %						Residual elements							
			C	Si	Mn	S max.	P max.		Ni	Cr	Mo	Cu	Sn	V	Al
Carbon and carbon-manganese	320	Semi-killed or killed	≤0,16	–	0,40–0,70	0,050	0,050	Ni 0,30 max. Cr 0,25 max. Mo 0,10 max. Cu 0,30 max. Total 0,70 max.	0,30 max.	0,70–1,10	0,45 – 0,65	0,25 max.	0,03 max.	—	≤0,020
	360		≤0,17	≤0,35	0,40–0,80	0,045	0,045								
	410	Killed	≤0,21	≤0,35	0,40–1,20	0,045	0,045								
	460		≤0,22	≤0,35	0,80–1,40	0,045	0,045								
	490		≤0,23	≤0,35	0,80–1,50	0,045	0,045								
1Cr½Mo	440	Killed	0,10–0,18	0,10–0,35	0,40–0,70	0,040	0,040		0,30 max.	2,0–2,5	0,90–1,20	0,25 max.	0,03 max.	—	≤0,020
2¼Cr1Mo	410 490	Killed	0,08–0,15	0,10–0,50	0,40–0,70	0,040	0,040		0,30 max.	2,0–2,5	0,90–1,20	0,25 max.	0,03 max.	—	≤0,020
½Cr½Mo¼V	460	Killed	0,10–0,18	0,10–0,35	0,40–0,70	0,040	0,040		0,30	0,30–0,60	0,50–0,70	0,25 max.	0,03 max.	0,22–0,32	≤0,020

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2.3 Heat treatment

2.3.1 Pipes are to be supplied in the condition given in Table 6.2.3.

2.4 Mechanical tests

2.4.1 All pipes are to be presented in batches as defined in Section 1.

2.4.2 Each pressure pipe selected for test is to be subjected to tensile and flattening or bend tests.

2.4.3 The results of all mechanical tests are to comply with the appropriate requirements given in Table 6.2.2.

2.5 Mechanical properties for design

2.5.1 Values for nominal minimum lower yield or 0,2 per cent proof stress at temperatures of 50°C and higher are given in Table 6.2.4 and are intended for design purposes only. Verification of these values is not required, except for materials complying with National or proprietary specification where the elevated temperature properties used for design are higher than those given in Table 6.2.4.

2.5.2 In such cases, at least one tensile test at the proposed design or other agreed temperature is to be made on each cast. The test specimen is to be taken from material adjacent to that used for tests at ambient temperature and tested in accordance with the procedures given in Chapter 2. If tubes or pipes of more than one thickness are supplied from one cast, the test is to be made on the thickest tube or pipe.

Table 6.2.3 Heat treatment

Type of steel		Condition of supply
Carbon and carbon-manganese		
Hot finished		Hot finished (*see* Note 1) Normalised (*see* Note 2)
Cold finished		Normalised (*see* Note 2)
Alloy steel		
1Cr1/2Mo		Normalised and tempered
2 1/4Cr1Mo	Grade 410	Fully annealed
	Grade 490	Normalised and tempered 650—780°C
	Grade 490	Normalised and tempered 650—750°C
1/2Cr1/2Mo1/4V		Normalised and tempered

NOTES
1. Provided that the finishing temperature is sufficiently high to soften the material.
2. Normalised and tempered at the option of the manufacturer.

2.5.3 As an alternative to 2.5.2, a manufacturer may carry out an agreed comprehensive test program for a stated grade of steel to demonstrate that the specified minimum mechanical properties at elevated temperatures can be consistently obtained. This test program is to be carried out under the supervision of the Surveyors, and the results submitted for assessment and approval. When a manufacturer is approved on this basis, tensile tests at elevated temperatures are not required for acceptance purposes, but at the discretion of the Surveyors occasional check tests of this type may be requested.

2.5.4 Values for the estimated average stress to rupture in 100 000 hours are given in Table 6.2.5 and may be used for design purposes.

Table 6.2.2 Mechanical properties for acceptance purposes: seamless pressure pipes (maximum wall thickness 40 mm), *see* 2.1.2

Type of steel	Grade	Yield stress N/mm²	Tensile strength N/mm²	Elongation on $5{,}65\sqrt{S_o}$ % minimum	Flattening test constant *C*	Bend test diameter of former (*t* = thickness)
Carbon and carbon-manganese	320	195	320—440	25	0,10	4*t*
	360	215	360—480	24	0,10	
	410	235	410—530	22	0,08	
	460	265	460—580	21	0,07	
	490	285	490—610	21	0,07	
1Cr1/2Mo	440	275	440—590	22	0,07	4*t*
2 1/4Cr1Mo	410 (*see* Note 1)	135	410—560	20	0,07	4*t*
	490 (*see* Note 2)	275	490—640	16		
1/2Cr1/2Mo1/4V	460	275	460—610	15	0,07	4*t*

NOTES
1. Annealed condition.
2. Normalised and tempered condition.

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Table 6.2.4 Mechanical properties for design purposes: seamless pressure pipes

Type of steel	Grade	Nominal minimum lower yield or 0,2% proof stress N/mm^2											
		Temperature °C											
		50	100	150	200	250	300	350	400	450	500	550	600
Carbon and carbon-manganese	320	172	168	158	147	125	100	91	88	87	—	—	—
	360	192	187	176	165	145	122	111	109	107	—	—	—
	410	217	210	199	188	170	149	137	134	132	—	—	—
	460	241	234	223	212	195	177	162	159	156	—	—	—
	490	256	249	237	226	210	193	177	174	171	—	—	—
1Cr1/2Mo	440	254	240	230	220	210	183	169	164	161	156	151	—
2 1/2Cr1Mo	410 (*see* Note 1)	121	108	99	92	85	80	76	72	69	66	64	62
	490 (*see* Note 2)	268	261	253	245	236	230	224	218	205	189	167	145
1/2Cr1/2Mo1/4V	460	266	259	248	235	218	192	184	177	168	155	148	—

NOTES
1. Annealed condition.
2. Normalised and tempered condition.

Table 6.2.5 Mechanical properties for design purposes: seamless pressure pipes – Estimated values for stress to rupture in 100 000 hours (units N/mm^2)

Temperature °C	Carbon and carbon-manganese		1Cr1/2Mo	2 1/4Cr1Mo		1/2Cr1/2Mo1/4V
	Grade 320 360 410	Grade 460 490	Grade 440	Grade 410 Annealed	Grade 490 Normalised and tempered (*see* Note)	Grade 460
380	171	227	—	—	—	—
390	155	203	—	—	—	—
400	141	179	—	—	—	—
410	127	157	—	—	—	—
420	114	136	—	—	—	—
430	102	117	—	—	—	—
440	90	100	—	—	—	—
450	78	85	—	196	221	—
460	67	73	—	182	204	—
470	57	63	—	168	186	—
480	47	55	210	154	170	218
490	36	47	177	141	153	191
500	—	41	146	127	137	170
510	—	—	121	115	122	150
520	—	—	99	102	107	131
530	—	—	81	90	93	116
540	—	—	67	78	79	100
550	—	—	54	69	69	85
560	—	—	43	59	59	72
570	—	—	35	51	51	59
580	—	—	—	44	44	46

NOTE
When the tempering temperature exceeds 750°C, the values for Grade 410 are to be used.

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■ *Section 3*
Welded pressure pipes

3.1 Scope

3.1.1 Provision is made in this Section for welded pressure pipes in carbon, carbon-manganese and low alloy steels.

3.2 Manufacture and chemical composition

3.2.1 Pipes are to be manufactured by the electric resistance or induction welding process and, if required, may be subsequently hot reduced or cold finished.

3.2.2 Where it is proposed to use other welding processes, details of the welding processes and procedures are to be submitted for review.

3.2.3 In all cases, welding procedure tests are required. Test samples are to be subjected to the same heat treatment as the pipe.

3.2.4 The method of deoxidation and the chemical composition of ladle samples are to comply with the appropriate requirements given in Table 6.3.1.

3.3 Heat treatment

3.3.1 Pipes are to be supplied in the heat treated condition given in Table 6.3.3.

3.4 Mechanical tests

3.4.1 All pipes are to be presented in batches as defined in Section 1.

3.4.2 Each pressure pipe selected for test is to be subjected to tensile and flattening or bend tests.

3.4.3 The results of all mechanical tests are to comply with the appropriate requirements given in Table 6.3.2.

3.5 Mechanical properties for design

3.5.1 The mechanical properties at elevated temperature for carbon and carbon-manganese steels in Grades 320 to 460 and 1Cr½Mo steel can be taken from the appropriate Tables in Section 2.

Table 6.3.1 Chemical composition of welded pressure pipes

Type of steel	Grade	Method of deoxidation	Chemical composition of ladle samples %																
			C	Si	Mn	S max.	P max.	Residual elements											
Carbon and carbon-manganese	320	Any method (see Note)	≤0,16	–	0,30–0,70	0,050	0,050	Ni 0,30 max. Cr 0,25 max. Mo 0,10 max. Cu 0,30 max. Total 0,70 max.											
	360		≤0,17	≤0,35	0,40–1,00	0,045	0,045												
	410	Killed	≤0,21	≤0,35	0,40–1,20	0,045	0,045												
	460		≤0,22	≤0,35	0,80–1,40	0,045	0,045												
								Ni		Cr		Mo		Cu		Sn		Al	
1Cr½Mo	440	Killed	0,10–0,18	0,10–0,35	0,40–0,70	0,040	0,040	0,30 max.		0,70–1,10		0,45–0,65		0,25 max.		0,03 max.		≤0,020	

NOTE
For rimming steels, the carbon content may be increased to 0,19% max.

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Table 6.3.2 Mechanical properties for acceptance purposes: welded pressure pipes

Type of steel	Grade	Yield stress N/mm^2	Tensile strength N/mm^2	Elongation on $5{,}65\sqrt{S_o}$ % minimum	Flattening test constant *C*
Carbon and carbon-manganese	320	195	320 – 440	25	0,10
	360	215	360 – 480	24	0,10
	410	235	410 – 530	22	0,08
	460	265	460 – 580	21	0,07
1Cr^1/$_2$Mo	440	275	440 – 590	22	0,07

Table 6.3.3 Heat treatment: welded pressure pipes

Type of steel	Condition of supply
Carbon and carbon-manganese, *see* Note	Normalised (Normalised and tempered at the option of the manufacturer)
1Cr^1/$_2$Mo	Normalised and tempered
NOTE Subject to special approval, electric resistance welded (ERW) pipes and tubes in grades 320 and 360 may be supplied without heat treatment for the following applications: (a) Class 2 piping systems, except for liquefied gases or other low temperature applications. (b) Class 3 piping systems.	

■ *Section 4*
Ferritic steel pressure pipes for low temperature service

4.1 Scope

4.1.1 Provision is made in this Section for carbon, carbon-manganese and nickel pipes intended for use in the piping arrangements for liquefied gases where the design temperature is less than 0°C. These requirements are also applicable for other types of pressure piping systems where the use of steels with guaranteed impact properties at low temperatures is required.

4.2 Manufacture and chemical composition

4.2.1 Carbon and carbon-manganese steel pipes are to be manufactured by a seamless, electric resistance or induction welding process.

4.2.2 Nickel steel pipes are to be manufactured by a seamless process.

4.2.3 Seamless pipes may be hot finished or cold finished. Welded pipes may be as-welded, hot finished or cold finished. The terms 'hot finished', 'cold finished' and 'as-welded' apply to the condition of the pipes before final heat treatment.

4.2.4 The method of deoxidation and the chemical composition of ladle samples are to comply with the appropriate requirements given in Table 6.4.1.

4.3 Heat treatment

4.3.1 Pipes are to be supplied in the condition given in Table 6.4.3.

4.4 Mechanical tests

4.4.1 All pipes are to be presented for test in batches as defined in Section 1 for Class 1 pressure piping systems, but in addition the material in each batch is to be from the same cast.

4.4.2 At least two per cent of the number of lengths in each batch is to be selected at random for the preparation of tests.

4.4.3 Each pressure pipe selected for test is to be subjected to tensile, flattening or bend test at room temperature and, where the wall thickness is 6 mm or greater, an impact test at the test temperature specified in Table 6.4.2.

4.4.4 The impact tests are to consist of a set of three Charpy V-notch test specimens cut in the longitudinal direction with the notch perpendicular to the original surface of the pipe. The dimensions of the test specimens are to be in accordance with the requirements of Chapter 2.

4.4.5 The results of all tensile, flattening and bend tests are to comply with the appropriate values in Table 6.4.2.

4.4.6 The average value for impact test specimens is to comply with the appropriate requirements of Table 6.4.2. One individual value may be less than the required average value provided that it is not less than 70 per cent of this value. *See* Ch 2,1.4.1 for re-test procedures.

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Table 6.4.1 Chemical composition

Type of steel	Grade	Method of deoxidation	Chemical composition of ladle sample %							
			C max.	Si	Mn	P max.	S max.	Ni	Al_{sol} *see* Note	Residual elements
Carbon	360	Fully killed	0,17	0,10–0,35	0,40–1,00	0,030	0,025	–	0,015 min.	Cr 0,25 Cu 0,30 Mo 0,10 Ni 0,30 Total 0,70
Carbon-manganese	410 and 460		0,20	0,10–0,35	0,60–1,40	0,030	0,025	–	0,015 min.	
3½Ni	440		0,15	0,15–0,35	0,30–0,90	0,025	0,020	3,25–3,75	–	Cr 0,25 Cu 0,30 Mo 0,10
9Ni	690		0,13	0,15–0,30	0,30–0,90	0,025	0,020	8,50–9,50	–	Total 0,60

NOTE
Where a minimum Al_{sol} of 0,015% is specified, the determination of the total aluminium is acceptable provided that the result is not less than 0,020%.

Table 6.4.2 Mechanical properties for acceptance purposes

Type of steel	Grade	Yield stress N/mm²	Tensile strength N/mm²	Elongation on $5{,}65\sqrt{S_o}$ % minimum	Flattening test constant *C*	Bend test diameter of former (*t* = thickness)	Charpy V-notch impact tests	
							Test temperature °C	Average energy J minimum
Carbon	360	210	360–480	24	0,10	4*t*	–40	27
Carbon-manganese	410 460	235 260	410–530 460–580	22 21	0,08 0,07	4*t*	–50	27
3½Ni	440	245	440–590	16	0,08	4*t*	–95	34
9Ni	690	510	690–840	15	0,08	4*t*	–196	41

For standard subsidiary impact test specimens, the minimum energy values are to be as follows:

Required average energy value for standard 10 mm x 10 mm	Subsidiary 10 mm x 7,5 mm	Subsidiary 10 mm x 5 mm
	Average energy	Average energy
27 J	22 J	18 J
34 J	28 J	23 J
41 J	34 J	27 J

Table 6.4.3 Heat treatment

Type of steel	Condition of supply
Carbon and carbon-manganese	Hot finished Normalised Normalised and tempered
3½ Ni	Normalised Normalised and tempered
9Ni	Double normalised and tempered Quenched and tempered

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■ *Section 5*
Austenitic stainless steel pressure pipes

5.1 Scope

5.1.1 Provision is made in this Section for austenitic stainless steel pipes suitable for use in the construction of the piping systems for chemicals and for liquefied gases where the design temperature is not less than minus 165°C and for bulk chemical tankers.

5.1.2 Austenitic stainless steels are also suitable for service at elevated temperatures. Where such applications are proposed, details of the chemical composition, heat treatment and mechanical properties are to be submitted for consideration and approval.

5.1.3 Where it is intended to supply seamless pipes in the direct quenched condition, a programme of tests for approval is to be carried out under the supervision of the Surveyors, and the results are to be to the satisfaction of LR, *see* Ch 1,2.2.

5.2 Manufacture and chemical composition

5.2.1 Pipes are to be manufactured by a seamless or a continuous automatic electric fusion welding process.

5.2.2 Welding is to be in a longitudinal direction, with or without the addition of filler metal.

5.2.3 The chemical composition of the ladle samples is to comply with the appropriate requirements of Table 6.5.1.

5.3 Heat treatment

5.3.1 Pipes are generally to be supplied by the manufacturer in the solution treated condition over their full length.

5.3.2 Alternatively, seamless pipes may be direct quenched immediately after hot forming, while the temperature of the pipes is not less than the specified minimum solution treatment temperature.

5.4 Mechanical tests

5.4.1 All pipes are to be presented in batches as defined in Section 1 for Class I and II piping systems.

5.4.2 Each pipe selected for test is to be subjected to tensile and flattening or bend tests.

5.4.3 The results of all mechanical tests are to comply with the appropriate requirements given in Table 6.5.2.

Table 6.5.1 Chemical composition

Type of steel	Grade	Chemical composition of ladle sample %								
		C max.	Si	Mn	P max.	S max.	Cr	Mo	Ni	Others
304L	490	0,03	<1,00	<2,00	0,045	0,030	17,0 – 19,0	—	9,0 – 13,0	—
316L	490	0,03	<1,00	<2,00	0,045	0,030	16,0 – 18,5	2,0–3,0	11,0 – 14,5	—
321	510	0,08	<1,00	<2,00	0,045	0,030	17,0 – 19,0	—	9,0 – 13,0	Ti ≥5 x C ≤0,80
347	510	0,08	<1,00	<2,00	0,045	0,030	17,0 – 19,0	—	9,0 – 13,0	Nb ≥10 x C ≤1,00

Table 6.5.2 Mechanical properties for acceptance purposes

Type of steel	Grade	0,2% proof stress N/mm^2 (*see* Note)	1,0% proof stress N/mm^2	Tensile strength N/mm^2	Elongation on $5{,}65\sqrt{S_o}$ % minimum	Flattening test constant *C*	Bend test diameter of former (*t* = thickness)
304L	490	175	205	490 – 690	30	0,09	3*t*
316L	490	185	215	490 – 690	30	0,09	3*t*
321	510	195	235	510 – 710	30	0,09	3*t*
347	510	205	245	510 – 710	30	0,09	3*t*

NOTE
The 0,2% proof stress values given for information purposes and unless otherwise agreed are not required to be verified by test.

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5.5 Intergranular corrosion tests

5.5.1 For materials used for piping systems for chemicals, intercrystalline corrosion tests are to be carried out on one per cent of the number of pipes in each batch, with a minimum of one pipe.

5.5.2 For pipes with an outside diameter not exceeding 40 mm, the test specimens are to consist of a full cross-section. For larger pipes, the test specimens are to be cut as circumferential strips of full wall thickness and having a width of not less than 12,5 mm. In both cases, the total surface area is to be between 15 and 35 cm^2.

5.5.3 Unless otherwise agreed or required for a particular chemical cargo, the testing procedure is to be in accordance with Ch 2,8.

5.5.4 After immersion, the full cross-section test specimens are to be subjected to a flattening test in accordance with the requirements of Chapter 2. The strip test specimens are to be subjected to a bend test through 90° over a mandrel of diameter equal to twice the thickness of the test specimen.

5.6 Fabricated pipework

5.6.1 Fabricated pipework is to be produced from material manufactured in accordance with 5.2, 5.3, 5.4 and 5.5.

5.6.2 Welding is to be carried out in accordance with an approved and qualified procedure by suitably qualified welders.

5.6.3 Fabricated pipework may be supplied in the as-welded condition without subsequent solution treatment provided that welding procedure tests have demonstrated satisfactory material properties including resistance to intercrystalline corrosion.

5.6.4 In addition, butt welds are to be subjected to 5 per cent radiographic examination for Class I, and 2 per cent for Class II pipes.

5.6.5 Fabricated pipework in the as-welded condition and intended for systems located on deck is to be protected by a suitable corrosion control coating.

5.7 Certification of materials

5.7.1 Each test certificate is to be of the type and give the information detailed in Ch 1,3.1 together with general details of heat treatment and, where applicable, the results obtained from intercrystalline corrosion tests. As a minimum, the chemical composition is to include the content of all the elements detailed in Table 6.5.1.

■ *Section 6* Boiler and superheater tubes

6.1 Scope

6.1.1 Provision is made in this Section for boiler and superheater tubes in carbon, carbon-manganese and low alloy steels.

6.1.2 Austenitic stainless steels may also be used for this type of service. Where such applications are proposed, details of the chemical composition, heat treatment and mechanical properties are to be submitted for consideration and approval.

6.2 Manufacture and chemical composition

6.2.1 Tubes are to be seamless or welded and are to be manufactured in accordance with the requirements of Sections 2 and 3, respectively.

6.2.2 The method of deoxidation and the chemical composition of ladle samples are to comply with the requirements given in Table 6.2.1 or 6.3.1, as appropriate.

6.3 Heat treatment

6.3.1 All tubes are to be supplied in accordance with the requirements given in Table 6.2.3 or 6.3.3 as appropriate, except that 1Cr½Mo steel may be supplied in the normalised only condition when the carbon content does not exceed 0,15 per cent.

6.4 Mechanical tests

6.4.1 Tubes are to be presented for test in batches as defined in Section 1.

6.4.2 Each boiler and superheater tube selected for test is to be subjected to at least the following:
(a) Tensile test.
(b) Flattening or bending test.
(c) Expanding or flanging test.

6.4.3 The results of all mechanical tests are to comply with the appropriate requirements given in Table 6.6.1.

6.5 Mechanical properties for design

6.5.1 The mechanical properties at elevated temperature for carbon and carbon-manganese steels in Grades 320 to 460, 1Cr½Mo and 2¼Cr1Mo steels can be taken from the appropriate Tables in Section 2.

6.5.2 Where rimming steel is used, the design temperature is limited to 400°C.

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Table 6.6.1 Mechanical properties for acceptance purposes: boiler and superheater tubes

Type of steel	Grade	Yield stress N/mm^2	Tensile strength N/mm^2	Elongation on $5{,}65\sqrt{S_o}$ % minimum	Flattening test constant *C*	Bend test diameter of former (*t* = thickness)	Drift expanding and flanging test minimum % increase in outside diameter		
							Ratio $\frac{\text{Inside diameter}}{\text{Outside diameter}}$		
							≤0,6	>0,6 ≤0,8	>0,8
Carbon and carbon-manganese	320	195	320–440	25	0,10		12	15	19
	360	215	360–480	24	0,10		12	15	19
	410	235	410–530	22	0,08	4*t*	10	12	17
	460	265	460–580	21	0,07		8	10	15
1Cr^1/$_2$Mo	440	275	440–590	22	0,07	4*t*	8	10	15
2^1/$_2$Cr1Mo	410 (*see* Note 1)	135	410–560	20	0,07	4*t*	8	10	15
	490 (*see* Note 2)	275	490–640	16					

NOTES
1. Annealed condition.
2. Normalised and tempered condition.

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Iron Castings

Section

1 **General requirements**

2 **Grey iron castings**

3 **Spheroidal or nodular graphite iron castings**

4 **Iron castings for crankshafts**

■ *Section 1* General requirements

1.1 Scope

1.1.1 This Section gives the general requirements for both grey (flake) and spheroidal (nodular) graphite iron castings intended for use in the construction of ships, other marine structures, machinery, boilers, pressure vessels and piping systems.

1.1.2 Where required by the relevant Rules dealing with design and construction, castings are to be manufactured and tested in accordance with Chapters 1 and 2, together with the requirements given in this Section and either Section 2 for grey iron castings or Section 3 for spheroidal graphite iron castings. Castings for crankshafts are additionally to comply with the requirements detailed in Section 4.

1.1.3 As an alternative to 1.1.2, castings which comply with National or proprietary specifications may be accepted, provided that these specifications give reasonable equivalence to the requirements of this Chapter or alternatively are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

1.1.4 Where small castings are produced in large quantities, or where castings of the same type are produced in regular quantities, alternative survey procedures, in accordance with Ch 1,2.2, may be adopted subject to approval by Lloyd's Register (hereinafter referred to as 'LR').

1.2 Manufacture

1.2.1 Castings as designated in 1.1.2 are to be made at foundries approved by LR.

1.2.2 Suitable mechanical methods are to be employed for the removal of surplus material from castings. Thermal cutting processes are not acceptable, except as a preliminary operation to mechanical methods.

1.3 Quality of castings

1.3.1 Castings are to be free from surface or internal defects which would be prejudicial to their proper application in service. The surface finish is to be in accordance with good practice and any specific requirements of the approved plan.

1.4 Chemical composition

1.4.1 The chemical composition of the iron used is left to the discretion of the manufacturer, who is to ensure that it is suitable to obtain the mechanical properties specified for the castings.

1.5 Heat treatment

1.5.1 Except as required by 1.5.2, castings may be supplied in either the as cast or heat treated condition.

1.5.2 For some applications, such as elevated temperature service, or where dimensional stability is important, castings may require to be given a suitable tempering or stress relieving heat treatment. This is to be carried out after any refining heat treatment and before machining.

1.5.3 Where it is proposed to carry out local hardening of the surface of a casting, full details of the proposed procedure are to be submitted for approval.

1.6 Test material

1.6.1 At least one test sample is to be provided for each casting or batch of castings. For large castings, where more than one ladle of metal is used, one test sample is to be provided, from each ladle used.

1.6.2 A batch testing procedure may be adopted for castings with a fettled mass of 1 tonne or less. All castings in a batch are to be of similar type and dimensions, and cast from the same ladle of metal. One test sample is to be provided for each multiple of two tonnes of fettled castings in the batch.

1.6.3 Where separately cast test samples are used, they are to be cast in moulds made from the same type of material as used for the castings and are not to be stripped from the moulds until the temperature is below 500°C.

1.6.4 All test samples are to be suitably marked to identify them with the castings which they represent.

1.6.5 Where castings are supplied in the heat treated condition, the test samples are to be heat treated together with the castings which they represent. For cast-on test samples, the sample is not to be separated from the casting until after heat treatment.

1.7 Mechanical tests

1.7.1 One tensile specimen is to be prepared from each test sample. The dimensions of the test specimens and the testing procedures used are to be in accordance with Chapter 2.

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1.7.2 The results of all tensile tests are to comply with the requirements given in Section 2, 3 or 4, as appropriate.

1.7.3 In the case of castings supplied in the as cast condition which initially do not meet the requirements of 1.7.2, the manufacturer, by agreement with the purchaser, has the right to heat treat the castings, together with the representative test samples, and re-submit them for acceptance.

1.7.4 In the case of a batch of castings supplied in the heat treated condition which initially do not meet the requirements of 1.7.2, the manufacturer has the right to re-heat treat the batch together with the representative test samples, and re-submit the castings for acceptance. The number of reheat treatments and retestings will be restricted to two.

1.8 Visual and non-destructive examination

1.8.1 All castings are to be cleaned and adequately prepared for examination. The surfaces are not to be hammered, peened or treated in any way which may obscure defects.

1.8.2 The accuracy and verification of dimensions are the responsibility of the manufacturer, unless otherwise agreed.

1.8.3 All castings are to be presented to the Surveyor for visual examination and this is to include the examination of internal surfaces where applicable.

1.8.4 The non-destructive examination of castings is not required unless otherwise stated in the approved plan or where there is reason to suspect the soundness of the casting.

1.8.5 In the event of any casting proving defective during subsequent machining or testing it is to be rejected notwithstanding any previous certification.

1.9 Rectification of defective castings

1.9.1 At the discretion of the Surveyor, small surface blemishes may be removed by local grinding.

1.9.2 Subject to the prior approval of the Surveyor, castings containing local porosity may be rectified by vacuum impregnation with a suitable plastic filler, provided that the extent of the porosity is such that it does not adversely affect the strength of the casting.

1.9.3 Repairs by welding are not permitted on grey cast iron parts and generally not permitted for spheroidal or nodular graphite iron castings, but may be considered in special circumstances for spheroidal or nodular graphite iron castings. In such cases, full details of the proposed repair procedure are to be submitted for approval prior to the commencement of the proposed rectification.

1.10 Pressure testing

1.10.1 When required by the relevant Rules, castings are to be pressure tested before final acceptance. These tests are to be carried out in the presence and to the satisfaction of the Surveyor.

1.11 Identification of castings

1.11.1 The manufacturer is to adopt a system of identification which will enable all finished castings to be traced to the original cast, and the Surveyor is to be given full facilities for tracing the castings when required.

1.11.2 Before acceptance, all castings which have been tested and inspected with satisfactory results are to be clearly marked by the manufacturer with the following particulars:

(a) Type and grade of cast iron.
(b) Identification number, cast number or other marking which will enable the full history of the casting to be traced.
(c) Manufacturer's name or trade mark.
(d) LR or Lloyd's Register and the abbreviated name of LR's local office.
(e) Personal stamp of Surveyor responsible for inspection.
(f) Test pressure, where applicable.
(g) Date of final inspection.

1.11.3 Where small castings are manufactured in large numbers, modified arrangements for identification may be specially agreed with the Surveyor.

1.12 Certification of materials

1.12.1 A LR certificate is to be issued, *see* Ch 1,3.1.

1.12.2 The manufacturer is to provide the Surveyor with a written statement giving the following particulars for each casting or batch of castings which has been accepted:

(a) Purchaser's name and order number.
(b) Description of castings and quality of cast iron.
(c) Identification number.
(d) General details of heat treatment, where applicable.
(e) Results of mechanical tests.
(f) Test pressure, where applicable.
(g) When specially required, the chemical analysis of ladle samples.

1.12.3 Where applicable, the manufacturer is to provide a signed statement regarding non-destructive testing as required by 1.8, together with a statement and/or a sketch detailing the extent and position of all weld repairs made to each casting as required by 1.9.

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■ *Section 2* Grey iron castings

2.1 Scope

2.1.1 This Section gives the specific requirements for grey cast iron castings.

2.2 Test material

2.2.1 Separately cast test samples in the form of cylindrical bars, 30 mm diameter and of a suitable length, are to be used unless otherwise agreed by LR. Test samples of other dimensions may be specially required for some components as may cast-on samples. In these circumstances, the tensile strength requirements are to be agreed.

2.2.2 When two or more test samples are cast simultaneously in a single mould, the bars are to be at least 50 mm apart.

2.2.3 Test samples may be cast integrally when a casting is both more than 20 mm thick and its mass exceeds 200 kg, subject to agreement between the manufacturer and the purchaser. The type and location of the samples are to be such as to provide approximately the same cooling conditions as for the casting it represents and are also subject to agreement.

2.2.4 For continuous melting of the same grade of cast iron in large tonnages the mass of a batch may be taken as the output of two hours of pouring.

2.2.5 Where 2.2.4 applies and production is carefully monitored by systematic checking of the melting process by, for example, chill testing, chemical analysis or thermal analysis, test samples may be taken at longer intervals as agreed by the Surveyor.

2.3 Mechanical tests

2.3.1 Only the tensile strength is to be determined, and the results obtained from tests are to comply with the minimum value specified for the castings being supplied. Except for crankshaft castings (*see* Section 4), the specified tensile strength is to be not less than 200 N/mm^2 subject to any additional requirements of the relevant Rules. The fractured surfaces of all tensile test specimens are to be granular and entirely grey in appearance.

■ *Section 3* Spheroidal or nodular graphite iron castings

3.1 Scope

3.1.1 This Section gives the specific requirements for spheroidal or nodular graphite iron castings.

3.1.2 These requirements are generally applicable to castings intended for use at ambient temperatures. Additional requirements will be necessary when the castings are intended for service at either low or elevated temperatures. Impact test requirements are given for low temperature service in 3.4.2.

3.2 Heat treatment

3.2.1 The special qualities with 350 N/mm^2 and 400 N/mm^2 nominal tensile strength and impact test are to undergo a ferritising heat treatment, *see* 3.4.2.

3.3 Test material

3.3.1 The test samples are to be as detailed in Figs. 7.3.1, 7.3.2 or 7.3.3 The dimensions of the test specimens and testing procedures used are to be in accordance with Chapter 2. Test samples of other dimensions may be specially required for some castings and these are to be agreed with the Surveyor.

3.3.2 The test samples may be either gated to the casting or separately cast.

3.3.3 Where separately cast test samples are used, they are to be taken towards the end of pouring of the castings.

3.4 Mechanical tests

3.4.1 The tensile strength and elongation are to be determined and are to comply with the requirements of Table 7.3.1. Minimum values for the 0,2 per cent proof stress are also included in this Table but are to be determined only if included in the specification. Typical ranges of hardness values are also given in Table 7.3.1 and are intended for information purposes.

3.4.2 Impact tests may be required for some applications in which case the selection of the grade is to be confined to those listed in Table 7.3.2. These castings are to be given a ferritising heat treatment. The mechanical test results are to comply with Table 7.3.2.

3.4.3 Castings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Tables 7.3.1 and 7.3.2 but subject to any additional requirements of the relevant Rules.

3.5 Metallographic examination

3.5.1 Samples for metallographic examination are to be prepared for spheroidal or nodular graphite iron castings. These samples are to be representative of each ladle used and may conveniently be taken from the tensile test specimens. Alternative arrangements for the provision of these samples may, however, be adopted subject to the concurrence of the Surveyor. They are, however, to be taken towards the end of the pour.

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Dimension	Standard sample, mm	Alternative samples when specially required, mm		
u	25	12	50	75
v	55	40	90	125
x	40	30	60	65
y	100	80	150	165
Z	To suit testing machine			
Rs	Approximately 5			

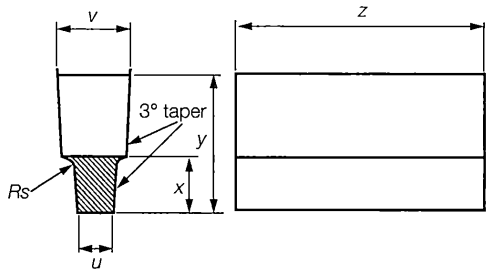

Fig. 7.3.1 Type A (U-type) test samples

Dimension	Standard sample, mm
u	25
v	90
x	40
y	100
Z	To suit testing machine
Rs	Approximately 5

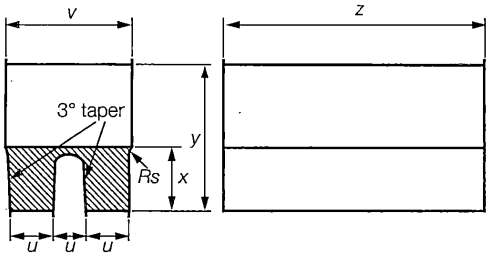

Fig. 7.3.2 Type B (Double U-type) test samples

3.5.2 Examination of the samples is to show that at least 90 per cent of the graphite is in a dispersed spheroidal or nodular form. Details of typical matrix structures are given in Table 7.3.1 and are intended for information purposes.

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Dimension	Standard sample, mm	Alternative samples when specially required, mm		
u	25	12	50	75
v	55	40	100	125
x	40	25	50	65
y	140	135	150	175
Z	To suit testing machine			
Minimum thickness of mould surrounding test sample	40	40	80	80

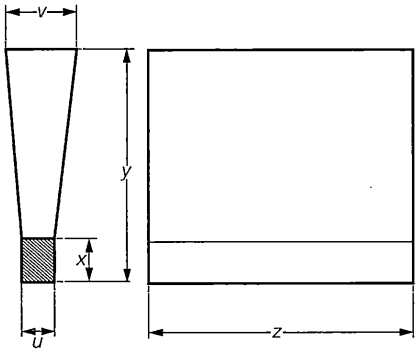

Fig. 7.3.3 Type C (Y-type) test samples

Table 7.3.1 Mechanical properties for acceptance purposes: spheroidal or nodular graphite iron castings

Specified minimum tensile strength N/mm^2	0,2% proof stress (*see* Note) N/mm^2 minimum	Elongation on $5{,}65\sqrt{S_o}$ % minimum	Typical hardness value HB (*see* 3.4.1)	Typical structure of matrix (*see* 3.5.1)
370	230	17	120 – 180	Ferrite
400	250	12	140 – 200	Ferrite
500	320	7	170 – 240	Ferrite/pearlite
600	370	3	190 – 270	Pearlite/ferrite
700	420	2	230 – 300	Pearlite
800	480	2	250 – 350	Pearlite or tempered structure

NOTE
Proof stresses need only be determined if specifically requested.

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Table 7.3.2 Mechanical properties: special qualities

Specified minimum tensile strength N/mm^2	0,2% proof stress minimum (*see* Note 1) N/mm^2	Elongation on 5,65 $\sqrt{S_o}$ minimum % (*see* Note 2)	Typical hardness value	Charpy V-notch impact tests	
				Test temperature °C (*see* Note 3)	Average energy J minimum (*see* Note 4)
350	220	22	110 – 170	20 –40	17 (14) 12 (10)
400	250	18	140 – 200	20 –20	14 (11) 12 (10)

NOTES
1. Proof stresses need only be determined if specifically requested.
2. In the case of integrally cast samples, the acceptable elongation may be taken as 2 percentage points less.
3. Tests need only be made at either of the temperatures listed, as appropriate.
4. The average value measured on three Charpy V-notch specimens. One of the three values may be below the specified minimum average value, but not less than the value shown in brackets.
5. Typical structure of the matrix is ferrite.

■ *Section 4*
Iron castings for crankshafts

4.1 Scope

4.1.1 This Section gives additional requirements for cast iron crankshafts intended for diesel engines and compressors. For both of these applications, details of the proposed specification are to be submitted for approval.

4.1.2 Crankshaft castings in grey iron are acceptable only for compressors, and the specified minimum tensile strength is to be not less than 300 N/mm^2.

4.1.3 For crankshaft castings in spheroidal or nodular graphite iron, the specified minimum tensile strength is to be not less than 370 N/mm^2.

4.2 Manufacture

4.2.1 Details of the method of manufacture, including the arrangements proposed for the provision of test material, are to be submitted for approval.

4.2.2 Tests to demonstrate the soundness of prototype castings and the mechanical properties at important locations will be required.

4.3 Heat treatment

4.3.1 In general, crankshaft castings other than those which are fully annealed, normalised or oil quenched and tempered, are to receive a suitable stress relief heat treatment before machining.

4.3.2 Where it is proposed to harden the surfaces of machined pins and/or journals of cast iron crankshafts, details of the process are to be submitted for approval. Before such a process is applied to a crankshaft it is to be demonstrated by procedure tests, and to the satisfaction of the Surveyor, that the process is suitably controlled and does not impair the strength or soundness of the material.

4.4 Test material

4.4.1 Unless otherwise approved, the dimensions of the test samples are to be such as to ensure that they have mechanical properties representative of those of the average section of the crankshaft casting.

4.4.2 For large crankshaft castings, the test samples are to be cast integral with, or gated from, each casting.

4.4.3 The batch testing procedure detailed in 1.6.2 may be adopted only where small and identical crankshaft castings are produced in quantity. Generally, the fettled mass of each casting in a batch is not to exceed 100 kg, and in addition to tensile tests, the hardness of each casting is to be determined. For this purpose, a small flat is to be ground on each crankshaft, and Brinell hardness tests are to be carried out. The results obtained from these tests are to comply with the approved specification.

4.5 Non-destructive examination

4.5.1 Cast crankshafts are to be subjected to a full magnetic particle or dye penetrant examination after final machining and completion of any surface hardening operations.

4.5.2 Particular attention is to be given to the testing of the pins, journals and associated fillet radii.

4.5.3 Cracks and crack-like defects are not acceptable. Fillet radii are to be free from any indications.

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4.6 Rectification of defective castings

4.6.1 Cast iron crankshafts are not to be repaired by welding, and blemishes are not to be plugged with a filler.

4.7 Certification of materials

4.7.1 The chemical composition of ladle samples is to be given in addition to the other particulars detailed in 1.12.2.

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Aluminium Alloys

Chapter 8

Section 1

Section

1 **Plates, bars and sections**

2 **Aluminium alloy rivets**

3 **Aluminium alloy castings**

4 **Aluminium/steel transition joints**

■ *Section 1* Plates, bars and sections

1.1 Scope

1.1.1 This Section makes provision for aluminium alloy plates, bars and sections intended for use in the construction of ships and other marine structures and for cryogenic applications.

1.1.2 Except as provided in 1.1.4, all items are to be manufactured and tested in accordance with the appropriate requirements of Chapters 1 and 2 and those detailed in this Section.

1.1.3 Plates and sections less than 3,0 mm thick may be manufactured and tested in accordance with the requirements of an acceptable national specification.

1.1.4 Plates less than 3,0 mm thick and sections less than 40 mm x 40 mm x 3,0 mm may be manufactured and tested in accordance with the requirements of an acceptable National specification.

1.1.5 Materials intended for the construction of cargo tanks or storage for liquefied gases, and for other low temperature applications, are to be manufactured in the 5083 alloy in the annealed condition.

1.1.6 As an alternative to 1.1.2 and 1.1.4, materials which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Section and are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

1.2 Manufacture

1.2.1 Aluminium alloys are to be manufactured at works approved by Lloyd's Register (hereinafter referred to as 'LR').

1.2.2 The alloys may be cast either in ingot moulds or by an approved continuous casting process. Plates are to be formed by rolling and may be hot or cold finished. Bars and sections may be formed by extrusion, rolling or drawing.

1.2.3 All melts are to be suitably degassed prior to casting such that the aim hydrogen content is less than 0,2 ml per 100 g.

1.3 Quality of materials

1.3.1 Materials are to be free from surface or internal defects of such a nature as would be harmful in service.

1.3.2 The manufacturer is to verify the integrity of pressure welds of closed extrusion profiles in accordance with 1.10.

1.4 Dimensional tolerances

1.4.1 Underthickness tolerances for rolled products for marine construction are given in Table 8.1.1.

Table 8.1.1 Underthickness tolerances for rolled products for marine construction

Nominal thickness range, mm	Underthickness tolerance for nominal width range, mm		
	≤1500	>1500 ≤2000	>2000 ≤3500
≥3,0 <4,0	0,10	0,15	0,15
≥4,0 <8,0	0,20	0,20	0,25
≥8,0 <12	0,25	0,25	0,25
≥12 <20	0,35	0,40	0,50
≥20 <50	0,45	0,50	0,65

1.4.2 Underthickness tolerances for extruded products are to comply with an acceptable National or International Standard.

1.4.3 There are to be no underthickness tolerances for materials for application in cryogenic process pressure vessels.

1.4.4 Dimensional tolerances other than permitted underthicknesses are to comply with an acceptable National or International Standard.

1.4.5 Verification of dimensions is the responsibility of the manufacturer. Acceptance by Surveyors of material which is later found to be defective does not absolve the manufacturer from this responsibility.

1.5 Chemical composition

1.5.1 Samples for chemical analysis are to be taken representative of each cast, or the equivalent where a continuous melting process is involved.

1.5.2 The chemical composition of these samples is to comply with the requirements of Table 8.1.2.

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Table 8.1.2 Chemical composition, percentage

Element	5083	5383	5059	5086	5754	5456	6005–A (*see* Note 1)	6061 (*see* Note 1)	6082
Copper	0,10 max.	0,20 max.	0,25 max.	0,10 max.	0,10 max.	0,10 max.	0,30 max.	0,15—0,40	0,10 max.
Magnesium	4,0—4,9	4,0—5,2	5,0—6,0	3,5—4,5	2,6—3,6	4,7—5,5	0,40—0,70	0,80—1,20	0,60—1,20
Silicon	0,40 max.	0,25 max.	0,45 max.	0,40 max.	0,40 max.	0,25 max.	0,50—0,90	0,40—0,80	0,70—1,30
Iron	0,40 max.	0,25 max.	0,50 max.	0,50 max.	0,40 max.	0,40 max.	0,35 max.	0,70 max.	0,50 max.
Manganese	0,40—1,00	0,7—1,0	0,6—1,2	0,20—0,70	0,50 max. (*see* Note 2)	0,50—1,00	0,50 max. (*see* Note 3)	0,15 max.	0,40—1,00
Zinc	0,25 max.	0,40 max.	0,40—0,90	0,25 max.	0,20 max.	0,25 max.	0,20 max.	0,25 max.	0,20 max.
Chromium	0,05—0,25	0,25 max	0,25 max.	0,05—0,25	0,30 max. (*see* Note 2)	0,05—0,20	0,30 max. (*see* Note 3)	0,04—0,35	0,25 max.
Titanium	0,15 max.	0,15 max.	0,20 max.	0,15 max.	0,15 max.	0,20 max.	0,10 max.	0,15 max.	0,10 max.
Zirconium		0,20 max.	0,05—0,25						
Other elements: each	0,05 max.	0,05 max.	0,05 max.	0,05 max.	0,05 max.	0,05 max.	0,05 max.	0,05 max.	0,05 max.
total	0,15 max.	0,15 max.	0,15 max.	0,15 max.	0,15 max.	0,15 max.	0,15 max.	0,15 max.	0,15 max.

NOTES
1. These alloys are not normally acceptable for application in direct contact with sea-water.
2. Mn + Cr = 0,10 min., 0,60 max.
3. Mn + Cr = 0,12 min., 0,50 max.

1.6 Heat treatment

1.6.1 The Aluminium 5000 series alloys, capable of being strain hardened, are to be supplied in any of the following temper conditions:

- O annealed
- H111 annealed with slight strain hardening
- H112 strain hardened from working at elevated temperatures
- H116 strain hardened and with specified resistance to exfoliation corrosion for alloys where the magnesium content is 4 per cent or more
- H321 strain hardened and stabilised.

1.6.2 The H116 temper is specially developed for use in a marine environment.

1.6.3 The Aluminium 6000 series alloys, capable of being age hardened, are to be supplied in either of the following temper conditions:

- T5 hot worked and artificially aged
- T6 solution treated and artificially aged.

1.7 Test material

1.7.1 Materials of the same product form, (i.e. plates, sections or bars) and thickness and from a single cast or equivalent, are to be presented for test in batches of not more than 2 tonnes, with the exceptions of those given in 1.7.2, 1.7.3 and 1.7.4.

1.7.2 For single plates or coils weighing more than 2 tonnes, only one tensile specimen per plate or coil is to be taken.

1.7.3 A tensile test specimen is required from each plate to be used in the construction of cargo tanks, secondary barriers and process pressure vessels with design temperatures below –55°C.

1.7.4 Extrusions, bars and sections of less than 1 kg/m in nominal weight are to be tested in batches of 1 tonne. Where the nominal weight is greater than 5 kg/m, one tensile test is to be carried out for every three tonnes produced, or fractions thereof.

1.7.5 If the material is supplied in the heat treated condition, each batch is to be treated in the same furnace charge or subjected to the same finishing treatment when a continuous furnace is used.

1.7.6 For plates over 300 mm in width, tensile test specimens are to be cut with their length transverse to the principal direction of rolling. For narrow plates and for sections and bars, the test specimens are to be cut in the longitudinal direction. Longitudinal tensile test specimens are accepted for the strain hardenable 5000 series alloys.

1.7.7 Longitudinal tensile test specimens from a plate are to be taken at 1/3 width from the longitudinal edge. Longitudinal tensile test specimens taken from extruded sections should be taken in the range from 1/3 to 1/2 of the distance from the edge to the centre of the thickest region of the section.

1.8 Mechanical tests

1.8.1 At least one tensile test specimen is to be prepared from each batch of material submitted for acceptance.

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Table 8.1.3 Minimum mechanical properties for acceptance purposes of selected rolled aluminium alloy products

Alloy and temper condition	Thickness, t, mm	0,2% proof stress R_p, N/mm^2	Tensile strength R_m N/mm^2	Elongation on $4d$, %	Elongation on $5{,}65\sqrt{S_o}$, %
5083-O	$3 \le t \le 50$	125	275–350	16	14
5083-H112	$3 \le t \le 50$	125	275	12	10
5083-H116	$3 \le t \le 50$	215	305	12 (*see* Note 1)	10
5083-H321	$3 \le t \le 50$	215–295	305–380	12	10
5086-O	$3 \le t \le 50$	100	240–305	16	14
5086-H112	$3 \le t \le 12{,}5$ $12{,}5 < t \le 50$	125 105	250 240	8 —	— 9
5086-H116	$3 \le t \le 50$	195	275	10 (*see* Note 2)	9
5059-O	$3 \le t \le 50$	160	330	24	24
5059-H116	$3 \le t \le 20$ $20 < t \le 50$	270 260	370 360	10 10	10 10
5059-H321	$3 \le t \le 20$ $20 < t \le 50$	270 260	370 360	10 10	10 10
5383-O	$3 \le t \le 50$	145	290	16	17
5383-H116	$3 \le t \le 50$	220	305	10	10
5383-H321	$3 \le t \le 50$	220	305	10	10
5456-O	$3 \le t \le 6{,}3$ $6{,}3 \le t \le 50$	130–205 125–205	290–365 285–360	16 16	— 14
5456-H116	$3 \le t \le 30$ $30 < t \le 40$ $40 < t \le 50$	230 215 200	315 305 285	10 — —	10 10 10
5456-H321	$3 \le t \le 12{,}5$ $12{,}5 \le t \le 40$ $40 \le t \le 50$	230–315 215–305 200–295	315–405 305–385 285–370	12 — —	— 10 10
5754-O	$3 \le t \le 50$	80	190–240	18	17

NOTES
1. 10% for thickness up to and including 12,5 mm.
2. 8% for thickness up to and including 6,3 mm.
3. For application to liquefied natural gas carriers or liquefied natural gas tankers where thicknesses are in excess of 50 mm, the mechanical properties given in this table are, in general, to be complied with.

1.8.2 Tensile test specimens are to be machined to the dimensions given in Fig. 2.2.3 in Chapter 2. Alternatively, machined proportional test specimens of circular cross-section in accordance with Fig. 2.2.2 in Chapter 2 may be used provided that the diameter is not less than 10 mm. Round bars may be tested in full section, or test specimens may be machined in accordance with the dimensions given in Fig. 2.2.2 in Chapter 2.

1.8.3 The results of all tensile tests are to comply with the values given in Table 8.1.4, as applicable.

1.9 Corrosion tests

1.9.1 Rolled 5000 series alloys of type 5083, 5383, 5059, 5456 and 5086 in the H116 and H321 tempers intended for use in marine hull construction or in marine applications with frequent direct contact with seawater are to be corrosion tested with respect to exfoliation and intergranular corrosion resistance.

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Table 8.1.4 Minimum mechanical properties for acceptance purposes of selected extruded aluminium alloy products

Alloy and temper condition	Thickness, t, mm	0,2% proof stress R_p, N/mm^2	Tensile strength R_m N/mm^2	Elongation on $4d$, %	Elongation on $5{,}65\sqrt{S_o}$, %
5083-O	$3 \le t \le 50$	110	270–350	14	12
5083-H111	$3 \le t \le 50$	165	275	12	10
5083-H112	$3 \le t \le 50$	110	270	12	10
5086-O	$3 \le t \le 50$	95	240–315	14	12
5086-H111	$3 \le t \le 50$	145	250	12	10
5086-H112	$3 \le t \le 50$	95	240	12	10
5059-H112	$3 \le t \le 50$	200	330	—	10
5383-O	$3 \le t \le 50$	145	290	17	17
5383-H111	$3 \le t \le 50$	145	290	17	17
5383-H112	$3 \le t \le 50$	190	310	—	13
6005A-T5	$3 \le t \le 50$	215	260	9	8
6005A-T6	$3 \le t \le 10$ $10 < t \le 50$	215 200	260 250	8 8	6 6
6061-T6	$3 \le t \le 50$	240	260	10	8
6082-T5	$3 \le t \le 50$	230	270	8	6
6082-T6	$3 \le t \le 5$ $5 < t \le 50$	250 260	290 310	6 10	— 8

NOTE
The values are applicable for longitudinal and transverse tensile test specimens as well.

1.9.2 The manufacturer is to establish the relationship between microstructure and resistance to corrosion when the above alloys are approved. A reference photomicrograph taken at 500x, is to be prepared for each of the alloy-tempers and thickness ranges relevant. The reference photographs are to be taken from samples which have exhibited no evidence of exfoliation corrosion and a pitting rating of PB or better, when subjected to the test described in ASTM G66 (ASSET).The samples are also to have exhibited resistance to intergranular corrosion at a mass loss no greater than 15 mg/cm^2, when subjected to the test described in ASTM G67. Upon satisfactory establishment of the relationship between microstructure and resistance to corrosion, the master photomicrographs and the results of the corrosion tests are to be approved by LR. Production practices are not to be changed after approval of the reference micrographs.

1.9.3 For batch acceptance of 5000 series alloys in the H116 and H321 tempers, metallographic examination of one sample selected from mid width at one end of a coil or random sheet or plate is to be carried out. The microstructure of the sample is to be compared to the reference photomicrograph of acceptable material in the presence of the Surveyor. A longitudinal section perpendicular to the rolled surface is to be prepared for metallographic examination. If the microstructure shows evidence of continuous grain boundary network of aluminium-magnesium precipitate in excess of the reference photomicrographs of acceptable material, the batch is either to be rejected or tested for exfoliation corrosion resistance and intergranular corrosion resistance subject to the agreement of the Surveyor. The corrosion tests are to be in accordance with ASTM G66 and G67 or equivalent standards. If the results from testing satisfy the acceptance criteria stated in 1.9.2 the batch is accepted, otherwise it is to be rejected.

1.9.4 As an alternative to metallographic examination, each batch may be tested for exfoliation corrosion resistance and intergranular corrosion resistance, in accordance with ASTM G66 and G67 or equivalent standards.

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1.9.5 Tempers that are corrosion tested in accordance with 1.9.3 are to be marked 'M' after the temper condition, e.g. 5083 H321 M.

1.10 Pressure weld tests

1.10.1 The integrity of pressure welds of closed profile extrusions is to be verified by examination of macrosections or drift expansion tests.

1.10.2 Every closed profile extrusion is to be sampled, except where the closed profile extrusions are equal to or shorter than 6,0 m long, in which case a batch is to comprise five profiles. Every sample is to be tested at both ends after final heat treatment.

1.10.3 Where verification is by examination of macrosections, no indication of lack of fusion is permitted.

1.10.4 Where verification of fusion at pressure welds of closed profile extrusions is by drift expansion test, testing is to be generally in accordance with Ch 2,4.3. The minimum included angle of the mandrel is to be 60°, and the minimum specimen length, 50 mm. For acceptance, there is to be no failure by a clean split along the weld line.

1.11 Visual and non-destructive examination

1.11.1 Surface inspection and verification of dimensions are the responsibility of the manufacturer, and acceptance by the Surveyors of material later found to be defective shall not absolve the manufacturer from this responsibility.

1.11.2 In general, the non-destructive examination of materials is not required for acceptance purposes. Manufacturers are expected, however, to employ suitable methods of non-destructive examination for the general maintenance of quality standards.

1.11.3 For applications where the non-destructive examination of materials is considered to be necessary, the extent of this examination, together with appropriate acceptance standards, are to be agreed between the purchaser, manufacturer and Surveyor.

1.12 Rectification of defects

1.12.1 Slight surface imperfections may be removed by mechanical means, provided that the prior agreement of the Surveyor is obtained, that the work is carried out to his satisfaction and that the final dimensions are acceptable. The repair of defects by welding is not allowed.

1.13 Identification

1.13.1 The manufacturer is to adopt a system of identification which will ensure that all finished material in a batch presented for test is of the same nominal chemical composition.

1.13.2 Products are to be clearly marked by the manufacturer in accordance with the requirements of Chapter 1. The following details are to be shown on all materials which have been accepted:

(a) Manufacturer's name or trade mark.
(b) Alloy grade and temper condition.
(c) Identification mark which will enable the full history of the item to be traced.
(d) The stamp of the LR brand, ℞.

1.14 Certification of materials

1.14.1 A manufacturer's certificate validated by LR is to be issued, *see* Ch 1,3.1.

1.14.2 Each test certificate is to include the following particulars:

(a) Purchaser's name and order number.
(b) Contract number.
(c) Address to which material is to be despatched.
(d) Description and dimensions.
(e) Alloy grade and temper condition.
(f) Identification mark which will enable the full history of the item to be traced.
(g) Chemical composition.
(h) Mechanical test results (not required on shipping statement).
(j) Details of temper condition and heat treatment, where applicable.

1.14.3 Where the alloy is not produced at the works at which it is wrought, a certificate is to be supplied by the manufacturer of the alloy stating the cast number and chemical composition. The works at which the alloy was produced must be approved by LR.

■ *Section 2* Aluminium alloy rivets

2.1 Scope

2.1.1 Provision is made in this Section for aluminium alloy rivets intended for use in the construction of marine structures.

2.1.2 They are to be manufactured and tested in accordance with the appropriate requirements of Section 1 and those detailed in this Section.

2.2 Chemical composition

2.2.1 The chemical composition of bars used for the manufacture of rivets is to comply with the requirements of Table 8.2.1.

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Table 8.2.1 Chemical composition, percentage

Element	5154A	6082
Copper	0,10 max.	0,10 max.
Magnesium	3,1 – 3,9	0,6 – 1,2
Silicon	0,50 max.	0,7 – 1,3
Iron	0,50 max.	0,50 max.
Manganese	0,1 – 0,5	0,4 – 1,0
Zinc	0,20 max.	0,20 max.
Chromium	0,25 max.	0,25 max.
Titanium	0,20 max.	0,10 max.
Other elements: each	0,05 max.	0,05 max.
total	0,15 max.	0,15 max.
Aluminium	Remainder	Remainder

2.3 Heat treatment

2.3.1 Rivets are to be supplied in the following condition:
5154A – annealed
6082 – solution treated.

2.4 Test material

2.4.1 Bars intended for the manufacture of rivets are to be presented for test in batches of not more than 250 kg. The material in each batch is to be the same diameter and nominal chemical composition.

2.4.2 At least one test sample is to be selected from each batch and, prior to testing, is to be heat treated in full cross-section and in a manner simulating the heat treatment applied to the finished rivets.

2.5 Mechanical tests

2.5.1 At least one tensile and one dump test specimen are to be prepared from each test sample.

2.5.2 The tensile test specimen may be either a suitable length of bar tested in full cross-section or a specimen machined to the dimensions given in Fig. 2.2.2 in Chapter 2.

2.5.3 The dump test specimen is to consist of a section cut from the bar with the ends perpendicular to the axis. The length of this section is to be equal to the diameter of the bar.

2.5.4 The results of tensile tests are to comply with the appropriate requirements of Table 8.2.2.

Table 8.2.2 Mechanical properties for acceptance purposes

Mechanical properties	5154A	6082
0,2% proof stress N/mm^2 min.	90	120
Tensile strength N/mm^2 min.	220	190
Elongation on $5{,}65\sqrt{S_o}$ % min.	18	16

2.5.5 The dump test is to be carried out at ambient temperature and is to consist of compressing the specimen until the diameter is increased to 1,6 times the original diameter. After compression, the specimen is to be free from cracks.

2.6 Tests from manufactured rivets

2.6.1 At least three samples are to be selected from each consignment of manufactured rivets. Dump tests as detailed in 2.5 are to be carried out on each sample.

2.7 Identification

2.7.1 Each package of manufactured rivets is to be identified with attached labels giving the following details:
(a) Manufacturer's name or trade mark.
(b) Alloy grade.
(c) Rivet size.

2.8 Certification of materials

2.8.1 A manufacturer's certificate is to be issued (*see* Ch 1,3.1) and for each consignment of manufactured rivets is to include the following particulars:
(a) Purchaser's name and order number.
(b) Description and dimensions.
(c) Specification.

■ *Section 3* Aluminium alloy castings

3.1 Scope

3.1.1 Provision is made in this Section for aluminium alloy castings intended for use in the construction of ships, ships for liquid chemicals and other marine structures and liquefied gas piping systems where the design temperature is not lower than minus 165°C. These materials should not be used for piping systems outside cargo tanks except for short lengths of pipes attached to the cargo tanks in which case fire-resisting insulation should be provided.

3.1.2 Castings are to be manufactured and tested in accordance with Chapters 1 and 2 and also with the requirements of this Section.

3.1.3 As an alternative to 3.1.2, castings which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Section or are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

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3.2 Manufacture

3.2.1 Castings are to be manufactured at foundries approved by LR.

3.3 Quality of castings

3.3.1 All castings are to be free from surface or internal defects which would be prejudicial to their proper application in service.

3.4 Chemical composition

3.4.1 The chemical composition of a sample from each cast is to comply with the requirements given in Table 8.3.1. Suitable grain refining elements may be used at the discretion of the manufacturer. The content of such elements is to be reported in the ladle analysis.

Table 8.3.1 Chemical composition, percentage

Alloy Element	Al–Mg 3	Al–Si 12	Al–Si 10 Mg	Al–Si 7 High purity
Copper	0,1 max.	0,1 max.	0,1 max.	0,1 max.
Magnesium	2,5—4,5	0,1 max.	0,15—0,4	0,25—0,45
Silicon	0,5 max.	11,0—13,5	9,0—11,0	6,5—7,5
Iron	0,5 max.	0,7 max.	0,6 max.	0,2 max.
Manganese	0,6 max.	0,5 max.	0,6 max.	0,1 max.
Zinc	0,2 max.	0,1 max.	0,1 max.	0,1 max.
Chromium	0,1 max.	—	—	—
Titanium	0,2 max.	0,2 max.	0,2 max.	0,2 max.
Others each	0,05 max.	0,05 max.	0,05 max.	0,05 max.
Total	0,15 max.	0,15 max.	0,15 max.	0,15 max.
Aluminium	Remainder	Remainder	Remainder	Remainder

3.4.2 Where it is proposed to use alloys not specified in Table 8.3.1, details of the chemical composition, heat treatment and mechanical properties are to be submitted for approval.

3.4.3 When a cast is wholly prepared from ingots for which an analysis is already available, and provided that no significant alloy additions are made during melting, the ingot maker's certified analysis can be accepted subject to occasional checks as required by the Surveyor.

3.5 Heat treatment

3.5.1 Castings are to be supplied in the following conditions:

Grade Al-Mg 3 – as-manufactured
Grade Al-Si 12 – as-manufactured
Grade Al-Si 10 Mg – as-manufactured or solution heat treated and precipitation hardened
Grade Al-Si 7 Mg (high purity) – solution heat treated and precipitation hardened.

3.6 Mechanical tests

3.6.1 At least one tensile specimen is to be tested from each cast and, where heat treatment is involved, for each heat treatment batch from each cast. Where continuous melting is employed, 500 kg of fettled castings may be regarded as a cast.

3.6.2 The test samples are to be separately cast in moulds made from the same type of material as used for the castings. These moulds should conform to National Standards.

3.6.3 The method and procedures for the identification of the test specimens, and the castings they represent, are to be agreed with the Surveyor. The identification marks are to be maintained during the preparation of test specimens.

3.6.4 Where castings are supplied in the heat treated condition, the test samples are to be heat treated together with the castings which they represent prior to testing.

3.6.5 The results of all tensile tests are to comply with the appropriate requirements given in Table 8.3.2 and/or Table 8.3.3.

Table 8.3.2 Minimum mechanical properties for acceptance purposes of sand-cast and investment cast reference test pieces

Alloy	Temper (*see* Note)	Tensile strength N/mm^2	Elongation %
Al–Mg 3	M	150	5
Al–Si 12	M	150	3
Al–Si 10 Mg	M	150	2
Al–Si 10 Mg	TF	220	1
Al–Si 7 Mg	TF	230	5

NOTE
M refers to as cast condition.
TF refers to solution heat treated and precipitation hardened condition.

3.6.6 Where the results of a test do not comply with the requirements, the re-test procedure detailed in Ch 2,1.4 is to be applied. Where castings are to be used in the heat treated condition, the re-test sample must have been heat treated together with the castings it represents.

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Table 8.3.3 Minimum mechanical properties for acceptance purposes of chill-cast reference test piece

Alloy	Temper (*see* Note)	Tensile strength N/mm^2	Elongation %
Al–Mg 3	M	150	5
Al–Si 12	M	170	3
Al–Si 10 Mg	M	170	3
Al–Si 10 Mg	TF	240	1,5
Al–Si 7 Mg	TF	250	5

NOTE
M refers to as cast condition.
TF refers to solution heat treated and precipitation hardened condition.

3.7 Visual examination

3.7.1 All castings are to be cleaned and adequately prepared for inspection.

3.7.2 The accuracy and verification of dimensions are the responsibility of the manufacturer, unless otherwise agreed.

3.7.3 Before acceptance, all castings are to be presented to the Surveyor for visual examination.

3.8 Rectification of defective castings

3.8.1 At the discretion of the Surveyor, small surface blemishes may be removed by local grinding.

3.8.2 Where appropriate, repair by welding may be accepted at the discretion of the Surveyor. Such repair is to be made in accordance with an approved procedure.

3.9 Pressure testing

3.9.1 Where required by the relevant Rules, castings are to be pressure tested before final acceptance. Unless otherwise agreed, these tests are to be carried out in the presence and to the satisfaction of the Surveyor.

3.10 Identification

3.10.1 The manufacturer is to adopt a system of identification which will enable all finished castings to be traced to the original cast and the Surveyor is to be given full facilities for tracing the casting when required.

3.10.2 All castings which have been tested and inspected with satisfactory results are to be clearly marked with the following details:
(a) Identification number, cast number or other markings which will enable the full history of the casting to be traced.
(b) LR or Lloyd's Register and the abbreviated name of LR's local office.
(c) Personal stamp of the Surveyor responsible for the inspection.
(d) Test pressure where applicable.
(e) Date of final inspection.

3.10.3 Where small castings are manufactured in large numbers, modified arrangements for identification may be specially agreed with the Surveyor.

3.11 Certification of materials

3.11.1 A LR certificate is to be issued (*see* Ch 1,3.1) giving the following particulars for each casting or batch of castings which have been accepted:
(a) Purchaser's name and order number.
(b) Description of castings and alloy type.
(c) Identification number.
(d) Ingot or cast analysis.
(e) General details of heat treatment, where applicable.
(f) Results of mechanical tests.
(g) Test pressure, where applicable.

■ *Section 4* Aluminium/steel transition joints

4.1 Scope

4.1.1 Provision is made in this Section for explosion bonded composite aluminium/steel transition joints used for connecting aluminium structures to steel plating.

4.1.2 Each individual application is to be separately approved as required by the relevant Rules dealing with design and construction.

4.2 Manufacture

4.2.1 Transition joints are to be manufactured by an approved producer in accordance with an approved specification which is to include the maximum temperature allowable at the interface during welding.

4.2.2 The aluminium material is to comply with the requirements of Section 1 and the steel is to be of an appropriate grade complying with the requirements of Ch 3,2.

4.2.3 Alternative materials which comply with International, National or proprietary specifications may be accepted provided that they give reasonable equivalence to the requirements of 4.2.2 or are approved for a specific application.

4.2.4 Intermediate layers between the aluminium and steel may be used, in which case the material of any such layer is to be specified by the manufacturer and is to be recorded in the approval certificate. Any such intermediate layer is then to be used in all production transition joints.

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4.3 Visual and non-destructive examination

4.3.1 Each composite plate is to be subjected to 100 per cent visual and ultrasonic examination in accordance with a relevant National Standard to determine the extent of any unbonded areas. Unbonded areas are unacceptable and any such area plus 25 mm of surrounding sound material is to be discarded.

4.4 Mechanical tests

4.4.1 Two shear test specimens and two tensile test specimens are to be taken from each end of each composite plate for tests to be made on the bond strength. One shear and one tensile test specimen from each end are to be tested at ambient temperature after heating to the maximum allowable interface temperature, *see* 4.2.1; the other two specimens are to be tested without heat treatment.

4.4.2 Shear tests may be made on a specimen as shown in Fig. 8.4.1 or an appropriate equivalent. Tensile tests may be made across the interface by welding extension pieces to each surface or by the ram method shown in Fig. 8.4.2 or by an appropriate alternative method.

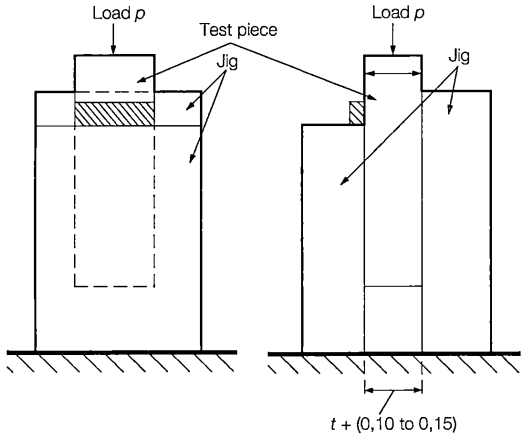

Fig. 8.4.1 Specimen and procedure for shear tests

4.4.3 The shear and tensile strengths of all the test specimens are to comply with the requirements of the manufacturing specification.

4.4.4 If either the shear or tensile strength of the bond is less than the specified minimum but not less than 70 per cent of the specified minimum, two additional shear and two tensile test specimens from each end of the composite plate are to be tested and, in addition, bend tests as described in 4.4.6 and Table 8.4.1 are to be made.

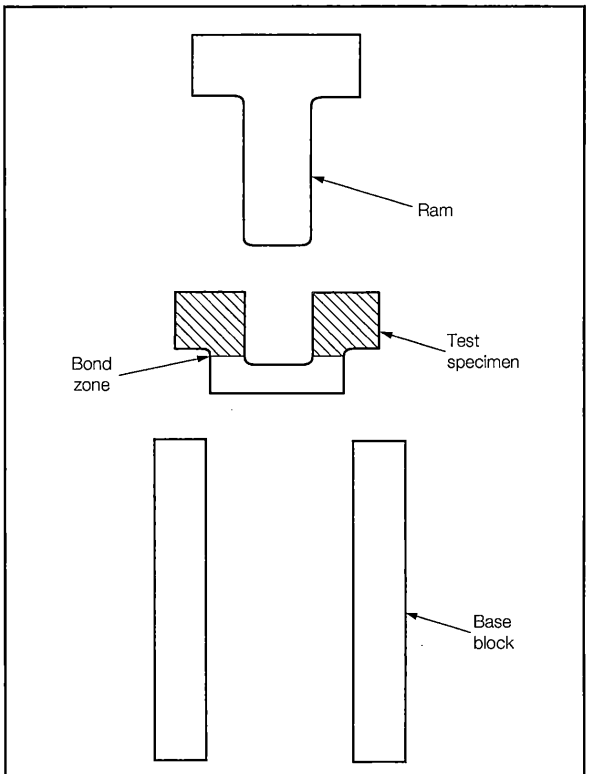

Fig. 8.4.2 Ram tensile test

4.4.5 If either the shear or tensile strength of the bond is less than 70 per cent of the specified minimum the cause is to be investigated. After evaluation of the results of this investigation, LR will consider the extent of composite plate which is to be rejected.

4.4.6 Bend tests, when required, are to be made under the following conditions, as listed in Table 8.4.1:

(a) The aluminium plate is in tension.
(b) The steel plate is in tension.
(c) A side bend is applied.

Table 8.4.1 Bend tests on explosion bonded aluminium/steel composites

Type of test	Minimum bend, degrees	Diameter of former
Aluminium in tension	90	3*T*
Steel in tension	90	3*T*
Side bend	90	6*T*

NOTE
T is the total thickness of the composite plate.

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4.5 Identification

4.5.1 Each acceptable transition strip is to be clearly marked with the following particulars:

(a) LR or Lloyd's Register and the abbreviated name of LR's local office.
(b) Manufacturer's name or trade mark.
(c) Identification mark for the grade of aluminium.
(d) Identification mark for the grade of steel.

The particulars are to be stamped on the aluminium surface at one end of the strip.

4.6 Certification of materials

4.6.1 A manufacturer's certificate validated by LR is to be issued (*see* Ch 1,3.1) and as a minimum is to include the following particulars:

(a) Purchaser's name and order number.
(b) The contract number for which the material is intended, if known.
(c) Address to which the material is dispatched.
(d) Description and dimensions of the material.
(e) Specifications or grades of both the aluminium alloy and the steel and any intermediate layer.
(f) Cast numbers of the steel and aluminium plates.
(g) Identification number of the composite plate.
(h) Mechanical test results (not required on shipping statement).

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Section

1 **Castings for propellers**

2 **Castings for valves, liners and bushes**

3 **Tubes**

■ *Section 1* Castings for propellers

1.1 Scope

1.1.1 This Section gives the requirements for copper alloy castings for one-piece propellers and separately cast blades and bosses for fixed pitch and controllable pitch propellers (CPP). These include contra-rotating propellers and propulsors fitted to podded drives and azimuth units.

1.1.2 These castings are to be manufactured and tested in accordance with the appropriate requirements of Chapters 1 and 2 and the specific requirements of this Section.

1.1.3 As an alternative to 1.1.2, castings which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Section or alternatively are approved for a specific application.

1.1.4 The appropriate requirements of this Section may also be applied to the repair and inspection of propellers which have been damaged during service.

1.1.5 Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

1.2 Manufacture

1.2.1 All castings are to be manufactured at foundries approved by Lloyd's Register (hereinafter referred to as 'LR').

1.2.2 The pouring is to be carried out into dried moulds using degassed liquid metal. The pouring is to avoid turbulent flow. Special devices and/or procedures are to be used to prevent slag flowing into the mould.

1.3 Quality of castings

1.3.1 All castings are to be free from surface or internal defects which would be prejudicial to their proper application in service.

1.3.2 The removal and repair of defects are dealt with in 1.9 and 1.10.

1.4 Chemical composition

1.4.1 The chemical compositions of samples from each melt are to comply with the manufacturing specification approved by LR and also with the overall limits given in Table 9.1.1. In addition to carrying out chemical analysis for the elements given in the Table, it is expected that manufacturers will ensure that any harmful residual elements are within acceptable limits.

1.4.2 The use of alloys whose chemical compositions are different from those detailed in Table 9.1.1 will be given special consideration by LR.

1.4.3 The manufacturer is to maintain records of all chemical analyses, which are to be made available to the Surveyor so that he can satisfy himself that the chemical composition of each casting is within the specified limits.

Table 9.1.1 Chemical composition of propeller and propeller blade castings

Alloy designation	Chemical composition of ladle samples %							
	Cu	Sn	Zn	Pb	Ni	Fe	Al	Mn
Grade Cu 1 Manganese bronze (high tensile brass)	52–62	0,1–1,5	35–40	0,5 max.	1,0 max.	0,5–2,5	0,5–3,0	0,5–4,0
Grade Cu 2 Ni-manganese bronze (high tensile brass)	50–57	0,1–1,5	33–38	0,5 max.	2,5–8,0	0,5–2,5	0,5–2,0	1,0–4,0
Grade Cu 3 Ni-aluminium bronze	77–82	0,1 max.	1,0 max.	0,03 max.	3,0–6,0 (*see* Note)	2,0–6,0 (*see* Note)	7,0–11,0	0,5–4,0
Grade Cu 4 Mn–aluminium bronze	70–80	1,0 max.	6,0 max.	0,05 max.	1,5–3,0	2,0–5,0	6,5–9,0	8,0–20,0

NOTE
For Naval ships, the nickel content is to be higher than the iron content.

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1.4.4 When a melt is wholly prepared from ingots for which an analysis is already available, and provided that no significant alloy additions are made during melting, the ingot maker's certified analysis can be accepted subject to occasional checks as required by the Surveyor. If any foundry returns are added to the melts, the ingot manufacturer's chemical analyses are to be supplemented by frequent checks as required by the Surveyor.

1.4.5 For alloys Grade Cu 1 and Cu 2, the zinc equivalent shall not exceed 45 per cent, and is to be calculated using the following formula:

$$\text{zinc equivalent \%} = 100 - \frac{100 \times \%Cu}{100 + A}$$

where A is the algebraic sum of the following:

1 x % Sn
5 x % Al
–0,5 x % Mn
–0,1 x % Fe
–2,3 x % Ni

1.4.6 Samples for metallographic examination are to be prepared from the ends of test bars cast from every melt of Grade Cu 1 and Cu 2 alloys. The proportion of alpha-phase determined from the average of at least five counts is to be not less than 25 per cent.

1.5 Heat treatment

1.5.1 At the option of the manufacturer, castings may be supplied in the 'as-cast' or heat treated condition. However, if heat treatment is to be applied, full details are to be included in the manufacturing specification.

1.5.2 If any welds are made in the propeller casting, stress relief heat treatment is required in order to minimise the residual stresses. Requirements concerning such heat treatment are given in 1.10.

1.6 Test material

1.6.1 Test samples are to be cast separately from each melt used for the manufacture of propeller or propeller blade castings.

1.6.2 The test samples are to be of the keel block type, generally in accordance with the dimensions given in Fig. 9.1.1 and are to be cast in moulds made from the same type of material as used for the castings.

1.6.3 The method and procedures for the identification of the test specimens, and the castings they represent, are to be agreed with the Surveyor. The identification marks are to be transferred and maintained during the preparation of test specimens.

1.6.4 Where castings are supplied in the heat treated condition, the test samples are to be heat treated together with the castings which they represent.

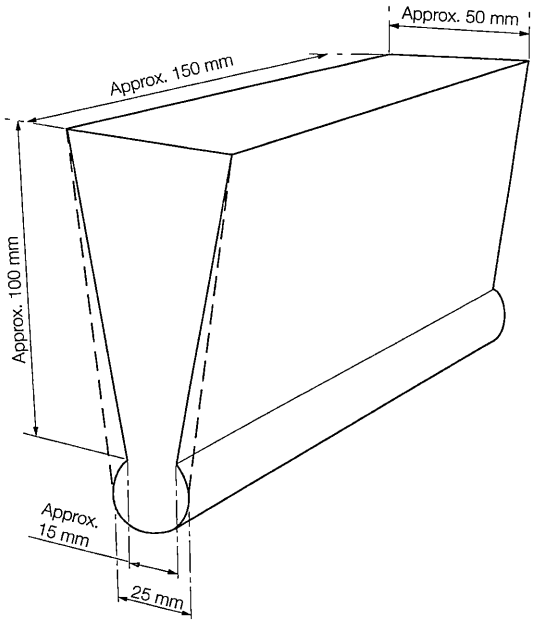

Fig. 9.1.1 Keel block type test sample

1.7 Mechanical tests

1.7.1 At least one tensile test specimen representative of each cast is to be prepared. The dimensions of this test specimen are to be in accordance with Fig. 2.2.1 in Chapter 2.

1.7.2 The results of all tensile tests are to comply with the requirements given in Table 9.1.2.

1.7.3 The mechanical properties of alloys whose chemical compositions do not accord with Table 9.1.1 are to comply with a manufacturing specification approved by LR.

Table 9.1.2 Mechanical properties for acceptance purposes: propeller and propeller blade castings

Alloy designation	0,2% proof stress N/mm^2 minimum	Tensile strength N/mm^2 minimum	Elongation on $5{,}65\sqrt{S_o}$ % minimum
Grade Cu 1 Manganese bronze (high tensile brass)	175	440	20
Grade Cu 2 Ni-manganese bronze (high tensile brass)	175	440	20
Grade Cu 3 Ni-aluminium bronze	245	590	16
Grade Cu 4 Mn-aluminium bronze	275	630	18

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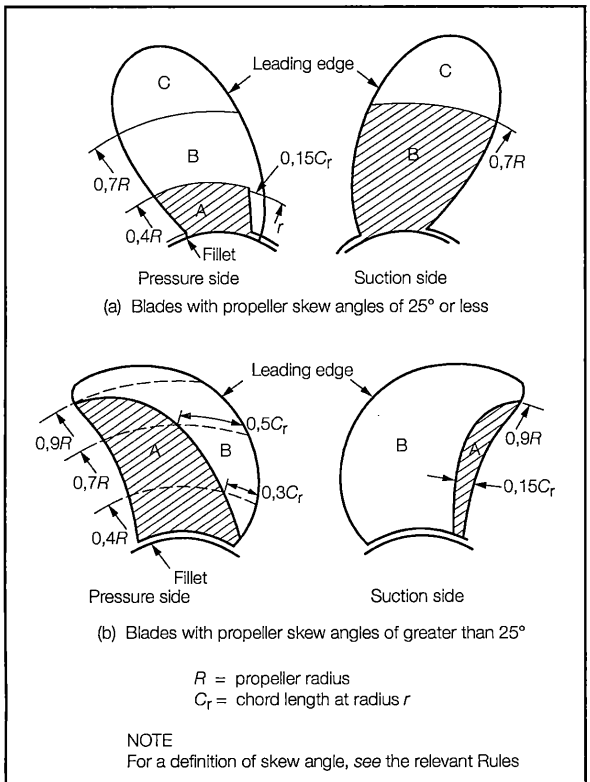
1.8 Inspection and non-destructive examination

1.8.1 Propeller castings should be visually inspected at all stages of manufacture. The manufacturer is to draw any significant imperfections to the attention of the Surveyor. Such imperfections are to be verified in accordance with 1.9.

1.8.2 All finished castings are to be subjected to a comprehensive visual examination by the Surveyor, including internal surfaces such as the bore and bolt holes.

1.8.3 For the purpose of these requirements, the blades of propellers, including CPP blades, are divided into three severity Zones A, B and C as shown in Fig. 9.1.2 and detailed in 1.8.4 for blades having skew angles of 25° or less and 1.8.5 for blades having skew angles of greater than 25°.



(a) Blades with propeller skew angles of 25° or less

(b) Blades with propeller skew angles of greater than 25°

R = propeller radius
C_r = chord length at radius r

NOTE
For a definition of skew angle, *see* the relevant Rules

Fig. 9.1.2 Severity zones in all propeller blades

1.8.4 **Skew angles of 25° or less:**

- Zone A is the area on the pressure side of the blade from and including the root fillet to 0,4*R* and bounded by the trailing edge and by a line at a distance 0,15 times the chord length from the leading edge.
- Zone B includes the areas inside 0,7*R* on both sides of the blade, excluding Zone A.
- Zone C includes the areas outside 0,7*R* on both sides of the blade.

1.8.5 **Skew angles of greater than 25°:**

- Zone A is the area on the pressure side of the blade bounded by, and including, the root fillet and a line running from the junction of the leading edge with the root fillet to the trailing edge at 0,9*R* and passing through the mid-point of the chord at 0,7*R* and a point situated at 0,3 of the chord length from the leading edge at 0,4*R*.
- Zone A also includes the area along the trailing edge on the suction side of the blade from the root to 0,9*R* and with its inner boundary at 0,15 of the chord length tapering to meet the trailing edge at 0,9*R*.
- Zone B constitutes the whole of the remainder of the blade surfaces.

1.8.6 In propeller blades with continuously loaded tips (CLT), the whole of the tip plate and the adjoining blade to a distance of 100 mm is to be regarded as severity Zone B, *see* Fig. 9.1.3. For propellers with diameters less than 2 m, the width of this zone may be reduced to one tenth of the propeller radius.

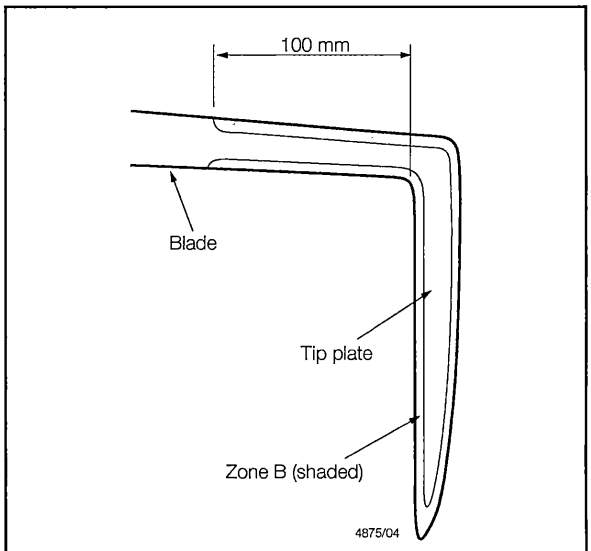


Fig. 9.1.3
Severity Zone B at Continuously loaded blade tip

1.8.7 In addition, the palm of a CPP blade is divided into severity Zones A and B as shown in Fig. 9.1.4.

1.8.8 If a CPP blade has an integrally cast journal, the fillets of the journal and the adjoining material up to a distance of 20 mm from the fillet run-outs are to be regarded as Zone B, as indicated in Fig. 9.1.5. The remainder of the surface of the journal may be regarded as Zone C.

1.8.9 Hubs of controllable pitch propellers are to contain a Zone A region at each blade port as shown in Fig. 9.1.6. The remainder may be regarded as Zone C.

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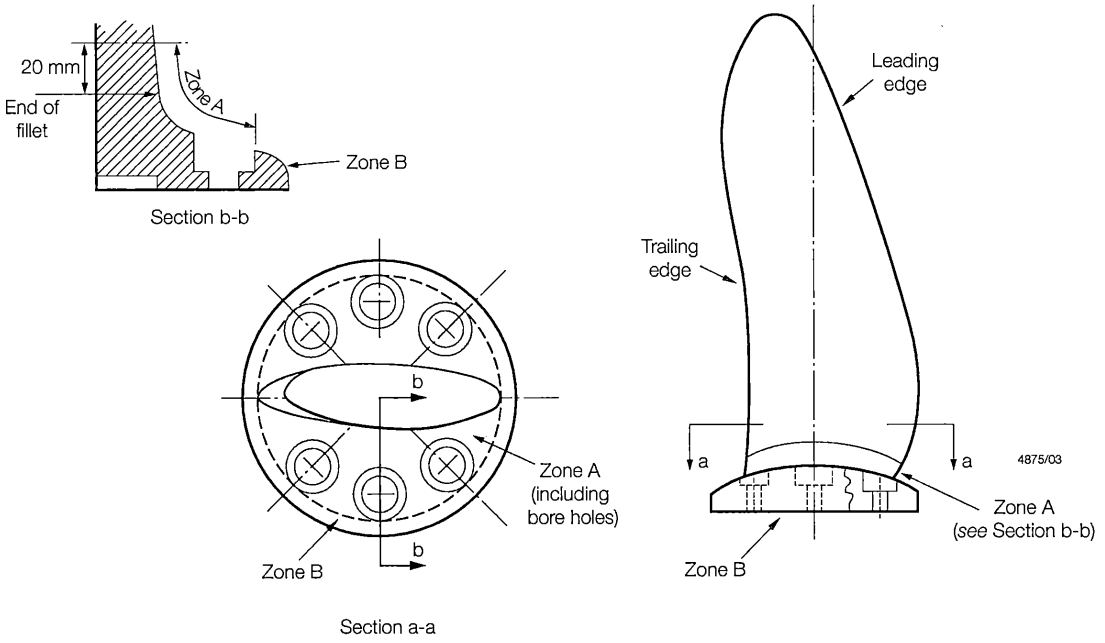
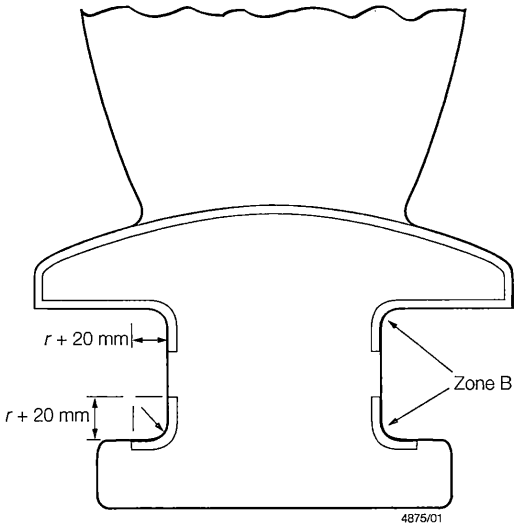


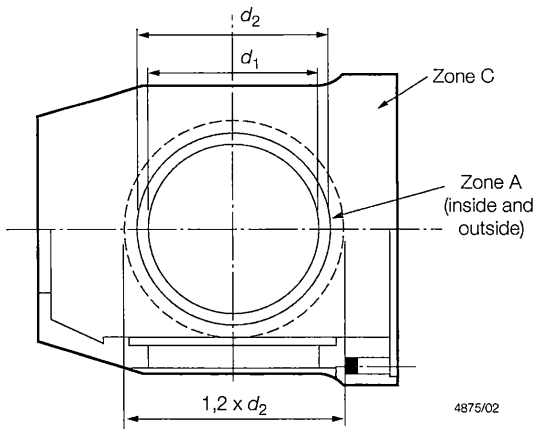
The surfaces of blades are to be divided into severity zones in accordance with Fig. 9.1.2

Fig. 9.1.4 Severity zones for controllable pitch propeller blades



The surfaces of the journal which are not shaded are to be regarded as severity Zone C

Fig. 9.1.5
Severity zones in integrally cast CPP blade journals



(d_1 and d_2 = diameters)

Fig. 9.1.6
Severity zones for controllable pitch propeller hub

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1.8.10 On completion of machining and grinding, the whole surface of each casting is to be subjected to a dye penetrant inspection in accordance with a procedure acceptable to LR.

1.8.11 All dye penetrant inspections on Zone A areas in the finished condition are to be made in the presence of the Surveyor.

1.8.12 Dye penetrant inspections on Zones B and C are to be performed by the manufacturer and may be witnessed at the Surveyor's request.

1.8.13 The surface to be inspected shall be divided into reference areas of 100 cm^2. The indications detected shall, with respect to their size and number, not exceed the values given in Table 9.1.3. The area shall be taken in the most unfavourable location relative to the indication being evaluated.

1.8.14 Indications exceeding the acceptance standard in Table 9.1.3 shall be repaired in accordance with 1.9.

1.8.15 All defects requiring repair by welding in new propeller castings are to be recorded on sketches showing their locations and dimensions. Copies of these sketches are to be presented to the Surveyor prior to repair.

1.8.16 Where repairs have been made either by grinding or welding, the repaired areas are to be subjected to dye penetrant inspection in the presence of the Surveyor, regardless of their location.

1.8.17 Where no welds have to be made on a casting, the manufacturer is to provide the Surveyor with a statement that this is the case.

1.8.18 Where it is suspected that a casting contains internal defects, radiographic and/or ultrasonic examination may be required by the Surveyor. The acceptance criteria are to be agreed between the manufacturer and LR in accordance with a recognised standard. The standard ASTM E272-99 (Severity Level 2) or equivalent is to be the radiographic acceptance standard for copper alloy castings. Ultrasonic testing of Cu 1 and Cu 2 is not considered in these Rules. For Cu 3 and Cu 4, ultrasonic inspection of defects may be possible and is to comply with the requirements for steel castings.

1.8.19 The measurement of dimensional accuracy is the responsibility of the manufacturer but the report on dimensional inspection is to be presented to the Surveyor who may require checks to be made and to witness such checks.

1.8.20 Static balancing is to be carried out on all propellers in accordance with the approved plan. Dynamic balancing is necessary for propellers running above 500 rpm.

1.9 Rectification of defective castings

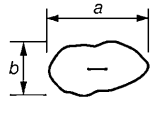
1.9.1 The rectification of defective propeller and propeller blade castings is to be carried out in accordance with the requirements given in 1.9.2 to 1.9.12.

Table 9.1.3 Allowable number and size of dye penetrant indications in a reference area of 100 cm^2 (*see* Note 1)

Severity Zones	Max. total number of indications	Type of indications (*see* Note 2)	Max. number of each type (*see* Notes 3 and 4)	Max. acceptable value for 'a' or 'l' of indications (mm) (*see* Note 2)
A	7	Non-linear Linear Aligned	5 2 2	4 3 3
B	14	Non-linear Linear Aligned	10 4 4	6 6 6
C	20	Non-linear Linear Aligned	14 6 6	8 6 6

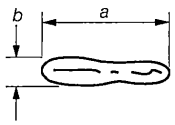
NOTES

1. The reference area is defined as an area of 0,1 m^2, which may be square or rectangular, with the major dimension not exceeding 250 mm. The area shall be taken in the most unfavourable location relative to the indication being evaluated.
2. Non-linear, linear and aligned indications are defined as follows:



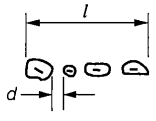
$\frac{a}{b} < 3$

non-linear



$\frac{a}{b} \geq 3$

linear



$d \leq 2$ mm

aligned

3. Only indications that have any dimension greater than 1,5 mm shall be considered relevant.
4. Single non-linear indications less than 2 mm in Zone A and less than 3 mm in other zones may be disregarded.
5. The total number of non-linear indications may be increased to the maximum total number, or part thereof, represented by the absence of linear or aligned indications.

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1.9.2 The rectification of small indications within the acceptance standard of Table 9.1.3 is not generally required except where they occur in closely spaced groups.

1.9.3 Where, in the surface of the end face or bore of a propeller boss, local pores are present which do not themselves adversely affect the strength of the casting, they may be filled with a suitable plastic filler after the appropriate preparation of the defective area. The foundry is to maintain records and details of all castings which have been so rectified.

1.9.4 Where unacceptable defects are found in a casting, they are to be removed by mechanical means, and the surfaces of the resulting depressions are subsequently to be ground smooth. Complete elimination of the defects is to be proved by adequate dye penetrant inspection.

1.9.5 Shallow grooves or depressions resulting from the removal of defects may, at the discretion of the Surveyor, be accepted provided that they will cause no appreciable reduction in the strength of the castings and that they are suitably blended by grinding.

1.9.6 Welded repairs are to be undertaken only when they are considered to be necessary and approved by the Surveyor. In general, welds having an area less than 5 cm^2 are to be avoided.

1.9.7 All weld repairs are to be carried out in accordance with qualified procedures by suitably qualified welders, and are to be completed to the satisfaction of the Surveyor. Records are to be made available to the Surveyor.

1.9.8 Welding is generally not permitted in Zone A and will only be allowed after special consideration.

1.9.9 Prior approval by the Surveyor is required for any welds in Zone B. Complete details of the repair procedure are to be submitted for each case.

1.9.10 Repair by welding is allowed in Zone C provided that there is compliance with 1.9.6 and 1.9.7.

1.9.11 The maximum area of any single repair and the maximum total area of repair in any one zone or region are given in Table 9.1.4.

1.9.12 Where it is proposed to exceed the areas given in Table 9.1.4, the nature and extent of the repair work are to be approved by the Surveyor before commencement of the repair.

Table 9.1.4 Permissible rectification of new propellers by welding

Severity zone or region	Maximum individual area of repair	Maximum total area of repairs
Zone A	Weld repairs not generally permitted	
Zone B	60 cm^2 or 0,6% x S whichever is the greater	200 cm^2 or 2% x S, whichever is the greater in combined Zones B and C but not more than 100 cm^2 or 0,8% x S, whichever is the greater, in Zone B on the pressure side
Zone C		
Other regions (*see* Note)	17 cm^2 or 1,5% area of the region whichever is the greater	50 cm^2 or 5% x area of the region whichever is the greater

where S = area of one side of a blade = $0{,}79 \frac{D^2 B}{N}$

D = finished diameter of propeller
B = developed area ratio
N = number of blades

NOTE
Other regions include:
(a) the bore;
(b) the forward and aft faces of the boss;
(c) the outer surface of the boss to the start of the blade root fillets;
(d) the inner face of a CPP blade palm;
(e) all surfaces of CPP nose cones;
(f) the surfaces of integral journals to CPP blades other than the fillets.

1.10 Weld repair procedure

1.10.1 Welding is to be carried out under cover in positions free from draughts and adverse weather conditions.

1.10.2 The manufacturer is to submit a detailed welding procedure specification covering the weld preparation, welding parameters, filler metal, preheating, post-weld heat treatment and inspection procedures.

1.10.3 Before welding is started, Welding Procedure Qualification tests are to be carried out and witnessed by the Surveyor. Each welder is to be qualified to carry out the proposed welding using the same process, consumable and position which are to be used for the repair.

1.10.4 Defects to be repaired by welding are to be removed completely by mechanical means (e.g. grinding, chipping or milling). Removal of defects in accordance with the requirements for Zone A is to be demonstrated by dye penetrant inspection in the presence of the Surveyor. The excavation is to be prepared in a manner which will allow good fusion and is to be clean and dry.

1.10.5 Metal arc welding with the electrodes or filler wire used in the procedure tests is to be used for all types of repairs. Welds should preferably be made in the downhand (flat) position. Where necessary, suitable preheat is to be applied before welding, and the preheat temperature is to be maintained until welding is completed.

1.10.6 When flux coated electrodes are used they are to be dried immediately before use, in accordance with the manufacturer's instructions.

1.10.7 All slag, undercuts and other defects are to be removed before the subsequent run is deposited.

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1.10.8 With the exception given in 1.10.9, all weld repairs in areas of solid propellers exposed to sea-water, and all repairs to separately cast blades, are to be stress relief heat treated.

1.10.9 Stress relief heat treatment is not mandatory after welding Grade Cu 3 castings in Zone C unless a welding consumable susceptible to stress corrosion (e.g. complying with the composition range of Grade Cu 4) is used. All welds in Zones A and B however, must be stress relieved by heat treatment, regardless of alloy.

1.10.10 Propeller and propeller blades are to be stress relieved within the following temperature ranges:

alloy Grades Cu 1 and Cu 2	350°C to 550°C
alloy Grade Cu 3	450°C to 500°C
alloy Grade Cu 4	450°C to 600°C

Soaking times are to be in accordance with Table 9.1.5, and subsequent cooling from the soaking temperature is to be suitably controlled to minimise residual stresses and is not to exceed 50°C per hour until the temperature is below 200°C. Care should be taken to avoid heating castings in the Grade Cu 3 alloy at temperatures between 300° and 400°C for prolonged periods.

Table 9.1.5 Soaking times for stress relief heat treatment of copper alloy propellers

Stress relief temperature °C (*see* Notes)	Alloy Grade Cu1 and Cu2		Alloy Grade Cu3 and Cu4	
	Hours per 25 mm of thickness	Maximum recommended total time hours	Hours per 25 mm of thickness	Maximum recommended total time hours
350	5	15	—	—
400	1	5	—	—
450	1/2	2	5	15
500	1/4	1	1	5
550	1/4	1/2	1/2	2
600	—	—	1/4	1

NOTES
1. Treatment at 550°C is not applicable to alloy Grade Cu3.
2. Treatment at 600°C is only applicable to alloy Grade Cu4.

1.10.11 Stress relief heat treatment is to be carried out, where possible, in furnaces having suitable atmosphere and temperature control. Sufficient thermocouples are to be attached to the casting to measure the temperature at positions of extremes of thickness.

1.10.12 As an alternative to 1.10.11, local stress relief heat treatment may be accepted, provided that the Surveyor is satisfied that the technique will be effective and that adequate precautions are taken to prevent the introduction of detrimental temperature gradients. Where local stress relief heat treatment is approved, adequate temperature control is to be provided. The area of the propeller or blade adjacent to the repair is to be suitably monitored and insulated to ensure that the required temperature is maintained and that temperature gradients are moderate. Care should be taken to select the shape of an area to be heat treated which will minimise residual stresses.

1.10.13 On completion, welds are to be ground smooth for visual examination and dye penetrant inspection. Where a propeller or propeller blade is to be stress relief heat treated, a visual examination is to be made before heat treatment, and both visual and dye penetrant examinations are to be made after the stress relief heat treatment. Irrespective of location, all weld repairs are to be assessed according to Zone A in Table 9.1.3.

1.10.14 The foundry is to maintain full records detailing the weld procedure, heat treatment and extent and location on drawings of repairs made to each casting. These records are to be available for review by the Surveyor, and copies of individual records are to be supplied to the Surveyor on request.

1.10.15 LR reserves the right to restrict the amount of repair work accepted from a manufacturer when it appears that repetitive defects are the result of improper foundry techniques or practices.

1.11 Identification

1.11.1 Castings are to be clearly marked by the manufacturer in accordance with the requirements of Chapter 1. The following details are to be shown on all castings which have been accepted:

(a) Identification mark which will enable the full history of the item to be traced.
(b) Alloy grade.
(c) LR or Lloyd's Register and the abbreviated name of LR local office.
(d) Personal stamp of Surveyor responsible for the final inspection.
(e) Date of final inspection.
(f) Skew angle, if in excess of 25°. *See* Pt 5, Ch 7,1 of the Rules for Ships for the definition of skew angle.

1.12 Certification of materials

1.12.1 A LR certificate is to be issued for each propeller, *see* Ch 1,3.1

1.12.2 The manufacturer is to provide the Surveyor with the following particulars for each casting:

(a) Purchaser's name and order number.
(b) Description of casting.
(c) Alloy designation and/or trade name.
(d) Identification number of casting.
(e) Cast identification number if different from (d).
(f) Details of heat treatment, where applicable.
(g) Skew angle, if in excess of 25°. *See* the relevant Rules for the definition of skew angle.
(h) Final weight of casting.
(j) Results of non-destructive tests and details of test procedures.
(k) Proportion of alpha-structure for Cu1 and Cu2 alloys.
(l) Results of mechanical tests.
(m) A sketch showing the location and extent of welding repairs (if any).

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■ *Section 2*
Castings for valves, liners and bushes

2.1 Scope

2.1.1 This Section makes provision for copper alloy castings for valves, liners, bushes and other fittings intended for use in the construction of ships, other marine structures, machinery and pressure piping systems.

2.1.2 Castings are to be manufactured and tested in accordance with Chapters 1 and 2, and also with the requirements given in this Section.

2.1.3 As an alternative to 2.1.2, castings which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Section or alternatively are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

2.2 Manufacture

2.2.1 Castings are to be manufactured at foundries approved by LR.

2.3 Quality of castings

2.3.1 All castings are to be free from surface or internal defects which would be prejudicial to their proper application in service.

2.4 Chemical composition

2.4.1 The chemical composition is to comply with the requirements of a National or International Standard and, where appropriate, with the limits for the principal elements of the preferred alloys listed in Tables 9.2.1 and 9.2.2.

2.4.2 With the exception given in 2.4.3, chemical analysis is required on each cast.

2.4.3 Where a cast is wholly prepared from ingots for which an analysis is already available, and provided that no significant alloy additions are made during melting, the ingot maker's certified analysis can be accepted subject to occasional check tests as requested by the Surveyor. The frequency of these check tests should, as a minimum, be one in every ten casts. If one of these check analyses fails to comply with the specification, checks are to be made on the previous and subsequent melts. If one or both of these further analyses is unsatisfactory, chemical analysis is to be carried out on all further melts until the Surveyor is satisfied that a return can be made to the use of occasional check tests.

2.5 Heat treatment

2.5.1 Where required by the specification, castings may be supplied in either the 'as-cast' or heat treated condition.

2.5.2 Where castings are supplied in a heat treated condition, the test samples are to be heat treated with the castings they represent prior to the preparation of the tensile test specimens.

2.6 Test material

2.6.1 Test material sufficient for the tests specified in 2.6.4 and for possible re-test purposes is to be provided for each cast of material.

2.6.2 The test material is to be separately cast into moulds made of the same material as that used for the castings they represent.

2.6.3 For the alloys listed in Table 9.2.1, sand cast test bars are generally to be in accordance with Fig. 9.2.1.

2.6.4 For the alloys listed in Table 9.2.2, keel block type test samples are to be in accordance with Fig. 9.1.1.

Table 9.2.1 Chemical compositions of long freezing range alloys: principal elements only

Alloy type	Designation	Chemical composition						Typical applications
		Cu	Sn	Zn	Pb	Ni	P	
Phosphor bronze	Cu Sn11P Cu Sn12	87,0 – 89,5 85,0 – 88,5	10,0 – 11,5 11,0 – 13,0	0,05 max. 0,50 max.	0,25 max. 0,7 max.	0,10 max. 2,0 max.	0,5 – 1,0 0,60 max.	Liners, bushes, valves and fittings
Gunmetal	Cu Sn10 Zn2	Remainder	9,5 – 10,5	1,75 – 2,75	1,5 max.	1,0 max.	—	Liners, valves and fittings
Leaded gunmetal	Cu Sn5 Zn5 Pb5 Cu Sn7 Zn2 Pb3 Cu Sn7 Zn4 Pb7 Cu Sn6 Zn4 Pb2	83,0 – 87,0 85,0 – 89,0 81,0 – 85,0 86,0 – 90,0	4,0 – 6,0 6,0 – 8,0 6,0 – 8,0 5,5 – 6,5	4,0 – 6,0 1,5 – 3,0 2,0 – 5,0 3,0 – 5,0	4,0 – 6,0 2,5 – 3,5 5,0 – 8,0 1,0 – 2,0	2,0 max. 2,0 max. 2,0 max. 1,0 max.	0,10 max. 0,10 max. 0,10 max. 0,05 max.	Bushes, valves and fittings
Leaded bronze	Cu Sn10 Pb10 Cu Sn5 Pb9 Cu Sn7 Pb15 Cu Sn5 Pb20	78,0 – 82,0 80,0 – 87,0 74,0 – 80,0 70,0 – 78,0	9,0 – 11,0 4,0 – 6,0 6,0 – 8,0 4,0– 6,0	2,0 max. 2,0 max. 2,0 max. 2,0 max.	8,0 – 11,0 8,0 – 10,0 13,0 – 17,0 18,0 – 23,0	2,0 max. 2,0 max. 0,5 – 2,0 0,5 – 2,5	0,10 max. 0,10 max. 0,10 max. 0,10 max.	Bushes

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Table 9.2.2 Chemical compositions of short freezing range alloys: principal elements only

Alloy type	Designation	Chemical composition								Typical applications
		Cu	Ni	Fe	Mn	Cr	Nb	Si	Al	
Copper 30% nickel	Cu Ni30 Fe1 Mn1	64,5 min.	29,0–31,0	0,5–1,5	0,6–1,2	–	–	0,1 max.	–	Flanges, valves and fittings
	Cu Ni30 Fe1 Mn1 Nb Si	Remainder	29,0–31,0	0,5–1,5	0,6–1,2	–	0,5–1,0	0,3–0,7	–	
	Cu Ni30 Cr2 Fe Mn Si (*see* Note 1)	Remainder	29,0–32,0	0,5–1,0	0,5–1,0	1,5–2,0	–	0,15–0,50	–	
Copper 10% nickel	Cu Ni10 Fe1 Mn1	84,5 min.	9,0–11,0	1,0–1,8	1,0–1,5	–	1,0 max.	0,10 max.	–	Flanges, valves and fittings
Aluminium bronze	Cu Al10 Fe5 Ni5	76,0–83,0	4,0–6,0 (*see* Note 2)	4,0–5,5 (*see* Note 2)	3,0 max.	–	–	0,1 max.	8,5–10,5	Bushes, valves and fittings
	Cu Al11 Fe6 Ni6	72,0–78,0	4,0–7,5 (*see* Note 2)	4,0–7,0 (*see* Note 2)	2,5 max.	–	–	0,1 max.	10,0–12,0	

NOTES
1. Normally alloy Cu Ni30 Cr2 Fe Mn Si contains 0,1 to 0,25% titanium and 0,05 to 0,15% zirconium.
2. For Naval ships, the nickel content is to be higher than the iron content.

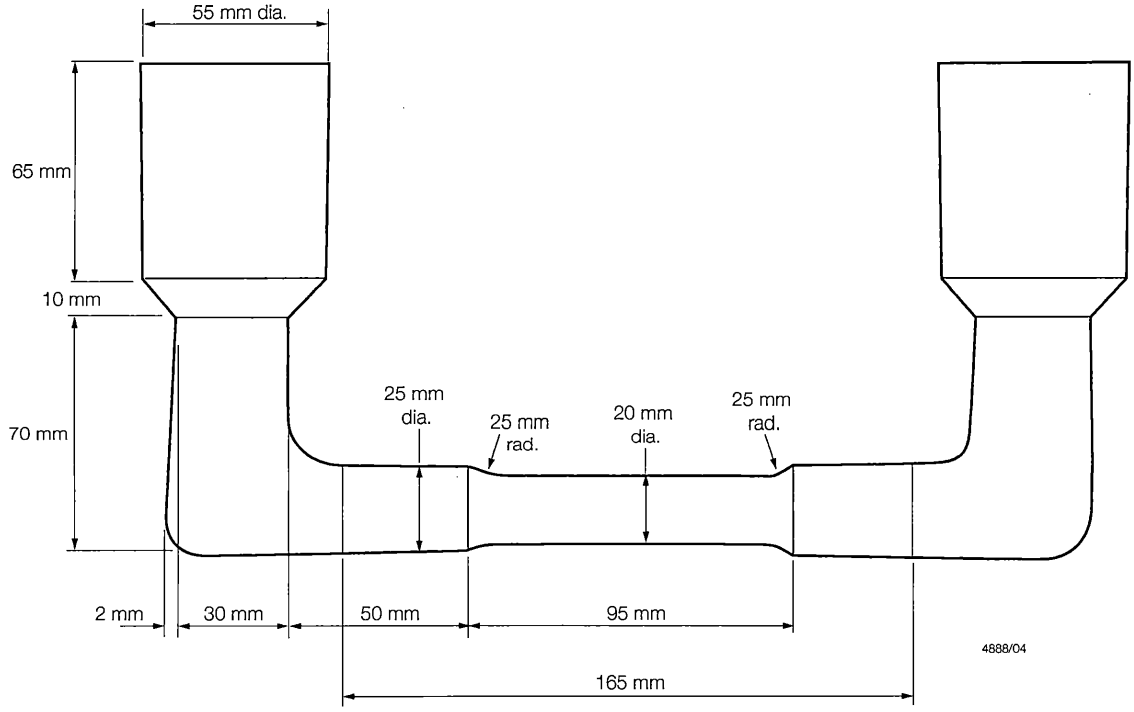

Fig. 9.2.1 Sand cast test bars for long freezing range alloys

2.6.5 If it is proposed to use any other form of test bar, this is to be agreed in advance with the Surveyor.

2.6.6 As an alternative, for liners and bushes, the test material may be taken from the ends of the castings.

2.7 Mechanical tests

2.7.1 A tensile test specimen is to be prepared from each test sample. The dimensions of the specimens are to comply with Fig. 2.2.1 or Fig. 2.2.2 in Chapter 2.

2.7.2 The results of all tests are to comply with the appropriate requirements given in Tables 9.2.3 and 9.2.4.

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Table 9.2.3 Mechanical properties of long freezing range alloys for acceptance purposes

Alloy type	Designation	0,2% proof stress N/mm² minimum (*See* Note 1)		Tensile strength N/mm² minimum		Elongation on $5{,}65\sqrt{S_o}$ % minimum	
		Sand	Centrifugal	Sand	Centrifugal	Sand	Centrifugal
Phosphor bronze	Cu Sn11 P	130	170	250	330	5	4
	Cu Sn12	140	150	260	280	7	5
Gunmetal	Cu Sn10 Zn2	130	130	270	250	13	5
Leaded gunmetal	Cu Sn5 Zn5 Pb5	90	110	200	250	13	13
	Cu Sn7 Zn2 Pb3	130	130	230	260	14	12
	Cu Sn7 Zn4 Pb7	120	120	230	260	15	12
	Cu Sn6 Zn4 Pb2	110	110	220	240	15	12
Leaded bronze	Cu Sn10 Pb10	80	110	180	220	8	6
	Cu Sn5 Pb9	60	90	160	200	7	6
	Cu Sn7 Pb15	80	90	170	200	8	7
	Cu Sn5 Pb20	70	80	150	170	5	6

NOTES
1. The 0,2% proof stress values are given for information purposes only and, unless otherwise agreed, are not required to be verified by test.
2. Castings may be supplied in the chill cast condition in which case the mechanical properties requirements are to be in accordance with a specification agreed by LR.

Table 9.2.4 Mechanical properties of short freezing range alloys for acceptance purposes

Alloy type	Designation	0,2% proof stress N/mm² minimum (*See* Note 1)		Tensile strength N/mm² minimum		Elongation on $5{,}65\sqrt{S_o}$ % minimum	
		Sand	Centrifugal	Sand	Centrifugal	Sand	Centrifugal
Copper 30% Nickel	Cu Ni30 Fe1 Mn1	120	120	340	340	18	18
	Cu Ni30 Fe1 Mn1 Nb Si	230	—	440	—	18	—
	Cu Ni30 Cr2 Fe Mn Si	250	—	440	—	18	—
Copper 10% Nickel	Cu Ni10 Fe1 Mn1	120	100	280	280	20	25
Aluminium Bronze	Cu Al10 Fe5 Ni5	250	280	600	650	13	13
	Cu Al11 Fe6 Ni6	320	380	680	750	5	5

2.8 Inspection

2.8.1 All castings are to be cleaned and adequately prepared for inspection. Before acceptance, all castings are to be presented to the Surveyor for visual examination. This is to include the examination of internal surfaces, where applicable.

2.8.2 For valves and other pressure components, dye penetrant inspection is required and the Surveyor is to witness the tests. Unless otherwise agreed, the acceptance criteria to be applied are to meet the requirements of Table 9.2.5, or equivalent.

2.8.3 The accuracy and verification of dimensions are the responsibility of the manufacturer. However, the report on dimensional inspection is to be presented to the Surveyor who may request to witness confirmatory measurements.

Table 9.2.5 Visual and surface NDE acceptance criteria for valves and pressure components

Defect type	Acceptance criteria for visual and surface NDE, *see* Note
Linear indications	Not permitted
Porosity	Individual pores are not to exceed 3 mm diameter bleed out, and the sum of the diameters of all indications in an area of 70 x 70 mm is not to exceed 24 mm²

NOTE
Inspection is to be in accordance with a procedure acceptable to LR.

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2.9 Rectification of defective castings

2.9.1 Subject to the prior approval of the Surveyor, castings containing local porosity may be rectified by impregnation with a suitable plastic filler provided that the extent of the porosity is such that it does not adversely affect the strength of the casting.

2.9.2 Proposals to repair a defective casting by welding are to be submitted to the Surveyor before this work is commenced. The Surveyor is to be satisfied that the number, position and size of the defects are such that the castings can be efficiently repaired.

2.9.3 Where approval is given for the repair by welding, complete elimination of the defects is to be proven by adequate non-destructive testing.

2.9.4 All welding is to be in accordance with an approved and qualified weld procedure and carried out by a qualified welder.

2.9.5 A statement and/or sketch detailing the extent and position of all weld repairs is to be prepared by the manufacturer as a permanent record. These records are to be available for review by the Surveyor, and copies of individual records are to be supplied to the Surveyor on request.

2.9.6 The alloys listed in Table 9.2.1 are not satisfactory for repair by welding which is generally not permitted. Weld repairs may, however, be considered in special circumstances provided that a suitable procedure, with proof of previous satisfactory repairs is submitted to the Surveyor.

2.9.7 The welding during manufacture of liners is not permitted in any alloy containing more than 0,5 per cent lead.

2.10 Pressure testing

2.10.1 Where required by the relevant Rules, castings are to be pressure tested before final acceptance. Unless otherwise agreed, these tests are to be carried out in the presence of the Surveyors and are to be to their satisfaction.

2.11 Identification

2.11.1 The manufacturer is to adopt a system of identification which will enable all finished castings to be traced to the original cast, and the Surveyor is to be given full facilities for tracing the casting when required.

2.11.2 Before acceptance, all castings which have been tested and inspected with satisfactory results are to be clearly marked by the manufacturer with the following details:

(a) Identification number, cast number or other markings which will enable the full history of the casting to be traced.
(b) LR or Lloyd's Register and the abbreviated name of LR's local office.
(c) Personal stamp of the Surveyor responsible for inspection.
(d) Test pressure, where applicable.
(e) Date of final inspection.

2.11.3 Where small castings are manufactured in large numbers, modified arrangements for identification may be specially agreed with the Surveyor.

2.12 Certification of materials

2.12.1 A LR certificate is to be issued, *see* Ch 1,3.1.

2.12.2 The manufacturer is to provide the Surveyor with the following particulars for each casting or batch of castings which has been accepted:

(a) Purchaser's name and order number.
(b) Description of castings and alloy grade.
(c) Identification number.
(d) Ingot or cast analysis.
(e) Full details of heat treatment, where applicable.
(f) Mechanical test results.
(g) Test pressure, where applicable.

2.12.3 In addition to 2.12.2, the manufacturer is to provide, where applicable, a statement and/or sketch detailing the extent and position of all weld repairs made to each casting.

■ *Section 3* Tubes

3.1 Scope

3.1.1 Provision is made in this Section for seamless copper and copper alloy tubes intended for use in condensers, heat exchangers and pressure piping systems.

3.1.2 Tubes for Class I and II pressure systems (as defined in the relevant Rules) are to be manufactured and tested in accordance with the requirements of Chapters 1 and 2 and the requirements of this Section.

3.1.3 As an alternative to 3.1.2, tubes which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Section or alternatively are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

3.1.4 Tubes for Class III pressure systems are to be manufactured and tested in accordance with the requirements of a National or International Standard recognised by LR. The manufacturer's test certificate will be acceptable and is to be provided for each batch of material.

3.2 Manufacture

3.2.1 Tubes for Class I and II pressure systems are to be manufactured at a works approved by LR for the grade of material being supplied.

3.2.2 Tubes for Class III pressure systems are not required to be manufactured at a works approved by LR.

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3.3 Quality

3.3.1 Tubes are to be clean and free from surface and internal defects and residues from manufacturing operations.

3.3.2 The tubes are to be supplied in smooth, round, straight lengths, free from deleterious films in the bore. The ends are to be cut clean and square with the axis of the tube and are to be de-burred.

3.4 Dimensional tolerances

3.4.1 The tolerances on the wall thickness and diameter of the tubes are to be in accordance with a National or International Standard recognised by LR.

3.4.2 The measurement of dimensional accuracy and compliance with the specification are the responsibility of the manufacturer, but the reports are to be made available to the LR Surveyors, who may require checks to be made in their presence.

3.5 Chemical composition

3.5.1 The chemical composition is to comply with the requirements of a National or International Standard recognised by LR and comply with the base limits for the principal elements given in Table 9.3.1.

3.6 Heat treatment

3.6.1 Copper-phosphorus and aluminium brass tubes are to be supplied in the annealed condition. Aluminium brass tubes may additionally be required to be given a suitable stress relieving heat treatment when subjected to a cold straightening operation after annealing.

3.6.2 Tubes in the copper-nickel iron alloys are to be supplied in a solution heat treated condition to ensure that no iron rich phases are present.

3.7 Mechanical tests

3.7.1 Tubes are to be presented for test in batches of 300 lengths. A batch is to consist of tubes of the same size, manufactured from the same material grade.

3.7.2 At least one length is to be selected at random from each batch and subjected to the following tests:
(a) Tensile test.
(b) Flattening test.
(c) Drift expanding test.

3.7.3 The procedures for mechanical tests and the dimensions of the test specimens are to be in accordance with Chapter 2.

3.7.4 The flattening test is to be continued until the interior surfaces of the tube meet.

3.7.5 For the drift expanding test, the mandrel is to have an included angle of 45°.

3.7.6 The results of all mechanical tests are to comply with the appropriate requirements given in Table 9.3.2.

3.7.7 At the discretion of the Surveyor, a modified testing procedure may be adopted for small quantities of materials. In such cases, these may be accepted on the manufacturer's declared chemical composition and hardness tests or other evidence of satisfactory properties.

Table 9.3.1 Chemical composition of principal elements only

Designation	Chemical composition %								
	Cu	As	P	Fe	Pb	Ni	Al	Mn	Zn
Copper-phosphorus deoxidised–non-arsenical	99,85 min.	–	0,013–0,050	—	—	—	—	—	—
Copper-phosphorus deoxidised–arsenical	99,2 min.	0,30–0,50	0,013–0,050		—	—	—	—	—
Aluminium brass	76,0–79,0	0,02–0,06	—	0,06 max.	0,07 max.	—	1,8–2,5	—	Remainder
90/10 Copper-nickel-iron (*see* Note)	Remainder	—	—	1,0-2,0	—	9,0–11,0	—	0,5–1,0	—
70/30 Copper-nickel-iron (*see* Note)	Remainder	—	—	0,40–1,00	—	29,0–33,0	—	0,5–1,5	—

NOTE
Where the purchaser specifies that the product is intended for subsequent welding applications, the following limits will apply:

Zn	0,50% max.	S	0,02% max.
Pb	0,02% max.	C	0,05% max.
P	0,02% max.		

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Table 9.3.2 Mechanical properties for acceptance purposes

Designation	0,2% proof stress N/mm^2 minimum	Tensile strength N/mm^2 minimum	Elongation on $5{,}65\sqrt{S_o}$ % minimum	Drift expansion test % minimum	Grain size mm maximum (*see* Note)
Copper-phosphorus deoxidised–non-arsenical	65	220	40	40	—
Copper-phosphorus deoxidised–arsenical	65	220	40	40	—
Aluminium brass	125	320	40	30	0,045
90/10 Copper-nickel-iron	100	270	30	30	0,045
70/30 Copper-nickel-iron	120	360	30	30	0,045

NOTE
When a maximum grain size is specified, the structure is to be completely re-crystallised. The manufacturer is to guarantee the grain size, but testing of each batch will not be required.

3.8 Visual examination

3.8.1 All tubes are to be visually examined. The manufacturer is to provide adequate lighting conditions to enable an internal and external examination of the tubes to be carried out.

3.8.2 The inner and outer surfaces are to be clean and smooth but may have a superficial, dull iridescent film on both the inner and outer surfaces.

3.9 Stress corrosion cracking test

3.9.1 This is an accelerated test for detecting the presence in tubes of internal stresses which might result in failure, in storage or in service, due to stress corrosion cracking.

3.9.2 The test is applicable only to aluminium brass and copper-nickel-iron tubes.

3.9.3 The test specimen is to consist of a 150 mm length cut from the tube selected for mechanical tests in accordance with 3.7.2.

3.9.4 The test is to be carried out in accordance with a National or International Standard recognised by LR or by the test method given in 3.9.5.

3.9.5 The test specimen is to be immersed in a mercurous nitrate solution at room temperature for 30 minutes. Aluminium brass specimens are to be examined for cracks immediately after rinsing, while copper-nickel-iron specimens are to be examined 24 hours after rinsing.

3.9.6 Should any specimen fail to meet the requirements of this test, then all tubes represented by that specimen are to be withdrawn. The tubes may be re-submitted after stress relieving treatments for full testing in accordance with 3.7 and 3.9.

3.10 Hydraulic test

3.10.1 Each tube is to be subjected to a hydraulic test at the manufacturer's works.

3.10.2 The hydraulic test pressure is to be determined from the following formula, except that the maximum test pressure need not exceed 70 bar:

$$P = \frac{20st}{D}$$

where

P = test pressure, in bar
D = nominal outside diameter, in mm
t = nominal wall thickness, in mm
s = 40 for copper-phosphorus
60 for Al-brass and
90/10 copper nickel iron
75 for 70/30 copper nickel iron.

3.10.3 The test pressure is to be maintained for sufficient time to permit proof that the tubes do not weep, leak or undergo a permanent increase in diameter. Unless otherwise agreed, the manufacturer's certificate of satisfactory hydraulic test will be accepted.

3.10.4 Where it is proposed to adopt a test pressure other than that determined in 3.10.2, the proposal will be subject to special consideration.

3.10.5 Subject to special approval, an automated eddy current test can be accepted in lieu of the hydraulic test. Discontinuous irregularities on the external and internal surfaces of the tubes are permitted if they are within the agreed dimensional tolerances, with the exception of cracks, which are not permitted.

3.11 Rectification of defects

3.11.1 The repair of defects by welding is not permitted.

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3.12 Identification

3.12.1 Tubes are to be clearly marked by the manufacturer in accordance with the requirements of Chapter 1. The following details are to be shown on all materials which have been accepted:

(a) LR or Lloyd's Register.
(b) Manufacturer's name or trade mark.
(c) Grade of material or designation code.
(d) Identification number and/or initials which will enable the full history of the item to be traced.

3.12.2 Identification is to be by rubber stamp or stencils. Hard stamping is not permitted.

3.13 Certification of materials

3.13.1 A manufacturer's certificate validated by LR is to be issued (*see* Ch 1,3.1), giving the following particulars for each casting or batch of castings which has been accepted:

(a) Purchaser's name and order number.
(b) Specification or grade of material.
(c) Description and dimensions.
(d) Cast number and chemical composition.
(e) Mechanical test results.
(f) Results of stress corrosion cracking test, where applicable.
(g) Hydraulic test report.

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Equipment for Mooring and Anchoring

Chapter 10

Section 1

Section

1 **Anchors**

2 **Stud link chain cables for ships**

3 **Stud link mooring chain cables**

4 **Studless mooring chain cables**

5 **Short link chain cables**

6 **Steel wire ropes**

7 **Fibre ropes**

Section 1 Anchors

1.1 Scope

1.1.1 This Section makes provision for the manufacture and testing of anchors constructed from cast, forged and fabricated components.

1.1.2 This Section is applicable to the following types of anchor:
(a) Ordinary.
(b) High holding power (HHP).
(c) Super high holding power (SHHP).

1.1.3 In the context of this Section, the reference to swivels refers to those directly attached to the anchor shank in lieu of the conventional 'D' shackle. For other mooring equipment swivels, *see* 2.13.

1.2 Manufacture

1.2.1 All anchors are to be of an approved design.

1.3 Cast steel anchors

1.3.1 Cast steel anchor heads, shanks, shackles and swivels are to be manufactured and tested in accordance with the requirements of Ch 4,1 and Ch 4,2. The Special grade quality is to be used for anchor heads, shanks and shackles.

1.3.2 Special consideration will be given to the use of other grades of steel for the manufacture of swivels.

1.3.3 To confirm the quality of cast anchor components, the Surveyor is to witness drop and hammering tests.

1.3.4 When drop and hammering tests are required, they are to be carried out as follows:
(a) Each anchor, or the components of an anchor made from more than one piece, is to be dropped from a clear height of 4 m onto a steel slab laid on a solid foundation.
(b) Separately cast flukes, shanks and shackles are to be suspended horizontally from a clear height of 4 m before being dropped.
(c) Anchors cast in one piece are to be drop tested twice from a clear height of 4 m. For the first test, the shank and flukes are to be horizontal. For the second test, two steel blocks are to be placed on the slab, arranged so that the middle of each fluke makes contact with the blocks without the crown making contact with the slab, and the orientation of the anchor is to be vertical with the crown nearest the slab.
(d) If the slab is broken by the impact, the test is to be repeated on a new slab.

1.3.5 When hammering tests are required, they are to be carried out after the drop test on each anchor head and shank, which is slung clear of the ground, using a non-metallic sling, and hammered to check the soundness of the component. A hammer of at least 3 kg mass is to be used.

1.3.6 As part of the manufacturer's works approval, consideration may be given to carrying out drop tests in alternative locations to the manufacturer's when the facilities and location are not suitable.

1.3.7 Repair of fractures or unsoundness detected during the drop or hammering tests are not permitted and the component is to be rejected.

1.4 Forged steel anchors

1.4.1 Forged steel anchor pins, swivels, shanks and shackles are to be manufactured and tested in accordance with the requirements of Ch 5,1 and Ch 5,2 carbon and carbon-manganese steel for welded construction. Rolled steel bar may be used provided that the requirements of Ch 5,1.2.9 are met.

1.4.2 Special consideration will be given to other grades of steel for the manufacture of swivels.

1.5 Fabricated steel anchors

1.5.1 Where it is proposed to use plate material for fabricated steel anchors, it is to comply with the requirements of Ch 3,2 or Ch 3,3, and the proposed manufacturing procedure is to be submitted for approval.

1.5.2 Fabricated anchors are to be manufactured in accordance with Chapter 13.

1.5.3 Stress relief is to be carried out as required in the approved welding procedure.

1.6 Rectification

1.6.1 All rectification is to be agreed with the Surveyor.

1.6.2 Rectification of defective castings is to be carried out in accordance with Ch 4,1.9.

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1.6.3 Rectification of defective forgings is to be carried out in accordance with Ch 5,1.9.

1.6.4 Rectification of defective fabricated anchors is to be carried out by suitably qualified welders within the parameters of the approved welding procedure used in construction.

1.6.5 Rectification of defective castings, forgings or fabricated anchors by welding is to be carried out using qualified weld procedures in accordance with Ch 12,1 and Ch 12,2, and in accordance with Ch 13,1 and Ch 13,2.

1.7 Super high holding power (SHHP) anchors

1.7.1 The impact test requirements for SHHP anchor shackles are to be in accordance with the requirements for Grade U3 in Table 10.2.1.

1.8 Assembly

1.8.1 Assembly and fitting is to be carried out in accordance with the approved design.

1.8.2 Securing of anchor pins, shackle pins or swivels by welding is to be carried out by suitably qualified welders in accordance with an approved welding procedure.

1.9 Proof test of anchors

1.9.1 Anchors having a mass of 75 kg or more inclusive of stock (56 kg in the case of high holding power anchors) are to be tested in the presence of the Surveyor at a proving establishment recognised by LR. A list of recognised proving establishments is published separately by LR. In addition to the requirements stated in this Chapter, attention must be given to any relevant statutory requirements of the National Authority of the country in which the ship or mobile offshore unit is to be registered.

1.9.2 The anchor is to be visually examined before application of the proof test load to ensure that it is free from cracks, notches, inclusions and other surface defects that would impair the performance of the product.

1.9.3 As required by 1.9.1, each anchor is to be subjected to a proof loading test in an approved testing machine and is to withstand the load given in Table 10.1.1 for the appropriate mass of the anchor. The proof load is to be applied on the arm or on the palm at a spot which, measured from the extremity of the bill, is one-third of the distance between it and the centre of the crown. For stocked anchors, each arm is to be tested individually. For stockless anchors, both arms are to be tested at the same time, first on one side of the shank, then reversed and tested on the other.

Table 10.1.1 Proof load tests for anchors
(*see* Notes 1 and 2)

Mass of anchor (1.6.5) kg	Proof test load kN	Mass of anchor (1.6.5) kg	Proof test load kN	Mass of anchor (1.6.5) kg	Proof test load kN
50	23,2	2200	376,0	7800	861,0
55	25,2	2300	388,0	8000	877,0
60	27,1	2400	401,0	8200	892,0
65	28,9	2500	414,0	8400	908,0
70	30,7	2600	427,0	8600	922,0
75	32,4	2700	438,0	8800	936,0
80	33,9	2800	450,0	9000	949,0
90	36,3	2900	462,0	9200	961,0
100	39,1	3000	474,0	9400	975,0
120	44,3	3100	484,0	9600	987,0
140	49,0	3200	495,0	9800	998,0
160	53,3	3300	506,0	10 000	1010,0
180	57,4	3400	517,0	10 500	1040,0
200	61,3	3500	528,0	11 000	1070,0
225	65,8	3600	537,0	11 500	1090,0
250	70,4	3700	547,0	12 000	1110,0
275	74,9	3800	557,0	12 500	1130,0
300	79,5	3900	567,0	13 000	1160,0
325	84,1	4000	577,0	13 500	1180,0
350	88,8	4100	586,0	14 000	1210,0
375	93,4	4200	595,0	14 500	1230,0
400	97,9	4300	604,0	15 000	1260,0
425	103,0	4400	613,0	15 500	1280,0
450	107,0	4500	622,0	16 000	1300,0
475	112,0	4600	631,0	16 500	1330,0
500	116,0	4700	638,0	17 000	1360,0
550	125,0	4800	645,0	17 500	1390,0
600	132,0	4900	653,0	18 000	1410,0
650	140,0	5000	661,0	18 500	1440,0
700	149,0	5100	669,0	19 000	1470,0
750	158,0	5200	677,0	19 500	1490,0
800	166,0	5300	685,0	20 000	1520,0
850	175,0	5400	691,0	21 000	1570,0
900	182,0	5500	699,0	22 000	1620,0
950	191,0	5600	706,0	23 000	1670,0
1000	199,0	5700	713,0	24 000	1720,0
1050	208,0	5800	721,0	25 000	1770,0
1100	216,0	5900	728,0	26 000	1800,0
1150	224,0	6000	735,0	27 000	1850,0
1200	231,0	6100	740,0	28 000	1900,0
1250	239,0	6200	747,0	29 000	1940,0
1300	247,0	6300	754,0	30 000	1990,0
1350	255,0	6400	760,0	31 000	2030,0
1400	262,0	6500	767,0	32 000	2070,0
1450	270,0	6600	773,0	34 000	2160,0
1500	278,0	6700	779,0	36 000	2250,0
1600	292,0	6800	786,0	38 000	2330,0
1700	307,0	6900	794,0	40 000	2410,0
1800	321,0	7000	804,0	42 000	2490,0
1900	335,0	7200	818,0	44 000	2570,0
2000	349,0	7400	832,0	46 000	2650,0
2100	362,0	7600	845,0	48 000	2730,0

Proof loads for intermediate mass are to be determined by linear interpolation

NOTES

1. Where ordinary anchors have a mass exceeding 48 000 kg, the proof loads are to be taken as 2,059 (mass of anchor in kg)$^{2/3}$ kN.
2. Where high holding power anchors have a mass exceeding 36 000 kg, the proof loads are to be taken as 2,452 (actual mass of anchor in kg)$^{2/3}$ kN.

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1.9.4 The general arrangements for the test are to be such that the complete anchor, including the shackle, shackle pins and any welded or bolted connections are included in the test. If a replacement shackle is needed which requires welding or heating for fitting, the combined anchor and shackle are to be proof load tested. If welding or heating is not involved in fitting, the shackle may be proof load tested separately from the anchor.

1.9.5 The mass to be used in Table 10.1.1 is:

(a) For stockless anchors, the total mass of the anchor.
(b) For stocked anchors, the mass of the anchor excluding the stock.
(c) For high holding power anchors, a nominal mass equal to 1,33 times the actual total mass of the anchor.
(d) For mooring anchors, including positional mooring anchors, a nominal mass equal to 1,33 times the actual total mass of the anchor, unless specifically agreed otherwise.
(e) For super high holding power anchors, a nominal mass equal to twice the actual total mass of the anchor.

1.9.6 For positional mooring anchors, the proof test loading is to be that required by 1.9.3 or 50 per cent of the minimum break strength of the intended anchor line, whichever is the greater.

1.9.7 The gauge length is to be measured with 10 per cent of the required load applied, before and after proof test. The two measurements shall differ by no more than 1 per cent. The gauge length is the distance between the tip of each fluke and a point on the shank adjacent to the shackle pin, *see* Fig. 10.1.1.

1.9.8 After proof testing, all accessible surfaces are to be visually inspected by the Surveyor.

1.9.9 Following proof testing, NDE is to be conducted as described in Table 10.1.2 for ordinary and HHP anchors and Table 10.1.3 for SHHP anchors.

1.9.10 Each casting is to be subjected to ultrasonic inspection in the region of runners and risers, or where excess material has been removed by thermal methods. This examination is to extend around the whole periphery of the casting and for a distance of $t/3$ beyond the area affected, where t is the maximum thickness. In addition, random areas are to be selected by the Surveyor and examined.

1.9.11 Acceptance criteria for castings are to be in accordance with Chapter 4.

1.9.12 Acceptance criteria for forgings are to be in accordance with Chapter 5.

1.9.13 Paint or anti-corrosive coatings are not to be applied until these inspections are completed to the satisfaction of the Surveyor.

Table 10.1.2 NDE requirements following proof testing for Ordinary and HHP anchors

Location	Method of NDE
Feeder heads, runners and risers of castings	Magnetic particle inspection and ultrasonic test, *see* Note 1
All welds	Magnetic particle inspection
Forged components	Not required
Fabrication welds	Magnetic particle inspection
NOTES 1. *See also* 1.9.10. 2. Penetrant testing is to be used in lieu of magnetic particle testing for stainless steel, aluminium and copper alloy anchors.	

Table 10.1.3 NDE requirements following proof testing for SHHP anchors

Location	Method of NDE
Feeder heads, runners and risers of castings	Magnetic particle inspection and ultrasonic test, *see* Note 1
All surfaces of castings	Magnetic particle inspection
All welds	Magnetic particle inspection
Forged components	Not required
Fabrication welds	Magnetic particle inspection
NOTES 1. *See also* 1.9.10. 2. Additionally, all surfaces of all SHHP anchors are to be surface inspected by the magnetic particle or penetrant method as appropriate. 3. Penetrant is to be used in lieu of magnetic particle testing for stainless steel, aluminium and copper alloy anchors.	

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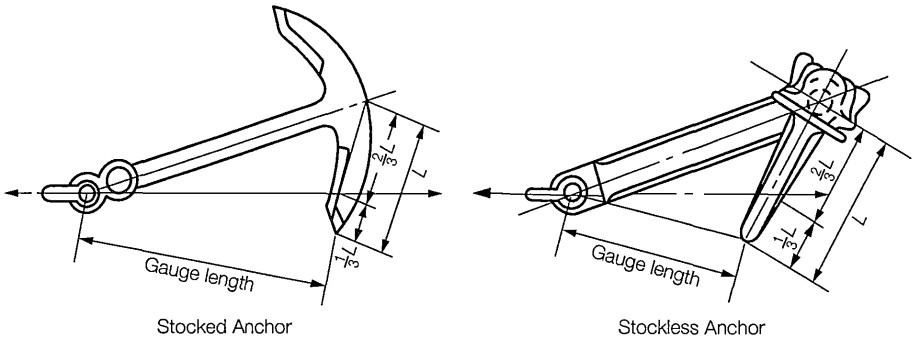

Fig. 10.1.1 Location of gauge length measurement during proof load

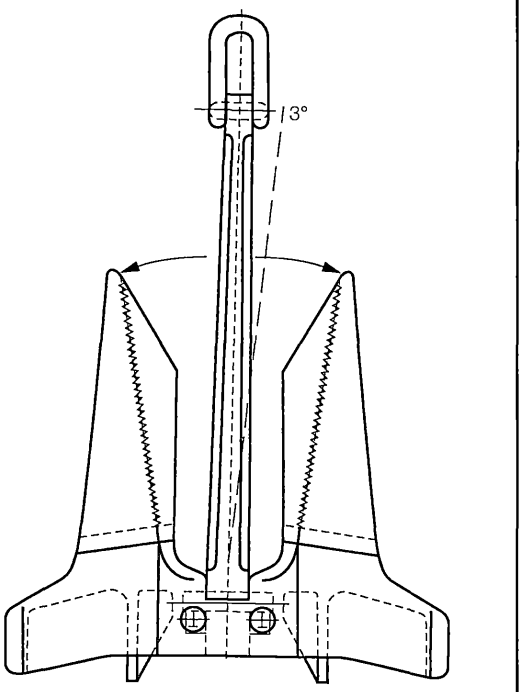

Fig. 10.1.2 Allowable lateral movement of shank

1.9.14 On completion of the proof testing, anchors made in more than one piece are to be examined for free movement of their heads over the complete range of rotation.

1.10 Clearances and tolerances

1.10.1 Where no fitting tolerances are specified on the approved plans the following assembly and fitting tolerance are to be applied.

1.10.2 The clearance either side of the shank within the shackle jaws and the shackle pin in the shank end hole is to be no more than 3 mm for small anchors up to 3 tonnes, 4 mm for anchors up to 5 tonnes, 6 mm for anchors up to 7 tonnes and is not to exceed 12 mm for larger anchors.

1.10.3 The shackle pin is to be a push fit in the eyes of the shackle, which are to be chamfered on the outside to ensure a good tightness when the pin is clenched over on fitting. The shackle pin to hole tolerance is to be no more than 0,5 mm for pins up to 57 mm and 1,0 mm for pins of larger diameter.

1.10.4 The trunnion pin is to be a snug fit within the chamber and be long enough to prevent horizontal movement. The gap is to be no more than 1 per cent of the chamber length.

1.10.5 The lateral movement of the shank is not to exceed 3 degrees from the centreline datum, *see* Fig. 10.1.2.

1.10.6 Unless otherwise agreed, the verification of mass and dimensions is the responsibility of the manufacturer. The Surveyor is only required to monitor this inspection. The mass of the anchor is to exclude the mass of the swivel, unless the swivel is in lieu of the conventional 'D' shackle.

1.11 Identification

1.11.1 Identification marks on the shank are to be approximately level with the fluke tips. On the fluke, these markings are to be approximately at a distance of two thirds from the tip of the bill to the centre line of the crown on the right hand fluke, looking from the crown towards the shank.

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1.11.2 The following details are to be shown on all anchors:
(a) LR or Lloyd's Register and abbreviated name of LR's local office issuing the certificate.
(b) Number of the certificate.
(c) Month and year of test.
(d) Mass (also the letters 'HHP' when approved as high holding power anchors or 'SHHP' when approved as super high holding power anchors).
(e) Mass of stock (in the case of stocked anchors).
(f) National Authority requirements, as applicable.
(g) Manufacturer's mark.

1.11.3 In addition to 1.11.2, each important part of an anchor is to be plainly marked by the maker with the words 'forged steel' or 'cast steel' as appropriate. Fabricated steel anchor heads do not require special marking.

1.12 Certification

1.12.1 The manufacturer is to provide the Surveyor with a written statement that the anchor has been manufactured and tested in accordance with LR Rules together with the following particulars:
(a) Purchaser's name and order number.
(b) Type of anchor and principal dimensions.
(c) Mass of anchor.
(d) Identification mark which will enable the full history of manufacture to be traced.
(e) Chemical composition.
(f) Details of heat treatment.
(g) Mechanical test results.
(h) Proof load.
(j) Results of the non-destructive examination.
(k) Weld location maps (cast steel anchors only).

1.12.2 Shanks, heads, pins, shackles and swivels are to be certified by LR in accordance with the relevant sections of Chapters 3, 4 and 5.

1.12.3 An LR Anchor Certificate is to be issued for the completed anchor which will include the following particulars:
(a) Manufacturer's name.
(b) Type of anchor.
(c) Mass of anchor.
(d) Grade of materials.
(e) Proof test load.
(f) Heat treatment.
(g) Marking applied to anchor.
(h) Dimensions.
(j) General Approval of an Anchor Design Certificate Number.
(k) Fluke and shank identification numbers.

Section 2
Stud link chain cables for ships

2.1 Scope

2.1.1 Provision is made in this Section for a range of grades, U1, U2 and U3, of stud link chain and fittings intended for anchor or mooring cables for ships.

2.1.2 The requirements for offshore mooring chain cables are given in Section 3.

2.2 Manufacture

2.2.1 All grades of chain cable and accessories are to be manufactured by approved procedures at works approved by LR. A list of approved manufacturers of stud link chain cables and fittings is published separately by LR.

2.2.2 The links may be made by the flash-butt or other approved welding process, or in the case of Grades U2 and U3 they may be flash-butt welded or drop forged, designated U2(a) or U3(a), or cast steel designated U2(b) or U3(b), *see* Table 10.2.5.

2.2.3 As far as practicable, consecutive links in all chain cable should originate from a single cast or batch of bar stock (*see* Ch 3,9.6.1), and indicating marks should be stamped on the final link formed from one cast or batch and the first link formed from a separate cast or batch.

2.2.4 A length of chain cable is to measure not more than 27,5 m and is to comprise an odd number of links. In this context, a length is a statutory term and is the basis for the number of test samples.

2.3 Flash butt welded chain cable

2.3.1 Bar material is to comply with the requirements of Ch 3,9 and may be heated either by electrical resistance or in a furnace. For electrical resistance heating, the process is to be controlled by an optical heat sensor. For furnace heating, thermocouples in close proximity to the bars are to be used for control. The temperature is to be continuously recorded. In both cases, the controls are to be checked at least once every eight hours and checks are to be recorded.

2.3.2 Mechanical properties testing of U1 cable is not required. For Grade U2 cable supplied in the as-welded condition, and Grade U3 in all conditions, one tensile and one set of three Charpy V-notch impact test specimens are to be taken at the side of a link opposite the weld from at least every fourth 27,5 m length of cable. A further set of three impact test specimens is to be taken with the notch positioned at the centre of the weld, *see* Table 10.2.3. The test specimens are not to be selected from the same length as that from which the breaking test sample is taken, unless breaking test samples are to be taken from every length of the batch. All test samples are to be correctly identified with the lengths of cable represented.

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2.3.3 The test links from which the mechanical test specimens are prepared are to be made as part of the chain cable and are to be heat treated with it. They may be removed from the cable prior to heat treatment provided that each sample is heat treated with, and in the same manner as, the chain it represents and is subjected to the proof load appropriate to the chain grade and diameter prior to preparation of the mechanical test specimens.

2.3.4 The results of tests on specimens taken from the non-welded areas are to comply with the appropriate requirements of Table 10.2.1. The results of tests on the welds are to comply with the requirements of Table 10.2.6.

2.4 Cast chain cables

2.4.1 The manufacture of cast steel chain cable is generally to be in accordance with the requirements of Ch 4,1, as appropriate.

2.4.2 The chemical composition of ladle samples is to comply with the specification approved by LR.

2.4.3 Separately cast test samples are to be provided from each cast. They are to be of similar dimensions to the links they represent and are to be heat treated together with, and in the same manner as, the completed chain cable, *see* Table 10.2.3.

2.4.4 Tensile and Charpy V-notch impact test specimens are to be taken from each test sample and machined to the dimensions given in Ch 2,3.

2.4.5 The results of all tests are to comply with the requirements given in Table 10.2.1 for the relevant grade.

2.5 Forged chain cables

2.5.1 The procedure for the manufacture and testing of drop forgings for chain cable will be specially considered, but is generally to be in accordance with the appropriate requirements of Ch 5,1.

2.5.2 The chemical composition is to comply with Table 10.2.2.

2.5.3 The completed forgings are to be heat treated in accordance with Table 10.2.3.

2.5.4 Test samples in the form of forgings of similar dimensions to the links they represent and from the same cast and heat treatment charge are to be provided.

2.5.5 One tensile and three Charpy V-notch specimens are to be taken from each test sample.

2.5.6 The results of mechanical tests are to comply with the requirements of Table 10.2.1 for the relevant grade.

2.6 Stud material

2.6.1 Steel studs are to be used for all grades of welded chain cable. In general, the carbon content should not exceed 0,23 per cent but mechanical tests for acceptance purposes are not required.

2.7 Welding of studs

2.7.1 Where studs are welded into the links this is to be completed before the chain cable is heat treated.

2.7.2 The stud ends must be a good fit inside the link, and the weld is to be confined to the stud end opposite the flash-butt weld. The full periphery of the stud end is to be welded. If, however, it can be demonstrated to the Surveyor that the quality of welding is of a high standard then partial peripheral welding may be accepted provided that welds are made only at the sides of the stud and that each run extends continuously for at least 25 per cent of the stud periphery. Weld start/stop positions are not to be located in the plane of the chain cable.

2.7.3 The welds are to be made by qualified welders using an approved procedure and consumables approved to Grade 3 and low hydrogen, in accordance with Chapter 11.

2.7.4 The welds are to be of good quality and free from defects liable to impair the proper use of the chain. Undercuts, end craters and similar stress raising defects shall, where necessary, be ground off.

2.7.5 At least one stud weld within each length of cable is to be inspected using dye penetrant testing in accordance with Ch 1,5 after the chain has been proof loaded. If a crack is found, the stud welds in the adjoining links are to be inspected; if a crack is found in either link, all the stud welds in that length are to be inspected using dye penetrant.

2.7.6 The size of the stud welds is to be in accordance with Fig. 10.3.1.

2.8 Heat treatment of completed chain cables

2.8.1 The completed chain cable is to be heat treated in accordance with Table 10.2.3 for the appropriate grade of cable.

2.8.2 Special consideration will be given to the heat treatment of certain types of drop forged chain cable.

2.8.3 In all cases, heat treatment is to be carried out prior to the proof loading and breaking tests.

2.8.4 All test samples are to be heat treated with, and in the same way as, the chain cables they represent.

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Table 10.2.1 Mechanical properties of finished chain cable and fittings

Grade	Yield stress N/mm² minimum	Tensile strength N/mm²	Elongation on $5{,}65\sqrt{S_o}$ % minimum	Reduction of area % minimum	Charpy V-notch impact tests	
					Test temperature °C	Average energy J minimum
U2	295	490 – 690	22	—	0 (*see* Note 1)	27
U3	410	690 minimum	17	40	0 –20 (*see* Note 2)	60 35

NOTES
1. When required *see* Table 10.2.3.
2. Testing may be carried out at either 0°C or –20°C.
3. Mechanical testing is not required for finished chain cables and fittings in Grade U1.

Table 10.2.2 Chemical composition of butt welded and forged chain cable

Grade	Chemical composition %												
	C max.	Si	Mn	P max.	S max.	Al	N max.	Cr max.	Cu max.	Nb max.	Ni max.	V max.	Mo max.
U1	0,20	0,15 – 0,35	0,40 min.	0,04	0,04	—	—	—	—	—	—	—	—
U2	0,24	0,15 – 0,55	1,60 max.	0,035	0,035	0,02 min. *see* Note 1	—	—	—	—	—	—	—
U3	0,33	0,15 – 0,35	1,90 max.	0,04	0,04	0,065 max. *see* Note 2	0,015	0,25	0,35	0,05 *see* Note 2	0,40	0,10 *see* Note 2	0,08

NOTES
1. Aluminium may be partly replaced by other grain refining elements.
2. To obtain fine grain steel, at least one of these grain refining elements must be present in sufficient amount.

Table 10.2.3 Condition of supply and scope of mechanical tests for finished chain cables and fittings

Grade	Manufacturing method	Condition of supply	Number of test specimens on every four lengths of chain cable of 27,5 m or less, or on each batch of fittings		
			Tensile test on base materials	Charpy V-notch impact test	
				Base material	Weldment
U1 cable	Flash butt welded	As welded Normalised	— —	— —	— —
U2 cable	Flash butt welded	As welded Normalised	1 —	3 —	3 —
U3 cable	Flash butt welded	Normalised Normalised and Tempered Quenched and Tempered	1	3	3
U2 cable	Cast or drop forged	Normalised	1	3	—
U3 cable	Cast or drop forged	Normalised Normalised and Tempered Quenched and Tempered	1	3	—
U2 fittings	Cast or drop forged	Normalised	1	3	—
U3 fittings	Cast or drop forged	Normalised Normalised and Tempered Quenched and Tempered	1	3	—

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2.9 Testing of completed chain cables

2.9.1 All chain cables are to be subjected to a Proof Load test and a Breaking Load test. In addition, mechanical tests should be carried out where required, *see* Table 10.2.3.

2.9.2 All chain cables are to be tested in the presence of a Surveyor, at a proving establishment recognised by LR. A list of recognised proving establishments is published separately by LR. In addition to the requirements stated in this Chapter, attention must be given to any relevant statutory requirements of the National Authority of the country in which the ship is to be registered.

2.10 Proof load tests

2.10.1 Each length of chain cable is to be subjected to a proof loading test in an approved testing machine and is to withstand the load given in Table 10.2.4 for the appropriate grade and size of cable.

2.10.2 On completion of the test, each link is to be visually examined and is to be free from significant defects. Special attention is to be given to welds.

2.10.3 Should any link be found to be defective it is to be replaced by an approved connecting link (joining shackle or substitute link as detailed in 2.14). The chain is then to be subjected to a repeat of the proof load test followed by re-examination.

2.10.4 If a link breaks during proof load testing, a sample consisting of three common links is to be taken from each side of the broken link and subjected to a breaking test as detailed in 2.10. If either of these samples fails, the length of cable is not to be accepted. A thorough examination of all broken links is to be made to determine the cause of failure and, after evaluation, LR will consider the extent of cable which is to be rejected.

2.11 Breaking load tests

2.11.1 Breaking load tests are to be carried out on three-link samples selected by the Surveyor from the completed (including heat treatment) chain. The test links may be removed from the chain prior to heat treatment provided that each sample is heat treated with, and in the same manner as the chain it represents. They are to be properly identified with the lengths of chain they represent.

2.11.2 The number of tests required is to be in accordance with Table 10.2.5 except that for chafing chain for Emergency Towing Arrangements (ETA), *see* Pt 3, Ch 13,10.2, one test is to be carried out on each 110 m of finished chains.

2.11.3 Breaking test specimens are to withstand the load given in Table 10.2.4 for the appropriate grade and size of cable. The specimen is considered to have passed this test if it has shown no sign of fracture after application of the required load for a minimum of 30 seconds.

2.11.4 Where a breaking test specimen fails, a further specimen is to be cut from the same length of cable and subjected to test. If this re-test fails, the length of cable from which it was taken is to be rejected. When this test is also representative of other lengths, each of the remaining lengths is to be individually tested by taking a breaking test specimen from each length of the batch. If one of these further tests fails, the entire set of lengths represented by the original test is to be rejected.

2.11.5 For large diameter cables where the required breaking load is greater than the capacity of the testing machines, special consideration will be given to acceptance of an alternative testing procedure.

2.12 Dimensional inspection

2.12.1 After proof testing, the entire chain is to be checked for length, five links at a time with an overlap of two links, which is to include the first five links, to ensure that the chain meets the tolerances given in 2.15.5. The measurements are to be made while the chain is loaded to about 10 per cent of the proof load.

2.12.2 The links held in the end blocks may be excluded from these measurements.

2.12.3 If a five link length of chain exceeds the tolerance given in 2.15.5, then the oversize links are to be removed and an approved connecting link inserted.

2.12.4 Checks of all other dimensions are to be made on three links, selected by the Surveyor, from every four 27,5 m lengths.

2.12.5 If one of the links detailed in 2.12.4 fails to comply with the required tolerances, measurements are to be made on a further five links in every four 27,5 m lengths.

2.12.6 If more than one link in a 27,5 m length of chain cable fails to meet the tolerance requirements, all the links in that length are to be measured.

2.12.7 All links failing to comply with the maximum dimensional tolerances are to be removed and replaced by connecting links of an approved type. The chain is then to be subjected to a further proof load test and re-examined.

2.12.8 If the length over five links is less than the nominal, then the chain may be stretched by loading above the specified proof test load provided that the applied load is not greater than ten per cent above the proof test load, and only random lengths of the chain need to be stretched.

2.12.9 Loads used for plastic straining to set studs are not to exceed 0,8 per cent of the proof load unless specifically approved for higher loads.

2.12.10 Paint or anti-corrosive coatings are not to be applied until these inspections are completed to the satisfaction of the Surveyor.

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Table 10.2.4 Test loads for stud link anchor chain cables

Chain diameter	Grade U1		Grade U2		Grade U3	
	Proof load kN	Breaking load kN	Proof load kN	Breaking load kN	Proof load kN	Breaking load kN
d mm	$0{,}00686d^2$ $(44-0{,}08d)$	$0{,}00981d^2$ $(44-0{,}08d)$	$0{,}00981d^2$ $(44-0{,}08d)$	$0{,}01373d^2$ $(44-0{,}08d)$	$0{,}01373d^2$ $(44-0{,}08d)$	$0{,}01961d^2$ $(44-0{,}08d)$
12,5	46	66	66	92	—	—
14	58	82	82	115	—	—
16	75	107	107	150	—	—
17,5	89	128	128	179	—	—
19	105	150	150	211	—	—
20,5	122	175	175	244	244	349
22	140	201	201	281	281	401
24	166	238	238	333	333	475
26	194	278	278	389	389	556
28	225	321	321	450	450	642
30	257	367	367	514	514	734
32	291	416	416	583	583	832
34	327	468	468	655	655	936
36	366	523	523	732	732	1045
38	406	580	580	812	812	1160
40	448	640	640	896	896	1280
42	492	703	703	984	984	1406
44	538	769	769	1076	1076	1537
46	585	837	837	1171	1171	1673
48	635	908	908	1270	1270	1814
50	686	981	981	1373	1373	1961
52	739	1057	1057	1479	1479	2113
54	794	1135	1135	1589	1589	2269
56	850	1216	1216	1702	1702	2430
58	908	1299	1299	1818	1818	2597
60	968	1384	1384	1938	1938	2767
62	1029	1472	1472	2060	2060	2943
64	1092	1562	1562	2187	2187	3123
66	1157	1655	1655	2316	2316	3308
68	1223	1749	1749	2448	2448	3496
70	1291	1846	1846	2583	2583	3690
73	1395	1995	1995	2792	2792	3988
76	1503	2149	2149	3007	3007	4295
78	1576	2254	2254	3154	3154	4505
81	1689	2415	2415	3380	3380	4827
84	1805	2580	2580	3612	3612	5158
87	1923	2750	2750	3849	3849	5498
90	2045	2924	2924	4093	4093	5845
92	2127	3042	3042	4258	4258	6081
95	2254	3223	3223	4510	4510	6442
97	2339	3345	3345	4682	4682	6687
100	2470	3532	3532	4943	4943	7060
102	2558	3658	3658	5120	5120	7312
105	2692	3850	3850	5389	5389	7697
107	2783	3980	3980	5571	5571	7957
111	2968	4245	4245	5941	5941	8486
114	3110	4447	4447	6224	6224	8889
117	3253	4652	4652	6511	6511	9299
120	3398	4859	4859	6801	6801	9714
122	3496	4999	4999	6997	6997	9994
124	3595	5141	5141	7195	7195	10276
127	3744	5354	5354	7494	7494	10703
130	3895	5571	5571	7796	7796	11135
132	3997	5716	5716	8000	8000	11426
137	4254	6083	6083	8514	8514	12161
142	4515	6456	6456	9036	9036	12906
147	4779	6834	6834	9565	9565	13662
152	5046	7217	7217	10100	10100	14426
157	5316	7602	7602	10640	10640	15197
162	5588	7991	7991	11185	11185	15975

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Table 10.2.5 Number of breaking tests from completed cables

Designation	Method of manufacture	Number of breaking test specimens
Grade U1	Flash-butt welded and heat treated	One from every four lengths of 27,5 m or less
Grade U2(a) U3(a)	Flash-butt welded, or drop forged and heat treated	One from every four lengths of 27,5 m or less
Grade U1 U2(a)	Flash-butt welded but not heat treated	One from each length of 27,5 m or less
Grade U2(b) U3(b)	Cast and heat treated	One per heat treatment batch with a minimum of one from every four lengths of 27,5 m or less

Table 10.2.6 Mechanical properties of welds in chain cables

Grade	Charpy V-notch impact test	
	Test temperature °C	Average energy J min
U1	—	—
U2	0 (*see* Note 1)	27
U3	0	50
	–20 (*see* Note 2)	27

NOTES
1. Impact tests are only required if the chain cable is not heat treated.
2. Impact testing may be carried out at 0°C or minus 20°C.

2.13 Fittings for chain cables

2.13.1 Cable fittings are to be manufactured at an approved works.

2.13.2 The materials from which the fittings are made are to be manufactured at approved works, in accordance with the appropriate requirements of Ch 4,1 or Ch 5,1 respectively. Alternative arrangements may be agreed provided that full details concerning the manufacturer are submitted to LR.

2.13.3 All fittings are to be manufactured to an approved manufacturing specification, and provision is to be made for tensile specimens and, where applicable, impact test specimens, *see* Table 10.2.3. The test samples are to be prepared in accordance with 2.4.3 or 2.5.4 as applicable. The test specimens are to be subjected to heat treatment with the fittings they represent. The mechanical test requirements are the same as those for the relevant grade of chain cable, *see* Table 10.2.1. A batch of fittings is to be of the same grade, size and heat treatment charge and to have originated from a single cast of steel. Enlarged and end links need not be tested provided that they are manufactured and heat treated together with the chain cable. Mechanical tests of pins are to be taken in accordance with 3.8.15.

2.13.4 Fittings such as shackles, swivels and swivel shackles are to be forged or cast in steel of at least Grade U2. The welded construction of fittings may also be approved providing that full details of the manufacturing process and the heat treatment are submitted.

2.13.5 All chain cable accessories, including spares, are to be subjected to the proof loads appropriate to the grade and size of cable for which they are intended. These include shackles, swivels, swivel shackles, enlarged links and end links. Anchor shackles, however, are to be tested in combination with the anchor, *see* 1.4.

2.13.6 The appropriate breaking load is to be applied for a minimum of 30 seconds to at least one item out of every batch of up to 25 (1 in 50 for lugless (Kenter) shackles), and this item is to be destroyed and not used as part of an outfit. For the purpose of break load testing, a batch of accessories is to be of the same grade, size and heat treatment charge and may consist of items from different casts, provided that the sample tested is from the cast with the lowest tensile properties. Enlarged and end links need not be tested provided that they are manufactured and heat treated together with the chain cable.

2.13.7 If the sample fails to withstand the breaking load without fracture, two more samples from the same batch may be tested. If either of these samples fails, the batch is to be rejected.

2.13.8 Where the items are of increased dimensions, and have been specially approved, or if material of a higher grade than is specified is used, then the breaking load is to be applied to each item, and the items so tested included with the outfit. For the purpose of this paragraph, items of increased dimensions are those so designed that their breaking strength is not less than 1,4 times the Rule minimum breaking load of the chain cable with which they are to be used.

2.13.9 LR may waive the breaking load test provided that:
(a) the breaking load test has been completed satisfactorily during approval testing, and
(b) the tensile and impact properties of each manufacturing batch are proved and
(c) the accessories are subjected to suitable non-destructive testing.

2.13.10 All testing is to be carried out in the presence of the Surveyor and to his satisfaction.

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2.13.11 All fittings are to be stamped in accordance with 2.16.

2.14 Substitute single links

2.14.1 Single links to connect lengths of chain cable or to substitute for defective links, without the necessity for re-heat treatment of the whole cable length, are to be made by the chain manufacturer in accordance with an approved procedure. Separate approvals are required for each grade of chain cable and the tests are to be made on the maximum size of chain for which approval is sought. Re-approval is required annually.

2.14.2 Manufacture and heat treatment of the substitute link are not to affect the strength of the adjoining links. The temperature reached by these links is nowhere to exceed 250°C.

2.14.3 The steel bar used is to conform with the specification for the chain in accordance with Ch 3,9.

2.14.4 Details of the method of manufacture, including heat treatment, are to be submitted for approval, together with the results of a series of tests laid down by LR.

2.14.5 All links involved in the approval tests are to be destroyed and are not to be used as part of a chain cable.

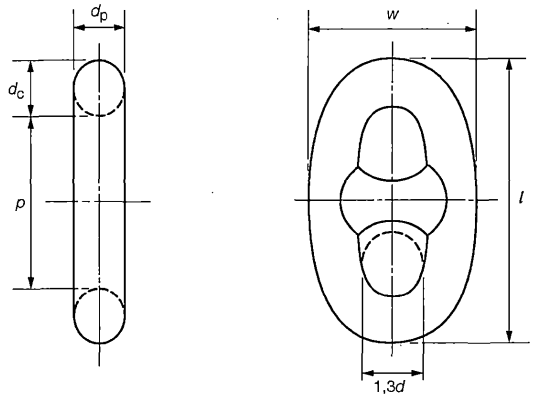
2.14.6 Every substitute link included in a chain cable is to be subjected to the proof load appropriate to the grade and size of chain in which it is incorporated, as detailed in Table 10.2.4.

2.14.7 Each substitute link is to be stamped on the stud with the identification marks listed in 2.16.1 plus a unique number for the link. The adjoining links are also to be stamped on the studs.

2.15 Dimensions and tolerances

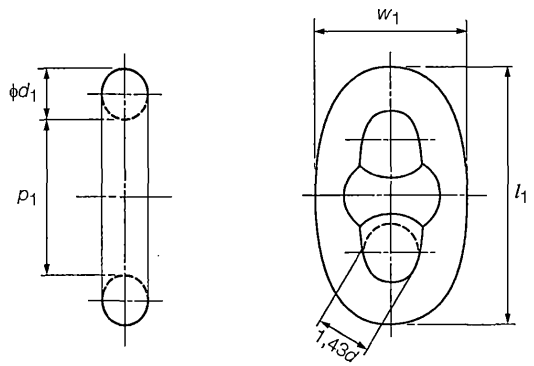
2.15.1 The form and proportion of links and shackles are to be in accordance with ISO/1704-2008, *see* Figs. 10.2.1 to 10.2.8. Design of chain cables must be to a standard recognised by LR, such as ISO 1704; alternatively the design may be specifically approved by LR.

2.15.2 Manufacturing tolerances on stud link chain are to be within ±2,5 per cent (taking into account that all components of the chain are to be a good fit with one another), except for those detailed in 2.15.3.



d_c = nominal diameter at crown measured in plane of link
d_p = nominal diameter at crown measured perpendicular to plane of link
l = 6d
p = 4d
w = 3,6d to the nearest millimetre

Fig. 10.2.1 Common link



d = nominal diameter of common stud link
d_1 = nominal diameter of enlarged stud link = 1,1d
l_1 = 6d_1 ≈ 6,6d
p_1 = 4d_1 ≈ 4,4d
w_1 = 3,6d_1 ≈ 3,96d

Fig. 10.2.2 Enlarged link

2.15.3 The nominal diameter, d, is to be the average of the diameters, measured in the plane of the link, d_c, and perpendicular to the plane of the link, d_p, *see* Fig. 10.2.1. The negative tolerance on the nominal diameter is not to exceed the following:

Minus 1 mm when $d \leq 40$ mm
Minus 2 mm when 40 mm $< d \leq 84$ mm
Minus 3 mm when 84 mm $< d \leq 122$ mm
Minus 4 mm when $d > 122$ mm

The plus tolerance on the diameter at the crown measured out of the plane of the link, d_p, is not to exceed 5 per cent.

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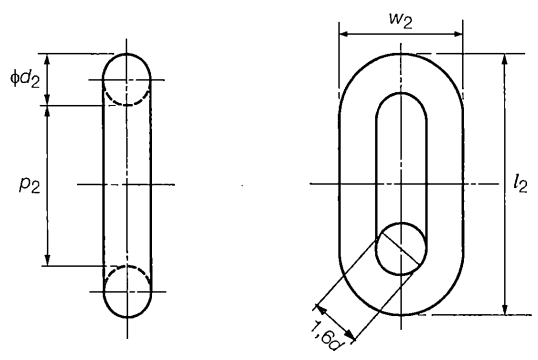

d = nominal diameter of common stud link
d_2 = nominal diameter of end link = 1,2d (d_2 – 1,2d)
l_2 = $p_2 + 2d_2 \approx 6{,}75d$
p_2 = $3{,}65d_2 \approx 4{,}35d$
w_2 = $3{,}3d_2 \approx 4d$

Fig. 10.2.3 End link

2.15.4 The cross-sectional area is to be calculated using the nominal diameter, d. The cross-sectional area at the crown of the link is to have no negative tolerance.

2.15.5 The diameter measured at locations other than the crown is to have no negative tolerance. The plus tolerance is to be in accordance with Table 3.9.3 of Chapter 3 except at the butt weld where it is to be in accordance with the manufacturer's specification, which is to be agreed by LR.

2.15.6 The maximum allowable tolerance on a length of five links measured in accordance with 2.12.1 is plus 2,5 per cent. No under-tolerance is permitted.

2.15.7 All measurements are to be made on links selected by the Surveyor and are to be carried out to the Surveyor's satisfaction.

2.15.8 Studs are to be located in the links centrally, and at right angles to the sides of the link, although the studs of the final link at each end of any length may also be located off-centre to facilitate the insertion of the joining shackle. Tolerances in accordance with Fig. 10.3.1 are acceptable provided that the stud fits snugly and its ends lie flush against the inside of the link.

2.15.9 The following tolerances are applicable to accessories:

Nominal diameter: plus 5 per cent, minus 0 per cent
Other dimensions: ±2,5 per cent.

2.15.10 For lugless shackles of the Kenter type, the radii indicated in Fig. 10.2.8 are to be not less than 0,03 times the chain diameter.

2.15.11 All materials are to be free from internal and surface defects that might impair proper workability, use and strength. Subject to agreement by the Surveyor, surface defects may be removed by grinding provided the acceptable tolerances are not exceeded.

2.16 Identification

2.16.1 All lengths of Grades U1, U2 and U3 cable and all fittings are to be stamped with the following identification marks:

(a) LR or Lloyd's Register and abbreviated name of LR's local office issuing the certificate.
(b) Number of certificate.
(c) Proof load and grade of chain.
(d) Surveyor's personal stamp.
(e) Each length of chain cable is to be stamped on both ends.

2.17 Certification

2.17.1 An LR certificate is to be issued for chain cable only, fittings only or chain cable with associated fittings.

2.17.2 Each test certificate is to include the following particulars for all items included on the certificate:

(a) Purchaser's name and order number.
(b) Description and dimensions.
(c) Grade of chain cable.
(d) Identification mark which will enable the full history of the chain or fitting to be traced.
(e) Chemical composition.
(f) Details of heat treatment.
(g) Mechanical test results.
(h) Breaking test load.
(j) Proof load.

2.17.3 Where appropriate, the certificate is to include a list of all substitute links together with their grade of steel, the name of the steelmaker, the heat number and the purchase order number.

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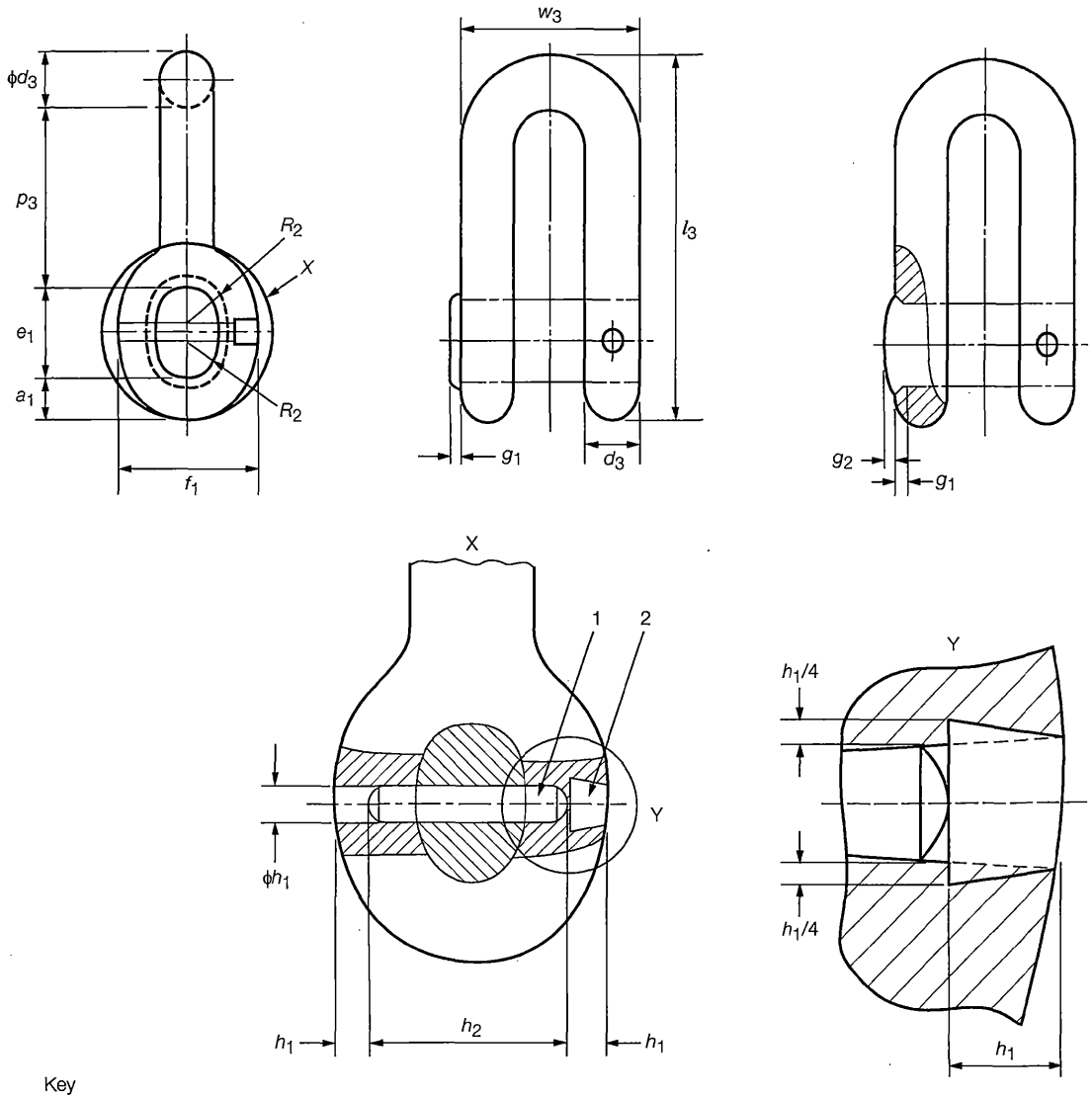

Key
X retaining pin
Y dovetail chamber

d	=	nominal diameter of common stud link	f_1	=	$2{,}8d$
d_3	=	nominal diameter of joining shackle = $1{,}3d$	g_1	=	$0{,}2d$
l_3	=	$7{,}1d$	g_2	=	$0{,}1d$
p_3	=	$l_3 - (d_3 + a_1 + e_1) = 3{,}4d$	h_1	=	nominal diameter of taper pin
w_3	=	$4d$	h_2	=	nominal length of taper pin
a_1	=	$0{,}8d$	R_1	=	$0{,}6d$
e_1	=	$1{,}6d$	R_2	=	$0{,}5d$

Fig. 10.2.4 End shackle

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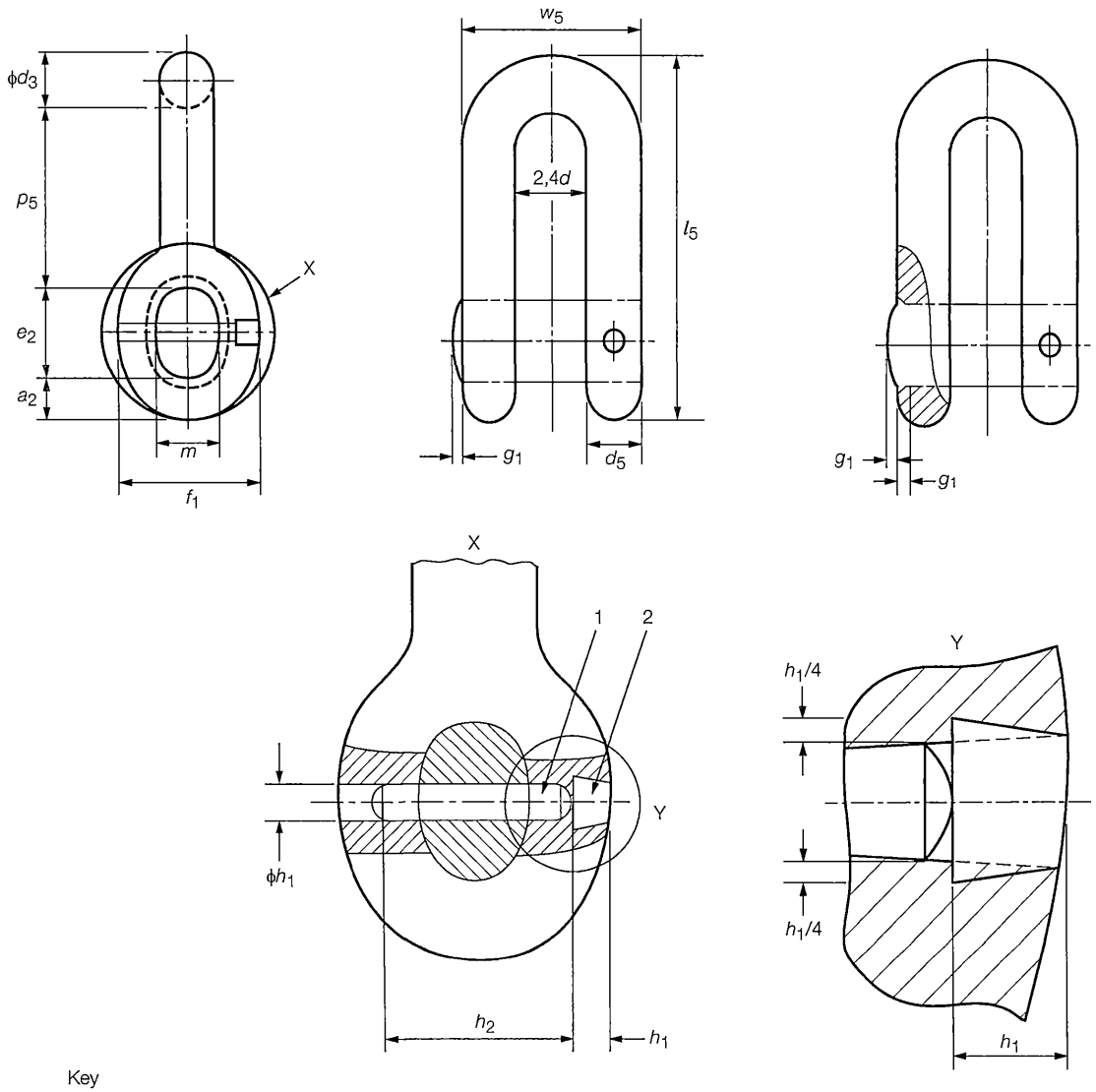

Key
X retaining pin
Y dovetail chamber

d	=	nominal diameter of common stud link	f_2	=	3,1d
d_5	=	nominal diameter of end shackle = 1,4d	g_1	=	0,2d
l_5	=	8,7d	g_2	=	0,1d
p_5	=	$l_5 - (d_3 + a_2 + e_2) = 4{,}5d$	m	=	1,4d
w_5	=	5,2d	h_1	=	nominal diameter of taper pin
a_2	=	0,9d	h_2	=	nominal length of taper pin
e_2	=	1,8d			

Fig. 10.2.5 Dee shackle

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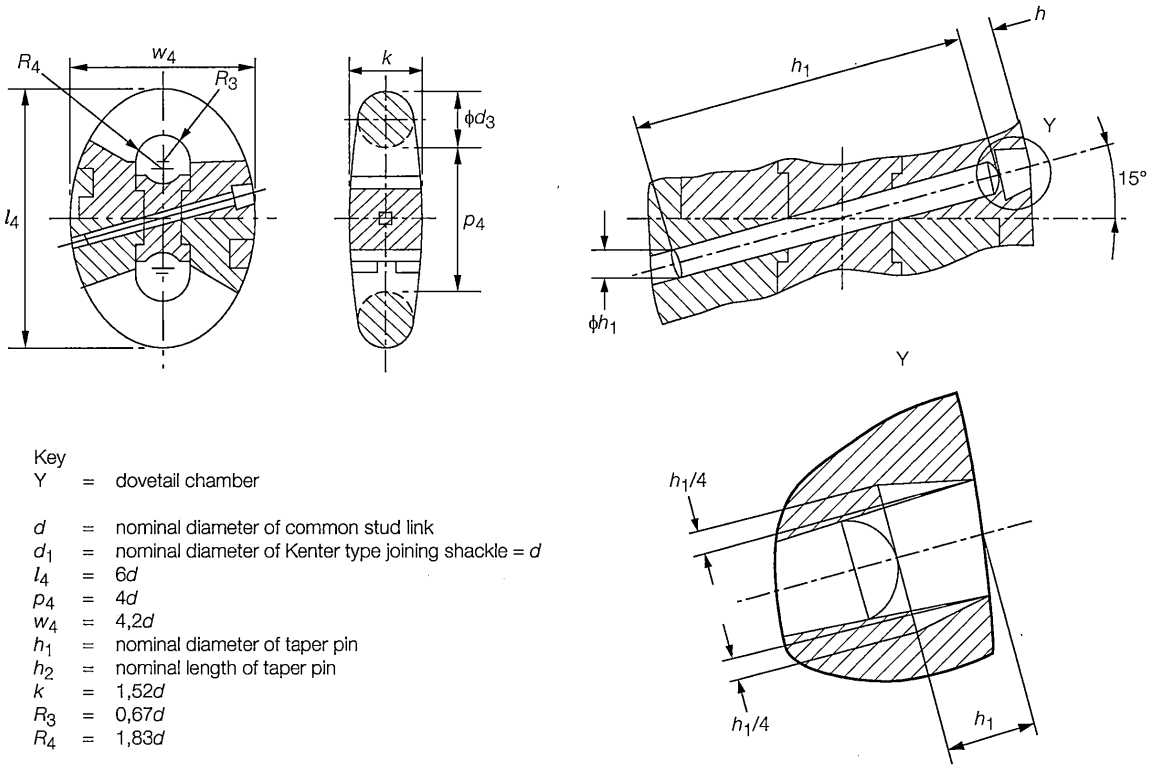
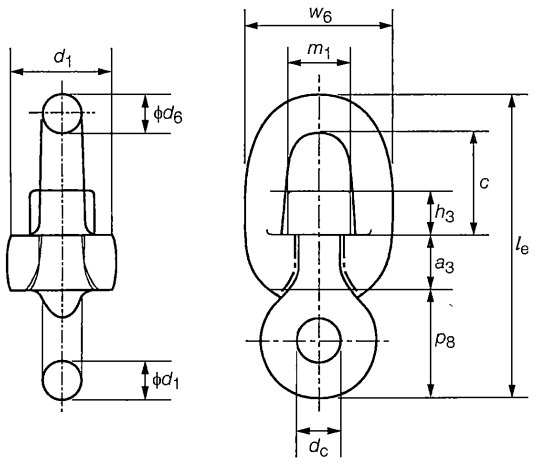


Key
Y = dovetail chamber

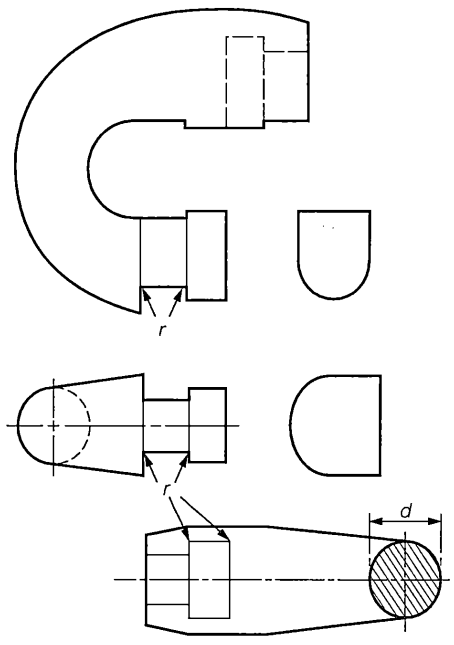
d = nominal diameter of common stud link
d_1 = nominal diameter of Kenter type joining shackle = d
l_4 = 6d
p_4 = 4d
w_4 = 4,2d
h_1 = nominal diameter of taper pin
h_2 = nominal length of taper pin
k = 1,52d
R_3 = 0,67d
R_4 = 1,83d

Fig. 10.2.6 Lugless shackle



d = nominal diameter of common stud link
d_6 = nominal diameter of swivel = 1,2d
l_e = 9,7d
p_e = d_g – 3,4d
w_6 = 4,7d
d_7 = 1,1d
a_3 = 1,76d
m_1 = 2d
h_3 = d_g – 1,4d
c = 3,35d

Fig. 10.2.7 Swivel



The radii indicated by r are to be not less than 0,03 x d

Fig. 10.2.8 Lugless shackle of the Kenter type

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■ *Section 3*
Stud link mooring chain cables

3.1 Scope

3.1.1 Provision is made in this Section for five grades, R3, R3S, R4, R4S and R5, of stud link chain intended for offshore mooring applications such as mooring of mobile offshore units, offshore loading systems and gravity based structures during fabrication.

3.1.2 In addition, chain cable conforming to the requirements of the current edition of API specification 2F is acceptable provided that it has been manufactured, inspected and tested under Survey by LR, and that the bar stock has also been certified by LR in accordance with Ch 3,9.

3.2 Manufacture

3.2.1 All grades of chain cable and accessories are to be manufactured by approved procedures at works approved by LR. A list of approved manufacturers for stud link chain cables is published separately by LR.

3.2.2 The works in which the chain is manufactured is to have a quality system approved by LR. The provision of such a quality system is required in addition to and not in lieu of the witnessing of tests by a Surveyor.

3.2.3 Approval is confined to a single works and is limited to one grade of cable made from bar from a nominated and approved supplier. Separate approvals are required if steel bar is supplied from more than one works and for other grades of cable, *see also* Ch 3,9.

3.2.4 Details of the method of manufacture and the specification of the steel, are to be submitted.

3.2.5 Offshore mooring chains are to be made in continuous lengths by flash-butt welding.

3.2.6 Bar material may be heated either by electric resistance or in a furnace. For electrical resistance heating, the process is to be controlled by an optical heat sensor. For furnace heating, thermocouples in close proximity to the bars are to be used for control and the temperature is to be continuously recorded. In both cases, the controls are to be checked at least once every eight hours and records taken.

3.2.7 The following welding parameters (as approved in the weld procedure) are to be controlled during welding of each link:

(a) platen motion;
(b) current as a function of time; and
(c) hydraulic pressure.

The controls are to be checked at least once every four hours.

3.2.8 The records of bar heating, flash-butt welding and heat treatment are to be made available to the Surveyor when required.

3.2.9 As far as practicable, consecutive links in all chain cable should originate from a single batch of bar stock (*see* Ch 3,9.6.1) and indicating marks should be stamped on the final link formed from one batch and the first link formed from a separate batch.

3.3 Dimensions and tolerances

3.3.1 The form and proportions of links and shackles are to be in accordance with ISO/1704-2008, *see* Figs. 10.2.1 to 10.2.8. Design of chain cables must be to a recognised standard, such as ISO 1704; alternatively the design may be specifically approved by LR. Link tolerances are to be in accordance with 3.3.2 to 3.3.6.

3.3.2 Diameter measured at the crown:

Minus 1 mm when $d_c \leq 40$ mm
Minus 2 mm when 40 mm $< d_c \leq 84$ mm
Minus 3 mm when 84 mm $< d_c \leq 122$ mm
Minus 4 mm when 122 mm $< d_c \leq 152$ mm
Minus 6 mm when 152 mm $< d_c \leq 184$ mm
Minus 7,5 mm when 184 mm $< d_c \leq 210$ mm

The plus tolerance must not exceed 5 per cent of the nominal diameter, and the cross-sectional area at the crown is to have no negative tolerance.

3.3.3 The diameter measured at locations other than the crown is to have no negative tolerance. The plus tolerance is to be in accordance with Table 3.9.3 except at the butt weld where it is to be in accordance with the manufacturer's specification, which is to be agreed by LR.

3.3.4 The maximum allowable tolerance on a length of five links measured in accordance with 2.12.1 is +2,5 per cent. No under-tolerance is permitted.

3.3.5 A manufacturing tolerance on all other dimensions of ±2,5 per cent is acceptable subject to all parts fitting properly together.

3.3.6 The tolerances for common links are to be measured in accordance with Fig. 10.3.3.

3.3.7 All measurements are to be made on links selected by the Surveyor and are to be carried out to the Surveyor's satisfaction.

3.3.8 Studs are to be located in the links centrally, and at right angles to the sides of the link, although the studs of the final link at each end of any length may also be located off-centre to facilitate the insertion of the joining shackle. The tolerances in accordance with Fig. 10.3.2 are acceptable provided that the stud fits snugly and its ends lie flush against the inside of the link.

3.4 Studs

3.4.1 The studs are to be made of steel corresponding to that of the chain or in compliance with a specification approved by LR. In general, the carbon content should not exceed 0,23 per cent if the studs are to be welded in place.

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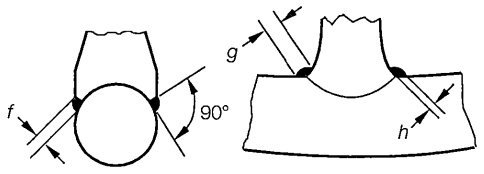
3.4.2 Studs may be welded into grade R3 and R3S chains. The welding of studs into grade R4, R4S and R5 chain is not permitted unless specially approved.

3.4.3 In all cases where studs are welded into links, this is to be carried out in accordance with 2.7.

3.4.4 The size of the stud welds is to be in accordance with Fig. 10.3.1.



Dimension Designation	Nominal Dimension	Minus Tolerance
f	0,10*d*	0,01*d*
g	0,20*d*	0,02*d*
h	0,09*d*	0,01*d*

d = Nominal diameter of barstock

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Fig. 10.3.1
Dimensions and tolerances of stud welds

3.4.5 All stud welds are to be visually inspected. At least 10 per cent of all stud welds within each length of chain are to be examined by magnetic particle inspection after proof load testing. Stress raising defects such as cracks, lack of fusion, gross porosity, and undercuts exceeding 1 mm are not permitted; if any such defects are found, then all stud welds in that length of chain are to be examined by means of magnetic particle inspection.

3.4.6 Where plastic straining is used to set studs, the applied load is not to be greater than that qualified in approval tests. The combined effect of shape and depth of the impression of the stud in the link is not to cause any harmful notch effect or stress concentration.

3.5 Heat treatment of completed chain cables

3.5.1 The chain is to be normalised, normalised and tempered or quenched and tempered in accordance with the specification approved by LR.

3.5.2 The chains are to be heat treated in a continuous furnace; batch heat treatment is not permitted.

3.5.3 The temperature and time, or temperature and chain speed, are to be controlled and continuously recorded.

3.5.4 Heat treatment is to be carried out prior to the proof loading and breaking tests.

3.5.5 Calibration of furnaces is to be verified by measurement and recording of actual link temperature (surface and internal).

3.6 Testing of completed chain cables

3.6.1 All chain cables are to be tested in the presence of a Surveyor, at a proving establishment recognised by LR. A list of recognised proving establishments is published by LR. In addition to the requirements stated in this Chapter, attention must be given to any relevant statutory requirements of the National Authority of the country in which the ship is to be registered.

3.6.2 The entire length of chain cable is to be subjected to a proof loading test in an approved testing machine and is to withstand the load given in Table 10.3.1 for the appropriate grade and size of cable.

3.6.3 Care should be taken to obtain a uniform stress distribution in the links being tested.

3.6.4 The chain is to be shot or sand blasted prior to testing in order to ensure that its surfaces are free from scale, paint or other coating for inspection.

3.6.5 On completion of the proof load test, each link is to be visually examined and is to be free from significant defects such as mill defects, surface cracks, dents and cuts, especially where gripped by clamping dies during flash butt welding. Studs are to be securely fastened and any burrs, irregularities and rough edges are to be removed by careful grinding.

3.6.6 All flash butt welds, including the area gripped by the clamping dies, are to be examined by magnetic particle inspection. The area is to be free from cracks, lack of fusion, gross porosity and any other stress concentrations.

3.6.7 Surface defects in the region of the flash butt welds may be removed by grinding, provided that the depth of grinding does not exceed five per cent of the link diameter and is smoothly contoured into the surrounding material. The final dimensions are still to conform with the agreed standard.

3.6.8 All flash butt welds are also to be examined by ultrasonic inspection and are to be free from defects such as internal cracks or lack of fusion.

3.6.9 All non-destructive examination is to be carried out in accordance with approved procedures, in accordance with Ch 1,5.

3.6.10 All non-destructive examination operators are to be qualified to a minimum Level II, qualified in accordance with a recognised standard.

3.6.11 After proof testing, the entire chain is to be checked for length, five links at a time with an overlap of two links, which is to include the first five links, to ensure that the chain meets the tolerances given in 2.15.5. The measurements are to be made while the chain is loaded to about 10 per cent of the proof load.

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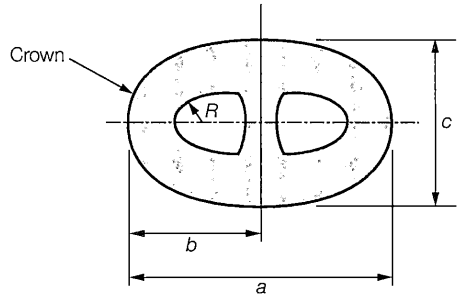
Fig. 10.3.2 Stud link tolerances

The internal link radii (*R*) and external radii should be uniform



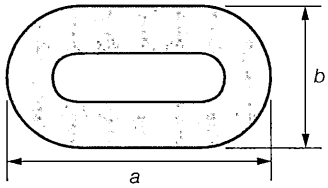
Designation	Description	Nominal dimension of the link	Minus tolerance	Plus tolerance
a	Link length	6*d*	0,15*d*	0,15*d*
b	Link half length	*a**/2	0,10*d*	0,10*d*
c	Link width	3,6*d*	0,09*d*	0,09*d*
e	Stud angular misalignment	0 degrees	4 degrees	4 degrees
R	Inner radius	0,65*d*	0	—

Symbols

d = nominal diameter of chain
*a** = actual link length

Fig. 10.3.3 Studless and common link tolerances

The internal link radii (*R*) and external radii should be uniform



Designation	Description	Nominal dimension of the link	Minus tolerance	Plus tolerance
a	Link length	6*d*	0,15*d*	0,15*d*
b	Link width	3,35*d*	0,09*d*	0,09*d*
R	Inner radius	0,60*d*	0	—

Symbols

d = nominal diameter of chain

NOTE
Other dimensional ratios are subject to special approval.

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Table 10.3.1 Test loads for mooring chain cables *(continued)*

Nominal diameter *d*	Grade R3			Grade R3S			Grade R4			Grade R4S			Grade R5		
	Proof test load		Break test load	Proof test load		Break test load	Proof test load		Break test load	Proof test load		Break test load	Proof test load		Break test load
	Stud link chain	Studless chain		Stud link chain	Studless chain		Stud link chain	Studless chain		Stud link chain	Studless chain		Stud link chain	Studless chain	
mm	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN
50	1480	1480	2230	1800	1740	2490	2160	1920	2740	2400	2130	3040	2510	2230	3200
52	1594	1594	2402	1939	1874	2682	2327	2068	2952	2585	2295	3275	2704	2402	3447
54	1712	1712	2580	2083	2013	2881	2499	2222	3170	2777	2465	3517	2904	2580	3703
56	1834	1834	2764	2231	2156	3086	2677	2380	3396	2974	2640	3768	3111	2764	3966
58	1960	1960	2953	2383	2304	3297	2860	2542	3628	3178	2820	4025	3323	2953	4237
60	2089	2089	3147	2540	2455	3514	3048	2710	3867	3387	3006	4290	3542	3147	4516
62	2221	2221	3347	2701	2611	3737	3242	2881	4112	3602	3196	4562	3767	3347	4802
64	2357	2357	3551	2867	2771	3965	3440	3058	4364	3822	3392	4841	3997	3551	5096
66	2496	2496	3761	3036	2935	4200	3643	3238	4621	4048	3593	5127	4233	3761	5397
68	2639	2639	3976	3209	3102	4440	3851	3423	4885	4279	3798	5420	4475	3976	5706
70	2785	2785	4196	3387	3274	4685	4064	3613	5156	4516	4008	5720	4723	4196	6021
73	3010	3010	4535	3660	3538	5064	4392	3904	5572	4881	4331	6182	5104	4535	6507
76	3242	3242	4884	3942	3811	5454	4731	4205	6001	5257	4665	6658	5498	4884	7009
78	3400	3400	5123	4135	3997	5720	4962	4411	6295	5514	4893	6984	5766	5123	7351
81	3643	3643	5490	4431	4283	6130	5317	4726	6745	5908	5243	7484	6179	5490	7877
84	3893	3893	5866	4735	4577	6550	5682	5051	7208	6313	5603	7997	6602	5866	8418
87	4149	4149	6252	5046	4878	6981	6056	5383	7682	6729	5972	8523	7037	6252	8971
90	4412	4412	6647	5365	5187	7422	6439	5723	8167	7154	6349	9062	7482	6647	9539
92	4590	4590	6916	5582	5396	7722	6699	5954	8497	7443	6606	9428	7784	6916	9924
95	4862	4862	7326	5913	5716	8180	7096	6307	9001	7884	6997	9987	8246	7326	10512
97	5047	5047	7604	6138	5933	8490	7365	6547	9343	8184	7263	10366	8559	7604	10911
100	5328	5328	8028	6480	6264	8964	7776	6912	9864	8640	7668	10944	9036	8028	11520
102	5519	5519	8315	6712	6488	9285	8054	7159	10217	8949	7942	11336	9359	8315	11932
105	5809	5809	8753	7065	6829	9773	8478	7536	10754	9420	8360	11932	9851	8753	12560
107	6005	6005	9048	7304	7060	10103	8764	7790	11118	9738	8643	12335	10184	9048	12984
111	6404	6404	9650	7789	7529	10775	9347	8308	11856	10385	9217	13154	10861	9650	13847
114	6709	6709	10109	8159	7887	11287	9791	8703	12420	10879	9655	13780	11378	10109	14506
117	7018	7018	10574	8535	8251	11807	10242	9104	12993	11380	10100	14415	11902	10574	15174
120	7331	7331	11047	8916	8619	12334	10700	9511	13573	11889	10551	15059	12434	11047	15852
122	7542	7542	11365	9173	8868	12690	11008	9785	13964	12231	10855	15493	12792	11365	16308
124	7755	7755	11686	9432	9118	13048	11319	10061	14358	12576	11161	15930	13153	11686	16768
127	8078	8078	12171	9824	9497	13591	11789	10479	14955	13099	11626	16592	13700	12171	17466
130	8404	8404	12663	10221	9880	14139	12265	10903	15559	13628	12095	17262	14253	12663	18171
132	8623	8623	12993	10488	10138	14508	12585	11187	15965	13984	12411	17713	14625	12993	18645
137	9178	9178	13829	11162	10790	15441	13395	11906	16992	14883	13209	18852	15565	13829	19844

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Table 10.3.1 Test loads for mooring chain cables (*conclusion*)

Nominal diameter *d*	Grade R3			Grade R3S			Grade R4			Grade R4S			Grade R5		
	Proof test load		Break test load	Proof test load		Break test load	Proof test load		Break test load	Proof test load		Break test load	Proof test load		Break test load
	Stud link chain	Studless chain		Stud link chain	Studless chain		Stud link chain	Studless chain		Stud link chain	Studless chain		Stud link chain	Studless chain	
mm	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN
142	9741	9741	14677	11847	11452	16388	14216	12637	18033	15796	14019	20008	16520	14677	21061
147	10311	10311	15536	12540	12122	17347	15048	13376	19089	16720	14839	21179	17487	15536	22294
152	10887	10887	16405	13241	12800	18317	15890	14124	20156	17655	15669	22363	18464	16405	23540
157	11469	11469	17282	13949	13484	19297	16739	14879	21234	18599	16507	23559	19452	17282	24799
162	12056	12056	18166	14663	14174	20284	17596	15641	22320	19551	17351	24764	20447	18166	26068
167	12647	12647	19056	15381	14869	21278	18458	16407	23414	20508	18201	25977	21448	19056	27345
172	13240	13240	19950	16103	15566	22276	19324	17177	24513	21471	19055	27196	22455	19950	28628
177	13836	13836	20847	16827	16267	23278	20193	17949	25615	22437	19912	28420	23465	20847	29915
182	14433	14433	21746	17553	16968	24282	21064	18723	26720	23404	20771	29645	24477	21746	31205
187	15029	15029	22646	18279	17670	25286	21935	19498	27825	24372	21630	30871	25489	22646	32496
192	15626	15626	23544	19004	18371	26289	22805	20271	28929	25339	22488	32096	26500	23544	33785
197	16220	16220	24440	19727	19070	27290	23673	21043	30029	26303	23344	33317	27509	24440	35071
202	16813	16813	25332	20448	19766	28286	24537	21811	31126	27264	24196	34534	28513	25332	36351
207	17401	17401	26220	21164	20459	29277	25397	22575	32216	28219	25044	35744	29512	26220	37625
210	17753	17753	26749	21591	20872	29868	25910	23031	32867	28788	25550	36465	30108	26749	38385

Grade R3		
Proof test load	Stud link chain	$0{,}0148d^2\ (44 - 0{,}08d)$
	Studless chain	$0{,}0148d^2\ (44 - 0{,}08d)$
Break test load		$0{,}0223d^2\ (44 - 0{,}08d)$
Grade R3S		
Proof test load	Stud link chain	$0.0180d^2\ (44 - 0{,}08d)$
	Studless chain	$0{,}0174d^2\ (44 - 0{,}08d)$
Break test load		$0{,}0249d^2\ (44 - 0{,}08d)$
Grade R4		
Proof test load	Stud link chain	$0{,}0216d^2\ (44 - 0{,}08d)$
	Studless chain	$0{,}0192d^2\ (44 - 0{,}08d)$
Break test load		$0{,}0274d^2\ (44 - 0{,}08d)$
Grade R4S		
Proof test load	Stud link chain	$0{,}0240d^2\ (44 - 0{,}08d)$
	Studless chain	$0{,}0213d^2\ (44 - 0{,}08d)$
Break test load		$0{,}0304d^2\ (44 - 0{,}08d)$
Grade R5		
Proof test load	Stud link chain	$0{,}0251d^2\ (44 - 0{,}08d)$
	Studless chain	$0{,}0223d^2\ (44 - 0{,}08d)$
Break test load		$0{,}0320d^2\ (44 - 0{,}08d)$

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3.6.12 The links held in the end blocks may be excluded from these measurements.

3.6.13 If the length over five links is less than the nominal, the chain may be stretched by loading above the specified proof test load provided that the applied load is not greater than ten per cent above the proof test load, and that only random lengths of the chain need to be stretched.

3.6.14 Loads used for plastic straining to set studs are not to exceed those approved in qualification tests.

3.6.15 Checks of all other dimensions are to be made on at least five per cent of the links in the cable.

3.6.16 If any link fails to meet the dimensional tolerance requirements (*see* 3.3), measurements are to be made on 20 more links on each side of the incorrect one. If failure to meet any particular dimensional requirements occurs in more than two of the measured links, then all the links are to be dimensionally checked.

3.6.17 Should any link be found to be defective or fail to meet the dimensional tolerance requirements or if a five link length of chain exceeds the specified tolerance, the unsatisfactory links are to be removed from the chain, and connecting common links complying with the requirements of 3.7 inserted in their places.

3.6.18 The chain is then to be subjected to a further proof load test and re-examined.

3.6.19 The number of connecting common links which may be used to replace defective links is not to exceed three in any 100 m length of chain. The number and type of joining shackles which may be used are to be subject to the written agreement of the end user.

3.6.20 If a link breaks during proof load testing, a sample consisting of three common links is to be taken from each side of the broken link and subjected to a breaking test as detailed in 3.6.21 and 3.6.22. If either of these samples fails, the proof loaded length of cable is not to be accepted. A thorough examination of all broken links is to be made to determine the cause of failure and, after evaluation, LR will consider the extent of cable which is to be rejected and also the possibility that similar factors to those which caused the failure may also be present in other parts of the cable, or other chain cables. The Surveyor is to be advised in advance of all examinations, with reasonable notice being given.

3.6.21 In addition to the requirements of 3.6.2, three link samples are to be selected by the Surveyors from the completed chain for breaking tests. The number of tests required is to be in accordance with Table 10.3.2. Extra links are to be provided for the mechanical tests detailed in 3.6.25. All test links are to be made as part of the chain cable and are to be heat treated with it. These may be removed from the cable prior to heat treatment provided that each sample is heat treated with, and in the same manner as, the chain it represents and is subjected to the proof load appropriate to the chain grade and diameter prior to selection of the mechanical test specimens. They are to be properly identified with the length of chain they represent.

Table 10.3.2 Frequency of break and mechanical tests

Nominal chain diameter mm	Maximum sampling interval m (*See* Note)
Min. — 48	91
49 — 60	110
61 — 73	131
74 — 85	152
86 — 98	175
99 — 111	198
112 — 124	222
125 — 137	250
138 — 149	274
150 — 162	297
163 — 175	322
176 — 186	346
187 — 199	370
199 — 210	395

NOTE
If the sampling interval contains links made from more than one cast, extra break and mechanical tests are required so that tests are made on every cast.

3.6.22 Breaking test specimens are to withstand the load given in Table 10.3.1 for the appropriate grade and size of cable for a period of 30 seconds. The specimen is considered to have passed this test if it has shown no sign of fracture after application of the required load.

3.6.23 If a breaking test specimen fails, two further specimens are to be cut from the same sampling length and both are to be subjected to the breaking test load. If one of the re-test specimens fails the length is to be rejected. All the broken links are to be subjected to an investigation into the cause of failure. LR will then decide which lengths of chain can be accepted and on further action.

3.6.24 For large diameter cables where the required breaking load is greater than the capacity of the testing machines, special consideration will be given to acceptance of an alternative testing procedure.

3.6.25 One tensile and three sets of Charpy V-notch impact test specimens are to be taken from links cut from the heat treated and proof loaded chain at intervals no greater than those indicated in Table 10.3.2 provided that every cast is sampled. The tensile specimen and one set of impact specimens are to be taken from the side of the link opposite the weld. One set of impact test specimens is to have the notches positioned at the centre of the flash butt weld and the third set is to be taken from the bend. All the specimens are to be taken from positions in accordance with Fig. 10.3.4.

3.6.26 The frequency of testing at the link bends may be reduced at the discretion of LR provided it can be verified that the required toughness is achieved consistently.

3.6.27 The results of the mechanical tests are to comply with the requirements of Table 10.3.3.

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Table 10.3.3 Mechanical properties of chain cable materials

Grade	Yield stress N/mm² minimum	Tensile strength N/mm²	Elongation % minimum	Reduction of area % minimum (See Note 3)	Charpy V-notch impact tests		
					Test temperature °C	Average energy J minimum	Average energy flash weld J minimum
R3	410 (See Note 1)	690 minimum (See Note 1)	17	50	0 –20 (See Note 2)	60 40	50 30
R3S	490 (See Note 1)	770 minimum (See Note 1)	15	50	0 –20 (See Note 2)	65 45	53 33
R4	580 (See Note 1)	860 minimum (See Note 1)	12	50	–20	50	36
R4S (See Note 4)	700 (See Note 1)	960 (See Note 1)	12	50	–20	56	40
R5 (See Note 4)	760 (See Note 1)	1000 (See Note 1)	12	50	–20	58	42

NOTES
1. The ratio of yield strength to tensile strength should not exceed 0,92.
2. Testing may be carried out at either 0°C or –20°C.
3. For cast fittings, the minimum values for reduction of area are to be 40% for Grades R3 and R3S and 35% for Grades R4, R4S and R5.
4. The maximum hardness for Grade R4S is to be HB330, and for Grade R5 is to be HB340.

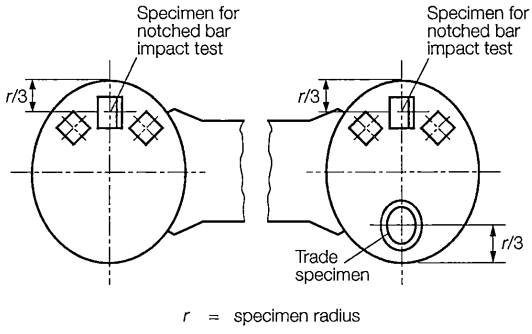

Fig. 10.3.4 Sampling of chain links

3.6.28 If the tensile test requirements are not achieved, two further specimens from the same sample are to be tested. The related length of chain will be considered acceptable if both re-test specimens meet the requirements but failure of either of the re-test specimens will result in rejection of the sampling length of chain represented by the tests.

3.6.29 If the impact test requirements are not achieved, re-tests may be carried out in accordance with Ch 1,2.4. Failure to meet the re-test requirements will result in rejection of the sampling length of chain represented by the tests.

3.6.30 The mass per unit length of stud link mooring cable is to comply with Table 10.3.4.

3.7 Connecting common links or substitute links

3.7.1 Single links to connect lengths of heat treated chain cable or to substitute for test links or defective links without the necessity for re-heat treatment of the whole length of cable are to be made by the chain manufacturer in accordance with an approved procedure. Separate approvals are required for each grade of chain cable and tests are to be made on the maximum size of chain for which approval is sought.

3.7.2 Manufacture and heat treatment of the connecting common link is not to affect the strength of the adjoining links. The temperature reached by these links is nowhere to exceed 250°C.

3.7.3 The steel bar used is to conform with the specification for the chain and approved by LR in accordance with Ch 3,9.

3.7.4 Details of the method of manufacture, including heat treatment, are to be submitted for approval, together with the results of a series of tests laid down by LR.

3.7.5 All links involved in the approval tests are to be destroyed and are not to be used as part of a chain cable.

3.7.6 Every connecting common link included in a chain cable is to be subjected to the proof load appropriate to the grade and size of chain in which it is incorporated as detailed in Table 10.3.1.

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Table 10.3.4 Mass per unit length of chain cable

Nominal chain diameter (mm)	Mass per unit length $0{,}0291d^2$ (kg/m)
50	73
55	88
60	105
65	123
70	143
75	164
80	186
85	210
90	236
95	263
100	291
105	321
110	352
115	385
120	419
125	455
130	492
135	530
140	570
145	612
150	655
155	699
160	745
165	792
170	841
175	891
180	943
185	996
190	1051
195	1107
200	1164
205	1223
210	1283

3.7.7 Every connecting common link is to be inspected in accordance with 3.6.5 to 3.6.10.

3.7.8 A second identical link is to be made for mechanical tests which are to be in accordance with 3.6.25. This test link is also to be inspected in accordance with 3.7.7.

3.7.9 Each connecting common link is to be stamped on the stud with the identification marks listed in 3.9.1 plus a unique number for the link. The adjoining links are also to be stamped on the studs.

3.8 Fittings for offshore mooring chain

3.8.1 Cable fittings are to be manufactured at an approved works. Fittings include, but are not limited to, shackles, triplates, end shackles, swivels, and swivel shackles.

3.8.2 The materials from which the fittings are made are to be manufactured at approved works, in accordance with the appropriate requirements of Ch 4,1 or Ch 5,1, and 3.8.3 to 3.8.6. Alternative arrangements may be agreed provided that full details concerning the manufacturer are submitted to LR.

3.8.3 Steel used for fittings must be manufactured by an approved process, and be killed and fine grain treated.

3.8.4 The austenite grain size of steel used for fittings must be 6 or finer as measured in accordance with ASTM E112.

3.8.5 Steel used for forgings or castings for grades R4S and R5 must be vacuum degassed.

3.8.6 For steel used for forgings or castings for grades R4S and R5 the following tests are to be carried out on each heat:

(a) Assessment and quantification of the level of non-metallic micro inclusions. These must be acceptable for the final product.

(b) Macro etching on representative sample, in accordance with ASTM E381 or equivalent, this must be free from any injurious segregation or porosity.

(c) Jominy hardenability tests in accordance with ASTM A255 or equivalent.

The results of these tests are to be supplied by the steel manufacturer, and the results are to be included in the final accessory documentation.

3.8.7 Fittings for chain are to be heat treated in accordance with procedures that have been approved by LR.

3.8.8 All fittings are to be manufactured to a manufacturing specification approved by LR, and provision is to be made for tensile and impact test specimens. The test samples are to be subjected to heat treatment with the fittings they represent. The mechanical test requirements are the same as those for the relevant grade of chain cable, *see* Table 10.3.3.

3.8.9 A batch is defined as fittings from the same heat of steel that have been part of the same heat treatment charge.

3.8.10 Mechanical tests for fittings are to be taken from full size fittings that have been heat treated with the production batch they represent, and the tests are to be taken after the fitting has been proof load tested. It is not permitted to use separate representative coupons unless approved by LR in accordance with 3.8.14.

3.8.11 Forged shackle bodies and forged Kenter shackles are to have a set of three Charpy impact tests and a tensile test taken from the crown of the shackle. For smaller diameter shackles, where the geometry does not allow for the tensile test to be taken from the crown, this may be taken from the straight portion from the locations specified in Fig. 10.3.5, with the Charpy impact test specimens on the outside radius.

3.8.12 The test pieces for cast shackle bodies and cast Kenter shackles can be taken from the straight portion of the fitting from the locations shown in Fig. 10.3.5.

3.8.13 For fittings with complex geometries the locations of test pieces taken are to be approved by LR.

3.8.14 Where fittings are produced in small batches (less than 5) alternative testing may be approved; a proposal must be submitted in a written procedure for consideration.

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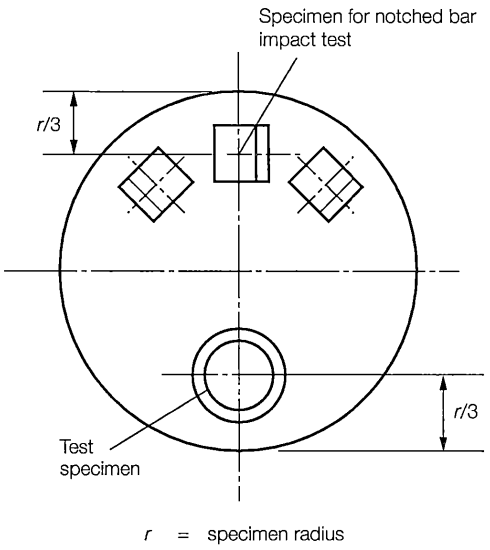

Fig. 10.3.5
Sampling of steel bars, forgings and castings

3.8.15 Mechanical tests of pins are to be taken as shown in Fig. 10.3.6 from the mid length of a sacrificial pin of the same diameter as the final pin. For oval pins, the diameter taken is to represent the smaller dimension. Mechanical tests may be taken from an extended pin of the same diameter as the final pin that incorporates a test prolongation and a heat treatment buffer prolongation, where equivalence with mid length test values have been established. The length of the buffer is to be at least equal to 1 pin diameter which is removed after the heat treatment cycle is finished. The test coupon can then be removed from the pin. The buffer and test are to come from the same end of the pin, as shown in Fig. 10.3.6.

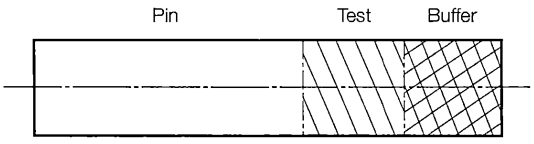

Fig. 10.3.6
Buffer and test piece location for pins

3.8.16 Manufacturers intending to supply accessories in the machined condition (e.g. Kenter type shackles) are to submit detailed drawings for approval by LR.

3.8.17 All chain cable accessories, including spares, are to be subjected to the proof loads appropriate to the grade and size of cable for which they are intended, *see* Table 10.3.1. Prior to this test, the accessories are to be shot or sand blasted to ensure that their surfaces are free from scale, paint or any other coating which could interfere with any subsequent inspection.

3.8.18 The appropriate breaking load as required by Table 10.3.1 is to be applied to at least one item out of every batch of up to 25, and this item is to be destroyed and not used as part of an outfit.

3.8.19 If the sample fails to withstand the breaking load without fracture, or in the event of failure of any other test, then the entire batch is to be rejected unless the cause of failure has been determined and it can be demonstrated that the condition causing failure is not present in any of the other accessories in the batch. If this can be demonstrated then two more samples from the same batch may be tested. If either of these samples fails, the batch is to be rejected.

3.8.20 For very large fittings where the required breaking load is greater than the capacity of the testing machine and for individually produced accessories or accessories produced in small batches, proposals for an alternative method of testing will be given special consideration. All proposals for alternative testing methods are to be detailed in writing and submitted.

3.8.21 At least one accessory from each batch is to be checked dimensionally after proof load testing. The manufacturer is to provide a statement that the dimensions comply with the specified requirements.

3.8.22 The following tolerances apply of the unmachined dimensions of all fittings;

(a) nominal diameter plus 5 per cent, minus 0 per cent; and
(b) other dimensions plus or minus 2,5 per cent.

3.8.23 All accessories are to be subjected to close visual examination after proof load testing, particular attention being paid to machined surfaces and highly stressed regions. All accessories are also to be examined by magnetic particle or dye penetrant inspection and ultrasonic testing. All NDE is to be carried out in accordance with 3.6.9 and 3.6.10. The manufacturer is to provide a statement that the non-destructive examination has been carried out with satisfactory results; this statement is to include reference to the techniques used and the operator's qualifications.

3.8.24 All testing is to be carried out to the satisfaction and in the presence of the Surveyor.

3.8.25 Fittings with increased dimensions, or fittings of a higher material grade, may be specially approved and included in an outfit, provided that;

(a) each item is successfully tested at the required breaking load for the chain cable for which they are intended; and
(b) items of increased dimensions are so designed that their breaking strength is not less than 1,4 times the Rule minimum breaking load for the chain cable for which they are intended, and this has been verified by procedure tests.

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3.9 Identification

3.9.1 Each length of chain is to be permanently marked with the following:

(a) LR and abbreviated name of LR's local office issuing the certificate.
(b) Certificate number (this may be abbreviated provided it is stated in the certificate).
(c) Grade and proof load of chain.

3.9.2 The chain is to be marked as follows:

(a) at each end (the marking should identify the leading and tail end of each chain),
(b) at intervals not exceeding 100m,
(c) on all connecting common links or shackles and the immediately adjacent links,
(d) on the first and last common link of each individual charge used in the continuous length.

3.9.3 All identification marks are to be made on the studs and are to be permanent and legible throughout the expected service life of the chain.

3.10 Documentation

3.10.1 A complete Chain Inspection and Testing Report, in booklet form, is to be provided by the chain manufacturer for each continuous chain length, and for each order for chain and fittings. It is to include all dimensional checks, test and inspection reports, non-destructive test reports, process records, as well as any non-conformity, together with corrective action and repair work.

3.10.2 All documents, including reports and appendices, are to contain a reference to the relevant certificate number.

3.10.3 The chain manufacturer is responsible for storing all the documentation in a safe and retrievable manner for a period of at least 10 years.

3.11 Certification

3.11.1 An LR certificate is to be issued for each continuous single length of chain, and each type of fitting, *see* Ch 1,3.1.

3.11.2 Each test certificate is to include the following particulars:

(a) Purchaser's name and order number.
(b) Description and dimensions.
(c) Grade of chain cable.
(d) Identification mark which will enable the full history of the chain to be traced.
(e) Chemical composition.
(f) Details of heat treatment.
(g) Mechanical test results.
(h) Breaking test load.
(j) Proof load.
(k) The number and locations of all connecting common links and all marked links.

Section 4
Studless mooring chain cables

4.1 Scope

4.1.1 Provision is made in this Section for five grades, R3, R3S, R4, R4S and R5 of studless flash butt welded chain cable intended for long term mooring applications.

4.1.2 The chain is generally expected to be deployed only once for a pre-determined service life.

4.1.3 Each studless chain link design will require to be approved by LR. The plan submitted for this approval is to include the minimum proof and breaking test loads, and the chain mass calculations.

4.2 Manufacture

4.2.1 All the requirements of 3.2, with the exception of that relating to studs, apply to the manufacture of studless mooring chain cables.

4.3 Shape and dimensions of links

4.3.1 The shape and dimensions of the links are to be in accordance with the approved design.

4.4 Dimensional tolerances

4.4.1 The dimensional tolerances of studless links are to be in accordance with the requirements of 3.3.1 to 3.3.7.

4.5 Heat treatment

4.5.1 Heat treatment of the chain is to be in accordance with the requirements of 3.5.

4.6 Testing of completed chain

4.6.1 All chain cables are to be tested in the presence of a Surveyor, at a proving establishment recognised by LR. A list of recognised proving establishments is published by LR. In addition to the requirements stated in this Chapter, attention must be given to any relevant statutory requirements of the National Authority of the country in which the ship is to be registered.

4.6.2 The entire length of chain cable is to be subjected to a proof load test in an approved testing machine and is to withstand the load given in Table 10.3.1 for the appropriate grade and diameter of the chain, *see also* 4.1.3.

4.6.3 Inspection after proof load testing is to be in accordance with the requirements given in 3.6.3 to 3.6.20, excluding that related to checking of studs in 3.6.5.

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4.6.4 In addition to the inspection of the flash butt welded areas as required in 3.6.6, the surfaces of the bends of at least 10 per cent of the links are to be examined by magnetic particle inspection and are to be free from cracks or other defects.

4.6.5 If stretching of links is required in order to maintain dimensional tolerances, the load applied is not to exceed the proof load by more than 10 per cent, and only random lengths of the chain need to be stretched.

4.6.6 Breaking load tests are to be carried out in accordance with 3.6.21 to 3.6.23 and Tables 10.3.1 and 10.3.2.

4.6.7 Alternative procedures to breaking load testing (*see* 3.6.24) are not permissible unless prior agreement is given by LR after special consideration.

4.6.8 Mechanical testing is to be carried out in accordance with 3.6.25 to 3.6.30 and Table 3.3.3.

4.6.9 The weight of the chain cable is to be in accordance with the approved plan.

4.7 Connecting or substitute links

4.7.1 Connecting links and substitute links are to be in accordance with the requirements of 3.7.

4.8 Fittings

4.8.1 Fittings for studless chain are to comply with the requirements of 3.8.

4.9 Identification

4.9.1 All chain and each fitting is to be identified in accordance with 3.9.1 and 3.9.2.

4.9.2 Identification marks are to be made on the outside of the straight part of the link, opposite the flash butt weld.

4.10 Certification

4.10.1 Certificates are to be issued in accordance with 3.11.

4.11 Documentation

4.11.1 Documentation in accordance with 3.11 is to be provided by the manufacturer.

■ *Section 5* Short link chain cables

5.1 Scope

5.1.1 This Section gives the requirements for electrically welded steel short link chain cable for marine use but excluding those applications covered by the *Code for Lifting Appliances in a Marine Environment*.

5.1.2 Provision is made for grade M(4), as defined in ISO 1834:1999. Allowance is also made for the requirements of ISO 4565.

5.2 Manufacture

5.2.1 Short link chain cables are to be manufactured at works approved by LR. A list of approved manufacturers for short link chain cable is published separately by LR.

5.2.2 The chain is to be supplied in either the normalised or quenched and tempered condition. Heat treatment is to be carried out prior to proof and breaking load testing.

5.2.3 The chain may be galvanised using a hot dipping process provided that this is carried out prior to proof and breaking load testing. If galvanised, it is recommended that the thickness of the zinc coating be not less than 70 microns.

5.2.4 Unless otherwise agreed, the finished chain is to be free from coatings other than zinc.

5.3 Bar material

5.3.1 Bars for the manufacture of short link chain cable are to be made and tested in accordance with the appropriate requirements of Ch 3,1 and to the requirements of an International or acceptable National Standard.

5.3.2 The bars are to be made at a works approved by LR.

5.3.3 The steel is to be fully killed and fine grain treated.

5.3.4 The steel is to have mechanical properties which will allow the chain to meet the mechanical test requirements of 5.4.7 and Table 10.5.1.

5.4 Testing and inspection of chain cables

5.4.1 All chain cable of 12,5 mm diameter and above, and all steering chains irrespective of diameter, are to be tested in the presence of a Surveyor at a proving establishment recognised by LR. A list of recognised proving establishments is published by LR. In addition to the requirements stated in this Chapter, attention is to be given to any relevant statutory requirements of the National Authority of the country in which the ship or other marine structure is to be registered.

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Table 10.5.1 Mechanical test requirements for short link chain cables

Chain diameter mm	Grade M(4)	
	Proof load kN	Breaking load minimum kN
5	7,9	15,8
6,3	12,5	25
7,1	15,9	31,8
8	20,2	40,4
9	25,5	51
10	29,5	63
11,2	31,5	79
12,5	49,1	98,2
14	63	126
16	81	162
18	102	204
20	126	252
22,4	158	316
25	197	394
28	247	494
32	322	644
36	408	816
40	503	1006
45	637	1274

5.4.2 For chain of diameter less than 12,5 mm, other than steering chains, the manufacturer's tests will be acceptable.

5.4.3 After completion of all manufacturing processes, including heat treatment and galvanising, the whole of the chain is to be subjected to the appropriate proof load specified in Table 10.5.1.

5.4.4 The whole of the chain is to be inspected after the proof load test and is to be free from significant defects.

5.4.5 At least one sample, consisting of seven or more links, is to be selected by the Surveyor from each 200 m or less of chain for breaking load tests. Two additional links may be required for engagement in the jaws of the testing machine. These extra links are not to be taken into account in determining the total elongation, *see* 5.4.7.

5.4.6 The breaking load is to comply with the appropriate requirements of Table 10.5.1.

5.4.7 The total elongation of the breaking load sample at fracture, expressed as a percentage of the original inside length of the sample after proof loading, is to be not less than 20 per cent.

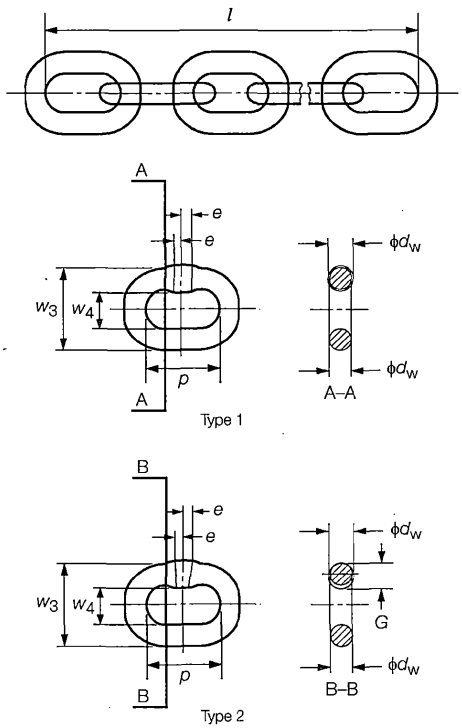
5.5 Dimensions and tolerances

5.5.1 The form and proportions of links are to be in accordance with Fig. 10.5.1.

5.5.2 Manufacturing tolerances are to be within the following limits:

Nominal diameter, d_n	± 5%
Pitch of chain, p_1	± 3%
Length measured over 11 links, l	± 2%
Inside width, w_1	$1{,}35d_n$ minimum
Outside width, w	$3{,}6d_n$ maximum

The tolerances are to apply after galvanising. All measurements are to be taken after proof testing.



l = multiple pitch length
p = pitch (internal link length)
d_n = measured diameter of the material, except at the weld
d_w = measured diameter of the material at the weld (Type 1) or weld dimension perpendicular to the plane of the link (Type 2)
G = dimension in other planes as per individual chain specification (Type 2)
e = length affected by welding, on either side of the centre link
w_1 = internal link width away from the weld
w_2 = external link width away from the weld
w_3 = external link width over the weld
w_4 = internal link width at the weld

Fig. 10.5.1 Form and proportions of links

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5.6 Identification

5.6.1 All lengths of cable are to be stamped with the following identification marks:
(a) Inspector's mark and date.
(b) Reference mark or number of certificate.
(c) Manufacturer's mark or name.
(d) Chain cable quality mark, M, is to be stamped on at least each twentieth link or at intervals of one metre, whichever is the lesser distance.

5.6.2 Where the inspection is performed under LR's supervision, the inspector's mark and date are to be replaced by LR and the abbreviated name of LR's local office issuing the certificate.

5.7 Certification

5.7.1 The manufacturer is to supply the Surveyor with a certificate stating compliance with an appropriate ISO standard, and also, in the event of the requirements of 5.4 being undertaken other than in the presence of the Surveyor, stating that the test and inspection requirements have been complied with at a recognised proving establishment.

5.7.2 Each test certificate is to include the following particulars:
(a) the quality and description of chain,
(b) identification mark,
(c) nominal size of chain,
(d) proof load,
(e) breaking load,
(f) total elongation at fracture,
(g) where appropriate, the name of the proving establishment.

■ *Section 6* Steel wire ropes

6.1 Scope

6.1.1 Provision is made in this Section for the requirements for the manufacture, testing and certification of steel wire ropes intended to be used for general marine purposes, as well as permanent anchoring, mooring and marine lifting applications.

6.2 General requirements

6.2.1 For general marine purposes, such as stream wires, towlines and ship mooring lines, the construction is to be in accordance with Table 10.6.1. The construction, diameter and strength of steel wire ropes for permanent offshore applications, such as mooring, anchoring and lifting, are covered by other LR Rules. Alternative applications of wire ropes may be accepted, subject to special consideration.

6.2.2 The manufacturer's plant and method of production are to be approved by LR. A list of approved manufacturers of steel wire ropes is published annually in the *List of Approved Manufacturers of Materials*.

6.2.3 For shaped wire, for example, for large diameter ropes for permanent mooring, where there are no established Standards, the manufacturer is to provide evidence by way of test reports that specifications have been developed and agreed with the purchaser and LR for the purposes intended.

6.3 Steel wire for ropes

6.3.1 Steel wire is to be of homogeneous quality, uniform strength and free of defects likely to impair the manufacture and performance of the rope.

6.3.2 For all ropes, the specified minimum tensile strength of the wire is to be 1420, 1570, 1770 or 1960 N/mm^2. The specified minimum tensile strength of the wire is the designated grade for the rope, unless otherwise defined by the purchaser's specification. The actual tensile strength of the wire is not to exceed 120 per cent of the specified minimum tensile strength.

Table 10.6.1 Recommended rope construction

Purpose	Construction of rope			Construction of strands
	Strands	Wires	Core	
Stream wires, towlines and mooring lines	6	24	Fibre	15 over 9 over fibre core
	6	37	Fibre	18 over 12 over 6 over 1
	6	26	Fibre	10 over (5 + 5) over 5 over 1
	6	31	Fibre	12 over (6 + 6) over 6 over 1
	6	36	Fibre	14 over (7 + 7) over 7 over 1
	6	41	Fibre	16 over (8 + 8) over 8 over 1
	6	30	Fibre	18 over 12 over fibre core
Towlines and mooring lines used in association with mooring winches	6	31	7 x 7 wire rope	12 over (6 + 6) over 6 over 1
	6	36	7 x 7 wire rope	14 over (7 + 7) over 7 over 1
	6	41	7 x 7 wire rope	16 over (8 + 8) over 8 over 1

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6.3.3 For new rope construction, the manufacturer is to carry out prototype testing suitable for the application of the rope and this is to include tests on wire used for the construction.

6.3.4 Tensile and torsion tests, coating, and adhesion (wrap) tests are to be carried out on wire used for the manufacture of rope.

6.3.5 At least 10 per cent of the spools used for the manufacture of the strand are to be tested. The manufacturer is to demonstrate that tests have been carried out on at least one wire intended for each of the outer and inner strands, and for each diameter and grade used.

6.3.6 The heat number, wire diameter and strength of wire used for a particular construction are to be recorded by the manufacturer.

6.3.7 Torsion tests are to be carried out on the wire by causing one or both of the securing vices to be revolved until fracture occurs (a tensile load not exceeding two per cent of the breaking load of the wire may be applied to keep the wire stretched).

6.3.8 The uncoated wire is to withstand, without fracture, the number of complete twists given for Grades 1 or 3 in Table 10.6.2.

6.3.9 The galvanised wire is to withstand, without fracture, the number of complete twists given in the specification, as agreed with the purchaser and LR. In the absence of a suitable specification, the results are to comply with Table 10.6.2.

6.3.10 Hot dipped galvanised steel wire is to be used for the manufacture of ropes for marine applications. Depending upon the application, the coating may comply with any of the grades in Table 10.6.3. Grades 1 and 2 are heavy coatings. Grade 3 is the minimum coating weight where the galvanising is carried out prior to final wire drawing. Uncoated wire may be considered for approved applications.

6.3.11 The mass per unit area of the zinc coating is to be determined in accordance with a recognised National or International Standard.

6.3.12 Zinc coating tests are to be carried out for each designated grade of wire. The manufacturer is to demonstrate that the coatings are continuous and uniform and suitable for the intended purpose.

6.3.13 Unless otherwise specified by the purchaser, zinc coating tests are to be carried out on the wire prior to stranding.

6.3.14 The adhesion of the coating is to be tested by wrapping the wire round a cylindrical mandrel for 10 complete turns. The ratio between the diameter of the mandrel and that of the wire is to be as in Table 10.6.4. After wrapping on the appropriate mandrel, the zinc coating is to have neither flaked nor cracked to such an extent that any zinc can be removed by rubbing with a cloth.

Table 10.6.2 Torsion test

Diameter coated wire mm	Minimum number of twists					
	Grade 2		Grade 1 or 3			
	Minimum strength N/mm^2		Minimum strength N/mm^2			
	1570	1770	1420	1570	1770	1960
<1,3	19	18	29	26	23	23
≥1,3 <2,3	18	17	26	24	21	21
≥2,3 <3,0	16	14	24	22	—	19
≥3,0 <4,0	12	10	20	18	—	17
≥4,0 <4,6	—	—	18	16	—	—
≥4,6 <5,0	—	—	16	14	—	—
≥5,0 <6,0	—	—	14	11	—	—

NOTE
The minimum test length is 100*d* or 300 mm, where *d* is the wire diameter.

Table 10.6.3 Zinc coating

Diameter of coated wire mm	Zinc coating, minimum g/m^2		
	Grade1	Grade 2	Grade 3
≥0,20 <0,25	—	30	20
≥0,25 <0,33	—	45	30
≥0,33 <0,40	—	60	30
≥0,40 <0,50	60	75	40
≥0,50 <0,60	70	90	50
≥0,60 <0,80	85	110	60
≥0,80 <1,00	95	130	70
≥1,00 <1,20	110	150	80
≥1,20 <1,50	120	165	90
≥1,50 <1,90	130	180	100
≥1,90 <2,50	—	205	110
≥2,50 <3,20	—	230	125
≥3,20 <4,00	—	250	135

Table 10.6.4 Wrap test for adhesion of coating

Coating	Diameter of coated wire mm	Maximum ratio of mandrel to wire diameter
Grade 1 and 2	<1,5	4
	≥1,5	6
Grade 3	<1,5	2
	≥1,5	3

6.4 Tests on completed ropes

6.4.1 Every length of wire rope is to be subjected to a breaking strength test.

6.4.2 A sample of sufficient length is to be provided for the breaking load test. The rope ends are to be enclosed in a suitable socket. Testing is to be carried out in accordance with a recognised National or International Standard.

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6.4.3 The rope may be subject to cyclic loading for bedding purposes prior to testing. The rope is to be tested at a suitable strain rate in accordance with a recognised National or International Standard.

6.4.4 The load is to be applied until one wire break is witnessed or 130 per cent of the minimum breaking load is recorded. The maximum recorded load is to be reported by the manufacturer.

6.4.5 Tests in which a breakage occurs adjacent to and as a result of damage from the grips are to be rejected, if the applied load is less than the specified minimum requirement. The rope is to be retested to withstand the agreed minimum breaking load.

6.4.6 With the exception of offshore mooring ropes, consideration may be given to determining the breaking load by summation or aggregating actual test results on individual wires, if facilities are not available for undertaking a breaking test on a production basis. A suitable spin factor or lay-up deduction allowance in accordance with a recognised National or International Standard for the applicable rope diameter, designated grade and construction is to be applied.

6.4.7 Where spin factors or lay-up deduction allowances are proposed by the manufacturer, a report on suitable cyclic load testing of prototype ropes of the same construction, strength and diameter is to be approved by LR. In addition, the manufacturer is to show that a satisfactory breaking load test has been carried out in the previous two years, and witnessed by LR for the same rope construction, diameter and designated grade.

6.4.8 LR may give special consideration to spin factors or lay deductions based on data extrapolated from smaller diameter ropes of the same construction, provided that these ropes have been tested in accordance with 6.4.7.

6.4.9 All data arising from smaller diameter ropes for the extrapolation in 6.4.8 are to have been derived from tests carried out within two years of the manufacture of the larger diameter rope.

6.4.10 The finished rope is to have no more than one wire connecting weld in any length of 18*d*, where *d* is the diameter of the rope.

6.5 Inspection

6.5.1 A report on dimensional and visual examination is to be presented to the Surveyor by the manufacturer. The dimensions and discard criteria are to comply with an agreed National or International Standard.

6.5.2 Visual and dimensional checks are to be carried out in the presence of the Surveyor.

6.6 Identification

6.6.1 All completed ropes are to be identified with attached labels detailing the rope type, diameter and length.

6.7 Certification

6.7.1 A manufacturer's certificate, in accordance with Ch1,3.1.3(c), is to be issued. The certificate is to be validated by the manufacturer's representative, who is to be independent of the production process and LR.

6.7.2 Each test certificate is to contain the following particulars:

- Purchaser's name and order number.
- Details of the rope construction.
- Core material.
- Grade of zinc coating.
- Mechanical test results.
- Adhesion test results.
- Dimensions.
- Method of breaking load testing.
- Breaking load.

■ *Section 7* Fibre ropes

7.1 Manufacture

7.1.1 Fibre ropes intended as mooring lines may be made of coir, hemp, manila or sisal, or may be composed of synthetic (man-made) fibres. They may be three-strand (hawser laid), four-strand (shroud laid) or nine-strand (cable laid), but other constructions will be specially considered.

7.1.2 Each length of rope is to be manufactured from suitable material of good and consistent quality. Rope materials should, in general, comply with a recognised National Standard.

7.1.3 Synthetic fibre ropes are to be suitable for the purpose intended and should comply with a recognised standard.

7.1.4 Weighting and loading matter is not to be added, and any lubricant is to be kept to a minimum. Any rot-proofing or water repellancy treatment is not to be deleterious to the fibre nor is it to add to the weight or reduce the strength of the rope.

7.2 Tests of completed ropes

7.2.1 The breaking load is to be determined by testing to destruction a sample cut from the completed rope.

7.2.2 The minimum test length and the initial test load are to be as given in Table 10.7.1. After application of the initial load, the diameter and evenness of lay up of the sample are to be checked. The sample is then to be uniformly strained at the rate given in Table 10.7.1 until it breaks.

7.2.3 The actual breaking load is to be not less than that given in an appropriate National Standard.

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Table 10.7.1 Breaking load test

Material	Test length mm minimum	Initial load % (*see* Note)	Rate of straining mm/min
Natural fibre	1800	2	150 ± 50
Synthetic fibre	900	1	100 max.

NOTE
Percentage of specified minimum breaking load.

7.2.4 If the sample is held by grips and the break occurs within 150 mm of the grips, the test may be repeated, but not more than two tests may be made on any one coil.

7.2.5 Where difficulty is experienced in testing a sample of a completed synthetic fibre rope, LR will consider alternative methods of testing.

7.3 Identification

7.3.1 Each coil of rope is to be identified with an attached label detailing the material, construction, diameter and length.

7.4 Certification

7.4.1 A manufacturer's certificate, in accordance with Ch1,3.1.3(c), is to be issued. The certificate is to be validated by the manufacturer's representative, who is to be independent of the production process and LR.

7.4.2 Each test certificate is to include the following particulars:

- Manufacturer's name.
- Purchaser's name and order number.
- Rope type.
- Dimensions.
- Test length.
- Rate of straining.
- Breaking load.

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Approval of Welding Consumables

Chapter 11

Section 1

Section

1 **General**

2 **Mechanical testing procedures**

3 **Electrodes for manual and gravity welding**

4 **Wire-flux combinations for submerged-arc automatic welding**

5 **Wires and wire-gas combinations for manual, semi-automatic and automatic welding**

6 **Consumables for use in electro-slag and electro-gas welding**

7 **Consumables for use in one-side welding with temporary backing materials**

8 **Consumables for welding austenitic and duplex stainless steels**

9 **Consumables for welding aluminium alloys**

■ *Section 1* General

1.1 Scope

1.1.1 Provision is made in this Chapter for the approval by Lloyd's Register (hereinafter referred to as 'LR') of electrodes, wires, fluxes and other consumables intended for use in the welding of the following types of materials:

(a) Steel of various grades as represented by Grade A through to Grade FH69, *see* Sections 3 to 7.
(b) A wide range of low-temperature service steels, *see* Sections 3 to 7.
(c) Stainless steels including nitrogen strengthened grades and some of the duplex varieties, *see* Section 8.
(d) Aluminium alloys, *see* Section 9.

1.1.2 For this purpose, welding, consumables are categorised and subject to the special requirements of different Sections of this Chapter.

(a) Covered electrodes for manual welding and gravity welding.
(b) Combinations of wire and flux for automatic submerged-arc welding.
(c) Combinations of wire and gas for gas metal-arc welding and wires for self-shielding welding.
(d) Combinations for electro-slag and electro-gas welding.
(e) Combinations with temporary backing materials for one-side welding.
(f) Consumables for welding austenitic and duplex stainless steels.
(g) Combinations for welding aluminium.

1.2 Grading

1.2.1 Consumables for welding structural steels are graded into ten strength levels, and each of these is further subdivided into several levels in respect of notch toughness. The five basic levels of toughness are indicated by a number (1 to 5). Normal tensile strength is indicated by 'N'. Higher tensile strength is indicated by 'Y', and if the yield strength is higher than 375 N/mm^2 the Y is followed by a number (40 to 69), as shown in Table 11.1.1.

1.2.2 In addition to the grade, consumables are also allocated a suffix indicating the welding technique used. These are defined in the context of the following Sections of this Chapter.

1.2.3 Consumables for structural and low temperature service steels may be controlled low hydrogen and approved as such. Grade marking H15, H10 or H5 will be applied, as appropriate.

1.2.4 For joining higher strength steels, approval granted for 1Y consumables will be limited to maximum material thickness of 25 mm.

1.2.5 Test assemblies are not to be subjected to any heat treatment, except in those higher strength grades where it is considered necessary to use the welded joint in the stress relieved (tempered) condition. In those cases, the code 'sr' will be added to the approval grade.

1.2.6 Further details of grading are given in subsequent Sections of this Chapter.

1.3 Manufacture

1.3.1 The manufacturer's plant and method of production of welding consumables are to be such as to ensure reasonable uniformity in manufacture.

1.4 Approval procedures

1.4.1 Welding consumables will be approved subject to a satisfactory inspection of the works by the Surveyor for compliance with the test requirements detailed in subsequent Sections in this Chapter.

1.4.2 The test assemblies are to be prepared under the supervision of the Surveyor, and using samples selected by him. All tests are to be carried out in his presence.

1.4.3 For Charpy V-notch tests, a set of three test specimens is to be prepared and the average energy value is to comply with the requirements of subsequent Sections in this Chapter. One individual value may be less than the required average value provided that it is not less than 70 per cent of this value.

1.4.4 Where chemical analysis is required for approval, the results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

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Table 11.1.1 Welding consumable grades appropriate to structural and low temperature service steel grades

Consumable grade	Suitable for steel grades (*see* Notes)			
1. Ship Grade Steels (Ch 3,2 and Ch 3,3)				
1N	A	***AH27S***	—	—
2N	B, D	***DH27S***	—	—
3N	E	***EH27S***	—	—
1Y	A	***AH27S***	***AH32***	***AH36***
2Y	B, D	***DH27S***	***DH32***	***DH36***
3Y	E	***EH27S***	***EH32***	***EH36***
4Y	—	***FH27S***	***FH32***	***FH36***
2Y40	***AH32***	***AH36***	***AH40***	—
2Y40	***DH32***	***DH36***	***DH40***	—
3Y40	***EH32***	***EH36***	***EH40***	—
4Y40	***FH32***	***FH36***	***FH40***	—
5Y40	***FH32***	***FH36***	***FH40***	—
2. Higher and High Strength Steels (Ch 3,3 and Ch 3,10)				
3Y42	***AH36***	***AH40***	AH42	—
3Y42	***DH36***	***DH40***	DH42	—
4Y42	***EH36***	***EH40***	EH42	—
5Y42	***FH36***	***FH40***	FH42	—
3Y46	***AH40***	AH42	AH46	—
3Y46	***DH40***	DH42	DH46	—
4Y46	***EH40***	EH42	EH46	—
5Y46	***FH40***	FH42	FH46	—
3Y50	AH42	AH46	AH50	—
3Y50	DH42	DH46	DH50	—
4Y50	EH42	EH46	EH50	—
5Y50	FH42	FH46	FH50	—
3Y55	AH50	AH55	—	—
3Y55	DH50	DH55	—	—
4Y55	EH50	EH55	—	—
5Y55	FH50	FH55	—	—
3Y62	AH55	AH62	—	—
3Y62	DH55	DH62	—	—
4Y62	EH55	EH62	—	—
5Y62	FH55	FH62	—	—
3Y69	AH62	AH69	—	—
3Y69	DH62	DH69	—	—
4Y69	EH62	EH69	—	—
5Y69	FH62	FH69	—	—
3. Ferritic Low Temperature Service Steels (Ch 3,6)				
$1^1/_2$ Ni	$1^1/_2$ Ni	—	—	—
$3^1/_2$ Ni	$3^1/_2$ Ni	—	—	—
5 Ni	5 Ni	—	—	—
9 Ni	9 Ni	—	—	—

NOTES
1. Steel grades shown in bold italic type include the equivalent (LT-xxxx) low temperature service grades referenced in Ch 3,6.
2. The Table applies to the multi-run welding techniques (i.e. m, S, M).

1.4.5 LR may require, in any particular case, such additional tests or requirements as may be necessary.

1.4.6 A *List of Approved Welding Consumables* is published by LR.

1.4.7 LR is to be notified of any alteration proposed to be made in the process of manufacture subsequent to approval. Sufficient detail is to be provided to determine the need for further testing to maintain the approval.

1.4.8 Consideration will be given to alternative procedures for approval in the case of manufacturers producing consumables under the control of another manufacturer or plant already having approval of one or more products.

1.5 Annual inspection and tests

1.5.1 All establishments where approved welding consumables are manufactured, and the associated quality control procedures, are to be subjected to annual inspection. On these occasions, samples of the approved consumables are to be selected by the Surveyor and subjected to the tests detailed in subsequent Sections in this Chapter. These are to be completed and reported before the end of the one year period beginning at the initial approval date, and repeated annually so as to provide at least an average of one annual test per year.

1.6 Changes in grading

1.6.1 Changes in grading of welding consumables will be considered only at the manufacturer's request, preferably at the time of annual testing. For upgrading in connection with impact properties, and uprating in connection with tensile properties, tests from butt weld assemblies will be required in addition to the normal annual approval tests. For upgrading in connection with hydrogen testing, specific tests will be required in accordance with ISO 3690. Downgrading and downrating may be imposed by LR where tests and re-tests fail to meet the requirements of this Chapter.

1.7 Manufacturers' Quality Assurance Systems

1.7.1 As an alternative to 1.5, manufacturers may seek maintenance of approval based on acceptance by LR of their 'in house' quality assurance system, and by regular audit of that system carried out in accordance with procedures approved by LR.

1.8 Certification

1.8.1 Each carton or package of approved electrodes is to contain a certificate from the manufacturer, generally in accordance with the following: 'The *<insert name of manufacturer>* company certifies that the composition and quality of these electrodes conform with those of the electrodes used in making the test pieces submitted to and approved by the approval bodies nominated on the label of this package.'

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Section 2
Mechanical testing procedures

2.1 Dimensions of test specimens

2.1.1 Dimensions of test pieces for deposited metal tensile tests, butt weld tensile tests, bend tests and Charpy V-notch impact test are to machined to the dimensions and tolerances detailed in Chapter 2.

2.2 Testing procedures

2.2.1 The procedures used for all tensile and impact tests are to comply with the requirements of Chapter 2.

2.2.2 Butt weld bend test specimens are to be tested at ambient temperature and are to be bent through an angle of 120° over a former having a diameter which relates to the thickness of the test specimen as detailed in subsequent Sections. For each pair of bend test specimens, one specimen is to be tested with the face of the weld in tension and the other with the root of the weld in tension.

2.2.3 Macro examinations are to be carried out on polished and etched specimens at a maximum magnification not exceeding x10. The examination is to ensure complete fusion, inter-run penetration and freedom of defects.

2.3 Re-testing procedures

2.3.1 Re-testing procedures are to comply with Ch 2,1.4.

Section 3
Electrodes for manual and gravity welding

3.1 General

3.1.1 Dependent on the results of the mechanical and other tests, approval will be allocated as one of the grades from Table 11.1.1.

3.1.2 Approval of an electrode will be given in conjunction with a welding technique indicated by a suffix 'm' for manual welding, 'G' for gravity or contact electrode and 'p' for deep penetration electrode.

3.1.3 If the electrodes are in compliance with the requirements of the hydrogen test given in 3.4, a suffix 'H15' or 'H10' or 'H5' will be added to the grade mark. Table 11.3.1 shows the mandatory levels of low hydrogen approval for the various approval grades.

3.1.4 For each strength level, electrodes which have satisfied the requirements for a higher toughness grade are considered as complying with the requirements for a lower grade.

Table 11.3.1 Minimum low hydrogen approval requirements for manual and gravity electrodes

Approval grades	Low hydrogen grade required
1 (1N), 2 (2N), 3 (3N)	NR
2Y, 3Y, 4Y	H15 (*see* Note 2)
2Y40 to 5Y40	H15
3Y42 to 5Y42	H10
3Y46 to 5Y46	H10
3Y50 to 5Y50	H10
3Y55 to 5Y55	H5
3Y62 to 5Y62	H5
3Y69 to 5Y69	H5
$1^1/_2$ Ni	H15
$3^1/_2$ Ni	H15
5 Ni	NR (*see* Note 3)
9 Ni	NR (*see* Note 3)

NOTES
1. NR – Not required, but approval can be sought, if desired.
2. Optional in this case. If low hydrogen approval is not obtained, there is a limitation on the carbon equivalent of the steel which is permitted to be welded.
3. Assumes use of an austenitic, non-transformable, filler material.

3.1.5 Electrodes approved for normal and higher strength levels up to and including 'Y' are also considered suitable for welding steels in the three strength levels below that for which they have been approved.

3.1.6 Electrodes approved for strength levels between Y40 and up to and including Y50 are also considered suitable for welding steels in two strength levels below that for which they have been approved.

3.1.7 Electrodes approved for strength levels Y55 and above are also considered suitable for welding steels in only one strength level below that for which they have been approved.

3.1.8 The welding current used is to be within the range recommended by the manufacturer and, where an electrode is stated to be suitable for both a.c. and d.c., a.c. is to be used for the preparation of the test assemblies.

3.1.9 Where an electrode is submitted only for approval for fillet welding and to which the butt weld test provided in 3.3 is not considered applicable, approval tests are to consist of the fillet weld tests as given in 3.5 and deposited metal tests with chemical analyses as given in 3.2.

3.2 Deposited metal test assemblies

3.2.1 The deposited metal test assemblies are to be prepared in the downhand position as shown in Fig. 11.3.1, one with 4 mm diameter electrodes and the other with 8 mm diameter electrodes, or the largest size manufactured if this is less than 8 mm diameter. If an electrode is available in one diameter only, one test assembly is sufficient. Any of the grades of steel in Table 11.1.1 may be used for the preparation of these assemblies, up to a strength level which is not more than two levels above that for which approval is sought.

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3.2.2 The weld metal is to be deposited in single- or multi-run layers according to normal practice, and the direction of deposition of each layer is to alternate from each end of the plate, each run of weld metal being not less than 2 mm and not more than 4 mm thick. Between each run, the assembly is to be left in still air until it has cooled to less than 250°C, the temperature being taken in the centre of the weld, on the surface of the seam. After being welded, the test assemblies are not to be subjected to any heat treatment, except in those higher strength grades where it is considered necessary to use the welded joint in the stress-relieved (tempered) condition. In those cases, the code 'sr' will be added to the approval grading.

3.2.3 The chemical analysis of the deposited weld metal in each deposited metal test assembly is to be supplied by the manufacturer and is to include the content of all significant alloying elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

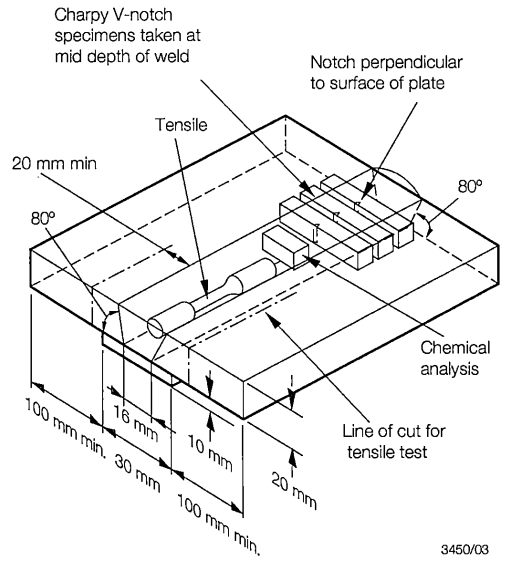

Fig. 11.3.1 Deposited metal test assembly

Table 11.3.2 Requirements for deposited metal tests (covered electrodes)

Grade (*see* Note 3)	Yield stress N/mm² minimum	Tensile strength N/mm² (*see* Note 1)	Elongation on 50 mm % minimum	Charpy V-notch impact tests	
				Test temperature °C	Average energy (*see* Note 2) J minimum
1N, 2N, 3N	305	400 – 560	22	+20, 0, –20	47
1Y, 2Y, 3Y, 4Y	375	490 – 660	22	+20, 0, –20, –40	47
2Y40	400	510 – 690	22	0	47
3Y40	400	510 – 690	22	–20	47
3Y42	420	530 - 680	20	–20	47
3Y46	460	570 – 720	20	–20	47
3Y50	500	610 – 770	18	–20	50
3Y55	550	670 – 830	18	–20	55
3Y62	620	720 – 890	18	–20	62
3Y69	690	770 – 940	17	–20	69
4Y40	400	510 – 690	22	–40	47
4Y42	420	530 – 680	20	–40	47
4Y46	460	570 – 720	20	–40	47
4Y50	500	610 – 770	18	–40	50
4Y55	550	670 – 830	18	–40	55
4Y62	620	720 – 890	18	–40	62
4Y69	690	770 – 940	17	–40	69
5Y40	400	510 – 690	22	–60	47
5Y42	420	530 – 680	20	–60	47
5Y46	460	570 – 720	20	–60	47
5Y50	500	610 – 770	18	–60	50
5Y55	550	670 – 830	18	–60	55
5Y62	620	720 – 890	18	–60	62
5Y69	690	770 – 940	17	–60	69
1½ Ni	375	460	22	–80	34
3½ Ni	375	420	25	–100	34
5 Ni	375	500	25	–120	34
9 Ni	375	600	25	–196	34

NOTES
1. Single values are the minimum requirements.
2. Energy values from individual impact test specimens are to comply with 1.4.3.
3. Grade 1Y is not applicable to SMAW consumables referenced in Section 3.

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3.2.4 One tensile and three impact test specimens are to be taken from each test assembly as shown in Fig. 11.3.1. Care is to be taken that the axis of the tensile test specimen coincides with the centre of the weld and the mid-thickness of the plates. The impact test specimens are to be cut perpendicular to the weld, with their axes 10 mm from the upper surface. The notch is to be positioned in the centre of the weld and cut in the face of the test specimen perpendicular to the surface of the plate.

3.2.5 The results of all tests are to comply with the requirements of Table 11.3.2 as appropriate.

3.3 Butt weld test assemblies

3.3.1 Butt weld assemblies, as shown in Fig. 11.3.2, are to be prepared for each welding position (downhand, horizontal-vertical, vertical-upward, vertical-downward, and overhead) for which the electrode is recommended by the manufacturer. In the case of electrodes for normal strength and higher strength steels (up to 355 N/mm^2 minimum specified yield strength), electrodes satisfying the requirements for downhand and vertical-upward positions will be considered as also complying with the requirements for the horizontal-vertical position. In all other cases, approval for the horizontal-vertical position will require a butt weld to be made in that position and fully tested.

3.3.2 Where the electrode is to be approved only in the downhand position, an additional test assembly is to be prepared in that position.

3.3.3 The grades of steel used for the preparation of the test assemblies are to be as follows:

Grade 1 (1N) electrodes	A
Grade 2 (2N) electrodes	A, B or D
Grade 3 (3N) electrodes	A, B, D or E
Grade 2Y electrodes	AH32, AH36, DH32 or DH36
Grade 3Y electrodes	AH32, AH36, DH32, DH36, EH32 or EH36
Grade 4Y electrodes	AH32 AH36, DH32, DH36, EH32, EH36, FH32 or FH36
Grade 2Y40 electrodes	AH40 or DH40
Grade 3Y40 electrodes	AH40, DH40 or EH40
Grade 4Y40 electrodes	AH40, DH40, EH40 or FH40
Grade 5Y40 electrodes	AH40, DH40, EH40 or FH40

Where Grade 32 higher tensile steel is used, the tensile strength is to be not less than 490 N/mm^2. The chemical composition, including the content of grain refining elements, is to be reported in all cases where higher tensile steel is used.

3.3.4 For all other grades, the steel plates used are to be selected by reference to Table 11.1.1, and are to have at least their chemical composition and tensile properties within the limits specified for that grade in Chapter 3. The strength grade used is to be the same as that for which approval is sought, and the toughness grade is to be no higher than that for which approval is also sought.

3.3.5 The test assemblies are to be made by welding together two plates of equal thickness (15 to 20 mm), not less than 100 mm in width and of sufficient length to allow the cutting out of test specimens of the prescribed number and size. The plate edges are to be prepared to form a single V-joint, the included angle between the fusion faces being 60° and the root gap 2 to 3 mm. The root face is to be 0 to 2 mm.

3.3.6 The following welding procedure is to be adopted in making the test assemblies:

Downhand (a). The first run with 4 mm diameter electrode. Remaining runs (except the last two layers) with 5 mm diameter electrodes or above according to the normal welding practice with the electrodes. The runs of the last two layers with the largest diameter of electrode manufactured or 8 mm whichever is the lesser.

Downhand (b) (where a second downhand test is required). First run with 4 mm diameter electrode. Next run with an electrode of intermediate diameter of 5 mm or 6 mm, and the remaining runs with the largest diameter of electrode manufactured or 8 mm whichever is the lesser.

Horizontal-vertical. First run with 4 mm or 5 mm diameter electrode. Subsequent runs with 5 mm diameter electrodes.

Vertical-upward and overhead. First run with 3,25 mm diameter electrode. Remaining runs with 4 mm diameter electrodes or possibly with 5 mm if this is recommended by the manufacturer for the positions concerned.

Vertical-downward. If the electrode being tested is intended for vertical welding in the downward direction, this technique is to be adopted for the preparation of the test assembly using electrode diameters as recommended by the manufacturer.

3.3.7 For all assemblies, the back sealing runs are to be made with 4 mm diameter electrodes in the welding position appropriate to each test sample, after cutting out the root run to clean metal. For electrodes suitable for downhand welding only, the test assemblies may be turned over to carry out the back sealing run.

3.3.8 Normal welding practice is to be used and, between each run, the assembly is to be left in still air until it has cooled to less than 250°C, the temperature being taken in the centre of the weld, on the surface of the seam. After being welded, the test assemblies are not to be subjected to any heat treatment, except in those higher strength grades where it is considered necessary to use the welded joint in the stress-relieved (tempered) condition. In those cases, the code 'sr' will be added to the approval grading.

3.3.9 It is recommended that the welded assemblies be subjected to a radiographic examination to ascertain if there are any defects in the weld prior to the preparation of test specimens.

3.3.10 The test specimens as shown in Figs. 11.3.2 and 11.3.3 are to be prepared from each test assembly.

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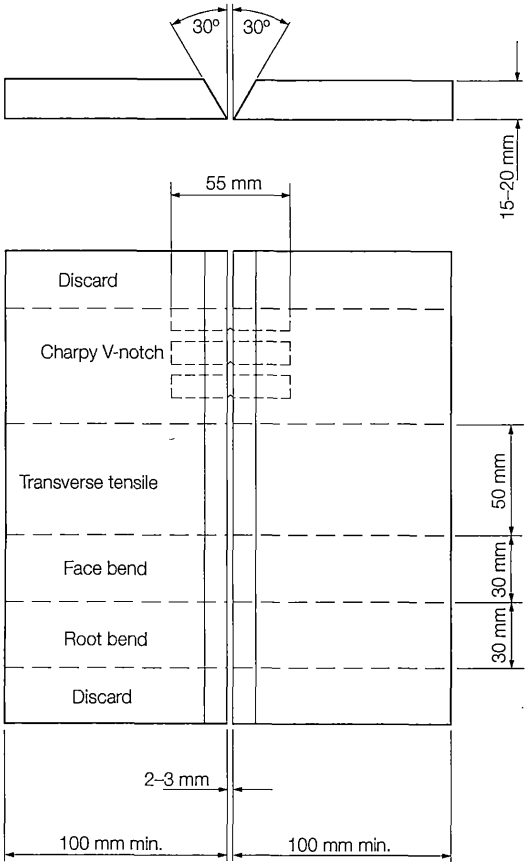

Fig. 11.3.2 Butt weld test assembly

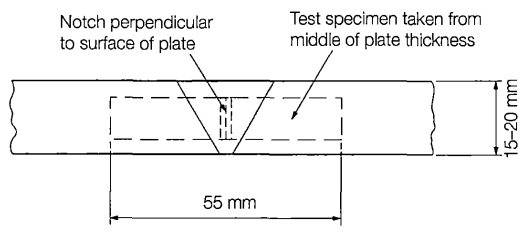

Fig. 11.3.3
Butt weld test assembly position of impact test specimens

3.3.11 The results of all tensile and impact tests are to comply with the requirements of Table 11.3.3 as appropriate. The position of fracture in the transverse tensile test is to be reported.

3.3.12 The bend test specimens can be considered as complying with the requirements if, after bending, no crack or other open defect exceeding 3 mm in dimensions can be seen on the outer surface.

3.4 Hydrogen test

3.4.1 The hydrogen gradings are specified in 3.1.3. The hydrogen grading required determines the method of testing permitted as shown in Table 11.3.4. Where ISO 3690 is used as the testing method, three test specimens are to be prepared and tested, and all three hydrogen test results must be below the maximum value for the hydrogen mark required.

3.5 Fillet weld test assemblies

3.5.1 Fillet weld assemblies as shown in Fig. 11.3.4 are to be prepared for each welding position (horizontal-vertical, vertical-upward, vertical-downward or overhead) for which the electrode is recommended by the manufacturer. The grade of steel used for the test assemblies is to be as detailed in 3.3.3. The length of the test assembly, *L*, is to be sufficient to allow at least the deposition of the entire length of the largest diameter electrode being tested. Where an electrode is submitted for approval of both butt and fillet welding, approval tests are to include the deposited metal tests as given in 3.2, the butt weld tests as given in 3.3, and only one fillet weld test as given in subsequent paragraphs of this sub-Section welded in the horizontal-vertical position.

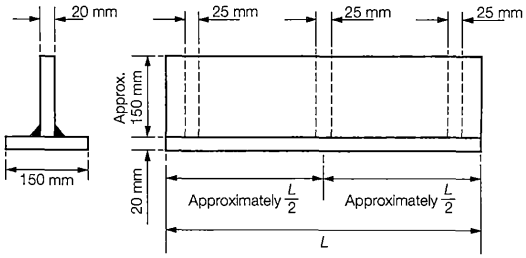

Fig. 11.3.4 Fillet weld test assembly

3.5.2 The electrode sizes to be used are the maximum and minimum diameters recommended by the manufacturer for fillet welding. The first side is to be welded using the maximum diameter. The second side is to be welded only after the assembly has been allowed to cool below 50°C using the minimum diameter. The size of these single run fillet welds will, in general, be determined by the electrode size and the welding current employed during testing and should represent the range of fillet weld bead sizes recommended by the manufacturer.

3.5.3 Each test assembly is to be sectioned to form three macro-sections, each about 25 mm thick. These are to be examined for root penetration, satisfactory profile, freedom from cracking and reasonable freedom from porosity and slag inclusions. Any undercut is not to exceed 0,5 mm in depth. Convexity or concavity of the profile is not to exceed one-tenth of the fillet bead throat dimension. All such observations are to be reported.

3.5.4 Hardness measurements are to be made on the central macro-section only, as shown in Fig. 11.3.5. The results are to be reported.

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Table 11.3.3 Requirements for butt weld tests (covered electrodes)

Grade (*see* Note 3)	Tensile strength N/mm^2	Bend test ratio: $\frac{D}{t}$	Charpy V-notch impact tests	
			Test temperature °C	Average energy (*see* Note 1) J minimum
				All positions (*see* Note 2)
1N, 2N, 3N	400	3	+20, 0, –20	47 (34)
1Y, 2Y, 3Y, 4Y	490	3	+20, 0, –20, –40	47 (34)
2Y40	510	3	0	47 (39)
3Y40	510	3	–20	47 (39)
3Y42	530 – 680	4	–20	47
3Y46	570 – 720	4	–20	47
3Y50	610 – 770	4	–20	50
3Y55	670 – 830	5	–20	55
3Y62	720 – 890	5	–20	62
3Y69	770 – 940	5	–20	69
4Y40	510	3	–40	47 (39)
4Y42	530 – 680	4	–40	47
4Y46	570 – 720	4	–40	47
4Y50	610 – 770	4	–40	50
4Y55	670 – 830	5	–40	55
4Y62	720 – 890	5	–40	62
4Y69	770 – 940	5	–40	69
5Y40	510	3	–60	39
5Y42	530 – 680	4	–60	47
5Y46	570 – 720	4	–60	47
5Y50	610 – 770	4	–60	50
5Y55	670 – 830	5	–60	55
5Y62	720 – 890	5	–60	62
5Y69	770 – 940	5	–60	69
1 1/2 Ni	490	3	–80	27
3 1/2 Ni	450	3	–100	27
5 Ni	540	4	–120	27
9 Ni	640	4	–196	27

NOTES
1. *Energy values from individual impact test specimens are to comply with 1.4.3.*
2. Values in ( ) apply only to welds made in the vertical position with upward progression.
3. Grade 1Y is not applicable to SMAW consumables referenced in Section 3.

Table 11.3.4 Permitted methods for obtaining low hydrogen grading

Hydrogen Grade	Permitted Method
H15	ISO 3690 (or Glycerine) (*See* Note)
H10	ISO 3690
H5	ISO 3690

NOTE
ISO method preferred.

3.5.5 One of the remaining sections of the assembly is to have the weld on the first side gouged or machined to facilitate breaking the fillet weld on the second side by closing the two plates together, subjecting the root of the weld to tension. On the other remaining section, the weld on the second side is to be gouged or machined and the section fractured using the same procedure. The fractured surfaces are to be examined. They are to show satisfactory penetration, freedom from cracks and reasonable freedom from porosity and this should be reported.

3.6 Electrodes designed for deep penetration welding

3.6.1 Where an electrode is designed solely for the deep penetration welding of downhand butt joints and horizontal-vertical fillets in normal tensile strength steel, only the tests detailed in 3.7 and 3.8 are required for approval purposes.

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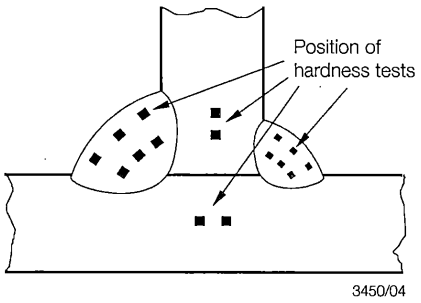

Fig. 11.3.5
Hardness tests for fillet weld test assembly

3.6.2 Electrodes designed solely for the deep penetration welding technique will be approved as complying with Grade 1 requirements only and will be given the suffix 'p'.

3.6.3 Where a manufacturer recommends that an electrode having deep penetrating properties can also be used for downhand butt welding of thicker plates with prepared edges, the electrode will be treated as a normal penetration electrode, and the full series of tests in the downhand position is to be carried out, together with the deep penetration tests given in 3.7 and 3.8.

3.6.4 Where a manufacturer desires to demonstrate that an electrode, in addition to its use as a normal penetration electrode, also has deep penetrating properties when used for downhand butt welding and horizontal fillet welding, the additional tests given in 3.7 and 3.8 are to be carried out.

3.6.5 Electrodes approved for both normal and deep penetration welding will have the suffix 'p' added after the appropriate grade mark for normal penetration welding.

3.6.6 Where the manufacturer prescribes a different welding current and procedure for the electrode when used as a deep penetration electrode and a normal penetration electrode, the recommended current and procedure are to be used when making the test assemblies in each case.

3.7 Deep penetration butt weld test assemblies

3.7.1 Two plates of thickness equal to twice the diameter of the core of the electrode plus 2 mm are to be butt welded together with one downhand run of welding from each side. The plates are to be not less than 100 mm wide and of sufficient length to allow the cutting out of the test specimens of the correct number and size as shown in Fig. 11.3.6. Grade A steel is to be used for these test assemblies. The joint edges are to be prepared square and smooth and, after tacking, the gap is not to exceed 0,25 mm. The test assembly is to be welded using an 8 mm diameter electrode, or the largest diameter manufactured if this is less than 8 mm and the assembly is to be allowed to cool below 50°C between runs.

3.7.2 The test specimens as shown in Figs. 11.3.3 and 11.3.6 are to be prepared from each test assembly.

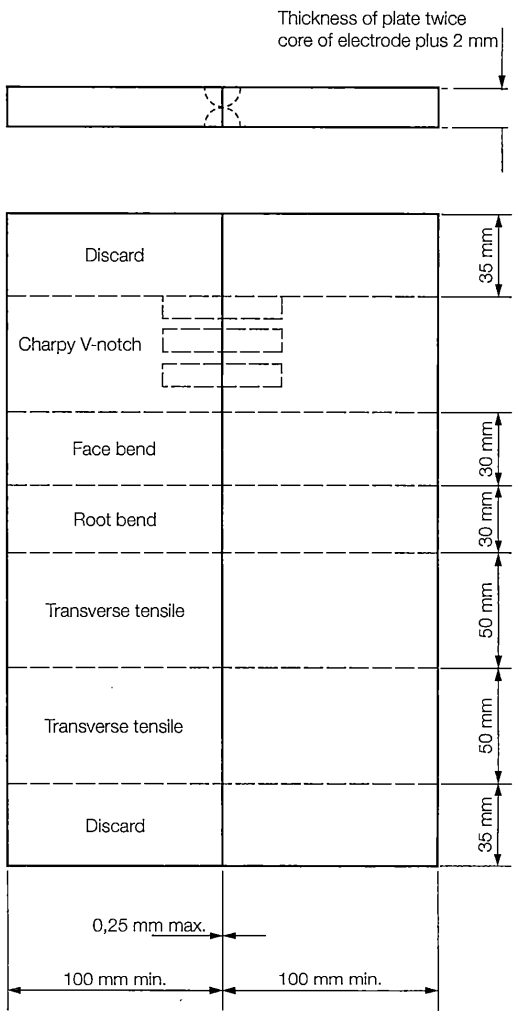

Fig. 11.3.6
Deep penetration butt weld test assembly

3.7.3 The results of tensile and impact tests are to comply with the requirements of Table 11.3.3 for Grade 1 electrodes. The position of fracture in the tensile test is to be reported. The bend test specimens are to be in accordance with 3.3.12.

3.7.4 The discards at the end of the welded assemblies are to be not more than 35 mm wide. The joints of these discards are to be polished and etched and must show complete fusion and inter-penetration of the weld beads. At each cut in the test assembly, the joints are also to be examined to ensure that complete fusion has taken place.

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3.8 Deep penetration fillet weld test assemblies

3.8.1 A fillet weld assembly is to be prepared as shown in Fig. 11.3.7 with plates about 12,5 mm in thickness. The welding is to be carried out with one run for each fillet with plate A in the horizontal plane during the welding operations. The length of the fillet is to be 160 mm and the gap between the plates is to be not more than 0,25 mm. Grade A steel is to be used for these test assemblies.

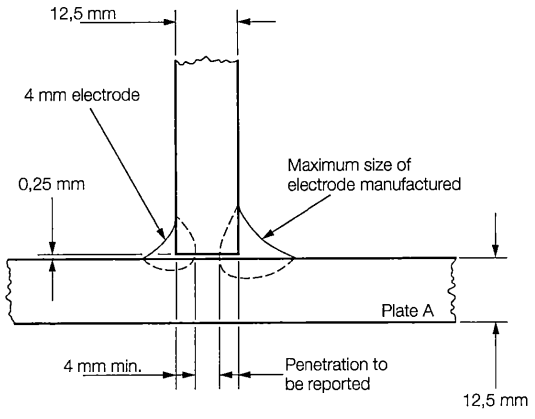

Fig. 11.3.7
Deep penetration fillet weld test assembly

3.8.2 The fillet weld on one side of the assembly is to be carried out with a 4 mm diameter electrode, and that on the other side with the maximum diameter of electrode manufactured. The welding current used is to be within the range recommended by the manufacturer, and the welding is to be carried out using normal welding practice except that the assembly is to be allowed to cool below 50°C between runs.

3.8.3 The welded assembly is to be cut by sawing or machining within 35 mm of the ends of the fillet welds, and the joints are to be polished and etched. The welding of the fillet made with a 4 mm diameter electrode is to show a penetration of 4 mm (*see* Fig. 11.3.7) and the corresponding penetration of the fillet made with the maximum diameter of electrode manufactured is to be reported.

3.9 Electrodes designed for gravity or contact welding

3.9.1 Approval for welding using the gravity, 'G', technique is available for welding only normal strength and higher tensile steels up to and including Grade 36.

3.9.2 Where an electrode is submitted solely for approval for use in contact welding using automatic gravity or similar welding devices, deposited metal tests, butt weld tests and, where appropriate, fillet weld tests similar to those for normal manual electrodes are to be carried out using the process for which the electrode is recommended by the manufacturer.

3.9.3 Where an electrode is submitted for approval for use in contact welding using automatic gravity or similar welding devices in addition to normal manual welding, butt weld and, where appropriate, fillet weld tests, using the gravity or other contact device as recommended by the manufacturer, are to be carried out in addition to the normal approval tests.

3.10 Annual tests

3.10.1 For normal penetration electrodes, the annual tests are to consist of two deposited metal test assemblies. These are to be prepared and tested in accordance with 3.2. If an electrode is available in one diameter only, one test assembly is sufficient.

3.10.2 Where an electrode is approved solely for deep penetration welding, the annual test is to consist of one butt welded test assembly. This is to be prepared and tested in accordance with 3.7.

3.10.3 Where an electrode is approved for both normal and deep penetration welding, annual tests as detailed in 3.10.1 and 3.10.2 are to be carried out.

3.10.4 Where an electrode is approved solely for gravity or contact welding, the annual test is to consist of one deposited metal test assembly using the gravity or other contact device as recommended by the manufacturer.

3.10.5 Where an electrode is approved for both manual and gravity welding, annual tests as detailed in 3.10.1 and 3.10.4 are to be carried out.

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Section 4
Wire-flux combinations for submerged-arc automatic welding

4.1 General

4.1.1 Wire-flux combinations for single and multiple electrode submerged-arc automatic welding, without the use of temporary backing, are divided into the following two categories:

- For use with the multi-run technique.
- For use with the two-run technique.

Where particular wire-flux combinations are intended for welding with both techniques, tests are to be carried out for each technique.

4.1.2 Dependent on the results of mechanical and other tests, approval will be allocated as one of the grades from Table 11.1.1.

4.1.3 The suffixes T or M will be added after the grade mark to indicate approval for the two-run technique or, multi-run technique respectively.

4.1.4 Wire-flux combinations satisfying the requirements for multi-run or two-run techniques will also be approved for fillet welding in the downhand and horizontal-vertical position, subject to agreement by the manufacturer.

4.1.5 If the consumable combination is in compliance with the requirements of the hydrogen test given in 3.4, a suffix H15, H10 or H5 will be added to the grade. Table 11.4.1 shows the mandatory levels of low hydrogen approval for the various approval grades.

Table 11.4.1 Minimum low hydrogen approval requirements for wire-flux combinations

Approval grade	'H' grade for Multi-run	'H' grade for Two-run
1 (1N), 2 (2N), 3 (3N)	NR	NR
1Y, 2Y, 3Y, 4Y	NR	NR
2Y40 to 5Y40	H15	NR
3Y42 to 5Y42	H10	H15
3Y46 to 5Y46	H10	H15
3Y50 to 5Y50	H10	H10
3Y55 to 5Y55	H5	H10
3Y62 to 5Y62	H5	H5
3Y69 to 5Y69	H5	H5
1½ Ni	H15	NR
3½ Ni	H15	NR
5 Ni (*see* Note 2)	NR	NR
9 Ni (*see* Note 2)	NR	NR

NOTES
1. NR – Not required, but approval can be sought, if desired.
2. Assumes use of an austenitic, non-transformable, filler material.

4.1.6 For each strength level, wire-flux combinations which have satisfied the requirements for a higher toughness grade are considered as complying with the requirements for a lower grade.

4.1.7 Wire-flux combinations approved with multi-run technique for normal and higher strength levels up to and including 'Y' are also considered suitable for welding steels in the three strength levels below that for which they have been approved.

4.1.8 Wire-flux combinations approved with multi-run technique for strength levels between Y40 and up to and including Y50 are also considered suitable for welding steels in two strength levels below that for which they have been approved.

4.1.9 Wire-flux combinations approved with multi-run technique for strength levels Y55 and above are also considered suitable for welding steels in only one strength level below that for which they have been approved.

4.1.10 Wire-flux combinations with two-run technique approval are not considered suitable for welding steels of any other strength level with that technique, *see* 4.5.1.

4.1.11 The welding current may be either a.c. or d.c. (electrode positive or negative) according to the recommendation of the manufacturer. If both a.c. and d.c. are recommended, a.c. is to be used for the tests.

4.1.12 Wire-flux combinations for multiple electrode submerged-arc welding will be subject to separate approval tests. These are to be carried out generally in accordance with the requirements of this Section.

4.1.13 Wire-flux combinations are not naturally low hydrogen in character, but for the lower strength grades of steel low hydrogen testing is not normally a requirement for approval. With higher strength steels it is more important and Table 11.4.1 shows the mandatory minimum low hydrogen status required for approval of wire-flux combinations.

4.2 Approval tests for multi-run technique

4.2.1 Where approval for use with the multi-run technique is requested, deposited metal and butt weld tests are to be carried out.

4.3 Deposited metal test assemblies (multi-run technique)

4.3.1 One deposited metal test assembly is to be prepared as shown in Fig. 11.4.1, using any of the grades of steel in Table 11.1.1 up to a strength level which is not more than two levels above that for which approval is sought.

4.3.2 The bevelling of the plate edges is to be carried out by machining or mechanised gas cutting. In the latter case any remaining scale is to be removed from the bevelled edges.

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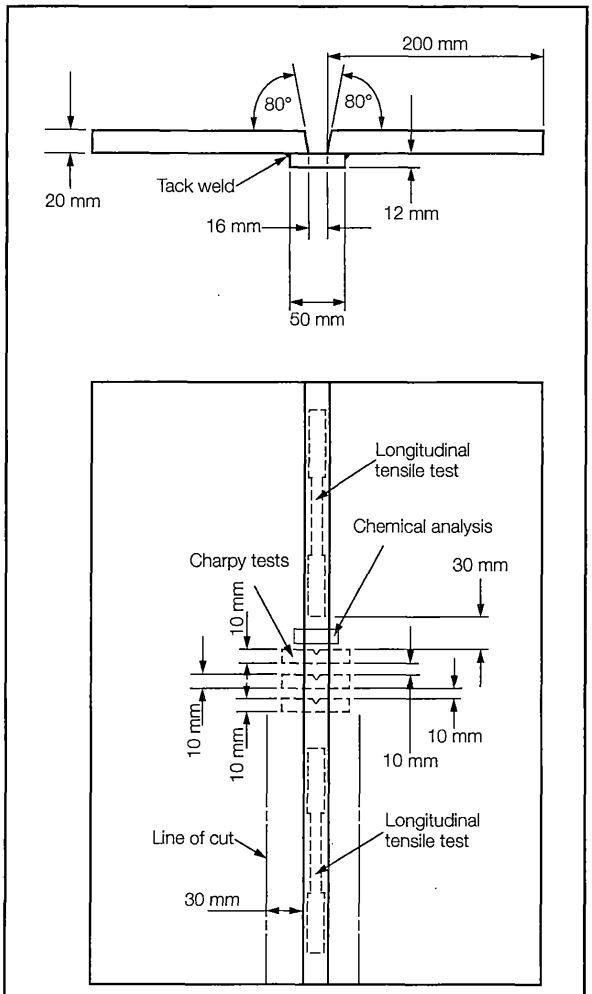

Fig. 11.4.1 Deposited metal test assembly

4.3.3 Welding is to be in the downhand position, and the direction of deposition of each run is to alternate from each end of the plate. After completion of each run, the flux and welding slag are to be removed. Between each run, the assembly is to be left in still air until it has cooled to less than 250°C, the temperature being taken in the centre of the weld, on the surface of the seam. The thickness of the layer is to be not less than the diameter of the wire nor less than 4 mm, unless it is clearly stated as part of the consumable manufacturer's published recommendations.

4.3.4 The welding conditions (amperage, voltage and rate of travel) are to be in accordance with the recommendations of the manufacturer and are to conform with normal good welding practice for multi-run welding.

4.3.5 The chemical analysis of the deposited weld metal in each test assembly is to be supplied by the manufacturer and is to include the content of all significant alloying elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

4.3.6 Two longitudinal tensile and three impact test specimens are to be taken from each test assembly as shown in Fig. 11.4.1. Care is to be taken that the axes of the tensile test specimens coincide with the centre of the weld and the mid-thickness of the plates. The impact test specimens are to be cut perpendicular to the weld with their axes 10 mm from the upper surface. The notch is to be positioned in the centre of the weld and cut in the face of the test specimen perpendicular to the surface of the plate.

4.3.7 In those cases where two-run technique approval is also sought, only one longitudinal tensile specimen need be prepared and tested from this assembly.

4.3.8 The results of all tests are to comply with the requirements of Table 11.4.2, as appropriate.

4.4 Butt weld test assemblies (multi-run technique)

4.4.1 One butt weld test assembly is to be prepared as shown in Fig. 11.4.2.

4.4.2 The grade of steel used for the preparation of the test assembly are to be as follows:

Grade 1 wire-flux combination	A
Grade 2 wire-flux combinations	A, B or D
Grade 3 wire-flux combinations	A, B, D or E
Grade 1Y wire-flux combination	AH32 or AH36
Grade 2Y wire-flux combinations	AH32, AH36, DH32 or DH36
Grade 3Y wire-flux combinations	AH32, AH36, DH32, DH36, EH32 or EH36
Grade 4Y wire-flux combinations	AH32, AH36, DH32, DH36, EH32, EH36, FH32 or FH36
Grade 2Y40 wire-flux combination	AH40 or DH40
Grade 3Y40 wire-flux combinations	AH40, DH40 or EH40
Grade 4Y40 wire-flux combinations	AH40, DH40, EH40 or FH40
Grade 5Y40 wire-flux combinations	AH40, DH40 EH40, FH40

Where Grade 32 higher tensile steel is used, the tensile strength is to be not less than 490 N/mm^2. The chemical composition, including the content of grain refining elements, is to be reported in all cases where higher tensile steel is used.

4.4.3 For all other grades, the steel plates used are to be selected by reference to Table 11.1.1, and are to have at least their chemical composition and tensile properties within the limits specified for that grade in Chapter 3. The strength grade used is to be the same as that for which approval is sought, and the toughness grade is to be no higher than that for which approval is also sought.

4.4.4 The plate edges are to be prepared to form a single V-joint, the included angle between the fusion faces being 60° and the root face being 4 mm. The bevelling of the plate edges is to be carried out by machining or mechanised gas cutting. In the latter case, any remaining scale is to be removed from bevelled edges.

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Table 11.4.2 Requirements for deposited metal tests (wire-flux combinations)

Grade	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation on 50 mm % minimum	Charpy V-notch impact tests	
				Test temperature °C	Average energy (*see* Note) J minimum
1N, 2N, 3N	305	400 – 560	22	+20, 0, –20	34
1Y, 2Y, 3Y, 4Y	375	490 – 660	22	+20, 0, –20, –40	34
2Y40	400	510 – 690	22	0	39
3Y40	400	510 – 690	22	–20	39
3Y42	420	530 – 680	20	–20	47
3Y46	460	570 – 720	20	–20	47
3Y50	500	610 – 770	18	–20	50
3Y55	550	670 – 830	18	–20	55
3Y62	620	720 – 890	18	–20	62
3Y69	690	770 – 940	17	–20	69
4Y40	400	510 – 690	22	–40	39
4Y42	420	530 – 680	20	–40	47
4Y46	460	570 – 720	20	–40	47
4Y50	500	610 – 770	18	–40	50
4Y55	550	670 – 830	18	–40	55
4Y62	620	720 – 890	18	–40	62
4Y69	690	770 – 940	17	–40	69
5Y40	400	510 –690	22	–60	39
5Y42	420	530 – 680	20	–60	47
5Y46	460	570 – 720	20	–60	47
5Y50	500	610 – 770	18	–60	50
5Y55	550	670 – 830	18	–60	55
5Y62	620	720 – 890	18	–60	62
5Y69	690	770 – 940	17	–60	69
1^1/$_2$ Ni	375	460	22	–80	34
3^1/$_2$ Ni	375	420	25	–100	34
5 Ni	375	500	25	–120	34
9 Ni	375	600	25	–196	34

NOTE
Energy values from individual impact test specimens are to comply with 1.4.3.

4.4.5 Welding is to be carried out in the downhand position by the multi-run technique, and the welding conditions are to be the same as those adopted for the deposited metal test assembly. The back sealing run is to be applied in the downhand position after cutting out the root run to clean metal.

4.4.6 It is recommended that the welded assembly be subjected to a radiographic examination to ascertain if there are any defects in the weld prior to the preparation of test specimens.

4.4.7 The test specimens as shown in Fig. 11.3.3 and Fig. 11.4.2 are to be prepared from each test assembly.

4.4.8 The results of all tensile and impact tests are to comply with the requirements of Table 11.4.3, as appropriate. The position of fracture of the transverse tensile test is to be reported.

4.4.9 The bend test specimens can be considered as complying with the requirements if, after bending, no cracks or other open defects exceeding 3 mm in dimension can be seen on the outer surface.

4.5 Approval tests for two-run technique

4.5.1 Where approval for use with the two-run technique is requested, two butt weld test assemblies are to be prepared and tested using plates of the strength level for which approval is required. Each strength level requires separate approval.

4.5.2 Two welded assemblies are to be made from a pair of plates of matching thicknesses. The thickness of the thicker pair of plates will be the maximum for which the approval is valid. The second assembly is to be welded from plates having approximately half of the thickness of the first assembly.

4.6 Butt weld test assemblies (two-run technique)

4.6.1 The grade of steel used for the preparation of the test assemblies is not to be of any higher grade (impact toughness) than that for which approval is required. The chemical composition, including the content of grain refining elements, and the strength properties of the plates used, are to be reported.

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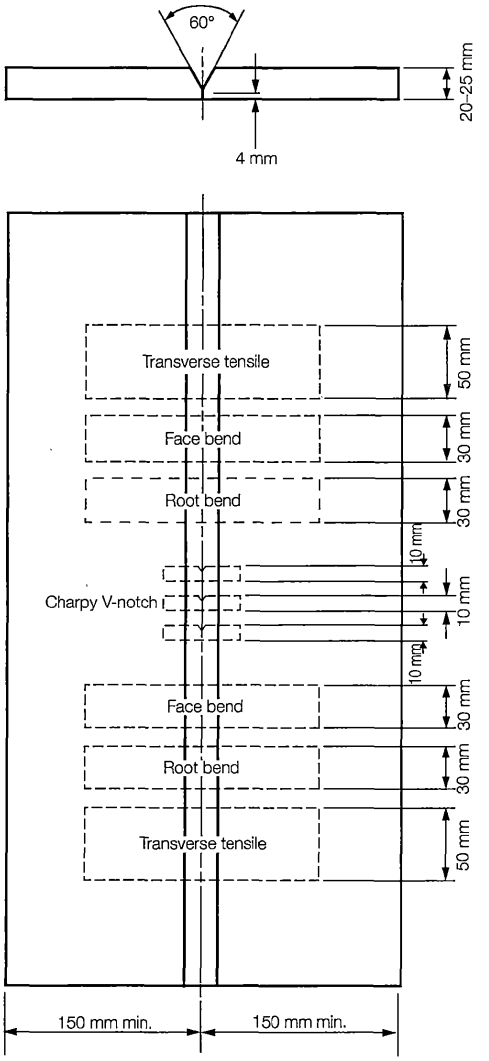

Fig. 11.4.2
Butt weld test assembly (multi-run technique)

4.6.2 The maximum diameter of wire and the edge preparation to be used are to be in accordance with Table 11.4.4. Small deviations in the edge preparation may be allowed if requested by the manufacturer. The bevelling of the plate edges is to be performed by machining or mechanised gas cutting. In the latter case, any remaining scale is to be removed from the bevelled edges. The root gap should not exceed 0,7 mm.

4.6.3 Each butt weld is to be welded in two runs, one from each side, using amperages, voltages and travel speeds in accordance with the recommendations of the manufacturer and normal good welding practice. After completion of the first run, the flux and welding slag are to be removed and the assembly is to be left in still air until it has cooled to less than 100°C, the temperature being taken in the centre of the weld, on the surface of the seam.

4.6.4 It is recommended that the butt weld assemblies be subjected to radiographic examination to ascertain if there are any defects in the weld prior to the preparation of test specimens.

4.6.5 The test specimens, as shown in Fig. 11.4.3 and Fig. 11.4.4, are to be prepared from each test assembly, except as detailed in 4.6.8. The edges of two of the discards are to be polished and etched, and must show complete fusion and inter-run penetration of the welds. At each cut in the test assembly, the edges are also to be examined to ensure that complete fusion has taken place.

4.6.6 The results of transverse tensile and impact tests are to comply with the requirements of Table 11.4.3 as appropriate. The position of fracture of the transverse tensile tests is to be reported.

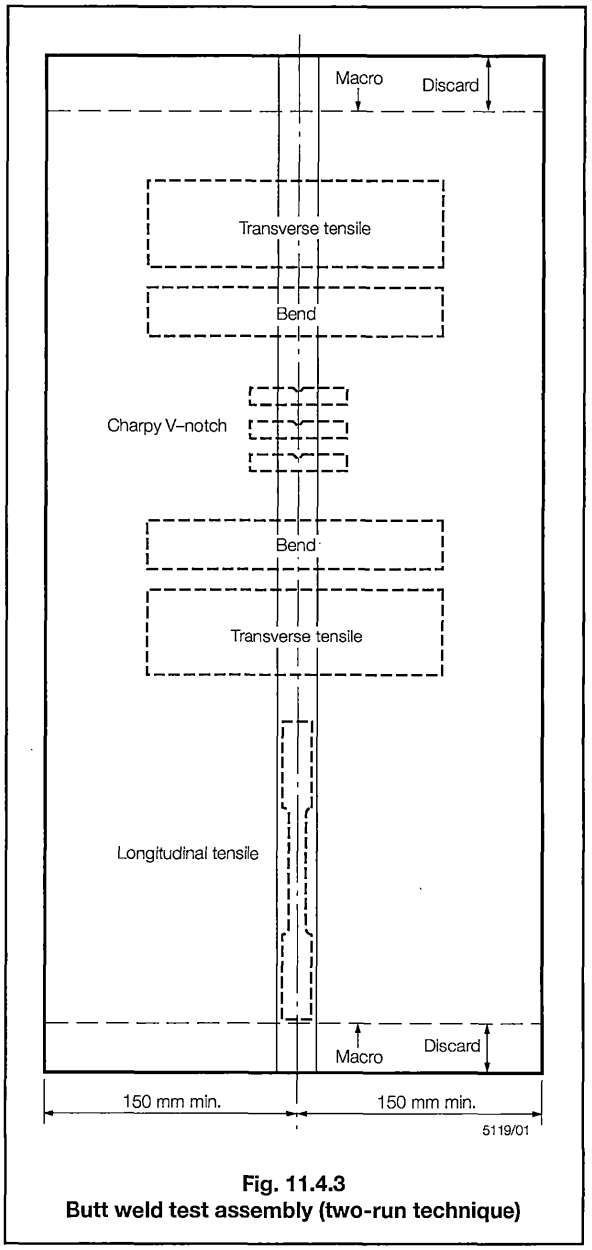

Fig. 11.4.3
Butt weld test assembly (two-run technique)

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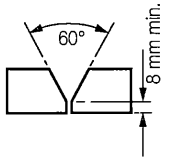
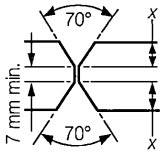
Table 11.4.3 Requirements for butt weld tests (wire-flux combinations)

Grade	Tensile strength N/mm^2	Bend test ratio: $\frac{D}{t}$	Charpy V-notch impact tests	
			Test temperature °C	Average energy (see Notes 1 and 2) J minimum
1N, 2N, 3N	400	3	+20, 0, –20	34
1Y, 2Y, 3Y, 4Y	490	3	+20, 0, –20, –40	34
2Y40	510	3	0	39
3Y40	510	3	–20	39
3Y42	530 – 680	4	–20	47 (41)
3Y46	570 – 720	4	–20	47
3Y50	610 – 770	4	–20	50
3Y55	670 – 830	5	–20	55
3Y62	720 – 890	5	–20	62
3Y69	770 – 940	5	–20	69
4Y40	510	3	–40	39
4Y42	530 – 680	4	–40	47 (41)
4Y46	570 – 720	4	–40	47
4Y50	610 – 770	4	–40	50
4Y55	670 – 830	5	–40	55
4Y62	720 – 890	5	–40	62
4Y69	770 – 940	5	–40	69
5Y40	510	3	–60	39
5Y42	530 – 680	4	–60	47 (41)
5Y46	570 – 720	4	–60	47
5Y50	610 – 770	4	–60	50
5Y55	670 – 830	5	–60	55
5Y62	720 – 890	5	–60	62
5Y69	770 – 940	5	–60	69
1 1/2 Ni	490	3	–80	27
3 1/2 Ni	450	3	–100	27
5 Ni	540	4	–120	27
9 Ni	640	4	–196	27

NOTES
1. Energy values from individual impact test specimens are to comply with 1.4.3.
2. Values in ( ) apply only to two-run technique impact test specimens.

Table 11.4.4 Butt weld assembly preparation

Plate thickness mm	Recommended diameter	Maximum diameter of wire mm
12,5		5
20–25		6
35–40		7

4.6.7 The bend test specimens can be considered as complying with the requirements if, after bending, no crack or other open defects exceeding 3 mm in dimensions can be seen on the outer surface. One of the specimens from each assembly is to be tested with the side first welded in tension, and the second specimen with the other side in tension.

4.6.8 The longitudinal tensile specimen shown in Fig. 11.4.3 is to be prepared from the thicker assembly, even in those cases where multi-run technique approval is also sought. This test specimen is to be machined to the dimensions shown in Ch 11,2.1.1, and the longitudinal axis is to coincide with the centre of the weld about 7 mm below the plate surface on the side from which the second run is made. The test specimen may be given a hydrogen release treatment in accordance with 2.1.1. The results of this test are to comply with the requirements of Table 11.4.2.

4.6.9 The chemical analysis of the weld metal of the second run in each assembly is to be determined and reported. This is to include the content of all significant elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

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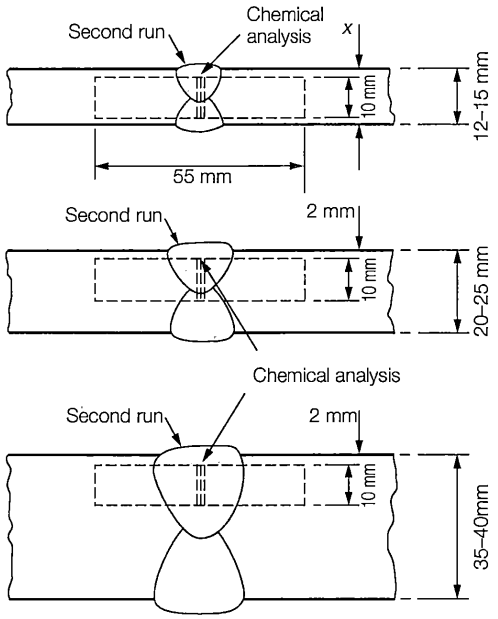

Fig. 11.4.4
Butt weld test assembly (two-run technique): position of impact test specimens

4.7 Annual tests

4.7.1 Annual tests are to consist of at least the following:
(a) For wire-flux combinations approved for the multi-run technique, one deposited metal test assembly.
(b) For wire-flux combinations approved for the two-run technique, one butt weld test assembly using plate material 20 to 25 mm in thickness.

4.7.2 The deposited metal assemblies are to be prepared and tested in accordance with 4.3, except that only one longitudinal tensile, three impact test specimens and a chemical analysis are required.

4.7.3 The butt weld test assemblies are to be prepared and tested in accordance with 4.6, except that only one transverse tensile, two bend, three impact test specimens and a chemical analysis are required. One longitudinal tensile test specimen is also to be prepared where the wire-flux combination is approved solely for the two-run technique.

4.7.4 Where a wire-flux combination is approved for welding a range of steels with different specified minimum strength levels, steel of the highest strength approved is to be used for the preparation of the butt weld assembly required by 4.7.1(b).

■ *Section 5*
Wires and wire-gas combinations for manual, semi-automatic and automatic welding

5.1 General

5.1.1 Wire-gas combinations and flux-cored or flux-coated wires (for use with or without a shielding gas) are divided into the following categories for the purposes of approval testing:
(a) For use in manual multi-run welding with the inert gas tungsten arc welding process (GTAW).
(b) For use in semi-automatic multi-run metal arc welding.
(c) For use in single electrode multi-run automatic metal arc and GTAW welding.
(d) For use in single electrode two-run automatic metal arc and GTAW welding.

5.1.2 The term 'manual' is used to describe the technique where the gas-shielded tungsten arc torch is held in one hand and the filler is added separately by the other hand.

5.1.3 The term 'semi-automatic' is used to describe processes in which the weld is made manually by a welder holding a gun through which the wire is continuously fed.

5.1.4 In the GTAW process, 'automatic' refers to the fully mechanised control and application of both torch and separate filler wire.

5.1.5 Dependent on the results of mechanical and other tests, approval will be allocated as one of the grades from Table 11.1.1.

5.1.6 A suffix S will be added after the grade mark to indicate approval for semi-automatic multi-run welding.

5.1.7 For wires intended for automatic welding, the suffixes T or M will be added after the grade mark to indicate approval for two-run or multi-run welding techniques, respectively.

5.1.8 For wires intended for both semi-automatic and automatic welding, the suffices will be added in combination.

5.1.9 Solid wire-gas combinations are considered naturally low hydrogen in character and qualify for 'H15' approval without testing. This is not so for cored wires and continuous coated wires which must be tested if there is a need for low hydrogen approval. For the lower strength grades of steel, low hydrogen testing is not normally a requirement for approval. With higher strength steels, it is more important and Table 11.5.1 shows the mandatory minimum low hydrogen status required for approval of wire-gas combinations.

5.1.10 The testing methods to be used for low hydrogen approval are to be in accordance with 3.4, modified to use the manufacturer's recommended welding conditions and adjusting the deposition rate to give a weld deposit weight per sample similar to that deposited when using manual electrodes.

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Table 11.5.1 Minimum low hydrogen approval requirements for wires and wire-gas combinations

Approval grade	'H' grade for m and S techniques	'H' grade for M technique	'H' grade for T technique
1 (1N), 2 (2N), 3 (3N)	NR	NR	NR
1Y, 2Y, 3Y, 4Y	H15 (*see* Note 2)	NR	NR
2Y40 to 5Y40	H15	H15	NR
3Y42 to 5Y42	H10	H10	H15
3Y46 to 5Y46	H10	H10	H15
3Y50 to 5Y50	H10	H10	H10
3Y55 to 5Y55	H5	H5	H10
3Y62 to 5Y62	H5	H5	H5
3Y69 to 5Y69	H5	H5	H5
$1^1/2$ Ni	H15	H15	NR
$3^1/2$ Ni	H15	H15	NR
5 Ni	NR (*see* Note 3)	NR	NR
9 Ni	NR (*see* Note 3)	NR	NR

NOTES
1. NR – Not required, but approval can be sought, if desired.
2. Optional in this case. If low hydrogen approval is not obtained, there is a limitation on the carbon equivalent of the steel which is permitted to be welded.
3. Assumes use of an austenitic, non-transformable, filler material.

5.1.11 Where applicable, the approved combination will name either the specific gas composition or its trade name, but in either case the composition of the shielding gas is to be reported. Unless otherwise agreed, additional approval tests are required when a shielding gas is used other than that used for the original approval tests. However a wire and gas combination approved with an argon/carbon dioxide shielding gas where the carbon dioxide is between 15-25 per cent is also approved for other combinations of argon/carbon dioxide, provided the carbon dioxide content is within the range 15-25 per cent. The range of approval is limited to ferritic consumables in solid wire, flux cored and coated wire forms and subject to the agreement of the consumable manufacturer and LR.

5.1.12 Wires and wire-gas combinations for multiple electrode automatic welding will be subject to separate approval tests. Any proposals are to be submitted for consideration.

5.1.13 Wires and wire-gas combinations approved with multi-run technique for normal and higher strength levels up to and including 'Y' are also considered suitable for welding steels in the three strength levels below that for which they have been approved.

5.1.14 Wires and wire-gas combinations approved with multi-run technique for strength levels between Y40 and up to and including Y50 are also considered suitable for welding steels in two strength levels below that for which they have been approved.

5.1.15 Wires and wire-gas combinations approved with multi-run technique for strength levels Y55 and above are also considered suitable for welding steels in only one strength level below that for which they have been approved.

5.1.16 Wires and wire-gas combinations with two-run technique approval are not considered suitable for welding steels of any other strength level with that technique, *see* 5.4.1.

5.2 Approval tests for manual and semi-automatic multi-run welding

5.2.1 Approval tests for manual (GTAW) and semi-automatic multi-run welding are to be carried out generally in accordance with the requirements of Section 3, except as required by 5.2, using the respective technique for the preparation of all test assemblies.

5.2.2 Two deposited metal test assemblies are to be prepared in the downhand position as shown in Fig. 11.3.1, one using the smallest diameter, and the other using the largest diameter of wire for which approval is required. Where only one diameter is manufactured, only one deposited metal assembly is to be prepared.

5.2.3 The weld metal is to be deposited according to the practice recommended by the manufacturer, and the thickness of each layer of weld metal is to be between 2 mm and 6 mm, unless it is clearly stated as part of the consumable manufacturer's published recommendations.

5.2.4 The chemical analysis of the deposited weld metal in each test assembly is to be supplied by the manufacturer and is to include the content of all significant alloying elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

5.2.5 Butt weld assemblies as shown in Fig. 11.3.2 are to be prepared for each welding position for which the wire is to be approved. In the case of approvals for normal and higher strength steels (up to 355 N/mm^2 minimum specified yield strength), tests satisfying the requirements in both the downhand and vertical-upward positions will be considered as having also satisfied the requirements for the horizontal-vertical position. In all other cases, approval in the horizontal-vertical position will require a butt weld to be made in that position and be fully tested.

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5.2.6 The downhand assembly is to be welded using, for the first run, wire of the smallest diameter to be approved and, for the remaining runs, wire of the largest diameter to be approved.

5.2.7 Where approval is requested only in the downhand position, an additional butt weld assembly is to be prepared in that position using, if possible, wires of different diameter from those required by 5.2.6. If only one wire diameter is to be approved, this second downhand butt weld should be made using either larger or smaller beads than the first assembly.

5.2.8 The butt weld assemblies, in positions other than downhand, are to be welded using, for the first run, wire of the smallest diameter to be approved, and for the remaining runs, the largest diameter of wire recommended by the manufacturer for the position concerned.

5.2.9 Fillet weld test assemblies as detailed in 3.5 are to be prepared, examined and tested.

5.2.10 Low hydrogen approval tests are to be carried out if required by 5.1.9.

5.2.11 Test specimens from each assembly are to be prepared and tested in accordance with the requirements of 3.2 and 3.3.

5.3 Approval tests for multi-run automatic welding

5.3.1 Approval tests for multi-run automatic welding are to be carried out generally in accordance with the requirements of Section 4, except as required by 5.3, using the multi-run automatic welding technique for the preparation of all test assemblies.

5.3.2 One deposited metal test assembly is to be prepared as shown in Fig. 11.4.1. Welding is to be as detailed in 4.3.3, except that the thickness of each layer is to be not less than 3 mm, unless it is clearly stated as part of the consumable manufacturer's published recommendations.

5.3.3 One butt weld test assembly is to be prepared as shown in Fig. 11.4.2 for each welding position to be approved for the automatic multi-run technique.

5.3.4 Test specimens from each test assembly are to be prepared and tested in accordance with the requirements of Section 4 for multi-run submerged-arc automatic welding.

5.3.5 Low hydrogen approval tests are to be made if required by 5.1.9.

5.3.6 At the discretion of LR, wires approved for semi-automatic welding in the downhand position may also be approved without additional tests, for use in multi-run automatic welding.

5.4 Approval tests for two-run automatic welding

5.4.1 Approval tests for two-run automatic welding are to be carried out generally in accordance with the requirements of Section 4, except as required by 5.4, using the two-run automatic welding technique for the preparation of all test assemblies. Two butt weld test assemblies are to be prepared and tested using plates of the strength level for which approval is required. Each strength level requires separate approval.

5.4.2 Two butt weld test assemblies are to be prepared generally as detailed in 4.5 and 4.6 using plates 12 to 15 mm and 20 to 25 mm in thickness.

5.4.3 If approval is requested for welding plate thicker than 25 mm, one assembly is to be prepared using plates approximately 20 mm in thickness and the other using plates of the maximum thickness for which approval is requested.

5.4.4 The edge preparation of the test assemblies is to be as shown in Fig. 11.5.1. Small deviations in edge preparation may be allowed, if these form part of the consumable manufacturer's recommendations. For assemblies using plates over 25 mm in thickness, the edge preparation is to be reported for information.

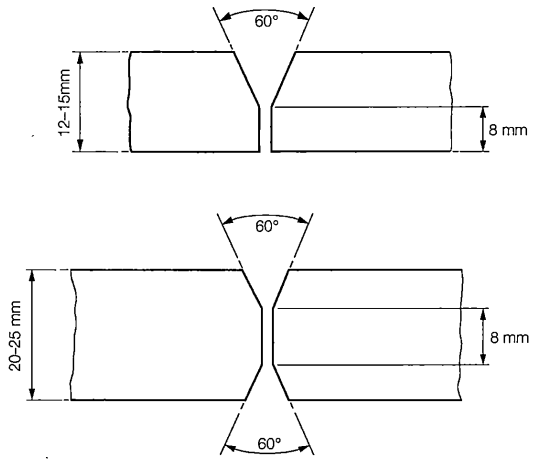

Fig. 11.5.1
Normal edge preparation for two-run butt weld test assemblies

5.4.5 The diameters of wires used are to be in accordance with the recommendations of the manufacturer and are to be reported.

5.4.6 Test specimens from each butt weld assembly are to be prepared and tested in accordance with the requirements of Section 4 for two-run submerged-arc automatic welding.

5.4.7 The weld metal chemical analysis is to be reported as in 4.6.9. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

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5.5 Annual tests

5.5.1 Annual tests are to consist of at least the following:

(a) Wires approved for manual welding or semi-automatic welding or either of these combined with approval for automatic multi-run welding:
one deposited metal test assembly prepared in accordance with 5.2 using a wire of diameter within the approved range.

(b) Wire approved for automatic multi-run welding:
one deposited metal test assembly prepared in accordance with 5.3 using a wire of diameter as stated in (a).

(c) Wires approved for two-run automatic welding:
one butt weld test assembly prepared in accordance with 5.4 using plates 20 to 25 mm in thickness or the maximum approved thickness. The diameter of wire used is to be reported.

■ *Section 6* Consumables for use in electro-slag and electro-gas welding

6.1 General

6.1.1 The requirements for the approval of consumables used for electro-slag or electro-gas welding (including consumable nozzles, where applicable) are generally as detailed in Section 4 for two-run submerged-arc welding consumables, except as otherwise detailed in this Section.

6.1.2 For each grade, approval may be restricted for use with specific compositional types of steel. For Grades 1Y, 2Y, 3Y, 4Y, 2Y40, 3Y40 and 4Y40 this will normally be in respect of the grain refining element content, and tests on niobium grain refined steel will normally qualify for use also on steels treated with aluminium or vanadium or combinations of these elements.

6.1.3 Superscript numbers are applied to the 'Y' of higher strength steel consumables, e.g. $2Y^1$, to indicate the type of parent steel for which approval is applicable as follows:

Y^1 approval Grade for higher strength steel is limited to parent steel which has been treated only with aluminium.

Y^2 approval Grade for higher strength steel is appropriate to niobium-treated steels, whether aluminium treated or not. It also covers steels treated only with aluminium.

6.1.4 Each strength level requires separate approval involving the welding and testing of two butt weld assemblies of different thickness. The greater thickness will determine the maximum approved thickness.

6.2 Butt weld test assemblies

6.2.1 Two butt weld test assemblies are to be prepared, one with plates 20 to 25 mm in thickness and the other with plates 35 to 40 mm in thickness. The steel used is not to be of any higher grade (impact toughness) than that for which approval is required. The limitations of 6.1.2 need to be considered in this Section. The chemical composition of the plate, including the content of grain refining elements, is to be reported.

6.2.2 The welding conditions and the edge preparation adopted are to be in accordance with the recommendations of the manufacturer and are to be reported in detail. The manufacturer's maximum recommended gap between plates is to be used in making the test assemblies.

6.2.3 It is recommended that the assemblies are subjected to radiographic examination to identify any defects before the preparation of any test specimens.

6.2.4 Test specimens as follows, and as shown in Fig. 11.6.1, are to be prepared from each test assembly:

(a) Two longitudinal tensile test specimens.
(b) Two transverse tensile test specimens.
(c) Two bend test specimens.
(d) Two macro-sections.
(e) Two sets of three impact test specimens notched in accordance with Fig. 11.6.2.

6.2.5 The chemical analysis of the weld metal in each assembly is to be determined and reported. This is to be supplied by the manufacturer and is to include the content of all significant elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

6.2.6 The results of all transverse tensile and impact tests are to comply with the requirements given in Table 11.4.3 as appropriate. The position of fracture of the transverse tensile test is to be reported. The Charpy V-notch impact test requirements are as for the two-run technique in Table 11.4.3.

6.2.7 The results of all longitudinal tensile tests are to comply with the requirements of Table 11.4.2.

6.2.8 The bend test specimens are to be in accordance with 4.6.7 and Table 11.4.3. Each surface of the weld is to be tested in tension.

6.3 Annual tests

6.3.1 Annual tests are to consist of at least one butt weld test assembly using plate material 20 to 25 mm in thickness.

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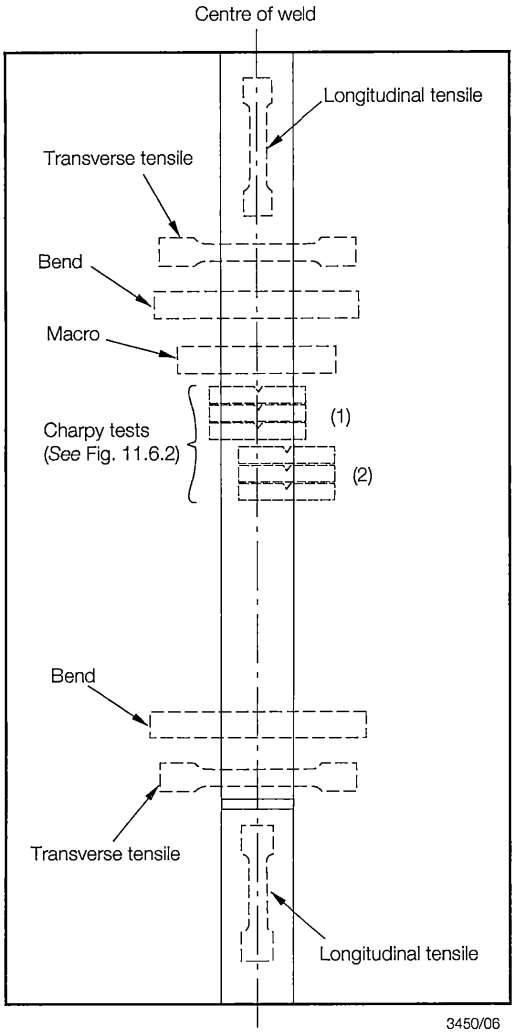

Fig. 11.6.1
Butt weld test assembly for electro-slag or electro-gas welding

6.3.2 The assembly is to be prepared and tested in accordance with 6.2 except that only the following tests are required:

(a) One longitudinal tensile test.
(b) One transverse tensile test.
(c) Two bend tests.
(d) Two sets of three Charpy V-notch impact tests; one set with the notch at the centre of the weld (Position (1) in Fig. 11.6.2), and one set with the notch in the weld metal 2 mm from the fusion line (Position (2) in Fig.11.6.2).
(e) Chemical analysis.
(f) One macro section.

6.3.3 Where a consumable or combination is approved for a range of steels with different specified minimum strength levels, steel of the highest strength level is to be used for the preparation for the assembly required by 6.3.1.

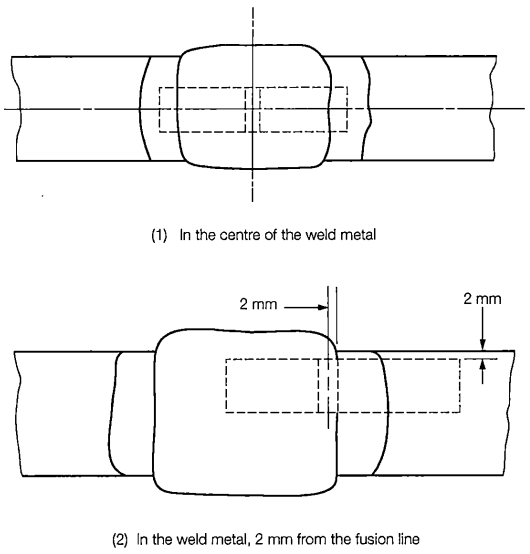

Fig. 11.6.2
Position of Charpy V-notch impact test specimens

Section 7
Consumables for use in one-side welding with temporary backing materials

7.1 General

7.1.1 The requirements for approval of combinations including temporary backing material, for use in one-side welding techniques, are dependent on the technique used and which basic technique it most closely follows. The following are provided for:

(a) Technique m – for manual electrode/backing combinations.
(b) Technique S – for wire-gas/backing combinations used with semi-automatic multi-run technique.
(c) Technique M – for wire-flux or wire-gas in combination with backing material (and maybe supplementary filler materials) used with an automatic multi-run technique.
(d) Technique A – as for M but using a procedure with a high heat input rate (large bead size relative to thickness welded). This would apply to welds made by four or less runs in 20 mm thickness, or eight or less runs in 35 mm.

7.1.2 For technique m, S or M, a single butt weld is to be made in plate of 20–25 mm thickness. For technique A, two butt welds are to be made, one in plate of the maximum thickness recommended by the manufacturer, the other in plate of approximately half the thickness of the first. Usually this will involve thicknesses in the region of 35–40 mm and 20–25 mm respectively.

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7.1.3 A wire and gas combination approved with an argon/carbon dioxide shielding gas where the carbon dioxide content is between 15-25 per cent is also approved for other combinations of argon/carbon dioxide, provided the carbon dioxide content is within the range 15-25 per cent. The range of approval is limited to ferritic consumables in solid wire, flux cored and coated wire forms and subject to the agreement of the consumable manufacturer and LR.

7.1.4 Any unrecognised techniques or unusual combinations will be considered for approval subject to a test programme to be agreed based on the details of the technique and combination which are to be submitted in advance.

7.1.5 Where low hydrogen approval is required either by Table 11.7.1 or by the manufacturer, it should be noted that this will generally be achieved through separate testing of:

(a) the backing material, and
(b) the welding electrode or combination of wire-flux or wire-gas.

7.1.6 The hydrogen potential of the backing material is to be determined using the modified Gayley-Wooding method which expresses the total hydrogen content as water by weight per cent. The qualifying levels are:

To qualify as:	H_20 g/100g sample
H15	0,5
H10	0,3
H5	0,2

7.1.7 The sampling and approval of the combinations without the backing are to follow the general requirements of Sections 3, 4 or 5, as appropriate.

7.1.8 Combinations approved with multi-run technique (m, S and M) for normal and higher strength levels up to and including 'Y' are also considered suitable for welding steels in the three strength levels below that for which they have been approved.

7.1.9 Combinations approved with multi-run technique (m, S and M) for strength levels between Y40 and up to and including Y50 are also considered suitable for welding steels in two strength levels below that for which they have been approved.

7.1.10 Combinations approved with multi-run technique (m, S and M) for strength levels Y55 and above are also considered suitable for welding steels in only one strength level below that for which they have been approved.

7.1.11 Combinations approved for the 'A' multi-run technique are not considered suitable for welding steels of any other strength level with that technique.

7.2 Approval tests for manual (m), semi-automatic (S) and automatic multi-run (M) techniques

7.2.1 For each position to be approved, one butt weld assembly is to be prepared using plates of 20–25 mm thickness as shown in Fig. 11.7.1. The grade of plate used is to be no higher in toughness than that for which approval is required. The strength is to be appropriate to the grade for which welding approval is requested.

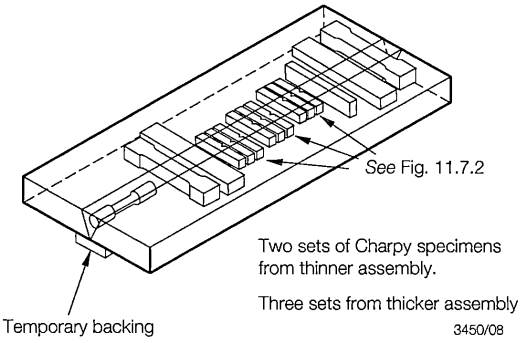

Fig. 11.7.1
Butt weld test assembly and specimens for all techniques

7.2.2 The edge preparation and welding conditions are to be in accordance with the recommendations of the manufacturers.

7.2.3 Test specimens are to be prepared as shown in Fig. 11.7.1 and Fig. 11.7.2(a):

(a) One longitudinal tensile test specimen (from the centre of the weld).
(b) Two transverse tensile specimens.
(c) Two bend test specimens, one with the face in tension, the other with the root in tension.
(d) One macrosection.
(e) Two sets of three Charpy impact test specimens positioned and notched in accordance with Fig.11.7.2(a).

7.2.4 The results of all transverse tensile, bend and impact tests are to comply with the requirements in Table 11.3.3 for m and S technique, and Table 11.4.3 for M technique. The position of fracture of the transverse tensile test is to be reported. The appearance of the bend test specimens is to be in accordance with 3.3.12.

7.2.5 The results of all longitudinal tensile tests are to comply with the requirements in Table 11.3.2.

7.2.6 Low hydrogen approval is required in accordance with Table 11.7.1.

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Table 11.7.1 Minimum low hydrogen approval requirements for one-side welding with combinations including temporary backing material

Approval grades	'H' grade for m and S techniques	'H' grade for M technique	'H' grade for A technique
1 (1N), 2 (2N), 3 (3N)	NR	NR	NR
1Y, 2Y, 3Y, 4Y	H15 (*see* Note 2)	NR	NR
2Y40 to 5Y40	H15	H15	NR
3Y42 to 5Y42	H10	H10	H15
3Y46 to 5Y46	H10	H10	H15
3Y50 to 5Y50	H10	H10	H10
3Y55 to 5Y55	H5	H5	H10
3Y62 to 5Y62	H5	H5	H5
3Y69 to 5Y69	H5	H5	H5
1 1/2 Ni	H15	H15	NR
3 1/2 Ni	H15	H15	NR
5 Ni (*see* Note 3)	NR	NR	NR
9 Ni (*see* Note 3)	NR	NR	NR

NOTES
1. NR – Not required, but approval can be sought, if desired.
2. Optional in this case. If low hydrogen approval is not obtained, there is a limitation on the carbon equivalent of the steel which is permitted to be welded.
3. Assumes the use of an austenitic, non-transformable, filler material.

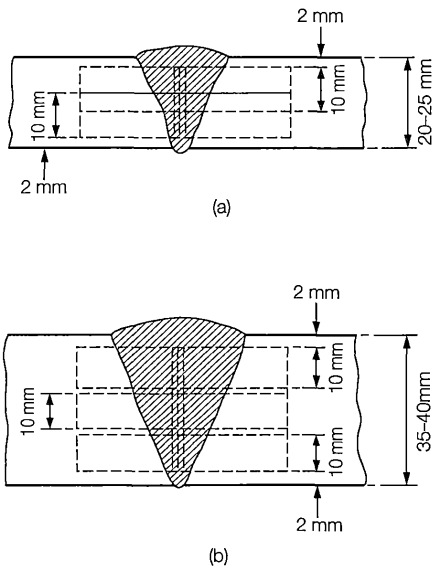

Fig. 11.7.2
Position of Charpy V-notch impact tests for one-side automatic welding

7.2.7 Chemical analyses are to be made and reported from positions corresponding to the weld metal in the upper and lower Charpy specimens of the downhand butt weld. These are to be supplied by the manufacturer and are to include the content of all significant elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

7.3 Approval tests for high heat input automatic (A) techniques

7.3.1 Two butt weld assemblies are to be prepared, usually one of 35–40 mm thickness, the other 20–25 mm, as shown in Fig. 11.7.1, noting that in the thinner assembly only two sets of Charpy specimens are required. The grade of plates used is to be no higher in toughness than that for which approval is required. The strength is to be appropriate to the grade for which welding approval is requested.

7.3.2 The edge preparation and welding conditions are to be in accordance with the manufacturer's recommendations, and are to be reported to LR.

7.3.3 Test specimens as follows are to be prepared as shown in Fig. 11.7.1 and Figs. 11.7.2(a) and (b):
(a) One longitudinal tensile test specimen (from centre of weld).
(b) Two transverse tensile test specimens.
(c) Two bend test specimens.
(d) One macro-section.
(e) From assembly 20 to 25 mm thick, two sets of three impact test specimens positioned and notched in accordance with Fig. 11.7.2(a).
(f) From assembly 35 to 40 mm thick, three sets of three impact test specimens positioned and notched in accordance with Fig. 11.7.2(b).

The bend specimens are to be tested, one with the face in tension, the other with the root in tension.

7.3.4 The results of all transverse tensile, bend and impact tests are to comply with the requirements of Table 11.4.3. The appearance of the bend test specimens is to be in accordance with 3.3.12. The Charpy V-notch impact test requirements are as for the two-run technique in Table 11.4.3.

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7.3.5 The results of all longitudinal tensile tests are to comply with the requirements in Table 11.3.2, except that for Grades 1Y, 2Y and 3Y the tensile strength is to be not less than 490 N/mm^2.

7.3.6 Low hydrogen approval is required in accordance with Table 11.7.1.

7.3.7 Chemical analyses are to be made and reported from positions corresponding to the weld metal in the uppermost and lowest Charpy specimens in the thicker plate weld. This is to be supplied by the manufacturer and is to include the content of all significant elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

7.4 Annual tests

7.4.1 Annual tests are to consist of, at least, one butt weld test assembly, for each technique approved, using plates of 20 to 25 mm thickness.

7.4.2 The assembly is to be prepared and tested in accordance with 7.2 or 7.3, as appropriate, except that only the following tests are required:

(a) One longitudinal tensile test (from centre of weld).
(b) One transverse tensile test.
(c) Two bend tests.
(d) One set of three impact tests taken from the root of the weld and the specimens notched in accordance with Fig. 11.7.2.
(e) Chemical analysis (one only).

■ *Section 8* Consumables for welding austenitic and duplex stainless steels

8.1 General

8.1.1 Tests for the approval of consumables intended for welding the austenitic and duplex stainless steels detailed in Ch 3,7 are to be carried out generally in accordance with the Section (3, 4, 5, 6 or 7) relevant to the type of consumable or combination.

8.1.2 Approval will be indicated by the grade or grades of parent stainless steel for which the consumable or combination is approved.

8.1.3 Where a shielding gas is employed separate approval will be required for each specific shielding gas composition.

8.1.4 Consumables for welding the austenitic stainless steels and the duplex stainless steels to carbon or carbon-manganese steels will be approved in a similar manner. Parent plate used for the butt and fillet weld test assemblies will be carbon or carbon-manganese steel with either austenitic stainless steel or duplex stainless steel, as appropriate. Approval will be indicated by 'SS/CMn' and 'Dup/CMn' respectively, however, no buttering of test assembly plates is allowed for these two approvals.

8.1.5 Separate approval will be given for welding chemical and cryogenic applications. For chemical use, evidence of relevant corrosion resistance will be required. Charpy impact toughness tests will be required for all uses, but for cryogenic use the Charpy impact toughness requirements are more severe.

8.1.6 The welding technique will be indicated in the approval grading by a letter:

m – for manual SMAW or GTAW welding.
S – for wire-gas combinations used with a semi-automatic multi-run technique.
M – for wire-flux or wire-gas combinations used with an automatic multi-run technique.
T – for wire-flux or wire-gas combinations used with an automatic two-run technique.
A – as for M but using a procedure with a high heat input rate (large bead size relative to thickness welded). This would apply to welds made by four or less runs in 20 mm thickness, or eight or less runs in 35 mm.

8.2 Deposited metal test assemblies

8.2.1 Where the relevant Section requires deposited metal assemblies to be made and tested, the plates used must be either of the type for which approval is required or of normal strength carbon, or carbon-manganese steel with the prepared edges built up with stainless steel weld metal and finished with a layer of weld metal from the consumable to be approved.

8.2.2 The chemical analysis of the deposited weld metal is to be reported, including all significant elements. The elements reported will be dependent on the type of stainless steel for which approval of the consumables is requested. Any unusual weld metal compositions will have to be justified in respect of the particular approval requested. This is to be supplied by the manufacturer and is to include the content of all significant elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

8.2.3 The results of all tensile and notch impact tests are to comply with the requirements given in Table 11.8.1 as appropriate.

8.2.4 The ferrite content in the last weld run from each deposited metal assembly is to be determined by physical or metallographic means, and reported, indicating the method of determination.

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Table 11.8.1 Requirements for deposited metal tests (manual, semi-automatic and automatic multi-run techniques)

Grade	0,2% proof stress N/mm^2 *minimum*	1% proof stress N/mm^2 *minimum*	Tensile strength N/mm^2 minimum	Elongation on 50 mm % minimum	Charpy V-notch impact tests		
					Chemical test temperature °C	Cryogenic test temperature °C	Average energy *See* Note 1 J minimum
304L	270	310	500	25	–20	–196	29
304LN	305	345	530	22	–20	–196	29
316L	270	310	500	22	–20	–196	29
316LN	305	345	530	22	–20	–196	29
317L	305	345	530	22	–20	–196	29
317LN	340	380	570	22	–20	–196	29
321	290	330	550	22	–20	–196	29
347	290	330	550	22	–20	–196	29
S 31254	370	410	650	22	–20	–196	29
N 08904	270	310	500	22	–20	–196	29
SS/CMn	270	310	500	22	–20	–60	29
S 31260	485	525	690	20	–20	*see* Note 2	40
S 31803	450	490	620	25	–20		40
S 32550	550	590	760	15	–20		40
S 32750	550	590	800	15	–20		40
S 32760	550	590	750	25	–20		40
Dup/CMn	270	310	500	22	–20	*see* Note 2	40

NOTES
1. Energy values from individual impact test specimens are to comply with 1.4.3.
2. Approval for cryogenic applications is to be obtained at the procedure approval stage.

8.3 Butt weld test assemblies

8.3.1 Where the relevant Section requires butt weld assemblies to be made and tested, the plates used are to be either of the type for which approval is required or of steel having strength and ductility within the range specified for the grade to be approved. In the latter case, provided the consumable is metallurgically compatible with the base material to be used, the prepared edges are to be built up with a layer of weld metal before final machining of the weld preparation.

8.3.2 The results of transverse tensile, notch impact and bend tests are to comply with the requirements of Table 11.8.2 as appropriate. The position of fracture is to be reported to LR.

8.3.3 The ferrite content at the centre of the weld metal in each butt weld assembly is to be determined by physical or metallographic means, and meet the requirements in Table 11.8.2. The method of determination is to be reported.

8.3.4 For austenitic and duplex stainless steel approvals (except for types 304L, 316L, 321 and 347), an appropriate sample from each butt weld assembly is to be submitted to the corrosion testing provided in ASTM G48, Method 'C'. The results are to be reported so as to allow confirmation of the maximum acceptable pitting corrosion resistance temperature. This will be part of the approval grading and will be set at 5°C intervals. The minimum pitting corrosion temperature would not be expected to be less than 20°C.

8.4 Fillet weld test assemblies

8.4.1 Where the relevant Section requires fillet weld assemblies to be made and tested, the plates used must be either of the type for which approval is required or of steel having strength and ductility within the range specified for the grade to be approved. In the latter case, the surfaces on which the fillet weld beads are to be deposited are to be cut back by machining and then built up to original dimensions with weld metal from the consumable to be approved.

8.4.2 The ferrite content at the centre of the weld metal in each fillet weld bead of each assembly is to be determined from the centre macro-section by physical or metallographic means, and reported. The method of determination is also to be reported to LR.

8.4.3 Where approval is sought for fillet welding only, corrosion testing is to be carried out in accordance with 8.3.4 from a sample taken from the deposited metal test assembly.

8.5 Annual tests

8.5.1 Annual tests are to be carried out as required by the relevant Section appropriate to the type of consumable and welding technique. The tests are to include a weld ferrite content in accordance with 8.2.4 or 8.3.3 as appropriate.

8.5.2 The results of all tests are to comply with the requirements given in Table 11.8.1 and Table 11.8.2 as appropriate.

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Table 11.8.2 Requirements for butt weld tests (all techniques)

Grade	Tensile strength N/mm² minimum	Bend test ratio: $\frac{D}{t}$	Weld ferrite content %	Charpy V-notch impact tests		
				Chemical test temperature °C	Cryogenic test temperature °C	Average energy (*see* Note 1) J minimum
304L	500	3	4–12	–20	–196	27
304LN	530	3	4–12	–20	–196	27
316L	500	3	4–12	–20	–196	27
316LN	530	3	4–12	–20	–196	27
317L	530	3	4–12	–20	–196	27
317LN	570	3	4–12	–20	–196	27
321	550	3	4–12	–20	–196	27
347	550	3	4–12	–20	–196	27
S 31254	650	3	(*see* Note 2)	–20	–196	27
N 08904	500	3	(*see* Note 2)	–20	–196	27
SS/CMn	500	3	4–12	–20	–60	27
S 31260	690	4	35–65	–20	(*see* Note 3)	40
S 31803	620	3	35–65	–20		40
S 32550	760	6	35–65	–20		40
S 32750	800	6	35–65	–20		40
S 32760	750	6	35–65	–20		40
Dup/CMn	500	3	(*see* Note 2)	–20	(*see* Note 3)	40

NOTES
1. Energy values from individual impact test specimens are to comply with 1.4.3.
2. To be reported for special consideration.
3. Approval for cryogenic applications is to be obtained at the procedure approval stage.

■ *Section 9* Consumables for welding aluminium alloys

9.1 General

9.1.1 Tests for the approval of consumables intended for welding the aluminium alloys detailed in Chapter 8 are to be carried out generally in accordance with the requirements of Sections 1, 2 and 5, except as otherwise detailed in this Section.

9.1.2 Approval will be indicated by the grade shown in Table 11.9.1. Plate of the corresponding type of aluminium alloy and of appropriate thickness is to be used for the preparation of the weld test assemblies, and may be of any temper listed in LR Rules.

9.1.3 The welding technique will be indicated in the approval grading by a letter:

m – manual multi-run welding (GTAW),
S – semi-automatic multi-run welding (GMAW),
M – automatic multi-run welding (GTAW or GMAW),
T – automatic two-run welding (GMAW).

9.1.4 The compositions of the shielding gas and the filler/electrode wire are to be reported.

Table 11.9.1 Requirements for butt weld tests

Consumable Approval Grade (*see* Note 1)	Base material used for the test	Tensile strength N/mm² minimum	Bend test ratio $\frac{D}{t}$
LR RA/LR WA	5754	190	3
LR RB/LR WB	5086	240	6
LR RC1/LR WC1	5083	275	6
LR RC2/LR WC2 (*see* Note 2)	5383 or 5456	290	6
LR RC3/LR WC3 (*see* Note 2)	5059	330	6
LR RD/LR WD (*see* Note 4)	6005A	170	6
	6061	170	6
	6082	170	6

NOTES
1. The prefixes 'R' and 'W' indicate 'rod' form (for Gas Tungsten Arc Welding (GTAW)) or 'wire' form (for Gas Metal Arc Welding (GMAW) and GTAW).
2. Approval of grade LR RC2/LR WC2 confers approval of 5383, 5456 and 5083 base material grade.
3. Approval of grade LR RC3/LR WC3 confers approval of 5059, 5383, 5456 and 5083 base material grades.
4. Approval of grade LR RD/LR WD confers approval of 6005A, 6061 and 6082 base material grades.

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9.1.5 Approval granted using the multi-run technique for a specific filler/electrode wire with a gas in one of the groups listed in Table 11.9.2 will extend to any other gas compositions within that same group, provided that the gas composition is within the range recommended by the consumable manufacturer, subject to agreement with LR.

Table 11.9.2 Shielding gas compositions

Group	Gas composition (Vol. %) (*see* Note)	
	Helium	Argon
I-1	–	100
I-2	100	–
I-3	>0 ≤33	Remainder
I-4	>33 ≤66	Remainder
I-5	>66 ≤95	Remainder
S	Special gas	

NOTE
Gases of other composition (mixed gases) or special purity may be considered as special gases and will require separate approval tests.

9.1.6 Approval granted for the two-run technique will be for a specific shielding gas composition; additional tests may be required if a change in shielding gas composition is sought.

9.1.7 On completion of welding, assemblies are to be allowed to cool naturally to ambient temperature. Welded test assemblies and test specimens are not to be subjected to any heat treatment after welding except for the alloy Grades 6005A, 6061 and 6082. These are to be allowed to naturally age at ambient temperature for a period of 72 hours from the completion of welding, before testing is carried out. A second solution heat treatment is not permitted.

9.1.8 All butt test assemblies are to be subjected to both radiographic and visual examination and imperfections such as lack of fusion, lack of penetration, cavities, inclusions, pores and cracks assessed in accordance with Intermediate Level C of ISO 10042, aided where necessary by dye penetrant and ultrasonic examination.

9.1.9 Fillet weld test assemblies and macro-sections are to be visually examined for imperfections, such as lack of fusion, lack of penetration, cavities, inclusions, pores and cracks, in accordance with Intermediate Level C of ISO 10042, aided where necessary by radiographic and dye penetrant examination.

9.2 Approval tests for manual, semi-automatic and automatic multi-run techniques

9.2.1 Plate of the corresponding type of aluminium alloy and of appropriate thickness is to be used for the preparation of the weld test assemblies.

9.2.2 The welding parameters are to be within the range recommended by the manufacturer and are to be reported.

9.2.3 Welded assemblies are to be prepared and tested in accordance with 9.3, 9.4 and 9.5.

9.3 Deposited metal test assembly

9.3.1 One assembly is to be prepared in the downhand position as shown in Fig. 11.9.1.

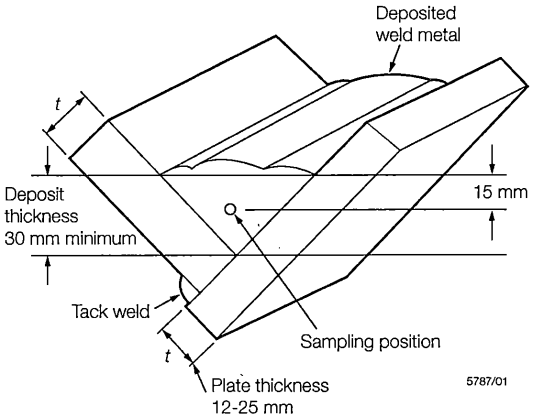

Fig. 11.9.1 Deposited metal test assembly

9.3.2 The chemical composition of the plate used for the assembly is to be compatible with the weld metal.

9.3.3 The thickness of the plate used, and the length of the assembly, are to be appropriate to the welding process. The plate thickness is to be not less than 12 mm.

9.3.4 For the approval of filler wire/gas and electrode wire/gas combinations for manual or semi-automatic welding by GTAW or GMAW, one test assembly is to be welded using any size of wire within the range for which approval is sought.

9.3.5 For automatic multi-run approval, one test assembly is to be welded by the respective process using the recommended diameter of wire.

9.3.6 The weld metal is to be deposited in multi-run layers in accordance with normal practice. The direction of deposition of each layer is to alternate from each end of the plate.

9.3.7 The deposited weld metal in the assembly is to be analysed and reported including the contents of all significant elements. The elements reported will be dependent on the type of aluminium alloy for which approval of the consumables is requested. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

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9.4 Butt weld test assemblies

9.4.1 Plate of the corresponding type of aluminium alloy and of an appropriate thickness is to be used for the preparation of the test assemblies.

9.4.2 In order to ensure sound and representative welds, it is essential that test assemblies are cleaned and degreased prior to welding. Assemblies as shown in Fig. 11.9.2 are to be prepared for each welding position (downhand, horizontal-vertical, vertical-upward, vertical-downward, and overhead) for which the consumable is recommended by the manufacturer; except that consumables satisfying the requirements for downhand and vertical-upward positions will be considered as also complying with the requirements for the horizontal-vertical position. Any wire diameter(s) to be approved may be used.

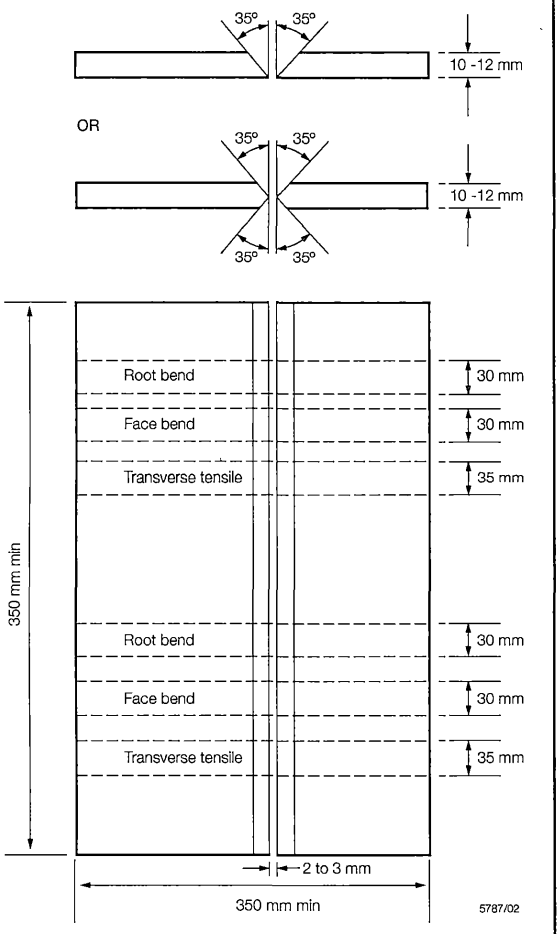

Fig. 11.9.2
Butt weld test assembly
(positional, multi-run technique)

9.4.3 One assembly, as shown in Fig. 11.9.3, is to be prepared for welding in the downhand position. The assembly is to be welded using, for the first run, wire of the smallest diameter recommended by the manufacturer and, for the remaining runs, wire of the largest diameter to be approved.

9.4.4 The welding conditions are to be in accordance with the recommendations of the manufacturer and are to be reported in detail.

9.4.5 The welded assemblies are to be subjected to NDE. Imperfections are to be assessed in accordance with 9.1.8.

9.4.6 The test specimens are to be taken from the welded assemblies as shown in Fig. 11.9.2 and Fig. 11.9.3. For each assembly they are to comprise:

- 2 transverse tensile specimens;
- 2 face bend specimens; and
- 2 root bend specimens.

9.4.7 All tensile test specimens are to have a tensile strength not less than the respective value shown in Table 11.9.1. The position of each fracture is to be reported.

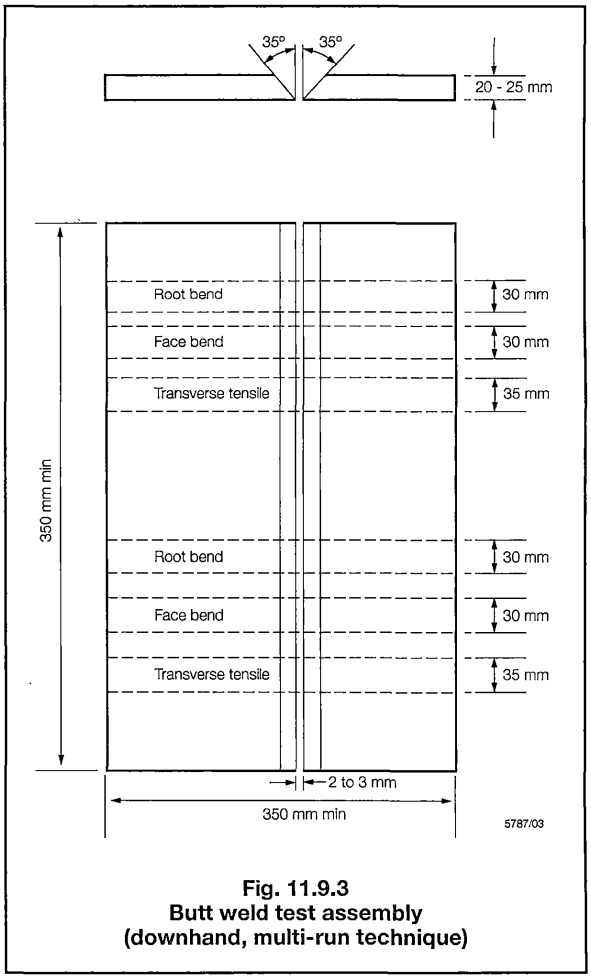

Fig. 11.9.3
Butt weld test assembly
(downhand, multi-run technique)

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9.4.8 The bend test specimens are to be bent around a former having a diameter not more than the number of times the thickness of the test specimen, as shown in Table 11.9.1, and can be considered as complying with the requirements if, after bending to an angle of not less than 180°, no crack or other open defect exceeding 3 mm in length can be seen on the outer surface. Flaws appearing at the corners of a test specimen may be ignored.

9.4.9 In order to obtain uniform bending of the bend test specimens, it is recommended that the wrap-around or guided bend test using a roller method is employed.

9.5 Fillet weld test assembly

9.5.1 When approval is being sought for both butt and fillet welding, one assembly is to be prepared and welded in the horizontal-vertical position and tested in accordance with the appropriate requirements of 3.5, except that the plates are to be of an aluminium alloy compatible with the weld metal, that no hardness tests are required and that for automatic multi-run approval only one fillet weld bead is to be made using the recommended wire diameter. In this case, the bead size is to be as large as the maximum single bead size recommended by the manufacturer for fillet welding.

9.5.2 When approval is being sought for fillet welding only, one assembly is to be prepared and welded in each position for which approval is sought, and tested as detailed in 9.5.1.

9.5.3 The results of examination of the macro-specimens and the fractured fillet welds are to be reported in accordance with 3.5.3 and 3.5.5. Imperfections are to be assessed in accordance with 9.1.9.

9.6 Approval tests for two-run technique

9.6.1 Two butt weld test assemblies are to be prepared using the following plate thicknesses:

(a) one with the maximum thickness for which approval is requested,

(b) one with a thickness approximately one half to two thirds that of the maximum thickness.

9.7 Butt weld test assemblies (two-run technique)

9.7.1 The plates used are to be of the aluminium alloy appropriate to the approval required as shown in Table 11.9.1. The composition of the plate material is to be within the range specified for that alloy in Table 8.1.2 in Chapter 8 and is to be reported including all significant elements.

9.7.2 The wire diameter, edge preparation, welding current, arc voltage and travel speed are to be in accordance with the manufacturer's recommendations and are to be reported.

9.7.3 Each butt weld is to be made in two runs, one from each side. After completion of the first run, the assembly is to be left in still air until it has cooled to less than 50°C.

9.7.4 The welded assemblies are to be subjected to NDE. Imperfections are to be assessed in accordance with 9.1.8.

9.7.5 The test specimens as shown in Fig. 11.9.4 are to be prepared from each test assembly. The edges of the discards are to be polished and etched, and must show complete fusion and inter-run penetration of the welds. Each cut in the assembly is also to be examined to confirm that complete fusion and penetration have been achieved.

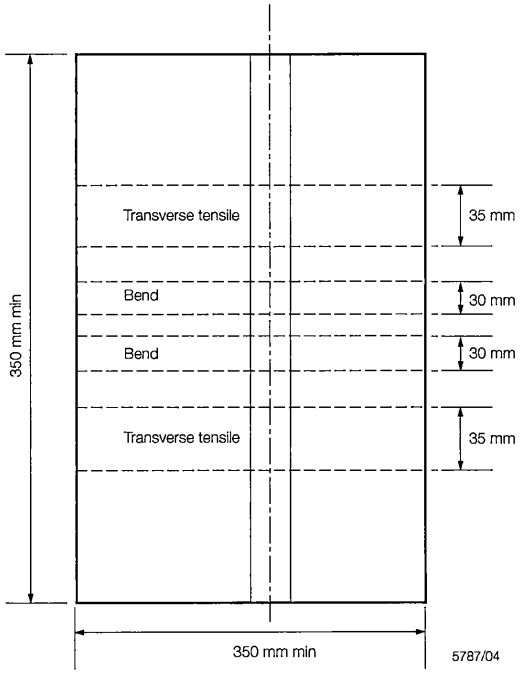

Fig. 11.9.4
Butt weld test assembly (two-run technique)

9.7.6 The results of the transverse tensile tests are to be as in 9.4.7 and of the bend tests as in 9.4.8. The position of the fracture in each transverse tensile specimen is to be reported.

9.8 Annual tests

9.8.1 Annual tests are to consist of the following:

(a) for combinations approved for the multi-run technique, one deposited metal assembly in 9.3 and one downhand butt assembly in 9.4;

(b) for combinations approved for the two-run technique, one butt weld assembly in plate material of thickness equal to one half to two thirds that of the maximum thickness approved.

9.8.2 For the automatic two-run technique, one butt weld assembly is to be prepared and tested in accordance with 9.7.

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Welding Qualifications

Chapter 12

Sections 1 & 2

Section

1 **General qualification requirements**

2 **Welding Procedure Qualification Tests for Steels**

3 **Specific requirements for stainless steels**

4 **Welding procedure tests for non-ferrous alloys**

5 **Welder qualification tests**

■ *Section 1* General qualification requirements

1.1 General

1.1.1 This Section applies to all welding qualifications and tests required to be performed in the course of new construction, conversions, modifications or repairs made on ships, other marine structures and their associated pressure vessels, machinery and equipment.

1.1.2 These Rules also apply to all welding work related to other applications for which Lloyd's Register (hereinafter referred to as LR) have issued Rules or have an interest.

1.1.3 It is the responsibility of the manufacturer to ensure compliance with all aspects of these Rules. All deviations are to be recorded as non-compliances and brought to the attention of the Surveyor along with the corrective actions taken. Failure to do this is considered to render the welding tests as not complying with the Rules.

1.1.4 Welding tests are to be performed under survey at the manufacturer's works. Welding procedure qualification tests and welder qualifications tests are to be performed and approved prior to commencement of fabrication or construction.

1.1.5 Weld procedure tests made in accordance with EN, ISO, JIS, ASME or AWS may be considered for acceptance provided that, as a minimum, they are equivalent to and meet the technical intent of these Rules to the satisfaction of the Surveyor.

1.1.7 The responsibility for the performance of the weld tests rests with the manufacturer. Aspects of the welding tests, such as mechanical testing, non-destructive testing and heat treatment, may be subcontracted by the manufacturer provided that the subcontractor performs the work under the technical control and direction of the manufacturer, and this is agreed with the Surveyor prior to commencing the work.

1.1.8 In these Rules, the term 'manufacturer' is considered to include any firm or organisation that performs welding and is considered to be the shipbuilder, or construction firm, or fabricator, or material manufacturer.

1.2 Design

1.2.1 Welding procedure qualification tests are required to give assurance that construction welds made in accordance with the approved plans or the approved design have acceptable properties. It is the manufacturer's responsibility to establish and document whether a procedure is suitable for a particular application.

1.2.2 The requirements relate to mechanical properties of the weld and heat affected zone, however, other tests may be required on certain materials, for example, corrosion or fatigue tests, in order to ensure suitability for the proposed application.

1.3 Materials

1.3.1 Materials used for testing are to be of the same grade, type and from the same manufacturing process as those to be used for construction, unless prior agreement is obtained from the Surveyor. Such agreements will only apply on a case-by-case basis.

1.3.2 All materials used for testing are to be suitably marked and identifiable to the original manufacturer's material certificate.

1.4 Performance of welding tests

1.4.1 All welding and subsequent testing is to be performed in accordance with the requirements of this Chapter.

1.4.2 The manufacturer is responsible for monitoring the tests and for recording all the welding variables as specified in 2.2 and for compiling all the non-destructive examination (NDE) reports and mechanical test records for submission to the Surveyor.

1.4.3 The laboratory or testing establishment used to perform the tests is to have the necessary equipment, maintained in good order and suitably calibrated. The Surveyor is to be satisfied that the laboratory personnel have the appropriate skills and are appropriately qualified in accordance with Ch 2,1.2.1.

■ *Section 2* Welding Procedure Qualification Tests for Steels

2.1 General

2.1.1 The requirements of this Section relate to welding procedure test requirements of carbon, carbon-manganese steels and low alloys steels. Additional requirements for austenitic and austenitic/ferritic duplex stainless steels, aluminium and copper alloys are specified in Sections 3 and 4 respectively.

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2.1.2 Prior to performing the welding procedure qualification test, the manufacturer is to present to the Surveyor a preliminary Welding Procedure Specification (pWPS) detailing the welding processes, positions, joint types, materials and heat treatments to be performed during the test. The pWPS is to be presented for information prior to commencing the test.

2.1.3 The type and extent of testing to be applied to each welding procedure test is to be in accordance with subsequent Sections of this Chapter.

2.1.4 For the welding procedure approval, the welding procedure qualification tests given in this Section are to be carried out with satisfactory results. Welding procedure specifications are to refer to the test results achieved during welding procedure qualification testing.

2.2 Welding variables

2.2.1 In order that the conditions of the qualification test may be applied to production welding operations, the appropriate variables are to be recorded by the manufacturer during welding and testing from the following list:

(a) The unique qualification reference number and the date of welding;
(b) The material type, grade, product form, dimensions and identification;
(c) Welding process(es), including tack welds;
(d) Joint type, dimensions and surface condition;
(e) Welding position(s);
(f) Welding technique(s), weaving, multiple electrodes, etc;
(g) Welding consumables including fluxes, shielding gases, etc;
(h) Control of consumables, baking or drying conditions, etc;
(j) Welding parameters, current, voltages, travel speeds, etc;
(k) Number and sequence of weld runs;
(l) Backing materials including any backing gas;
(m) Preheats and interpass temperatures;
(n) Methods used for cleaning and inspection of root deposits;
(o) Post-weld heat treatment, temperature and cycle times;
(p) Special weld profiling requirements.

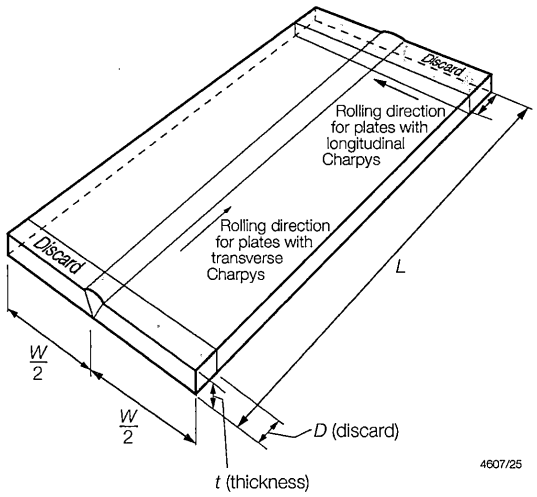
2.2.2 Other variables may need to be recorded depending on the particular welding process or application and are to be agreed with the Surveyor, for example the peak and base current and cycle times for pulse welding, electrode type and nozzle size for GTAW welding, etc.

2.3 Steel test assemblies

2.3.1 Tests are to be performed using the welding process and positions anticipated for actual construction. The weld test assemblies are to be representative of construction conditions and are to be welded in the same manner as intended for the actual production welds. Where pre-fabrication primers are used in the shipyard, these are to be included in the test assemblies.

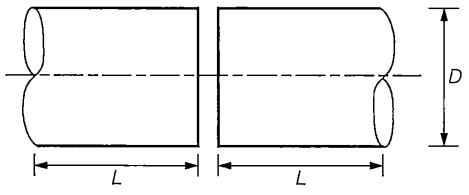
2.3.2 For plate tests, the direction of plate rolling relative to the weld direction is to be considered. Where the material used for the test requires longitudinal impact tests, the plate rolling direction is to be perpendicular to the weld direction and for material which requires impact testing in the transverse direction, the rolling direction is to be parallel to the weld direction.

2.3.3 Typical test assemblies are shown in Fig. 12.2.1(a) to (c). These are a minimum requirement to permit the removal of all the necessary mechanical test specimens. Where impact tests or other toughness tests are required, the total width is not to be less than 8 times the material thickness of the thicker material being joined.



Welding Processes	*L* (min) mm	*W* (min) mm	*D* (min) mm
Manual/Semi-automatic	350	300	50
Automatic	1000	400	75

Fig. 12.2.1(a) Butt weld test assembly in plate



L = 150 mm minimum
D = Outside diameter

Fig. 12.2.1(b) Butt weld test assembly in pipe

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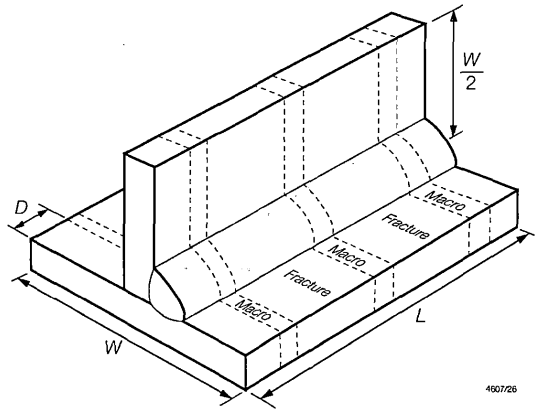

Welding Processes	*L* (min) mm	*W* (min) mm	*D* (min) mm
Manual/Semi-automatic	350	300	50
Automatic	1000	300	75

Fig. 12.2.1(c) Fillet weld test assembly in plate

2.3.4 Welding procedure test assemblies are to be welded separately from production welds and are to be marked with the unique test identification number. The individual pieces of the test assembly may be held together to maintain their relative joint conditions by means of suitable tack welds, clamps or strongbacks.

2.3.5 Welding of the test assemblies and testing of test specimens is to be monitored by the Surveyor.

2.3.6 The test assembly is to be placed in one of the welding positions shown in Fig. 12.2.2(a) to (d), as specified in the test Welding Procedure Specification (pWPS) and the specified level of preheat applied prior to the start of welding.

2.3.7 Designations for equivalent welding positions shown by different standards are shown in Table 12.2.1.

2.4 Welding of steel test assemblies

2.4.1 Welding of the test assembly is to be carried out in accordance with the agreed pWPS. Where, during the progress of the test, it is found necessary to change the conditions specified on the pWPS, this is to be brought to the attention of the Surveyor. If agreed, the test may be permitted to continue with the new conditions and these are to be recorded.

2.4.2 Where the production work requires welding over tack welds, the test is to simulate this condition and the tack welds are to be included in the inspection length of the test weld and their position recorded.

2.4.3 For manual and semi-automatic welding processes, weld stops and re-starts are to be included in the inspection length of the test weld.

Table 12.2.1 Equivalent designations of welding positions

Weld position		Standard	
		ISO 6947	AWS
Plate butt welds			
Flat	D	PA	1G
Horizontal	X	PC	2G
Vertical, weld up	Vu	PF	3G
Vertical, weld down	Vd	PG	3G
Overhead	O	PE	4G
Pipe butt welds			
Pipe horizontal, rotated, weld horizontal	D	PA	1G
Pipe vertical, not rotated, weld horizontal	X	PC	2G
Pipe horizontal, not rotated, weld flat, vertical and overhead	D+Vu+O D+Vd+O	PF PG	5G
Pipe inclination fixed, not rotated	45°	H-L045 J-L045	6G
Plate fillet welds			
Flat	D	PA	1F
Horizontal	X	PB	2F
Vertical up	Vu	PF	3F
Vertical down	Vd	PG	3F
Overhead	O	PD	4F
Pipe fillet welds			
Flat, pipe rotated	D	PA	1FR
Horizontal, pipe fixed	X	PB	2F
Horizontal, pipe rotated	D	PB	2FR
Overhead, pipe fixed	O	PD	4F
Multiple, pipe fixed	D+Vu+O D+Vd+O	PF PG	5F

2.4.4 Fillet weld test assemblies are welded on one side only.

2.4.5 Where the construction welding is predominately fillet welding, in addition to the butt weld qualification test, a fillet weld qualification test is to be performed to confirm that acceptable weld quality is achieved.

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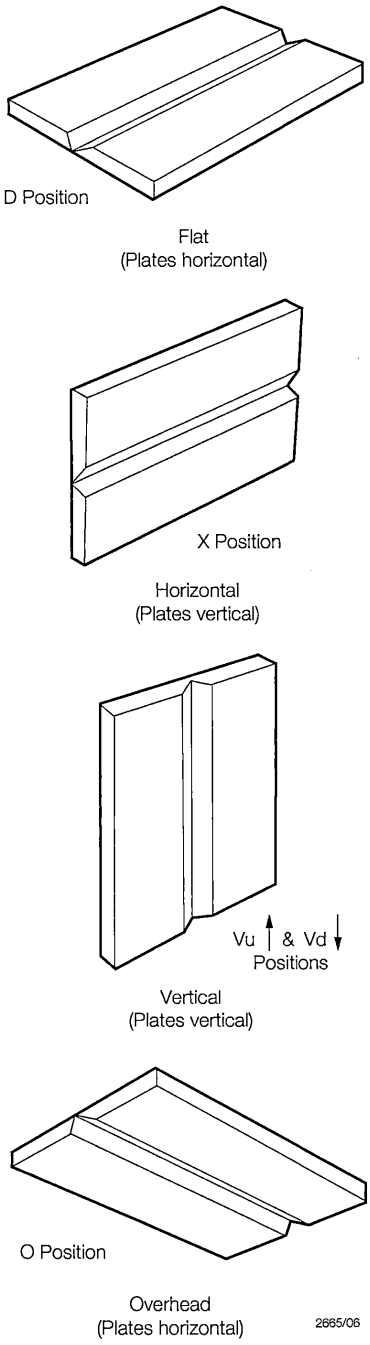
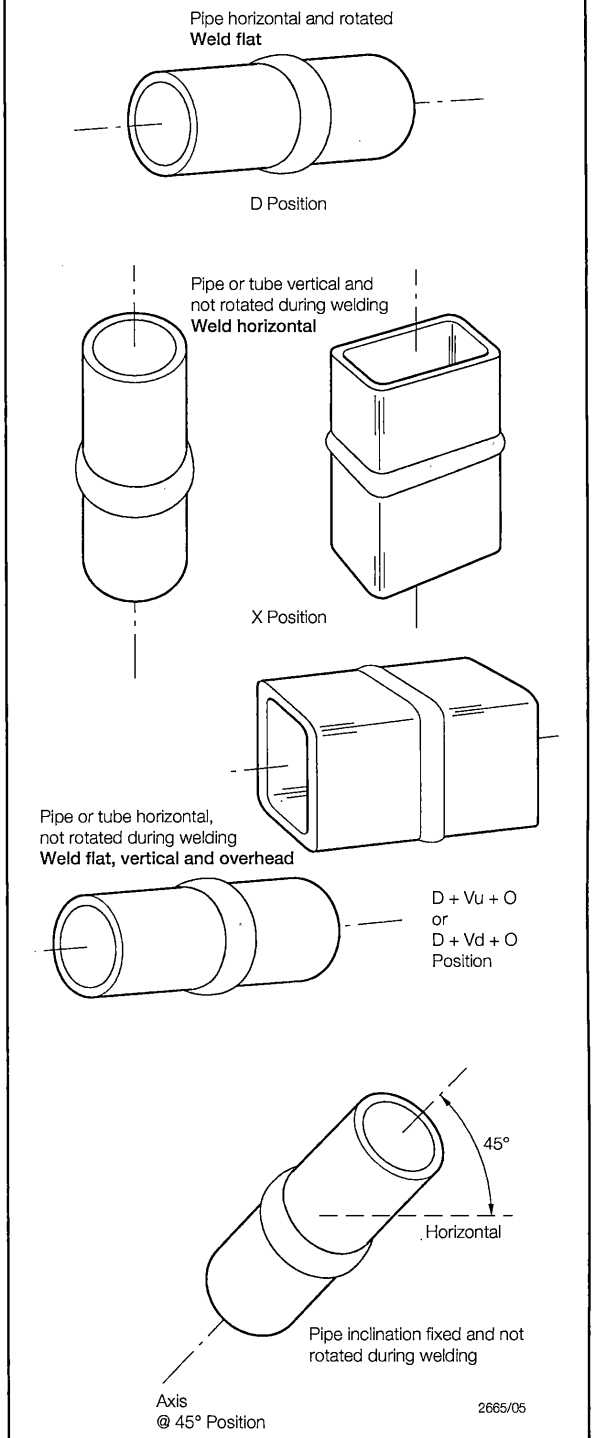


Position of test plates for plate assemblies

Fig. 12.2.2(a) Plate butt weld test positions



Position of pipes and welds for qualification weld test assemblies

Fig. 12.2.2(b) Pipe butt weld test positions

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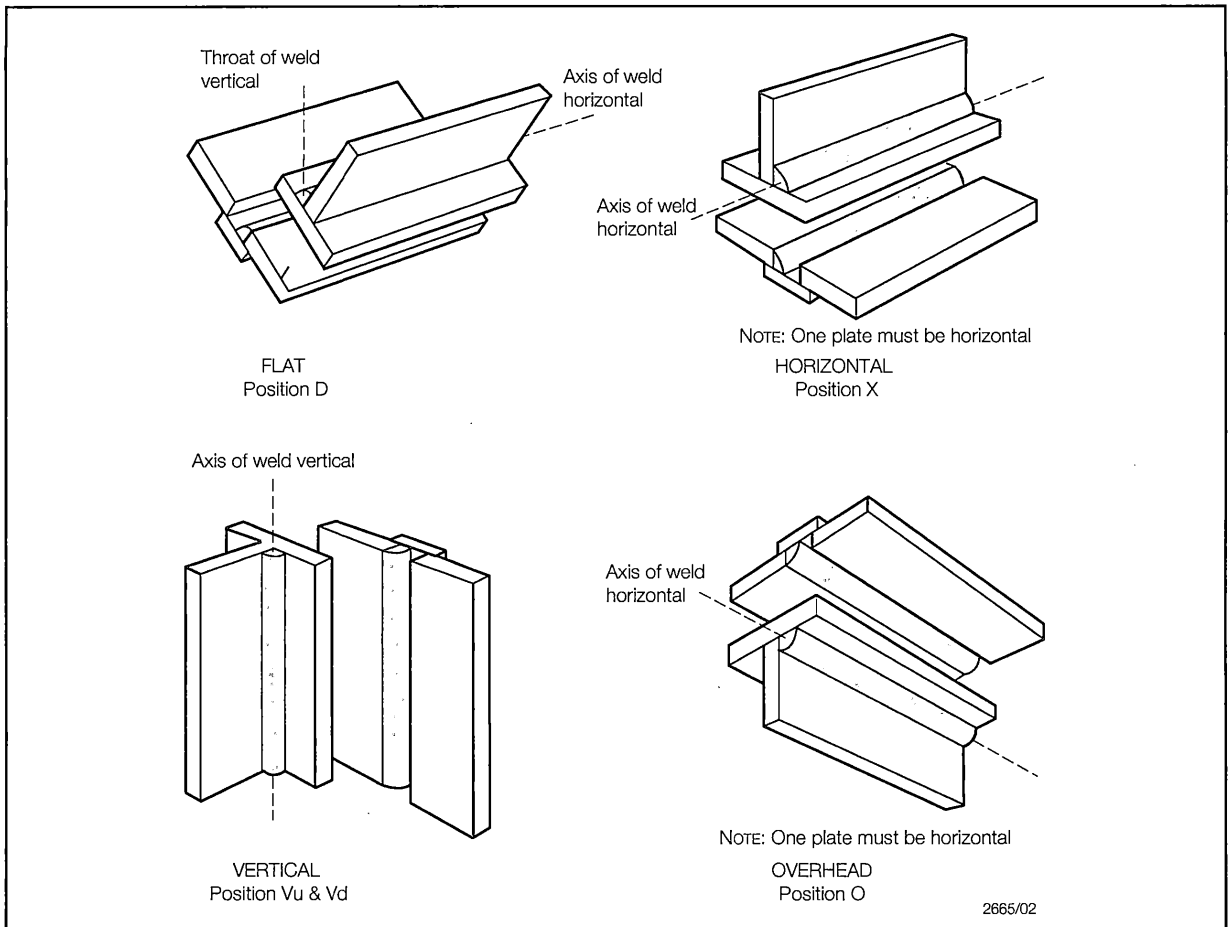

Fig. 12.2.2(c) Plate fillet weld test positions

2.5 Non-destructive examination (NDE)

2.5.1 On completion of welding, prior to sectioning for mechanical tests, the inspection length of the test assembly is to be subjected to both visual examination and surface crack detection.

2.5.2 Butt weld assemblies are also to be subjected to radiographic or ultrasonic examination over the whole inspection length of the weld.

2.5.3 For welds in steels with specified yield strength up to 400 N/mm^2, and with carbon equivalent less than or equal to 0,41 per cent, NDE may be performed as soon as the test assembly has cooled to ambient temperature. For other steels, NDE is to be delayed for a period of at least 48 hours after the test assembly has cooled to ambient temperature.

2.5.4 Where post-weld heat treatment is required, NDE is to be performed after the heat treatment is complete.

2.5.5 All NDEs are to be carried out in accordance with the requirements of Ch 1,5. Assessment of results is to be in accordance with ISO 5817 Level B except for excess convexity and excess throat thickness where Level C will apply. Linear porosity is not permitted.

2.5.6 As an alternative to radiography, ultrasonic examination may be carried out and acceptance criteria that are considered to result in equivalent weld quality (in accordance with 2.5.5) are to be agreed, with the Surveyor, prior to the tests being carried out. Ultrasonic testing will be subject to the thickness limitation specified in Ch 13,2.12.5.

2.5.7 Where the test assembly does not satisfy the non-destructive examination acceptance criteria, the test is to be rejected. A duplicate test assembly may be welded using the original welding conditions. If this fails NDE, the welding procedure is to be considered as incapable of achieving the requirements without modification.

2.5.8 Subject to prior agreement with the Surveyor, where unacceptable imperfections are of a volumetric nature and are localised in one small area of the test assembly, the test may be permitted to continue and specimens for destructive testing may be removed, avoiding this area.

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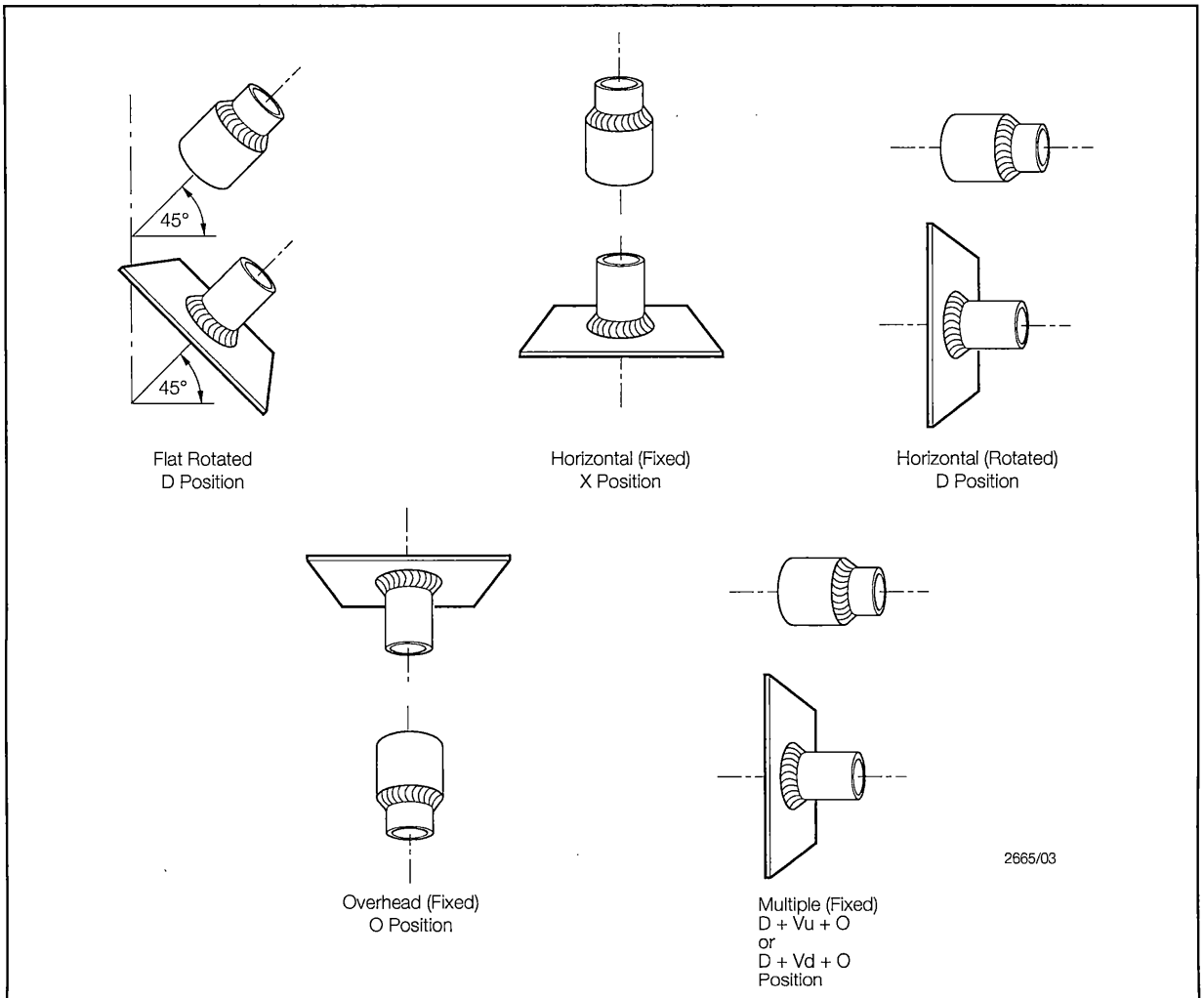

Fig. 12.2.2(d) Pipe fillet weld test positions

2.6 Destructive tests – General requirements

2.6.1 The weld test assembly may only be sectioned for destructive testing after any heat treatment and the required non-destructive examinations have been completed successfully.

2.6.2 The dimensions of the test specimens and testing conditions are to be in accordance with the requirements specified in Chapter 2.

2.6.3 The results of destructive tests are to be assessed in accordance with the acceptance criteria specified in 2.12, unless other, more stringent requirements are specified for the application.

2.6.4 Where a weld test is made between materials of different grades, the acceptance criteria that are to be applied are those applicable to the lower grade material.

2.7 Destructive tests for steel butt welds

2.7.1 The test assembly is to be sectioned for mechanical testing in accordance with Figs. 12.2.3 or 12.2.4.

2.7.2 The longitudinal all weld metal tensile test specimen is to be of circular cross-section as detailed in Ch 11,2.1.1. Where more than one welding process or type of consumable has been used to make the weld, test specimens are to be removed from each respective area of the weld. This does not apply to the process or consumables used to make the root or first weld run. During the test, the yield or proof stress, ultimate tensile strength, and elongation to failure are to be recorded.

2.7.3 Where approved welding consumables have been used, the longitudinal all weld metal tensile test may be omitted.

2.7.4 The transverse tensile test specimen is to be of full thickness with the dimensions shown in Ch 11,2.1.1. The tensile strength and fracture locations are to be reported.

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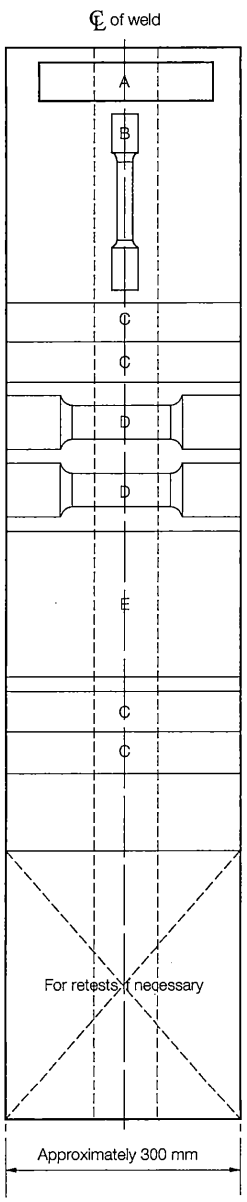

Test requirements
A One macro including hardness survey
B All weld metal tensile test
C Four bend tests.
Two root bends and two face bends for thickness up to 12 mm.
For thickness above 12 mm four side bends
D Two transverse tensiles
E Five sets of Charpy V-notch impact tests, notched at the following positions:
1 set at weld centre
1 set at fusion line (FL)
1 set at FL + 2 mm
1 set at FL + 5 mm (if required by Figs. 12.2.6 and 12.2.7)
1 set at FL + 10 mm (if required)

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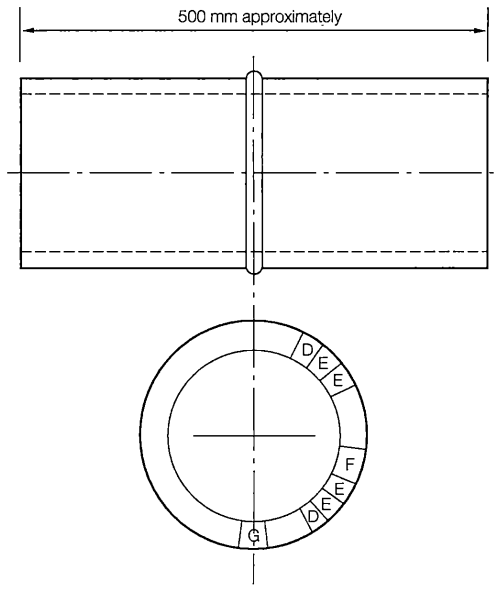
Fig. 12.2.3
Butt welds in plate and pipe over 750 mm diameter



The diameter of the test piece is to be a minimum of *D*/2
where
D is the maximum diameter of the pipe to be welded in construction

Test requirements
A Visual examination
B Surface crack detection
C 100% radiographic examination
D Two transverse tensile tests
E Four bend tests.
Four side bends for thickness greater than 12 mm.
In other cases, two face and two root bends
F Four sets Charpy V-notch impact tests
1 set notched at centre of weld
1 set notched at fusion line (FL)
1 set notched at FL + 2 mm
1 set notched at FL + 5 mm (if required by Figs. 12.2.6 and 12.2.7)
G One macro specimen including hardness survey

Fig. 12.2.4
Butt welds in pipe less than 750 mm diameter

2.7.5 Where the maximum load required to fracture the transverse tensile specimen is likely to exceed the capacity of the tensile testing equipment, several tensile specimens may be removed through the thickness and tested. Specimens are to be prepared such that they overlap in the thickness direction so that the full plate thickness is tested.

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2.7.6 Transverse bend specimens of rectangular section are to be prepared with the weld centred in the middle of the specimen as shown in Fig. 12.2.5. For material of thickness 12 mm or greater, the face and root bends may be substituted by side bend tests. The weld reinforcement may be removed by grinding or machining prior to testing and the edges rounded to a radius not exceeding 10 per cent of the specimen thickness. Each specimen is to be bent through an angle of at least 180°. The bend test ratio is to be the lesser of the following:

(a) $D_f = (D/t) + 1$

or

(b) $D_f = 100/E_m$ (rounded up to the next whole number)

where

D_f = is the bend test ratio

(D/t) = is the value from Tables 11.3.3, 11.4.3 or 11.8.2 in Chapter 11, as appropriate

E_m = is the minimum specified percentage elongation for the test material (based on a proportional gauge length of $5{,}65\sqrt{S_o}$)

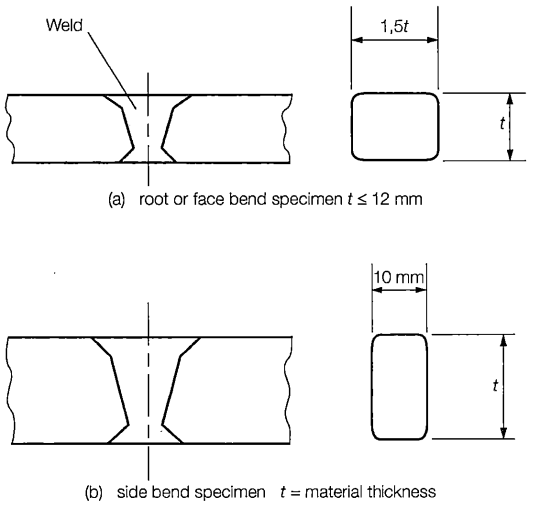

Fig. 12.2.5 Transverse bend test specimens

2.7.7 Where the weld test is made between different material types, the requirements of 2.7.8 are to be applied to the material with the lower toughness specification.

2.7.8 For hull structural steels, impact test specimens are to be prepared from the locations shown in Figs. 12.2.6 or 12.2.7, with the notch perpendicular to the plate surface and have the dimensions and proportions in accordance with Ch 2,3. Where more than one welding process or type of consumable has been used to make the weld, test specimens are also to be removed from these respective parts of the weld. Note that this does not apply to the welding process or consumables used solely to make the root or first weld run. Where the weld thickness exceeds 50 mm, an additional set of impact tests is required from the root area of the weld irrespective or whether different welding process or welding consumables are used as shown in Figs. 12.2.6 and 12.2.7.

2.7.9 For offshore structures and pressure vessels, impact test specimens are not required to be notched at the FL + 10 mm location. Where more than one welding process or type of consumable has been used to make the weld, test specimens are to be removed from the respective areas of the weld. This does not apply to the process or consumables used solely to make the root or first weld run.

2.7.10 At least one macro examination specimen is to be removed from the test plate, near the end where welding started. The specimen is to include the complete cross-section of the weld and the heat affected zone and be prepared and etched to clearly reveal the weld runs and the heat affected zone. Examination is to be performed under a magnification of between x5 and x10.

2.7.11 A chemical analysis of the weld metal is to be performed on the macro specimen where approved welding consumables have not been used. The results are to comply with the limits given in the welding consumable specification.

2.7.12 A Vickers hardness survey is to be performed on the macro specimen taken from the weld start end of the test assembly in accordance with that shown in Fig. 12.2.8, using a test load not in excess of 10 kg. For each row of indents, there are to be a minimum of 3 individual indentations in the weld metal, the heat affected zones (both sides) and the base metal (both sides). The recommended distance between indents is 1,0 mm, but the distance between indents should not be less than the minimum specified in ISO 6507/1.

2.8 Destructive tests for steel fillet welds

2.8.1 Fillet weld test assemblies are to be sectioned for destructive testing in accordance with Fig. 12.2.1(c) and as follows:

(a) two fracture tests;

(b) three macro-sections;

(c) one hardness survey.

2.8.2 Two fracture test specimens are to be removed from the test weld and are to be subjected to testing by bending the upright plate onto the through plate to produce fracture, as shown in Fig. 12.2.1(c).

2.8.3 At least three macro examination specimens are to be removed from the test plate. The specimens are to include the complete cross-section of the weld and the heat affected zone and is to be prepared to clearly reveal the weld runs and the heat affected zone. One of the specimens is to include a weld stop/start position. Examination is to be performed under a magnification of between x5 and x10.

2.8.4 A Vickers hardness survey is to be performed on the macro specimen taken from the weld start end of the test assembly in accordance with that shown in Fig. 12.2.9, using a test load not exceeding 10 kg.

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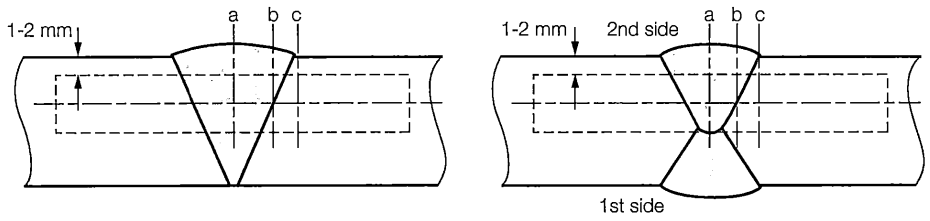
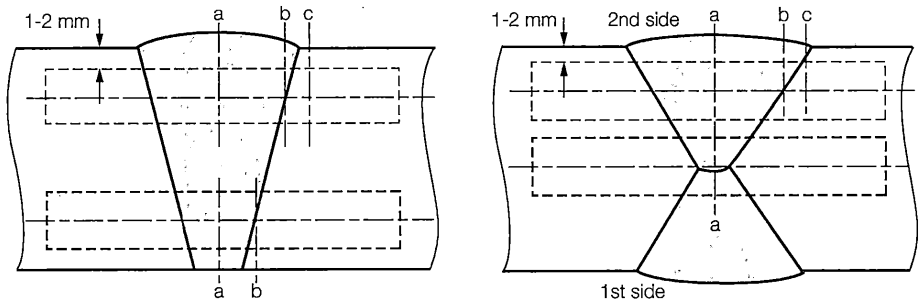
(a) $t \leq 50$ mm, *see* Note



NOTE
For one side single run welding over 20 mm notch location 'a' is to be added on root side

(a) $t > 50$ mm



Notch locations:
a : centre of weld 'WM'
b : on fusion line 'FL'
c : in HAZ, 2mm from fusion line

Fig. 12.2.6 Locations of V-notch for butt weld of normal heat input (heat input ≤ 50 kJ/cm)

2.9 Destructive tests for T, K, Y steel nozzle welds

2.9.1 Full penetration 'T', 'K' and 'Y' joints for structural applications and nozzle welds for pressure vessels are to be sectioned for testing in accordance with Fig. 12.2.10 and tested as detailed below:

(a) three macro specimens;
(b) impact tests from the weld, fusion line and fusion line + 2 (where the material thickness permits);
(c) one hardness survey.

In addition, butt weld tests are to be performed in accordance with 2.7, using the same welding conditions, in order to verify acceptable weld and heat affected zone properties.

2.9.2 The impact tests are to be removed from the vertical (up) position 'B' in Fig. 12.2.10 and tested in accordance with 2.7.8.

2.9.3 A Vickers hardness survey is to be performed on the macro-section removed from position 'A' or 'C' in accordance with that shown in Fig. 12.2.11 using a test load not exceeding 10 kg.

2.10 Destructive tests for steel pipe branch welds

2.10.1 Pipe branch welds may be by either full penetration, partial penetration or fillet welded, depending on the application and the approved plans. Where these types of welded joints are used, tests are to be performed which simulate the construction conditions.

2.10.2 The test weld assembly is to simulate the smallest angle between the branch and main pipe and is to be subjected to macro-examination and hardness testing, as follows:

(a) For a branch weld that is full penetration, testing is to be performed in accordance with the requirements for 'T', 'K' and 'Y' joints in 2.9.
(b) For a branch weld that is either a partial penetration or fillet weld, testing is to be in accordance with the requirements for fillet welds in 2.8.

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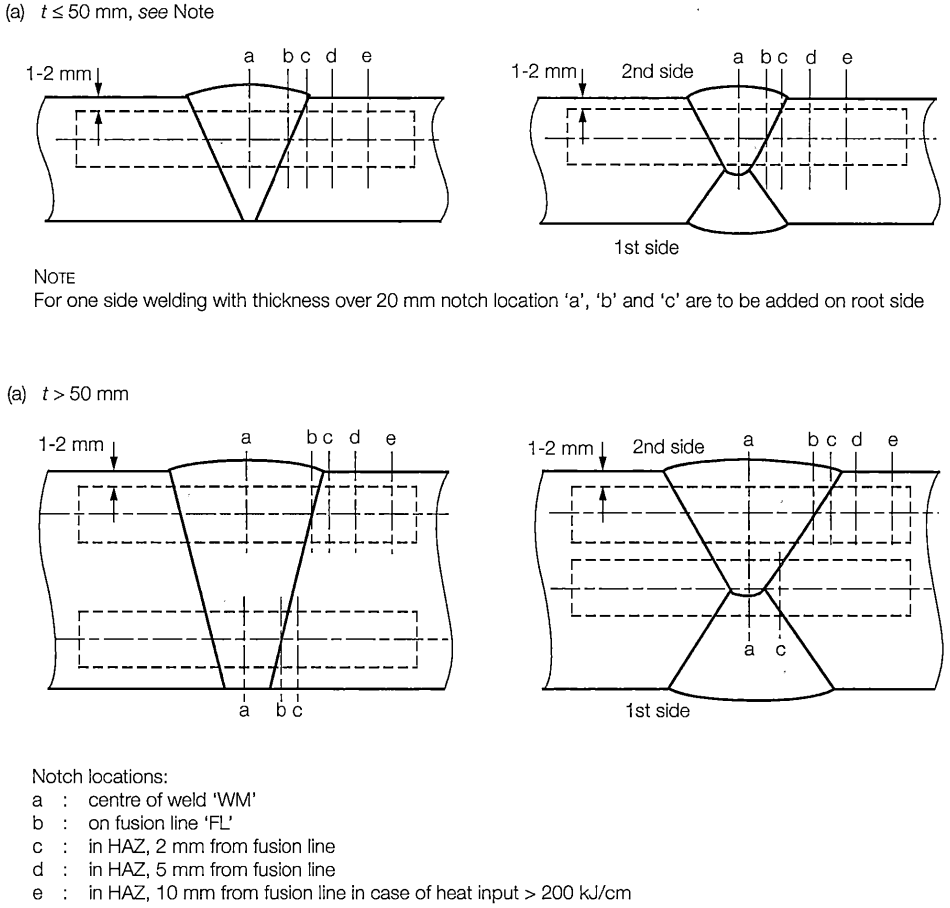

Fig. 12.2.7 Locations of V-notch for butt weld of high heat input (heat input > 50 kJ/cm)

2.11 Destructive tests for weld cladding of steel

2.11.1 Where weld cladding or overlay is allowed by Chapter 13, and is considered as providing strength to the component to which it is welded, the type and location of test specimens are to be in accordance with Fig. 12.2.12, except that micro-sections are not required. Impact tests may be omitted where the base material does not have specified impact properties. The longitudinal tensile and bend tests are to be tested in a similar manner to transverse specimens specified in 2.7.2 and 2.7.6, respectively.

2.11.2 Where the weld cladding is not considered as contributing to the strength of the component, but is required for corrosion or wear resistance, the type and location of test specimens are to be in accordance with Fig. 12.2.12, except that tensile and impact tests are not required.

2.11.3 Where the weld cladding is applied for corrosion resistance, in addition to the above, weld metal analysis is to be performed on one of the micro-sections, on the final weld surface but 2 mm deep. The analysis is to be within the limits specified for the corrosion resistance required.

2.12 Mechanical test acceptance criteria for steels

2.12.1 **Longitudinal all weld metal tensile test**:

(a) In general, the longitudinal all weld tensile test is to meet the minimum properties specified in Tables 11.3.2 or 11.4.2 in Chapter 11, as appropriate to the grade of steel and welding process used in the test.

(b) Where the application is such that no consumable approvals are specified in Chapter 11, the longitudinal all weld tensile test tensile is to meet the minimum properties specified for the base materials used in the test.

(c) For pressure vessels manufactured from carbon or carbon/manganese steels, the tensile strength from the longitudinal all weld tensile test is not to be less than the minimum specified for the plate material and is not to be more than 145 N/mm^2 above this value, *see* Ch 13,4.8.3.

2.12.2 **Transverse tensile test**: The tensile strength measured from the transverse tensile test is not to be less than the minimum specified for the base material used in the test.

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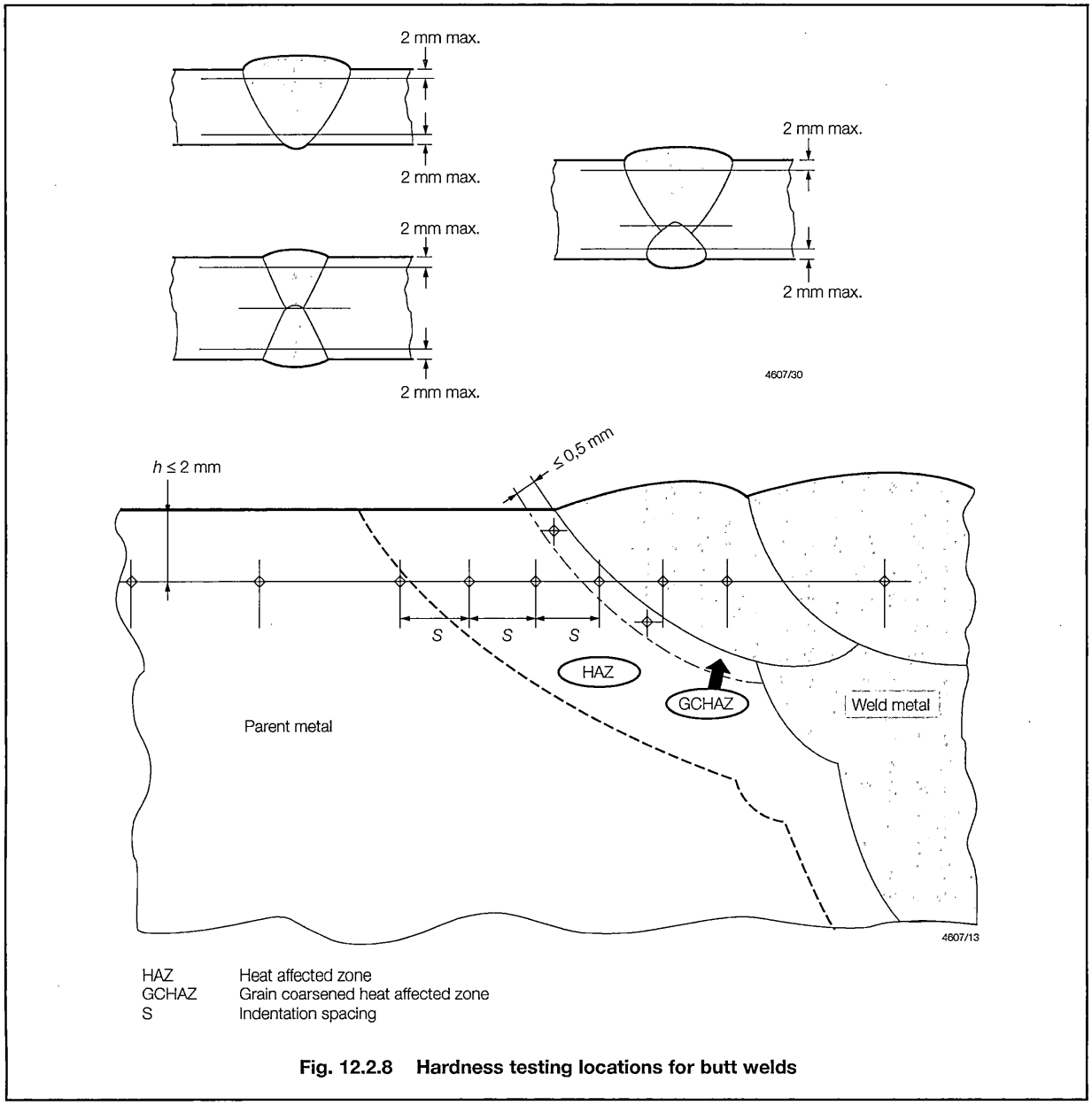

Fig. 12.2.8 Hardness testing locations for butt welds

2.12.3 **Bend tests:**

(a) In general, bend tests are to exhibit no defects exceeding 3,0 mm measured in any direction across the tension face of the specimen after being bent over the required diameter of former to the appropriate angle.

(b) Bend tests for pressure vessel applications are to exhibit no defects exceeding 3,0 mm measured along the specimen or 1,5 mm measured transverse to the specimen axis, after bending.

(c) In all cases, premature failure of the bend tests at the edges of the specimen is to not be cause for rejection unless these are associated with a weld defect.

2.12.4 **Impact toughness tests:**

(a) Impact test specimens for hull construction are to be tested at the temperature, and are to achieve the minimum impact energy, as specified in Table 12.2.2.

(b) Impact test specimens for applications other than hull construction are to be tested at the same temperature and achieve the same minimum energy values, as specified for the base materials used in the test.

(c) Impact test acceptance criteria are to be in accordance with the above unless the Rules applicable to the particular construction specify more stringent requirements.

(d) For quench and tempered steels, the required test temperature and absorbed energy are to be in accordance with that specified for the parent materials.

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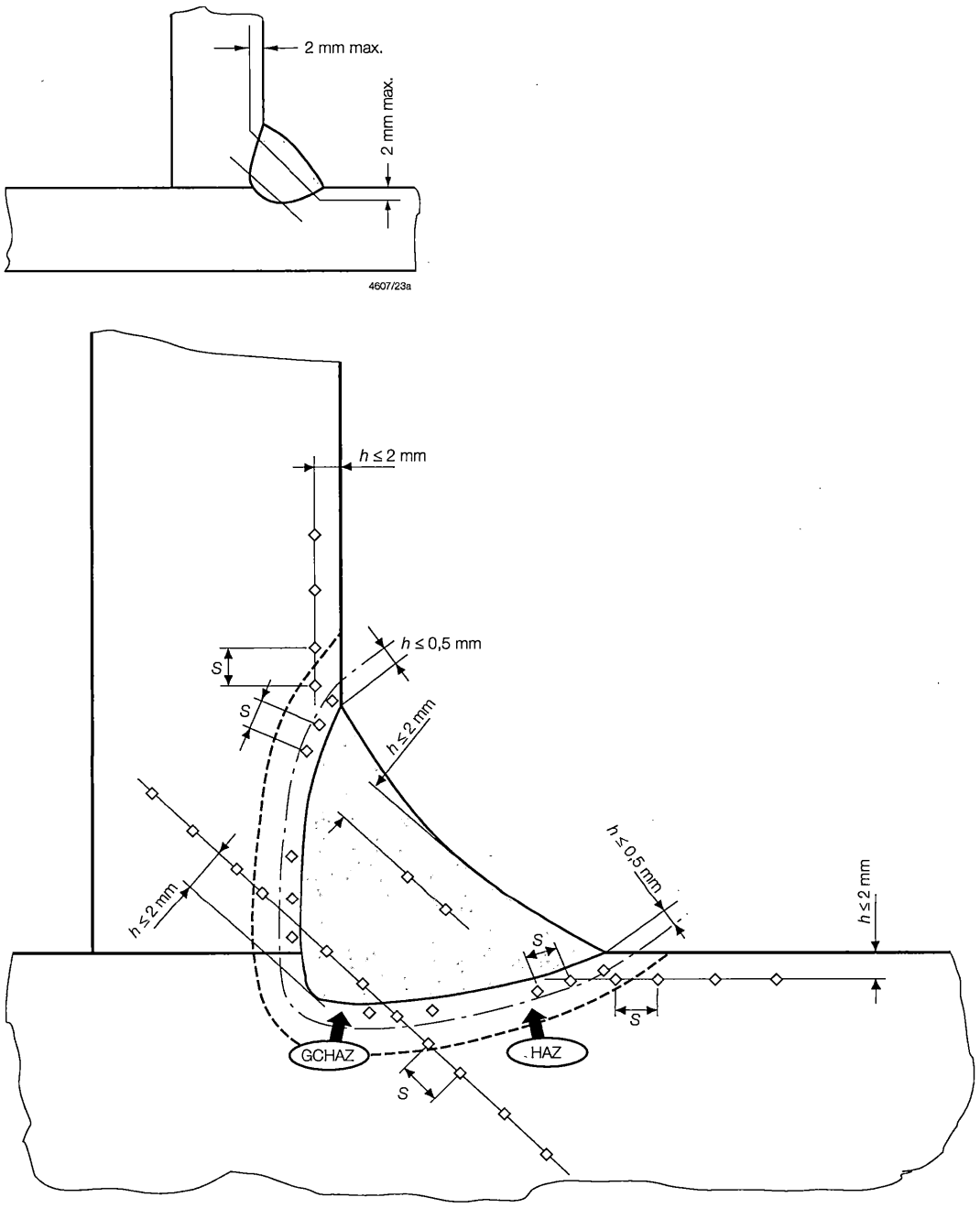

HAZ Heat affected zone
GCHAZ Grain coarsened heat affected zone
S Indentation spacing

Fig. 12.2.9 Hardness test locations for fillet welds

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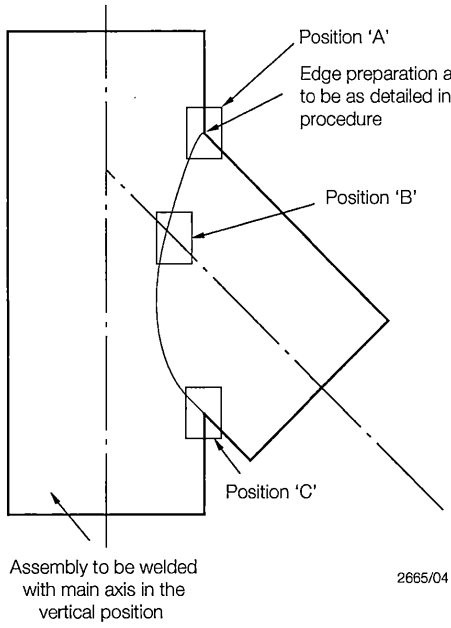
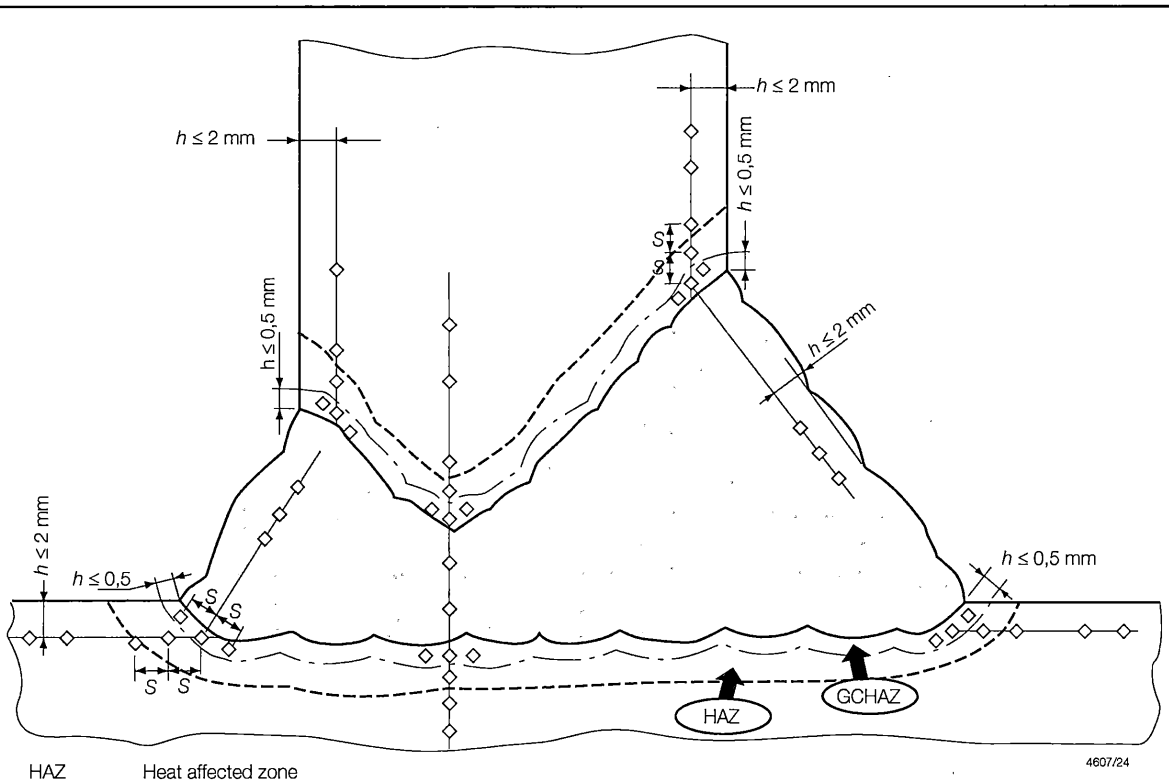


Fig. 12.2.10
Location of macro-examination test specimens for T, K and Y joints

2.12.5 **Macro-examination**: The macro-section is to reveal an even weld profile blending smoothly with the base material. The weld dimensions are to be in accordance with the requirements of the pWPS and any defects present are to be assessed against the non-destructive examination acceptance criteria given in 2.5.5.

2.12.6 **Hardness surveys**: The maximum hardness value reported is not to exceed 350 Hv for steels with a specified minimum yield strength up to ≤ 420 N/mm^2, nor exceed 420 Hv for steels with a specified minimum yield strength in the range 420 N/mm^2 to 690 N/mm^2.

2.12.7 **Weld fracture or break tests (for pressure vessel test welds)**: The faces of the broken fillet weld fracture or weld break test are to be examined for defects and assessed in accordance with the non-destructive acceptance criteria given in ISO 5817 Level B, except for excess convexity and excess throat thickness where Level C will apply.



HAZ Heat affected zone
GCHAZ Grain coarsened heat affected zone
S Indentation spacing

Fig. 12.2.11 Hardness test locations for T, K and Y joints

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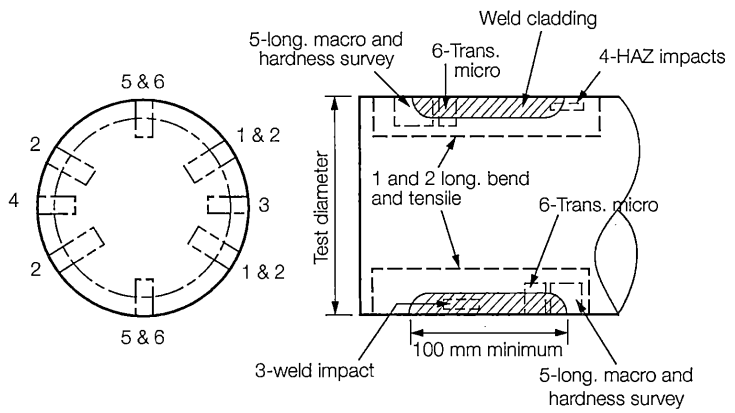

Test specimens
1 Longitudinal tensile test to include the weld metal, heat affected zone (HAZ) and base metal.
2 Longitudinal side bend test to include the weld metal, heat affected zone (HAZ) and base metal.
3 Weld metal Charpy V notch impact test.
4 HAZ Charpy impact test from Fusion Line and Fusion Line + 2 mm.
5 Longitudinal macro-section and hardness survey.
6 Transverse micro-section.

NOTE
In the case of shafts and pipes of circular section, the longitudinal direction is parallel to the centreline of the shaft or pipe axis.

Fig. 12.2.12 Type and location of test specimens for weld cladding

Table 12.2.2 Impact test requirements for butt joints ($t \leq 50$ mm) *see* Notes 1 and 2

Grade of steel	Test temperature (°C) *see* Note 4	Value of minimum energy absorbed (J), *see* Note 4		
		Manual or semi-automatic welded joints		Automatically welded joints
		Downhand, Horizontal, Overhead	Vertical upward, Vertical downward	
A, *see* Note 3 B, *see* Note 3, D E A32, A36 D32, D36 E32, E36 F32, F36	20 0 –20 20 0 –20 –40	47	34	34
A40 D40 E40 F40	20 0 –20 –40		39	39
>40	As specified for parent material	As specified in Ch 11,4.3		

NOTES
1. For thickness above 50 mm, impact test requirements are to be specially agreed.
2. These requirements are to apply to test piece of which butt weld is perpendicular to the rolling direction of the plates.
3. For grade A and B steels average absorbed energy on fusion line and in heat affected zone is to be a minimum of 27 J.
4. For Naval ships both the test temperature and value of minimum energy absorbed are to be those specified for the parent material.

2.13 Failure to meet requirements (Retests)

2.13.1 Where a tensile, bend or hardness specimen fails to meet requirements, further test specimens may be removed and tested in accordance with the requirements of Ch 2,1.4.1.

2.13.2 Where an impact specimen fails to meet requirements, a further set of three specimens may be removed and tested in accordance with the requirements of Ch 2,1.4.4.

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2.13.3 Where a macro specimen reveals a defect that is planar in nature, the welding procedure test is to be considered as not satisfying the requirements and a new test assembly is required.

2.13.4 Where a macro specimen does not meet requirements as a result of a volumetric imperfection exceeding the permitted size, two additional specimens may be removed from the same test weld and examined. If either of these macro-sections also fails to satisfy the requirements, the welding procedure is to be considered as not having met the requirements.

2.13.5 If there is a single hardness value above the maximum values specified, additional hardness tests are to be carried out, either on the reverse of the specimen, or after sufficient grinding of the tested surface. None of the additional hardness values is to exceed the maximum hardness values specified, otherwise the welding procedure is to be considered as not having met the requirements.

2.13.6 Where there is insufficient material available in the welded test assembly to provide re-test specimens, subject to prior agreement with the Surveyor, a second assembly may be welded using the same conditions as the original test weld.

2.14 Test records

2.14.1 The procedure qualification record (PQR) is to be prepared by the manufacturer and is to include details of the welding conditions used in the test specified in 2.2 and the results of all the non-destructive examinations and destructive tests, including re-tests.

2.14.2 Provided that the PQR lists all the relevant variables and there are no inconsistent features and the results satisfy the requirements, the PQR may be endorsed by the Surveyor as satisfying the requirement of the Rules, *see also* 1.1.4.

2.15 Range of approval

2.15.1 A welding procedure qualification test that has successfully met the requirements may be used for a wider range of applications than those used during the test.

2.15.2 Changes outside of the ranges specified are to require a new welding procedure test.

2.15.3 Other ranges of approval from those specified in this Section may be agreed with the Surveyor, provided that they are in accordance with recognised National or International Standards.

2.15.4 **Manufacturer.** A welding procedure qualified by a manufacturer is valid for welding in workshops under the same technical and quality management.

2.15.5 **Welding process and technique.** The welding process and welding techniques approved are to be those employed during the welding procedure qualification test. Where multiple welding processes are used, these are to be employed in the same order as that used in the welding procedure qualification test. However, it may be acceptable to delete or add a welding process where it has been used solely to make the first weld run in the root of the joint, provided back gouging or grinding of the root weld is specified on the WPS. For multi-process procedures, the welding procedure approval may be carried out with separate welding procedure tests for each welding process.

2.15.6 **Welding positions.** Approval for a test made in any position is restricted to that position. To qualify a range of positions, test assemblies are to be welded for the highest heat input position, and the lowest heat input position, and all applicable tests are to be made on those assemblies. The above excludes welding in the vertical position with travel in the downward direction which will always require separate qualification testing and only be acceptable for that position.

2.15.7 **Joint types.** A qualification test performed on a butt weld may be considered acceptable for fillet and partial penetration welds, provided the same welding conditions are used. The range of approval depending on the type of joint for butt welds is given in Table 12.2.3.

Table 12.2.3 Range of approval for different types of butt joints

Type of welded joint for test assembly				Range of approval
Butt welding	One side	With backing	A	A,C,D
		Without backing	B	A,B,C,D
	Both sides	With gouging	C	C
		Without gouging	D	C,D

2.15.8 **Range of material types:**

(a) A qualification test performed on one strength level of steel may be used to weld all similar materials with the same or lower specified minimum yield stress with the exception of the two-run (T) or high welding heat input (A) techniques where acceptance is limited to the strength level used in the test. Similarly, a qualification test performed on a steel with one toughness level may be considered acceptable for welding all similar materials with the same or three toughness grades lower specified minimum toughness level.

(b) For high strength quenched and tempered steels, for each strength level, welding procedures are considered applicable to the same and lower toughness grades as that tested. For each toughness grade, welding procedures are considered applicable to the same and one lower strength level as that tested. The approval of quenched and tempered steels does not qualify thermo-mechanically rolled steels (TMCP steels) and vice versa.

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(c) For weldable C and C-Mn steel forgings, welding procedures are applicable to the same and lower strength level as that tested. The approval of quenched and tempered steel forgings does not qualify other delivery conditions and vice versa.

(d) For weldable C and C-Mn steel castings, welding procedures are applicable to the same and lower strength level as that tested. The approval of quenched and tempered steel castings does not qualify other delivery conditions and vice versa.

Dissimilar materials. Where a qualification test has been performed using dissimilar materials, acceptance is to be limited to the materials used in the test.

2.15.9 **Thickness and diameter range:**

(a) For straight butt welds, the material thickness range to be approved is to be based on the thickness of the test piece and the type of weld as shown in Table 12.2.4.

(b) For butt welds between plates of unequal thickness, the lesser thickness is the ruling dimension.

(c) For fillet welds and 'T' butt welds, Table 12.2.4 is to be applicable to both the abutting and through member thicknesses. In addition to the requirements of Table 12.2.4, the range of approval of throat thickness '*a*' for fillet welds is to be as follows:

- single run: 0,75*a* to 1,5*a*
- multi-run: as for butt welds with multi-run (i.e. $a = t$)

(d) Notwithstanding any of the above, the approval of maximum thickness of base metal for any technique is to be restricted to the thickness of the test assembly if three of the hardness values in the heat affected zone are found to be within 25 Hv of the maximum permitted.

(e) The material diameter range to be approved is to be based on the diameter of the test piece and type of weld as shown in Table 12.2.5.

Table 12.2.4 Welding procedure thickness approval range – Butt welds

Test thickness, *see* Note 1 (*t* in mm)	Range approved	
	All multi-run butt welds and all fillet welds *see* Notes 3 and 4	All single-run or two-run two-run (T technique) butt welds
$t \leq 3$	*t* to 2*t*	0,7*t* to 1,1*t*
$3 < t \leq 12$	3 to 2*t*	0,7*t* to 1,1*t*
$12 < t \leq 100$	0,5*t* to 2*t*, *see* Note 2	0,7*t* to 1,1*t* *see* Note 5
$t > 100$	0,5*t* to 1,5*t*	0,7*t* to 1,1*t* *see* Note 5

NOTES
1. Where the test plates have dissimilar thickness, the thickness, *t*, is to be based on the minimum thickness for butt welds and the maximum thickness for fillet welds.
2. Subject to a maximum limit of 150 mm.
3. For multi process procedures, the recorded thickness contribution of each process is to be used as a basis for the range of approval of the individual welding process.
4. For vertical down welding, the test piece thickness, *t*, is the upper limit of the range of application.
5. For processes with heat input over 5,0 kJ/mm, the upper limit of the range of approval is to be 1,0 *t*.

Table 12.2.5 Diameter range approved

Diameter used for test, *see* Note 1	Range of diameters approved
$D \leq 25$ mm	0,5*D* to 2*D*
$D > 25$ mm	> 0,5*D*, *see* Note 2

NOTES
1. *D* is the outside diameter of the pipe or the smallest side dimension of rectangular hollow section.
2. Lower diameter range limited to 25 mm minimum.

2.15.10 **Welding consumables:**

(a) For manual and semi-automatic welding used for the fill and capping weld runs, it may be acceptable to change the brand or trade name of the welding electrode or wire from that used in the test, provided the proposed alternative has the same or higher approval grading and the same flux type (e.g. basic low hydrogen, rutile, etc.) as used in that test.

(b) For the consumable used to make the root weld of full penetration butt welds made from one side only, no change in the type or trade name of the consumable or backing material is permitted. Alternative backing materials may be used provided they are equivalent to those used for approval. Where the approved backing material is a low hydrogen grade and the steel being welded requires a low hydrogen backing material, testing of the alternative backing material is to confirm compliance with the requirements of Ch 11,7

(c) For processes with heat input over 5 kJ/mm, no change in the type or trade name of the consumable is permitted.

2.15.11 **Shielding gas.** For gas shielded welding processes, a change in shielding gas composition from that used in the test will require a new qualification test.

2.15.12 **Heat Input**. The upper limit of heat input approved is 25 per cent greater than that used in the test, or 5,5 kJ/mm, whichever is the smaller. With heat input over 5,0 KJ/mm, the upper limit is 10 per cent above that used in the test. In all cases, the lower limit of heat input approved is 25 per cent lower than that used in the test.

2.15.13 **Current type**. The current type used during the qualification test is to be the only type approved. Additionally, changes from or to pulsed current require new qualification tests.

2.15.14 **Preheat temperature**. The temperature used during the test is to be the minimum approved. Higher temperatures may be specified for production welds up to the maximum interpass temperature. Where hardness tests have been performed that exhibit results near the maximum permitted, an increase in preheat temperature is required when welding material of greater thickness than that used in the test.

2.15.15 **Interpass temperature**. The maximum interpass temperature recorded during qualification testing is to be the maximum approved. Lower temperatures may be specified for production welding, but no lower than the minimum preheat temperature.

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2.15.16 **Post-weld heat treatment.** A qualification test performed with no post weld heat treatment is only acceptable for production welding where no heat treatment is applied. Where the qualification test has included a post weld heat treatment, this is to be applied to all welds made with the welding procedure. The average specified soak temperature may vary by up to 25°C from that tested.

2.15.17 **Shop primers.** Welding procedure qualification with shop primers qualifies welds without primer, but not vice versa.

2.16 Welding procedure specification (WPS)

2.16.1 A welding procedure specification (WPS) is to be prepared by the manufacturer detailing the welding conditions and techniques to be employed for production welding. The WPS is to be based on the conditions and variables used during the qualification test, and is to include all the ranges of the essential variables specified in 2.2.1 and 2.15.

2.16.2 The WPS should reference the procedure qualification record upon which it is based and is to be approved by the Surveyor prior to commencing production welding.

■ *Section 3* Specific requirements for stainless steels

3.1 Scope

3.1.1 The requirements of this Section relate to the group of steel materials classed as stainless steels and include austenitic and duplex grades and martensitic grades.

3.1.2 In all cases, welding procedure tests are to be performed generally in accordance with Section 2 with the specific requirements specified below.

3.2 Austenitic stainless steels

3.2.1 The requirements of this Section relate to the group of stainless steel materials that are austenitic at ambient and sub-zero temperatures, (e.g. 304L, 316L types), *see* Table 3.7.1 in Chapter 3.

3.2.2 Impact tests are to be performed from specimens removed from the weld metal. Tests in the heat affected zone are not required.

3.2.3 Hardness tests are generally not required.

3.2.4 For cryogenic or corrosion resistant applications, the ferrite content in the weld cap region is to be measured and is to be in the range 2 to 10 per cent, with the exception of grades S 31245 and N 08904 where the content is to be nominally zero.

3.2.5 A qualification test performed on an austenitic grade may be considered acceptable for welding other austenitic steels with the same or lower level of alloying elements and the same or lower tensile strength.

3.2.6 A qualification test performed for cryogenic applications may be considered acceptable for chemical applications, but not vice versa.

3.3 Duplex stainless steels

3.3.1 The requirements of this Section relate to the group of stainless steel materials that have a ferritic-austenitic structure and are usually referred to as duplex or super duplex stainless steels (e.g. S 31803, S 32760).

3.3.2 Impact test specimens are to be removed from the weld and heat affected zone in accordance with Section 2 with the exception that impact test specimens notched at the FL + 10 mm location are not required. The specimens are to be tested at a temperature of –20°C or the minimum design temperature whichever is the lower and exhibit a minimum average energy of 40 J.

3.3.3 The corrosion resistance is to be maintained in the welded condition and the following tests are to be performed to demonstrate acceptable resistance, unless agreed otherwise.

(a) A sample is to be removed from the weld and heat affected zone for micro-structural examination and is to be suitably prepared and etched so that the micro-structures of the weld and heat affected zones can be examined at a magnification of x200 or higher. The micro-structure of the weld and heat affected zone is to be examined, the percentage grain boundary carbides and intermetallic precipitates is to be reported.

(b) The ferrite content in the un-reheated weld cap and cap HAZ along with the weld root and root HAZ are to be measured and reported. The ferrite content is to be in accordance with Table 12.3.1. Where the intended construction is such that the corrosion medium is only in contact with one surface of the weld (i.e. the weld root), the ferrite determination need only be reported in that surface area.

(c) Corrosion testing is to be performed on samples removed from the weld such that both the weld and HAZ are included in the test. The critical pitting temperature is to be determined in accordance with ASTM G48 Method C and meet the requirements specified in Table 12.3.1. The cap and root surfaces are to be inspected for evidence of pitting and may require probing the surface with a needle. Pitting found on the ends of the specimen in the weld cross-section may be ignored. The use of the weight loss method for corrosion testing may be accepted subject to special consideration.

3.3.4 Where the test weld is between a grade of carbon steel and duplex stainless steel, the test requirements of 3.3.3(a) and (c) are not required and the ferrite content of the weld and the duplex heat affected zone are to be reported for information.

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Table 12.3.1 Requirements for ferrite content and corrosion tests for duplex stainless steel test welds

Duplex Stainless Steel Material Grade	Weld and HAZ Ferrite content	Minimum Critical Pitting Temperature (CPT)
S 31260	30 to 70%	20°C
S 31803	30 to 70%	20°C
S 32550	35 to 65%	25°C
S 32750	35 to 65%	25°C
S 32760	35 to 65%	25°C

3.3.5 A qualification test performed on a duplex stainless steel grade may be considered acceptable for welding other duplex grades which have the same or less stringent mechanical or corrosion properties.

3.3.6 The range of heat input is not to vary by more than +10 per cent or –25 per cent from that used during testing.

3.4 Martensitic stainless steels

3.4.1 The requirements of this Section relate to the group of stainless steel materials that have a martensitic structure at ambient temperatures, *see* Table 4.5.1 in Chapter 4.

3.4.2 The results of the hardness survey results are to be reported for information purposes only.

3.4.3 A qualification test is considered acceptable only for the grade of material used in the test.

■ *Section 4* Welding procedure tests for non-ferrous alloys

4.1 Requirements for aluminium alloys

4.1.1 The requirements for welding procedure qualification tests for aluminium alloys are to be in accordance with the general requirements of Section 2 with the following exceptions and specific requirements.

4.1.2 Non-destructive examination is to be performed in accordance with 2.5 and the assessment of results is to be in accordance with Table 12.4.1 and Table 12.4.2.

Table 12.4.1 Acceptance criteria for surface imperfections of aluminium alloys

Surface discontinuity	Classification according to ISO 6520-1	Acceptance criteria
Crack	100	Not permitted
Lack of fusion	401	Not permitted
Incomplete root penetration in butt joints welded from one side	4021	Not permitted
Surface pore	2017	$d \leq 0{,}1s$ or $0{,}1a$ max. 1,0 mm
Uniformly distributed porosity (*see* Note 1)	2012	≤ 0,5% of area
Clustered porosity	2013	Not permitted
Continuous undercut	5011	Not permitted
Intermittent undercut	5012	$h \leq 0{,}1t$ or 0,5 mm (whichever is the lesser)
Excess weld metal (*see* Note 2)	502	$h \leq 1{,}5$ mm + $0{,}1b$ or 6 mm (whichever is the lesser)
Excess penetration	504	$h \leq 4$ mm
Root concavity (*see* Note 2)	515	$h \leq 0{,}05t$ or 0,5 mm (whichever is the lesser)
Linear misalignment (*see* Notes 3 and 4)	507	$h \leq 0{,}2t$ or 2,0 mm (whichever is the lesser)

Symbols

a = nominal throat thickness of a fillet weld
b = width of weld reinforcement
d = diameter of a gas pore
h = height or width of an imperfection
s = nominal butt weld thickness
t = wall or plate thickness (nominal size)

NOTES
1. To be in accordance with EN ISO 10042.
2. A smooth transition is required.
3. The limits for linear misalignment relate to deviations from the correct position. Unless otherwise specified, the correct position is to be taken when the centrelines coincide.
4. Dimensional tolerances not specified in these Rules are to be mutually agreed between the manufacturer and the Surveyor.

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4.1.3 Acceptance of the mechanical tests is to be in accordance with Ch 11,9. Welding of the strain hardened and heat treatable aluminium alloys will generally result in a loss of tensile strength in the heat affected zone below that specified for the base materials and the tensile strength acceptance criteria to be applied is that specified for the material in the annealed or 'as fabricated' condition. Minimum values of tensile strength measured on the transverse tensile samples are given in Table 12.4.3.

4.1.4 Impact tests and hardness surveys are not required for aluminium alloys.

4.1.5 Four side bend tests may be used in place of root and face bends where the test thickness exceeds 12 mm, and longitudinal bend tests may be used instead of transverse tests where the test weld is between different grades of alloy. Bend specimens are to be bent round a former in accordance with Table 11.9.1 in Chapter 11, with the exception that the 6000 series alloys may be bent round a former with $D/t = 7$.

4.1.6 The ranges of approval to be applied to the WPS are to be as specified for steel in 2.15 with the following exceptions:

(a) The welding positions approved are as detailed in Table 12.4.4.

(b) The aluminium alloys are grouped into three groups as follows:

- Group A: aluminium-magnesium alloys, with Mg content ≤3,5 per cent (alloy 5754).
- Group B: aluminium-magnesium alloys with 4 per cent ≤Mg ≤5,6 per cent (alloys 5059, 5083, 5086, 5383 and 5456).
- Group C: aluminium-magnesium-silicon alloys (alloys 6005A, 6061 and 6082).

For each group, the qualification made on one alloy qualifies the procedure also for the other alloys in the group, with equal or lower tensile strength after welding. The qualification made on group B alloys qualifies the procedure for Group A alloys also. Approval for the range of material grades is summarised in Table 12.4.5.

(c) The qualification of a procedure carried out on a test assembly of thickness t is valid for the thickness range given in Table 12.4.6. In the case of butt joints between dissimilar thicknesses, t is the thickness of the thinner material. In the case of fillet joints between dissimilar thicknesses, t is the thickness of the thicker material. In addition to the requirements of Table 12.4.6, the range of the qualification of throat thickness of fillet welds, a, is given in Table 12.4.7. Where a fillet weld is qualified by a butt weld test, the throat thickness range qualified is to be based on the thickness of the deposited weld metal.

Table 12.4.2 Acceptance criteria for internal imperfections of aluminium alloys

Internal discontinuity	Classification according to ISO 6520-1	Acceptance criteria
Crack	100	Not permitted
Lack of fusion	401	Not permitted
Incomplete penetration	402	Not permitted
Single gas pore	2011	$d \le 0{,}2s$ or $0{,}2a$ or 4 mm (whichever is the lesser)
Linear porosity (*see* Note 2)	2014	Not permitted
Uniformly distributed porosity (*see* Note 2)	2012	$0{,}5t$ to $3t$ ≤ 1% of area $> 3t$ to $12t$ ≤ 2% of area $> 12t$ to $30t$ ≤ 3% of area $> 30t$ ≤ 4% of area
Clustered porosity (*see* Note 1)	2013	$dA \le 15$ mm or wp (whichever is the lesser)
Elongated cavity	2015	$l \le 0{,}2s$ or $0{,}2a$ or 3 mm (whichever is the lesser)
Wormhole	2016	
Oxide inclusion (*see* Note 2)	303	$l \le 0{,}2s$ or $0{,}2a$ or 3 mm (whichever is the lesser)
Tungsten inclusion	3041	$l \le 0{,}2s$ or $0{,}2a$ or 3 mm (whichever is the lesser)
Copper inclusion	3042	Not permitted
Multiple imperfections in any cross-section	—	The sum of the acceptable individual imperfections in any cross-section is not to exceed $0{,}2t$ or $0{,}2a$ (whichever is the lesser)

Symbols

a = nominal throat thickness of a fillet weld
d = diameter of a gas pore
h = height or width of an imperfection
s = nominal butt weld thickness
t = wall or plate thickness (nominal size), in mm
wp = width of weld or width or height of cross-sectional area
dA = diameter of area surrounding gas pores
l = length of imperfection in longitudinal direction of weld

NOTES
1. For this acceptance criterion, linear porosity is to be considered as three aligned gas pores in a length of 25 mm.
2. Porosity is to be determined in accordance with ISO 10042. The requirements for a single gas pore are to be met by all the gas pores within this circle. Systematic clustered porosity is not permitted.

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Table 12.4.3 Tensile strength requirements by grade for aluminium alloys

Parent material Grade (alloy designation)	Minimum tensile strength (N/mm^2)
5754	190
5086	240
5083	275
5383	290
5059	330
5456	290
6005A	170
6061	170
6082	170

Table 12.4.4 Welding procedure approval, welding positions for aluminium alloys

Test position		Positions approved
Downhand	D	D
Horizontal-vertical	X	D, X
Vertical up	Vu	D, X, Vu
Overhead	O	D, X, Vu and O
NOTE Welding in vertical down (Vd) position is not recommended.		

(d) The range of shielding gas compositions approved is to be in accordance with Table 11.9.2 in Chapter 11.

(e) A change in the brand or trade name of the filler metal from that used in the test is acceptable, provided that the proposed consumable has the same or higher strength grading.

(f) A change in post-weld heat treatment or ageing is not permitted, except that for the heat treatable alloys, artificial ageing may give approval for prolonged natural ageing.

4.2 Requirements for copper alloys

4.2.1 The requirements for welding procedure qualification tests for copper alloys are to be in accordance with the requirements for steel as given in Section 2 with the following exceptions and additions.

4.2.2 Impact tests on copper alloys are not required.

4.2.3 Hardness tests are not required for seawater service.

4.2.4 For the welding of cast copper alloys for propellers, the minimum tensile strength from the transverse tensile test is to be in accordance with Table 12.4.8.

4.2.5 Bend tests are to be performed over a diameter of former as detailed in Table 12.4.9.

Table 12.4.5 Welding procedure approval, aluminium material grades approved

Material used in qualification test	Material Grades approved				
5754	5754				
5086	5086	5754			
5083	5083	5086	5754		
5383	5383	5083	5086	5754	
5059	5059	5383	5083	5086	5754
5456	5456	5383	5083	5086	5754
6005A	6005A	6082	6061		
6082	6005A	6082	6061		
6061	6005A	6082	6061		
NOTE Approval includes all the different strained and tempered conditions in each case.					

Table 12.4.6 Range of qualification for parent material thickness

Thickness of test assembly, t (mm)	Range of qualification Multi pass welds	Range of qualification All single-run or two-run (T technique) butt welds
$t \leq 3$	0,5 to 2t	0,5t to 1,1t
$3 < t \leq 20$	3 to 2t	0,5t to 1,1t
$t > 20$	$\geq 0,8t$	0,5t to 1,1t

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Table 12.4.7 Range of qualification of throat thickness for fillet welds

Throat thickness of test piece, *a* (mm)	Range of qualification
$a < 10$	0,75 *a* to 1,5 *a*
$a \geq 10$	≥ 7,5

Table 12.4.8 Minimum transverse tensile strengths for welded copper alloy propellers

Alloy designation	Minimum tensile strength (N/mm^2)
CU 1	370
CU 2	410
CU 3	500
CU 4	550

Table 12.4.9 Former diameters for bend testing of copper alloy welds

Alloy designation (*see* Chapter 9)	Former diameter (*D/t*)
Cast propellers:	
CU1	4
CU2	4
CU3	6, *see* Note
CU4	6, *see* Note
Other short freezing range castings:	
Copper-Nickel 90/10	4
Copper-Nickel 70/30	4
Aluminium bronze	6
Wrought alloys (tubes and pipes):	
Copper-phosphorus	3
Aluminium-brass	3
90/10 Copper-nickel-iron	3
70/30 Copper-nickel-iron	3
NOTE Where the qualification tests for these alloys are subjected to post-weld heat treatment the former diameter may be increased to *D/t* = 10.	

4.2.6 The range of approval to be applied to the WPS is to be as specified in 2.15 with the exception of the material grades which are detailed in Table 12.4.10.

Table 12.4.10 Range of approval for copper alloy material grades

Category	Alloy grade used in the qualification test	Alloy grades approved
Propellers	CU1 CU2 CU3 CU4	CU1 CU1 and CU2 CU1, CU2 and CU3 CU4 *see* Note 1
Tubes/pipes	90/10 Copper-Nickel-Iron 70/30 Copper-Nickel-Iron	90/10 Copper-Nickel-Iron 70/30 Copper-Nickel-Iron and 90/10 Copper-Nickel-Iron
Tupes/pipes *see* Note 2	Copper-Phosphorus deoxidised – arsenical Copper-Phosphorus deoxisised – non arsenical *Aluminium-brass*	Copper-Phosphorus deoxidised – arsenical Copper-Phosphorus deoxisised – non arsenical *Aluminium-brass*
NOTES 1. Where a CU3 type welding consumable has been used for the qualification test, the range of approval may also include welding of CU3. 2. These grades have limited weldability and approval to weld is subject to the materials satisfying the requirements of Table 9.3.1 in Chapter 9.		

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■ *Section 5*

Welder qualification tests

5.1 Scope

5.1.1 The requirements of this Section relate to qualification of welders involved in welded construction associated with ships, or other marine structures, and products or components intended for use on or in these structures.

5.1.2 The requirements relate to fusion welding processes that are designated as manual, semi-automatic or partly mechanised. Special consideration will be given to other welding processes adapted from these requirements.

5.1.3 Prior to commencing production welding, the welder is to have performed a qualification test that satisfies these requirements. It is the responsibility of the manufacturer to ensure that the welder possesses the required level of skill for the work to be undertaken.

5.1.4 The qualification of welders is to be documented by the manufacturer and the records are to be available for review by the Surveyor.

5.1.5 Welder qualification tests made in accordance with EN, ISO, JIS, ASME or AWS may be considered for acceptance provided that, as a minimum, they are equivalent to, and meet the technical intent of these Rules to the satisfaction of the Surveyor.

5.2 Welder qualification test assemblies

5.2.1 The welding of the welder qualification test assembly is to simulate, as far as practicable, the conditions to be experienced in production and be witnessed by the Surveyor. The test is to be carried out on a test assembly piece and not by way of production welding.

5.2.2 The test is to simulate, as far as practicable, the welding techniques and practices to be encountered during production welding. The test assembly is to be designed to test the skill of the welder and have the shape and dimensions appropriate to the range of approval required.

5.2.3 The inspection length of the test weld is to be such as to permit the removal of all the necessary test specimens and for plate tests, but in no case is to be less than 250 mm. The test assembly is to be set in one of the positions as shown in Fig. 12.2.2 appropriate to the welding positions to be approved.

5.2.4 A welding procedure specification (WPS) is required for the execution of the qualification test and is to include the information specified in 2.2.1, as a minimum.

5.2.5 The test assembly is to be marked with a unique identification and the inspection length is to be identified prior to commencing welding. For pipe welds, the whole circumference is to be considered as the inspection length.

5.2.6 During welding of the test assembly, the welding time is to be similar to that expected under production conditions. For manual or semi-automatic processes, at least one stop and re-start in the root and in the top surface layer is to be included in the inspection length and marked for future inspection.

5.2.7 During welding of the test assembly, minor imperfections may be removed by the welder by any method that is used in production, except on the surface layer.

5.2.8 The Surveyor may stop the test if the welding conditions are not correct or if there is any doubt about the competence of the welder to achieve the required standard.

5.3 Examination and testing

5.3.1 Each completed test weld is to be examined and tested in accordance with the requirements of Table 12.5.1.

5.3.2 Visual examination is to be performed in the as welded state prior to any other assessment.

5.3.3 For plate butt welds, fracture testing may be used in place of radiography.

5.3.4 Where a backing strip has been used, it is to be retained for non-destructive examinations, but is to be removed prior to performing any bend or fracture tests.

5.3.5 Where fracture tests are required, they are to sample as much of the inspection length as practicable and the test assembly may be cut into several test specimens to achieve this. Testing is to be performed as shown in Figs. 12.5.1(a) or 12.5.1(b).

5.3.6 For butt weld tests in aluminium alloys both radiography and bend tests are required.

5.3.7 When bend tests are required, 2 root and 2 face bends are to be tested and where the test thickness exceeds 12 mm, these may be substituted by 4 side bends specimens. The diameter of former to be used is to be in accordance with that specified for welding procedure qualification testing given in 2.7.6(a).

5.3.8 Where macro examination is required, the specimen is to be polished and etched to reveal the weld runs and heat affected zones, and be examined at a magnification between x5 and x10.

5.4 Acceptance criteria

5.4.1 The acceptance criteria are to be in accordance with 2.5.5.

5.4.2 Fracture tests and macro-sections are to be assessed in accordance with the non-destructive examination acceptance criteria.

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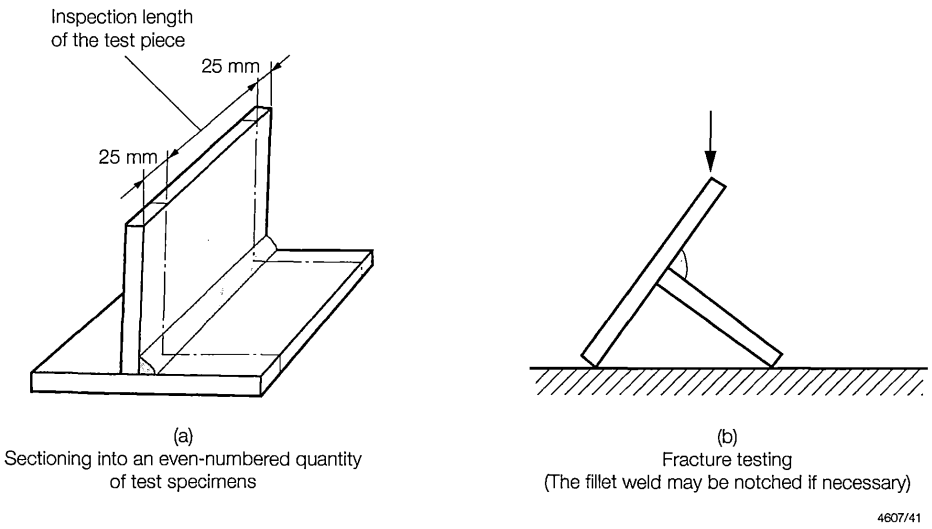
Table 12.5.1 Welder qualification test requirements

Examination type	Butt welds	Fillet welds	Pipe branch welds
Visual	100%	100%	100%
Surface crack detection	*See* Note 1	100%	100%
Radiography	100% *See* Notes 2 and 6	Not required	Not required
Bend tests	4 required *See* Notes 3 and 6	Not required	Not required
Fracture tests	Not required	1 required *See* Note 4	Not required
Macro	Not required	1 required *See* Note 4	4 required *See* Note 5

NOTES
1. Surface crack detection examination may be required by the Surveyor in order to clarify the acceptability of any weld feature.
2. Radiography may be replaced by ultrasonic examination for carbon and low alloy steels where the thickness exceeds 8 mm.
3. Bend tests are required for gas metal arc welding with solid wire (GMAW) and oxy-acetylene welding.
4. The fracture test may be replaced with 4 macro sections equally spaced along the inspection length.
5. Macro-sections are to be separated by 90° measured around the abutting pipe member.
6. Radiography and bend tests are required for tests in aluminium alloys.



(a)
Sectioning into an even-numbered quantity of test specimens

(b)
Fracture testing
(The fillet weld may be notched if necessary)

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Fig. 12.5.1(a) Preparation and fracture testing of test specimens for a fillet weld in plate

5.4.3 Bend tests are considered acceptable if after bending through an angle of at least 180°, there are no defects on the tension side of the specimen greater than 3 mm in any direction.

5.5 Failure to meet requirements

5.5.1 Where a macro-section fails to meet requirements, one additional specimen may be removed from the test assembly and examined.

5.5.2 Where a bend or fracture test specimen fails to meet requirements, two additional specimens may be prepared from the same test assembly. If there is insufficient material, the welder may be permitted to weld an additional assembly to the same WPS, at the discretion of the Surveyor.

5.5.3 Where any of the additional test specimens fails to satisfy the requirements, the test will be considered as not meeting the requirements.

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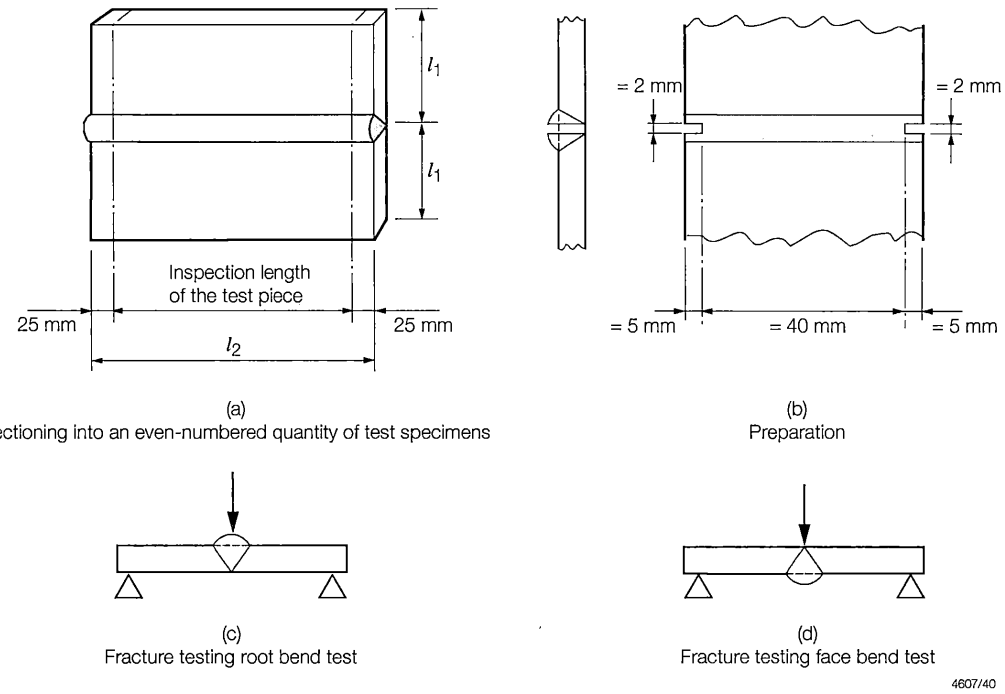

Fig. 12.5.1(b) Preparation and fracture testing of test specimens for a butt weld in plate

5.5.4 Where a test fails to comply with the acceptance criteria, the welder may be permitted to weld a second test piece. If this does not meet requirements, the welder is to be considered as not being capable of achieving the requirements.

5.6 Range of approval

5.6.1 Upon successful completion of all the necessary examinations and tests, the welder is to be considered qualified. The essential variables and the range of welding conditions for which the welder is considered approved are specified in the following paragraphs.

5.6.2 Welding variables such as preheat, interpass temperature, heat input and current type are not considered welder qualification variables. However, if the WPS used for testing specify these, they are to be included in the test and the welder is expected to follow the specific instructions.

5.6.3 Where the WPS used for the welder qualification test specifies post weld heat treatment, this need not be applied to the test weld unless bend tests are required and the material exhibits low ductility in the as welded condition.

5.6.4 The qualification test performed by a manufacturer is only applicable to workshops under the same technical control and quality system as that used for the test.

5.6.5 The welding process used in the qualification test is the process approved. However, it is possible for the welder to use more than one process in the test and the range of approval that may be applied to each will be within the limits of the essential variables appropriate to the part of the test where each welding process was used.

5.6.6 Material types are to be grouped as shown in Table 12.5.2 for welder qualifications. A qualification test performed on one material from a group will permit welding of all other materials within the same group. In addition, qualification on one group of materials may confer approval to weld other groups as shown in Table 12.5.3.

5.6.7 A qualification test performed on one thickness will confer approval to weld other thicknesses as specified in Table 12.5.4. Where welding is required between materials of different thickness, the reference thickness for approval purposes is to be the lesser thickness.

5.6.8 A qualification test performed on plate confers approval to weld on pipes having an outside diameter greater than 500 mm in a fixed position (*see* Table 12.5.5 and Table 12.5.6).

5.6.9 A qualification test performed using a specific diameter of pipe will give approval to weld other diameters as shown in Table 12.5.5. For branch welds, the diameter upon which approval is based is to be the branch member.

5.6.10 A qualification test performed on a butt weld may be considered as giving approval for fillet welds.

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Table 12.5.2 Welder qualification materials groupings

Material group	Material description	Typical LR Grades	Rules for Material references
WQ 01	Low carbon unalloyed, C/Mn, or Low alloyed steels (Re ≤ 360 N/mm^2)	A, B, D and E AH to FH32 and 36 Boiler 510FG and lower LT-AH to FH32 and 36 U1 and U2 Steel castings Steel pipes	Ch 3,2 Ch 3,3 Ch 3,4 Ch 3,6 Ch 3,9 and Ch 10 Ch 4,2, 3, 6 and 7 Ch 6,2, 3, 4 and 6
WQ 02	Cr-Mo, or Cr-Mo-V creep resisting steels	13CrMo45 and 11CrMo910 1Cr½Mo and 2¼Cr1Mo ½Cr½Mo¼V	Ch 3,4 Ch 4,6 and Ch 6,2, 3 and 6 Ch 4,6 and Ch 6,2
WQ 03	High strength fine grained, Normalised or quenched, or Tempered structural steels (2,0 – 5% Ni, with Re > 360 N/mm^2)	AH to FH40 to 69 LT-AH to LT-FH40 1½ , 3½ Ni steels and castings U3, R3, R3S and R4	Ch 3,3 and 10 Ch 3,6 Ch 3,6, Ch 4,7 and Ch 6,4 Ch 3,9 and Ch 10
WQ 04	Ferritic, or martensitic stainless steels (12 to 20% Cr)	13% Cr (martensitic)	Ch 4,5 (martensitic)
WQ 05	Ferritic low temperature steels	5Ni and 9Ni	Ch 3,6
WQ 011	Ferritic-austenitic stainless steels, Austenitic stainless steels, or Cr-Ni steels	304, 316, 317, 321 and 347 S31260, S31803, S32550 and S32750	Ch 3,7 and 8 Ch 4,8 and Ch 6,5
WQ 22a	Aluminium alloy – Non-heat treatable Mg < 3,5%	5754	Chapter 8
WQ 22b	Aluminium alloy – Non-heat treatable 3,5% < Mg < 5,6%	5083 and 5086	Chapter 8
WQ 23	Aluminium alloy – Heat treatable	6005-A, 6061 and 6082	Chapter 8
WQ 30	Copper alloys for propellers – Manganese bronze	Cu1	Ch 9,1
WQ 31	Copper alloys for propellers – Nickel-manganese bronze	Cu2	Ch 9,1
WQ 32	Copper alloys for propellers – Nickel-aluminium bronze	Cu3	Ch 9,1
WQ 33	Copper alloys for propellers – Manganese-aluminium bronze	Cu4	Ch 9,1
WQ 34	Copper alloys for tubes – Copper phosphorus	Deoxidised – non-arsenical and arsenical	Ch 9,3
WQ 35	Copper alloys for tubes – Aluminium brass	Aluminium brass	Ch 9,3
WQ 36	Copper alloys for tubes – Copper-nickel-iron	70/30 Cu/Ni and 90/10 Cu/Ni	Ch 9,3

5.6.11 A butt qualification test welded from one side, with the root unsupported (i.e. no backing), will give approval for welds made from both sides with or without back gouging or grinding, but not vice versa.

5.6.12 A qualification test performed in one position will give approval to weld in other positions as shown in Table 12.5.6.

5.6.13 For manual metal arc welding with covered electrodes, a qualification test performed using an electrode with one type of coating will only be approved for welding with that type of coating. However, a qualification test performed using a basic low hydrogen type coating will confer approval to use electrodes with rutile coatings.

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Table 12.5.3 Welder qualification, range of approval for material groups

Material group used for testing	Material groups approved to weld			
WQ 01	WQ 01			
WQ 02	WQ 01	WQ 02		
WQ 03	WQ 01	WQ 02	WQ 03	
WQ 04	WQ 01	WQ 02	WQ 04	
WQ 05	WQ 05			
WQ 11	WQ 11	WQ 05, *see* Note	WQ 04, *see* Note	
WQ 22a	WQ 22a	WQ 22b		
WQ 22b	WQ 22a	WQ 22b		
WQ 23	WQ 22a	WQ 22b	WQ 23	
WQ 30	WQ 30	WQ 31	WQ 32	WQ 33
WQ 31	WQ 30	WQ 31	WQ 32	WQ 33
WQ 32	WQ 30	WQ 31	WQ 32	WQ 33
WQ 33	WQ 30	WQ 31	WQ 32	WQ 33
WQ 34	WQ 34	WQ 35		
WQ 35	WQ 34	WQ 35		
WQ 36	WQ 36			

NOTE
Provided an austenitic welding consumable compatible with material group WQ 11 is used.

Table 12.5.4 Welder qualification, range of approval for material thickness

Material type	Test piece thickness (mm)	Range approved, *see* Note (mm)
Steel and copper alloys	$t \leq 3$ $3 < t \leq 12$ $t > 12$	t to $2t$ 3,0 to $2t$ ≥ 5,0
Aluminium alloys	$t \leq 6$ $6 < t \leq 15$ $t > 40$ mm	0,7 to $2{,}5t$ $6{,}0 < t \leq 40{,}0$ 41 to $2t$

NOTE
For oxy-acetylene welding the maximum thickness is limited to 1,5 t.

Table 12.5.5 Welder qualification, diameter range of approval for pipes and hollow sections

Material type	Test piece diameter (mm)	Range approved (mm)
Steel and copper alloys	$D \leq 25$ $25 < D \leq 150$ $D > 150$ Plate, *see* Note 2	D to $2D$ $0{,}5D$ to $2D$, *see* Note 1 ≥ $0{,}5D$ ≥ 500
Aluminium alloys	$D \leq 125$ $D > 125$ Plate, *see* Note 2	$0{,}25D$ to $2D$ ≥ $0{,}5D$ ≥ 500

NOTES
1. Subject to 25 mm minimum diameter.
2. Plate qualification will approve welding on pipes greater than 150 mm diameter when the pipe is rotated.

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Table 12.5.6 Welding position ranges for welder qualification

Test weld conditions		Positions qualified			
		Plate		Pipe, *see* Note 1	
Type of weld	Test position	Butt weld	Fillet weld	Butt weld	Fillet weld
Plate butt, *see* Note 5	D	D	D	D	D
	X	D,X	D, X	D	D, X
	Vu	D, Vu	D, X, Vu	D	D, Vu
	Vd	Vd	Vd	–	–
	O	D, X, Vu, O	D, X, Vu, O	D	D, X, Vu, O
Plate Fillet, *see* Note 5	D	–	D	–	D
	X	–	D, X	–	D, X
	Vu	–	D, X, Vu	–	D, X, Vu
	Vd	–	Vd	–	–
	O	–	D, X, Vu, O	–	D, X, Vu, O
Pipe butt	D	D	D, X	D	D, X
	X	D, X	D, X	D, X	D, X
	D+Vu+O, *see* Note 3	D, Vu, O	D, X, Vu, O	D, Vu, O	D, X, Vu, O
	D+Vd+O, *see Notes 2 and 3*	Vd	Vd	Vd	Vd
	Axis at 45°, *see* Note 4, Travel Vu	D, X, Vu, O	D, X, Vu, O	D, X, Vu, O	D, X, Vu, O
	Axis at 45°, *see* Notes 2, 3 and 4, Travel Vd	Vd	Vd	Vd	Vd
Pipe fillet	D	–	D	–	D
	X	–	D, X	–	D, X
	D+Vu+O *see* Note 3	–	D, X, Vu, O	–	D, X, Vu, O
	D+Vd+O *see* Note 3	–	Vd	–	Vd

NOTES
1. Pipe D position means pipe in horizontal position and rotated, *see* Fig. 12.2.2(b) and Fig. 12.2.2(d).
2. Vd position not usually recommended for pipe welds less than 500 mm diameter.
3. Pipe fixed with axis in the horizontal position (e.g. ASME 5G).
4. Pipe fixed with axis at 45° to the horizontal (e.g. ASME 6G).
5. Plate qualification tests confers approval to weld pipes with diameter greater than 500 mm.

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5.6.14 For gas shielded welding processes that use a single component shielding gas, no change to the gas composition is permitted from that tested. Where the test has used a two component shielding gas, a change in the ratio of component gases is permitted, provided that one of the components is not reduced to zero. Where the test has used a three component shielding gas, changes are permitted in the ratio of component gases and the gas with the smallest ratio may be reduced to zero, provided this does not change the shielding gas from an active one to an inert one or vice versa. In addition, where a change in shielding gas composition requires a different welding method or technique to be employed, a new qualification test will be required.

5.6.15 A change of welding flux from that used for the test is permitted.

5.7 Welders qualification certification

5.7.1 All the relevant conditions used during the test are to be entered on the welder's qualification certificate along with the permitted range of approval.

5.7.2 If the Surveyor is satisfied that the welder has demonstrated the appropriate level of skill and all tests are satisfactory, the Surveyor will endorse the certificate verifying that the details contained on it are correct and that the test welds were prepared, welded and tested in accordance with the specified Rules, Codes or Standards.

5.7.3 The welder is considered to be approved for an initial validity period of 2 years. The welder is considered to have retained the qualification subject to the manufacturer confirming every 6 months that the welder has used the welding process with acceptable performance in the preceding 6 months.

5.7.4 After 2 years, the Surveyor may extend the validity of the approval for another period of two years provided that records or documented evidence is made available confirming acceptable welding performance, within the original range of approval, without a break exceeding 6 months. The Surveyor will signify acceptance of the extension to the validity by endorsing the certificate.

5.7.5 Where there is any reason to question the welder's ability, or there is a lack of continuity in the use of the welding process, or insufficient recorded evidence of acceptable weld performance, the welder is to perform a new qualification test.

5.7.6 Where the manufacturer has existing welders that have previously performed qualification tests, these may be considered for acceptance provided they satisfy the above requirements and the tests have been performed in the presence of an independent examiner that is acceptable to the Society.

5.7.7 Not withstanding the above, the Surveyor may at any time request a review of a welder's qualification records. If there is any reason for doubt concerning the skill of the welder, the Surveyor may withdraw the qualification and require a re-qualification test to be performed.

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Requirements for Welded Construction

Chapter 13

Section

1 **General welding requirements**

2 **Specific requirements for ship hull structure and machinery**

3 **Specific requirements for fabricated steel sections**

4 **Specific requirements for fusion welded pressure vessels**

5 **Specific requirements for pressure pipework**

6 **Repair of existing ships by welding**

7 **Austenitic and duplex stainless steel – Specific requirements**

Section 1
General welding requirements

1.1 Scope

1.1.1 This Chapter specifies requirements for fabrication and welding during construction and repair of ships or other marine structures, and their associated pressure vessels, machinery, equipment, components and products intended for use in these structures.

1.1.2 The requirements relate to fusion welding. Special consideration will be given to the use of other welding processes based on these requirements.

1.1.3 It is the responsibility of the manufacturer to ensure compliance with all aspects of these Rules and inform the Surveyor of any deviations that have occurred. All deviations are to be recorded as non-compliances along with the corrective actions taken and failure to do this is considered to render the fabrication to be in non-compliance with the Rules.

1.1.4 Welded constructions that comply with National or International specifications may be accepted to the satisfaction of the surveyor, provided that these specifications give reasonable equivalence to the requirements of this Chapter.

1.1.5 All welded construction is to be to the satisfaction of the Surveyor.

1.2 Design

1.2.1 Prior to commencing any work, the component to be manufactured is to be subjected to design review and approval in accordance with the Rule requirements.

1.2.2 The material characteristics that are affected by welding, particularly the loss of strength (e.g. in precipitation or strain hardened aluminium alloys) are to be considered in the design. The weld joints in such materials are to be arranged such that they are in areas of lower stress.

1.3 Materials

1.3.1 Materials used in welded construction are to be manufactured at works approved by LR. The use of materials from alternative sources will be subject to agreement of the Surveyor and satisfactory verification testing.

1.3.2 Materials are to be supplied and certified in accordance with the requirements of Chapters 1 to 10 of these Rules.

1.3.3 Materials used in welded construction are to be readily weldable and are to have proven weldability, unless requirements are agreed with LR in advance.

1.3.4 Where the construction details are such that materials are subject to through-thickness strains, consideration is to be given to using material with specified through-thickness properties as specified in Ch 3,8.

1.3.5 When ordering materials for construction, consideration is to be taken of the possible degradation of properties during fabrication or post-weld heat treatment. Where these materials are used, consideration is to be given to additional test requirements being specified to the supplier.

1.3.6 The identity of materials is to be established by way of markings etc, during fabrication, so that traceability to the original manufacturer's certificate is maintained.

1.3.7 Pre-fabrication shop primers may be applied prior to welding, provided that they are of an approved type and have been tested to demonstrate that they have no deleterious effects on the completed weld.

1.3.8 Where it is proposed to weld forgings and/or castings, full details of the joint details, welding procedures and post-weld heat treatments are to be submitted for consideration.

1.4 Requirements for manufacture and workmanship

1.4.1 The welding workshops are to be assessed by the Surveyor for their capability to produce work of the required quality in accordance with the requirements specified for the type of construction, *see* Sections 2 to 5.

1.4.2 Where structural components are to be assembled and welded in works sub-contracted by the builder, the Surveyor is to inspect the sub-contractor's works to ensure that compliance with the requirements of this Chapter is achieved.

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1.4.3 The manufacturer is to provide a system of regular supervision of all welding, by suitably qualified and experienced personnel.

1.4.4 Welding is to be performed in covered workshops as far as practicable. Where this is not possible, provision is to be made in the welding area to give adequate protection from wind, rain and cold, etc.

1.4.5 Where required, arrangements are to be such as to permit adequate ventilation and access for preheating, and for the satisfactory completion of all welding operations.

1.4.6 The location of welding connections and sequences of welding are to be arranged to minimise distortion and the build up of residual stresses. Welded joints are to be so arranged as to facilitate the use of downhand welding wherever possible.

1.4.7 In the case of repairs to existing structures or components, care is to be exercised when attaching fit-up aids by welding to ensure that the base materials in way of the attachments are of weldable quality.

1.4.8 In order to prevent cross-contamination of different material types, the welding of carbon steel materials is to be in areas segregated from that used for either austenitic or non-ferrous materials, *see* Section 7.

1.5 Cutting of materials

1.5.1 Materials may be cut to the required dimensions by thermal means, shearing or machining in accordance with the manufacturing drawings or specifications.

1.5.2 Cold shearing is not to be used on materials in excess of 25 mm thick. Where used, the cut edges that are to remain un-welded are to be cut back by machining or grinding for a minimum distance of 3 mm.

1.5.3 Material, which has been thermally cut, is to be free from excessive oxides, scale and notches.

1.5.4 All cut edges are to be examined to ensure freedom from material and/or cutting defects. Visual examination may be supplemented by other techniques.

1.5.5 Thermal cutting of alloy and high carbon steels may require the application of preheat, and special examination of these cut edges will be required to ensure no cracking. In these cases, the cut edge is to be machined or ground back a distance of at least 2 mm, unless it has been demonstrated that the cutting process has not damaged the material.

1.5.6 Any material damaged in the process of cutting is to be removed by machining, grinding or chipping back to sound metal. Weld repair may only be performed with the agreement of the Surveyor.

1.6 Forming and bending

1.6.1 Plates, pipes, etc., may be formed to the required shape by any process which does not impair the quality of the material.

1.6.2 Where hot forming is employed or during cold forming where the material is subjected to a permanent strain exceeding 10 per cent or formed to a diameter to thickness ratio less than 10, tests are required to be performed to demonstrate that the material properties remain acceptable.

1.6.3 As far as practicable, forming is to be performed by the application of steady continuous loading using a machine designed for that purpose. The use of hammering, in either the hot or cold condition is not to be employed.

1.6.4 Material may be welded prior to forming or bending, provided that it can be demonstrated that the weld mechanical properties are not impaired by the forming operation. All welds subjected to bending are to be inspected on completion to ensure freedom from surface breaking defects.

1.7 Assembly and preparation for welding

1.7.1 Excessive force is not to be used in fairing and closing the work. Where excessive root gaps exist between surfaces or edges to be joined, corrective measures are to be adopted.

1.7.2 Provision is to be made for retaining correct alignment during welding operations in accordance with the approved manufacturing specifications and welding procedures.

1.7.3 Tack welds are to be avoided as far as practicable. When used, tack welds are to be of the same quality as the finished welds, made in accordance with approved welding procedures, and where they are to be retained as part of the finished weld, they are to be clean and free from defects.

1.7.4 Generally, tack welds are not to be applied in lengths of less than 30 mm for mild steel grades and aluminium alloys, and 50 mm for higher tensile steel grades. Smaller tack welds may be accepted for steels, provided that the carbon equivalent of the materials being welded is not greater than 0,36 per cent.

1.7.5 Where deep penetration welding is used (*see* 2.4.6), welding procedure tests are to demonstrate that the specified degree of penetration is achieved in way of tack welds left in place.

1.7.6 Where temporary bridge pieces or strong-backs are used, they are to be of similar materials to the base materials and welded in accordance with approved welding procedures.

1.7.7 Any fit-up aids and tack welds, where welded to clad materials, are to be attached to the base material and not to the cladding.

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1.7.8 Surfaces of all parts to be welded, are to be clean, dry and free from rust, grease, debris and other forms of contamination.

1.7.9 When misalignment of structural members either side of bulkheads, decks etc., exceeds the agreed tolerance, the misaligned item is to be released, realigned and re-welded in accordance with an approved procedure.

1.8 Welding equipment and welding consumables

1.8.1 Welding plant and equipment is to be suitable for the purpose intended and properly maintained, taking into account relevant safety precautions.

1.8.2 Suitable means of measuring the welding parameters (i.e. current, voltage and travel speed) are to be available. Electrical meters are to be properly maintained and have current calibrations.

1.8.3 Welding consumables are to be suitable for the type of joint and grade of material to be welded, and in general, are to be LR Approved in accordance with Chapter 11.

1.8.4 Special care is to be taken in the distribution, storage and handling of all welding consumables. They are to be kept in heated dry storage areas with a relatively uniform temperature in accordance with the consumable manufacturer's recommendations. Condensation on the metal surface (e.g. wire electrodes and studs) during storage and use is to be avoided.

1.8.5 Prior to use, welding consumables are to be dried and/or baked in accordance with the consumable manufacturer's recommendations.

1.8.6 Satisfactory storage and handling facilities for consumables are to be provided close to working areas and the condition of welding consumables are to be subject to regular inspections.

1.9 Welding procedure and welder qualifications

1.9.1 Welding procedures are to be developed by the manufacturer for all welding, include weld repairs, and are to be capable of achieving the mechanical property requirements and non-destructive examination quality appropriate to the work being undertaken.

1.9.2 Welding procedures are to be established for the welding of all joints and are to be qualified by testing in accordance with Chapter 12. The welding procedures are to give details of the welding process, type of consumable, joint preparation, welding position and filler metals to be used.

1.9.3 The proposed welding procedures are to be approved by the Surveyor prior to construction.

1.9.4 All welders and welding operators are to be qualified in accordance with the requirements of Chapter 12. Qualification records to demonstrate that welding personnel have the skills to achieve the required standard of workmanship are to be available to the Surveyor.

1.10 Welding during construction

1.10.1 Materials to be assembled for welding are to be retained in position by suitable means such that the root gaps and alignment are in accordance with the approved manufacturing specifications and welding procedures.

1.10.2 Surfaces of all parts to be welded, are to be clean, dry and reasonably free from rust, scale and grease.

1.10.3 Pre-heat is to be applied, as specified in the approved welding procedure, for a distance of at least 75 mm from the joint preparation edges. The method of application and temperature control are to be such as to maintain the required level throughout the welding operation.

1.10.4 When the ambient temperature is 0°C or less, or where moisture resides on the surfaces to be welded, due care is to be taken to pre-heat the joint to a minimum of 20°C, unless a higher pre-heat temperature is specified.

1.10.5 Where tack welds are to be removed from the root of the weld joint, this is to be carried out such that the surrounding material and joint preparation is not damaged.

1.10.6 The welding arc is to be struck on the parent metal which forms part of the weld joint or on previously deposited weld metal.

1.10.7 Where the welding process used is slag forming (e.g. manual metal arc, submerged arc, etc.) each run of deposit is to be cleaned and free from slag before the next run is applied.

1.10.8 Full penetration welds are to be made from both sides of the joint as far as practicable. Prior to welding the second side, the weld root is to be cleaned, in accordance with the requirements of the approved welding procedure, to ensure freedom from defects. When air-arc gouging is used, care is to be taken to ensure that the ensuing groove is slag and oxide free and has a profile suitable for welding.

1.10.9 Where welding from one side only, care is to be exercised to ensure the root gap is in accordance with the approved welding procedure and the root is properly fused.

1.10.10 Particular care is to be exercised in welding in the vertical position with direction of travel downward (Vd) to avoid welding defects. The use of solid wire gas metal arc (GMAW) process in the vertical down position is to be avoided.

1.10.11 Welding is to proceed systematically with each welded joint being completed in correct sequence without undue interruption.

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1.10.12 After welding has been stopped for any reason, care is to be taken in restarting to ensure that the previously deposited weld metal is thoroughly cleaned of slag and debris, and preheat has been re-established.

1.10.13 Care is to be taken to avoid stress concentrations such as sharp corners or abrupt changes of section, and completed welds are to have an even contour, blending smoothly with the base materials. The weld shape and size is to be in accordance with that specified in the approved drawings or specifications.

1.10.14 Welded temporary attachments used to aid construction are to be removed carefully by grinding, cutting or chipping. The surface of the material is to be finished smooth by grinding followed by crack detection.

1.10.15 Where fabricated and welded components require to be machined, all major welding operations are to be completed prior to final machining.

1.10.16 Welding to parts which are subjected to rotating fatigue (e.g. shafts) is not generally permitted.

1.10.17 Welding onto parts that have been hardened for wear resistance or strength (e.g. gear teeth) is not permitted.

1.10.18 Where welding of clad ferritic steel plates is to be undertaken, the clad materials are to be ground back from the prepared edge by at least 10 mm. In general, the ferritic materials are to be welded prior to welding of the cladding material.

1.11 Non-destructive examination of welds

1.11.1 Non-destructive examinations are to be made in accordance with a definitive written procedure prepared and endorsed by a person qualified according to a Nationally Recognised Scheme with a grade equivalent to Level III qualification of ISO 9712, SNT-TC-1A, EN473, or ASNT Central Certification Program (ACCP). As a minimum, the procedure will identify personnel qualification levels, NDE datum and identification system, extent of testing, methods to be applied with technique sheets, acceptance criteria and reporting requirements. These procedures are to be reviewed by the Surveyor. *See* Ch 1,5.

1.11.2 Non-destructive examinations are to be undertaken by personnel qualified according to a Nationally Recognised Scheme with a grade equivalent to Level II qualification of ISO 9712, SNT-TC-1A, EN473 or ASNT Central Certification Program (ACCP). Operators qualified to Level I of the above schemes (or equivalent recognised by LR) may be engaged in testing under the supervision of personnel qualified to Level II or III (or equivalent recognised by LR). Personnel qualifications are to be verified by certification.

1.11.3 Effective arrangements are to be provided by the manufacturer for the inspection of finished welds to ensure that all welding, and where necessary, all post-weld heat treatment, has been satisfactorily completed.

1.11.4 Welds are to be clean and free from paint at the time of visual inspection unless specified otherwise in the following Sections.

1.11.5 The weld surface finish is to ensure accurate and reliable detection of defects. Where the weld surface is irregular or has other features likely to interfere with the interpretation of non-destructive examination, the weld is to be ground or machined.

1.11.6 Prior to inspection, welded temporary attachments and lifting eyes used to aid construction are to be removed carefully by grinding, cutting or chipping or other approved means. The surface of the material is to be finished smooth by grinding followed by crack detection. Any defects caused in the removal process are to be repaired and re-inspected.

1.11.7 For welds in steels with specified yield strength up to 400 N/mm^2, and with carbon equivalent less than or equal to 0,41 per cent, NDE may be performed as soon as the test assembly has cooled to ambient temperature. For other steels, NDE is to be delayed for a period of at least 48 hours after the test assembly has cooled to ambient temperature.

1.11.8 Non-destructive examinations are to be performed in accordance with the requirements of the Rules. Examinations are to be in accordance with agreed written procedures prepared by the manufacturer or ship builder.

1.11.9 The Surveyor may request additional inspections where there is reason to question the quality of workmanship, or where the weld is part of a complicated fabrication where there is high restraint or high residual stresses.

1.11.10 Welds are to be examined after completion of any post-weld heat treatment.

1.11.11 Where weld defects are discovered, the full extent is to be ascertained by applying additional non-destructive examinations where required. Unacceptable defects are to be completely removed and, where necessary, weld repaired in accordance with the relevant Sections of this Chapter. The repairs are to be re-inspected using the same technique as the original inspection.

1.11.12 Results of non-destructive examinations are to be recorded and evaluated by the constructor on a continual basis in order that the quality of welding can be monitored. These records are to be available to the Surveyor.

1.11.13 The constructor is to be responsible for the review, interpretation, evaluation and acceptance of the results of NDE. Reports stating compliance or otherwise with the criteria established in the inspection procedure are to be issued. Reports are to comply, as a minimum, with the requirements of Ch 1,5.

1.11.14 The extent of applied non-destructive examination is to be increased when warranted by the analysis of previous results.

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1.12 Routine weld tests

1.12.1 Routine or production weld tests may be specified as a means of monitoring the quality of the welded joints. This type of quality control test is generally specified for pressure vessel and LNG construction but may be used for other types of welded fabrication.

1.12.2 Routine weld tests may be requested by the Surveyor where there is reason to doubt the quality of workmanship.

1.12.3 Where routine test welds have been agreed, they are to be performed in accordance with the general requirements for the type of construction, *see* Sections 3 and 4.

1.13 Rectification of material defects

1.13.1 Repair of defects found in base materials is not to be carried out without the prior approval of the Surveyor.

1.13.2 In general, surface defects in the material may be removed by grinding, chipping, etc., provided the remaining material thickness is not reduced below the minimum thickness tolerance, and the area is ground to blend in smoothly with the surrounding material.

1.13.3 Confirmation that the defect has been removed is required by performing visual examination, augmented by either magnetic particle or dye penetrant examination techniques.

1.13.4 Surface defects, which cannot be repaired by the above method, may be repaired by welding where permitted by Chapters 3 to 9. Such repairs are to be performed in accordance with the requirements of this Section and those specified in Chapters 3 to 9.

1.13.5 Any defects in the structure resulting from the removal of temporary attachments are to be prepared, efficiently welded and ground smooth so as to achieve a defect free repair.

1.14 Rectification of distortion

1.14.1 Fairing, by linear or spot heating, to correct distortions due to welding, may be carried out. In order to ensure that the properties of the material are not adversely affected, approved procedures are to be utilised. On completion of such processes, visual examination of all heat affected areas in the vicinity is to be carried out to ensure freedom from cracking.

1.14.2 When misalignment of members exceeds the agreed tolerance, the misaligned item is to be cut apart, realigned and re-welded in accordance with an approved procedure.

1.15 Rectification of welds defects

1.15.1 Where repairs are extensive the manufacturer is to investigate the reason for the defects and take the necessary actions to prevent recurrence. In addition, consideration is to be given to the sequence of repairs and to providing temporary supports to prevent misalignment or collapse.

1.15.2 Cracks are to be reported to the Surveyor and the cause established prior to undertaking weld repairs.

1.15.3 Defects may be removed by grinding, chipping or thermal gouging. Where thermal gouging is used, the repair groove is to be subsequently ground clean to remove oxides and debris. The groove is to have a profile suitable for welding.

1.15.4 Prior to commencing repair welding, it is to be confirmed that no defect exists on the prepared surface by performing visual examination, augmented by either magnetic particle or dye penetrant examination techniques.

1.15.5 Repair welding is to be performed using approved welding procedures.

1.15.6 Completed repairs are to be re-examined by the non-destructive examination method(s) that detected the original defect and are to confirm that the original defect has been removed.

1.15.7 Where the component or structure has been subjected to post-weld heat treatment prior to weld repair, this is to be repeated after completion of all repair welding.

1.15.8 Where non-destructive examination reveals that the original defect has not been successfully removed, one more repair attempt may be performed.

1.15.9 The manufacturer is to monitor the quality of welding and maintain records of welding repairs and take the necessary corrective actions where repair rates are outside normal limits.

1.16 Post-weld heat treatment

1.16.1 On completion of welding, post-weld heat treatment may be required depending on the type of welded construction, the material type and thickness as specified by the relevant Parts or Sections of the Rules.

1.16.2 In general, heat treatment after welding is to be a stress relief treatment in order to reduce residual stresses introduced by welding and is generally applicable to ferritic steels. Where other types of heat treatment (e.g. normalising, solution annealing) are proposed, demonstration of acceptable mechanical properties of the weldment are to be confirmed by a welding procedure test which includes a simulated heat treatment.

1.16.3 Parts are to be properly prepared for heat treatment. Machined surfaces (e.g. flange faces, screw threads, etc.) are to be protected against scaling and sufficient temporary supports provided to prevent distortion or collapse of the structure.

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1.16.4 Details of the heat treatment to be applied, soaking time and temperature, heating and cooling rates, etc., are to be submitted for review prior to commencing.

1.16.5 Post-weld heat treatment is to be carried out in a purpose built furnace which is efficiently maintained. In special cases, where the configuration of the component is such that thermal stresses during heating and cooling can be minimised, local post-weld heat treatment may be used. This would not normally apply to the complex geometry of cast materials during manufacture within the foundry environment.

1.16.6 In all cases, the heat treatment facilities and arrangements are to be capable of controlling the temperature throughout the heat treatment cycle and adequate means of measuring and recording the component temperature are to be provided. Thermocouples are to be attached so they are in contact with the component.

1.16.7 Unless specified otherwise, stress relief heat treatment is to be carried out by means of controlled heating from 300°C, to the soak temperature, holding within the prescribed soaking temperature range for the time specified (usually 1 hour per 25 mm of weld thickness) followed by controlled cooling to below 300°C.

1.16.8 Where post-weld stress relief is specified for welded constructions that contain joints between different materials (e.g. ferritic to austenitic steels), the details of the materials, welding procedures and heat treatment cycle to be applied are to be submitted for special consideration and approval.

1.16.9 Non-destructive examination of welds is to be performed after completion of any heat treatment.

1.17 Certification

1.17.1 Products or components are not to be considered complete until all the requirements of the construction specification have been met and all activities have been completed.

1.17.2 Upon completion of the works, the manufacturer is to provide documentation which indicates that:

(a) All welds are complete and there are no outstanding repairs.
(b) The appropriate post-weld heat treatments have been performed.
(c) Appropriate destructive tests have been performed.
(d) Proof testing of welds has been performed.

1.17.3 Before the test certificates or shipping statements are signed by the Surveyor, the manufacturer is required to provide a written declaration stating that the product is in accordance with the requirements of 1.17.2.

■ *Section 2*
Specific requirements for ship hull structure and machinery

2.1 Scope

2.1.1 The requirements of this Section apply to the construction of ships, including hull structure, superstructure and deckhouses, components forming part of the ship structure and its machinery (excluding pressure equipment and piping, *see* Section 4). These requirements are in addition to the general welding requirements specified in Section 1.

2.1.2 The shipyard and manufacturer's works are to be assessed to give assurance that they have the facilities, equipment, personnel and quality control procedures to produce work of the required quality.

2.2 Welding consumables

2.2.1 Welding consumables used for hull construction are to be approved in accordance with Chapter 11 and are to be suitable for the type of joint and grade of material to be welded.

2.2.2 Steel welding consumable approvals, up to and including Grade Y40, are considered acceptable for hull construction in line with Table 11.1.1 in Chapter 11, Ch 12,2.2.2 in Chpater 12 and the following:

(a) Consumables are acceptable for welding steels up to 3 strength levels below that for which the approval applies, e.g. a consumable with approval grading 3Y is acceptable for welding EH36, EH32 and EH27S higher tensile ship steels and grade E normal strength ship steel.
(b) Consumables with an approved impact toughness grading are acceptable for welding steels with lower specified impact properties subject to (a) above, e.g. a consumable with approval grading 3Y is acceptable for welding EH, DH and AH materials.
(c) For welding steels of different grades or different strength levels, the welding consumables may be of a type suitable for the lesser grade or strength being connected. The use of a higher grade of welding consumable may be required at discontinuities or other points of stress concentration.

2.2.3 In general, the use of preheating and hydrogen controlled welding consumables for welding of ship steels up to strength grade H40 is to be in accordance with Table 13.2.1. The carbon equivalent is to be calculated from the ladle analysis using the formula given below:

$$\text{Carbon equivalent} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Nl + Cu}{15}$$

Preheat and the use of low hydrogen controlled consumables will be required for welding of steel grades higher than Grade H40.

2.2.4 All aluminium alloy welding consumables are to be approved in accordance with Chapter 11 and are suitable for welding the grades of material as shown in Table 13.2.2.

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Table 13.2.1 Preheat and consumable requirements for welding of carbon and carbon manganese steels up to strength grade H40

Carbon equivalent C_{eq}	Pre-heat	Hydrogen controlled consumables
C_{eq} equal to or less than 0,41%	Not required	Not required, *see* Note 3
C_{eq} above 0,41 but not exceeding 0,45%	Not required, *see* Notes 1 and 2	Required
C_{eq} greater than 0,45%	Required	Required

NOTES
1. Preheat may need to be applied in order to meet the maximum hardness values specified in Ch 12,2.12.6.
2. Under conditions of high restraint or low ambient temperature preheat may need to be applied.
3. Hydrogen controlled consumables may need to be considered for welding of
   (a) Thicker materials (i.e. > 35 mm).
   (b) Higher strength materials.
   (c) Welds subject to high restraint.

Table 13.2.2 Welding of aluminium alloys – Consumable requirements

Consumable approval grade	Base material alloy grade
RA or WA	5754
RB or WB	5086, 5754
RC or WC	5083, 5086, 5754
RD or WD	6005A, 6061, 6082

2.2.5 All austenitic stainless steel and duplex stainless steel welding consumables are to be approved in accordance with the Chapter 11 and are suitable for welding the grades of material as shown in Table 13.2.3.

2.3 Welding procedure and welder qualifications

2.3.1 Welding procedures and welder qualifications are to be tested and approved in accordance with the requirements of Chapter 12.

2.4 Construction and workmanship

2.4.1 Weld preparations and openings may be formed by thermal cutting, machining or chipping. Chipped surfaces that will not be subsequently covered by weld metal are to be ground smooth.

2.4.2 Prior to welding, the alignment of plates and stiffeners forming part of the hull structure is to be in accordance with the tolerances specified in the relevant part of the Rules.

Table 13.2.3 Welding of austenitic stainless and duplex stainless steels – Consumable requirements

Consumable approval grade	Suitable for welding material alloy grades
Austenitic stainless steels	
321 347	321 347 and 321
Austenitic stainless steel – Low carbon	
304L (*see* Note 3) 304LN (*see* Note 3) 316L 316LN 317L 317LN	304L 304LN and 304L 316L and 304L 316LN, 316L, 304LN and 304L 317L, 316LN, 316L, 304LN and 304L 317LN, 317L, 316LN, 316L, 304LN and 304L
Super austenitic stainless steels, *see* Note 2	
S31254 N08904	S31254 and N08904 N08904
Duplex stainless steels, *see* Note 1	
S31260 S31803 S32550 S32750 S32760	S31260 and S31803 S31803 S32550 S32750 and S32550 S32760, S32550, S31260 and S31803
Stainless steels welded to carbon steels	
SS/CMn Duplex/CMn	Carbon steel to all steels in Sections 1, 2 and 3 Carbon steel to all duplex stainless steel in Section 4

NOTES
1. The use of a different welding consumable grade from that of the base material may require demonstration of acceptable corrosion properties.
2. May be used for welding low carbon austenitic grades provided measures are taken to prevent solidification cracking from occurring.
3. These are LR Grades and do not correspond to any National or International Standards/Grades.

2.4.3 When welding from one side only, care is to be exercised to ensure the root gap and fit up are in accordance with the approved welding procedure and the root is properly fused.

2.4.4 Where it is proposed to use permanent backing strips, the intended locations and welding procedures are to be submitted for consideration.

2.4.5 Temporary backing strips may be used provided they are in accordance with approved welding procedures and are subsequently removed on completion of welding.

2.4.6 The outer surfaces of completed welds are to blend smoothly with the base materials and provide a smooth transition and gradual change of section.

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2.4.7 Weld joints in parts of oil engine structures that are stressed by the main gas or inertia loads are to be designed as continuous full penetration welds. They are to be arranged so that welds do not intersect, and that welding can be effected without difficulty.

2.4.8 When modifications or repairs have been made which result in openings having to be closed by welded inserts, particular care is to be given to the fit of the insert and the welding sequence. The welding is also to be subject to non-destructive examination.

2.4.9 Where welding of aluminium alloy is employed, the following additional requirements are to be complied with so far as they are applicable:

(a) Welding is to be performed by fusion welding using inert gas or tungsten inert gas process or by the friction stir welding process. Where it is proposed to use other welding processes, details are to be submitted for approval.

(b) The weld joint surfaces should be scratch brushed, preferably immediately before welding, in order to remove oxide or adhering films of dirt, filings, etc.

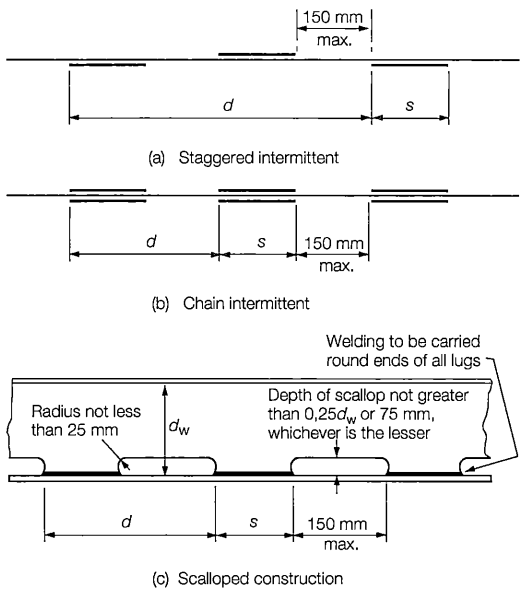
2.5 Butt welds

2.5.1 Where the ship hull is constructed of plates of different thicknesses, the thicker plates are to be chamfered in accordance with the approved plans. In all cases the chamfer is not to exceed a slope of 1 in 3 so that the plates are of equal thickness at the weld seam. Alternatively, if so desired, the width of the weld may be included as part of the smooth taper to the thicker plate provided the difference in thickness is not greater than 3 mm.

2.5.2 Where stiffening members are attached by continuous fillet welds and cross completely finished butt or seam welds, these are to be made flush in way of the fillet weld. Similarly for butt welds in webs of stiffening members, the butt weld is to be complete and generally made flush with the stiffening member before the fillet weld is made. Where these conditions cannot be complied with, a scallop is to be arranged in the web of the stiffening member, *see* Fig. 13.2.1. Scallops are to be of such a size and in such a position that a satisfactory weld can be made.

2.6 Lap connections

2.6.1 Overlaps are generally not to be used to connect plates which may be subjected to high tensile or compressive loading and alternative arrangements are to be considered. However, where plate overlaps are adopted, the width of the overlap is not to exceed four times, nor be less than three times the thickness of the thinner plate and the joints are to be positioned to allow adequate access for completion of sound welds. The faying surfaces of lap joints are to be in close contact and both edges of the overlap are to have continuous fillet welds.



NOTE *s* to be not less than 75 mm, in all cases

Fig. 13.2.1 Weld types

2.7 Closing plates

2.7.1 For the connection of plating to internal webs, where access for welding is not practicable, the closing plating is to be attached by continuous full penetration welds or by slot fillet welds to face plates fitted to the webs. Slots are to have a minimum length of 90 mm and a minimum width of twice the plating thickness, with well rounded ends. Slots cut in plating are to be smooth and clean and are to be spaced not more than 230 mm apart, centre to centre. Slots are not to be filled with welding.

2.7.2 For the attachment of rudder shell plating to the internal stiffening of the rudder, slots are to have a minimum length of 75 mm and, in general, a minimum width of twice the side plating thickness. The ends of the slots are to be rounded and the space between them is not to exceed 150 mm.

2.8 Stud welding

2.8.1 Where permanent or temporary studs are to be attached by welding to main structural parts in areas subject to high stress, the proposed location of the studs and the welding procedures adopted are to be approved.

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2.9 Fillet welds

2.9.1 T-connections are generally to be made by fillet welds on both sides of the abutting plate, the dimensions and spacing of which are shown in Fig. 13.2.1. Where the connection is highly stressed, deep penetration or full penetration welding may be required. Where full penetration welding is required, the abutting plate may be required to be bevelled.

2.9.2 Where an approved deep penetration procedure is used, the fillet leg length calculated may be reduced by 15 per cent provided that the manufacturer is able to meet the following requirements:

(a) Use of a welding consumable approved for deep penetration welding in accordance with Chapter 11 for either the 'p' or 'T' techniques.

(b) Demonstrations by way of production weld testing that the minimum required penetration depths (i.e. throat thicknesses) are maintained. This is to be documented on a monthly basis by the manufacturer and be available to the Surveyor.

2.9.3 The calculated fillet leg length may be reduced by 20 per cent, provided that in addition to the requirements of 2.9.2(a) and (b), the manufacturer is able to consistently meet the following additional requirements:

(a) The documentation required in 2.9.2(b) is to be completed and made available to the Surveyor upon request on a weekly basis.

(b) Suitable process selection confirmed by satisfactory welding procedure tests covering both minimum and maximum root gaps.

2.9.4 Where intermittent welding is used, the welding is to be made continuous in way of brackets, lugs and scallops and at orthogonal connections with other members.

2.10 Post-weld heat treatment

2.10.1 Post-weld stress relief heat treatment is applied to improve the fatigue performance or to improve resistance to brittle fracture and is generally required for carbon and carbon-manganese and low alloy steels under any of the following conditions:

(a) Where the material thickness exceeds 65 mm.

(b) For complicated weld joints where there are high stress concentrations.

(c) Where fatigue loads are considered high.

2.10.2 Post-weld heat treatment is to be applied to the following types of welded construction:

(a) Welding of steel castings where the thickness of the casting at the weld exceeds 30 mm, except where castings are directly welded to the hull structure.

(b) Oil engine bedplates except engine types where the bedplate as a whole is not subjected to direct loading from the cylinder pressure. For these types, only the transverse girder assemblies need to be stress relieved.

(c) Welding of gear wheels.

(d) Welding of gear cases associated with main or auxiliary engines, *see* Part 5 of the Rules for Ships.

2.10.3 Where required, heat treatment is to be performed in accordance with the requirements specified in 4.6 for pressure vessel construction.

2.10.4 Special consideration may be given to omit the required post-weld heat treatment. Evaluation is to be based on critical engineering assessment involving fracture mechanics testing and proposals are to be submitted which include full details of the application, materials, welding procedures, inspection procedures, design stresses, fatigue loads and cycles. Evidence will be required to demonstrate that the inspection techniques and procedures to be employed are able to detect flaws down to the sizes determined from the fracture mechanics (and or fatigue) calculations.

2.11 Tolerances

2.11.1 Tolerances after welding are to be in accordance with the relevant Part of the Rules.

2.11.2 Distortion which has resulted from welding may be corrected by spot heating in accordance with 1.14.

2.12 Non-destructive examination of welds

2.12.1 All finished welds are to be sound and free from cracks and substantially free from lack of fusion, incomplete penetration, porosity and slag. The surfaces of welds are to be reasonably smooth and substantially free from undercut and overlap. Care is to be taken to ensure that the specified dimensions of welds have been achieved and that both excessive reinforcement and under-fill of welds is avoided.

2.12.2 Welds forming part of the hull and superstructure may be coated with a thin layer of protective primer prior to inspection provided it does not interfere with inspection and is removed, if required by the Surveyor, for closer interpretation of possible defective areas.

2.12.3 All welds are to be visually inspected by personnel designated by the builder. Visual inspection of all welds may be supplemented by other non-destructive examination techniques in cases of unclear interpretation, as considered necessary. The acceptance criteria for visual testing are given in Table 13.2.4.

2.12.4 In addition to visual inspection, welded joints are to be examined using any one or a combination of ultrasonic, radiographic, magnetic particle, eddy current, dye penetrant or other acceptable methods appropriate to the configuration of the weld.

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Table 13.2.4 Acceptance criteria for visual testing, magnetic particle and liquid penetrant testing

Surface discontinuity	Classification according to ISO 6520-1	Acceptance criteria for visual testing
Crack	100	Not accepted
Lack of fusion	401	Not accepted
Incomplete root penetration in butt joints welded from one side	4021	Not accepted
Surface pore	2017	Single pore diameter $d \leq 0{,}25t$, for butt welds, with maximum diameter 3 mm, *see* Note 1 $d \leq 0{,}25a$, for fillet welds, with maximum diameter 3 mm, *see* Note 1 2,5d as minimum distance to adjacent pore
Undercut in butt welds	501	Depth ≤ 0,5 mm, whatever the length Depth ≤ 0,8 mm, with a maximum continuous length of 90 mm, *see* Note 2
Undercut in fillet welds	501	Depth ≤ 0,8 mm, whatever the length

NOTES
1. t is the plate thickness of the thinnest plate, and a is the throat of the fillet weld.
2. Adjacent undercuts separated by a distance shorter than the shortest undercut are to be regarded as a single continuous undercut.

2.12.5 The method to be used for the volumetric examinations of welds is the responsibility of the builder. Radiography is generally preferred for the examination of butt welds of 8 mm thickness or less. Ultrasonic testing is acceptable for welds of 8 mm thickness or greater and is to be used for the examination of full penetration tee butt or cruciform welds or joints of similar configuration. Advanced ultrasonic techniques, such as Phased Array Ultrasonic Testing (PAUT), may be used as a volumetric testing method in lieu of radiography or manual ultrasonic testing. If these methods are used, the thickness limitations for manual ultrasonic testing apply.

2.12.6 The acceptance criteria for radiographic testing are given in Table 13.2.5, and those for ultrasonic testing in Table 13.2.6. Alternative NDE acceptance criteria will be subject to special consideration provided that they are equivalent to these requirements.

2.12.7 Checkpoints examined at the pre-assembly stage are to include ultrasonic testing on examples of the stop/start points of automatic welding and magnetic particle inspection of weld ends.

2.12.8 Checkpoints examined at the assembly stage are generally to be selected from those welds intended to be examined as part of the agreed quality control programme to be applied by the builder. The locations and number of checkpoints are to be approved by the Surveyor.

2.12.9 Where components of the structure are subcontracted for fabrication, the same inspection regime is to be applied as if the item had been constructed within the main contractor's works. In these cases, particular attention is to be given to highly loaded fabrications (such as stabiliser fin boxes) forming an integral part of the hull envelope.

2.12.10 Particular attention is to be paid to highly stressed items. Magnetic particle inspection is to be used at ends of fillet welds, T-joints, joints or crossings in main structural members and at stern frame connections.

2.12.11 Special attention is to be given to the examination of plating in way of lifting eye plate positions to ensure freedom from cracks. This examination is not restricted to the positions where eye plates have been removed, but includes the positions where lifting eye plates are permanent fixtures.

2.12.12 Checkpoints for volumetric examination are to be selected so that a representative sample of welding is examined.

2.12.13 Typical locations for volumetric examination and number of checkpoints to be taken are given in the relevant Sections of the Rules. A list of the proposed items to be examined is to be submitted for approval.

2.12.14 For the hull structure of refrigerated spaces, and of ships designed to operate in low air temperatures, the extent of non-destructive examination will be specially considered. For non-destructive examination of gas ships *see* the *Rules for the carriage for Liquefied Gases*.

2.12.15 For all ship types, the builder is to carry out random non-destructive examination at the request of the Surveyor.

2.12.16 Results of non-destructive examinations made during construction are to be recorded and evaluated by the builder on a continual basis in order that the quality of welding can be monitored. These records are to be available to the Surveyor.

2.12.17 The extent of applied non-destructive examinations is to be increased when warranted by the analysis of previous results.

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Table 13.2.5 Acceptance criteria for radiographic testing

Discontinuity	Classification according to ISO 6520-1	Acceptance criteria for radiographic testing, *see* Note 1
Crack	100	Not accepted
Lack of fusion	401	Continuous maximum length $t/2$ or 25 mm, whichever is the less, *see* Note 2 Intermittent cumulative length maximum t or 50 mm, whichever is less, *see* Note 3
Lack of root fusion	4013	Not accepted in butt joints welded from one side
Incomplete root penetration	4021	Not accepted in butt joints welded from one side
		Continuous maximum length $t/2$ or 25 mm, whichever is lesser, *see* Note 2 Intermittent cumulative maximum length t or 50 mm, whichever is less, *see* Note 3
Slag inclusion	301	Continuous maximum length t or 50 mm, whichever is less, *see* Note 2 Intermittent cumulative length maximum $2t$ or 100 mm, whichever is less, *see* Notes 3 and 4
Gas pore	2011	Maximum dimension for a single pore: $d \leq 0{,}2t$, max. 4,0 mm *see* Note 5
Uniformly distributed porosity	2012	Maximum dimension of the area of imperfections: For single run welds: ≤ 1,5% For multi-run welds: ≤ 3% *See* Notes 6 and 7
Clustered (localised) porosity	2013	Maximum dimension of the summation of the projected area of the imperfection: ≤ 8% *See* Notes 6 and 7
Elongated cavity	2015	$h \leq 0{,}3t$, max. 3,0 mm $l \leq t$, max. 50 mm *See* Notes 8 and 9
Wormholes	2016	$h \leq 0{,}3t$, max. 3,0 mm $l \leq t$, max. 50 mm *See* Notes 8 and 9
Metallic inclusions other than copper	304	$h \leq 0{,}3t$, max. 3,0 mm *See* Note 8
Copper inclusions	3042	Not permitted

NOTES
1. t is the thickness of the thinnest plate.
2. Two adjacent individual discontinuities of length l_d1 and l_d2 situated on a line and where the distance l_d between them is shorter than the shortest discontinuity are to be regarded as a continuous discontinuity of length $l_d1 + l_d + l_d2$.
3. Sum of the length of individual continuous discontinuities.
4. Parallel inclusions not separated by more than 3 times the width of the largest inclusion are to be regarded as one continuous discontinuity.
5. d is the diameter of the gas pore.
6. The limits for the maximum single gas pore within this group still apply.
7. Further reference to porosity limits may be obtained in ISO 5817:2007.
8. h is the width of the imperfection.
9. l is the length of the imperfection.

2.13 Weld repairs

2.13.1 The full extent of any weld defect is to be ascertained by applying additional non-destructive examination where required. Unacceptable defects are to be completely removed and, where necessary, re-welded and re-examined in accordance with the requirements of 1.15.

2.13.2 During the assembly of large components, root gaps in excess of those specified in the approved welding procedure may be rectified by welding.

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Table 13.2.6 Acceptance criteria for ultrasonic testing

Echo height	Acceptance criteria for ultrasonic testing, *see* Note
Greater than 100% of DAC curve	Maximum length *t*/2 or 25 mm, whichever is less
Greater than 50% of DAC curve, but less than 100% of DAC curve	Maximum length *t* or 50 mm, whichever is less
Indications evaluated to be cracks are unacceptable regardless of echo height; Indications evaluated to be lack of penetration or lack of root fusion in joints welded from one side are unacceptable regardless of echo height.	
NOTE Two adjacent individual discontinuities of length L1 and L2 situated on a line and where the distance L between them is shorter than the shortest discontinuity are to be regarded as a continuous discontinuity of length L1 + L + L2.	

2.13.3 Rectification of wide root gaps in butt welds, up to a maximum gap of 16 mm, may be performed provided that the length of these areas is small in relation to the whole weld length. Repairs may be executed by applying weld buttering layers to one edge of the weld joint, followed by machining or grinding to return the root opening to the required dimensions. The weld buttering and filling of the joint are to be in accordance with welding procedures qualified in accordance with Chapter 12.

2.13.4 For sub-assemblies, rectification of wide root gaps may be performed using a backing strip, provided that it is removed on completion of the welding.

2.13.5 Rectification of wide root gaps in fillet welds may be carried out as follows:

(a) where the root gap, *g*, is in excess of 3 mm, but not greater than 5 mm, the fillet leg length, *z*, may be increased by *g* – 2,0 mm;

(b) where the root gap is in excess of 5 mm, the joint detail may be changed into a full penetration weld.

2.13.6 Where repair welds are made using small weld beads, suitable precautions (including preheat) are to be taken to avoid high hardness and possible cold cracking.

2.14 Welding afloat with water backing

2.14.1 Welding afloat with water backing is not recommended due to the additional precautions required during survey and therefore, is generally not permitted. However consideration may be given to welding afloat with water backing after specific LR approval has been obtained by the yard or fabricator prior to such welding being carried out. Such approval will only be given once all of the following conditions are satisfied:

(a) The welding procedure qualification tests are carried out on steel plates with water backing and the water is maintained at the flow rate and minimum water temperature anticipated during fabrication.

(b) The carbon equivalent of the steel plates used in the welding procedure qualification tests are to be greater than 0,41 per cent based on the IIW formula. Where it can be shown that all hull steel plates and new sections will have a carbon equivalent value below this figure, steel plates with the maximum carbon equivalent value may be used for the welding procedure qualification tests.

(c) Welding procedure qualification tests are carried out without preheat.

(d) The thickness of steel plate used in the welding procedure qualification test is the minimum hull plate thickness to be used during fabrication.

(e) The maximum measured hardness on the completed welding procedure qualification assembly is less than or equal to 350 HV10. Following fabrication welding, 10 per cent of welds are to be hardness tested in way of heat-affected zones at weld starts to confirm compliance with the 350 HV10 limit.

(f) The heat input used in the welding qualification test is the minimum permitted heat input during fabrication.

(g) Only low hydrogen welding consumables (H5) are used.

(h) In addition to normal non-destructive testing for welds, 10 per cent of the welds are additionally subject to magnetic particle inspection 48 hours after welding is complete.

(j) The welding procedure qualification tests for the repair of welds carried out afloat with water backing are to be carried out on test pieces that have previously been welded afloat and also meet the requirements above.

2.14.2 Welding in, or underwater, is not permitted.

■ *Section 3*
Specific requirements for fabricated steel sections

3.1 Scope

3.1.1 Fabricated steel sections are items used in place of rolled sections and as such will not be regarded as sub-assemblies. Products regarded as sub-assemblies are subject to requirements of welded construction specified in Section 2.

3.1.2 The requirements for structural steel sections are based on these being manufactured from flat products by automatic welding and intended for use in the construction of ships and other marine structures.

3.1.3 Fabricated steel sections are to be manufactured in accordance with the requirements of this Section and the general requirements of Section 1.

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3.1.4 In all cases, sections are to be manufactured at works, which have been assessed and approved in accordance with *Materials and Qualification Procedures for Ships, Book J, MQPS Procedure 12-1*.

3.2 Dimensions and tolerances

3.2.1 Products are to conform dimensionally to the provisions of an acceptable National or International Standard.

3.2.2 The *minimum* throat thickness of fillet welds is to be determined from:

Throat thickness = 0,34*t* but not to be taken as less than 3 mm

where

t = plate thickness of the thinner member to be joined (generally the web).

3.2.3 Where a welding procedure using deep penetration welding is used (*see* Chapter 11, 'p' and 'T' welding techniques) the minimum leg length required will be specially considered provided the requirements of 2.9.2 are complied with.

3.2.4 *Unless agreed otherwise, the leg length of the weld* is to be not less than 1,4 times the specified throat thickness.

3.3 Identification of products

3.3.1 Every finished item is to be clearly marked by the manufacturer in at least one place with the following particulars:

(a) The manufacturer's name or trade mark.
(b) Identification mark for the grade of steel.
(c) Identification number and/or initials which will enable the full history of the item to be traced.
(d) Where required by the purchaser, the order number or other identification mark.
(e) The letters 'LR'.
(f) The Surveyor's personal stamp.

The above particulars, but excluding the manufacturer's name or trade mark where this is embossed on finished products, are to be encircled with paint or otherwise marked so as to be easily recognisable.

3.3.2 In the event of any material bearing LR's brand failing to comply with the test requirements, the brand is to be removed or unmistakably defaced, *see also* Ch 1,4.7.

3.4 Manufacture and workmanship

3.4.1 For cut edges that are to remain unwelded, it is to be demonstrated that the plate preparation procedures used are able to achieve edges that are free from cracks or other deleterious imperfections.

3.4.2 Where assembly jigs and devices are used to bring the web into contact with the flanges and hold these in place during welding, means are to be provided to ensure that the degree of contact is maintained until welding is complete.

3.4.3 Welding procedures are to be established for the welding of all joints including weld repairs and are to be approved in accordance with Chapter 12. Welders are to be approved in accordance with Chapter 12, and qualification records are to be available to the Surveyor.

3.4.4 The welding consumables used are to be approved in accordance with Chapter 11 and are to be suitable for the type of joint and grade of steel as described in 2.2. For joining steel of different tensile strengths, the consumables are to be suitable for the tensile strength of the component considered in the determination of weld size.

3.4.5 The application of pre-heat and the use of low hydrogen welding consumables are to be in accordance with the requirements of 2.2.

3.4.6 Welding is to be double continuous fillet welding or full penetration welding as specified in the approved plans.

3.4.7 Where deep penetration welding is used, the requirements of 2.9.2 are to be complied with.

3.5 Non-destructive examination

3.5.1 Surface inspection and verification of dimensions are the responsibility of the manufacturer and are to be carried out on all materials prior to despatch. Acceptance by the Surveyor of material later found to be defective does not absolve the manufacturer from this responsibility.

3.5.2 The Surveyor will carry out checks to ensure that the weld size and profile are in accordance with the manufacturing specification and the manufacturer's Quality Control Procedures.

3.5.3 The manufacturer is to examine the welds by magnetic particle or dye penetrant methods. The length examined is to be 200 mm at each end, for each length cut for delivery.

3.5.4 If cracks are revealed, these are to be reported to the Surveyor and the whole of the length is to be examined by magnetic particle or dye penetrant methods. Corrective action in respect of the manufacturing process, and repairs are to be as indicated in the manufacturers' Quality Control Manual.

3.5.5 The weld defect is not to exceed the acceptance levels given in Table 13.2.4.

3.6 Routine weld tests

3.6.1 One production batch test is required for every 500 m of fabricated section manufactured, or fraction thereof. From each batch test, two samples are to be removed, one from near the beginning of the production run and one from near the end. From each of these test samples one macro specimen and one fracture test specimen are to be taken.

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3.6.2 The macro specimens are to be prepared and etched to demonstrate freedom from unacceptable defects and that the weld penetration is in accordance with the manufacturing specification. The fracture specimens are to be broken, one for each side of the fillet weld, and the fractured surfaces examined for compliance with the requirements of Table 13.2.5.

3.6.3 Where the welding procedure used has employed the deep penetration technique, the amount of root penetration is to be measured on the macro specimen and is not to be less than that demonstrated during welding procedure approval testing.

3.6.4 For the purposes of this Section, a batch is to consist of products of only one size and grade of material.

3.7 Certification and records

3.7.1 Each test certificate is to include the following particulars:

(a) Purchaser's name and order number.
(b) Where known, the contract number for which the material is intended.
(c) Address to which material is despatched.
(d) Description and dimensions of the product.
(e) Specification or grade of the steel.
(f) Identification number and/or initials.
(g) Cast number and chemical composition of ladle samples of constituent plates.
(h) Mechanical test results of constituent plates.
(j) Condition of supply when other than as-rolled.
(k) Make and brand of welding consumables.

3.7.2 Test certificates or shipping statements may be signed by the Surveyor, provided the documentation requirements of 1.17 are satisfied. The following form of declaration will be accepted if stamped or printed on each test certificate or shipping statement with the name of the works and signed by an authorised representative of the manufacturer:

'We hereby certify that the material has been made by an approved procedure in accordance with the Lloyd's Register's Rules for Materials'.

3.7.3 The manufacturer is to maintain records by which sources of material can be identified together with the results of all inspections and tests.

■ *Section 4*
Specific requirements for fusion welded pressure vessels

4.1 Scope

4.1.1 The requirements of this Section apply to fusion welded pressure vessels and process equipment, heating and steam raising boilers, and steam or gas turbine rotors and cylinders and are in addition to those requirements referred to in Section 1.

4.1.2 The allocation of pressure vessel Class is determined from the design criteria in Pt 5, Ch 10 and 11 of the Rules for Ships. Prior to commencing construction, the design of the vessel is to be approved. Construction requirements for turbine rotors and cylinders are to be in accordance with Class 2/1, unless a higher Class is specified in the approved plans.

4.1.3 Pressure vessels will be accepted only if manufactured by firms equipped and competent to undertake the quality of welding work required for the Class of vessel proposed. The manufacturer's works are to be approved in accordance with the requirements specified in *Materials and Qualification Procedures for Ships, Book A, Procedure MQPS 0-4*.

4.1.4 The term 'fusion weld', for the purpose of these requirements, is applicable to welded joints made by manual, semi-automatic, or automatic electric arc welding processes. Special consideration will be given to the proposed use of other fusion welding processes.

4.2 Cutting and forming of shells and heads

4.2.1 Cut or chipped surfaces which will not be subsequently covered by weld metal are to be ground smooth.

4.2.2 Shell plates and heads are to be formed to the correct contour up to the extreme edge of the plate.

4.2.3 Vessels manufactured from carbon or carbon manganese steel plates (*see* Table 3.4.1 in Chapter 3, grades 360AR to 510FG), which have been hot formed or locally heated for forming, are to be re-heat treated in accordance with the original supplied condition on completion of this operation. Vessels formed from plates supplied in the as-rolled condition are to be heat treated in accordance with the material manufacturer's recommendations.

4.2.4 Subsequent heat treatment will not be required where steels are supplied in the as-rolled, normalised or normalised and controlled rolled condition, or hot forming is carried out entirely at a temperature within the normalising range.

4.2.5 For alloy steel vessels where hot forming is employed (*see* Table 3.4.1 in Chapter 3, 13Cr Mo 45, etc.), the plates are to be heat treated on completion in accordance with the material manufacturer's recommendations.

4.2.6 Where plates are cold formed, subsequent heat treatment is to be performed where the internal radius is less than 10 times the plate thickness. For carbon and carbon-manganese steels this heat treatment may be a stress relief heat treatment.

4.2.7 In all cases where hot forming is employed, and for cold forming to a radius less than 10 times the thickness, the manufacturer is required to demonstrate that the forming process and subsequent heat treatments result in acceptable properties.

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4.3 Fitting of shell plates and attachments

4.3.1 The location of welded joints is to be such as to avoid intersecting butt welds in the vessel shell plates. The attachment of nozzles and openings in the vessels are to be arranged to avoid main shell weld seams.

4.3.2 The surfaces of the plates at the longitudinal or circumferential seams are not to be out of alignment with each other, at any point, by more than 10 per cent of the plate thickness. In no case is the misalignment to exceed 3 mm for longitudinal seams, or 4 mm for circumferential seams.

4.3.3 Where a vessel is constructed of plates of different thicknesses (tube plate and wrapper plate), the plates are to be so arranged that their centrelines form a continuous circle.

4.3.4 For longitudinal seams, the thicker plate is to be equally chamfered inside and outside by machining over a circumferential distance not less than twice the difference in thickness, so that the plates are of equal thickness at the longitudinal weld seam. For the circumferential seam, the thickest plate is to be similarly prepared over the same distance longitudinally.

4.3.5 For the circumferential seam, where the difference in the thickness is the same throughout the circumference, the thicker plate is to be reduced in thickness by machining to a taper for a distance not less than four times the offset, so that the two plates are of equal thickness at the weld joint. A parallel portion may be provided between the end of the taper and the weld edge preparation; alternatively, if so desired, the width of the weld may be included as part of the smooth taper to the thicker plate.

4.3.6 All attachments (lugs, brackets, reinforcing plates, etc.) are to conform to the shape of the surface to which they are attached.

4.4 Welding

4.4.1 Welding procedures are to be established for all welds joining pressure containing parts and for welds made directly onto pressure containing parts. Welding procedures are to be based on qualification tests performed in accordance with Chapter 12.

4.4.2 In all cases where tack welds, in the root of the weld seam, are used to retain plates or parts in position prior to welding, they are to be removed in the process of welding the seam.

4.4.3 Steel backing strips may be used for the circumferential seams of Class 2/1, Class 2/2 and Class 3 pressure vessels and are to be the same nominal composition as the plates to be welded.

4.4.4 Fillet welds are to be made to ensure proper fusion and penetration at the root of the fillet. At least two layers of weld metal are to be deposited at each weld affixing branch pipes, flanges and seatings.

4.4.5 The outer surface of completed welds is to be at least flush with the surface of the plates joined, and any weld reinforcement is to provide a smooth transition and gradual change of section with the plate surface.

4.4.6 Where attachment of lugs, brackets, branches, manhole frames, reinforcement plates and other members are to be made to the main pressure shell by welding, this is to be to the same standard as required for the main vessel shell construction.

4.4.7 The main weld seams and all welded attachments made to pressure containing parts are to be completed prior to post weld heat treatment.

4.4.8 The finish of welds attaching pressure parts and non-pressure parts to the main pressure shell is to be such as to allow satisfactory examination of the welds. In the case of Class 1 and Class 2/1 pressure vessels, these welds are to be ground smooth, if necessary, to provide a suitable finish for examination.

4.5 General requirements for routine weld production tests

4.5.1 Routine weld production tests are specified as a means of monitoring the quality of the welded joints and are required for pressure vessel Classes 1, 2/1 and 2/2.

4.5.2 Routine production test plates are required during the manufacture of vessels and as part of the initial approval test programme for Class 1 vessel manufacturers, refer to MQPS 0-4.

4.5.3 Routine production weld tests are not required for Class 3 pressure vessels unless there are doubts about the weld quality where check tests may be requested by the Surveyor.

4.5.4 Routine production test plates are not required for circumferential seams of cylindrical pressure vessels. Spherical vessels are to have one test plate prepared having a welded joint which is a simulation of the circumferential seams.

4.5.5 Routine production weld tests may be requested by the Surveyor where there is reason to doubt the quality of workmanship.

4.6 Production test plate assembly requirements

4.6.1 Two test plates and one complete test assembly, of sufficient dimensions to provide all the required mechanical test specimens is to be prepared for each vessel and is to be welded as a continuation and simulation of the longitudinal weld joint.

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4.6.2 For Class 2/2 vessels, where a large number are made concurrently at the same works using the same welding procedure and the plate thicknesses do not vary by more than 5 mm, one test may be performed for each 37 m of longitudinal plus circumferential weld seam. In these cases the thickness of the test plate is to be equal to the thickest shell plate used in the construction.

4.6.3 Where the vessel size or design results in a small number of longitudinal weld seams, one test assembly may be prepared for testing provided that the welding details are the same for each seam.

4.6.4 Test plate materials are to be the same grade, thickness and supply condition and from the same cast as that of the vessel shell. The test assembly is to be welded at the same time as the vessel weld to which it relates and is to be supported so that distortion during welding is minimised.

4.6.5 As far as practicable, welding is to be performed by different welders where there is a requirement for several routine tests to be welded.

4.6.6 The test assembly may be detached from the vessel weld only after the Surveyor has performed a visual examination and has added his mark or stamp. Straightening of test welds prior to mechanical testing is not permitted.

4.6.7 Where the pressure vessel is required to be subjected to post-weld heat treatment, the test weld is to be heat treated, after welding, in accordance with the same requirements. This may be performed separately from the vessel.

4.7 Inspection and testing

4.7.1 The test weld is to be subjected to the same type of non-destructive examination and acceptance criteria as specified for the weld seam to which the test relates. Non-destructive examination is to be performed prior to removing specimens for mechanical testing, but after any post-weld heat treatment.

4.7.2 The test weld is to be sectioned to remove the number and type of test specimens for mechanical testing as given in 4.8.

4.8 Mechanical requirements

4.8.1 The routine production test assembly is to be machined to provide the following test specimens:

(a) Tensile.
(b) Bend.
(c) Hardness.
(d) Impact (*see* Table 13.4.1).
(e) Macrograph and hardness survey of full weld section.

4.8.2 One set of specimens for mechanical testing are to be removed, as shown in Figs. 13.4.1 or 13.4.2 as appropriate for the Class of approval. Impact tests are to be removed and tested where required by Table 13.4.1.

4.8.3 **Longitudinal tensile test for weld metal.** An all-weld metal longitudinal tensile test is required. For thicknesses in excess of 20 mm, where more than one welding process or type of consumable has been used to complete the joint, additional longitudinal tests are required from the respective area of the weld. This does not apply to the welding process or consumables used solely to deposit the root weld. Specimens are to be tested in accordance with the following requirements:

(a) The diameter and gauge length of the test specimen is to be in accordance with Ch 11,2.1.1.
(b) For carbon and carbon-manganese steels the tensile strength of the weld metal is to be not less than the minimum specified for the plate material and not more than 145 N/mm^2 above this value. The percentage elongation, A, is to be not less than that given by:

A = (980-R)/21,6 but not less than 80 per cent of the minimum elongation specified for the plate

where

R is the tensile strength, in N/mm^2, obtained from the all weld metal tensile tests.

(c) For other materials the tensile strength and percentage elongation is not to be less than that specified for the base materials welded.

4.8.4 **Transverse tensile test for joint.** Transverse tensile test specimens are to be removed and tested in accordance with the following requirements:

(a) One reduced section tensile test specimen is to be cut transversely to the weld to the dimensions shown in Ch 11,2.1.1 and the weld reinforcement is to be removed.

Table 13.4.1 Impact test requirements

Pressure vessel Class	Minimum design temperature	Plate material thickness t	Impact test temperature
Class 1 *see* Note	–10°C or above	All	5°C below the minimum design temperature or 20°C, whichever is the lower
All Classes	Below –10°C	$t \leq 20$ mm	5°C below the minimum design temperature
		20 mm $< t \leq 40$ mm	10°C below the minimum design temperature
		Over 40 mm	Subject to special consideration
NOTE Impact testing is not required for Classes 2/1, 2/2 and 3.			

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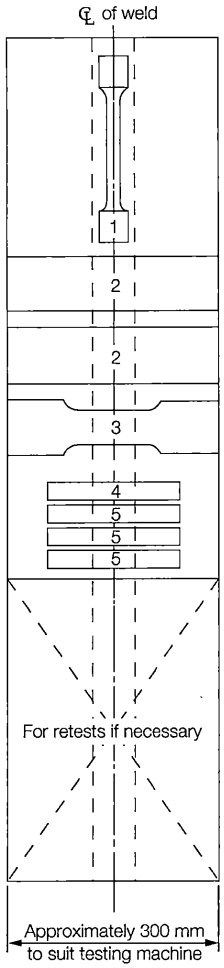
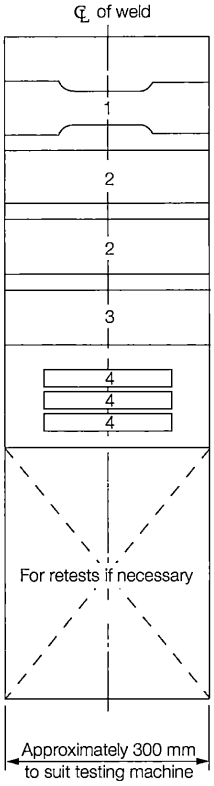


1. All weld metal tensile test specimen.
2. Bend test specimens.
3. Tensile test for joints.
4. Macro-test specimen.
5. Charpy V-notch impact.
(For all Class 1 pressure vessels and other Classes of pressure vessels where the minimum design temperature is below –10°C).

Fig. 13.4.1
Routine weld test – Test specimens for Class 1 and Class 2/1



1. Tensile test for joints.
2. Bend test specimens.
3. Nicked bend test specimen.
4. Charpy V-notch impact test specimens (if required by Table 13.4.1).

Fig. 13.4.2
Routine weld tests – Test specimens for Class 2/2 and Class 3

(b) In general, where the plate thickness exceeds 30 mm, or where the capacity of the tensile test machine prevents full thickness tests, each tensile test may be made up of several reduced section specimens, provided that the whole thickness of the weld is subjected to testing.

(c) The tensile strength obtained is to be not less than the minimum specified tensile strength for the plate material, and the location of the fracture is to be reported.

4.8.5 **Transverse bend test**. The bend test specimens are to be removed and tested in accordance with the following requirements:

(a) Two bend test specimens of rectangular section are to be cut transversely to the weld, one bent with the outer surface of the weld in tension (face bend), and the other with the inner surface in tension (root bend).

(b) The specimen dimensions are to be in accordance with Chapter 2.

(c) Each specimen is to be mounted on roller supports with the centre of the weld midway between the supports. The former is to have a diameter specified in Ch 12,2.7.6 depending on the material being welded.

(d) After bending through an angle of at least 180° there is to be no crack or defect exceeding 1,5 mm measured across the specimen or 3 mm measured along the specimen. Premature failure at the edges of the specimen is not to be cause for rejection, unless this is associated with a weld defect.

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4.8.6 **Macro-specimen and hardness survey.** A macro examination specimen is to be removed from the test assembly near the end where welding started. The specimen is to include the complete cross-section of the weld and the heat affected zone. The specimen is to be prepared and examined in accordance with the following requirements:

(a) The cross-section of the specimen is to be ground, polished and etched to clearly reveal the weld runs, and the heat affected zones.

(b) The specimen is to show an even weld profile that blends smoothly with the base material and have satisfactory penetration and fusion, and an absence of significant inclusions or other defects.

(c) Where there is doubt in the condition of the weld as shown by macro-etching, the area concerned is to be microscopically examined.

(d) For carbon, carbon manganese and low alloy steels, a Vickers hardness survey is to be performed on the macro-specimen using either a 5 kg or 10 kg load. Testing is to include the base material, the weld and the heat affected zone. Hardness scans on the cross-section are to be performed as specified in Fig. 12.2.8 in Chapter 12. The maximum recorded hardness is to not exceed 350 Hv.

4.8.7 **Charpy V-notch impact test.** Charpy V notch impact test specimens are to be prepared and tested as required by Table 13.4.1 and in accordance with the following requirements:

(a) The dimensions and tolerances of the specimens are to be in accordance with Chapter 2.

(b) Charpy V-notch impact specimens and are to be removed with the notch perpendicular to the plate surface.

(c) Specimens are to be removed for testing from the weld centreline and the heat affected zone (fusion line and fusion line + 2 mm locations) detailed in Fig. 12.2.6 or Fig. 12.2.7 in Chapter 12, as appropriate. Heat affected zone impact tests may be omitted where the minimum design temperature is above +20°C.

(d) For thicknesses in excess of 20 mm, where more than one welding process or type of consumable has been used to complete the joint, impact tests are required from the respective areas of the weld. This does not apply to the welding process or consumables used solely to deposit the root weld.

(e) The average energy of a set of three specimens is not to be less than 27 J or the minimum specified for the base material, whichever is the higher. The minimum energy for each individual specimen is to meet the requirements of Ch 1,4.5.2.

4.8.8 **Nick break bend tests.** A nick bend or fracture test specimen is to be a minimum of 100 mm long measured along the weld direction and is to be tested in accordance with and meet the requirements of the following:

(a) The specimen is to have a slot cut into each side along the centreline of the weld and perpendicular to the plate surface.

(b) The specimen is to be bent along the weld centreline until fracture occurs and the fracture faces are to be examined for defects. The weld is to be sound, with no evidence of cracking or lack of fusion or penetration and be substantially free from slag inclusions and porosity.

4.9 Failure to meet requirements

4.9.1 Where any test specimen fails to meet the requirements, additional specimens may be removed and re-tested in accordance with Ch 2,1.4.

4.9.2 Where a routine weld test fails to meet requirements, the welds to which it relates will be considered as not having met the requirements. The reason for the failure is to be established, and the manufacturer is to take such steps as necessary to either

(a) Remove the affected welds and have them re-welded, or

(b) Demonstrate that the affected production welds have acceptable properties.

4.10 Heat treatment

4.10.1 Fusion welded pressure vessels, where indicated in Table 13.4.2, are to be heat treated on completion of the welding of the seams and of all attachments to the shell and ends, and before the hydraulic test is carried out.

4.10.2 Tubes which have been expanded into headers or drums may be seal welded without further post-weld heat treatment.

4.10.3 Steam and gas turbine cylinders and rotors are to be subjected to post-weld heat treatment irrespective of thickness.

4.10.4 Where the weld attaches parts of different thicknesses, the thickness to be used when applying the requirements for post-weld heat treatment is to be either the thinner of the two plates for butt welded connections, or the thickness of the shell for welds to flanges, tubeplates and similar connections.

4.10.5 Care is to be exercised to provide drilled holes in double reinforcing plates and other closed spaces prior to heat treatment.

4.11 Basic requirements for heat treatment of fusion welded pressure vessels

4.11.1 Recommended soaking temperatures and soak durations for post-weld heat treatment are given in Table 13.4.3 for different materials. Where other materials are used for pressure vessel construction, full details of the proposed heat treatment are to be submitted for consideration.

4.11.2 Where pressure vessels are of dimensions that the whole length cannot be accommodated in the furnace at one time, the pressure vessels may be heated in sections, provided that sufficient overlap is allowed to ensure the heat treatment of the entire length of the longitudinal seam.

4.11.3 Where materials other than those detailed in Table 13.4.3 are used or where it is proposed to adopt special methods of heat treatment, full particulars are to be submitted for consideration. In such cases, it may be necessary to carry out tests to show the effect of the proposed heat treatment.

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Table 13.4.2 Post-weld heat treatment requirements

Type of steel	Plate thickness above which post-weld heat treatment (PWHT) is required	
	Steam raising plant	Other pressure vessels
Carbon and carbon/manganese steels without low temperature impact values	20 mm	30 mm
Carbon and carbon/manganese steels with low temperature impact values	20 mm	40 mm
1Cr ½Mo	All thicknesses	All thicknesses
2¼Cr 1Mo	All thicknesses	All thicknesses
½Cr ½Mo ¼V	All thicknesses	All thicknesses
Other alloy steels	Subject to special consideration	

Table 13.4.3 Post-weld soak temperatures and times

Material type	Soak temperature (°C)	Soak period
Carbon and carbon/manganese grades	580–620°	1 hour per 25 mm of thickness, minimum of 1 hour
1Cr ½Mo	620–660°	1 hour per 25 mm of thickness, minimum of 1 hour
2¼Cr 1Mo	650–690°	1 hour per 25 mm of thickness, minimum of 1 hour
½Cr ½Mo ¼V	670–720°	1 hour per 25 mm of thickness, minimum of 1 hour
NOTE For materials supplied in the tempered condition, the post-weld heat treatment temperature is to be lower than the material tempering temperature.		

4.12 Non-Destructive Examination of welds

4.12.1 Non-Destructive Examinations (NDE) of pressure vessel welds are to be carried out in accordance with a nationally recognised code or standard.

4.12.2 NDE is not to be applied until an interval of at least 48 hours has elapsed since the completion of welding.

4.12.3 NDE Personnel are to be qualified to an appropriate level of a nationally recognised certification scheme.

4.12.4 Qualification schemes are to include assessments of practical ability for Levels I and II individuals. These examinations are to be made on representative test pieces containing relevant defects.

4.13 Extent of NDE for Class 1 pressure vessels

4.13.1 All butt welded seams in drums, shells, headers and test plates, together with tubes or nozzles with outside diameter greater than 170 mm, are subject to 100 per cent volumetric and surface crack detection inspections.

4.13.2 For circumferential butt welds in extruded connections, tubes, headers and other tubular parts with an outside diameter of 170 mm or less, at least 10 per cent of the total number of welds is to be subjected to volumetric examination and surface crack detection inspections.

4.13.3 Full penetration tube sheet to shell welds are to be subjected to 10 per cent volumetric examination and 10 per cent surface inspection, prior to the installation of the tubes.

4.13.4 In addition to the acceptance limits stated in Tables 13.2.4 to 13.2.6, no cracks, lack of fusion, or lack of penetration is permitted.

4.13.5 When an unacceptable indication is detected, the full length of the weld is to be subjected to 100 per cent examination by the same method, testing conditions and acceptance criteria.

4.14 Extent of NDE for Class 2/1 pressure vessels

4.14.1 For Class 2/1 pressure vessels, volumetric and surface crack detection inspections are to be applied at selected regions of each main seam. At least 10 per cent of each main seam is to be examined together with the full length of each welded test plate. When an unacceptable indication is detected, at least two additional check points in the seam are to be selected by the surveyor for examination using the same inspection method. Where further unacceptable defects are found either:

(a) the whole length of weld represented is to be cut out and re-welded and re-examined as if it was a new weld with the test plates being similarly treated, or

(b) the whole length of the weld represented is to be re-examined using the same inspection methods.

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4.14.2 Butt welds in furnaces, combustion chambers and other pressure parts for fired pressure vessels under external pressure, are to be subject to spot volumetric examination. The minimum length for each check point is to be 300 mm.

4.14.3 The extent of NDE for turbine cylinders and rotors is to be agreed with the Surveyor.

4.14.4 The requirements of 4.13.3, 4.13.4 and 4.13.5 apply to Class 2/1 pressure vessels.

4.15 NDE Method

4.15.1 Volumetric examinations may be made by radiography. For welds of nominal thickness greater or equal to 10 mm, the examinations may be by ultrasonic testing. The preferred method for surface crack detection in ferrous metals is magnetic particle inspection. The preferred method for non-magnetic materials is liquid penetrant inspection.

4.16 Evaluation and reports

4.16.1 The manufacturer is to be responsible for the review, interpretation, evaluation and acceptance of the results of NDE. Reports stating compliance, or non-compliance, with the criteria established in the inspection procedure are to be issued. Reports are to comply, as a minimum, with the requirements of Ch 1,5.

4.17 Repair to welds

4.17.1 Where non-destructive examinations reveal unacceptable defects in the welded seams, they are to be repaired in accordance with 1.15 and are to be shown by further non-destructive examinations to have been eliminated.

4.17.2 In the case where spot radiography has revealed unacceptable defects, the requirements of 4.14.1 apply.

4.17.3 Where post-weld heat treatment is required in accordance with 4.10, weld repairs to the vessel or cylindrical shell or parts attaching to the shell are to be subjected to a subsequent heat treatment in accordance with 4.10.

4.17.4 In the event of unsuccessful weld repair of a defect, only one more repair attempt may be made of the same defect. Any subsequent repairs may require the re-repair excavation to be enlarged to remove the original repair heat affected zone.

Section 5
Specific requirements for pressure pipework

5.1 Scope

5.1.1 Fabrication of pipework is to be carried out in accordance with the requirements of this Section and the general requirements given in Section 1, unless more stringent requirements have been specified.

5.1.2 Piping systems are to be constructed in accordance with the approved plans and specifications.

5.1.3 Fabricated pipework will be accepted only if manufactured by firms that have demonstrated that they have the facilities and equipment and are competent to undertake the quality of welding required for the Class of pipework proposed.

5.2 Manufacture and workmanship

5.2.1 Pipe welding may be performed using manual, semi-automatic or fully automatic electric arc processes. The use of oxy-acetylene welding will be limited to Class 3 pipework in carbon steel or carbon/manganese material that is not for carrying flammable fluids and limited to butt joints in pipes not exceeding 100 mm diameter or 9,5 mm thickness.

5.2.2 Welding of pipework, including attachment welds directly to pressure retaining parts is to be performed in accordance with approved welding procedures that have been qualified in accordance with Chapter 12.

5.2.3 Where the work involves a significant number of branch connections, tests will be required to demonstrate that the type of joint(s) and welding techniques employed are capable of achieving the required quality.

5.2.4 Where pressure pipework is assembled and butt welded insitu, the piping is to be arranged well clear of adjacent structures to allow sufficient access for preheating, welding, heat-treatment and non-destructive examination of the joints.

5.2.5 Alignment of pipe butt welds is to be in accordance with Table 13.5.1 unless more stringent requirements have been agreed. Where fusible inserts are used, the alignment is to be within 0,5 mm in all cases.

5.2.6 The number of welds is to be kept to a minimum. The minimum separation between welds, measured toe-to-toe, is to be not be less than 75 mm. Where it is not possible to achieve this, adjacent welds are to be subjected to surface crack detection NDE.

5.2.7 Welding consumables and fusible root inserts, where used, are to be suitable for the materials being joined.

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Table 13.5.1 Pipe butt weld alignment tolerances

Pipe size	Maximum permitted misalignment
$D < 150$ mm and $t \leq 6$ mm	1,0 mm or 25% of t, whichever is the lesser
$D < 300$ mm and $t \leq 9,5$ mm	1,5 mm or 25% of t, whichever is the lesser
$D \geq 300$ and $t > 9,5$ mm	2,0 mm or 25% of t, whichever is the lesser
where D = pipe internal diameter; t = pipe wall thickness	

5.2.8 Acceptable methods of flange attachment are to be used, *see* Fig. 12.2.2 in Pt 5, Ch 12 of the Rules for Ships. Where backing rings are used with flange type (a) they are to fit closely to the bore of the pipe and be removed after welding. The rings are to be made of the same material as the pipes. The use of flange types (b) and (c) with alloy steel pipes is limited to pipes up to and including 168,3 mm outside diameter.

5.2.9 Where socket welded fittings are employed, the diametrical clearance between the outside diameter of the pipe and the base of the fitting is not to exceed 0,8 mm, and a gap of approximately 1,5 mm is to be provided between the end of the pipe and the internal step at the bottom of the socket.

5.2.10 For welding of carbon, carbon/manganese and low alloy steels, the preheat to be applied will be dependent on the material grade, thickness and hydrogen grading of the welding consumable in accordance with Table 13.5.2, unless welding procedure testing indicates that a higher level is required.

5.2.11 Welding without filler metal is generally not permitted for welding of duplex stainless steel materials.

5.2.12 All welds in high pressure, high temperature pipelines are to have a smooth surface finish and even contour; and where necessary, made smooth by grinding.

5.2.13 Check tests of the quality of the welding are to be carried out periodically.

5.3 Heat treatment after bending of pipes

5.3.1 After forming or bending of pipes, the heat treatments specified in this Section are to be applied unless the pipe material manufacturer specifies or recommends other requirements.

5.3.2 Generally, hot forming is to be carried out within the normalising temperature range. When carried out within this temperature range, no subsequent heat treatment is required for carbon and carbon/manganese steels. For alloy steels, 1Cr ½Mo, 2¼Cr 1Mo and ½Cr ½Mo ¼V, a subsequent tempering heat treatment in accordance with the temperatures and times specified in Table 13.5.3 is required, irrespective of material thickness.

5.3.3 When hot forming is performed outside the normalising temperature range, a subsequent heat treatment in accordance with Table 13.5.3 is required.

5.3.4 After cold forming to a radius (measured at the centreline of the pipe) of less than four times the outside diameter, heat treatment in accordance with Table 13.5.3 is required.

5.3.5 Heat treatment should be carried out in accordance with 1.16.

Table 13.5.2 Welding preheat levels for pipework

Material Grade	Thickness, t (mm) *see* Note 4	Minimum preheat temperature (°C) *See* Note 1	
		Non-low H_2	Low H_2 *see* Note 2
Carbon and carbon/manganese grades: 320 and 360	$t \leq 15$ $t \geq 15$	50 100	10 50
Carbon and carbon/manganese grades: 410, 460 and 490	$t \leq 15$ $t \geq 15$	75 150	20 100
1Cr ½Mo	$t < 13$ $t \geq 13$	*See* Note 3	100 150
2¼Cr 1Mo	$t < 13$ $t \geq 13$	*See* Note 3	150 200
½Cr ½Mo ¼V	$t < 13$ $t \geq 13$	*See* Note 3	150 200

NOTES
1. Where the ambient temperature is 0°C or below, pre-warming of the weld joint is required in all cases.
2. Low hydrogen process or consumables are those that have been tested and have achieved a grading of H15 or better (*see* Chapter 11).
3. Low hydrogen welding process is required for these materials.
4. t = the thickness of the thinner member for butt welds, and the thicker member for fillet and branch welds.

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Table 13.5.3 Heat treatment after bending of pipes

Type of steel	Heat treatment required
Carbon and carbon/manganese: Grades 320, 360, 410, 460 and 490	Normalise at 880 to 940°C
1Cr ½Mo	Normalise at 900 to 940°C, followed by tempering at 640 to 720°C
2¼Cr 1Mo	Normalise at 900 to 960°C, followed by tempering at 650 to 780°C
½Cr ½Mo ¼V	Normalise at 930 to 980°C, followed by tempering at 670 to 720°C
Other alloy steels	Subject to special consideration

5.3.6 Bending procedures and subsequent heat treatment for other alloy steels will be subject to special consideration.

5.4 Post-weld heat treatment

5.4.1 Post-weld heat treatment is to be carried out in accordance with the general requirements specified in 1.16 and 4.10.

5.4.2 The thickness limits, the recommended soaking temperatures and periods, for application of post-weld heat treatment are given in Table 13.5.4.

5.4.3 Where the use of oxy-acetylene welding is proposed, due consideration is to be given to the need for normalising and tempering after such welding.

5.5 Non-destructive examination

5.5.1 Non-destructive examination of pipe welds is to be carried out in accordance with the general requirements of 1.11 and the following.

5.5.2 Butt welds in Class 1 pipes with an outside diameter greater or equal to 75 mm are to be subject to 100 per cent volumetric and visual inspections. Consideration is to be given to the extent and method of testing applied to butt welds in Class 1 pipes with an outside diameter less than 75 mm.

5.5.3 Butt welds in Class II pipes are to be subjected to at least 10 per cent random volumetric inspections when the outside diameter is greater than 100 mm.

5.5.4 NDE for Class II pipes with a diameter less than 100 mm is to be at the discretion of the Surveyor.

5.5.5 Non-destructive examination procedures, methods and the evaluation of reports are to be in accordance with 4.15 and 4.16.

5.5.6 Fillet welds on flange pipe connections of Class I pipes are to be examined by surface crack detection methods.

5.6 Repairs to pipe welds

5.6.1 Where non-destructive examinations reveal unacceptable defects in a weld, the defects are to be removed and repaired in accordance with 1.15. Completed repairs are to be shown by further non-destructive examination to have eliminated the defects.

5.6.2 For pipes with diameter less than 88 mm and where unacceptable defects have been found during non-destructive examination, consideration is to be given to cutting the weld out completely, re-making the weld preparation and re-welding as a new joint (because of the difficulty of making small repairs).

Table 13.5.4 Post-weld heat treatment requirements for pipework

Material Grade	Thickness for which post-weld heat treatment is required	Soak temperature (°C) *see* Note 2	Soak period
Carbon and carbon/manganese grades: 320, 360, 410, 460, 490	Over 30 mm	580–620°C	1 hour per 25 mm of thickness, minimum of 1 hour
1Cr ½Mo	Over 8 mm	620–660°C	1 hour per 25 mm of thickness, minimum of 1 hour
2¼Cr 1Mo	All	650–690°C	1 hour per 25 mm of thickness, minimum of 1 hour
½Cr ½Mo ¼V	All, *see* Note 1	670–720°C	1 hour per 25 mm of thickness, minimum of 1 hour

NOTES
1. Heat treatment may be omitted for thicknesses up to 8 mm and diameters not exceeding 100 mm provided welding procedure tests have demonstrated acceptable properties in the as welded condition.
2. For materials supplied in the tempered condition, the post weld heat treatment temperature is to be at least 20°C less than the material tempering temperature.

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5.6.3 Where repeated weld repairs have to be made to a weld, only two such attempts are to be permitted, thereafter the weld is to be cut apart and removed, and re-welded as a new joint.

5.6.4 Where pipework requires post-weld heat treatment weld, repairs to the pressure retaining parts are to be subjected to a subsequent heat treatment. Similarly, where welding is conducted after pressure testing, a further pressure test is to be required unless specific exemption has been agreed.

■ *Section 6* Repair of existing ships by welding

6.1 Scope

6.1.1 This Section specifies requirements for repairs made by welding after introduction into service. This Section includes defects to hull structures, machinery, equipment and components. It also includes replacement of structure due to damage or corrosion. These requirements are in addition to those specified in the preceding Sections of this Chapter.

6.1.2 These requirements apply unless the original builder or manufacturer has specified alternative requirements.

6.2 Materials used for repairs

6.2.1 Permanent materials used in the repair are to be in accordance with 1.3.

6.2.2 Prior to commencing any welding, the material grades present in the original structure in way of the repair are to be determined. Where the materials cannot be identified from the ship records, test samples may be removed for chemical analysis and mechanical testing in order to determine the material grades.

6.2.3 Temporary materials that are to be welded to the main structure to assist in executing the repairs, but removed on completion, are to be of weldable quality.

6.3 Workmanship

6.3.1 A repair method is to be established by the shipyard or repair yard and is to be agreed by the Surveyor prior to commencing any repair work.

6.3.2 The removal of crack-like defects is to be confirmed by visual examination and surface crack detection NDE. This may be augmented by ultrasonic examination where several defects are reported at different depths at the same location.

6.3.3 The weld joint or groove shape used for the repair is to have a profile suitable for welding.

6.3.4 The weld area is to be carefully cleaned, in particular, where the material surface has been painted or has been subjected to an oily or greasy environment.

6.4 Non-destructive examination

6.4.1 On completion of welding and any post-weld heat treatment, repair welds are to be subjected to the type and extent of NDE and assessed in accordance with the acceptance criteria specified for the original construction.

6.4.2 Where the original construction specification did not specify NDE, the completed welds are to be, as a minimum, subject to visual examination. Consideration of other NDE techniques is to take due cognisance of the location or the repair within the vessel.

6.4.3 Where spot NDE is applied and defects are found, the extent of NDE is to be increased to include an equal amount of weld length. Where this reveals unacceptable defects, either the whole weld will be rejected or the extent of inspection increased to 100 per cent examination.

6.4.4 The acceptance criteria to be applied are to generally be in accordance with the original build specification. Where conflict of requirements exist, the NDE acceptance limits for welding procedure tests specified in Ch 12,2.5.5 may be used as a minimum requirement.

6.5 Repairs to welds defects

6.5.1 Where NDE reveals unacceptable defects, these are to be repaired in accordance with 1.15.

■ *Section 7* Austenitic and duplex stainless steel – Specific requirements

7.1 Scope

7.1.1 This Section specifies requirements for the fabrication and welding of austenitic and duplex stainless steels, and is in addition to those detailed above.

7.1.2 Fabrication and welding of these materials is to be in designated areas which are separated from those used for other materials, such as carbon steels and copper alloys. Where work is performed in the same workshop as other materials, adequate barriers or screening are to be provided to prevent cross-contamination of different material types.

7.1.3 All tools and equipment used are to be suitable for use on stainless steel materials. The use of tools or equipment made of carbon steel materials is to be avoided. It is permissible to use carbon steel tools provided that the surfaces that come into contact with the austenitic and duplex stainless materials are protected with an austenitic or nickel base alloy.

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7.2 Design

7.2.1 Care is to be exercised in the weld design to prevent crevice corrosion from occurring, particularly where austenitic materials are used. In this respect fillet welds and partial penetration welds are to be continuous and welded on both sides of the joint.

7.3 Forming and bending

7.3.1 Materials that are cold formed, such that the total strain exceeds 15 per cent (i.e. where the formed diameter to thickness ratio is less than 6:1) are to be subjected to a subsequent softening heat treatment in accordance with the material manufacturers recommendations, unless it is demonstrated by testing that the material properties are acceptable in the 'as formed' condition.

7.3.2 Materials may be hot formed provided that a subsequent softening heat treatment is carried out. The forming process and the subsequent heat treatment are to be in accordance with the material manufacturer's recommendations.

7.4 Fabrication and welding

7.4.1 Welding may be performed using shielded manual arc welding (SMAW), gas tungsten arc welding (GTAW), MIG/MAG welding (GMAW), flux cored arc welding (FCAW), plasma arc welding (PAW) and submerged arc welding (SAW). The use of other welding processes will be subject to special consideration and will require submission of the process details, consumables and the weld properties achieved.

7.4.2 Misalignment may be corrected by the application of steady even force (e.g. using hydraulic or screw-type clamps). Hammering or heating is not permitted.

7.4.3 For full penetration welds, a backing or shielding gas is to be provided to prevent oxidation of the root weld. The backing gas is to be maintained until completion of, at least, the root and first fill layer. The backing gas may be omitted where the weld is back gouged or ground to remove the root weld.

7.4.4 Shielding and backing gases are to be an inert type of high purity and oxygen free.

7.4.5 For welding of Duplex stainless, the use of backing gases that contain up to 2 per cent nitrogen is permitted.

7.4.6 Welding of duplex stainless steels without filler metal is generally not permitted.

7.4.7 Degreasing agents, acid solutions, washing water etc. used for cleaning and any marking crayons and paints used are to be free of chlorides.

7.5 Repairs

7.5.1 Correction of distortion by the application of heat is not permitted.

■ *Section 8* Specific requirements for welded aluminium

8.1 Scope

8.1.1 This Section specifies requirements for the fabrication and welding of aluminium alloys, and is in addition to those detailed in this Chapter.

8.1.2 Fabrication and welding of these materials is to be in designated areas which are separated from those used for other materials, such as carbon steels, stainless steels and copper alloys. Where work is performed in the same workshop as other materials, adequate barriers or screening are to be provided to prevent cross-contamination of different material types.

8.1.3 All tools and equipment used are to be suitable for use on aluminium alloy materials. The use of tools made of carbon steel materials is to be avoided where possible.

8.2 Forming and bending

8.2.1 Aluminium alloys are to be subject to cold forming and cold bending only.

8.3 Fabrication and welding

8.3.1 Welding may be performed using gas tungsten arc welding (GTAW) or metal inert gas welding (GMAW), MIG/MAG welding (GMAW), or variants thereof. The use of other welding processes such as friction stir welding (FSW) will be subject to special consideration and will require submission of the process details, consumables and the weld properties achieved.

8.3.2 Misalignment may be corrected by the application of steady even force (e.g. using hydraulic or screw-type clamps). Hammering or heating is not permitted.

8.3.3 Correction of distortion by the application of heat is not permitted.

8.4 Non-destructive examination

8.4.1 The requirements of Ch 13,1.11 and Ch 13,2.12 apply; however, acceptance criteria applicable to aluminium are to be in accordance with Table 13.8.1 and Table 13.8.2.

8.4.2 Alternative NDE acceptance criteria will be subject to special consideration provided that they are equivalent to these requirements.

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Table 13.8.1 Acceptance criteria for surface imperfections of aluminium

Surface discontinuity	Classification according to ISO 6520-1	Acceptance criteria
Crack	100	Not permitted
Lack of fusion	401	Not permitted
Incomplete root penetration in butt joints welded from one side	4021	Not permitted
Surface pore	2017	$d \leq 0{,}3s$ or $0{,}3a$ or 1,5 mm (whichever is the lesser)
Linear porosity (*see* Note 1)	2014	Not permitted
Uniformly distributed porosity (*see* Note 2)	2012	≤ 1% of area
Clustered porosity	2013	Not permitted
Continuous undercut	5011	$h \leq 0{,}1t$ or 0,5 mm (whichever is the lesser)
Intermittent undercut	5012	$h \leq 0{,}1t$ or 1,0 mm (whichever is the lesser)
Excess weld metal (*see* Note 3)	502	$h \leq 1{,}5$ mm + $0{,}15b$ or 8 mm (whichever is the lesser)
Excess penetration	504	$h \leq 4$ mm
Root concavity (*see* Note 3)	515	$h \leq 0{,}1t$ or 1 mm (whichever is the lesser)
Linear misalignment (*see* Notes 4 and 5)	507	$h \leq 0{,}1t$ or 1,0 mm (whichever is the lesser)
Angular misalignment	508	(*see* Note 6)

Symbols

a = nominal throat thickness of a fillet weld
b = width of weld reinforcement
d = diameter of a gas pore
h = height or width of an imperfection
s = nominal butt weld thickness
t = wall or plate thickness (nominal size)

NOTES
1. For these acceptance criteria, linear porosity is to be considered as three aligned gas pores in a length of 25 mm.
2. To be in accordance with EN ISO 10042.
3. A smooth transition is required.
4. Linear misalignment is to be a maximum of 0,5 mm in highly stressed areas. For other areas, the linear misalignment is to be a maximum of 1,0 mm locally, where the sum of the length of imperfection is not more than 10% of the weld length.
5. The limits for linear misalignment relate to deviations from the correct position. Unless otherwise specified, the correct position is that when the centrelines coincide.
6. Angular misalignment shall be mutually agreed between the designer and the fabricator.

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Table 13.8.2 Acceptance criteria for internal imperfections of aluminium

Internal discontinuity	Classification according to ISO 6520-1	Acceptance criteria (*see* Note 1)
Crack	100	Not permitted
Lack of fusion	401	Not permitted
Incomplete penetration	402	Not permitted
Single gas pore	2017	$d \leq 0{,}3s$ or $0{,}3a$ or 5 mm (whichever is the lesser)
Linear porosity	2014	Assess as lack of fusion
Uniformly distributed porosity (*see* Note 1)	2012	$0{,}5 < t < 3$ mm ≤ 2% of area $3 < t < 12$ mm ≤ 4% of area $12 < t < 30$ mm ≤ 6% of area $t > 30$ mm ≤ 8% of area
Clustered porosity (*see* Note 1)	2013	$dA \leq 20$ mm or wp (whichever is the lesser)
Elongated cavity Wormhole	2015 2016	$l \leq 0{,}3s$ or $0{,}3a$ or 4 mm (whichever is the lesser)
Oxide inclusion (*see* Note 2)	303	$l \leq 0{,}5s$ or $0{,}5a$ or 5 mm (whichever is the lesser)
Tungsten inclusion	3041	$l \leq 0{,}3s$ or $0{,}3a$ or 4 mm (whichever is the lesser)
Copper inclusion	3042	Not permitted
Multiple imperfections in any cross-section	—	The sum of the acceptable individual imperfections in any cross-section is not to exceed $0{,}3t$ or $0{,}3a$ (whichever is the lesser)

Symbols

a = nominal throat thickness of a fillet weld
b = width of weld reinforcement
d = diameter of a gas pore
h = height or width of an imperfection
s = nominal butt weld thickness
t = wall or plate thickness (nominal size)
wp = width of weld or width or height of cross-sectional area
dA = diameter of area surrounding gas pores
l = length of imperfection in longitudinal direction of weld

NOTES
1. Porosity is to be determined in accordance with ISO 10042. The requirements for a single gas pore are to be met by all the gas pores within this circle. Systematic clustered porosity is not permitted.
2. If several oxide inclusions l_1, l_2, l_3, ... exist in one cross-section, then they are summed: $l = l_1 + l_2 + l_3 + ... + l_n$.

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Plastics Materials and other Non-Metallic Materials

Chapter 14

Section

1 **General requirements**

2 **Tests on polymers, resins, reinforcements and associated materials**

3 **Testing procedures**

4 **Plastics pipes and fittings**

5 **Control of material quality for composite construction**

Section 1 General requirements

1.1 Scope

1.1.1 Provision is made in this Chapter for the manufacture and testing of plastics pipes, together with approval requirements for base materials used in the construction or repair of composite vessels, other marine structures, piping and any associated machinery components and fittings which are to be certified or are intended for classification.

1.1.2 These materials and products are to be manufactured and surveyed in accordance with the general requirements of Sections 1, 2 and 3 of this Chapter; and LR's *Materials and Qualification Procedures for Ships (MQPS) Book K*, see Ch 1,2.2.2, which, in addition to the test programme, also details the procedures for application for approval of manufacturers and products and details of the information to be supplied by the manufacturer.

1.1.3 For base materials, the manufacturer's works do not require approval by Lloyd's Register (hereinafter referred to as 'LR'), however the Quality Control procedures must be acceptable in accordance with the appropriate Section of this Chapter.

1.1.4 Where a requirement exists for the material to be approved, the test requirements and information to be submitted for approval of polymers, resins, reinforcements and associated materials are defined in Sections 2 and 3.

1.1.5 Specific material requirements relating to the design and manufacture of plastics pipes and fittings are indicated in Section 4, with the material requirements for hull structures contained in Section 5.

1.1.6 For Builders constructing composite vessels, Section 5 provides the minimum material control requirements for acceptance of the works by LR.

1.1.7 For the purposes of these Rules a 'plastics material' is regarded as an organic substance which may be thermosetting or thermoplastic and which, in its finished state, may contain reinforcements or additives.

1.1.8 Materials not listed in 2.1.1 may be considered for approval on a case-by-case basis. The approved test results will be listed on the issued certificate. Subject to satisfactory service experience and validation of approval, the material may be entered in 2.1.1 of the Rules.

1.2 Information on material quality and application

1.2.1 Where plastics products are to be classed or certified, the manufacturer is to provide the material producer with such information as is essential to ensure that the base materials to be used are in accordance with the approval requirements and the product specification. This information is to include any survey requirements for the materials.

1.3 Manufacture

1.3.1 Plastics products are to be made at works which have been approved (or accepted) for the type of product being supplied using base materials that have been approved.

1.3.2 Base materials are to be approved in accordance with the requirements of Sections 2 and 3.

1.3.3 In order that a works can be approved (or accepted), the manufacturer is required to demonstrate to the satisfaction of LR that the necessary manufacturing and testing facilities are available and are supervised by qualified personnel. A specified programme of tests is to be carried out under the supervision of the Surveyors, and the results are to be to the satisfaction of LR. When a manufacturer has more than one works, the approval (or acceptance) is only valid for the individual works which carried out the test programme.

1.3.4 In order to maintain approval, the manufacturer is required to confirm in writing that there have been no changes in the formulation or production process for the material in question and that the site of manufacture remains unchanged.

1.4 Survey procedure

1.4.1 The Surveyors are to be allowed access to all relevant parts of the works and are to be provided with the necessary facilities and information to enable them to verify that manufacture is being carried out in accordance with the approved procedure. Facilities are also to be provided for the selection of test material, the witnessing of specified tests and the examination of materials, as required by the Rules.

1.4.2 Prior to the provision of test material for acceptance, manufacturers are to provide the Surveyors with details of the order, specification and any special conditions additional to the Rule requirements.

1.4.3 Before final acceptance, all test materials are to be confirmed as typical of the manufactured product and be submitted to the specified tests and examinations under conditions acceptable to the Surveyors. The results are to comply with the specification and any Rule requirements and are to be to the satisfaction of the Surveyors.

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1.4.4 These specified tests and examinations are to be carried out prior to the despatch of finished products from the manufacturer's works.

1.4.5 In the event of any material proving unsatisfactory, during subsequent working, machining or fabrication, it is to be rejected, notwithstanding any previous certification.

1.5 Alternative survey procedure

1.5.1 Where materials are manufactured in quantity by semi-continuous or continuous processes under closely controlled conditions, an alternative system for testing and inspection may be adopted, subject to the agreement of the Surveyors.

1.5.2 In order to be considered for approval, manufacturers are to comply with the requirements of Ch 1,2.

1.6 Post-cure heating

1.6.1 Post-cure heating is to be carried out in properly constructed ovens which are efficiently maintained and have adequate means for control and recording of temperature. The oven is to be such as to allow the whole item to be uniformly heated to the necessary temperature. In the case of very large components which require post-cure heating, alternative methods will be specially considered.

1.7 Test material

1.7.1 Sufficient material is to be provided for the preparation of the test specimens detailed in the specific requirements. It is, however, in the interests of manufacturers to provide additional material for any re-tests which may be necessary, as insufficient or unacceptable test material may be a cause for rejection.

1.7.2 Where test materials, (either base materials or product sample materials) are selected by the Surveyor or a person nominated by LR, these are to be suitably identified by markings which are to be maintained during the preparation of the test specimens.

1.7.3 All base material samples for testing are to be prepared under conditions that are as close as possible to those under which the product is to be manufactured. Where this is not possible, a suitable procedure is to be agreed with the Surveyor.

1.7.4 During production, check test samples are to be provided as requested by the Surveyor.

1.7.5 Should the taking of these samples prove impossible, model samples are to be prepared concurrently with production. The procedure for the preparation of these samples is to be agreed with the Surveyor.

1.7.6 The dimensions, number and orientation of test specimens are to be in accordance with the requirements of a National or International Standard acceptable to LR.

1.8 Re-test procedure

1.8.1 Where test material fails to meet the specified requirement, two additional tests of the same type may be made at the discretion of the Surveyor.

1.8.2 Where an individual test result in a group (minimum five) deviates from the mean by more than two standard deviations in either the higher or lower direction, the result is to be excluded and a re-test made. Excluded results of tests are to be reported with confirmation that they have been excluded. Only one exclusion is acceptable in any group of tests.

1.9 Visual and non-destructive examination

1.9.1 Prior to the final acceptance, surface inspection, verification of dimensions and non-destructive examination are to be carried out in accordance with the requirements detailed in Sections 3, 4 and 5 of this Chapter.

1.9.2 When there is visible evidence to doubt the soundness of any material or component, such as flaws or suspicious surface marks, it is to be the responsibility of the manufacturer to prove the quality of the material by any suitable method.

1.10 Rectification of defective material

1.10.1 Small surface blemishes may be removed by mechanical means provided that, after such treatment, the dimensions are acceptable, the area is proved free from structural defects and the rectification has been completed to the satisfaction of the Surveyor.

1.10.2 Repair procedures for larger defects are to be agreed with LR prior to implementation.

1.11 Identification of products and base materials

1.11.1 The manufacturer of approved materials is to identify each batch with a unique number.

1.11.2 The manufacturer of plastics products is to adopt a system of identification which will enable all finished products to be traced to the original batches of base materials. Surveyors are to be given full facilities for tracing any component or material when required.

1.11.3 When any item has been identified by the personal mark of a Surveyor, or deputy, this is not to be removed until an acceptable new identification mark has been made by a Surveyor. Failure to comply with this condition will render the item liable to rejection.

1.11.4 Before any pipe or fitting is finally accepted it is to be clearly marked by the manufacturer in at least one place with the particulars detailed in the appropriate specific requirements as given in Section 4.

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1.11.5 Where a number of identical items are securely fastened together in bundles, the manufacturer need only brand the top item of each bundle. Alternatively, a durable label giving the required particulars may be attached to each bundle.

1.12 Certification

1.12.1 Certification of the finished product is to be in accordance with the requirements of the appropriate Sections.

■ *Section 2*
Tests on polymers, resins, reinforcements and associated materials

2.1 Scope

2.1.1 This Section gives the tests and data required by LR for materials approval and/or inspection purposes on the following:

(a) Thermoplastic polymers.
(b) Thermosetting resins.
(c) Reinforcements.
(d) Reinforced thermoplastic polymers.
(e) Reinforced thermosetting resins.
(f) Core materials.
  (i) End-grain balsa.
  (ii) Rigid foams.
  (iii) Synthetic felt type materials.
(g) Machinery chocking compounds.
(h) Rudder and pintle bearings.
(j) Stern tube bearings.
(k) Plywoods.
(l) Adhesive and sealant materials.
(m) Repair compounds.

2.2 Thermoplastic polymers

2.2.1 The following data is to be provided by the manufacturer for each thermoplastic polymer:

(a) Melting point.
(b) Melt flow index.
(c) Density.
(d) Bulk density.
(e) Filler content, where applicable.
(f) Pigment content, where applicable.
(g) Colour.

2.2.2 Samples for testing are to be prepared by moulding or extrusion under the polymer manufacturer's recommended conditions.

2.2.3 The following tests are to be carried out on these samples:

(a) Tensile stress at yield and break.
(b) Modulus of elasticity in tension.
(c) Tensile strain at yield and break.
(d) Compressive stress at yield and break.
(e) Compressive modulus.
(f) Temperature of deflection under load.
(g) Determination of water absorption.

2.3 Thermosetting resins

2.3.1 The data listed in Table 14.2.1 is to be provided by the manufacturer for each thermosetting resin.

Table 14.2.1 Data requirements for thermosetting resins

Data	Type of resin		
	Polyester (*see* Note 3 for vinylester)	Epoxide	Phenolic
Specific gravity of liquid resin	required	required	required
Viscosity	required	required	required
Gel time	required	required	not applicable
Appearance	required	required	required
Mineral content (*see* Note 1)	required	required	not applicable (*see* Note 2)
Volatile content	required	not applicable	not applicable
Acid value	required	not applicable	not applicable
Epoxide content	not applicable	required	not applicable
Free phenol	not applicable	not applicable	required
Free formaldehyde	not applicable	not applicable	required

NOTES
1. This is to be the total filler in the system, including thixotrope, filler, pigments, etc., and is to be expressed in parts by weight per hundred parts of pure resin.
2. If the resin is pre-filled, the mineral content is required.
3. Vinylesters are to be treated as equivalent to polyesters.

2.3.2 Cast samples are to be prepared in accordance with the manufacturer's recommendations and are to be cured and post-cured in a manner consistent with the intended use. The curing system used and the ratio of curing agent (or catalyst) to resin are to be recorded. Where post-cure conditions equivalent to ambient-cure conditions apply, *see* 3.2.2 and 3.2.3.

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2.3.3 The following are to be determined using these samples:
(a) Tensile strength (stress at maximum load) and stress at break.
(b) Tensile strain at maximum load.
(c) Tensile secant modulus at 0,5 per cent and 0,25 per cent strain respectively.
(d) Temperature of deflection under load.
(e) Barcol hardness.
(f) Determination of water absorption.
(g) Volume shrinkage after cure.
(h) Specific gravity of cast resin.

2.3.4 In addition, for gel coat resins the stress at break and modulus of elasticity in flexure are to be determined.

2.3.5 Where resins which have been modified by the addition of waxes or polymers, for example 'low styrene emission or air inhibited' materials, it is to be confirmed that the use of such resins will not result in poor interlaminar adhesion when interruptions to the laminating process occur. The test procedure is to be as follows:
(a) A conventional room temperature curing catalyst/accelerator system is to be used with the resin for laminate preparation.
(b) A laminate of 25 to 35 per cent glass content in mass is to be prepared using two plies of 450 g/m^2 chopped strand mat. The laminate is to be prepared at ambient temperature (18° to 21°C). The laminate is to be allowed to stand for a minimum of four days but no longer than 6 days at ambient temperature.
(c) A further two plies of 450 g/m^2 chopped strand mat are to be laminated onto the exposed surface and cured at ambient temperature for 24 hours. The finished laminate is then to be post-cured at 40°C for 16 hours. The finished laminate is to have a glass content of 25 to 35 per cent.
(d) After cooling, the apparent interlaminar shear strength of the laminate is to be determined in accordance with ISO 14130; the minimum value is given in Table 14.5.5. Before testing the samples shall be conditioned at 23°C and relative humidity of 50 per cent for a period of 88 hours before testing.
(e) If the tests are undertaken at the resin manufacturer's own laboratory, the individual test values are to be reported and the broken test specimens retained for examination by LR.

Alternative test procedures will be considered with prior agreement.

2.4 Reinforcements

2.4.1 The following data is to be provided, where applicable, for each type of reinforcement:
(a) Reinforcement type.
(b) Fibre type for each direction.
(c) Fibre tex value.
(d) Fibre finish and/or treatment.
(e) Yarn count in each direction.
(f) Width of manufactured reinforcement.
(g) Weight per unit area of manufactured reinforcement.
(h) Weight per linear metre of manufactured reinforcement.
(j) Compatibility (e.g. suitable for polyesters, epoxides, etc.).
(k) Constructional stitching – details of yarn, specific gravity, type, frequency and direction.
(l) Weave type.
(m) Binder type and content.
(n) Density of the fibre material.

2.4.2 Tests of the mechanical properties are to be made on laminate samples containing the reinforcement and prepared as follows:
(a) an approved resin of suitable type is to be used;
(b) a minimum of three layers of the reinforcement is to be laid with parallel ply to give a laminate not less than 4 mm thick;
(c) the weights of resin and reinforcement used are to be recorded together with the measured thickness of the laminate, including the measured weight per unit area of the reinforcement used;
(d) for glass reinforcements, the glass/resin ratios, by weight, as shown in Table 14.2.2 are to be used;
(e) for reinforcement type other than glass, a fibre volume fraction, as shown in Table 14.2.3, is to be used.

2.4.3 Rovings intended for filament winding are to be tested as unidirectional rovings.

2.4.4 The following tests as defined in Section 3 are to be made on the samples:
(a) Tensile strength (stress at maximum load).
(b) Tensile strain at break.
(c) Tensile secant modulus at 0,5 per cent and 0,25 per cent strain respectively.
(d) Compressive strength (stress at maximum load).
(e) Compressive modulus.
(f) Flexural strength (stress at maximum load).
(g) Modulus of elasticity in flexure.
(h) Apparent interlaminar shear.
(j) Fibre content.
(k) Determination of water absorption.

Table 14.2.2 Glass fraction by weight for different reinforcement types

Reinforcement type	Glass fraction nominal values
Unidirectional	0,60
Chopped strand mat	0,30
Woven roving	0,50
Woven cloth	0,50
Composite roving (*see* Note)	0,45
Gun rovings	0,33
±45° stitched parallel plied roving	0,50
Triaxial parallel plied roving	0,50
Quadriaxial parallel plied roving	0,50
NOTE Continuous fibre reinforcement with attached chopped strand mat.	

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Table 14.2.3 Content by volume for different reinforcement types

Reinforcement type	Content by volume nominal values
Unidirectional	0,41
Chopped strand mat	0,17
Woven roving	0,32
Woven cloth	0,32
Composite roving (*see* Note)	0,28
Gun rovings	0,19
±45° stitched parallel plied roving	0,32
Triaxial parallel plied roving	0,32
Quadriaxial parallel plied roving	0,32

NOTE
The volume content may be converted to weight fractions by use of the formula:

$W_F = V_F D_F/(D_F V_F + D_R V_R)$

where

W_F = fibre fraction by weight
D_F = density of fibre
D_R = density of cured resin
V_F = fibre fraction by volume
V_R = resin fraction by volume

2.4.5 The laminate is to be tested in air in the directions indicated by Table 14.2.4.

2.4.6 Additionally, tests in 2.4.4(c) and (f) are to be repeated, in one direction only, after immersion in fresh water at 35°C for 28 days with the exception of 2.4.4(k).

Table 14.2.4 Fibre orientations in reinforced test specimens

Type of reinforcement	Test orientations
Unidirectional	0°
Chopped strand mat Gun roving	any direction
Woven roving Woven cloth Composite roving	0° and 90°
± 45° parallel plied roving Triaxial plied roving Quadriaxial plied roving	0°, 45°, 90° and –45°

2.5 Reinforced thermoplastic polymers

2.5.1 Thermoplastic polymers intended for use with reinforcements are to be tested in accordance with 2.2.1 to 2.2.3.

2.5.2 A laminate is to be prepared using the polymer and an approved reinforcement in accordance with a manufacturing specification. The laminate is to be tested in accordance with the appropriate requirements of 2.4.4. Testing may be confined to one direction only.

2.6 Reinforced thermosetting resins

2.6.1 Thermosetting resins intended for use with reinforcements are to be tested in accordance with 2.3.1 to 2.3.4.

2.6.2 No further tests are required for gel coat resins.

2.6.3 For laminating resins, a laminate is to be prepared using the resin and an approved reinforcement as follows:
(a) For polyester resins, chopped strand mat.
(b) For epoxide resins, a balanced woven roving.
(c) For phenolic resins, a balanced woven material.

2.6.4 The laminate is to be tested in accordance with 2.4.4 in one fibre direction only.

2.7 Core materials

2.7.1 **General requirements.** The following data is to be provided for each type of core material:
(a) Type of material.
(b) Density.
(c) Description (block, scrim mounted, grooved).
(d) Thickness and tolerance.
(e) Sheet/block dimensions.
(f) Surface treatment.

2.7.2 Manufacturers are required to provide a full application procedure for use of the product.

2.8 Specific requirements for end-grain balsa

2.8.1 The supplier is to provide a signed statement that the balsa (ochroma lozopus) is cut to end-grain, is of good quality, being free from unsound or loose knots, holes, splits, rot, pith and corcho, and that it has been treated against fungal and insect attack, shortly after felling, followed by homogenisation, sterilisation and kiln drying to an average moisture content of no more than 12 per cent.

2.8.2 The following tests are to be carried out on the virgin material, both parallel to and perpendicular to the grain:
(a) Compressive strength (stress at maximum load).
(b) Compressive modulus of elasticity.
(c) Tensile strength (stress at maximum load).
The density of the virgin material is also to be tested.

2.8.3 Where the balsa is mounted on a carrier material (e.g. scrim), any adhesive used is to be of a type compatible with the proposed resin system.

2.8.4 Core shear properties are to be determined according to the requirements of 3.8.1.

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2.9 Specific requirements for rigid foams (PVC, Polyurethane and other types)

2.9.1 The foam is to be of the closed cell type and compatible with the proposed resin system (e.g. polyester, epoxide, etc.).

2.9.2 Foams are to be of uniform cell structure.

2.9.3 Data is to be provided on the dimensional stability of the foam by measurement of the shrinkage.

2.9.4 The following test data is to be submitted for each type of foam:
(a) Density.
(b) Tensile strength (stress at maximum load).
(c) Tensile modulus of elasticity.
(d) Compressive strength (stress at maximum load).
(e) Compressive modulus of elasticity.

2.9.5 Core shear properties are to be determined according to the requirements of 3.8.1.

2.9.6 Additionally, the compressive properties (*see* 2.9.4(d) and (e)) are to be determined at a minimum of five points over the temperature range ambient to maximum recommended service or 70°C, whichever is the greater.

2.10 Synthetic felt type materials with or without microspheres

2.10.1 For materials of this type, the following data is required in addition to the requirements of 2.7.1:
(a) Fibre type.
(b) Width.
(c) Width of finished material.
(d) Weight per unit area of the manufactured material.
(e) Weight per linear metre of the manufactured material.
(f) Compatibility.
(g) Details of the method of combining.

2.10.2 A laminate of the material is to be prepared using a suitable approved resin under conditions recommended by the manufacturer.

2.10.3 The following properties are to be determined:
(a) Tensile strength (stress at maximum load).
(b) Tensile strain at break.
(c) Modulus of elasticity in tension or secant modulus at 0,25 per cent and 0,5 per cent strain.
(d) Compressive strength (stress at maximum load).
(e) Compressive modulus.
(f) Flexural strength (stress at maximum load).
(g) Modulus of elasticity in flexure.
(h) Fibre content.
(j) Water absorption.

2.10.4 In the case of anisotropic materials (e.g. where combined with other reinforcements) the tests listed in 2.10.3 are to be conducted in the 0°, 90° directions and in any other reinforcement direction.

2.10.5 Additionally, the tests listed in 2.10.3 are to be repeated after immersion in fresh water at 35°C for 28 days. For anisotropic materials, the requirement is for this test to be carried out in one direction only.

2.10.6 The shear properties (of the resin filled system) are to be determined according to 3.8.1.

2.11 Machinery chocking compounds (resin chocks)

2.11.1 Thermosetting materials for filling the space between the base of machinery and its foundation where the maintenance of accurate alignment is necessary are to be approved by LR before use.

2.11.2 Approval will be considered by LR for use under the following service conditions:
- Loading of 2,5 N/mm^2 (max) for a temperature not exceeding 60°C.
- Loading of 3,5 N/mm^2 (max) for a temperature not exceeding 80°C.
- Other loading conditions.

2.11.3 The exotherm temperature, defined as the maximum temperature achieved by the reacting resin under conditions equivalent to those of intended use, is to be determined according to a procedure approved by LR.

2.11.4 The following properties are to be determined on chock material cured at the measured exotherm temperature:
(a) The impact resistance (Izod).
(b) Hardness.
(c) Compressive strength (stress at maximum load) and modulus of elasticity.
(d) Water absorption.
(e) Oil absorption.
(f) Heat deflection temperature.
(g) Compressive creep is to be measured according to 3.9.4.
(h) Curing linear shrinkage.
(j) Flammability.

2.11.5 The chocking compound approval is contingent on the material achieving the minimum exotherm value as specified when used on an installation under practical conditions.

2.11.6 Where the resin chock is to be used for installation of sterntubes and sternbushes in addition to the requirements of 2.11.4, the tensile strength and modulus of elasticity in tension are to be measured.

2.11.7 The manufacturer's installation procedure is required to be documented and is to be to the satisfaction of LR.

2.12 Rudder and pintle bearings

2.12.1 Materials used for rudder and pintle bearings are to be approved by LR before use.

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2.12.2 Initial approval is to be based on a review of the following physical properties of the material:
(a) Compressive strength (stress at maximum load) and modulus of elasticity.
(b) Tensile strength (stress at maximum load) and modulus of elasticity.
(c) Shear strength (stress at maximum load).
(d) Impact strength.
(e) Swelling in oil and in water.
(f) Hardness.

2.12.3 Additionally, friction data is to be provided under both wet and dry conditions.

2.12.4 Furthermore, the installation instructions (especially recommended clearances) are to be reviewed by LR prior to provisional approval being given.

2.12.5 If the above data is satisfactory, the material will be provisionally approved until sufficient service experience has been gained.

2.13 Sterntube bearings

2.13.1 Materials used for sterntube bearings are to be approved by LR before use.

2.13.2 Approval is to be based on a review of the physical properties as given by 2.12.2.

2.13.3 Friction data is to be provided under the lubrication system(s) proposed for the material(s).

2.14 Plywoods

2.14.1 All plywoods are to be approved to BS 1088 or equivalent National or International Standard in accordance with LR's Type Approval Procedure.

2.14.2 For structural applications in the marine environment, a minimum timber rating of moderate durability according to BS 1088 is required.

2.14.3 Enhancement of durability by use of preservatives is permitted, subject to each veneer layer being treated with a recognised preservative.

2.14.4 Where Okoume, as specified by BS 1088 is involved, (i.e. non-durable timber classification) this may only be used for marine structures subject to the specific application being acceptable to LR.

2.15 Adhesive and sealant materials

2.15.1 Materials of these types are to be accepted by LR before use.

2.15.2 The requirements for acceptance are dependent on the nature of the application.

2.15.3 In the first instance, the manufacturer is to submit full details of the product, procedure for method of use (including surface preparation) and the intended application. After review of these details, LR will provide a specific test schedule for confirmation of the material's properties.

2.15.4 Any acceptance granted will be limited to specific applications and will be contingent on the instructions for use being adhered to.

2.16 Repair compounds

2.16.1 Materials used for repairs are to be accepted by LR before use.

2.16.2 For acceptance purposes, the manufacturer is to submit full product details, and user instructions, listing the types of repair for which the system is to be used together with details of any installer accreditation schemes.

2.16.3 Dependent on the proposed uses, LR may require testing in accordance with a specified test programme.

2.16.4 Materials will not be accepted for the following uses unless specific evidence of their suitability is provided:
(a) Any component in rubbing contact.
(b) Any component subject to dynamic cyclic loading.
(c) Any pressure part in contact with gas or vapour.
(d) Any pressure part in contact with liquid above 3,5 bar.
(e) Any component where operating temperature exceeds 90°C.

All uses of materials of these types are subject to the discretion of the Surveyor.

■ *Section 3* Testing procedures

3.1 General

3.1.1 This Section gives details of the test methods to be used for base materials and on finished plastics products such as fibre reinforced plastics (FRP) piping and any testing required in the construction of composite vessels.

3.1.2 In general, testing is to be carried out by a competent independent test house which, at the discretion of LR, may or may not require witnessing by the Surveyor.

3.1.3 Alternatively, testing may be carried out by the manufacturer subject to these tests being witnessed by the Surveyor.

3.1.4 All testing is to be carried out by competent personnel.

3.1.5 Unless specified otherwise, testing is to be carried out in accordance with a recognised ISO Standard, where one exists, and all test programmes are to have written procedures.

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3.1.6 Alternatively, testing may be carried out in accordance with a National Standard provided that it conforms closely to an appropriate ISO standard and subject to prior agreement with the Surveyor.

3.1.7 Mechanical properties are to be established using suitable testing machines of approved types. The machines and other test equipment are to be maintained in a satisfactory and accurate condition and are to be recalibrated at approximately annual intervals. Calibration is to be undertaken by a nationally recognised authority or other organisation of standing and is to be to the satisfaction of the Surveyor. A record of all calibrations is to be kept available in the test house. The accuracy of test machines is to be within ±one per cent.

3.2 Preparation of test samples

3.2.1 Thermoplastic samples are to be prepared in accordance with the manufacturer's recommendations for moulding. For finished products, samples are to be taken from the product during production in accordance with the manufacturer's quality plan, but where this is impractical, separate test samples are to be prepared in a manner identical with that of the product.

3.2.2 Samples of thermosetting resins are to be prepared using the curing system recommended by the manufacturer and identical with that used for the finished product.

3.2.3 The post curing conditions for samples of thermosetting resins are to be as recommended by the manufacturer and identical with those used for the finished product. Where the samples are made for the general approval of a resin, the post curing conditions are to be those in which the resin is intended to be used.

3.2.4 Where curing of the product is intended to take place at room temperature, the sample is to be allowed to cure at room temperature (18 to 21°C) for 24 hours followed by a post-cure at 40°C for 16 hours.

3.2.5 Where a reinforcement is to be used, the ratio of reinforcement to resin or polymer is to be nominally the same as that of the finished product or in accordance with Table 14.2.2 or 14.2.3.

3.2.6 Where laminates are prepared specifically for approval test purposes, the reinforcement is to be laid parallel plied.

3.3 Preparation of test specimens

3.3.1 The test specimen is to be prepared in accordance with the appropriate ISO standard and the requirements of this Section.

3.3.2 Precautions are to be taken during machining to ensure that the temperature rise in the specimen is kept to a minimum.

3.4 Testing

3.4.1 Strain measurement is to be made by the use of a suitable extensometer or strain gauge.

3.4.2 The rate of strain is to be in accordance with the appropriate ISO standard.

3.4.3 The number of test specimens from each sample to be tested is to be in accordance with the ISO standard. For mechanical testing this is five.

3.5 Discarding of test specimens

3.5.1 If a test specimen fails because of faulty preparation or incorrect operation of the testing machine, it is to be discarded and replaced by a new specimen.

3.5.2 In addition, if the deviation of one result in a group of five exceeds the mean by more than two standard deviations, that result is to be discarded and one further specimen tested, *see* 1.8.1 and 1.8.2.

3.6 Reporting of results

3.6.1 All load/displacement graphs and tabulated results are to be reported, including mean values and the calculated standard deviation.

3.6.2 Additionally, full details of the sample and specimen preparation are to be provided including (where applicable):
(a) Catalyst/accelerator or curing agent types and mix ratio.
(b) Weights of resins, and/or reinforcements used.
(c) Casting/laminate dimensions.
(d) Number of layers of reinforcement used.
(e) Curing/post-curing conditions.

3.7 Tests for specific materials

3.7.1 The data requirements in 2.2 and 2.3 for thermoplastic or thermosetting resins or polymers are to be determined in accordance with suitable National or International Standards.

3.7.2 Recognised Standards to which specimens of unreinforced thermoplastic resins are to be tested are listed in Table 14.3.1.

3.7.3 Test standards for unreinforced cast thermosetting resins are given in Table 14.3.2.

3.7.4 The Standards to which laminate specimens of any type are to be tested are listed in Table 14.3.3.

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Table 14.3.1 Tests for unreinforced thermoplastic resins

Test	Standard	
Tensile properties	ISO 527-2:1993	Test speed = 5 mm/min Specimen 1A or 1B
Flexural properties	ISO 178:2001	Test speed = $\frac{\text{Thickness}}{2}$ mm/min
Water absorption	ISO 62:2008	Method 1
Temperature of deflection under load	ISO 75-2:2004	Method A
Compressive properties	ISO 604:2002	Test speed – as for ductile materials

NOTES
1. Water absorption – result to be expressed as milligrams.
2. Tensile modulus values are to be determined using an extensometer which may be removed for strain to failure.

Table 14.3.2 Tests on unreinforced cast thermoset resin specimens

Test	Standard	
Tensile properties	ISO 527-2:1993	Test speed = 5 mm/min Specimen 1A or 1B
Flexural properties	ISO 178:2001	Test speed = $\frac{\text{Thickness}}{2}$ mm/min
Water absorption	ISO 62:2008	Method 1
Temperature of deflection under load	ISO 75-2:2004	Method A
Compressive properties	ISO 604:2002	Test speed = 1 mm/min

NOTES
1. ISO 62:2008 – where resins are intended for use under ambient conditions to avoid additional post-curing, the requirement in ISO 62:2008 for pre-drying the test specimen at 50°C is to be omitted. The test result is to be expressed as mg of water.
2. ISO 527-2:1993 – tensile properties are to be measured using extensometry.

Table 14.3.3 Tests on laminate specimens

Test	Standard	
Tensile properties	ISO 527-4:1997	Test speed = 2 mm/min Specimens Types II or III
Flexural properties	ISO 14125:1998	Test speed = $\frac{\text{Thickness}}{2}$ mm/min Method A
Compressive properties	ISO 604:2002	Test speed = 1 mm/min
Interlaminar shear	ISO 14130:1997	
Water absorption	ISO 62:2008	Method 1
Glass content	ISO 1172:1996	

NOTES
1. ISO 62:2008 – where resins are intended for use under ambient conditions to avoid additional post-curing, the requirement in ISO 62:2008 for pre-drying the test specimen at 50°C is to be omitted. The test result is to be expressed as mg of water.
2. ISO 527-4:1997 – tensile properties are to be measured using extensometry.
3. Tensile modulus values are to be determined using an extensometer which may be removed for strain to failure.

3.8 Structural core materials

3.8.1 Initially, the core shear strength and modulus are to be determined by ISO 1922:2001 or ASTM C273/C273M. Test sandwich panels are then to be prepared and subjected to four-point flexural tests to determine the apparent shear properties according to ASTM C393/C393M:06 (short beam) at two representative thicknesses (i.e. 15 mm and 30 mm). Testing is to be carried out at ambient temperature and at 70°C. The following requirements are to be observed:

(a) Each skin is to be identical and have a thickness not greater than 21 per cent of the nominal core thickness. For hand laid constructions, each skin is to comprise a lightweight chopped strand mat reinforcement (300 g/m^2) consolidated at a glass content, by weight, of 0,3 against the core, plus the required number of woven reinforcements consolidated, using an isophthalic polyester resin, to give a minimum glass content, by weight, of 0,5.

(b) The method of construction of the sandwich laminate is to reflect the core material manufacturer's instructions for use, i.e. application of bonding paste, surface primer or any other recommended system.

(c) Where vacuum bagging techniques or equivalent systems are used, these will be subject to individual consideration.

(d) All resins and reinforcements are to hold current LR approval.

(e) Curing conditions are to be in accordance with 3.2.3 and 3.2.4.

(f) The dimensions of the test samples should be based on the requirements of ASTM C393 Paragraph 5.1, and the ratio parameters as indicated in ASTM C393 Paragraph 5.2, using a proportional limit stress (F) for the woven roving skins of 130 N/mm^2 and a span (a_2) of not less than 400 mm.

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3.8.2 For each type of test sample, the following data are to be reported, together with the submission of a representative test sample showing the mode of failure for each density of core material:

(a) Skin and core thickness, and core type and density.
(b) Resin/catalyst/accelerator ratio.
(c) Skin construction, including types and weight of reinforcements, resin(s), etc.
(d) Details of production method and curing conditions (temperature and times).
(e) Where additional preparation of the foam is involved, for example the use of primers or bonding pastes, full details are to be provided.
(f) Actual span between base supports for each type of test sample.

3.8.3 The following requirements apply to end-grain balsa:

(a) The data requirements of 2.7.1 are to be provided, where applicable, according to suitable National or International Standards.
(b) The balsa is to be tested according to the requirements of 3.8.1.
(c) The test methods for balsa are given in Table 14.3.4.

Table 14.3.4 Tests on end-grain balsa

Test	Standard
Density	ISO 845:2006
Tensile properties	ASTM C297/C297M:04 Test speed = $\frac{\text{Thickness}}{10}$ mm/min
Compressive properties	ISO 844:2007 Test speed = $\frac{\text{Thickness}}{10}$ mm/min
Shear properties	ISO 1922:2001 Test speed = 1mm/min

3.8.4 The following requirements apply to rigid foams:

(a) The data requirements of 2.7.1 are to be provided in accordance with a suitable National or International Standard.
(b) The foam is to be tested according to the requirements of 3.8.1.
(c) The test methods for rigid foams are to be in accordance with Table 14.3.4.

3.8.5 The following requirements apply to synthetic felt type materials:

(a) The data requirements of 2.10.1 are to be provided according to suitable National or International Standards.
(b) The material is to be tested according to the requirements of 3.8.1, with the following modifications:
  (i) The core of the laminate test sandwich panel is to be prepared with a fibre content as recommended by the manufacturer.
  (ii) The felt fibre/resin ratio is to be stated.
  (iii) The required test thicknesses of the cores are to be changed from 30 mm and 15 mm to 12 mm and 6 mm respectively.
(c) The prepared laminate of the base material is to be of minimum thickness 3,5 mm with a minimum of three layers.
(d) The specified tests on the laminate (*see* 2.10.3) are to be conducted according to the requirements of Table 14.3.3.

3.9 Machinery chocking compounds

3.9.1 Test samples of the cured chock resin are to be prepared under ambient conditions and then post-cured at the exotherm temperature as determined in 2.11.3.

3.9.2 The specified properties are to be determined as required by Table 14.3.5.

Table 14.3.5 Tests for machinery chocking compounds

Test	Standard
Izod Impact Resistance	ISO 180-2000 Unnotched
Barcol hardness	DIN EN59
Compressive strength	ISO 604:2002 Test speed = 1 mm/min
Water absorption	ISO 62:2008 Method 1 25 mm x 20 mm cylinder (to constant weight)
Oil absorption (light machine)	ISO 175:1999 25 mm x 20 mm cylinder (to constant weight)
Temperature of deflection under load	ISO 75-2 Method A

3.9.3 The percentage linear shrinkage of cured material is to be measured.

3.9.4 Creep is to be measured according to the following method:

(a) A 25 mm x 20 mm diameter parallel faced cylinder is to be pre-loaded against a steel base at 2,5 N/mm^2 or 3,5 N/mm^2, or at the specified higher loading condition, at ambient temperature for 16 hours.
(b) The temperature is to be increased at the rate of 8°C per hour until the service temperature (60°C or 80°C) is reached.
(c) During this time, the creep of the cylinder is to be measured at 15 minute intervals.
(d) The temperature and loading are to be maintained for a minimum of 100 days measuring the creep at intervals of 24 hours.
(e) A plot of creep in mm (linear scale) against time (log scale), together with full experimental details, is to be provided for review by LR.

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3.10 Rudder and pintle bearings

3.10.1 All mechanical properties as required by 2.12 are to be measured according to suitable National or International Standards.

3.10.2 Frictional properties are to be determined according to a method agreed with LR.

3.11 Sterntube bearings

3.11.1 The requirements for sterntube bearings are as defined in 2.13.

■ *Section 4* Plastics pipes and fittings

4.1 Scope

4.1.1 This Section gives the general requirements for plastics pipes and fittings, with or without reinforcement, intended for use in the services listed in the relevant Rules dealing with design and construction. Hoses and mechanical couplings are not covered by these requirements.

4.1.2 Pipes and fittings intended for application in Class I, Class II and Class III systems for which there are Rule requirements, are to be manufactured in accordance with the requirements of Section 1 and this Section.

4.1.3 As an alternative to 4.1.2, plastics pipes and fittings which comply with National or proprietary specifications may be accepted, provided that the specifications give reasonable equivalence to the requirements of this Section or, alternatively, are approved for a specific application. The survey and certification are however to be carried out in accordance with the requirements of this Section.

4.2 Design requirements

4.2.1 The requirements for design approval are detailed in the relevant Rules.

4.2.2 The design submission is to include a materials list with confirmation that the materials listed have properties and characteristics conforming with those values used in the design submission. As a minimum, the details given should include the following:

(a) Resin.
(b) Accelerator (type and concentration).
(c) Catalyst or curing agent (type and concentration).
(d) Reinforcement.
(e) Cure/post-cure conditions.
(f) Resin/reinforcement ratio.
(g) Wind angle (or lay-up sequence) and orientation.
(h) Dimensions and tolerances.

This submission is to include similar details for the fittings together with a description of the method of attachment of the fittings to the pipes.

4.2.3 Any alteration of the component materials or manufacturing operations from those used in the design submission will necessitate a completely new submission.

4.2.4 If the piping manufacturer anticipates the possible use of alternative materials, these should be listed in the design submission. Proof that the modified product will meet the specified requirements will be needed prior to its use.

4.3 Manufacture

4.3.1 Plastics pipes and fittings intended for use in Class I, Class II and Class III systems are to be manufactured at facilities approved by LR, using materials approved by LR.

4.3.2 A Manufacturing Specification is to be submitted. This is to contain details of the following:

(a) All constituent materials.
(b) Manufacturing procedures such as lay-up sequence or wind angle, the ratios of curing agent to resin and reinforcement to resin, the laminate thickness, the mandrel dwell time (initial cure) and the cure and post-cure conditions.
(c) Quality control procedures including details and frequency of tests on the incoming materials, tests made during production and on the finished piping.
(d) Acceptance standards and tolerances, including all dimensions.
(e) Procedures for cosmetic repair.
(f) System for traceability of the finished piping to the batches of raw materials.
(g) Method of bonding pipes and fittings.

4.3.3 Details of all raw materials are to be submitted for approval and are to be in accordance with the Manufacturing Specification and the design submission.

4.3.4 All batches of raw materials are to be provided with unique identifications by their manufacturers.

4.3.5 No batch of material is to be used later than its date of expiry.

4.3.6 The piping manufacturer is to ensure that all batches of materials are used sequentially.

4.3.7 The piping manufacturer is to maintain records of the amounts of resin and reinforcement used, in order to ensure that the proportions remain within the limits set in the Manufacturing Specification.

4.3.8 Records are to be kept of the wind angle and/or the orientation of the reinforcement.

4.3.9 The piping manufacturer is to ensure that each item of piping is traceable to the batch or batches of material used in its manufacture. The unique identifications referred to in 4.3.4 are to be included on all documents.

4.3.10 The curing oven is to be suitable for the intended purpose and all pyrometric equipment is to be calibrated at least annually and adequate records maintained.

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4.3.11 The temperature of the pipe or fitting is to be controlled and recorded by the attachment of suitably placed thermocouples.

4.4 Quality assurance

4.4.1 The piping manufacturer is to have a quality assurance system approved to ISO 9001 or equivalent. This system should ensure that the pipes and fittings are produced with uniform and consistent mechanical and physical properties in accordance with acceptable standards.

4.5 Dimensional tolerances

4.5.1 Dimensions and tolerances are to conform to the Manufacturing Specification.

4.5.2 The wall thicknesses of the pipes are to be measured at intervals around the circumference and along the length in accordance with an appropriate National Standard. The thicknesses are to accord with the Manufacturing Specification.

4.5.3 The responsibility for maintaining the required tolerances and making the necessary measurements rests with the manufacturer. Occasional checking by the Surveyor does not absolve the manufacturer from this responsibility.

4.6 Composition

4.6.1 The composition of the pipes and fittings is to be in accordance with the Manufacturing Specification.

4.6.2 Where alternative materials are used (*see* 4.2.4), the manufacturer is to demonstrate to the Surveyor's satisfaction, and prior to their introduction, their suitability with respect to the performance of the piping. Otherwise, full testing as specified in 4.7 will be required.

4.7 Testing

4.7.1 For thermoplastic pipes, the polymer manufacturer is to make the following measurements on samples taken from each batch:

(a) Melting point.
(b) Melt flow index.
(c) Density.
(d) Filler/pigment content, where applicable.
(e) Tensile stress at yield and break.
(f) Tensile strain at yield and break.

4.7.2 The values obtained are to be certified by the polymer manufacturer.

4.7.3 For reinforced thermoset pipes,the resin manufacturer is to determine, on samples taken from each batch, at least the following:

(a) All resins:
  (i) Viscosity.
  (ii) Gel time.
  (iii) Filler content, where applicable.
(b) Polyester resins:
  (i) Type (orthophthalic, isophthalic, etc.).
  (ii) Volatiles content.
  (iii) Acid value.
(c) Epoxide resins:
  (i) Free epoxide content.
(d) Phenolic resins:
  (i) Free phenol content.
  (ii) Free formaldehyde content.

4.7.4 The values obtained are to comply with the requirements of the Manufacturing Specification.

4.7.5 Where the resin manufacturer mixes batches, both the original batches and the mixed batch are to be tested in accordance with 4.7.1 to 4.7.3 as appropriate. The mixed batch is then to be given a unique batch number.

4.7.6 The polymer or resin manufacturer is to demonstrate that each batch of polymer or resin satisfies the requirement for temperature of deflection under load and this is not to be less than 80°C.

4.7.7 These measurements should be repeated on each batch by the piping manufacturer. Where this is not done, LR may require that the tests be made on a random basis by an independent laboratory.

4.7.8 The piping manufacturer is to confirm, by means of tests on at least one batch in twenty, that the temperature of deflection under load exceeds the specified minimum under manufacturing conditions.

4.7.9 Where reinforcements are used, at least the following are to be recorded, where applicable:

(a) Tex of yarn(s) or roving(s).
(b) Ends per 100 mm in all reinforcement orientations.
(c) Weight per square metre.
(d) Binder/size content.
(e) Stitch type and count.
(f) Type of fibre used.
(g) Surface treatment and/or finish.

4.7.10 All items in 4.7.9 are to comply with the Manufacturing Specification.

4.7.11 The piping manufacturer is to maintain accurate records of resin and glass usage and is to calculate the resin/glass ratio on an ongoing basis.

4.7.12 During manufacture of the piping, apart from the requirements of 4.7.5, 4.7.6 and 4.7.8, tests are to be carried out on the constituents and final product in accordance with Table 14.4.1.

4.7.13 The standards of acceptance are those listed in the Manufacturing Specification approved by LR.

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Table 14.4.1 Testing during manufacture of pipes

Component/ operation	Characteristic	Rate of testing
Resin/curing agent/catalyst	Gel time Rate of consumption	Two per shift Continuous
Reinforcement	Quality Wind angle Rate of consumption	Continuous Continuous Continuous
Resin/ reinforcement	Ratio	Continuous
Pipe	Post-cure: temperature of the pipe in oven	Continuous
	Cure level	At least eight per length
	Dimensions	Each length
	Hydraulic pressure test	Each length
	Electrical resistance	Each length (*see* Note)
	Hydraulic bursting test	At Surveyor's discretion
	Axial strength	At Surveyor's discretion

NOTE
Measurements of electrical resistance are only required on piping where the operating conditions given in Pt 5, Ch 12,5.2.4 of the *Rules and Regulations of the Classification of Ships* apply.

4.7.14 At the Surveyor's discretion, sections of pipe are to be subjected to hydraulic bursting tests and/or measurements of axial strength.

4.7.15 If the batch of resin or polymer, or the curing agent, or their ratio is changed during manufacture of a batch of pipes, at least two additional measurements of the gel time are to be carried out during each shift.

4.8 Visual examination

4.8.1 All pipes and fittings are to be visually examined and are to be free from surface defects and blemishes.

4.8.2 The pipes are to be reasonably straight and the cut ends are to be square to the axis of the pipe.

4.9 Hydraulic test

4.9.1 Each length of pipe is to be tested at a hydrostatic pressure not less than 1,5 times the rated pressure of the pipe.

4.9.2 The test pressure is to be maintained for sufficient time to permit proof and inspection. Unless otherwise agreed, the manufacturer's certificate of satisfactory hydraulic test, endorsed by the Surveyor, will be accepted.

4.10 Repair procedure

4.10.1 Repairs are not allowed, with the exception of minor cosmetic blemishes as detailed in 1.10.1.

4.10.2 A repair procedure for these minor blemishes is to be included in the Manufacturing Specification.

4.11 Identification

4.11.1 All piping is to be identified in such a manner that traceability to all the component materials used in its manufacture is ensured. The Surveyor is to be given full facilities for tracing the material when required.

4.11.2 Pipes and fittings are to be permanently marked by the manufacturer by moulding, hot stamping or by any other suitable method, such as printing, in accordance with 1.11. The markings are to include:

(a) Identification number, *see* 4.11.1.
(b) LR or Lloyd's Register, and the abbreviated name of LR's local office.
(c) Manufacturer's name or trademark.
(d) Pressure rating.
(e) Design standard.
(f) Material system with which the piping is made.
(g) Maximum service temperature.

4.12 Certification

4.12.1 The manufacturer is to provide the Surveyor with copies of the test certificates or shipping statements for all material which has been accepted.

4.12.2 Each test certificate is to contain the following particulars:

(a) Purchaser's name and order number.
(b) If known, the contract number for which the piping is intended.
(c) Address to which piping is despatched.
(d) Type and specification of material.
(e) Description and dimensions.
(f) Identification number, *see* 4.11.1.
(g) Test results.

■ *Section 5*
Control of material quality for composite construction

5.1 Scope

5.1.1 This Section gives the general requirements for control of material quality when used in the construction of composite craft.

5.1.2 For composite craft built under the Rules, the survey of materials is to be conducted in accordance with the requirements of Sections 1 to 3 and this Section.

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5.2 Design submission

5.2.1 The requirements for design submission are detailed in the appropriate Part of the Rules which includes full information on composite materials.

5.3 Construction

5.3.1 All constructions are to be carried out using materials approved or accepted by LR.

5.3.2 All materials are to be in accordance with the approved construction documentation.

5.3.3 All batches of materials are to be provided with unique identifications by their manufacturers. Components are to be similarly identified.

5.3.4 No batch of material is to be used later than its date of expiry.

5.3.5 The Builder is to ensure that all batches of materials are used systematically and sequentially.

5.3.6 The Builder is to maintain, on a continuous basis, records of the amounts of resin and reinforcement used, in order to ensure that the proportions remain within the limits set in the construction documentation.

5.3.7 Records are to be kept of the sequence and orientation of the reinforcements.

5.3.8 The Builder is to ensure that each section of the construction is traceable to the batch or batches of material used. The unique identifications required under 1.11.1 are to be included on all relevant quality control documentation.

5.3.9 Any curing system used is to be demonstrated as suitable for the intended purpose and all pyrometric equipment is to be calibrated at least annually and adequate records maintained.

5.3.10 The post-curing temperature is to be controlled and recorded by the attachment of suitably placed thermocouples.

5.4 Quality assurance

5.4.1 Where the Builder has a quality assurance system, this is to include the requirements of this Section.

5.5 Dimensional tolerances

5.5.1 Dimensions and tolerances are to conform to the approved construction documentation.

5.5.2 The thicknesses of the laminates are, in general, to be measured at not less than ten points, evenly distributed across the surface. In the case of large sections, at least ten evenly distributed measurements are to be taken in bands across the width at maximum spacing of two metres along the length.

5.5.3 The responsibility for maintaining the required tolerances and making the necessary measurements rests with the Builder. Monitoring and random checking by the Surveyor does not absolve the Builder from this responsibility.

5.5.4 Where ultrasonic thickness gauges are used, these are to be calibrated against an identical laminate (of measured thickness) to that on which the thickness measurement is to be carried out. If suitable pieces are not available from the construction, then a small sample of identical lay-up is to be prepared.

5.6 Material composition

5.6.1 The materials, prefabricated sections or components used are to be in accordance with the approved construction documentation.

5.6.2 Where alternative materials are used, these are to be of approved or accepted types and the manufacturer is to demonstrate to the Surveyor's satisfaction, prior to their introduction, their suitability with respect to performance, otherwise full testing as appropriate will be required.

5.7 Material testing

5.7.1 Where so required, the material manufacturer is to provide the purchaser with certificates of conformity for each batch of material supplied, indicating the relevant values specified in 5.7.4 to 5.7.8. These values are to comply with those specified by the approved construction documentation.

5.7.2 Where the Builders do not conduct verification testing of the information indicated in 5.7.4 to 5.7.8, they are to ensure that copies of all certificates of conformity (which must indicate the actual tested values) are obtained for all batches of materials received, and maintain accurate records. The Surveyor may at any time select a sample of a material for testing by an independent, where applicable, source and should such tests result in the material failing to meet the specification, then that batch will be rejected.

5.7.3 The following tests are to be carried out, where applicable, on receipt of any material:

(a) The consignment is to be divided into its respective batches and each batch is to be labelled accordingly.
(b) Each batch is to be visually examined for conformity with the batch number, visual quality and date of expiry.
(c) Each batch is to be separately labelled and stored separately.
(d) Each unit, within the batch, is to be labelled with the batch number.
(e) Records are to be maintained of the above and these are to be cross-referenced with the certificate of conformity for the material and/or the Builder's own test results.

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5.7.4 For thermosetting resins, reinforced or otherwise, the resin manufacturer is to have determined, on samples taken from each batch, at least the following:

(a) All resins:
  (i) Viscosity.
  (ii) Gel time.
  (iii) Filler content, where applicable.
(b) Polyester and vinylester resins:
  (i) Type (orthophthalic, isophthalic, etc.).
  (ii) Volatiles content.
  (iii) Acid value.
(c) Epoxide resins:
  (i) Free epoxide content.
(d) Phenolic resins:
  (i) Free phenol content.
  (ii) Free formaldehyde content.

5.7.5 For thermoplastics, the polymer manufacturer is to have made the following measurements on samples taken from each batch:

(a) Melting point.
(b) Melt flow index.
(c) Density.
(d) Filler/pigment content, where applicable.
(e) Tensile stress at yield and break.
(f) Tensile strain at yield and break.

5.7.6 Where the resin or polymer manufacturer mixes batches, both the original batches and the mixed batch are to be tested in accordance with 5.7.4 or 5.7.5 as appropriate. The mixed batch is then to be given a unique batch number.

5.7.7 For reinforcements, the material manufacturer is to have recorded, where applicable, the following for each batch of material:

(a) Tex of yarn(s) or roving(s).
(b) Ends per 100 mm in all reinforcement orientations.
(c) Weight per square metre.
(d) Binder/size content.
(e) Stitch type and count.
(f) Type of fibre used.
(g) Surface treatment and/or finish.

5.7.8 For core materials, the following properties are to be recorded by the manufacturer for each batch:

(a) Type of material.
(b) Density.
(c) Description (block, scrim mounted, grooved).
(d) Thickness and tolerance.
(e) Sheet/block dimensions.
(f) Surface treatment.

Together with the following mechanical properties:

In the case of rigid foams:

(g) Compressive strength (stress at maximum load) and modulus of elasticity.
(h) Core shear strength.

In the case of end-grain balsa:

(j) Tensile strength (stress at maximum load).
(k) Compressive strength (stress at maximum load) and modulus of elasticity.

5.7.9 During construction, tests are to be carried out on the constituents and final product in accordance with Table 14.5.1.

5.7.10 The standards of acceptance for testing are those listed in the material manufacturer's specification, approved construction documentation or agreed quality control procedures as applicable.

5.7.11 Laminate fibre content is to be determined at the request of the Surveyor, in particular where the thickness measured does not correlate with the specified fibre content, by weight. This will, in general, result in additional reinforcement being required.

5.7.12 If the batch of resin or polymer, or the curing agent, or their ratio is changed, at least two additional measurements of the gel time are to be carried out during each shift.

Table 14.5.1 Testing during construction

Component/operation	Characteristic	Rate of testing
Resin/curing agent/catalyst	Gel time	Two per shift
	Rate of consumption	Continuous
Reinforcement	Quality	Continuous
	Orientation	Continuous
	Rate of consumption	Continuous
Resin/reinforcement	Ratio	Continuous
Construction	Temperature during cure/post cure	Continuous
	Dimensions	Continuous against approved construction documentation
	Cure level (Barcol) against resin manufacturer's specification	At least one per square metre
	Laminate thickness	Continuous against material usage and approved construction documentation (*see also* 5.5.2 to 5.5.4)
	Laminate fibre content	At the Surveyor's request (*see* 5.7.11)

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5.8 Visual examination

5.8.1 All constructional mouldings and any components are to be visually examined and are to be free from surface defects and blemishes.

5.9 Repair procedure

5.9.1 Repairs of minor cosmetic blemishes are permitted providing that these are brought to the attention of the Surveyor.

5.9.2 A repair procedure for these minor blemishes is to be included in the agreed quality control procedures.

5.9.3 Structural repairs are subject to individual consideration and full written details must be approved by the plan approval office prior to introduction.

5.10 Material identification

5.10.1 Records of the construction are to be kept in such a manner that traceability of all the component materials used is ensured. The Surveyor is to be given full facilities for tracing the material's origin when required.

5.10.2 Small representative samples of each batch of material are to be retained, these being suitably labelled to ensure traceability.

5.10.3 When so requested by the Surveyor, the Builder is to provide copies of all test data and/or manufacturers' certificates of conformity appertaining to any material used.

5.11 Minimum tested requirements for material approval

5.11.1 This Section provides the minimum property values required of a material for approval or acceptance by LR and are applicable to materials cured under ambient conditions.

5.11.2 **Gel coat resins.** When the cast resin is tested according to the requirements of 2.3, Table 14.5.2 gives the minimum values for the respective properties.

5.11.3 **Laminating resins.** When tested according to the requirements of 2.3 and 2.4, Tables 14.5.3 and 14.5.4 give the minimum properties for the cast resin and chopped strand mat laminate respectively.

5.11.4 When tested to the requirements of 2.4 for reinforcements, Table 14.5.5 gives the minimum properties for laminates.

5.11.5 Alternatively, materials may be approved by use of the actual tested values whereby the approval value shall equal the mean of the tested values minus twice the standard deviation of a minimum of five tested values.

Table 14.5.2 Gel coat resins, minimum property values

Properties	Minimum value
Tensile strength (stress at maximum load)	40 N/mm^2
Tensile stress at break	40 N/mm^2
Tensile strain at maximum load	2,5%
Modulus of elasticity in tension	As measured
Flexural strength (stress at maximum load)	80 N/mm^2
Modulus of elasticity in flexure	As measured
Barcol hardness	As measured at full cure
Water absorption	70 mg (max)

Table 14.5.3 Laminating resins, minimum property values

Properties	Minimum value
Tensile strength (stress at maximum load)	40 N/mm^2
Tensile stress at break	40 N/mm^2
Tensile strain at maximum load	2,0%
Modulus of elasticity in tension	As measured
Barcol hardness	As measured at full cure
Temperature of deflection under load	55°C
NOTE These minimum values are for the recommended glass content by weight of 0,3.	

5.12 Closed cell foams for core construction based on PVC or polyurethane

5.12.1 Table 14.5.6 gives minimum values for closed cell forms for core construction based on PVC or polyurethane.

5.12.2 Other types of foam will be subjected to individual consideration. A minimum core shear strength of 0,5 N/mm^2 is to be achieved.

5.13 End-grain balsa

5.13.1 Table 14.5.7 gives the minimum property requirement for end-grain balsa.

5.14 Other materials

5.14.1 All other materials will be subject to special consideration.

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Table 14.5.4 Laminating resins, minimum values for properties for CSM laminate at 0,3 glass fraction by weight

Properties	Minimum value
Tensile strength (stress at maximum load)	90 N/mm^2
Secant modulus at 0,25% and 0,5% strain respectively	6,9 kN/mm^2
Compressive strength (stress at maximum load)	125 N/mm^2
Compressive modulus	6,4 kN/mm^2
Flexural strength (stress at maximum load)	160 N/mm^2
Modulus of elasticity in flexure	5,7 kN/mm^2
Apparent interlaminar shear strength (*see* Note)	18 N/mm^2
Fibre content	As measured (0,3)
Water absorption	70 mg (max)
NOTE Applicable only to the special test for environmental control resins.	

Table 14.5.5 Laminates, minimum property requirements

Material type	Property	Value
Chopped strand mat	Tensile strength (stress at maximum load) (N/mm^2)	$200G_c + 30$
	Modulus of elasticity in tension (kN/mm^2)	$15G_c + 2,4$
Bi-directional reinforcement	Tensile strength (stress at maximum load) (N/mm^2)	$400G_c - 10$
	Modulus of elasticity in tension (kN/mm^2)	$30G_c - 0,5$
Uni-directional reinforcement	Tensile strength (stress at maximum load) (N/mm^2)	$1800G_c^2 - 1400G_c + 510$
	Modulus of elasticity in tension (kN/mm^2)	$130G_c^2 - 114G_c + 39$
Chopped strand mat	Flexural (stress at maximum load) (N/mm^2)	$502G_c^2 + 114,6$
	Modulus of elasticity in flexure (kN/mm^2)	$33,4G_c^2 + 2,7$
All	Flexural strength (stress at maximum load) (N/mm^2)	$502G_c^2 + 106,8$
	Modulus of elasticity in flexure (kN/mm^2)	$33,4G_c^2 + 2,2$
	Compressive strength (stress at maximum load) (N/mm^2)	$150G_c + 72$
	Compressive modulus (kN/mm^2)	$40G_c - 6$
	Interlaminar shear strength (N/mm^2)	$22 - 13,5G_c$ (min 15)
	Water absorption (mg)	70 (maximum)
	Glass content (% by weight)	As measured
NOTES 1. After water immersion, the values shall be a minimum of 75% of the above. 2. Where materials have reinforcement in more than two directions, the requirement will be subject to individual consideration dependent on the construction. 3. G_c = glass fraction by weight.		

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Table 14.5.6 Minimum characteristics and mechanical properties of rigid expanded foams at 20°C

Material	Apparent density kg/m^3	Strength (stress at maximum load) (N/mm^2)			Modulus of elasticity (N/mm^2)	
		Tensile	Compressive	Shear	Compressive	Shear
Polyurethane	96	0,85	0,60	0,50	17,20	8,50
Polyvinylchloride	60					

Table 14.5.7 Minimum characteristics and mechanical properties of end-grain balsa

Apparent density (kg/m^3)	Strength (stress at maximum load) (N/mm^2)					Compressive modulus of elasticity (N/mm^2)		Shear modulus of elasticity (N/mm^2)
	Compressive		Tensile		Shear	Direction of stress		
	Direction of stress							
	Parallel to grain	Perpendicular to grain	Parallel to grain	Perpendicular to grain		Parallel to grain	Perpendicular to grain	
96	5,0	0,35	9,00	0,44	1,10	2300	35,2	105
144	10,6	0,57	14,6	0,70	1,64	3900	67,8	129
176	12,8	0,68	20,5	0,80	2,00	5300	89,6	145

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Volume 3
Parts 3 to 5

July 2011

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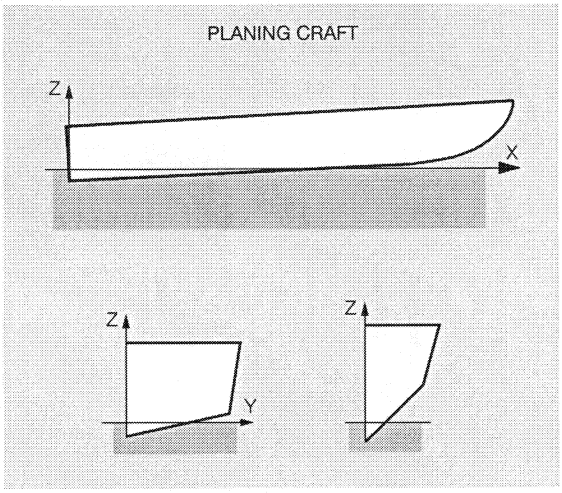
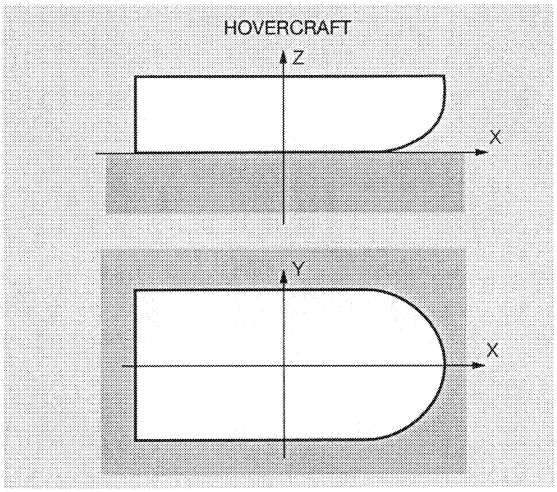
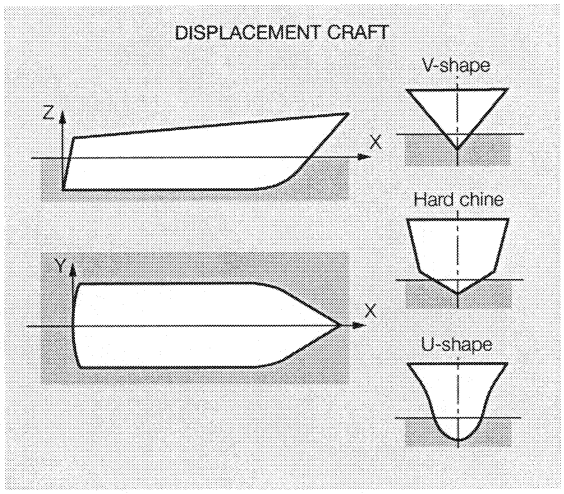
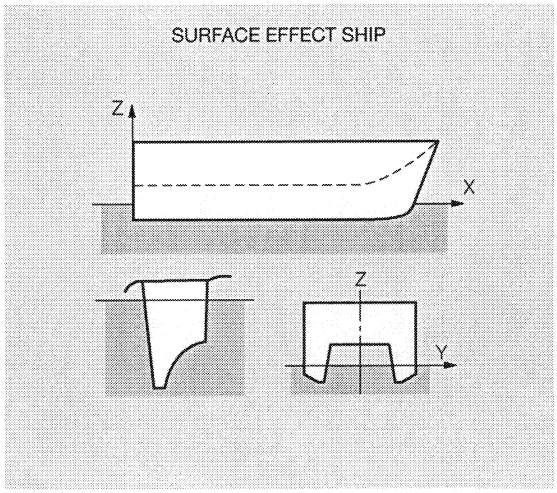
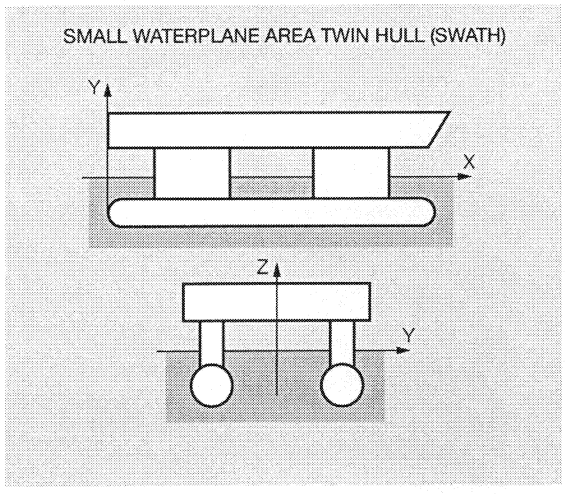
DIFFERENT TYPES OF HULL FORMS COVERED BY THE SPECIAL SERVICE CRAFT RULES

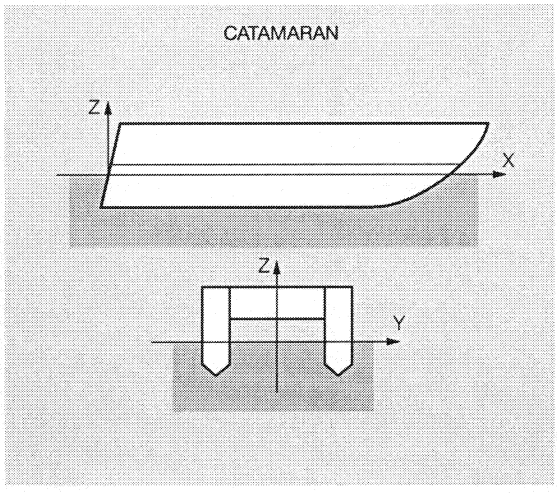












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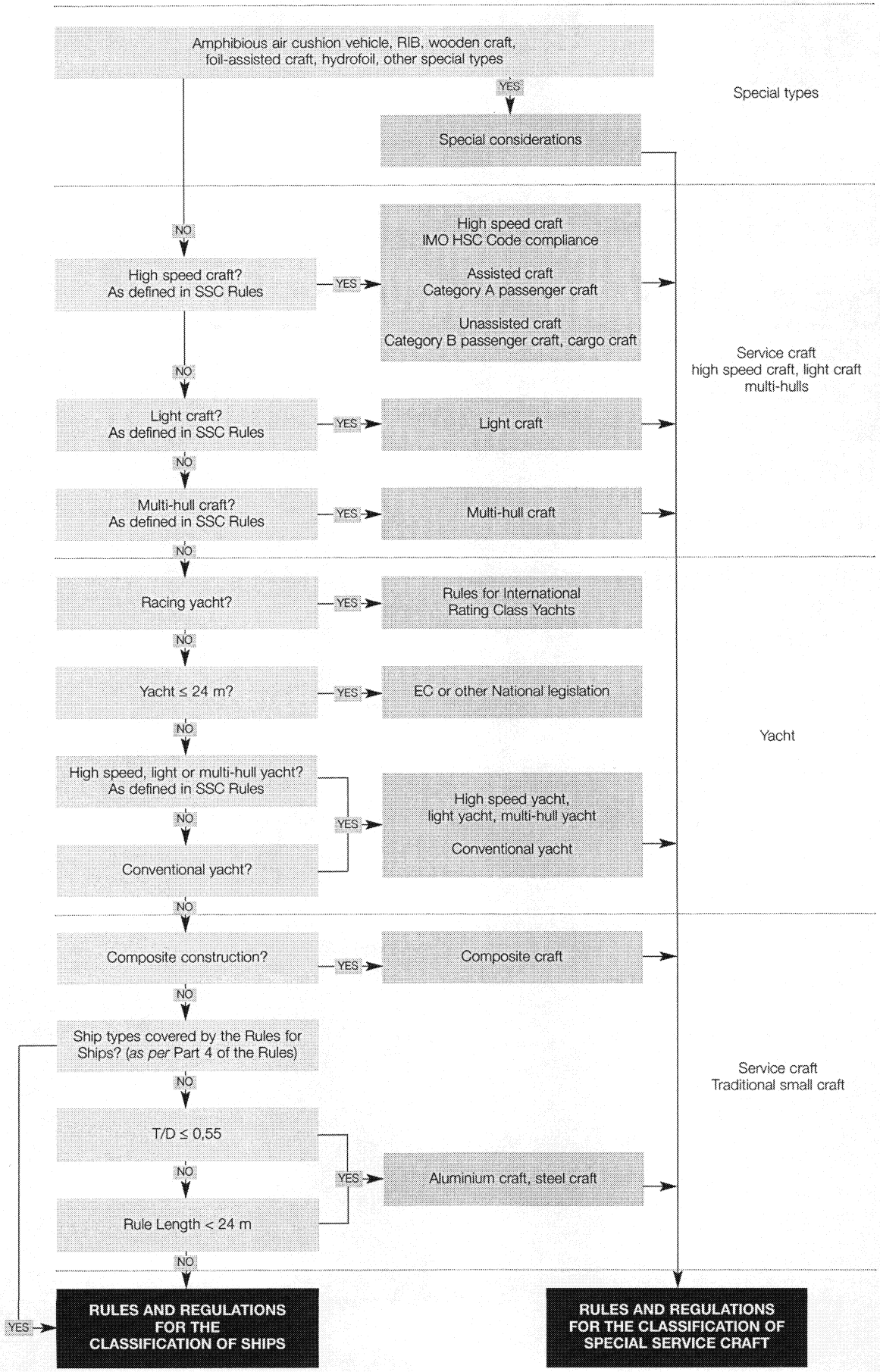

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8 **Building tolerances and associated repairs**

■ *Section 1* Rules application

1.1 General

1.1.1 The Rules apply to sea-going motor, sailing and auxiliary craft of normal form, proportions and speed, generally not exceeding a Rule length, L_R of 150 m.

1.2 Exceptions

1.2.1 Craft of unusual form, proportions or speed, or intended for the carriage of special cargoes, or for special or restricted service, not covered specifically by the Rules, will receive individual consideration based on the general standards of the Rules.

1.3 Loading

1.3.1 The Rules are framed on the understanding that craft will be properly loaded and handled; they do not, unless it is stated or implied in the class notation, provide for special distributions or concentrations of loading other than those included in the approved Loading Manual. The Committee may require additional strengthening to be fitted in any craft which, in their opinion, would otherwise be subjected to severe stresses due to particular features of the design, or where it is desired to make provision for exceptional load or ballast conditions.

1.4 Advisory services

1.4.1 The Rules do not cover certain technical characteristics, such as stability except as mentioned in Pt 1, Ch 2,1.1.11, 1.1.13 and 1.1.14, trim, vibration, docking arrangements, etc. The Committee cannot assume responsibility for these matters but is willing to advise upon them on request.

■ *Section 2* Direct calculations

2.1 General

2.1.1 Direct calculations may be specifically required by the Rules or may be required for craft having novel design features, as defined in 1.2, or may be submitted in support of alternative arrangements and scantlings. Lloyd's Register (hereinafter referred to as 'LR') may, when requested, undertake calculations on behalf of designers and make recommendations in regard to suitability of any required model tests.

2.1.2 Where model testing is undertaken to complement direct calculations the following details would normally be required to be submitted: Schedule of tests, details of test equipment, input data, analysis and calibration procedure together with tabulated and plotted output.

2.2 Submission of direct calculations

2.2.1 In cases where direct calculations have been carried out, the following supporting information should be submitted as applicable:

(a) Reference to the direct calculation procedure and technical program used.
(b) A description of the structural modelling.
(c) A summary of analysis parameters including properties and boundary conditions.
(d) Details of the loading conditions and the means of applying loads.
(e) A comprehensive summary of calculation results. Sample calculations should be submitted where appropriate.

2.2.2 In general, submission of large volumes of input and output data associated with such programs as finite element analysis will not be necessary.

2.2.3 The responsibility for error free specification and input of program data and the subsequent correct transposal of output rests with the Builder.

2.3 Global hull strength

2.3.1 Longitudinal strength calculations are to be submitted for all craft with a Rule length, L_R, exceeding that specified in Chapter 6, of Parts 6, 7 and 8, for steel, aluminium alloy and composite respectively, covering the range of load and ballast conditions proposed, in order to determine the required hull girder strength. Still water bending moments and shear forces are to be calculated for both departure and arrival conditions and for any special mid-voyage conditions caused by changes in ballast distribution.

2.3.2 Where the Rule length, L_R, does not exceed that indicated in 2.3.1, longitudinal strength calculations may be required at LR's discretion, dependent upon craft proportions, the proposed loading, structural configuration and material of construction.

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Section 3 Equivalents

3.1 Alternative arrangements and scantlings

3.1.1 In addition to cases where direct calculations are specifically required by the Rules, LR will consider alternative arrangements and scantlings which have been derived by direct calculations in lieu of specific Rule requirements. All direct calculations are to be submitted for examination.

3.1.2 Where calculation procedures other than those available within the LR *Software Guide* are employed, supporting documentation is to be submitted for appraisal and this is to include details of the following:

- calculation methods;
- assumptions and references;
- loading;
- structural modelling;
- design criteria and their derivation, e.g. permissible stresses;
- factors of safety against plate panel instability, etc.

3.1.3 LR will be ready to consider the use of Builder's programs for direct calculations in the following cases:

(a) Where it can be established that the program has previously been satisfactorily used to perform a direct calculation similar to that now submitted.

(b) Where sufficient information and evidence of satisfactory performance is submitted to substantiate the validity of the computation performed by the program.

3.1.4 Alternative arrangements or fittings which are considered to be equivalent to the Rule requirements will be accepted.

3.1.5 Where no special reference is made in this Part to specific requirements, the construction is to be efficient for the intended purpose and to conform to good practice.

3.1.6 Where items are of a novel or unconventional design or manufacture, it is the responsibility of the Builder to demonstrate their suitability and equivalence to the Rule requirements.

3.1.7 Alternative arrangements which are in accordance with the requirements of a National Authority may be accepted as equivalent to the requirements of this Part of the Rules.

Section 4 National and International Regulations

4.1 International Conventions

4.1.1 The Committee, when authorised, will act on behalf of Governments and, if requested, LR will certify compliance in respect of National and International statutory safety and other requirements for passenger and cargo craft.

4.1.2 In satisfying the Load Line Convention, the general structural strength of the craft is required to be sufficient for the draught corresponding to the freeboards to be assigned. Craft built and maintained in accordance with LR's Rules and Regulations possess adequate strength to satisfy the Load Line Convention. However, some National Authorities may, in addition, require to be supplied with calculations of bending moments and shear forces for certain conditions of loading.

4.2 International Association of Classification Societies (IACS)

4.2.1 Where applicable, the Rules take into account unified requirements and interpretations established by IACS.

4.3 International Maritime Organization (IMO)

4.3.1 Attention is drawn to the fact that Codes of Practice issued by IMO contain requirements which are outside the scope of classification as defined in these Rules and Regulations.

Section 5 Information required

5.1 General

5.1.1 The categories and lists of information required are given in 5.2.

5.1.2 Plans are generally to be submitted in triplicate, but one copy only is necessary for supporting documents and calculations.

5.1.3 Plans are to contain all necessary information to fully define the structure, including construction details, equipment and systems as appropriate.

5.1.4 Additional requirements for individual craft types are given in subsequent Chapters.

5.2 Submission of plans and data

5.2.1 Plans and data required to be submitted are indicated in Parts 6, 7 and 8 for steel, aluminium alloy and composite construction respectively, as appropriate.

5.2.2 Where an ***IWS** (In-water Survey) notation is to be assigned, *see* Pt 1, Ch 2,3.8.2, plans and information covering the following items are to be submitted:

- Details showing how rudder pintle and bush clearances are to be measured and how the security of the pintles in their sockets are to be verified with the craft afloat.
- Details showing how stern bush clearances are to be measured with the craft afloat.
- Details of high resistant paint, for information only.

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5.3 Standard designs

5.3.1 Where a craft is a standard design produced in several versions, the plans and data are to clearly define the differences between each version.

5.3.2 Where the craft is a Builder's standard design to be built from previously approved plans and data, a schedule of applicable plans, etc., is to accompany the Request for Survey. Plans of any proposed modifications and changes to the previously approved plans are to be submitted for approval prior to the commencement of any work.

5.3.3 Plan approval of standard designs is only valid so long as no applicable Rule changes take place. When the Rules are amended, the plans for standard types are to be submitted for re-approval.

5.4 Plans and data to be supplied to the craft

5.4.1 To facilitate the ordering of materials for repairs, plans are to be carried in the craft indicating the disposition and grades (other than Grade A) of hull structural steel, the extent and location of higher tensile steel together with details of specification and mechanical properties, and any recommendations for welding, working and treatment of these steels.

5.4.2 Similar information is to be provided when aluminium alloy, fibre composite or other materials are used in the hull construction.

5.4.3 A copy of the final Loading Manual, (where applicable) when approved, and details of the loadings applicable to approved decks, hatch covers and inner bottom are to be placed on board the craft.

5.4.4 Details of any corrosion control system fitted are to be placed on board the craft.

5.4.5 Copies of main scantling plans are to be placed on board.

5.4.6 Where an ***IWS** (In-water Survey) notation is to be assigned, approved plans and information covering the items detailed in 5.2.2 are to be placed on board.

5.5 Fire protection, detection and extinction

5.5.1 For information and plans required, *see* Part 17.

■ *Section 6* Definitions

6.1 General

6.1.1 The following definitions apply except where they are inappropriate or where specifically defined otherwise.

6.2 Principal particulars

6.2.1 **Rule length**, L_R, is the distance, in metres, on the summer load waterline from the forward side of the stem to the after side of the rudder post or to the centre of the rudder stock if there is no rudder post. L_R is to be not less than 96 per cent, and need not be greater than 97 per cent, of the extreme length on the summer load waterline. In craft without rudders, the Rule length, L_R, is to be taken as 97 per cent of the extreme length on the summer load waterline. In craft with unusual stem or stern arrangements the Rule length, L_R, will be specially considered.

6.2.2 **Length between perpendiculars**, L_{pp}, is the distance, in metres, on the summer load waterline from the fore side of the stem to the after side of the rudder post, or to the centre of the rudder stock if there is no rudder post. In craft with unusual stern arrangements the length, L_{pp}, will be specially considered. The forward perpendicular, F.P., is the perpendicular at the intersection of the summer load waterline with the fore side of the stem. The after perpendicular, A.P., is the perpendicular at the intersection of the summer load waterline with the after side of the rudder post or to the centre of the rudder stock for craft without a rudder post.

6.2.3 **Load line length**, L_L, is to be taken as 96 per cent of the total length on a waterline at 85 per cent of the least moulded depth measured from the top of the keel, or as the length from the fore side of the stem to the axis of the rudder stock on that waterline, if that is greater. In craft designed with a rake of keel, the waterline on which this length is measured is to be parallel to the designed waterline. The length L_L is to be measured in metres.

6.2.4 **Length overall**, L_{OA}, is the distance, in metres, measured parallel to the static load waterline from the foreside of the stem to the after side of the stern or transom, excluding rubbing strakes and other projections.

6.2.5 **Length waterline**, L_{WL}, is the distance, in metres, measured on the static load waterline from the foreside of the stem to the after side of the stern or transom.

6.2.6 **Amidships** is to be taken as the middle of the Rule length, L_R, measuring from the forward side of the stem.

6.2.7 **Breadth**, B, is the greatest moulded breadth, in metres, or, for craft of composite construction, the extreme breadth excluding rubbing strakes or other projections. For multi-hull craft it is to be taken as the sum of the breadths of the individual hulls.

6.2.8 **Depth**, D, is measured, in metres, at the middle of the Rule length, L_R, from top of keel to top of the deck beam at side on the uppermost continuous deck, or as defined in appropriate Chapters. When a rounded gunwale is arranged, the depth D is to be measured to the continuation of the moulded deck line at side.

6.2.9 **Draught**, T, is the summer draught, in metres, measured from top of keel.

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6.2.10 **Block coefficient**, C_b, is the moulded block coefficient at draught T corresponding to summer load waterline, based on Rule length L_R and moulded breadth B, as follows:

$$C_b = \frac{\text{moulded displacement (m}^3\text{) at draught } T}{L_R B T}$$

6.3 Freeboard deck

6.3.1 The freeboard deck is normally the uppermost complete deck exposed to weather and sea, which has permanent means of closing all openings in the weather part thereof, and below which all openings in the sides of the craft are fitted with permanent means of watertight closing. It is the deck from which the freeboard is measured.

6.4 Bulkhead deck

6.4.1 Bulkhead deck is the uppermost deck up to which the transverse watertight bulkheads are carried.

6.5 Strength deck

6.5.1 Strength deck is normally the uppermost continuous deck. Other decks may be considered as the strength deck provided that such decks are structurally effective.

6.6 Weather deck

6.6.1 A weather deck is a deck which is exposed to sea and weather loads.

6.6.2 The weather deck is the lowest continuous deck exposed to sea and weather loads, and is not to be taken lower than the bulkhead deck for the determination of the requirements for closing appliances from Chapter 4.

6.7 Wet deck

6.7.1 A wet deck is the lower most exposed surface of the cross-deck structure, connecting the hulls of a multi-hull craft.

6.8 Weathertight

6.8.1 A closing appliance is considered weathertight if it is designed to prevent the passage of water into the craft in any sea conditions.

6.8.2 Generally, all openings in the freeboard deck and in enclosed superstructures are to be provided with weathertight closing appliances.

6.9 Watertight

6.9.1 A closing appliance is considered watertight if it is designed to prevent the passage of water in either direction under a head of water for which the surrounding structure is designed.

6.9.2 Generally, all openings below the freeboard deck in the outer shell/envelope (and in main bulkheads) are to be fitted with permanent means of watertight closing.

6.10 Position 1 and Position 2

6.10.1 For the purpose of Load Line Conditions of Assignment, there are two basic positions of hatchways, doorways and ventilators defined as follows:

Position 1 — Upon exposed freeboard and raised quarterdecks, and exposed superstructure decks within the forward 0,25 of the Load Line length, L_L.

Position 2 — Upon exposed superstructure decks abaft the forward 0,25 of the load line length, L_L and located at least one standard height of superstructure above the freeboard deck.

Upon exposed superstructure decks within the forward 0,25 of the Load Line length, L_L and located at least two standard heights of superstructure above the freeboard deck.

6.11 Reference system

6.11.1 For hull reference purposes, the craft is divided into 21 equally spaced stations where Station 0 is the after perpendicular, Station 20 is the forward perpendicular, and Station 10 is mid-L_{pp}.

6.12 Co-ordinate system

6.12.1 Unless otherwise stated, the co-ordinate system is as shown in Fig. 1.6.1, that is, a right-hand co-ordinate system with the X axis positive forward, the Y axis positive to port and the Z axis positive upwards. Angular motions are considered positive in a clockwise direction about the X, Y or Z axes.

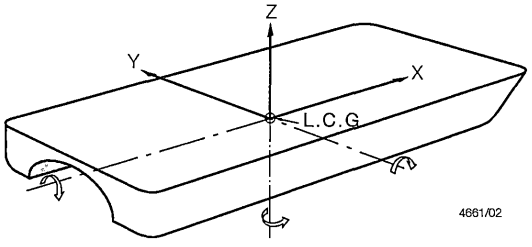

Fig. 1.6.1 Co-ordinate system

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6.13 Superstructure

6.13.1 A superstructure is defined as a decked structure on the freeboard deck, extending from side to side of the craft, or with the side plating being less than four per cent of the breadth, *B*, inboard of the shell plating.

6.13.2 An enclosed superstructure is a superstructure with:

(a) Enclosing bulkheads of efficient construction;
(b) Access openings, if any, in these bulkheads fitted with doors complying with the requirements of Ch 4,6.5;
(c) All other openings in sides or ends of the superstructure fitted with efficient weathertight means of closing.

6.13.3 The standard height of superstructure for L_L of 75 m or less is to be taken as 1,8 m, and for L_L of 125 m or greater is to be taken as 2,3 m. Intermediate values are to be determined by linear interpolation.

6.14 Deckhouse

6.14.1 A deckhouse is in general defined as a decked structure on or above the freeboard deck with side plating being four per cent or more of the breadth, *B*, inboard of the shell plating.

■ *Section 7*
Inspection, workmanship and testing procedures

7.1 General

7.1.1 The minimum requirements in respect of inspection, workmanship and testing are contained within Chapter 2, of Parts 6, 7 and 8, of the Rules for craft constructed in steel, aluminium alloy and composite respectively.

7.2 Construction standards

7.2.1 Construction standards for all materials are to be in accordance with National Standards or these Rules whichever are the higher.

7.2.2 The design requirements for welding and structural detail are to be found in Parts 6 and 7 of the Rules for craft constructed in steel and aluminium alloy respectively.

7.2.3 The design requirements for the bonding of all structural detail of composite materials are contained in Part 8.

7.3 Testing procedures

7.3.1 **Definitions.** For the purpose of these procedures the following definitions apply:

(a) **Protective coating** is the coating system applied to protect the structure from corrosion. This excludes the prefabrication primer.
(b) **Structural testing** is a hydrostatic test carried out to demonstrate the tightness of the tanks and the structural adequacy of the design. Where practical limitations prevail and hydrostatic testing is not feasible, hydro-pneumatic testing, *see* (e), may be carried out instead.
(c) **Leak testing** is an air or other medium test carried out to demonstrate the tightness of the structure.
(d) **Hose testing** is carried out to demonstrate the tightness of structural items not subjected to hydrostatic or leak testing, and other components which contribute to the watertight or weathertight integrity of the hull.
(e) **Hydropneumatic testing** is a combination of hydrostatic and air testing, consisting of filling the tank with water and applying an additional air pressure. The conditions are to simulate, as far as practicable, the actual loading of the tank and in no case is the air pressure to be less than given in 7.3.4.

7.3.2 **Application.** The testing requirements for tanks, including independent tanks, watertight and weathertight compartments, are listed in Table 1.7.1. Tests are to be carried out in the presence of the Surveyor at a stage sufficiently close to completion such that the strength and tightness are not subsequently impaired.

7.3.3 **Structural testing.** The attachment of fittings to oiltight surfaces is to be completed before tanks are structurally tested. Where it is intended to carry out structural tests after the protective coating has been applied welds are generally to be leak tested prior to the coating application.

For welds other than manual and automatic erection welds, manual fillet welds on tank boundaries and manual penetration welds, the leak test may be waived provided that careful visual inspection is carried out, to the satisfaction of the Surveyor, before the coating is applied. The cause of any discolouration or disturbance of the coating is to be ascertained, and any deficiencies repaired.

7.3.4 **Leak testing.** This is carried out by applying an efficient indicating liquid (e.g. soapy water solution) to the weld or outfitting penetration being tested, while the tank or compartment is subject to an air pressure of at least 0,15 bar (0,15 kgf/cm^2).

It is recommended that the air pressure be raised to 0,2 bar (0,2 kgf/cm^2) and kept at this level for about one hour to reach a stabilised state, with a minimum number of personnel in the vicinity, and then lowered to the test pressure prior to inspection. A U-tube filled with water to a height corresponding to the test pressure is to be fitted for verification and to avoid overpressure. The U-tube is to have a cross-section larger than that of the air supply pipe. In addition, the test pressure is to be verified by means of a pressure gauge, or alternative equivalent system.

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Table 1.7.1 Testing requirements

Item to be tested	Testing procedure	Testing requirement
Double bottom tanks	Structural (1)	The greater of: – head of water up to the top of the overflow – head of water up to the margin line – head of water representing the maximum pressure experienced in service
Cofferdams	Structural (1)	The greater of: – head of water up to the top of the overflow – 1,8 m head of water above highest point of tank (4)
Forepeak and aft peak used as tank(3)	Structural	
Tank bulkheads	Structural (1)	The greater of: – head of water up to the top of the overflow – 1,8 m head of water above the highest point of tank (4) – setting pressure of the safety valves, where relevant
Deep tanks	Structural (1)	
Scupper and discharge pipes in way of tanks	Structural (1)	
Double plate rudders	Structural (1), (5)	2,4 m head of water, and rudder should normally be tested while laid on its side
Watertight bulkheads, shaft tunnels, flats and recesses, etc.	Hose (2)	*See* 7.3.5
Watertight doors (below freeboard or bulkhead deck) when fitted in place	Hose (6)	
Weathertight hatch covers and closing appliances	Hose	
Forepeak not used as tank	Hose (2)	
Shell doors when fitted in place	Hose (7)	
Chain locker, if aft of collision bulkhead	Structural	Head of water up to the top
Separate oil fuel tanks	Structural	Head of water representing the maximum pressure which could be experienced in service, but not less than 3,5 m
After peak not used as tank	Leak	*See* 7.3.4

NOTES
1. Leak or hydropneumatic testing may be accepted, provided that at least one tank of each type is structurally tested, to be selected in connection with the approval of the design. (*See also* 7.3.9 and 7.3.10).
2. When hose testing cannot be performed without damaging possible outfittings already installed, it may be replaced by a careful visual inspection of all the crossings and welded joints. Where necessary, dye penetrant test or ultrasonic leak test may be required.
3. Testing of the aft peak is to be carried out after the sterntube has been fitted.
4. The highest point of the tank is generally to exclude hatchways. In holds for liquid cargo or ballast with large hatch openings, the highest point of the tank is to be taken to the top of the hatch.
5. If leak or hydropneumatic testing is carried out, arrangements are to be made to ensure that no pressure in excess of 0,30 bar (0,30 kgf/cm^2) can be applied.
6. *See also* SOLAS Reg. II-1/16. Where the door has been subject to the full hydrostatic test before installation, the hose test may be replaced by careful visual examination.
7. For shell doors providing watertight closure, watertightness is to be demonstrated through prototype testing before installation. The testing procedure is to be agreed with LR.

For tanks constructed of steel or aluminium, leak testing is to be carried out, prior to the application of a protective coating, on all fillet welds and erection welds on tank boundaries, excepting welds made by automatic processes and on all outfitting penetrations.

Selected locations of automatic erection welds and pre-erection manual or automatic welds may also be required to be tested before coating, at the discretion of the Surveyor, taking account of the quality control procedures of the shipyard. Where exempt from this requirement, leak testing may be carried out after the protective coating has been applied, provided that the welds have been carefully inspected to the satisfaction of the Surveyor.

7.3.5 **Hose testing.** This is to be carried out at a maximum distance of 1,5 m with a hose pressure not less than 2,0 bar (2,0 kgf /cm^2). The nozzle diameter is not to be less than 12 mm. The jet is to be targeted directly onto the weld or seal being tested.

7.3.6 **Hydropneumatic testing.** When this is performed, the safety precautions identified in 7.3.4 are to be followed.

7.3.7 For tanks of composite construction, leak testing is to be carried out to air pressures as indicated in 7.3.4.

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7.3.8 Structural testing may be carried out afloat where testing using water is undesirable in dry-dock or on the building berth. The testing afloat is to be carried out by separately filling each tank and cofferdam to the test head given in Table 1.7.1. Alternate tanks and cofferdams may be filled to the test head and the bottom and lower side shell in the intermediate empty tanks and cofferdams and all boundaries are to be examined and the remainder of the bottom and lower side shell and boundaries examined when the water is transferred to the remaining tanks.

7.3.9 Where permitted by Table 1.7.1, complete structural testing may be replaced by a combination of leak and structural testing, as follows. The leak test is generally to be carried out on each tank while the craft is in dry-dock or on the building berth.

(a) Double bottom tanks and cofferdams may be leak tested on the berth, and structural tests carried out afloat.

(b) All deep tanks are to be structurally tested. However, where a number of similar tanks is involved, one typical tank is to be structurally tested and for the remaining tanks the Surveyor may, at his discretion, permit leak testing in lieu of structural testing.

(c) Interconnecting deep and double bottom tanks and 'flume' type stabilisation tanks are to be structurally tested to the test head given in Table 1.7.1.

7.3.10 Equivalent proposals for testing will be considered.

7.3.11 **Trial trip and operational tests.** The items listed in Table 1.7.2 are to be tested on completion of the installation or at sea trials.

Table 1.7.2 Trial trip and operational tests

Item	Requirement
Sliding watertight doors	To be operated under working conditions.
Windlass	An anchoring test is to be carried out in the presence of the Surveyor. The test is to demonstrate that the windlass with brakes, etc., functions satisfactorily and that the power to raise the anchor can be developed and satisfies the Rule requirements. For Rule requirements, *see* Ch 5,8.
Steering gear, main and auxiliary	To be tested under working conditions, to the satisfaction of the Surveyors, to demonstrate that the Rule requirements are met. For Rule requirements, *see* Pt 14, Ch 1.
Davits and deck cranes	To be tested under working conditions to proof load to the satisfaction of the Surveyors.
Fire flaps	To be operated under working conditions to the satisfaction of the Surveyors.
Means of escape	Alternative means of escape from machinery and accommodation spaces is to be proven to the satisfaction of the Surveyors. For Rule requirements, *see* Ch 2,4.10.

Section 8 Building tolerances and associated repairs

8.1 Tolerances – General

8.1.1 Tolerances to be used regarding the acceptability of defects affecting raw materials are to be in accordance with 8.2.

8.1.2 Tolerances to be used for constructional misalignment for all materials are to be discussed between Owners/ Builders and the Surveyor and acceptable Standards agreed subject to the requirements of this Chapter or National Authority requirements where applicable. The permitted degree of inaccuracy/misalignment will vary according to whether the defect is:

(a) In primary structure.

(b) In secondary structure.

(c) Aesthetically pleasing.

8.1.3 The requirements in respect of constructional misalignment of steel/aluminium craft are to be found in 8.6. The requirements for construction using composite materials are contained in Pt 8, Ch 2.

8.2 Raw material surface tolerances

8.2.1 The surface cleanliness of steel/aluminium alloy materials in preparation for painting is to be in accordance with National or paint Manufacturer's Standards.

8.2.2 Where approved corrosion control coatings are to be used the quality of the surface treatment is to be in accordance with the grade specified in the approval documents.

8.3 Surface defects

8.3.1 The limits of depth and extent of surface defects on plate, cast or forged materials in relation to the material plate thickness are shown in Table 1.8.1.

8.3.2 Defects are to be made good by grinding only subject to the plate thickness not being reduced by more than seven per cent of the nominal thickness or 3 mm whichever is the lower, and the area involved not exceeding two per cent of the surface area.

8.3.3 When the limits in 8.3.1 are exceeded, plates may be made good by weld repair in accordance with the requirements specified in Chapter 13 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

8.3.4 Where the depth of the deepest imperfection exceeds 20 per cent of the nominal thickness, or the defective area exceeds two per cent of the total surface area, such areas are to be cropped and replaced. *See* 8.5.

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Table 1.8.1 Limits of surface defects

Normal thickness of material (mm)	Maximum permissible depth of defect (mm)	
	Area affected – Unlimited	Area affected ≤ 5% of Surface
< 8	0,2	0,4
8 to 25	0,3	0,5
25 to 40	0,4	0,6
≥ 40	0,5	0,8

NOTES
1. Defects are to be measured after shot blasting or plate cleaning.
2. The depth of the deepest imperfection is to be considered.
3. Defects not exceeding the limits shown need not be repaired.
4. Where the depth of the defect reduces the material thickness to below the rolling/forging/casting tolerance (stated in the Rules for Materials) the values in column 2 and 3 will be accepted provided the areas involved do not exceed 15% and 2% respectively, of the plate/forging/casting surface.
5. Defects exceeding the above limits are to be repaired.
6. Crack-like defects are always to be repaired irrespective of their depth.

8.3.5 Complete removal of the defects is to be verified by suitable non-destructive examination techniques and after welding the repair is to be proved free from further defects. The complete removal of defects is to be verified by non-destructive examination in accordance with the requirements specified in Chapter 13 of the Rules for Materials.

8.3.6 Care is to be taken in the repair of defects in higher tensile steel, and aluminium alloy materials. Low hydrogen electrodes with similar properties to the higher tensile steel is to be used with preheating as necessary. Aluminium alloys are to be heat treated after repair, *see* Pt 7, Ch 2,3.

8.4 Plate laminations

8.4.1 Plates in which laminations are suspected or detected are to be ultrasonically tested to determine the full extent of such laminations.

8.4.2 Where laminations are confined to the plate edge, are less than 300 mm long and whose penetration is not more than half the plate thickness, then the defect may be chipped or ground out and rebuilt with weld material.

8.4.3 Where laminations are isolated, located near to the plate surface, and where the total area of the defect does not exceed two per cent of the surface area of the plate, the defect may be repaired as in 8.4.2.

8.4.4 Defective plate, with defects in excess of those stated in 8.4.2 and 8.4.3, is to be cropped back and replaced. *See* 8.5.

8.4.5 Complete removal of the defect is to be verified by non-destructive examination, and after welding, the repair is to be proved free from further defects.

8.5 Part replacement of plates

8.5.1 When defects exceed the limits laid down in 8.3.4 and 8.4.4 above, the portion of the plate affected is to be cropped and replaced, *see* Table 1.8.2.

8.6 Structural misalignment and fit (steel and aluminium)

8.6.1 For the requirements for the alignment and structural continuity of joints, *see* Chapter 2 of Parts 6 and 7.

8.6.2 Tables 1.8.3, 1.8.4 and 1.8.5 define the minimum limits of accuracy required to be achieved in the various welded joint designs. When these values are not achieved, the defects are to be discussed and agreed by the Builder and the Surveyor before remedial action is taken.

8.6.3 Welding defects are generally to be dealt with in accordance with Chapter 13 of the Rules for Materials. Limits for weld undercut and remedial action to be taken depends on plate thickness and are to be discussed and agreed by the Builder and the Surveyor prior to commencement of repairs.

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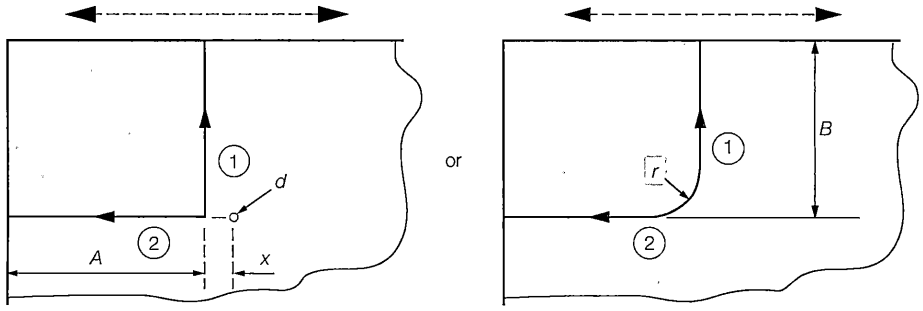
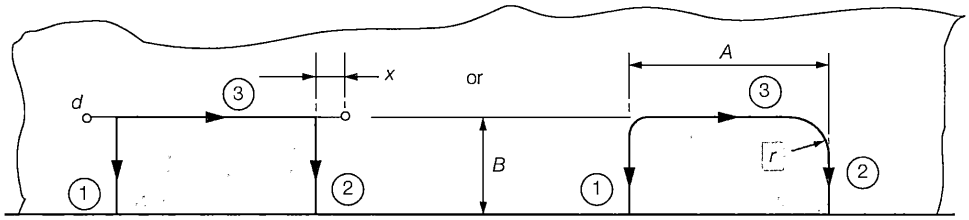
Table 1.8.2 Part replacement of plates

A x B	Parts to be replaced	Shell, strength deck, tank top, top and bottom strakes of longitudinal bulkheads	Elsewhere
	End and corner of plate	1000 x 1000	1000 x 300
	Side of plate	1000 x 300	1000 x 300
	Insert	1000 x 300	1000 x 300

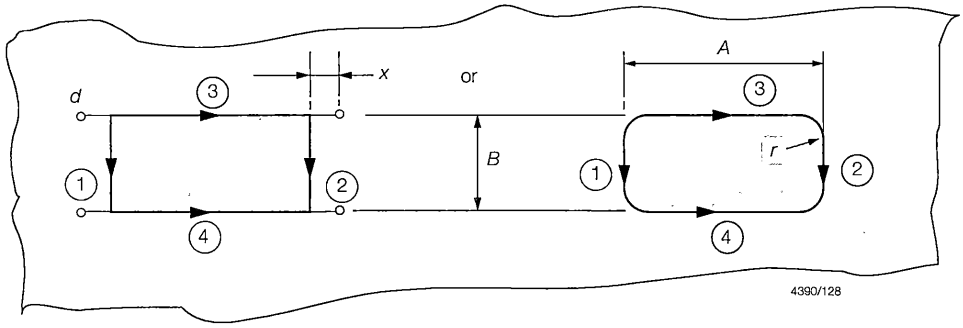
Line of plate replacement to be not less than 100 from extreme edge of defect.
All dimensions are in mm.



(a) Corner or end replacement



(b) Side replacement



(c) Internal replacement

1 Weld sequence

Weld direction

Direction of principal stress

NOTES
1. All dimensions are minimum.
2. Rolling direction of replaced plate to be the same as that of the parent plate.
3. Minimum distance from outermost defect to line of weld – 100 mm.
4. Dimensions in millimetres:
   x = 50
   d = 1,5 x plate thickness with minimum 6 and maximum 20
   r = 75 minimum

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Table 1.8.3 Structural misalignment and fit (steel and aluminium)

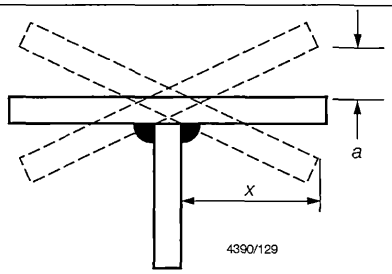
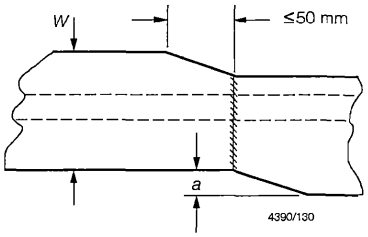
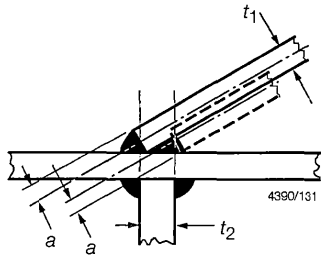
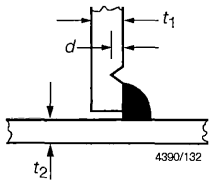
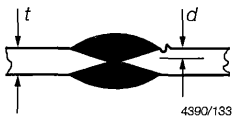
Joint	Location	Acceptable *dimensions (mm)*	Remedial action	
	Fabricated frames Beams, girders and longitudinals	$a \leq \pm 0{,}03$ x	$a > \pm 0{,}03$ x	Reject
	Butt welded face flats primary structure	$a \leq 0{,}03W$ (max 6 mm)	$a > 0{,}03W$	Reject
	Secondary structure	$a \leq 0{,}04W$ (max 8 mm)	$a > 0{,}04W$	Reject
	Obtuse angle fillet weld	$a \leq t_1/2$	$a > t_1/2$	Reject
	All areas	$d \leq 0{,}1t_1$ (max 0,8 mm)	$d > 0{,}1t_1$	Repair by welding or grinding depends on thickness 't_1' in accordance with 8.3
	All areas	$d \leq 0{,}1t$ (max 0,8 mm)	$d > 0{,}1t$	As above

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Table 1.8.4 Structural misalignment and fit (steel and aluminium)

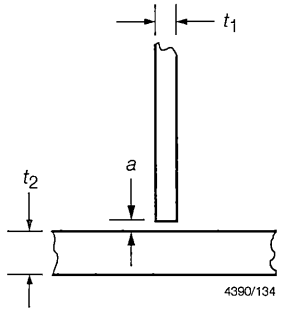
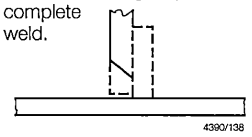
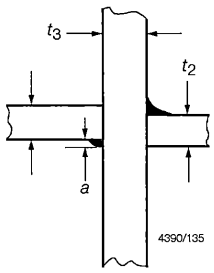
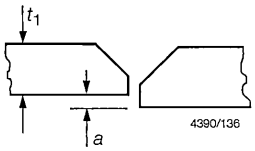
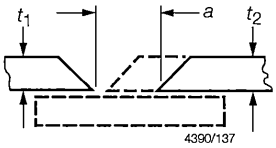
Joint	Location	Permitted misalignment	Remedial action	
	All areas (Continuous fillet weld)	a (mm) $a < 0,25t_1$ (max = 1 mm)	a (mm) $0,25t_1$ to $0,5t_1$ (t_1 max = 5 mm)	Increase weld leg length by 'a'
			$0,5t_1$ to t_1 (t_1 max = 15 mm)	Vee material to +/–45°. Fit backing strip and weld. Remove backing strip and complete weld. 
			$a > t_1$	Realign and replace
	All areas (intermittent weld)	$< 0,25t_1$	0,25 to $0,5t_1$ (t_1 max = 3 mm)	Increase weld lengths by 50%
			$0,25t_1$ to $0,5t_1$ (t_1 max = 5 mm)	Continuous weld
			$a > t_1$	As for continuous weld above
	Strength members	$a \le t_2/3$	$t_2/3 \le a \le t_1/2$	Increase weld leg length of welds by 10%
	Others	$a \le t_2/2$	$a > t_2/2$	Realign
	Higher tensile steel joint in designated critical areas	$a \le t_3/3$	$a > t_3/3$	Realign
	Strength members	$a \le 0,15t_1$ (max 3,0 mm)	$a > 0,15t_1$	Realign
	Others	$a \le 0,2t_1$ (max 3,0 mm)	$a > 0,2t_1$	Realign
	All areas	a in accordance with weld procedure	$a \le t_1$	Build one side of butt until a in accordance with weld procedure
			$a > t_1$ (max 10 mm)	Cut back 150 mm and fit insert plate

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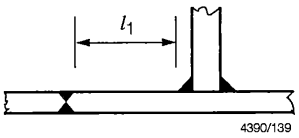
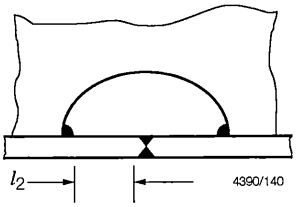
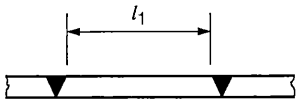
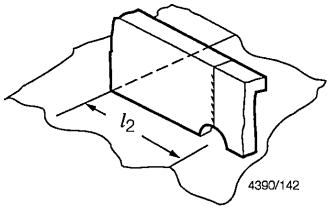
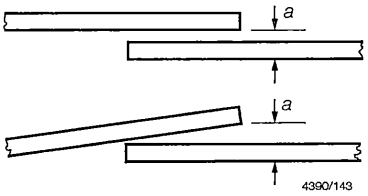
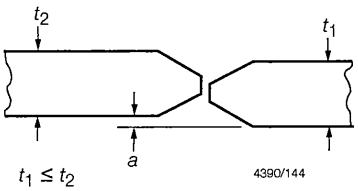
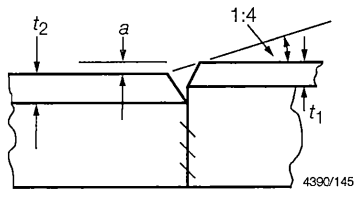
Table 1.8.5 Structural misalignment and fit (steel and aluminium)

Joint	Location	Acceptable dimensions (mm)	Remedial action	
	All	$l_1 \geq 40$ mm	—	Adjust to suit
	All	$l_2 \geq 20$ mm	—	Adjust to suit
	All	$l_1 > 50$ mm	$l_1 < 30$ mm	Treat as an insert
	All	$l_2 \geq 20$ mm	$l_2 < 15$ mm	Adjust to suit
	All All	$a \leq 1,0$ $a \leq 1,0$	$a < 5$ $a \leq 5$	Increase weld leg length by actual 'a' Adjust to suit
	Strength members Other	$a \leq 0,15t_1$ (max 3,0 mm) $a \leq 0,2t_1$ (max 3,0 mm)	$a > 0,15t_1$ $a > 0,2t_1$	Reject Reject
	All	For angle or tee longitudinal $a \leq 0,2t_1$ For offset bulb longitudinal $a \leq 0,2t_2$	$a > 0,2t_1$ $a > 0,2t_2$	Reject Reject

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8.7 Post welding plate deformation

8.7.1 Post welding plate deformation for steel and aluminium alloy construction is to be limited, *see* Table 1.8.6 and Fig. 1.8.1.

Table 1.8.6 Plate deformation limits

Position	*s/t*	δ_p/s
in 0,6*L* amidship	≤ 80 > 80	1/100 1/75
Remainder	all	1/50

Where
s = stiffener spacing, in mm
t = plating thickness, in mm
δ_p = panel deflection, in mm

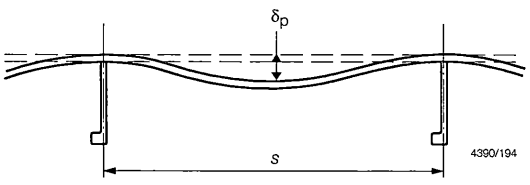

Fig. 1.8.1 Measurement of plate deformation

8.7.2 Deformation outside the limits of Fig. 1.8.1 is to be faired by local heating or the plating renewed.

8.7.3 Local heating of steel is not to exceed 900°C (red heat) when flame straightening is employed.

8.7.4 Local heating of aluminium alloys is not to be carried out. All repairs are to be by renewal of plating.

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Section

1 **General**

2 **Rule structural concept**

3 **Structural idealisation**

4 **Bulkhead arrangements**

5 **Fore and aft end arrangements**

6 **Machinery space arrangements**

7 **Superstructures, deckhouses and bulwarks**

8 **Particular requirements for multi-hulls**

■ *Section 1* General

1.1 Application

1.1.1 This Chapter illustrates the general principles to be adopted in applying the structural requirements given in Parts 4, 6, 7 and 8. In particular, consideration has been given to the layout of the Rules as regards the different regions of the craft, principles for taper of hull scantlings, definition of span point, derivation of section moduli and basic design loading for deck structures. Principles for subdivision are also covered.

1.1.2 Where additional requirements relating to particular craft types apply, these requirements are indicated in the appropriate Parts and are to be complied with as necessary.

■ *Section 2* Rule structural concept

2.1 General

2.1.1 The Rules are based on the concept that the structural and watertight integrity and general safe operation of the craft will not be compromised by static and dynamic loads experienced during normal operating conditions.

2.2 Scantlings

2.2.1 Scantlings are generally based on the strength required to withstand loads imposed by the sea, cargo, passengers, ballast, bunkers and other operational loads. However, the Rules assume that the nature and stowage of the cargo, ballast, etc., are such as to avoid excessive structural stress.

2.2.2 Design loads and pressures as given in Part 5, are to be used with scantling formulae or direct calculation methods to derive scantlings based on maximum allowable stress or other suitable strength criteria.

2.2.3 Hull structural vibration resulting from cyclic loadings arising from the sea and other sources are to be such that the normal operation and structural integrity of the craft are not impaired. However these aspects are outwith the scope of classification, *see* Pt 1, Ch 2,1.4.

2.3 Definition of requirements

2.3.1 Static loads are based on standard conditions defined in Part 5, or determined from loading conditions submitted by the Builder.

2.3.2 Dynamic loadings are examined for both the local and global structures. These loadings are based upon the designer's stated operational and environmental conditions or the Rule minimum criteria, whichever is the greater.

2.3.3 Wave induced loads are considered both in the static condition, i.e. hydrostatic and pitching pressures, and in the dynamic mode, i.e. impact, slamming and hogging and sagging wave landing conditions.

2.3.4 Hull girder strength will in general require to be investigated dependent upon the length, configuration, proportions, proposed loadings, etc., of the craft.

2.3.5 Scantling requirements in respect of miscellaneous items of structure such as local foundations, base plates, insert plates, etc., are not specifically indicated within these Rules. However the acceptance of such items will be specially considered on the basis of experience, good practice and direct calculation where appropriate.

2.4 Definitions and structural terms

2.4.1 The various definitions and structural terms for use throughout this Chapter are as indicated within the appropriate Section.

2.5 Symbols

2.5.1 The various symbols for use throughout this Chapter are as indicated within the appropriate Section.

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Section 3
Structural idealisation

3.1 General

3.1.1 The scantling formulae in the Rules are normally based on elastic or plastic theory using simple beam models supported at one or more points and with varying degrees of fixity at the ends, in association with an appropriate concentrated or distributed load for steel and aluminium craft.

3.1.2 Apart from a local requirement for web or flange thicknesses, the stiffener, beam or girder strength is defined by a section modulus and moment of inertia requirement.

3.1.3 For the derivation of scantlings for fibre composite structures, the formulae are based on equivalent load carrying capability, with limitations on both allowable stress and strain, in addition to deflection controls.

3.2 Geometric properties of sections

3.2.1 The symbols used in this sub-Section are defined as follows:

b = the actual width, in metres, of the load-bearing plating, i.e. one-half of the sum of spacings between parallel adjacent members or equivalent supports

$f = 0{,}3\left(\frac{l}{b}\right)^{2/3}$

but is not to exceed 1,0. Values of this factor are given in Table 2.3.1

l = the overall length, in metres, of the primary support member, as indicated in Fig. 3.1.2 in Pt 6, Ch 3 and Pt 7, Ch 3, respectively, for steel and aluminium alloy construction and Fig. 3.1.4 of Pt 8, Ch 3 for composite construction

t_p = the thickness, in mm, of the attached plating. Where this varies, the mean thickness over the appropriate span is to be used.

3.2.2 The effective geometric properties of rolled or built sections may be calculated directly from the dimensions of the section and associated effective area of attached plating. Where the web of the section is not normal to the attached plating, and the angle exceeds 20°, the properties of the section are to be determined about an axis parallel to the attached plating.

3.2.3 The geometric properties of rolled or built stiffener sections and of swedges are to be calculated in association with effective area of attached load bearing plating of thickness, t_p, mm and of width as given by Pt 6, Ch 3,1.10 or Pt 7, Ch 3,1.11 for steel and aluminium alloy construction respectively. In no case, however, is the width of plating to be taken as greater than either the spacing of the stiffeners or the width of the flat plating between swedges, whichever is appropriate. The thickness, t_p, is the actual thickness of the attached plating. Where this varies, the mean thickness over the appropriate span is to be used.

3.2.4 The effective section modulus of a corrugation over a spacing, s_c, is to be calculated from the dimensions and, for symmetrical corrugations, may be taken as:

$$z = \frac{d_w\,(3b\,t_p + c\,t_w)}{6000}\ \text{cm}^3$$

where

d_w, b, t_p, c and t_w are measured, in mm, and are as shown in Fig. 2.3.1. The value of b is to be taken not greater than:

$50t_p\sqrt{\frac{235}{\sigma_0}}$ for welded corrugations

$60t_p\sqrt{\frac{235}{\sigma_0}}$ for cold formed corrugations

where

σ_0 is defined in Ch 3,1.2.

The value of θ is not to be taken less than 40°. The moment of inertia is to be calculated from:

$$I = 0{,}05 d_w Z\ \text{cm}^4$$

Table 2.3.1 Values of factor *f*

$\frac{l}{b}$	f	$\frac{l}{b}$	f
0,5	0,19	3,5	0,69
1,0	0,30	4,0	0,76
1,5	0,39	4,5	0,82
2,0	0,48	5,0	0,88
2,5	0,55	5,5	0,94
3,0	0,62	6,0 and above	1,00

NOTE
Intermediate values to be obtained by linear interpolation.

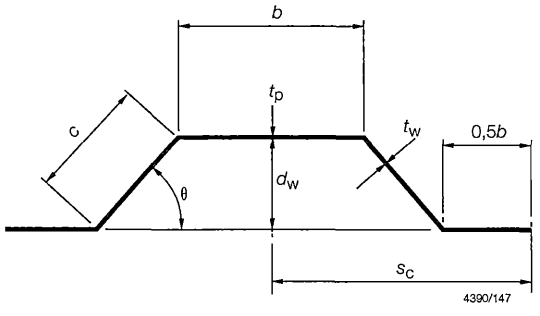

Fig. 2.3.1 Corrugation

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3.2.5 The section modulus of a double plate bulkhead over a spacing, b, may be calculated as:

$$Z = \frac{d_w (6f\, b\, t_p + d_w\, t_w)}{6000} \text{ cm}^3$$

where

d_w, b, t_p and t_w are measured, in mm, and are as shown in Fig. 2.3.2.

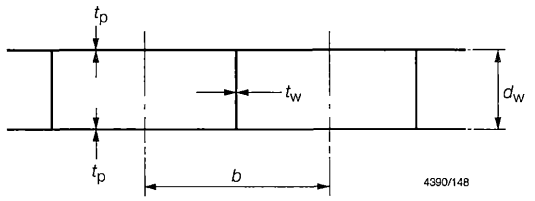

Fig. 2.3.2 Double plate bulkhead

3.2.6 The effective section modulus of a fabricated section may be taken as:

$$Z = \frac{a\, d_w}{10} + \frac{t_w\, d_w^2}{6000}\left(1 + \frac{200\,(A - a)}{200A + t_w\, d_w}\right) \text{ cm}^3$$

where

a = the area of the face plate of the member, in cm^2

d_w = the depth, in mm, of the web between the inside of the face plate and the attached plating. Where the member is at right angles to a line of corrugations, the minimum depth is to be taken

t_w = the thickness of the web of the section, in mm

A = the area, in cm^2, of the attached plating, *see* 3.2.7 If the calculated value of A is less than the face area, a, then A is to be taken as equal to a.

3.2.7 The geometric properties of primary support members (i.e. girders, transverses, webs, stringers, etc.) are to be calculated in association with an effective area of attached load bearing plating, A, determined as follows:

(a) For a member attached to plane plating:

$A = 10f\, b\, t_p$ cm^2

where

f is as defined in 3.2.1.

(b) For a member attached to corrugated plating and parallel to the corrugations:

$A = 10b\, t_p$ cm^2

(*See* Fig. 2.3.1)

(c) For a member attached to corrugated plating and at right angles to the corrugations:

A is to be taken as equivalent to the area of the face plate of the member.

3.3 Determination of span point

3.3.1 The effective span, l_e, of a stiffening member is to be as defined in Parts 6, 7 and 8, for steel, aluminium alloy and composite construction respectively.

3.4 Calculation of hull section properties

3.4.1 The particular requirements for the calculation of the hull section modulus for craft of steel and aluminium alloy construction are defined in Pt 6, Ch 6 and Pt 7, Ch 6 respectively. The particular requirements for the hull section stiffness for craft of composite construction are defined in Pt 8, Ch 6.

■ *Section 4* Bulkhead arrangements

4.1 General

4.1.1 Watertight bulkheads are, in general, to extend to the uppermost continuous watertight deck, hereinafter referred to as the bulkhead deck, and their construction is to be in accordance with Parts 6, 7 and 8 as appropriate.

4.1.2 Where openings are permitted in bulkheads they are to be provided with suitable closing devices in accordance with Ch 4,2.

4.2 Number and disposition of bulkheads

4.2.1 All craft with a Rule length, L_R, greater than 15 m are to have a collision bulkhead.

4.2.2 In motor craft with a Rule length, L_R, less than or equal to 15 m, the machinery is to be enclosed by gastight bulkheads to protect accommodation spaces from gas and vapour fumes from machinery, exhaust and fuel systems.

4.2.3 In all craft with a Rule length, L_R, less than or equal to 25 m, the sterntube is to be enclosed in a watertight compartment, wherever practicable.

4.2.4 All craft with a Rule length, L_R, greater than 25 m are to have an aft peak bulkhead, generally enclosing the sterntubes in a watertight compartment.

4.2.5 All craft with a Rule length, L_R, greater than 15 m are to have a watertight bulkhead at each end of the machinery space, where the machinery is amidships or a watertight bulkhead at the forward end of the machinery space, where the machinery is aft.

4.2.6 All craft with a Rule length, L_R, greater than 25 m are to have a watertight bulkhead at each end of the machinery space, with the aft peak bulkhead forming the aft bulkhead of the machinery space, where the machinery is aft.

4.2.7 Additional watertight bulkheads are to be fitted so that the total number of bulkheads is at least in accordance with Table 2.4.1.

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Table 2.4.1 Total number of bulkheads

Length, L_R, in metres	Total number of bulkheads	
	Machinery amidships	Machinery aft
> 15 ≤ 25	3	2
> 25 ≤ 65	4	3*
> 65 ≤ 85	4	4*
> 85 ≤ 90	5	5*
> 90 ≤ 105	5	5*
> 105 ≤ 115	6	5*
> 115 ≤ 125	6	6*
> 125 ≤ 145	7	6*
> 145	To be individually considered	

*With afterpeak bulkhead forming after boundary of machinery space

4.2.8 Bulkheads are to be spaced at reasonably uniform intervals. Where non-uniform spacing is unavoidable and the length of a compartment is unusually great, the transverse strength of the craft is to be maintained by fitting of web frames, increased framing, etc., and details are to be submitted.

4.2.9 Proposals to dispense with one or more of these bulkheads will be considered, subject to suitable structural compensation, if they interfere with the requirements of a special trade.

4.2.10 Where applicable, the number and disposition of bulkheads are to be arranged to suit the requirements for subdivision, floodability and damage stability, and are to be in accordance with the requirements of the National Authority.

4.3 Collision bulkhead

4.3.1 The collision bulkhead in all craft other than passenger craft, patrol craft and yachts is to be positioned as detailed in Table 2.4.2. Consideration will, however, be given to proposals for the collision bulkhead to be positioned slightly further aft on Arrangement (b) craft, but not more than $0{,}08L_L$ from the fore end of L_L, provided that the application is accompanied by calculations showing that flooding of the space forward of the collision bulkhead will not result in any part of the freeboard deck becoming submerged, or any unacceptable loss of stability. Special consideration may be given to the extent of the collision bulkhead above the bulkhead deck for multi-hull craft.

4.3.2 The collision bulkhead in passenger craft, patrol craft and yachts is to be in accordance with the following:

(a) A craft shall have a forepeak or collision bulkhead, which shall be watertight up to the bulkhead deck. (The bulkhead deck is the uppermost deck up to which the transverse watertight bulkheads are carried, *see* 4.2.10). This bulkhead is to be positioned as detailed in Table 2.4.3.

Table 2.4.2 Collision bulkhead position (excluding passenger craft, patrol craft and yachts)

Arrangement	Length, L_L	Distance of collision bulkhead aft of the fore end of L_L, in metres	
		Minimum	Maximum
(a)	≤ 150	$0{,}05L_L$	$0{,}08L_L$
(b)	≤ 150	$0{,}05L_L - f_1$	$0{,}08L_L - f_1$

Symbols and definitions

$f_1 = \frac{G}{2}$ or $0{,}015L_L$, whichever is the lesser

G = projection of bulbous bow forward of fore end of L_L, in metres

L_L is as defined in Ch 1,6.2

Arrangement (a) A craft that has no part of its underwater body extending forward of the fore end of L_L

Arrangement (b) A craft with part of its underwater body extending forward of the fore end of L_L (e.g. bulbous bow)

(b) If the craft has a long forward superstructure, the forepeak or collision bulkhead is to be extended weathertight to the deck next above the bulkhead deck. The extension need not be fitted directly over the bulkhead below, provided it is located within the limits specified in Table 2.4.3 with the exemption permitted by 4.6.3 and the part of the bulkhead deck which forms the step is made effectively weathertight.

4.3.3 Alternative arrangements may be submitted for consideration in the case of sailing and auxiliary craft.

4.3.4 For craft with pronounced rake of stem, the position of the collision bulkhead will be specially considered.

4.3.5 Accesses are not to be fitted in collision bulkheads. In particular designs where it would be impracticable to arrange access to the fore peak other than through the collision bulkhead, access may be permitted subject to special consideration. Where accesses are provided, the openings are to be as small as practicable and positioned as far above the design waterline as possible. The closing appliances are to be watertight, to open into the fore peak compartment and consideration will be given to operation from one side only.

4.4 Aft peak bulkhead

4.4.1 An aft peak bulkhead, where required to be fitted (in each half of a multi-hull craft) is, in general, to enclose the sterntube, water jet unit, etc., in a watertight compartment. In twin screw craft the sterntubes are to be enclosed in suitable watertight spaces. *See also* Table 2.4.1.

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Table 2.4.3 Collision bulkhead for passenger craft, patrol craft and yachts

Arrangement	Distance of collision bulkhead aft of fore perpendicular, in metres	
	Minimum	Maximum
(a)	$0{,}05L_{pp}$	$3 + 0{,}05L_{pp}$
(b)	$0{,}05L_{pp} - f$	$3 + 0{,}05L_{pp} - f$
Symbols and definitions		
$f = \frac{G}{2}$ or $0{,}015L_{pp}$, whichever is the lesser G = projection of bulbous bow forward of fore perpendicular, in metres L_{pp} is as defined in Ch 1, 6.2 Arrangement (a) A craft that has no part of its underwater body extending forward of the fore perpendicular. Arrangement (b) A craft with part of its underwater body extending forward of the fore perpendicular, e.g. bulbous bow.		

4.5 Height of bulkhead

4.5.1 The collision bulkhead is normally to extend to the uppermost continuous deck or, in the case of craft with combined bridge and forecastle or a long superstructure which includes a forecastle, to the superstructure deck. However, if a craft is fitted with more than one complete superstructure deck, the collision bulkhead may be terminated at the deck next above the freeboard deck. Where the collision bulkhead extends above the freeboard deck, the extension need only be to weathertight standards.

4.5.2 The aft peak bulkhead may terminate at the first deck above the load waterline, provided that this deck is made watertight to the stern or to a watertight transom floor. In passenger craft the aft peak bulkhead is to extend watertight to the bulkhead deck. However, it may be stepped below the bulkhead deck provided the degree of safety of the craft as regards watertight subdivision is not thereby diminished.

4.5.3 The remaining watertight bulkheads are to extend to the bulkhead deck. In passenger craft of restricted draught and all craft of unusual design, the height of the bulkheads will be specially considered.

4.6 Watertight recesses, flats and loading ramps

4.6.1 Watertight recesses in bulkheads are generally to be so framed and stiffened as to provide strength and stiffness equivalent to the requirements for watertight bulkheads.

4.6.2 In collision bulkheads, any recesses or steps in the bulkhead are to fall within the limits of bulkhead positions given in 4.3.1 or 4.3.3 as applicable. Where the bulkhead is extended above the freeboard deck, or bulkhead deck in passenger craft, the extension need only be to weathertight standards. If a step occurs at that deck, the deck need also only be to weathertight standards in way of the step, unless the step forms the crown of a tank, in which case the requirements for deep tank structures are to be complied with.

4.6.3 In craft fitted with bow doors, in which a sloping loading ramp forms part of the collision bulkhead above the freeboard or bulkhead deck, that part of the ramp which is more than 2,30 m above the freeboard or bulkhead deck may extend forward of the minimum limit specified in Table 2.4.2 or Table 2.4.3 as appropriate. Such a ramp is to be weathertight over its complete length.

4.7 Gastight bulkheads

4.7.1 Where bulkheads are required to be gastight in accordance with 4.2.2, and where it is proposed to pierce such bulkheads for the passage of cables, pipes, vent trunking, etc., gastight glands are to be provided to maintain the gastight integrity.

4.8 Tank bulkheads

4.8.1 The scantlings of deep tank bulkheads are to be in accordance with Ch 3,7 of Parts 6, 7 and 8, for steel, aluminium alloy and composite structures respectively.

4.8.2 A centreline bulkhead is, generally, to be fitted in deep tanks which extend from side to side of the craft. The bulkhead may be intact or perforated as desired. If intact, the scantlings are to be as required for boundary bulkheads. If perforated, the modulus of stiffeners may be 50 per cent of that required for boundary bulkheads, using a head measured to the crown of the tank.

4.8.3 The arm length of brackets at the ends of the stiffeners is to be 2,5 times the depth of stiffener. The thickness of the brackets is to be not less than the web thickness of the stiffener.

4.8.4 Air and sounding pipes are to comply with the requirements of Pt 15, Ch 2,11.

4.9 Cofferdams

4.9.1 Tanks carrying oil fuel or lubricating oil are to be separated by cofferdams from those carrying feed water, fresh water, edible oil or similar oils. Similarly tanks carrying vegetable or similar oils are to be separated by cofferdams from those carrying fresh or feed water. Cofferdams are to be fitted between freshwater tanks and black or grey water tanks.

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4.9.2 Lubricating oil tanks are also to be separated by cofferdams from those carrying oil fuel. However such cofferdams need not be fitted provided that:

(a) Common boundaries of lubricating oil and oil fuel tanks have full penetration welds.

(b) The tanks are arranged such that the oil fuel tanks are not generally subjected to a head of oil in excess of that in the adjacent lubricating oil tanks.

4.9.3 Cofferdams are not required between oil fuel double bottom tanks and deep tanks above, provided that the inner bottom plating is not subjected to a head of oil fuel.

4.9.4 Where fitted, cofferdams are to be suitably ventilated.

4.9.5 If oil fuel tanks are necessarily located within or adjacent to the machinery spaces, their arrangement is to be such as to avoid direct exposure of the bottom from rising heat resulting from an engine room fire. *See* Part 17 as applicable.

4.9.6 In passenger craft, water ballast is, in general, not to be carried in tanks intended for oil fuel. Attention is drawn to the Statutory Regulations issued by National Authorities in connection with the *International Convention for the Prevention of Pollution of the Sea by Oil, 1973/78.*

4.10 Means of escape

4.10.1 For the requirements for means of escape on service craft and yachts over 24 m in length, *see* Pt 17, Ch 2 and Pt 17, Ch 3 respectively.

4.10.2 The arrangement of the hull is to be such that all underdeck compartments are as accessible as practicable and provided with a satisfactory means of escape. Access and escape hatches to the machinery and tanks are not to be obstructed by deck coverings or furniture.

4.11 Carriage of low flash point fuels

4.11.1 Special provision is to be made for the carriage of low flash point fuel in accordance with Pt 15, Ch 3,5.

■ *Section 5* Fore and aft end arrangements

5.1 General

5.1.1 The requirements in respect of the general constructional arrangements for mono-hull craft covered by the Rules are contained within this Section.

5.2 Structural configuration

5.2.1 The Rules provide for both longitudinal and transverse framing systems.

5.3 Structural continuity

5.3.1 Suitable scarfing arrangements are to be made to ensure continuity of strength and the avoidance of abrupt structural changes.

5.3.2 Where longitudinal framing terminates and is replaced by a transverse system, adequate arrangements are to be made to avoid an abrupt changeover. Where a forecastle is fitted extending aft of 0,15L from the F.P., longitudinal framing at the upper deck and topsides is generally to be continued forward of the end bulkhead of this superstructure.

5.4 Minimum bow height and reserve buoyancy

5.4.1 All sea-going craft are to be fitted with forecastles, or increased sheer on the upper deck or equivalent, such that the distance from the summer load waterline to the top of the exposed deck at side at the F.P. is not less than:

$$H_b = \left(6075\left(\frac{L_L}{100}\right) - 1875\left(\frac{L_L}{100}\right)^2 + 200\left(\frac{L_L}{100}\right)^3\right) \times \left(2{,}08 + 0{,}609C_b - 1{,}603C_{wf} - 0{,}0129\left(\frac{L_L}{d_1}\right)\right)$$

where

d_1 = draught at 85 per cent of the depth D, in metres

A_{wf} = waterplane area forward of $\frac{L_L}{2}$ at draught d_1, in m^2

B = moulded breadth, in metres

C_b = block coefficient as defined in the Load Lines Convention

C_{wf} = the waterplane area coefficient forward of

$$C_{wf} = \frac{A_{wf}}{\left(\frac{L_L}{2}\right) \times B}$$

H_b = minimum bow height

L_L = Load Line length, in metres.

5.4.2 Craft which are designed to suit exceptional operational requirements, restricted in their service to Group G1, or of novel configuration will be specially considered on the basis of the Rules.

5.4.3 Where the bow height required in 5.4.1 is obtained by sheer, the sheer shall extend for at least 15 per cent of the length of the craft measured abaft the forward end of L_L. Where it is obtained by fitting a forecastle, the forecastle shall extend from the stem to a point at least 0,07L_L abaft the forward end of L_L, and shall be enclosed.

5.4.4 Craft shall have additional reserve buoyancy in the fore end in accordance with the Load Lines Convention.

5.5 Bow crumple zone

5.5.1 In general, the bow crumple zone is that space forward of the collision bulkhead. Passenger and crew accommodation and the carriage of fuel and other oils is not permitted in the bow crumple zone.

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5.6 Strengthening of bottom forward

5.6.1 Except for craft with **G1** and **G2** service notations, additional strengthening of bottom forward is required for craft with the rule length, L_R, greater than 65 m. Details are to be submitted for consideration.

5.7 Bulbous bows

5.7.1 Where a bulbous bow is fitted, the structural arrangements are to be such that the bulb is adequately supported and integrated into the fore peak structure.

5.7.2 At the fore end of the bulb the structure is generally to be supported by horizontal diaphragm plates spaced generally 1,0 m apart in conjunction with a deep centreline web.

5.7.3 In general, vertical transverse diaphragm plates are to be arranged in way of the transition from the peak framing to the bulb framing.

5.7.4 In way of a wide bulb, additional strengthening in the form of a centreline wash bulkhead is generally to be fitted.

5.7.5 In way of a long bulb, additional strengthening in the form of transverse wash bulkheads or substantial web frames spaced about five frame spaces apart are generally to be fitted.

5.7.6 The shell plating is to be increased in thickness at the fore end of the bulb and in other areas likely to be damaged by the anchors and chain cables. The increased plate thickness is to be the same as that required for plated stems.

5.8 Strengthening against bow flare slamming

5.8.1 Where a craft has pronounced flare or rake of bow, the structure in the forward region will be subject to special consideration, and the scantlings and arrangements may require additional strengthening.

■ *Section 6* Machinery space arrangements

6.1 General

6.1.1 This Section applies to all craft types. Only requirements particular to machinery spaces, including protected machinery casings and engine seatings, are given. For other scantlings and arrangement requirements, *see* the relevant Chapter in Parts 6, 7 and 8.

6.2 Structural configuration

6.2.1 Requirements are given for craft constructed using either a transverse or longitudinal framing system, or a combination of the two.

6.2.2 For machinery spaces situated aft, where the longitudinal framing terminates and is replaced by transverse framing, a suitable scarfing arrangement of the longitudinal framing is to be arranged. *See also* 5.3.

6.2.3 The maximum spacing, S_{max}, of web frames in longitudinally framed machinery spaces is not to exceed 3,8 m. Additionally for transversely framed craft, in way of a machinery space situated adjacent to the aft peak, the spacing of web frames is not to exceed six transverse frame spaces.

6.2.4 Where the machinery space is situated in the midship region, it is recommended that web frames be fitted in the engineroom, spaced not more than six frame spaces apart and extending from the tank top to the level of the lowest deck above the load waterline. The scantlings of these webs are to be such that the combined section modulus of the web frame and the main or 'tween deck frames is 50 per cent greater than that required for normal transverse framing. These webs may be omitted if the section modulus of the transverse frames is increased by 50 per cent.

6.3 Structural continuity

6.3.1 Suitable scarfing arrangements are to be made to ensure continuity of strength and the avoidance of abrupt discontinuities where structure which contributes to the main longitudinal strength of the craft is omitted in way of a machinery space.

6.4 Deck structure

6.4.1 The corners of machinery space openings are to be of suitable shape and design to minimise stress concentrations.

6.4.2 In motor craft having a Rule length, L_R, less than 15 m, the machinery is to be enclosed by gastight decks to protect accommodation spaces from gas and vapour fumes from machinery, exhaust and fuel systems.

6.5 Side shell structure

6.5.1 Side shell structure is to be constructed in accordance with the scantlings indicated in Parts 6, 7 and 8, for steel, aluminium alloy and composite structures respectively.

6.5.2 General requirements for web frames are given in this Section for both longitudinal and transverse framing systems. Where longitudinal framing is adopted in the midship region it is to be carried as far forward and aft as practicable.

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6.5.3 A transverse framing system is to be additionally reinforced by web frames fitted six frame spaces apart. Where a longitudinal framing system is adopted, the spacing of the transverses is not to exceed 2,5 m.

6.6 Double and single bottom structure

6.6.1 Where the Rule length, L_R, of the craft exceeds 50 m, a double bottom is to be fitted in the hull (or hulls in multi-hull craft), extending from the collision bulkhead to the forward watertight bulkhead for the machinery space.

6.6.2 Where the Rule length, L_R, of the craft exceeds 61 m, a double bottom is to be fitted outside the machinery space and is to extend to the collision bulkhead and the aft peak bulkhead. Where no aft peak bulkhead is fitted, the extent of the double bottom will be specially considered.

6.6.3 Where the Rule length, L_R, of the craft exceeds 76 m, the double bottom is to extend throughout the length of the craft.

6.6.4 For multi-hull craft and other craft which are to be assigned an **HSC** notation or which are to operate within **Restricted Service Groups G1**, **G2** and **G3**, the extent of the double bottom will be specially considered depending on the number of transverse watertight bulkheads and the requirements of the National Authority concerning stability after damage.

6.6.5 Margin plates and drainage wells are to be provided as necessary and subject to special consideration.

6.6.6 The scantlings of bottom stiffening, floors, centre girders and side girders are to be in accordance with the appropriate Sections of Parts 6, 7 and 8 of the Rules, for craft built in steel, aluminium alloy and composite respectively.

6.6.7 In motor craft the thickness of the floors in machinery spaces is to be 1mm greater than that required by the appropriate Sections of Parts 6 and 7 of the Rules, for craft built in steel and aluminium alloy respectively.

6.6.8 In craft having considerable rise of floor, the depth of the floor plate, or its height at side, may require to be increased. The transverse extent of double bottom will be specially considered.

6.6.9 Suitable arrangements are to be made to provide free passage of water from all parts of the bilge to the pump suctions.

6.6.10 A centreline girder is to be fitted in association with transverse frames, transverses supporting longitudinals or where the breadth of floors at the upper edge is greater than 1,5 m. Where the breadth of the floors at the upper edge exceeds 6,0 m a side girder is also to be fitted each side of the centre girder.

6.6.11 All girders are to extend as far forward and aft as practicable and care is to be taken to avoid any abrupt discontinuity.

6.6.12 Centreline girders fitted in association with flat plate keels are to be formed of intercostal or continuous plates with a continuous face flat welded on the upper edge.

6.6.13 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with 6.8.

6.7 Machinery casings

6.7.1 The scantlings and arrangements of exposed casings protecting machinery openings are to be in accordance with Ch 3,9.8, of Parts 6 and 7, for craft built in steel and aluminium alloy respectively.

6.7.2 Where casing stiffeners carry loads from deck transverses, girders, etc., or where they are in line with pillars below, they are to be suitably increased. *See also* Ch 3,10, Parts 6, 7 and 8, for craft built in steel, aluminium alloy and composite respectively.

6.7.3 Where casing sides act as girders supporting decks over, care is to be taken that access openings do not seriously weaken the structure. Openings are to be effectively framed and reinforced if found necessary. Particular care is to be paid to stiffening where the casing supports the funnel or exhaust uptakes.

6.7.4 Casing bulkheads are to be made gastight and the access doors are to be of a gastight self-closing type.

6.8 Integral fuel tanks

6.8.1 The scantlings of deep tank bulkheads are to be in accordance with Ch 3,7, of Parts 6, 7 and 8, for craft built in steel, aluminium alloy and composite respectively.

6.9 Machinery seatings

6.9.1 Main and auxiliary engines in motor and auxiliary sailing craft are to be effectively secured to the hull structure by seatings of adequate scantlings to resist the gravitational, thrust, torque and vibrating forces which may be imposed upon them.

6.9.2 The longitudinal girders forming the engine seatings are to extend as far forward and aft as practicable and be adequately supported by transverse floors or brackets.

6.9.3 In determining the scantlings of seats for oil engines, consideration is to be given to the general rigidity of the engine itself and to its design characteristics with regard to out of balance forces.

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6.9.4 The seats are to be so designed that they distribute the forces from the engine(s) as uniformly as possible into the supporting structure. Longitudinal girders supporting the seatings are to be arranged in single or double bottoms, and are, in general to extend over the full length of the machinery space. The ends of the girders are to be scarfed into the bottom structure for at least two frame spaces. Adequate transverse brackets are to be arranged in line with floors. Small brackets may be required under the top plate in way of holding down bolts.

6.9.5 For gas turbine installations, seats are to be so designed as to provide effective support and ensure their proper alignment with the gearing, and where applicable allow for thermal expansion of the casings. In general, the seats are not to be arranged in way of breaks or recesses in the double bottom.

6.9.6 Auxiliary machinery is to be secured on seatings, of adequate scantlings, so arranged as to distribute the loadings evenly into the supporting structure.

6.10 Thrust blocks

6.10.1 Main engines and thrust bearings are to be effectively secured to the hull structure by seatings of adequate scantlings to resist the various gravitational, thrust, torque, dynamic and vibratory forces which may be imposed on them.

6.10.2 For initial guidance, it is recommended that the scantlings for oil engine seatings be as indicated in 6.9.3.

■ *Section 7*
Superstructures, deckhouses and bulwarks

7.1 General

7.1.1 Superstructures, deckhouses and bulwarks are to be constructed in accordance with the scantlings indicated in Ch 3,9 of Parts 6, 7 and 8, for steel, aluminium alloy and composite structures respectively.

7.2 Definition of tiers

7.2.1 The lowest, or first tier, is normally that which is directly situated on the deck to which *D* is measured. The second tier is the next tier above the lowest tier and so on. *See* Fig. 2.7.1.

7.2.2 Where the vertical distance between the weatherdeck and the summer load waterline is equal to or greater than the sum of the minimum freeboard and one standard superstructure height, then proposals to treat the first tier erection as a second tier, and so on, will be specially considered. The standard height of superstructure is the height defined in Ch 1,6.13.3. *See* Fig. 2.7.1.

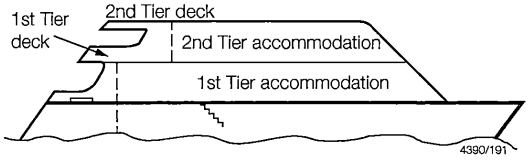

Fig. 2.7.1 Definition of tiers

7.2.3 Suitable scarfing arrangements are to be made to ensure continuity of strength and the avoidance of abrupt structural changes.

7.3 Unusual designs

7.3.1 Craft or structural arrangements which are of unusual design, form or proportions will be individually considered. Special features will be considered in each separate case.

■ *Section 8*
Particular requirements for multi-hulls

8.1 General

8.1.1 The requirements indicated in this Section are particular to multi-hull craft and are to be applied in addition to the general requirements of this Chapter.

8.1.2 The craft is to be considered as one complete structure when determining the minimum geometric summer freeboard. The block coefficient is to be calculated using the actual displacement determined from the hydrostatic data and using the total breadth of the structure and not just a single hull.

8.1.3 If, by using normal procedures, the minimum geometric summer freeboard determined is unreasonable for the operation of the craft, special consideration may be given, on a case by case basis, based on the proposed design configuration.

8.2 Structural configuration

8.2.1 The scantlings and arrangements indicated are for twin hulled craft. Craft with a greater number of hulls will be specially considered on the basis of the Rules.

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8.3 Structural continuity

8.3.1 Structural members which contribute to the overall hull girder strength are to be carefully aligned so as to avoid discontinuities resulting in abrupt variations of stresses and are to be kept clear of any form of openings which may affect their structural performances.

8.3.2 Particular care is to be given to the continuity and alignment in way of the end connections of transverse bridging structures.

8.4 Cross-deck structure

8.4.1 For craft with multi-hulls linked by cross-deck structures, sufficient clearance is to be provided between the cross-deck structure and water surface to limit impact loads.

8.4.2 Where part or all of the cross-deck is intended to provide additional buoyancy to limit craft motion, the loading will be specially considered.

8.4.3 In the determination of the clearance, the following factors should be considered:
(a) Relative motion in waves.
(b) The wave generated between the hulls when running.
(c) The bow sinkage.

8.4.4 The submitted clearances must be validated either by calculations according to accepted theories, model test, full scale measurements or by documentary evidence if similar structures have proved to be satisfactory in service.

8.4.5 Where it is not possible to provide sufficient clearance to reduce the likelihood of slamming of the cross-deck structure, direct calculations or other appropriate means are to be used to assess the loads, assuming the most severe conditions for which the craft is to be approved.

8.5 Bulkheads

8.5.1 Longitudinal watertight bulkheads are to be arranged within the bridging structures of multi-hull craft to prevent cross flooding and the spread of smoke and flames in the event of fire. The number and distribution of bulkheads will be specially considered dependent upon the structural configuration and size of the craft but in no case is the number to be less than two for catamarans and four for trimarans.These bulkheads are in general to be positioned in way of the inboard sides of the hulls.

8.6 Fore and aft ends

8.6.1 The forefoot and bow regions of fast craft that may be subjected to frequent impacts from flotsam are to be easily accessible for inspection. Access to the forepeak compartments may be provided through the forepeak bulkhead where access would otherwise be impracticable.

8.6.2 The aft end regions of all craft are to be easily accessible for inspections. Access may be provided through the aft peak bulkhead or by means of deck hatches or manholes.

8.7 Machinery spaces

8.7.1 Where an engine is fitted within a narrow hull, where engineroom temperatures may rise quickly, the ventilation requirements may require to be increased.

8.7.2 Within machinery spaces where space is limited access is to be provided for inspection.

8.8 Superstructures, deckhouses and bulwarks

8.8.1 Superstructures and deckhouses which enclose large flat open areas, that are subjected to racking loads and which may be of several tiers, are to be additionally stiffened with large web frames, partial bulkheads and pillars.

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Section

1 **General**

2 **Rudders**

3 **Sternframes and appendages**

4 **Fixed and steering nozzles, bow and stern thrust units**

5 **Stabiliser arrangements**

6 **Particular requirements for multi-hull craft**

■ *Section 1* General

1.1 Application

1.1.1 This Chapter applies to all the craft types detailed in the Rules, and requirements are given for rudders, nozzles, steering gear, bow and stern thrust unit structure and stabiliser structure.

1.2 General

1.2.1 The following symbols and definitions are applicable to this Chapter, unless otherwise stated:

σ_o = minimum yield stress or 0,5 per cent proof stress of the material, in N/mm^2 and is not to be taken greater than $0{,}7\sigma_T$

where

σ_T = ultimate tensile strength of the material, in N/mm^2.

1.2.2 The scantlings in aluminium alloy are to be obtained by multiplying the scantlings in mild steel, determined from this Chapter, by the following factors:

(a) Plating thickness factor = k_{ta}
where $k_{ta} = \sqrt{k_{aa}}$

(b) Section modulus and cross sectional area factor, k_{aa}
where

k_{aa} = $235/\sigma_{ya}$ or 1,36, whichever is the greater

σ_{ya} = specified minimum yield stress or 0,2 per cent proof stress of aluminium alloy in the welded condition, in N/mm^2.

1.3 Navigation in ice

1.3.1 Where an ice class notation is to be included in the class of a craft, the scantlings as determined from this Chapter will require to be specially considered. The additional requirements for operation in ice will, in general, be in accordance with Lloyd's Register's (hereinafter referred to as 'LR') *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships), Pt 3, Ch 9, where appropriate, and also Ch 5,6 of Parts 6, 7 and 8, for steel, aluminium and composite construction respectively.

1.4 Materials

1.4.1 The requirements for materials are contained in the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

■ *Section 2* Rudders

2.1 General

2.1.1 The scantlings of the rudder stock are to be not less than those required by Table 3.2.7.

2.1.2 For rudders having an increased diameter of rudder stock, *see* Fig. 3.2.1, the increased diameter is to be maintained to a point as far as practicable above the top of the lowest bearing. This diameter may then be tapered to the diameter required in way of the tiller. The length of the taper is to be at least three times the reduction in diameter. Particular care is to be taken to avoid the formation of a notch at the upper end of the taper.

2.1.3 Sudden changes of section or sharp corners in way of the rudder coupling, jumping collars and shoulders for rudder carriers, are to be avoided.

2.2 Definition and symbols

2.2.1 Definitions and symbols for use throughout this Section are indicated in the appropriate tables.

2.3 Direct calculations

2.3.1 Where the rudder is of a novel design, high aspect ratio or the speed of the craft exceeds 45 knots the scantlings of the rudder and rudder stock are to be determined by direct calculation methods incorporating model test results and structural analysis, where considered necessary by LR.

2.4 Equivalents

2.4.1 Alternative methods of determining the loads will be specially considered, provided that they are based on model tests, full scale measurements or generally accepted theories. In such cases, full details of the methods used are to be provided when plans are submitted for approval.

2.5 Rudder arrangements

2.5.1 Rudders considered are the types shown in Fig. 3.2.1, of double plate or single plate construction, constructed from steel, stainless steel or aluminium alloy. Other rudder types and materials will be subject to special consideration.

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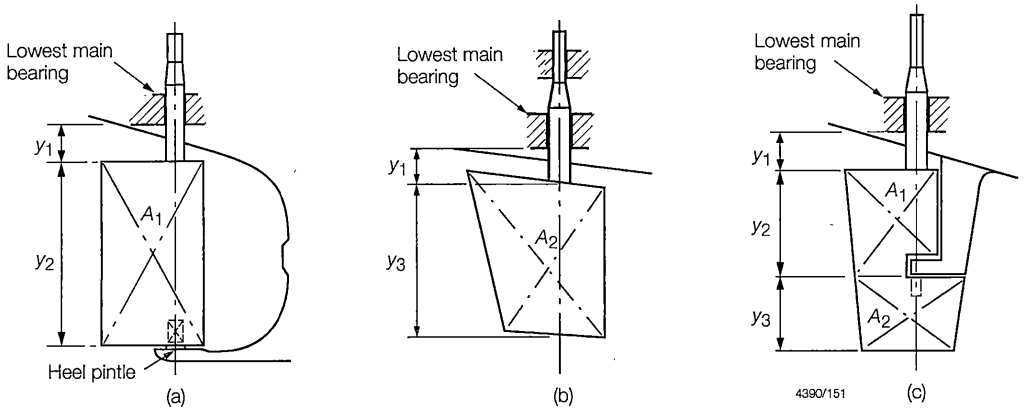

Fig. 3.2.1 Rudder types

2.6 Rudder profile coefficient f_R

2.6.1 The rudder profile coefficient f_R for use in Table 3.2.7 is to be as indicated in Table 3.2.1.

Table 3.2.1 Rudder profile coefficient f_R

Design criteria (*see* Fig. 3.2.2)	f_R ahead condition	f_R astern condition
Normal profile	1,0	0,97
Hollow profile	1,25	1,12
High lift profile	1,7	To be specially considered
Symbols		
f_R = rudder profile coefficient for use in Table 3.2.7		
NOTE Where a rudder is behind a fixed nozzle, the value of f_R given above, is to be multiplied by 1,3.		

2.7 Rudder angle coefficient f_θ

2.7.1 The rudder angle coefficient, f_θ, for use in Table 3.2.7 is to be as indicated in Table 3.2.2.

Table 3.2.2 Rudder angle coefficient f_θ

Rudder angle	2 x 35°	2 x 45°
f_θ	1,0	1,23
Symbols		
f_θ = rudder coefficient for use in Table 3.2.7. Intermediate values may be obtained by interpolation		

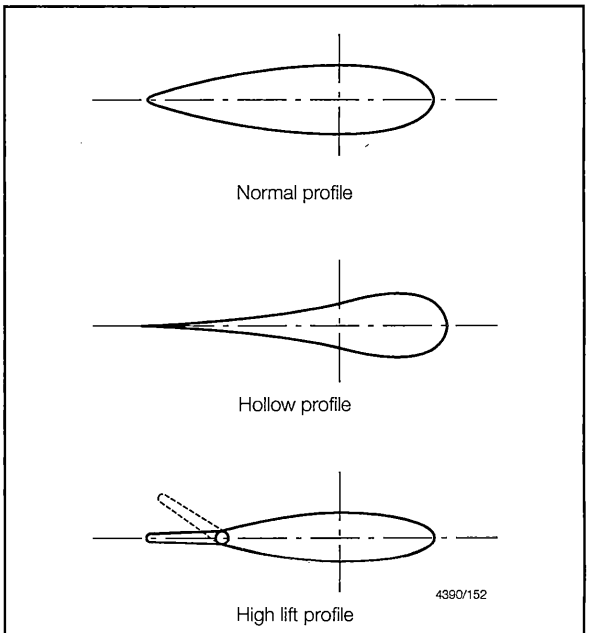

Fig. 3.2.2 Rudder profiles

2.8 Rudder position coefficient f_p

2.8.1 The rudder position coefficient, f_p, for use in Table 3.2.7 is to be as indicated in Table 3.2.3.

2.9 Rudder speed coefficient f_v

2.9.1 The rudder speed coefficient, f_v, for use in Table 3.2.7 is to be as indicated in Table 3.2.4.

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Table 3.2.3 Rudder position coefficient f_p

Design criteria		f_p
Ahead condition	Rudder in propeller slipstream	0,248
	Rudder out of propeller slipstream	0,235
Astern condition		0,185
Bow rudder		0,226
Symbols		
f_p = rudder coefficient for use in Table 3.2.7		

Table 3.2.4 Rudder speed coefficient f_v

Design criteria	f_v
Craft with $\frac{V}{\sqrt{L_{WL}}} < 3,0$	1,00
Craft with $\frac{V}{\sqrt{L_{WL}}} \geq 3,0$	1,12 – 0,005V
Symbols	
L_{WL} as defined in Ch 1,6.2.5 V as defined in Table 3.2.7 f_v = rudder speed coefficient for use in Table 3.2.7	

2.10 Pintle arrangement coefficient *N*

2.10.1 The pintle arrangement coefficient, N, for use in Table 3.2.7 is to be as indicated in Table 3.2.5.

Table 3.2.5 Pintle arrangement coefficient *N*

Support arrangement	Value of N
Two or more pintles Upper stock	$N = 0$
One or no pintle	$N = A_1(0,67y_1 + 0,17y_2) - A_2(y_1 + 0,5y_3)$
Symbols	
N = coefficient for use in Table 3.2.7 A_1, A_2 = part rudder areas, in m^2, *see* Fig. 3.2.1 y_1, y_2, y_3 = vertical dimensions, in metres, *see* Fig. 3.2.1 Any values of y and A not indicated in Fig. 3.2.1 are to be taken as zero.	
NOTE If, in semi-spade (Mariner) type rudders, the pintle is housed above the rudder horn gudgeon and not as shown in Fig. 3.2.1(c), y_2 and y_3 are to be measured to the top of the gudgeon.	

2.11 Centre of pressure

2.11.1 The position of centre of pressure for use in Table 3.2.7 is to be as indicated in Table 3.2.6.

Table 3.2.6 Position of centre of pressure

Design criteria	Value of x_{PF} and x_{PA} to be used in Table 3.2.7
Rectangular rudders; (a) Ahead condition	x_{PF} = $(0,33ex_B - x_L)$, but not less than $0,12x_B$
(b) Astern condition	x_{PA} = $(x_A - 0,25x_B)$, but not less than $0,12x_B$
Non-rectangular rudders; (a) Ahead condition	x_{PF} as calculated from geometric form
(b) Astern condition	x_{PA} (*see* Note) but not less than: $\frac{0,12A_R}{y_R}$
Symbols	
x_{PF} = horizontal distance from the centreline of the rudder pintles, or axle, to the centre of pressure in the ahead condition, in metres x_{PA} = horizontal distance from the centreline of the rudder pintles, or axle, to the centre of pressure in the astern condition, in metres x_B = breadth of rudder, in metres y_R = depth of rudder at centreline of stock, in metres A_R = rudder area, in m^2 x_L and x_A = horizontal distances from leading and after edges, respectively, of the rudder to the centreline of the rudder pintles, or axle, in metres x_S = horizontal length of any rectangular strip of rudder geometric form, in metres e = hull form factor at ahead condition for $L < 65$ m, $e = 1,0$ for $L \geq 65$ m, $e = 2\left(C_b + 10\frac{B}{L_R} - 2\right)\frac{V}{\sqrt{L_R}}$ or $e = 1 + \left(\frac{L_R - 65}{70}\right)$ whichever is the lesser, but not less than 1,0 and need not be taken greater than 1,5 L_R, B and C_b are as defined Ch 1,6.2 V is as defined in Table 3.2.7	
NOTE For rectangular strips the centre of pressure is to be assumed to be located as follows: (a) $0,33ex_S$ abaft leading edge of strip for ahead condition. (b) $0,25x_S$ from aft edge of strip for astern condition.	

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Table 3.2.7 Rudder stock diameter

Requirement
1. Basic stock diameter, d_s, at and below lowest bearing: $d_s = f_c f_p f_v \sqrt[3]{\left(\frac{235}{\sigma_0}\right)^m} f_R f_\theta (V+3)^2 \sqrt{A_R^2 x_p^2 + N^2}$ mm
2. Diameter in way of tiller, d_{SU}: $d_{SU} = d_s$ calculated from (1) with $N = 0$
3. Lateral force on rudder acting at centre of pressure of blade, P_L: $P_L = \left(\frac{f_p}{0,248}\right)^3 \frac{(V+3)^2 A_R f_R f_\theta}{10}$ kN
Symbols
f_c = 79 for craft of Rule length, L_R, 50 m and below varying up to 83,3 at a Rule length, L_R, of 70 m. Intermediate values to be obtained by interpolation 83,3 for craft of Rule length, L_R, 70 m and above f_p = rudder position coefficient, *see* Table 3.2.3 f_v = rudder speed coefficient, *see* Table 3.2.4 f_R = rudder profile coefficient, *see* Table 3.2.1 f_θ = rudder angle coefficient, *see* Table 3.2.2 m = 0,75 for $\sigma_0 > 235$ = 1,0 for $\sigma_0 \leq 235$ σ_0 = minimum yield stress, in N/mm^2, of material used, and is not to be taken greater than $0,7\sigma_T$ σ_T = ultimate tensile strength of the material used, in N/mm^2 V = the maximum speed for the astern and ahead condition, in knots. In no case to be less than 5 knots A_R = rudder area, in m^2 x_P = x_{Pa} or x_{Pf}, for the astern and ahead condition respectively, *see* Table 3.2.6 N = coefficient dependent on rudder support arrangement, *see* Table 3.2.5
NOTE Where higher tensile steel is used for the rudder stock, σ_0 is not to be taken as greater than 450 N/mm^2.

2.12 Rudder stock (tubular)

2.12.1 Tubular rudder stock scantlings are to be not less than that necessary to provide the equivalent strength of a solid stock as required by Table 3.2.7, and can be calculated from the following formula:

$$d_E = \sqrt[3]{\frac{d_1^4 - d_2^4}{d_1}} \text{ mm}$$

where

d_E = the diameter of the equivalent solid rudder stock, in mm

d_1, d_2 = external and internal diameters, respectively of the tubular stock, in mm.

2.13 Single plate rudders

2.13.1 The scantlings of a single plate rudder are to be not less than required by Table 3.2.8, *see also* 2.5.1.

2.13.2 Rudder arms are to be efficiently attached to the mainpiece.

Table 3.2.8 Single plate rudder construction

Item	Requirement
Blade thickness	$t_B = 0,0015V y_W + 2,5$ mm with a minimum of 10 mm
Arms	Spacing ≤ 1000 mm $Z_A = 0,0005V^2 x_a^2 y_W$ cm^3
Mainpiece	Diameter = d_s mm For spade rudders, the lower third may taper down to $0,75d_s$ mm
Symbols	
t_B = blade thickness, in mm y_W = vertical spacing of rudder arms, in mm V = maximum speed, in knots, as defined in Table 3.2.7 x_a = horizontal distance from the aft edge of the rudder to the centre of the rudder stock, in metres Z_A = section modulus of arm, in cm^3	

2.14 Double plate rudders

2.14.1 The scantlings of a double plated rudder are to be not less than required by Table 3.2.9.

2.14.2 In way of rudder couplings and heel pintles the plating thickness is to be suitably increased.

2.14.3 On semi-spade (Mariner) type rudders a notch effect in the corners in the bottom pintle region is to be avoided (*see* AA, Fig. 3.2.3). An insert plate, 1,6 times the Rule thickness of the side plating, is to be fitted at this position, extending aft of the main vertical web and having well rounded corners. The main vertical web is to be continuous over the full depth of the rudder and have a thickness not less than three times the thickness required by Table 3.2.9, Item (5). Where an additional continuous main vertical web is arranged to form an efficient box structure, the webs are to have a thickness not less than required by Table 3.2.9, Item (5).

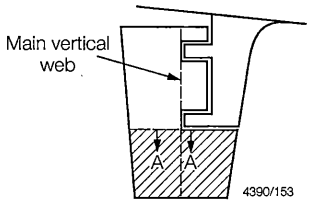

Fig. 3.2.3 Semi-spade (mariner) type rudder

2.14.4 Adequate hand or access holes are to be arranged in the rudder plating in way of pintles as required, and the rudder plating is to be reinforced locally in way of these openings. Continuity of the modulus of the rudder mainpiece is to be maintained in way of the openings.

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Table 3.2.9 Double plated rudder construction

Item	Requirement
(1) Side plating	$t = \beta F_a (0{,}003 y_w + 2{,}03)(1{,}45 + 0{,}1\sqrt{d_s})$ mm
(2) Webs - vertical and horizontal	As (1) above
(3) Top and bottom plates	As (1) above using y_w = maximum rudder width, in mm, at top or bottom, but not less than 900 mm
(4) Nose plates	$t_N \geq 1{,}25t$ from (1) above
(5) Mainpiece – fabricated rectangular	Breadth and width $\geq d_s$ $t_M = F_a (8{,}5 + 0{,}56\sqrt{d_s})$ mm Minimum fore and aft extent of side plating = $0{,}2x_B$ Stress due to bending $\leq$ 78,0 N/mm^2
(6) Mainpiece – tubular	Inside diameter $\geq d_s$ t_M as for (5) above Side plating as for (1) above Bending stress as for (5) above
Symbols	
β = $A_a (1 - 0{,}25A_a)$ A_a = panel aspect ratio, but is not to be taken as greater than 2,0 F_a = 1,0 for mild steel, 0,95 for aluminium alloy and 0,9 for stainless steel. Other materials will be specially considered t = thickness, in mm y_w = vertical spacing, in mm, of the horizontal webs or arms, but is not to exceed 900 mm d_s = basic stock diameter, given by Table 3.2.7, in mm t_N = thickness, in mm, of nose plate t_M = thickness, in mm, of side plating and vertical webs forming mainpiece x_B = breadth of rudder, in metres, on centreline of stock	

2.14.5 Connection of rudder side plating to vertical and horizontal webs, where internal access for welding is not practicable, is to be by means of slot welds onto flat bars on the webs. The slots are to have a minimum length of 75 mm and in general, a minimum width of twice the side plating thickness. The ends of the slots are to be rounded. The space between the slots is not to exceed 150 mm and welding is to be based on a weld factor of 0,44.

2.14.6 For testing of rudders, *see* Table 1.7.1 in Chapter 1.

2.14.7 Where the fabricated mainpiece of a spade rudder is connected to the horizontal coupling flange by welding, a full penetration weld is required.

2.15 Cast metal rudders

2.15.1 Where rudders are cast, the mechanical and chemical properties of the metal are to be submitted for approval. If the rudder stock is cast integral with the rudder blade, abrupt changes of section and sharp corners are to be avoided.

2.16 Lowest main bearing requirement

2.16.1 The design of the lowest bearing is to comply with the requirements of Table 3.2.10.

2.17 Bearings

2.17.1 Bearings are to be of approved materials and effectively secured to prevent rotational and axial movement.

2.17.2 Synthetic rudder stock bearing materials are to be of a type approved by LR.

2.17.3 Where it is proposed to use stainless steel bearings for rudder stocks, the chemical composition is to be submitted for approval.

2.17.4 When stainless steel bearings are used, arrangements to ensure an adequate supply of sea-water to the bearing are to be provided.

2.17.5 When the rudder stock or liner is grade 316L austenitic stainless steel, it is recommended that gunmetal, lignum vitae or a synthetic bearing material be used in the bush. If a stainless steel is used in the bush, it is to be of a different grade and with an adequate hardness difference. The use of a ferritic/austenitic duplex structure stainless steel is recommended for the bush but 17 per cent to 30 per cent chromium stainless steels are also suitable.

2.18 Liners

2.18.1 Where liners are fitted to rudder stocks or pintles, they are to be shrunk on or otherwise efficiently secured.

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Table 3.2.10 Lowest main bearing requirements

Item	Requirement	
Lowest main bearing	Depth Z_B, in mm $1{,}5d_s \geq Z_B \geq 1{,}0d_s$	Minimum thickness of wall, in mm lesser of $0{,}2d_s$ or 100
Bearing pressure (on the projected area of the lowest main bearing), where the projected area is to be taken as the length x diameter	Bearing material	Maximum pressure, in N/mm^2 *see* Note 4
	Metal Synthetic	7,0 5,5
Clearance in lowest main bearing on the diameter (note should be taken of the manufacturer's recommended clearances, particularly where bush material requires pre-soaking)	Bearing material	Minimum clearance, in mm *see* Note 3
	Metal, *see* Note 2 Synthetic	$0{,}001d_s + 1{,}0$ $0{,}002d_s + 1{,}0$ but not less than 1,5
Symbols		
d_s = stock diameter, given by Table 3.2.7, in mm		

NOTES
1. Where web stiffening is fitted on the bearing, a reduction in wall thickness will be considered.
2. For bearings which are pressure lubricated the clearance must be restricted to enable the pressure to be maintained.
3. Value of proposed minimum clearance is to be indicated on plans submitted for approval.
4. Proposals for higher pressures or other materials will be specially considered on the basis of satisfactory test results.

2.18.2 Where it is proposed to use stainless steel liners, the chemical composition is to be submitted for approval.

2.18.3 When stainless steel liners are used, arrangements to ensure an adequate supply of sea-water to the liner are to be provided.

2.19 Pintles

2.19.1 Rudder pintles and their bearings are to comply with the requirements of Table 3.2.11.

2.19.2 Where the lower pintle is housed above the rudder gudgeon, *see* Fig. 3.2.4, and not below as shown in Fig. 3.2.5, C_{PL} is to be measured to the top of the gudgeon.

2.19.3 Special attention is to be paid to the fit of the pintle taper into its socket. To facilitate removal of the pintles, it is recommended that the taper is to be not less than half the maximum value given in Table 3.2.11.

2.19.4 The distance between the lowest rudder stock bearing and the upper pintle is to be as short as possible.

2.19.5 Where liners are fitted to pintles, they are to be shrunk on or otherwise efficiently secured. If liners are to be shrunk on, the shrinkage allowance is to be indicated on the plans. Where liners are formed by stainless steel weld deposit, the pintles are to be of weldable quality steel and details of the procedure are to be submitted.

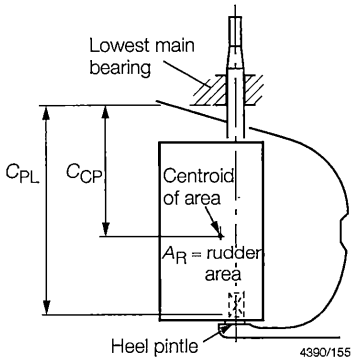

Fig. 3.2.4
Lower pintle housed above rudder gudgeon

2.19.6 The bottom pintle on semi-spade (Mariner) type rudders are:
(a) If inserted into their sockets from below, to be keyed to the rudder or sternframe as appropriate or to be hydraulically assembled, with the nut adequately locked, or
(b) If inserted into their sockets from above, to be provided with an appropriate locking device, the nut being adequately secured.

2.19.7 Where an ***IWS** (In-water Survey) notation is to be assigned, *see* 2.37.

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Table 3.2.11 Pintle requirements

Item	Requirement	
(1) Pintle diameter (measured outside liner if fitted)	$\delta_{PL} = \sqrt{\left(\frac{235}{\sigma_o}\right)^m}\ (31 + 4{,}17V\sqrt{A_{PL}})$ mm For single pintle rudders and lower pintle of semi-spade rudders:: $A_{PL} = \frac{A_R C_{CP}}{C_{PL}}$ m^2 but for semi spade rudders need not be taken greater than A_R Upper pintle on semi-spade rudders; $A_{PL} = A_R\left(1 - \frac{C_{CP}}{C_{PL}}\right)$ m^2 or $0{,}35A_R$ m^2, whichever is the greater For rudders with two or more pintles (except semi-spade rudders): $A_{PL} = \frac{A_R}{N_{PL}}$ m^2	
(2) Maximum pintle taper	Method of assembly	Taper (on diameter)
	Manual assembly, key fitted (pintle ≤ 200mm diameter)	1 in 6
	Manual assembly, key fitted (pintle ≥ 400mm diameter)	1 in 9
	For keyed and other manually assembled pintles with diameters between 200 mm and 400 mm, the taper is to be obtained by interpolation.	
	Hydraulic assembly, dry fit Hydraulic assembly, oil injection	1 in 12 1 in 15
(3) Bearing length	$Z_{PB} \geq 1{,}2\delta_{PL}$ mm May be less for very large pintles if bearing pressure is not greater than that given in (4), but Z_{PB} must not be less than $1{,}0\delta_{PL}$ mm	
(4) Bearing pressure (on projected area)	Bearing material	Pressure
	Metal Synthetic	7,0 N/mm^2 5,5 N/mm^2
	Using force acting on bearing: $P_{PL} = \frac{A_{PL}(V+3)^2 f_R}{10}$ kN A_{PL} as for item (1)	
(5) Gudgeon thickness in way of pintle (measured outside bush if fitted)	$b_G \geq 0{,}5\delta_{PL}$ but need not normally exceed 125mm	
(6) Pintle clearance (note should be taken of the manufacturer's recommended clearances particularly where bush material requires pre-soaking). Value of proposed minimum clearance is to be indicated on plans submitted for approval.	Bearing material	Minimum clearance, mm
	Metal Synthetic	$0{,}001\delta_{PL} + 1{,}0$ $0{,}002\delta_{PL} + 1{,}0$ but not less than 1,5

Symbols

δ_{PL} = pintle diameter, in mm
V = as defined in Table 3.2.7 but not less than 10 knots
A_{PL} = rudder area supported by the pintle, in m^2
C_{CP}, C_{PL} = dimensions in metres, as indicated in Figs. 3.2.4 and 3.2.5
A_R = rudder area, in m^2
σ_o = as defined in Table 3.2.7
N_{PL} = number of pintles on the rudder
Z_{PB} = pintle bearing length, in mm
P_{PL} = force acting on bearing, in kN
b_G = thickness of gudgeon material in way of pintle, in mm
f_R = rudder profile coefficient, *see* Table 3.2.1
m = as defined in Table 3.2.7

NOTE
Proposals for higher pressures or other materials will be specially considered on the basis of satisfactory test results.

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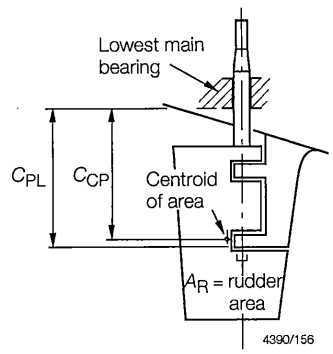

Fig. 3.2.5
Lower pintle housed below rudder gudgeon

2.20 Bolted couplings

2.20.1 Rudder coupling design is to be in accordance with Table 3.2.12.

2.20.2 Where coupling bolts are required they are to be fitted bolts. Suitable arrangements are to be made to lock the nuts.

2.20.3 For rudders with horizontal coupling arrangements, where the upper flange is welded to the rudder stock, a full penetration weld is required and its integrity is to be confirmed by non-destructive examination. Such rudder stocks are to be subjected to a furnace post-weld heat treatment (PWHT) after completion of all welding operations. For carbon or carbon manganese steels, the PWHT temperature is not to be less than 600°C.

Table 3.2.12 Rudder couplings to stock (*see continuation*)

Arrangement	Parameter	Requirement	
		Horizontal coupling	Vertical coupling
(1) Bolted couplings (*see* Notes)	n	≥ 6	≥ 8
	δ_b	$\frac{0{,}65 d_s}{\sqrt{n}}$	$\frac{0{,}81 d_s}{\sqrt{n}}$
	m	$0{,}00071 n\, d_s\, \delta_b^2$	$0{,}00043 d_s^3$
	t_f	$\geq \delta_b$, *see* Note 1	δ_b
	α_{max} *see* Note 2	$(53{,}82 - 35{,}29 k_1)\frac{d_s^3}{P_L h 10^6} - \left(1{,}8 - 6{,}3\frac{R}{d_s}\right)\frac{t_f - t_{fa}}{t_{fa}}$	—
	$\alpha_{as\ built}$ *see* Note 2	$\leq \alpha_{max}$	—
	w_f	$0{,}67\delta_b$	$0{,}67\delta_b$
(2) Conical couplings	θ_t	$\leq \frac{1}{K_1}$	
	l_t	$\geq 1{,}5 d_s$	
	$\overline{p}$	$\frac{P_R \theta_t \overline{\delta}_{ST} + 4M_T \sqrt{K_2\left(\left(\frac{P_R \overline{\delta}_{ST}}{2M_T}\right)^2 + 1\right) - \left(\frac{\theta_t}{2}\right)^2}}{5{,}66 \overline{\delta}_{ST}^2 l_t \left(K_2 - \left(\frac{\theta_t}{2}\right)^2\right)}$	
	w	$\frac{9{,}6 \times 10^{-6} \overline{p}\, \overline{\delta}_{ST}}{\theta_t (1 - \overline{f}^2)}$	
	P_u	Approximately equal to $2{,}83 \overline{p}\, l_t \overline{\delta}_{ST} \left(K_3 + \frac{\theta_t}{2}\right)$	
	P_o	Approximately equal to $2{,}83 \overline{p}\, l_t \overline{\delta}_{ST} \left(K_3 - \frac{\theta_t}{2}\right)$	
	σ_o	$\geq \frac{12{,}35 \times 10^4\, w\, \theta_t \sqrt{3 + f^4}}{\delta_{ST}}$	

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Table 3.2.12 Rudder couplings to stock (*see continuation*)

Arrangement	Parameter	Requirement	
		Horizontal coupling	Vertical coupling
(1) Bolted couplings (*see* Notes)	n	≥ 6	≥ 8
	δ_b	$\frac{0{,}65 d_s}{\sqrt{n}}$	$\frac{0{,}81 d_s}{\sqrt{n}}$
	m	$0{,}00071 n\, d_s\, \delta_b^2$	$0{,}00043 d_s^3$
	t_f	$\geq \delta_b$, *see* Note 1	δ_b
	α_{max} *see* Note 2	$(53{,}82 - 35{,}29 k_1)\frac{d_s^3}{P_L h 10^6} - \left(1{,}8 - 6{,}3\ \frac{R}{d_s}\right)\frac{t_f - t_{fa}}{t_{fa}}$	—
	$\alpha_{as\ built}$ *see* Note 2	$\leq \alpha_{max}$	—
	w_f	$0{,}67\delta_b$	$0{,}67\delta_b$
(2) Conical couplings	θ_t	$\leq \frac{1}{K_1}$	
	l_t	$\geq 1{,}5 d_s$	
	$\overline{p}$	$\frac{P_R \theta_t \overline{\delta}_{ST} + 4M_T \sqrt{K_2\left(\left(\frac{P_R \overline{\delta}_{ST}}{2M_T}\right)^2 + 1\right) - \left(\frac{\theta_t}{2}\right)^2}}{5{,}66 \overline{\delta}_{ST}^2\, l_t \left(K_2 - \left(\frac{\theta_t}{2}\right)^2\right)}$	
	w	$\frac{9{,}6 \times 10^{-6} \overline{p}\, \overline{\delta}_{ST}}{\theta_t (1 - \overline{f}^2)}$	
	P_u	Approximately equal to $2{,}83 \overline{p}\, l_t \overline{\delta}_{ST} \left(K_3 + \frac{\theta_t}{2}\right)$	
	P_o	Approximately equal to $2{,}83 \overline{p}\, l_t \overline{\delta}_{ST} \left(K_3 - \frac{\theta_t}{2}\right)$	
	σ_o	$\geq \frac{12{,}35 \times 10^4\, w\, \theta_t \sqrt{3 + f^4}}{\delta_{ST}}$	

2.20.4 The connecting bolts for coupling the rudder to the rudder stock are to be positioned with sufficient clearance to allow the fitting and removal of the bolts and nuts without contacting the palm radius, R, *see* Fig. 3.2.6(a). The surface forming the palm radius is to be free of hard and sharp corners and is to be machined smooth to the Surveyor's satisfaction. The surface in way of bolts and nuts is to be machined smooth to the Surveyor's satisfaction.

2.20.5 For spade rudders fitted with a fabricated rectangular mainpiece, the mainpiece is to be designed with its forward and aft transverse sections at equal distances forward and aft of the rudder stock transverse axis, *see* Fig. 3.2.6(b).

2.21 Conical couplings

2.21.1 Where a rudder stock is connected to a rudder by a keyless fitting, the rudder is to be a good fit on the rudder stock cone. During the fit-up, and before the push-up load is applied, an area of contact of at least 90 per cent of the theoretical area of contact is to be achieved, and this is to be evenly distributed. The relationship of the rudder to stock at which this occurs is to be marked, and the push-up then measured from that point. The upper edge of the upper mainpiece bore is to have a slight radius. After the final fitting of the stock to the rudder, positive means are to be used for locking the securing nut to the stock.

2.21.2 Where a keyed tapered fitting of a rudder stock to a rudder is proposed, a securing nut of adequate proportions is to be provided. After the final fitting of the stock to the rudder, positive means are to be used for locking this nut.

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Table 3.2.12 Rudder couplings to stock (*conclusion*)

Symbols

n = number of bolts in coupling
δ_b = diameter of coupling bolts, in mm
d_s, d_{su} = rudder stock diameter as defined in Table 3.2.7
m = first moment of area of bolts about centre of coupling, in cm^3
k_1 = the greater of k_s and k_f
$k_s = \left(\frac{235}{\sigma_o}\right)^m$ where σ_o is the specified minimum yield stress at the rudder stock and m is as defined in Table 3.2.7
$k_f = \left(\frac{235}{\sigma_o}\right)^m$ where σ_o is the specified minimum yield stress at the upper coupling flange and m is as defined in Table 3.2.7
h = vertical distance between the centre of pressure and the centre point of the palm radius, R, in metres, *see* Fig. 3.2.6(a)
R = palm radius between rudder stock and connected flange, not smaller than $\frac{d_s}{10}$, in mm
t_f = minimum thickness of coupling flange, in mm
t_{fa} = as built flange thickness, in mm
α_{max} = maximum allowable stress concentration factor
$\alpha_{as\ built}$ = stress concentration factor for as built scantlings $= \frac{0,73}{\sqrt{\left(\frac{R}{d_s}\right)}}$
w_f = width of flange material outside the bolt holes, in mm
θ_t = taper of conical coupling, on the diameter, e.g.: $\theta_t = \frac{1}{15} = 0,067$
l_t = length of taper, in mm
$\bar{p}$ = required mean grip stress, in N/mm^2
w = corresponding push-up of rudder stock, in mm
P_u, P_o = corresponding push-up, pull-off loads respectively, in N
σ_o = minimum yield stress of stock and gudgeon material, in N/mm^2. σ_o is not to be taken greater than 70 per cent of the ultimate tensile strength
P_R = effective weight of rudder, in N
$\overline{\delta_{ST}}$ = mean diameter of coupling taper, in mm
δ_{ST} = diameter of coupling taper at any position, in mm
$\overline{\delta_{GH}}$ = mean external diameter of gudgeon housing, in mm
δ_{GH} = external diameter of gudgeon housing at any position, in mm
$\overline{f}$ $\frac{\overline{\delta_{ST}}}{\delta_{GH}}$
f $\frac{\delta_{ST}}{\delta_{GH}}$
M_T = maximum torque applied to stock, and is to be taken as the greater of M_F, M_A or M_W.
M_F = $P_L X_{PF} \times 10^6$ Nmm in the ahead condition
M_A = $P_L X_{PA} \times 10^6$ Nmm in the astern condition
M_W = the torque generated by the steering gear at the maximum working pressure supplied by the manufacturer, in Nmm. M_W is not to exceed the greater of $3,0M_F$ or $3,0M_A$
P_L = lateral force on rudder acting at centre of pressure in ahead and astern conditions, as defined in Table 3.2.7, in kN
X_{PF}, X_{PA} = the horizontal distances, in metres, *see* Table 3.2.6

K_1, K_2, K_3 = constants depending on the type of assembly adopted as follows:

		K_1	K_2	K_3
Oil injection method	with key	15	0,0064	0,025
	without key	15	0,0036	0,025
Dry fit method	with key	12	0,0128	0,170
	without key	12	0,0072	0,170

NOTES
1. For spade rudders with horizontal coupling, t_f is not to be less than $0,25d_s$.
2. This requirement is applicable only for spade rudders with horizontal couplings, *see* Fig. 3.2.6.
3. Where materials vary for individual components, scantling calculations for such components are to be based on d_s for the relevant material.

2.22 Rudder carrier arrangements

2.22.1 The weight of the rudder is to be supported at the heel pintle or by a carrier attached to the rudder head. The hull structure supporting the carrier bearing is to be adequately strengthened. The plating under all rudder-head bearings or rudder carriers is to be increased in thickness.

2.23 Anti-jump collars

2.23.1 Suitable arrangements are to be provided to prevent the rudder from lifting.

2.23.2 Jumping collars are not to be welded to the rudder stock.

2.24 Drain plugs

2.24.1 Where rudders are of plated construction, drain plugs are to be provided to ensure that all compartments can be adequately drained. These plugs are to be locked and details of their scantlings, arrangements and position clearly indicated on the rudder plan.

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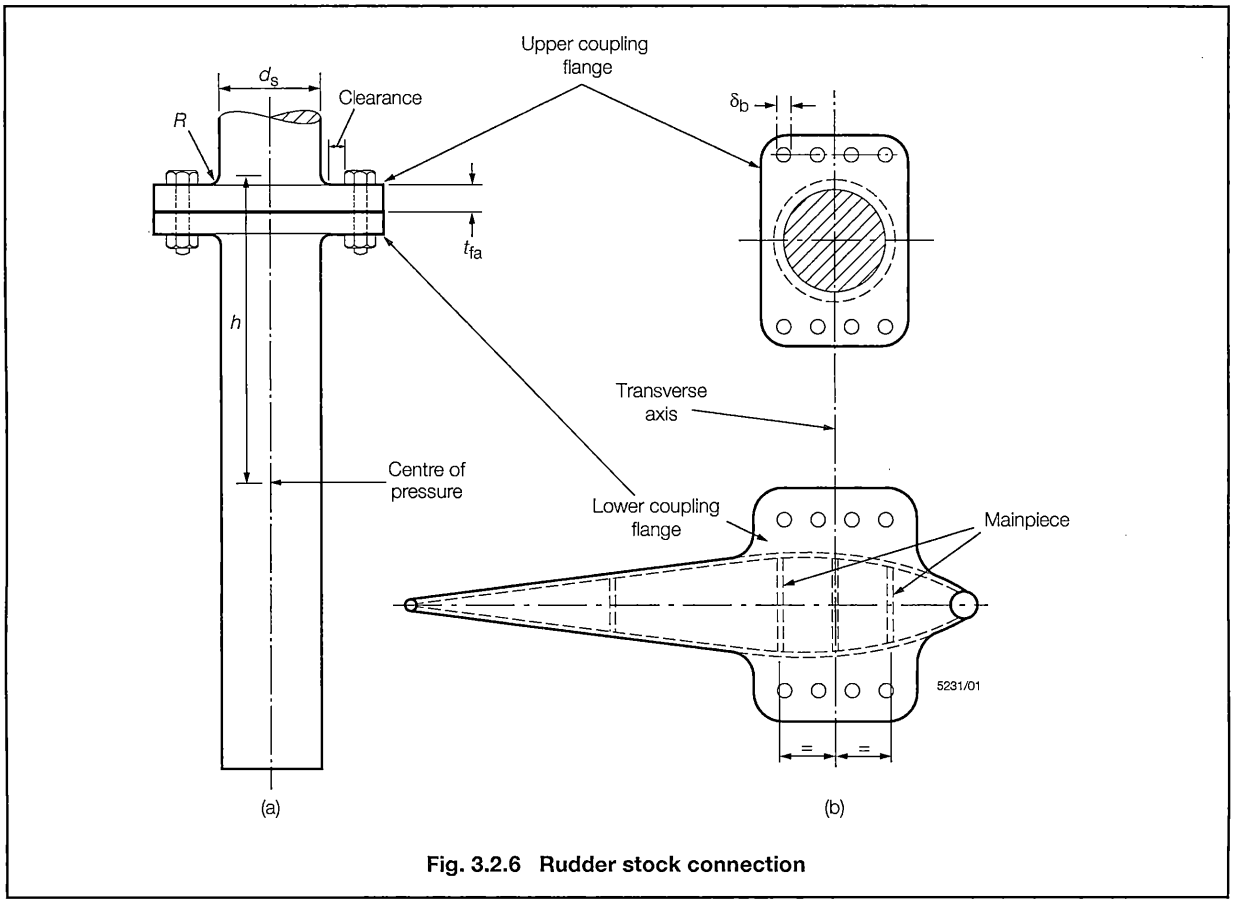

Fig. 3.2.6 Rudder stock connection

2.25 Corrosion protection

2.25.1 All metalwork, is to be suitably protected against corrosion. This may be by coating or, where applicable, by a system of cathodic protection.

2.25.2 Metalwork is to be suitably cleaned before the application of any coating. Where appropriate, blast cleaning or other equally effective means are to be employed for this purpose.

2.26 Dissimilar materials

2.26.1 Where materials vary for individual components, they are to be compatible to avoid galvanic corrosion. Scantling calculations for the components are to be based on d_s for the relevant material, *see* Table 3.2.7.

2.27 Internal coatings

2.27.1 Internal surfaces of the rudder are to be efficiently coated or the rudder is to be filled with foam plastics. Where it is intended to fill the rudder with plastic foam, details of the foam are to be submitted.

2.28 Pressure testing

2.28.1 For testing of rudders, *see* Table 1.7.1 in Chapter 1.

2.29 Tiller arms, quadrants

2.29.1 Tillers and quadrants are to comply with the requirements of Table 1.4.1 in Pt 14, Ch 1.

2.29.2 The steering gear is to be mounted on a seat and adequately secured.

2.30 Connecting bars

2.30.1 Connecting bars are to comply with the requirements of Pt 14, Ch 1,4.3.3.

2.31 Keys and keyways

2.31.1 Where the tiller or quadrant is bolted, a key having an effective cross-sectional area in shear of not less than $0{,}25d_{SU}^2$ mm^2 is to be fitted. The thickness of the key is to be not less than $d_{SU}/6$ mm. Alternatively, the rudder stock may be machined to a square section in lieu of fitting a key. d_{SU} is as defined in Table 3.2.7.

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2.31.2 Keyways are to extend over the full depth of the tiller boss.

2.31.3 Keyways in the rudder stock are to have rounded ends and the corners at the base of the keyway are to be radiused.

2.32 Stopping arrangements

2.32.1 Suitable rudder stops are to be provided to limit the rudder angle to the desired level port and starboard. These stops are to be of substantial construction and efficiently connected to the supporting structure.

2.33 Novel designs

2.33.1 Where rudders are of a novel design they may be specially considered on the basis of the Rules. Alternatively the Builder's/designer's calculations are to be submitted for consideration.

2.34 FRP double plated rudders

2.34.1 Fibre reinforced plastic rudders are to incorporate a metallic framework, consisting of a mainpiece fitted with arms, within the blade, or an equivalent arrangement. Where rudder blades are moulded in halves they are to be effectively joined together by means of external overbonding of the joint or suitable mechanical fastening or equivalent. Both halves of the rudder blade moulding are to be effectively connected to the metallic framework and mainpiece by either mechanical means or suitable bonded connection.

2.34.2 Rudders are to be filled with a suitable material upon completion of the join up, details of the filler material are to be submitted.

2.34.3 The diameter of the top of the rudder mainpiece must not be less than that of the rudder stock. For spade rudders this diameter may be gradually reduced for the lower third to not less than 75 per cent of the rudder stock diameter.

2.34.4 The rudder arms are to be efficiently attached to the mainpiece.

2.34.5 The laminate weight of moulded fibre reinforced plastics double plate rudders is to be determined by direct calculation, subject to a minimum laminate thickness of 5 mm.

2.35 Rudder tube arrangements

2.35.1 The rudder tube construction may be of aluminium alloy, steel, bronze or fibre reinforced plastic.

2.35.2 The scantlings of rudder tubes will be individually considered.

2.35.3 For steel and aluminium hulls, the bottom shell in way of the rudder tubes is to be additionally reinforced by means of an insert plate to increase the bottom shell thickness by 50 per cent.

2.35.4 For F.R.P. hulls, the bottom shell laminate in way of the rudder tubes is to be locally increased by 50 per cent. The increased thickness in way of the rudder tube need not exceed the rule keel thickness requirement.

2.35.5 For F.R.P. sandwich hulls the shell in way of the rudder tube connection is to be either:

(a) Reduced from the sandwich hull construction to single skin laminate for a distance of a least three times the rudder tube diameter about the rudder stock axis. The single skin region is to be additionally reinforced by a minimum of 50 per cent of the sum of the inner and outer sandwich laminate subject to this being at least equivalent to a 50 per cent increase in thickness of the Rule minimum bottom shell laminate for a single skin F.R.P. craft of the equivalent Rule length, L_R. The reinforced laminate need not be greater than the Rule keel laminate thickness.

(b) Reduced from the sandwich hull construction to a single skin laminate for a distance of three times the rudder tube diameter about the rudder stock axis. After bonding in the rudder tube to the single skin laminate the foam core and inner skin are then reinstated.

(c) Proposals to replace the sandwich core with a core having higher core shear strength and compressive strength than that of the adjacent structure prior to bonding the tube to the inner and outer skins will be the subject of special consideration.

2.35.6 The rudder tube may be connected to the shell by bonding, bolting or welding as applicable depending upon the construction material of the shell.

2.35.7 When bonding in rudder tubes the bonding angle is to be not less than the Rule minimum bottom shell weight. F.R.P. tubes are to be thoroughly abraded and degreased prior to installation and laminating. Bonded in metallic tubes are to be knurled in way of the bonding material and thoroughly degreased prior to installation.

2.35.8 Where rudder tubes are to be retained by bolting they are to be provided with a substantial flange securely attached to the hull structure. Where bolts are used, the nuts are to be suitably locked.

2.35.9 Where rudder tubes are to be welded to hull insert plates full penetration welding is required.

2.35.10 Rudder tubes are to be supported by suitable brackets and deep floors to avoid hard spots on the shell and to ensure continuity of the main hull structure.

2.35.11 Rudder bearings are to be secured against rotation within the rudder tubes by suitable pinch bolting or keys. Details are to be submitted for approval.

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2.36 Watertight gland

2.36.1 In rudder trunks which are open to the sea, a seal or stuffing box is to be fitted above the deepest load waterline, to prevent water from entering the steering gear compartment and the lubricant from being washed away from the rudder carrier. If the top of the rudder trunk is below the deepest waterline two separate stuffing boxes are to be provided. Rudder trunk boundaries where exposed to the sea are to have a corrosion protection coating applied in accordance with the manufacturer's instructions.

2.36.2 Where the top of the rudder tube is significantly higher than the deepest load waterline a lesser arrangement of watertightness, such as 'O' rings may be accepted.

2.36.3 The watertight gland body may be formed by the top of the fabricated or cast rudder tube. The gland packing being retained against the top bearing or a check in the wall of the rudder tube and is compressed by a gland packet which may be of the flange type, screwed cap or other suitable arrangement.

2.36.4 Alternative arrangements utilising lip seals or 'O' rings, either in isolation or in combination with one or other of the alternative seal arrangements, will be the subject of special consideration.

2.37 In-water Survey requirements

2.37.1 Where an ***IWS** (In-water Survey) notation is to be assigned, *see* Pt 1, Ch 2,3.8, means are to be provided for ascertaining the rudder pintle and bush clearances and for verifying the security of the pintles in their sockets with the craft afloat.

■ *Section 3* Sternframes and appendages

3.1 General

3.1.1 Stern frames, rudder horns and boss end brackets may be constructed of cast or forged steel, cast or forged aluminium alloy, fabricated from aluminium or steel plate or moulded from fibre reinforced plastic dependent upon the material of construction of the craft. Where shaft brackets are fitted these may be either fabricated, cast or forged from steel or aluminium alloy as applicable to the material of construction of the main hull.

3.1.2 In castings, sudden changes of section or possible constrictions to the flow of metal during casting are to be avoided. All fillets are to have adequate radii, which, in general, are to be not less than 50 to 75 mm, depending on the size of the casting.

3.1.3 Castings and forgings are to comply with the requirements of Chapters 4 and 5 of the Rules for Materials.

3.1.4 Sternframes, rudder horns, shaft brackets, etc., are to be effectively integrated into the craft structure, and their design is to be such as to facilitate this.

3.2 Sternframes

3.2.1 The scantlings of sternframes are to be determined from Table 3.3.1. In the case of very large craft, the scantlings and arrangements may be required to be verified by direct calculations.

3.2.2 Fabricated and cast propeller posts and rudder posts of twin screw craft are to be strengthened at intervals by webs. In way of the upper part of the sternframe arch, these webs are to line up with the floors.

3.2.3 Rudder posts and propeller posts are to be connected to floors of increased thickness. *See* Ch 3,5.10 of Parts 6 and 7 for steel and aluminium alloy construction respectively.

3.2.4 The requirements for sternframes of composite craft are to be in accordance with Pt 8, Ch 3,5.9.

3.3 Rudder horns

3.3.1 The requirements for the scantlings and arrangements of rudder horns are given in Ch 3,5.9 of Parts 6 and 7 for steel and aluminium alloy construction and Pt 8, Ch 3,5.8 for composite construction respectively.

3.4 Shaft bossing

3.4.1 Where the propeller shafting is enclosed in bossings extending back to the bearings supporting the propellers, the aft end of the bossings and the bearings are to be supported by substantially constructed boss end castings or fabrications. These are to be designed to transmit the loading from the shafting efficiently into the craft's internal structure.

3.4.2 For shaft bossings attached to shaft brackets, the length of the boss is to be adequate to accommodate the aftermost bearing and to allow for proper connection of the shaft brackets.

3.4.3 Cast steel supports are to be suitably radiused where they enter the main hull to line up with the boss plating radius. Where the hull sections are narrow, the two arms are generally to be connected to each other within the craft. The arms are to be strengthened at intervals by webs.

3.4.4 Fabricated supports are to be carefully designed to avoid or reduce the effect of hard spots. Continuity of the arms into the craft is to be maintained, and they are to be attached to substantial floor plates or other structure. The connection of the arms to the bearing boss is to be by full penetration welding.

3.4.5 The scantlings of supports will be specially considered. In the case of certain high powered craft, direct calculations may be required.

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Table 3.3.1 Sternframes (*see continuation*)

Item	Parameter	Requirement		
(1) Propeller posts		Cast steel (*see* Fig. 3.3.1(a))	Forged Steel (*see* Fig. 3.3.1(b))	Fabricated mild steel (*see* Fig. 3.3.1(c))
	l	$165\sqrt{T}$ mm	–	$200\sqrt{T}$ mm
	r	$20\sqrt{T}$ mm	–	$18\sqrt{T}$ mm
	t_W	$8\sqrt{T}$ mm (need not exceed 38 mm) (*see* Notes 1 and 2)	–	$6\sqrt{T}$ mm (need not exceed 30 mm) (*see* Notes 1 and 2)
	t_1	$12\sqrt{T}$ mm (min 19 mm)	–	$12\sqrt{T}$ mm
	t_2	$16\sqrt{T}$ mm (min 25 mm)	–	–
	W	$115\sqrt{T}$ mm	$40\sqrt{T}$ mm	$140\sqrt{T}$ mm
	A	–	$(10 + 0{,}5L_R)T$ cm^2 where $L_R \leq 60$ m $40T$ cm^2 where $L_R > 60$m	–
(2) Propeller boss (*see* Note 3 and Fig. 3.3.2)	t_b	$(0{,}1\delta_{TS} + 56)$ mm, but need not exceed $0{,}3\delta_{TS}$		
(3) Rudder posts or axles		Single screw with integral solepiece, *see* Fig. 3.3.5 (a)	Single screw with bolted rudder axle, with hull, *see* Fig. 3.3.3	Twin screw, integral *see* Fig. 3.3.4
	n	–	6 (*see* Note 4)	–
	r	–	–	$20\sqrt{T}$ mm
	r_b	–	δ_A mm	–
	t_F	–	δ_b mm	–
	t_1	–	–	$12\sqrt{T}$ mm
	t_2	–	–	$15\sqrt{T}$ mm
	t_3	–	–	$18\sqrt{T}$ mm
	w	–	–	$120\sqrt{T}$ mm
	z_{PB1}, z_{PB2}	–	$1{,}2\delta_{PL2}$ mm	–
	Z_T	$0{,}147A_R\,b(V + 3)^2$ cm^3	–	–
	δ_A	–	$(25T + 76)$ mm but need not exceed $0{,}9\delta_{PL2}$ mm	–
	δ_b	–	$6{,}25T + 19$ mm or $0{,}225\delta_{PL2}$ mm whichever is the greater	–
	δ_{PL1}, δ_{PL2} bearing pressure and pintle clearance	–	As for rudder pintles (*see* Table 3.2.11)	–
(4) Solepieces (*see* Notes 5,6 and 7)		With integral rudder post, *see* Fig. 3.3.5(a)	With bolted axle, *see* Fig. 3.3.5(b)	Open type (no rudder post), *see* Fig. 3.3.5(c)
(a) Cast steel	Z_T	$0{,}50W$ cm^3	$0{,}95W$ cm^3	$1{,}00W$ cm^3
	Z_V	$0{,}35W$ cm^3	$0{,}40W$ cm^3	$0{,}50W$ cm^3
(b) Fabricated mild steel	Z_T	$0{,}42W$ cm^3	$0{,}81W$ cm^3	$0{,}85W$ cm^3

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Table 3.3.1 Sternframes (*conclusion*)

Symbols	
L_R, T as defined in Ch1,6.2	$L_1 = L_R$, but is to be taken not less than 90 m
a,b,c = distances, in metres, as shown in Fig. 3.3.5	V = maximum service speed, in knots, with the craft in the loaded condition
n = number of bolts in palm coupling	$W = \dfrac{400 A_R C (V+3)^2 (3x+a)}{b (L_1 + 640)}$
r_b = mean distance of bolt centres from centre of palm, in mm	Z_T = section modulus against transverse bending, in cm^3
t_b = finished thickness of boss, in mm	Z_V = section modulus against vertical bending, in cm^3
x = distance, in metres, from centre of rudder stock to section under consideration	δ_b = diameter of coupling bolts, in mm
A = cross-sectional area of forged steel propeller post, in cm^2	δ_{TS} = diameter of tail shaft, in mm
A_R = total rudder area, in m^2	

NOTES

1. Where scantlings and proportions of the propeller post differ from those shown in Item 1, the section modulus about the longitudinal axis of the proposed section normal to the post is to be equivalent to that with Rule scantlings. t_1 is to be not less than $8\sqrt{T}$ (minimum of 19 mm for cast steel sternframes)
2. On sternframes without solepieces, the modulus of the post below the propeller boss, about the longitudinal axis may be gradually reduced to not less than 85% of that required by Note 1, subject to the same thickness limitations.
3. In fabricated sternframes the connection of the propeller post to the boss is to be by full penetration welds.
4. If more than six bolts are fitted, the arrangements are to provide equivalent strength.
5. In fabricated solepieces, transverse webs are to be fitted spaced not more than 760 mm apart. Where the breadth of the solepiece exceeds 900 mm, a centreline vertical web is also to be fitted.
6. Solepieces supporting fixed or movable nozzles will be specially considered (*see* 4.2).
7. For dredging and reclamation craft in restricted service Groups G1, G2 or G3, the scantlings of an 'open' type solepiece are to be such that:
   (a) $Z_T = 0{,}625W$ cm^3.
   (b) The cross-sectional area is not less than 18 cm^2.
   (c) The depth is not less than two-thirds of the width at any point.

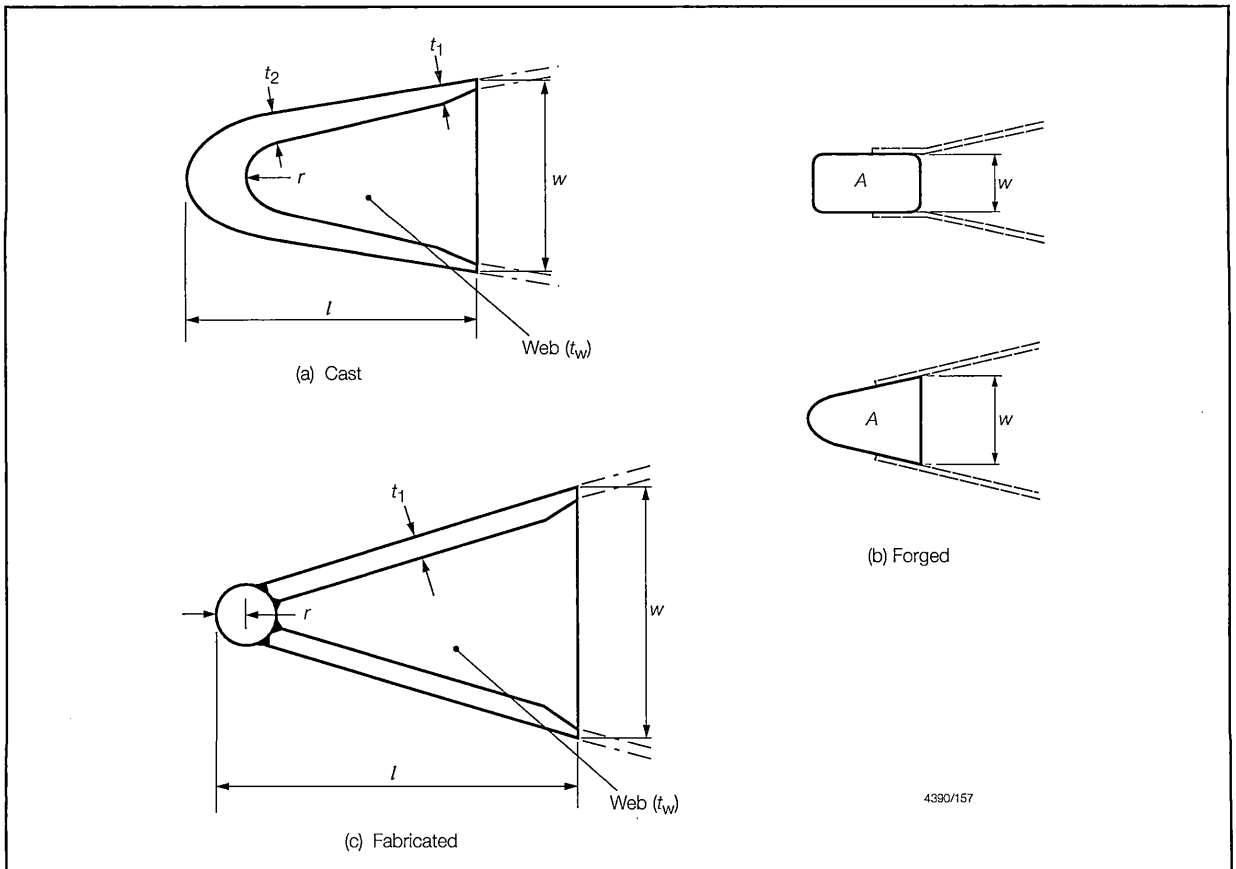

Fig. 3.3.1 Propeller posts

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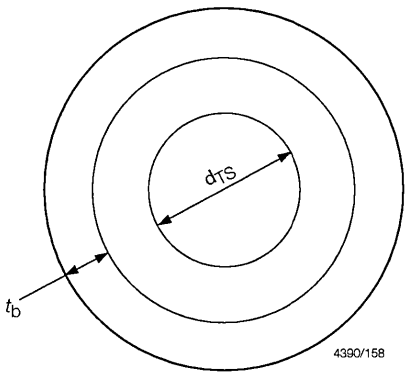

Fig. 3.3.2 Propeller boss

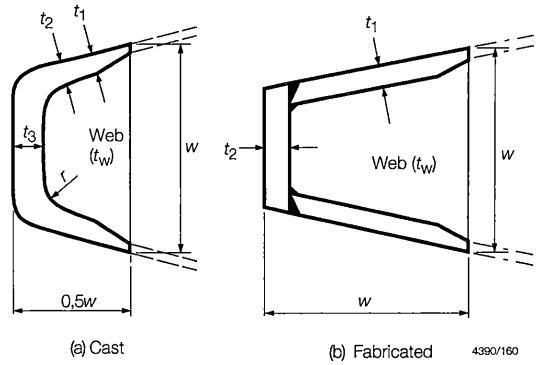

Fig. 3.3.4 Rudder post for twin screw craft

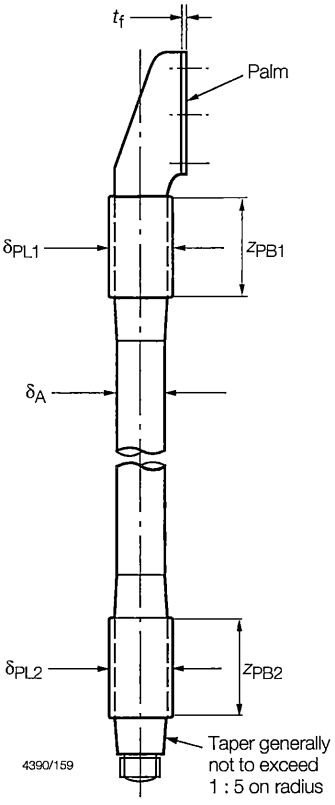

Fig. 3.3.3 Rudder axle

3.4.6 The boss plating is generally to be radiused into the shell plating and supported at the aft end by diaphragms at every frame. These diaphragms are to be suitably stiffened and connected to floors or a suitable arrangement of main and deep web frames. At the forward end, the main frames may be shaped to fit the bossing, but deep webs are generally to be fitted not more than four frame spaces apart.

3.5 Shaft brackets

3.5.1 The scantlings of the arms of shaft brackets, based on a breadth to thickness ratio of about five, are to be determined from 3.6.1 and 3.7.2.

3.5.2 Where the propeller shafting is exposed to the sea for some distance clear of the main hull, it is generally to be supported adjacent to the propeller by independent brackets having two arms. In very small craft the use of single arm brackets will be considered.

3.5.3 Fabricated brackets are to be designed to avoid or reduce the effect of hard spots and ensure a satisfactory connection to the hull structure. The connection of the arms to the bearing boss is to be by full penetration welding.

3.5.4 Where bracket arms are carried through the shell plating, they are to be attached to floors or girders of increased thickness. The shell plating is to be increased in thickness and connected to the arms by full penetration welding.

3.5.5 In the case of certain high powered craft direct calculations may be required.

3.5.6 For shaft brackets having hollow section arms, the cross-sectional areas at the root and the boss should be not less than that required for a solid arm which satisfies the Rule section modulus having the proportions stated in 3.5.1.

3.5.7 The length of the shaft bracket boss, l_b, is to be sufficient to support the length of the required bearing. In general l_b is not to be less than $4d_t$, where d_t is the Rule diameter of the screwshaft, in mm, *see* Pt 11, Ch 2,4.4. Proposals for a reduction in the required shaft bracket boss length will be considered in conjunction with details of the bearing material, allowable bearing operating pressure and installation arrangements, *see* Pt 11, Ch 2,4.16.2. However in no case is l_b to be less than the greater of:

(a) $2d_t$; or
(b) that recommended by the bearing manufacturer; or
(c) as required by 3.4.2.

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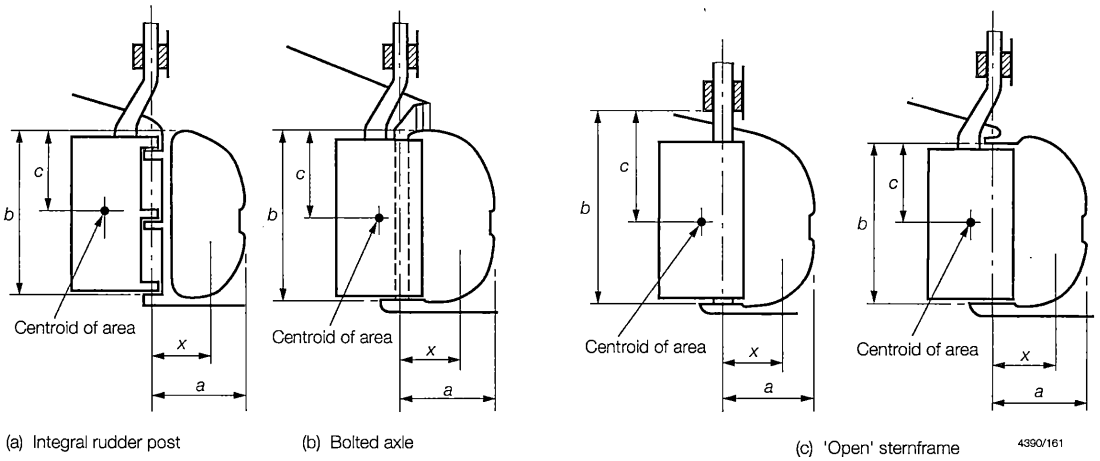

Fig. 3.3.5 Solepiece

3.5.8 Where the shaft and the shaft bracket boss are of the same material, the thickness of the shaft bracket boss is not to be less than $d_t/4$. Where the shaft and the shaft bracket boss are of dissimilar materials, the thickness of the boss, t_b, is to be not less than:

$$t_b = 0{,}75 d_t \left(\sqrt[3]{f_1} - 0{,}667 \right) \text{ mm}$$

NOTE:
In no case is t_b to be taken as less than 12 mm.

where

d_t = Rule diameter of the screwshaft, in the appropriate screwshaft material, in mm, *see* Pt 11, Ch 2,4

f_1 = σ_S/σ_B but not less than 0,825

σ_S = ultimate tensile strength of the shaft material, in N/mm^2

σ_B = ultimate tensile strength of the boss material, in N/mm^2.

3.5.9 The design of the shaft brackets with regard to disturbance of the hydrodynamic flow into the propeller and rudders is outwith the scope of classification.

3.6 Single arm shaft brackets ('P' – brackets)

3.6.1 Single arm shaft brackets are to have a section modulus, Z_{xx}, at the palm of not less than that determined from the formula:

$$Z_{xx} = \frac{a_s d_t^2 f}{45000} \text{ cm}^3$$

where

a_s = the length of the arm to be measured from the centre of the section at the palm to the centreline of the shaft boss, in mm, *see* Fig. 3.3.6

d_t = the Rule diameter for an unprotected screwshaft, in mm, as given in Pt 11, Ch 2,4, using $A = 1{,}0$

f = $400/\sigma_u$

σ_u = ultimate tensile strength of arm material, in N/mm^2

The cross-sectional area of the bracket at the boss is to be not less than 60 per cent of the area of the bracket at the palm.

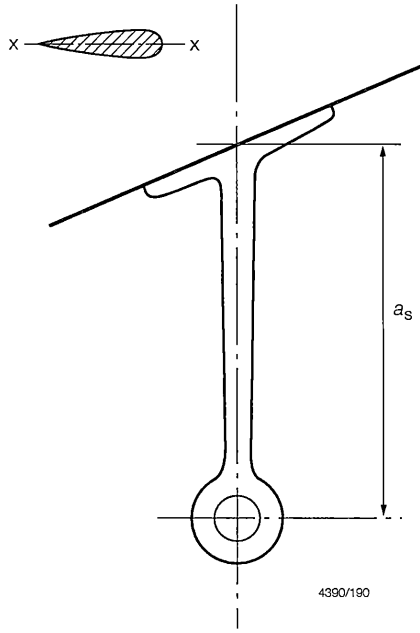

Fig. 3.3.6 Single arm shaft bracket

3.6.2 For single arm shaft brackets a vibration analysis may be required if deemed necessary by LR.

3.7 Double arm shaft brackets ('A' – brackets)

3.7.1 The angle between the arms for double arm shaft brackets is to be generally not less than 50°. Proposals for the angle between the arms to be less than 50° will be specially considered with supporting calculations to be submitted by the designers.

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3.7.2 The arms of double arm shaft brackets are to have a section modulus, Z_{xx}, of not less than that determined from the formula:

$$Z_{xx} = 0{,}45\, n^3 \quad cm^3$$

where

n = the minimum thickness, in cm, of a hydrofoil section obtained from:

$$n = d_t \sqrt{\left(\frac{f}{2000}\right)\left(1 + \sqrt{\left(1 + \left(\frac{0{,}0112}{f}\right)\left(\frac{a_d}{d_t}\right)^2\right)}\right)} \quad cm$$

a_d = the length of the longer strut, in mm, *see* Fig. 3.3.7

d_t and f are as given in 3.6.1.

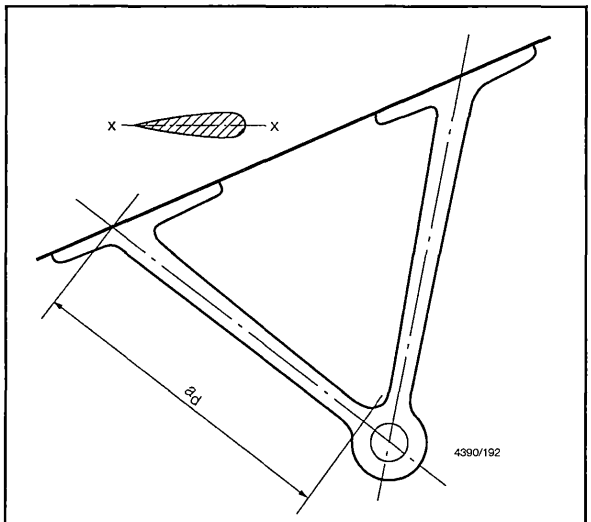

Fig. 3.3.7 Double arm shaft bracket

3.8 Intermediate shaft brackets

3.8.1 The length and thickness of the shaft bracket boss are to be as required by 3.5.7 or 3.5.8 as appropriate. The scantlings of the arms will be specially considered on the basis of the Rules.

3.9 Attachment of shaft brackets by welding

3.9.1 Fabricated supports are to be carefully designed to avoid or reduce the effect of hard spots. Continuity of the arms into the craft is to be maintained, and they are to be attached to substantial floor plates or other structure. The connection of the arms to the bearing boss is to be by full penetration welding.

3.10 Attachment of shaft brackets by bolting

3.10.1 The bottom shell thickness in way of the double arm propeller bracket palms is to be increased by 50 per cent. The bottom shell thickness in way of single arm propeller brackets palms is to be doubled in thickness. The insert plates, or reinforced shell laminate in FRP craft, are to be additionally supported by substantial floor plates or other structure.

3.10.2 Where shaft brackets are attached by bolts, they are to be provided with substantial palms securely attached to the hull structure which is to be adequately stiffened in way. Where bolts are used, the nuts are to be suitably locked.

3.10.3 The bracket palms may be bolted directly onto the shell using a suitable bedding compound. The palms may be bolted onto suitable shims or chocking compound, of an approved type, to facilitate alignment.

3.10.4 Where brackets are bolted onto resin chocks, plans indicating the following information are to be submitted for approval:

(a) The thrust and torque loads, where applicable, that will be applied to the chocked item.
(b) The torque load to be applied to the bracket mounting bolts.
(c) The material of the bracket mounting bolts.
(d) The number, thread size, shank diameter and length of the mounting bolts.

3.10.5 The minimum thickness of a resin chock is to be 12 mm.

3.10.6 The bracket palms are to have well radiused corners, and the faying surface to be dressed smooth. The palm thickness in way of the bolts is to be not less than the propeller bracket boss thickness from 3.5.7 or 3.5.8 as appropriate.

3.10.7 The diameter of the propeller bracket mounting bolts is to be not less than:

$$d_b = \sqrt{\frac{Z_{xx}}{8{,}75\,\pi\, n\, h \times 10^{-5}}} \quad mm$$

and not less than the shell plate thickness in way of the palm or 12 mm, whichever is greater

where

Z_{xx} = the section modulus of the bracket arm determined from 3.6.1 or 3.7.2, in cm^3, as appropriate

n = the number of bolts in each row

h = the distance between rows of bolts, in mm

d_b = the bolt diameter in the same material as the propeller bracket, in mm.

3.10.8 Where the shaft bracket and the shaft bracket mounting bolts are of dissimilar materials (which are galvanically compatible), the diameter of the propeller bracket mounting bolts, as determined from 3.10.7, is to be modified in proportion to the square root of the yield strengths of the particular materials. The corrected bolt diameter of the dissimilar material is to be not less than the propeller bracket boss thickness.

3.10.9 The propeller bracket palms are to have fitted bolts, and suitable arrangements provided to lock the nuts.

3.10.10 A washer plate is to be provided, generally of equal dimensions to the bracket palm with thickness $t_b/6$ mm, subject to a minimum of 3 mm.

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3.11 Attachment of shaft brackets by bonding

3.11.1 Proposals to connect shaft brackets to FRP hulls by bonding will be the subject of special consideration. Details of the following are to be submitted:

(a) Preparation of the hull penetration and internal bonding surface.

(b) Details of transverse through pinning of the shaft bracket strut.

(c) Details of over bonding of strut and pin arrangement and subsequent integration of strut into primary hull structure.

3.12 Alignment of shaft brackets

3.12.1 Particular care is to be paid to the alignment of shaft brackets to minimise vibration and cyclic loadings being transmitted from the propulsion shafting and propellers into the hull structure.

3.12.2 Alignment of bolted shaft brackets may be by means of suitable metallic shims or chocking resin of an approved type. *See* 3.10.2 and 3.10.3.

3.12.3 The alignment of shaft brackets connected by welding or bonding may be facilitated by boring of the bracket boss after attachment of the shaft bracket and stern tube.

3.13 Sterntubes

3.13.1 The sterntube construction may be of aluminium alloy, steel, bronze or fibre reinforced plastic.

3.13.2 The sterntube scantlings are to be individually considered.

3.13.3 For steel and aluminium hulls, the bottom shell, in way of the sterntube, is to be additionally reinforced by means of an insert plate to increase the bottom shell thickness by 50 per cent.

3.13.4 For FRP hulls, the bottom shell laminate, in way of the sterntube, is to be locally increased by 50 per cent by gradual tapering of the laminate. The increased thickness in way of the sterntube need not exceed the Rule keel thickness requirement.

3.13.5 For FRP sandwich hulls, the shell in way of the stern tube connection is to be either:

(a) Reduced from sandwich hull construction to single skin laminate by removal of the core and by combining the inner and outer skins. The single skin region is then to be additionally reinforced by a minimum of 50 per cent of the sum of the inner and outer sandwich laminate. The increased thickness in way of the sterntube need not be greater than the Rule keel thickness requirement.

(b) Reduced from the sandwich hull construction to a single skin laminate by removal of the core and combining the inner and outer skins. After bonding in the stern tube to the single skin laminate the foam core and the inner skin is to be reinstated.

(c) Proposals to replace the sandwich core with a core having higher core shear strength and compressive strength than that of the adjacent structure prior to bonding the tube to the inner and outer skins will be the subject of special consideration.

3.13.6 The sterntube may be connected to the shell by bonding, bolting or welding as applicable depending upon the construction material of the shell.

3.13.7 When bonding in sterntubes the bonding angle laminate weight is to be not less than the Rule minimum bottom weight. FRP tubes are to be thoroughly abraded and degreased prior to installation and laminating. Bonded in metallic tubes are to be knurled in way of the bonding material and thoroughly degreased prior to installation. During the bonding operation particular care is to be given to maintaining the sterntube alignment.

3.13.8 Where sterntubes are to be retained by bolting, they are to be provided with a substantial flange securely attached to the hull structure. Where bolts are used, the nuts are to be suitably locked.

3.13.9 Where sterntubes are to be welded to hull insert plates full penetration welding is required.

3.13.10 Where sterntubes are to be installed using a resin system, of an approved type, the requirements of Pt 11, Ch 2,4.16 are to be complied with.

3.13.11 The region where the shafting enters the craft, and the bearing in way, is to be adequately supported by floors or deep webs.

3.13.12 The shaft bearings are to be secured against rotation within the sterntube.

3.13.13 A suitable gland arrangement is to be provided at the inboard end of sterntubes in accordance with Pt 11, Ch 2,4.15.

3.14 Solepieces

3.14.1 The requirements for solepieces are as indicated in Table 3.3.1.

3.15 Propeller hull clearances

3.15.1 Recommended minimum clearances between the propeller and the sternframe, rudder or hull are given in Table 3.3.2. These are the minimum distances considered desirable in order to expect reasonable levels of propeller excited vibration. Attention is drawn to the importance of the local hull form characteristics, shaft power, water flow characteristics into the propeller disc and cavitation when considering the recommended clearances.

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Table 3.3.2 Recommended propeller hull clearances

Number of Blades	Hull clearances for single screw, in metres, *see* Fig. 3.3.8(a)				Hull clearances for twin screw, in metres, *see* Fig. 3.3.8(b)	
	a	b	c	d	e	f
3	$1{,}20K\delta$	$1{,}80K\delta$	$0{,}12\delta$	$0{,}03\delta$	$1{,}20K\delta$	$1{,}20K\delta$
4	$1{,}00K\delta$	$1{,}50K\delta$	$0{,}12\delta$	$0{,}03\delta$	$1{,}00K\delta$	$1{,}20K\delta$
5	$0{,}85K\delta$	$1{,}275K\delta$	$0{,}12\delta$	$0{,}03\delta$	$0{,}85K\delta$	$0{,}85K\delta$
6	$0{,}75K\delta$	$1{,}125K\delta$	$0{,}12\delta$	$0{,}03\delta$	$0{,}75K\delta$	$0{,}75K\delta$
Minimum value	$0{,}10\delta$	$0{,}15\delta$	t_R	—	3 and 4 blades, $0{,}20\delta$ 5 and 6 blades, $0{,}16\delta$	$0{,}15\delta$

Symbols

L_R and C_b as defined in Ch 1,6.1

$$K = \left(0{,}1 + \frac{L_R}{3050}\right)\left(\frac{3{,}48C_b P_s}{L_R^2} + 0{,}3\right)$$

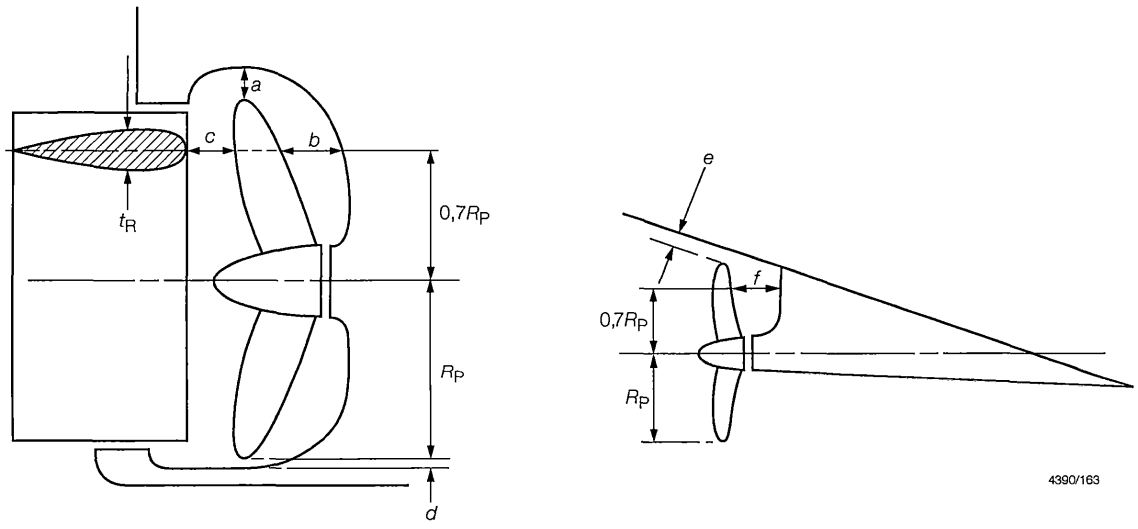
t_R = thickness of rudder, in metres measured at $0{,}7R_p$ above the shaft centreline

P_s = designed power on one shaft, in kW

R_p = propeller radius, in metres

δ = propeller diameter, in metres

NOTE
The above recommended minimum clearances also apply to semi-spade type rudders.



(a) Single screw (b) Twin screw

Fig. 3.3.8 Propeller clearance

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■ *Section 4*
Fixed and steering nozzles, bow and stern thrust units

4.1 General

4.1.1 The requirements for scantlings for fixed and steering nozzles are given, for guidance only, in 4.2 to 4.4 and Table 3.4.1.

4.1.2 The requirements, in general, apply to nozzles with a numeral not greater than 200, *see* Table 3.4.1. Nozzles exceeding this value will be specially considered.

4.2 Nozzle structure

4.2.1 For basic scantlings of the structure, *see* Table 3.4.1, in association with Fig. 3.4.1.

4.2.2 The shroud plating in way of the propeller tips is to be carried well forward and aft of this position, due allowance being made on steering nozzles for the rotation of the nozzle in relation to the propeller.

4.2.3 Fore and aft webs are to be fitted between the inner and outer skins of the nozzle. Both sides of the headbox and pintle support structure are to be connected to fore and aft webs of increased thickness. For thicknesses, *see* Table 3.4.1.

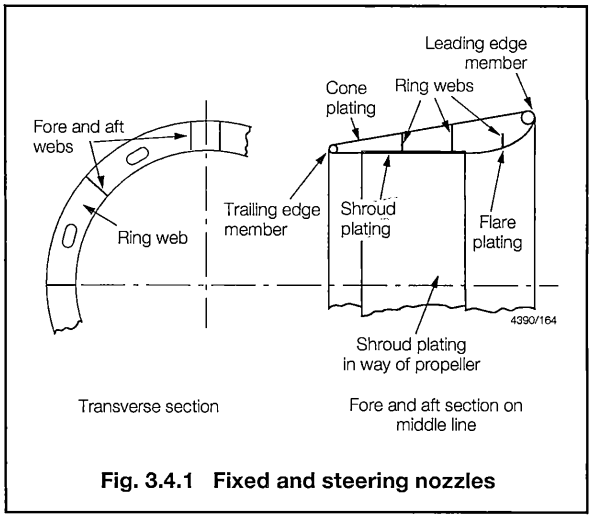

Fig. 3.4.1 Fixed and steering nozzles

Table 3.4.1 Nozzle construction requirements

Item	Requirement
(1) Nozzle Numeral	$N_N = 0{,}01P\delta_P$
(2) Shroud plating in way of propeller blade tips	For $N_N \leq 63$ $t_s = (11 + 0{,}1N_N)$ mm For $N_N > 63$ $t_s = (14 + 0{,}052N_N)$ mm
(3) Shroud plating clear of blade tips, flare and cone plating, wall thickness of leading and trailing edge members	$t_p = (t_s - 7)$ mm but not less than 8mm
(4) Webs and ring webs	As item (3) except in way of headbox and pintle support where $t_W = (t_s + 4)$ mm
(5) Nozzle stock	Combined stresses in stock at lower bearing $\leq 92{,}7$ N/mm^2 Torsional stress in upper stock $\leq 62{,}0$ N/mm^2
(6) Solepiece and strut	Bending stresses not to exceed 70,0 N/mm^2
Symbols	
N_N = a numeral dependent on the nozzle requirements P_s = power transmitted to the propellers, in kW δ_P = diameter of the propeller, in metres t_S = thickness of shroud plating in way of propeller tips, in mm t_p = thickness of plating, in mm t_W = thickness of webs and ring webs in way of headbox and pintle support, in mm	
NOTE Thicknesses given are for mild steel. Reductions in thickness will be considered for certain stainless steels.	

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4.2.4 The transverse strength of the nozzle is to be maintained by the fitting of ring webs. Two ring webs are to be fitted in nozzles not exceeding 2,5 m diameter. Nozzles between 2,5 and 3,0 m in diameter are generally to have two full ring webs and a half-depth web supporting the flare plating. The number of ring webs is to be increased as necessary on nozzles exceeding 3,0 m in diameter. Where ring webs are increased in thickness in way of the headbox and pintle support structure in accordance with Table 3.4.1, the increased thickness is to be maintained to the adjacent fore and aft web.

4.2.5 Local stiffening is to be fitted in way of the top and bottom supports which are to be integrated with the webs and ring webs. Continuity of bending strength is to be maintained in these regions.

4.2.6 Fin plating thickness is to be not less than the cone plating, and the fin is to be adequately reinforced. Solid fins are to be not less than 25 mm thick.

4.2.7 Care is to be taken in the manufacture of the nozzle to ensure its internal preservation and watertightness. The preservation and testing are to be as required for rudders, *see* 2.25 and 2.27, and Table 1.7.2 in Chapter 1.

4.3 Nozzle stock and solepiece

4.3.1 Stresses, derived using the maximum side load on the nozzle and fin acting at the assumed centre of pressure, are not to exceed the values given in Table 3.4.1, in both the ahead and astern conditions.

4.4 Ancillary items

4.4.1 The diameter and first moment of area about the stock axis of coupling bolts and the diameter of pintles, are to be derived from 2.20 and 2.19 respectively.

4.4.2 Suitable arrangements are to be provided to prevent the steering nozzle from lifting.

4.5 Steering gear and allied systems

4.5.1 For the requirements of steering gear, *see* Pt 12, Ch 1.

4.6 Thruster unit wall thickness

4.6.1 The wall thickness of the unit is, in general, to be in accordance with the manufacturer's practice, but is to be not less than:

(a) For steel hulls, the thickness of the adjacent shell plating plus 10 per cent or 2 mm whichever is the greater, subject to a minimum of 7 mm.

(b) For aluminium hulls, the thickness of the adjacent shell plating plus 10 per cent or 1 mm whichever is the greater, subject to a minimum of 8 mm.

(c) For FRP hulls, generally the thickness of the adjacent shell laminate plus 25 per cent subject to a minimum of 8 mm. Full details of the proposed laminate and resin system are to be submitted for approval.

4.7 Thruster unit installation details

4.7.1 The method of attachment of the tube is dependent upon the tube and the craft's construction materials which may be steel, aluminium alloy or FRP.

4.7.2 The tunnel tube is to be fitted either between a pair of deep floors or bulkheads extending to above the design waterline or in a separate watertight compartment.

4.7.3 The shell plating thickness is to be locally increased by 50 per cent in way of tunnel thruster connections.

4.7.4 For welded tube connections the welding is to be by full penetration welding.

4.7.5 For FRP tubes attached by bonding the total bonding reinforcement weight is to be at least that of the hull bottom laminate with the tube bonded internally and externally to the shell laminate. Prior to bonding *in situ* the areas to be bonded are to be thoroughly abraded and degreased and all cut FRP laminate edges resin sealed.

4.7.6 The tunnel tube is to be framed to the same standard as the surrounding shell plating.

4.7.7 The unit is to be adequately supported and stiffened.

4.8 Novel features

4.8.1 Where the Rules do not specifically define the requirements for novel features then the scantlings and arrangements are to be determined by direct calculations. Such calculations are be carried out on the basis of the Rules, recognised standards and good practice, and are to be submitted for consideration.

■ *Section 5* Stabiliser arrangements

5.1 General

5.1.1 The scantlings, arrangements and effectiveness of the stabilisers are outwith the scope of classification; however their foundations, supporting structure and watertight integrity are to be examined.

5.2 Fin stabilisers

5.2.1 Detailed plans are to be submitted clearly indicating the position, supporting structure and design loads for all fins.

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5.2.2 The design, construction, operational performance and control systems of the fin stabiliser unit are outside the scope of classification.

5.2.3 Fin stabilisers are to be contained within a watertight enclosure. The purpose of the watertight enclosure is to ensure that any impact to the stabiliser will not affect the survivability or safe operation of the craft. In addition to the requirements of 5.2.4, when determining the location and extent of the watertight enclosure the following should be considered:

(a) Stabiliser blade construction material
(b) Designed failure mode of stabiliser shaft
(c) Damage stability requirements of craft
(d) Survivability of craft after impact to the stabiliser
(e) Function of space containing stabiliser.

5.2.4 For non-retractable type stabilisers, the watertight divisions forming the forward and aft boundaries of the watertight enclosure are to be arranged not less than one third of the root chord length, C, from the fore and aft extents of the stabiliser, *see* Fig. 3.5.1. Main watertight subdivision bulkheads may be considered as watertight divisions where appropriate.

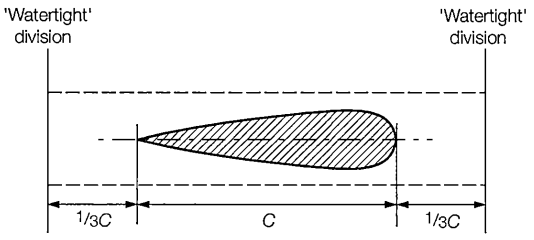

Fig. 3.5.1 Stabiliser positioning

5.2.5 For craft constructed of mild steel the watertight enclosure into which the stabilisers retract is to have a perimeter plating of the same thickness as the surrounding Rule shell plating plus 2 mm, and is to be stiffened to the same standard as the shell. For craft constructed from aluminium alloys the corrections in Ch 3,1.2.2 apply.

5.2.6 For craft constructed from composite materials the laminate thickness of the watertight enclosure into which the stabilisers retract is to be specially considered. Generally the thickness should not be less than that of the bottom shell.

5.2.7 Insert plates are to be fitted or laminate thickness increased in way of stabilisers. The thickness of the insert plate or increased laminate is to be at least 50 per cent greater than the bottom shell thickness in way, and is to extend over an area formed by 1,25 times the stabiliser root chord length and covering all operational angles. In addition, for retractable stabilisers the insert is to extend beyond the shell opening for a distance of not less than 25 per cent the length of the root chord.

5.2.8 Fin stabiliser systems are, in general, not to extend beyond the extreme moulded beam of the hull or below the horizontal line of keel. However, for retractable fins, alternative arrangements may be specially considered. Where the stabiliser fin extends beyond the extreme moulded beam of the hull in the active mode, the side shell is to be permanently marked indicating the forward and aft extent of the stabiliser when deployed. It is recommended that an appropriate symbol be placed on the hull side between the marks.

5.2.9 The stabiliser machinery and surrounding structure is to be adequately supported and stiffened. Where bending stresses are induced in the structure under fatigue conditions the maximum stress is not to exceed 39,0 N/mm^2 in mild steel. Where other materials are used for the supporting structure the limiting stress values will be specially considered on the basis of the Rules.

5.2.10 The scantlings of internal watertight bulkheads and stiffening for fixed installations are to be as specified by the designer/Builder and/or fin unit manufacturer but in no case are to be less than the scantlings for double bottoms as defined in Pt 6, Ch 3,6 for steel structures and Pt 7, Ch 3,6 for aluminium structures. Suitable access is to be provided to allow for maintenance and inspection purposes.

5.2.11 The scantlings and sealing arrangements for the pedestal and bearings will be specially considered, subject to the designer/Builder submitting the following:

(a) Detailed structural calculations for the proposed foundation and adjacent supporting structure.
(b) A detailed finite element model, if carried out, *see* Pt 3, Ch 1,2.
(c) Calculations demonstrating that the effect of damage to the stabiliser arrangement arising from high speed impact, grounding, fouling, etc will not compromise the structural and watertight integrity of the craft.
(d) Maximum torque, bending moments and bearing loads expected for the proposed design.
(e) The stabiliser fin stock material, together with its ultimate tensile and shear strength values (N/mm^2).

5.2.12 Fin bearing materials and seals are to be of an approved type.

5.2.13 Where retractable stabilisers are fitted, position indicators are to be provided on the bridge and adjacent to the stabiliser installation.

5.3 Stabiliser tanks

5.3.1 The general structure of the tank is to comply with the Rule requirements for deep tanks. Sloshing forces in the tank structure are to be taken into account. Where such forces are likely to be significant, the scantlings will be required to be verified by additional calculations.

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5.4 Ride control systems

5.4.1 The scantlings, arrangements and effectiveness of ride control systems are currently outwith the scope of classification; however their foundations, supporting structure and watertight integrity together with the associated reaction forces on the hull structure are to be examined. Details of the loadings and supporting calculations are to be submitted with the relevant construction plans for consideration.

5.5 Motion damping arrangements and devices

5.5.1 Motion damping devices are generally outwith the scope of the Rules. Where motion damping devices are fitted the designers/Builders are to submit details of the anticipated loadings and supporting calculations for appraisal of the adjacent hull structure.

5.6 Novel features

5.6.1 Where the Rules do not specifically define the requirements for novel features then the scantlings and arrangements are to be determined by direct calculations. Such calculations are to be carried out on the basis of the Rules, Recognised Standards and good practice, and are to be submitted for consideration.

■ *Section 6* Particular requirements for multi-hull craft

6.1 General

6.1.1 The requirements for control systems of multi-hull craft are generally in accordance with the requirements of Sections 1 to 5 for mono-hulls.

6.2 Rudders

6.2.1 The scantlings for rudders are to be generally in accordance with Ch 3,2. Where the proposed rudder is of a novel design or the speed of the craft exceeds 45 knots the scantlings of the rudder and rudder stock are to be determined from direct calculation methods incorporating model test results and structural analysis, as considered necessary by LR.

6.3 Sternframes and appendages

6.3.1 Sternframes and appendages are to be considered on the basis of the Rules. Reference is also to be made to Chapter 5, (Special Features) of Parts 6, 7 and 8 for steel, aluminium alloy and composite construction respectively.

6.4 Fixed and steering nozzles, bow and stern thrust units

6.4.1 In general, the requirements are to be in accordance with Ch 3,4.

6.5 Stabiliser arrangements

6.5.1 In general, the requirements for multi-hulls are to be in accordance with the requirements of Ch 3,5 and Ch 5,2.4 of Parts 6, 7 and 8, dependent upon the material of construction.

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Section

1 **General**

2 **Bulkhead openings**

3 **Double bottom openings**

4 **Side and stern doors and other shell openings**

5 **Hatches on exposed decks**

6 **Miscellaneous openings**

7 **Portlights, windows and viewing ports, skylights and glass walls**

8 **Bulwarks, guard rails and other means for the protection of crew**

9 **Deck drainage**

10 **Cabin sole and lining**

11 **Ventilators**

12 **Air and sounding pipes**

13 **Particular requirements for multi-hull craft**

Section 1 General

1.1 Application

1.1.1 The contents of this Chapter are applicable to mono-hull and multi-hull craft constructed in steel, aluminium alloy or composite materials.

1.1.2 Where the requirements of Pt 1, Ch 2,1.1.11 and 1.1.14 require the craft to be subdivided for damage stability aspects these will be considered in addition to the requirements of this Part.

1.1.3 Attention is, however, to be given to any other additional statutory requirements of the National Authority in which the craft is registered.

1.2 Downflooding

1.2.1 Yachts and craft to which the *International Convention on Load Lines*, 1966 is applicable, *see* Pt 1, Ch 2,1.1.11, are to comply with the requirements of this sub-Section.

1.2.2 Doors, hatches, ventilators, windows, portlights, etc. provided with closing appliances which can be secured weathertight, and small openings through which progressive flooding cannot take place are not considered as down flooding points.

1.2.3 Air pipes are to be fitted with automatic closing appliances unless it can be shown that, with the craft at its summer load waterline, the openings will not be immersed at an angle of heel of 40°, or the angle of downflooding if this is less than 40°.

1.3 Definitions and symbols

1.3.1 The **down flooding angle** is the least angle of heel at which openings in the hull, superstructure or deckhouses, which cannot be closed weathertight, immerse and allow flooding to occur.

1.3.2 L_L is the loadline length as defined in Ch 1,6.2.3.

1.3.3 Position 1 and Position 2 are as defined in Ch 1,6.10.

1.4 Bolted connections

1.4.1 Bolted connections are generally to be in accordance with Table 4.1.1. Further requirements are contained throughout this Chapter.

Table 4.1.1 Bolt pitch requirements for structural connections

Location	Pitch
Manhole covers to fuel tanks	$6d_b$
Manhole covers to water tanks	$8d_b$
Covers over void tanks/cofferdams	$10d_b$
Unstiffened portable plates in decks	$5d_b$
Bolted watertight door frames	$8d_b$
Window frames to superstructure	$20d_b$

NOTE
d_b is the diameter of the bolt

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■ *Section 2* Bulkhead openings

2.1 General

2.1.1 In addition to the requirements of this Section, where compliance with Pt 4, Ch 2,9 and Chapter X of SOLAS 1974, as amended *(High Speed Craft Code)*, is required, the number and construction of the watertight doors in bulkheads will be considered in accordance with these requirements. Each watertight door is to be subjected to a pressure test, *see* Table 1.7.1 in Chapter 1. The test may be carried out either before or after the door is fitted. Regulations regarding openings in watertight bulkheads relevant to passenger or cargo craft, as appropriate, contained in the *International Convention for the Safety of Life at Sea, 1974* and applicable amendments, and Pt 4, Ch 2,9 are also to be complied with.

2.2 Openings in bulkheads below the freeboard deck

2.2.1 Certain openings below the freeboard deck are permitted, but these must be kept to a minimum and provided with means of closing to watertight standards. All such openings are to be to the satisfaction of the Surveyor.

2.3 Watertight doors

2.3.1 Watertight doors are to be efficiently constructed and fitted, and are to be capable of being operated when the craft is listed up to 15° either way. They are to be operated under working conditions and hose tested in place. *See* Ch 1,7.3.

2.3.2 Where the doors are fitted in watertight bulkheads they are to be of equivalent strength to the unpierced bulkhead and capable of being closed watertight. Watertight doors are to be of a type, approved and pressure tested, *see* Table 1.7.1 in Chapter 1, from both sides for the maximum head of water indicated by any required damage stability calculations or up to the bulkhead deck whichever is the greater.

2.3.3 Indicators are to be provided on the bridge showing whether the doors are open or closed.

2.3.4 Doors are to be capable of being operated from both sides of the bulkhead. Power operated sliding doors are to be capable of being opened and closed locally by both power and efficient hand operated mechanisms.

2.3.5 Doors not required to be used at sea may be of the hinged or sliding type. A notice is to be fixed on the closing appliance saying it should be kept closed at all times while the craft is at sea.

2.3.6 Watertight doors which are intended to be used while at sea are to be of the sliding type capable of being remotely closed from the bridge. An audible alarm is to be provided at the door closure. The power, control and indicators are to be operable in the event of main power failure. Particular care is to be paid to minimising the effect of control system failure.

2.3.7 As an alternative to the sliding doors required by 2.3.6, special consideration will be given to the fitting of hinged watertight doors where it can be shown that they are as effective as the sliding type. A suitable log-book system is to be operated to ensure that such doors remain closed except when in use for access.

2.3.8 Subject to the requirements of 2.3.6 and 2.3.7, hinged watertight doors of approved pattern may be fitted in 'tween decks in approved positions. The hinges of these doors are to be fitted with a pin or bush of a suitable copper alloy in accordance with the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials), or of an equivalent material acceptable to Lloyd's Register (hereinafter referred to as 'LR').

2.3.9 No accesses are to be fitted in collision bulkheads. In particular designs where it would be impracticable to arrange access to the fore peak other than through the collision bulkhead, access may be permitted subject to special consideration. Where accesses are provided, the openings are to be as small as practicable and positioned as far above the design waterline as possible. The closing appliances are to be watertight, open into the fore peak compartment and consideration will be given to operation from one side only.

2.4 Pipe and cable ducts, ventilation trunks and other penetrations

2.4.1 Where subdivision and damage stability requirements apply and where penetration of watertight divisions by pipes, ducts, trunks or other penetrations is necessary, arrangements are to be made to maintain the watertight integrity.

2.4.2 Ventilators from deep tanks and tunnels passing through 'tween decks are to have scantlings suitable for withstanding pressures to which they may be subjected, and are to be made watertight.

■ *Section 3* Double bottom openings

3.1 General

3.1.1 Provision is to be made for the free passage of air and water from all parts of the tanks to the air pipes and suctions, account being taken of the pumping rates required.

3.1.2 Adequate access is also to be provided to all parts of the double bottom for future maintenance, surveys and repairs. The edges of all openings are to be smooth.

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3.2 Requirements

3.2.1 A plan showing the location of manholes and access openings within the double bottom is to be submitted. Attention is to be given to any relevant Statutory Requirements of the National Authority of the country in which the craft is to be registered.

3.2.2 The number and positioning of manholes are to be such that access under service conditions is neither difficult nor dangerous. Attention is to be given to any relevant international regulations regarding the minimum size of access openings.

3.2.3 Manholes and their covers are to be of an approved design or in accordance with a recognised National or International Standard.

3.2.4 The size of opening is not, in general, to exceed 50 per cent of the double bottom depth, unless edge reinforcement is provided. In way of outboard ends of floors and fore and aft girders at transverse bulkheads, the number and size of holes are to be kept to a minimum, and the openings are to be circular or elliptical. Edge stiffening may be required in these positions.

3.2.5 Manholes, lightening holes and other cut-outs are to be avoided in way of concentrated loads and areas of high shear. In particular, manholes and similar openings are not to be cut in vertical or horizontal diaphragm plates in narrow cofferdams or double plate bulkheads within one-third of their length from either end, nor in floors or double bottom girders close to their span ends, below the heels of pillars, nor in way of mast steps, unless the stresses in the plating and the panel buckling characteristics have been calculated and found satisfactory.

3.2.6 Manholes, lightening holes and other openings are to be suitably framed and stiffened where necessary.

3.2.7 Air and drain holes, notches and scallops are to be in accordance with Ch 2,4 of Parts 6 and 7 for steel and aluminium alloy construction respectively.

3.3 Alternative arrangements

3.3.1 The Rules are formed on the basis that access to double bottoms will be by means of manholes with bolted covers. However, alternative arrangements will be specially considered.

■ *Section 4*
Side and stern doors and other shell openings

4.1 General

4.1.1 These requirements cover cargo and service doors in the craft side (abaft the collision bulkhead) and stern area, below the freeboard deck and in enclosed superstructures.

4.1.2 For the requirements of bow doors, *see* Ch 5,4 of Parts 6 and 7 for steel and aluminium alloy construction respectively.

4.1.3 Side and stern doors are to be so fitted as to ensure tightness and structural integrity commensurate with their location and the surrounding structure. *See also* Ch 1,6.8.2 and 6.9.2.

4.1.4 In general, and for passenger craft in particular, the lower edge of door openings are not to be below a line drawn parallel to the freeboard deck at side, which is at its lowest point at least 230 mm above the upper edge of the uppermost Load Line.

4.1.5 When the lower edge is below the uppermost Load Line, the arrangement will be specially considered. Special consideration is to be given to preventing the spread of leakage water over the deck. The reference to the uppermost Load Line is to be taken as the tropical fresh water line.

4.1.6 Doors are generally to be arranged to open outwards, however inward opening doors will be considered provided strongbacks are fitted when the doors are situated in the first two 'tween decks above the waterline.

4.1.7 For passenger craft the following is also applicable:

(a) Gangway, cargo and service ports fitted below the margin line, *see* 1.2.2, are to satisfy the strength requirements given for side doors in this Section. They are to be effectively closed and secured watertight before the craft leaves port, and are to be kept closed during navigation. Such ports are not to have their lowest point below the deepest subdivision Load Line.

(b) Where the inboard end of a rubbish chute is below the margin line in a passenger craft, the inboard end cover is to be watertight and, in addition to the discharge flap interlock, a screwdown automatic non-return valve is to be fitted in an easily accessible position above the deepest subdivision. The valve is to be controlled from a position above the bulkhead deck and provided with an open/shut indicator, and kept closed when not in use. A suitable notice is to be displayed at the valve position.

4.1.8 Where doors and platforms are fitted in the shell, the structural and watertight integrity of the hull is to be maintained. Such doors and platforms are not to lead directly into the craft and an internal watertight compartment is to be provided in way of the shell openings. The doors and platforms are to be arranged to open outwards. The sill height of the access hull opening is not to be less than 300 mm above the waterline and the sill height of the internal access is to be not less than 300 mm higher than the hull sill. Alternative arrangements will be considered.

4.1.9 Doors may be of steel, aluminium alloy or FRP construction and are to be efficiently connected to the adjoining structure and of equivalent strength and are to have adequate securing and sealing arrangements. It is recommended that doors are hinged about their forward edges and open outwards. Details are to be submitted for approval. Other materials will be specially considered.

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4.1.10 For craft complying with the requirements of this Section, the securing, supporting and locking devices are defined as follows:

(a) A securing device is used to keep the door closed by preventing it from rotating about its hinges or other pivoted attachments to the craft.

(b) A supporting device is used to transmit external and internal loads from the door to a securing device and from the securing device to the craft's structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, that transmits loads from the door to the craft's structure.

(c) A locking device locks a securing device in the closed position.

4.2 Symbols

4.2.1 The symbols used in this Section are defined as follows:

σ = bending stress, in N/mm^2

σ_e = equivalent stress, in N/mm^2

$= \sqrt{\sigma^2 + 3\tau^2}$

τ = shear stress, in N/mm^2

σ_o is defined in Ch 3,1.2.

4.3 Scantlings

4.3.1 In general the strength of side and stern doors is to be equivalent to the strength of the surrounding structure.

4.3.2 Door openings in the side shell are to have well rounded corners and adequate compensation is to be arranged with web frames at sides and stringers or equivalent above and below. *See* Ch 3,3 of Parts 6, 7 and 8 for steel, aluminium alloy and composite construction respectively.

4.3.3 Doors are to be adequately stiffened, and means are to be provided to prevent movement of the doors when closed. Adequate strength is to be provided in the connections of the lifting/manoeuvring arms and hinges to the door structure and to the craft structure.

4.3.4 The thickness of the door plating is to be not less than the shell plating calculated with the door stiffener spacing, and in no case to be less than the minimum adjacent shell thickness.

4.3.5 Where stern doors are protected against direct wave impact by a permanent external ramp, the thickness of the stern door plating may be reduced by 20 per cent relative to the requirements of 4.3.4. Those parts of the stern door which are not protected by the ramp are to have the thickness of plating in full compliance with 4.3.4.

4.3.6 The section modulus of horizontal or vertical stiffeners is to be not less than required for the adjacent shell framing using the actual stiffener spacing. Consideration is to be given, where necessary, to differences in fixity between shell frames and door stiffeners.

4.3.7 Where necessary, door secondary stiffeners are to be supported by primary members constituting the main stiffening elements of the door.

4.3.8 The webs of primary members are to be adequately stiffened, preferably in a direction perpendicular to the shell plating.

4.3.9 The buckling strength of primary members is to be specially considered.

4.3.10 All load transmitting elements in the design load path from door through securing and supporting devices into the craft structure, including welded connections, are to be to the same strength standard as required for the securing and supporting devices.

4.4 Doors serving as ramps

4.4.1 Where doors also serve as vehicle ramps, the plating and stiffeners are to be not less than required for vehicle decks. *See* Ch 5,3 of Parts 6, 7 and 8 for steel, aluminium alloy and composite construction respectively.

4.4.2 The design of the hinges for these doors is to take into account the craft angle of trim or heel which may result in uneven loading of the hinges.

4.5 Closing, securing and supporting of doors

4.5.1 Doors are to be fitted with adequate means of closing, securing and supporting so as to be commensurate with the strength and stiffness of the surrounding structure. The hull supporting structure in way of the doors is to be suitable for the same design loads and design stresses as the securing and supporting devices. Where packing is required, the packing material is to be of comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be considered. Maximum design clearance between securing and supporting devices is not generally to exceed 3 mm.

4.5.2 Securing devices are to be simple to operate and easily accessible. They are to be of an approved type.

4.5.3 Securing devices are to be equipped with mechanical locking arrangements (self locking or separate arrangements), or are to be of gravity type. The opening and closing systems as well as securing and locking devices are to be interlocked in such a way that they can only operate in the proper sequence.

4.5.4 Means are to be provided to enable the doors to be mechanically fixed in the open position taking into account the self weight of the door and a minimum wind pressure of 1,5 kN/m^2 (0,153 tonne-f/m^2) acting on the maximum projected area in the open position.

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4.5.5 The spacing for cleats or closing devices is not to exceed 2,5 m and cleats or closing devices are to be positioned as close to the corners as practicable. Alternative arrangements for ensuring weathertight sealing will be specially considered.

4.5.6 Doors with a clear opening area of 12 m^2 or greater are to be provided with closing devices operable from a remote control position. Doors which are located partly or totally below the freeboard deck with a clear opening area greater than 6 m^2 are to be provided with an arrangement for remote control from a position above the freeboard deck. This remote control is provided for the:

(a) Closing and opening of the doors.

(b) Associated securing and locking devices.

4.5.7 The location of the remote control panel is to be such that the opening/closing operation can be easily observed by the operator or by other suitable means such as closed circuit television.

4.5.8 A notice is to be displayed at the operating panel stating that the door is to be fully closed and secured preferably before, or immediately prior to the craft leaving the berth and that this operation is to be entered in the craft's log. This notice is to be supplemented by warning indicator lights indicating if any door is not fully closed, secured and locked.

4.5.9 Means are to be provided to prevent unauthorised operation of the doors.

4.5.10 Where hydraulic securing devices are applied, the system is to be mechanically lockable in the closed position so that in the event of hydraulic system failure, the securing devices will remain locked. The hydraulic system for securing and locking devices is to be isolated from other hydraulic circuits when in the closed position.

4.5.11 The design force considered for the scantlings of primary members, securing and supporting devices of side shell doors and stern doors are to be taken not less than:

(a) Design forces for securing or supporting devices of doors opening inwards:
External force:
$F_e = Ap_e + F_p$ kN
Internal force:
$P_i = P_o + 10W$ kN

(b) Design forces for securing or supporting devices of doors opening outwards:
External force:
$F_e = Ap_e$ kN
Internal force:
$P_i = P_o + 10W + F_p$ kN

(c) Design forces for primary members:
External force:
$F_e = Ap_e$ kN
Internal force:
$P_i = P_o + 10W$ kN

whichever is the greater.

The symbols used are defined as follows:

p_e = external sea pressure, not to be taken less than 25 kN/m^2

A = total area of door opening, in m^2, to be determined on the basis of the load area taking account of the direction of pressure

F_p = total packing force, kN. When packing is fitted, the packing force per unit length is to be specified, normally not to be taken less than: 5 kN/m

P_c = accidental force, in kN, due to loose cargo, etc., to be uniformly distributed over the area A and not to be taken less than 300 kN. For small doors such as bunker doors and pilot doors, the value of P_c may be taken as zero, provided an additional structure such as an inner ramp is fitted, which is capable of protecting the door from accidental force due to loose cargoes

P_o = the greater of P_c and $5A$ kN

W = weight of the door, in tonnes.

4.6 Systems for indication and monitoring

4.6.1 The following requirements apply to doors in the boundaries of special category spaces or ro-ro spaces, as defined in the SOLAS Convention, through which such spaces may be flooded. For cargo craft, where no part of the door is below the uppermost waterline and the area of the door opening is not greater than 6 m^2, then the requirements of this Section need not be applied.

4.6.2 Separate indicator lights and audible alarms are to be provided on the navigation bridge and on each operating panel to indicate that the doors are closed and that their securing and locking devices are properly positioned. The indication panel is to be provided with a lamp test function. It is not to be possible to turn off the indicator light.

4.6.3 The indicator system is to be designed on the fail safe principle and is to indicate by visual alarms if the door is not fully closed and not fully locked, and by audible alarms if securing devices become open or locking devices become unsecured. The power supply for the indicator system is to be independent of the power supply for operating and closing the doors and is to be provided with a back-up power supply. The sensors of the indicator system are to be protected from water, ice formation and mechanical damages.

4.6.4 The indication panel on the navigation bridge is to be equipped with a mode selection function 'harbour/sea voyage', so arranged that audible alarm is given if the craft leaves harbour with side shell or stern doors not closed or with any of the securing devices not in the correct position.

4.6.5 For passenger craft, a water leakage detection system with audible alarm and television surveillance are to be arranged to provide an indication to the navigation bridge and to the engine control room of any leakage through the doors. For cargo craft, a water leakage detection system with audible alarm is to be arranged to provide an indication to the navigation bridge.

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Table 4.4.1 Permissible stress for bolts, closing and supporting devices

Material	Closing and supporting devices			Thread of bolts
	Direct stress N/mm^2	Shear stress N/mm^2	Equivalent stress N/mm^2	Direct stress N/mm^2
Steel	$\frac{120}{k_s}$	$\frac{80}{k_s}$	$\frac{150}{k_s}$	$\frac{120}{k_s}$
Aluminium	$\frac{64}{k_a}$	$\frac{43}{k_a}$	$\frac{80}{k_a}$	$\frac{64}{k_a}$

NOTES

1. $k_s = \frac{235}{\sigma_o}$, σ_o as defined in Ch 3,1.2.1

2. $k_a = \frac{120}{\sigma_{ya}}$, σ_{ya} as defined in Ch 3,1.2.2

4.7 Design of securing and supporting devices

4.7.1 Securing devices and supporting devices are to be designed to withstand the forces given in 4.5.11 using the permissible stresses given in Table 4.4.1. The terms 'securing device' and 'supporting device' are defined in Pt 6, Ch 5,4.3.

4.7.2 The nominal tensile stress in way of threads of bolts is not to exceed the permissible stress given in Table 4.4.1. The arrangement of securing and supporting devices is to be such that threaded bolts are not to carry support forces.

4.7.3 For steel to steel bearings in securing and supporting devices, the normal bearing pressure is not to exceed $0,8\sigma_o$. For other bearing materials, the permissible bearing pressure is to be determined according to the manufacturer's specification. The normal bearing pressure is to be calculated by dividing the design force by the projected bearing area.

4.7.4 The distribution of the reaction forces acting on the securing and supporting devices may require to be supported by direct calculations taking into account the flexibility of the hull structure and the actual position and stiffness of the supports. Small and/or flexible devices, such as cleats, intended to provide load compression of the packing material are not generally to be included in these calculations.

4.7.5 Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be considered in the calculation of the reaction forces acting on the devices.

4.7.6 The number of securing and supporting devices is generally to be the minimum practicable whilst complying with 4.5.3 and taking account of the available space in the hull for adequate support.

4.7.7 The arrangement of securing devices and supporting devices in way of these securing devices is to be designed with redundancy so that in the event of failure of any single securing or supporting device the remaining devices are capable of withstanding the reaction forces, without exceeding, by more than 20 per cent, the permissible stresses referred to in 4.7.1.

4.8 Operating and Maintenance Manual

4.8.1 An Operating and Maintenance Manual for the doors is to be provided on board and is to contain necessary information on:

(a) main particulars and design drawings;
(b) service conditions (e.g. service area restrictions, acceptable clearances for supports);
(c) maintenance and function testing;
(d) register of inspections and repairs.

This Manual is to be submitted for approval, and is to contain a note recommending that recorded inspections of the door supporting and securing devices be carried out by the craft's staff at monthly intervals or following incidents that could result in damage, including heavy weather or contact in the region of the doors. Any damages recorded during such inspections are to be reported to LR.

4.8.2 Documented operating procedures for closing and securing the doors are to be kept on board and posted at an appropriate place.

4.9 Engine removal arrangements

4.9.1 Where portable plates are required for unshipping machinery or for other similar reasons, they may be accepted provided they are of equivalent strength to the unpierced structure and are secured by gaskets and closely spaced bolts. The pitch spacing of the bolts will be specially considered depending on the hatch stiffening and support arrangements but should not exceed ten diameters.

4.10 Testing on completion

4.10.1 The items listed in Table 1.7.1 in Chapter 1, are to be hose tested to the satisfaction of the Surveyor.

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■ *Section 5* Hatches on exposed decks

5.1 General

5.1.1 This Section applies to small hatchways or access openings in the positions indicated in Fig. 4.5.1.

5.1.2 The number and size of hatchways and other access openings are to be kept to the minimum consistent with the satisfactory operation of the craft.

5.1.3 Hatch covers are to be weathertight when closed, of substantial construction and generally hinged. The means of securing are to be such that weathertightness can be maintained in any sea condition. Details are to be submitted for approval.

5.1.4 Hatch covers may be of steel, aluminium alloy or FRP construction. Where toggles are fitted, their diameter and spacing are to be in accordance with an ISO Standard or equivalent.

5.1.5 Hatches on the weatherdeck in the forward $0{,}25L_R$ or to machinery spaces are to be hinged on the forward side.

5.2 Coaming heights

5.2.1 Hatch coamings are to have a height above the deck surface in accordance with Table 4.5.1. Lower heights may be considered in relation to operational requirements and the nature of the spaces to which access is given.

5.2.2 Flush hatches will be specially considered.

5.2.3 Rope hatches may be accepted with reduced coamings, but generally not less than 380 mm, provided they are well secured and opened only at the Master's discretion. A suitable notice is to be displayed at the hatch.

5.3 Scantlings

5.3.1 Hatch covers are to be of equivalent strength to the deck on which they are fitted.

Table 4.5.1 Height of hatch coamings

Location/Access	Height (mm) (*see* Note 2)
(a) Weather deck/machinery compartment	460
(b) Weather deck/lower deck accommodation	230
(c) Weather deck/cargo hold	460

NOTES
1. For locations (a) and (b), *see* Fig. 4.5.1.
2. Reduced coaming heights will be specially considered based on a craft's service area restriction notation.

5.3.2 The thickness of the coamings is to be not less than the Rule thickness for the deck in the positions in which they are fitted. Stiffening of the coaming is to be appropriate to its length and height.

5.3.3 The covers are to be adequately stiffened.

5.4 Closing devices

5.4.1 Hinges are not to be used as securing devices unless specially considered.

5.4.2 Escape hatches are to be capable of being opened from either side.

5.5 Engine removal hatches

5.5.1 Where portable plates are required in decks for unshipping machinery or for other similar reasons, they may be accepted provided they are of equivalent strength to the unpierced deck and are secured by gaskets and closely spaced bolts. The pitch spacing of the bolts will be specially considered depending on the hatch stiffening and support arrangements but should not exceed ten diameters.

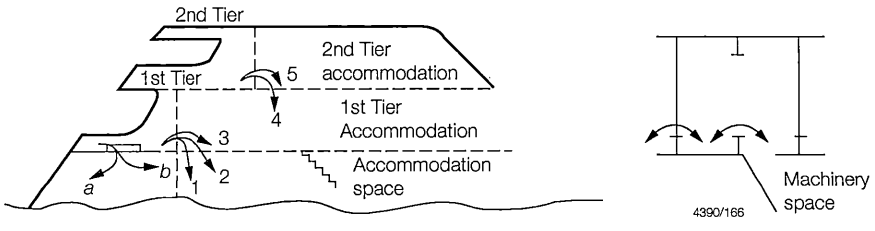

Fig. 4.5.1 Arrangement of doors, sills and hatch coamings

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5.6 Structural details

5.6.1 Various structural details for hatchways and access openings are given in the LR *Guidance Notes for Structural Details.*

5.7 Effective support for large hatch covers

5.7.1 The weight of hatch covers and any loads carried thereon, together with inertial forces generated by craft motions, are to be effectively transmitted to the craft structure. This may be achieved by continuous structural contact of the hatch cover with the craft structure or by means of defined bearing pads. The bearing pressure will be specially considered depending on the construction material.

5.8 National Authority requirements

5.8.1 The height of the hatch coaming may be subject to additional requirements of the National Authority.

5.9 Exceptions

5.9.1 Subject to the agreement of LR exceptions may be given to the requirements of this Section where they interfere with the operation of the craft. Such exceptions will be specially considered.

5.10 Testing upon completion

5.10.1 The items listed in Table 1.7.1 in Chapter 1, are to be hose tested to the satisfaction of the Surveyor.

5.11 Standard designs

5.11.1 Standard designs of hatches may be accepted, provided they are designed and manufactured in accordance with the requirements of a recognised National or International Standard which gives reasonable equivalence to the requirements of this Section.

5.11.2 Standard proprietary flush hatches, not exceeding 650 mm x 650 mm clear opening, which are of a type holding a valid Type Approval by LR, may be accepted for under deck access in non-working areas of craft below 24 m in length, L_R, dependent upon the Service Group Notation. Where the hatch type is not type approved, full details, including the material specification, are to be submitted for approval in each case.

5.12 Novel features

5.12.1 Hatchways of novel or unusual design will be specially considered.

■ *Section 6* Miscellaneous openings

6.1 General

6.1.1 This Section gives requirements for external doors, manholes and flush scuttles, hatchways within enclosed superstructures or 'tween decks and companionways, doors and accesses on weather decks.

6.1.2 Those items listed in Table 1.7.1 in Chapter 1, are to be hose tested to the satisfaction of the Surveyor.

6.2 External doors

6.2.1 Door sills are to have a height above the deck surface in accordance with Table 4.6.1.

Table 4.6.1 Height of door sills

Position/access	Height (mm)
(1) Weather deck/machinery compartment, *see* Note 2	460
(2) Weather deck/lower accommodation	230
(3) Weather deck/1st tier accommodation	150
(4) 1st tier/1st tier accommodation	100
(5) 1st tier/2nd tier accommodation	50

NOTES
1. For positions (1), (2), etc., *see* Fig. 4.5.1
2. Where the access to the machinery space is protected by an outer weathertight door, the inner door sill or hatch coaming may be 230 mm high in association with an outer sill height of 230 mm.

6.2.2 Reduced sill heights for doors will be considered as follows:
(a) dependent upon the service group notation,
(b) for doors which will only be used when the craft is in harbour, or calm water,
(c) where the sill height interferes with the operation of the craft,
(d) where doors do not give access to spaces below the freeboard deck.

6.2.3 The height of the door sill may be subject to additional requirements of the National Authorities.

6.2.4 Where the sill heights do not comply with the requirements of Table 4.6.1, interior deck openings are to be treated as if they were exposed on the weather deck.

6.3 Manholes and flush scuttles

6.3.1 Manholes and flush scuttles fitted in Positions 1 and 2, or within superstructures other than enclosed superstructures, are to be closed by substantial covers capable of being made watertight. Unless secured by closely spaced bolts, the covers are to be permanently attached.

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6.4 Hatchways within enclosed superstructures or 'tween decks

6.4.1 The requirements of Section 5 are to be complied with where applicable.

6.4.2 Access hatches within a superstructure or deckhouse in Position 1 or 2 need not be provided with means for closing if all openings in the surrounding bulkheads have weathertight closing appliances.

6.5 Companionways, doors and accesses on weather decks

6.5.1 Companionways on exposed decks are to be of equivalent construction, weathertightness and strength to a deckhouse in the same position and effectively secured to the deck.

6.5.2 Access openings in:

(a) Bulkheads at ends of enclosed superstructures,

(b) Deckhouses or companionways protecting openings leading into enclosed superstructures or to spaces below the freeboard deck, and

(c) Deckhouses on a deckhouse protecting an opening leading to a space below the freeboard deck,

may be fitted with doors of steel, aluminium alloy, FRP or other equivalent material, permanently and strongly attached to the bulkhead and framed, stiffened and fitted so that the whole structure is of equivalent strength to the unpierced bulkhead, and weathertight when closed. The doors are to be gasketed and secured weathertight by means of clamping devices or equivalent arrangements, permanently attached to the bulkhead or to the door. Doors are generally to open outwards and are to be capable of being operated and secured from both sides. The sill heights are to be as required by 6.2. Double doors are to be equivalent in strength to the unpierced bulkhead, and in Position 1, a centre pillar is to be provided which may be portable.

6.5.3 Elsewhere doors may be of hardwood or equivalent material and are to be of equivalent strength to the unpierced bulkhead.

6.5.4 Portlights or windows in doors are to comply with the requirements given in Section 7. Deadlights or storm covers may be external.

6.5.5 When the closing appliances of openings in superstructures and deckhouses do not comply with 6.5.2, interior deck openings are to be treated as if exposed on the weather deck.

6.5.6 Doors on the weather deck (first tier) protecting direct access to machinery spaces are to be of substantial construction in accordance with approved plans or a recognised National or International Standard. They are to be permanently attached to the casing, outward opening and gasketed weathertight with a minimum of six clips and have a sill height in accordance with 6.2.

6.5.7 Doors on the weather deck to accommodation or spaces protecting access below are to be as required by 6.5.6 with a minimum of four clips.

6.5.8 Where wood doors are proposed on the weather deck in lieu of doors as per 6.5.7, they are to be strongly constructed of hardwood not less than 45 mm thick and double gasketed. For doors in exposed locations, additional securing arrangements by slip bolts, clamps or equivalent will be required. These doors are not to be the sole means of entry or exit from the space. Where these doors may be required to be used as a means of escape in an emergency situation, the additional security arrangements are to be operable from both sides.

6.5.9 FRP doors are not to be fitted in access openings where 'A', 'B' or 'C' class fire integrity is required, or in engine room casings.

6.5.10 Doors in the second tier are to be as required by 6.5.6 with a minimum of four clips.

■ *Section 7*
Portlights, windows and viewing ports, skylights and glass walls

7.1 General

7.1.1 This Section gives the requirements for portlights, windows, viewing ports, sliding glass doors, glass walls, skylights, glazing materials, deadlights and storm covers.

7.1.2 Side scuttles and portholes are considered to be portlights.

7.1.3 A plan showing the location of portlights, windows, viewing ports, skylights and glass walls is to be submitted.

7.1.4 Portlights and windows, together with their glazing and deadlights if required, are to be of an approved design or in accordance with a recognised National or International Standard.

7.1.5 Glass in portlights, windows and skylights is to be thermally toughened safety glass with a thickness in accordance with approved plans or a recognised National or International Standard relative to their location.

7.1.6 Where consideration is given to the use of glazing materials other than thermally toughened glass, the thickness and arrangements are to take account of any different material properties and be approved.

7.1.7 The acceptance of 'glued-in' glazing material, when proposed, will be subject to Type Approval or individual approval and tests as appropriate.

7.1.8 The use of rubber frames is not generally acceptable.

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7.1.9 In position 2, cabin bulkheads and doors are considered effective between portlights or windows and access below.

7.1.10 Side scuttles are defined as being round or oval openings with an area not exceeding 0,16 m^2. Round or oval openings having areas exceeding 0,16 m^2 shall be treated as windows.

7.1.11 Windows are defined as being rectangular openings generally, having a radius at each corner relative to the window size and round or oval openings with an area exceeding 0,16 m^2.

7.2 Applications

7.2.1 As indicated in 1.1. *See also* Part 4 for additional requirements for yachts.

7.3 National Authority requirements

7.3.1 In addition to the requirements of this Section, where relevant, care is to be given to the statutory requirements of the National Authority.

7.4 Portlights

7.4.1 Portlights are to be in accordance with a recognised National or International Standard or of a type accepted for the respective position and having a valid LR Type Approval certificate. Where the portlight is not type approved, full details are to be sumitted for approval in each case.

7.4.2 Portlights may be round, elliptical or elongated and are to be of substantial construction

7.4.3 Portlights are not to be fitted in machinery spaces.

7.4.4 No portlight is to be fitted in such a position that its still is below a line drawn parallel to the freeboard deck at side and having its lowest point 2,5 per cent of the breadth, *B*, above the load waterline corresponding to the summer freeboard (as defined in Ch 1,6.2.7), or 500 mm, whichever is the greater distance, *see* Fig. 4.7.1.

7.4.5 Deadlights or storm covers for portlights are to be provided in accordance with 7.12.

7.5 Windows

7.5.1 Windows are to be in accordance with a recognised National or International Standard or of a type accepted for the respective position and having a valid LR Type Approval certificate.

7.5.2 Where the window is not type approved, full details are to be submitted for approval in each case and the prototype tested in accordance with the requirements of 7.5.3 to 7.5.5.

7.5.3 A hydrostatic test is to be carried out in order to examine watertightness. A design pressure *p*, where *p* is given in 7.8.1 is to be applied and maintained for at least 15 minutes.

7.5.4 A hydrostatic test is to be carried out in order to examine the capability of the frame, and glass retaining arrangements. A design pressure 4*p*, where *p* is given in 7.8.1 is to be applied. Alternatively this test may be carried out using a steel plate in place of the glass. Ideally the steel plate thickness should be of a suitable reduced thickness to simulate the flexural performance of the glass.

7.5.5 Equivalent proposals for testing will be considered. Where alternative testing procedures are proposed, these are to be agreed with LR before commencement.

7.5.6 Window glazing is, in general, to be toughened safety glass, fitted in substantial frames supporting both faces of the glass and effectively secured to the structure. Metal to glass contact is to be avoided.

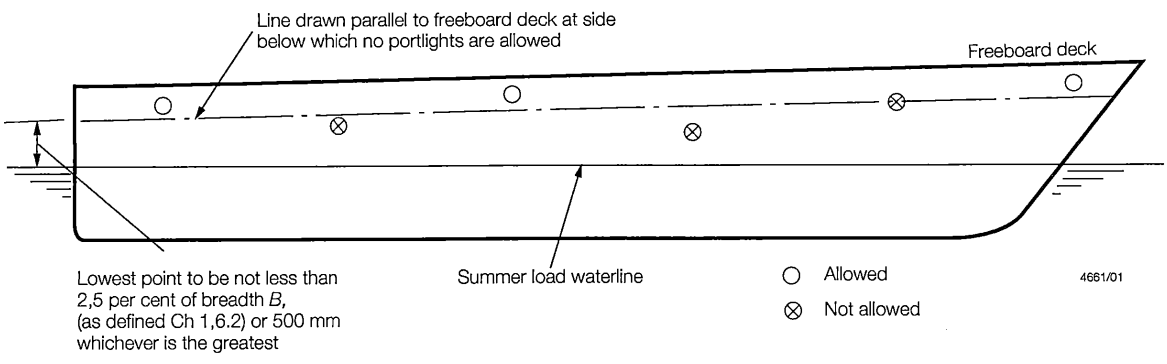

Fig. 4.7.1 Position of portlights

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7.5.7 In general, no windows are to be fitted in the following locations:
(a) below the freeboard deck;
(b) in the first tier end bulkheads or sides of enclosed superstructures; or
(c) in first tier deckhouses that are considered buoyant in the stability calculations.

7.5.8 Wheelhouse window glazing is to be toughened safety glass, or where it is of laminated or sandwich construction, the surface layers are to be of toughened safety glass.

7.5.9 Large windows in the aft end of superstructure or deckhouses will be specially considered.

7.5.10 Openings in the shell for windows are to have well rounded corners.

7.5.11 Storm covers or deadlights for windows are to be provided in accordance with 7.12.

7.6 Viewing ports

7.6.1 In general, viewing ports are not to be fitted in the bottom shell of high speed craft.

7.6.2 Viewing ports are to be watertight and of substantial construction in accordance with approved plans.

7.6.3 Glazing is to be fitted in substantial frames supporting both faces of the glazing and effectively secured to the hull structure.

7.6.4 Where practicable, viewing ports are to be fitted with efficient, hinged, deadlights which are capable of being effectively closed and secured watertight, with or without the glazing in place.

7.6.5 Hydrostatic pressure tests are to be carried out to confirm that the proposed construction, when fitted in the hull, is able to withstand a pressure of four times the design pressure and remain watertight. Where a deadlight is fitted, this test is also to be carried out with the glazing removed and the deadlight closed.

7.7 Sliding glass doors or 'glass walls'

7.7.1 Large glass doors or windows in the aft end of superstructures and deckhouses and other large glass structures forming the sides, ends or roofs of deckhouses will be specially considered.

7.7.2 When sliding glass doors are provided, or a 'glass wall' which includes an access, an alternative access or exit from the space is to be provided and the arrangements are to be in accordance with approved plans and weathertight commensurate with their position. Sill heights are, in general, to be in accordance with 6.2.

7.7.3 The glazing is to be toughened safety glass, or equivalent, and of substantial thickness in accordance with 7.8, 7.9 or 7.10 as appropriate.

7.7.4 Storm covers or roller shutters are to be provided in accordance with 7.12.11.

7.8 Toughened safety glass thickness

7.8.1 The thickness, t, of toughened safety glass is to be not less than 6 mm or that given by the following expression, whichever is the greater:
for glazing of rectangular form

$$t = 0{,}005b\sqrt{\beta p} \text{ mm}$$

for glazing of circular form

$$t = 0{,}00559r\sqrt{p} \text{ mm}$$

where
a = length of longer side of window, in mm
b = length of shorter side of glazing, in mm
p = design pressure in kN/m^2, as defined in Pt 5, Ch 3,3.1 and Ch 4,3.1
r = radius of the glazing, in mm
A_R = aspect ratio of window
= a/b
β = $-0{,}17 + 0{,}54A_R - 0{,}078A_R^2$ for $A_R \leq 3$
= 0,75 for $A_R > 3$.

7.8.2 For windows of trapezoidal form, the length of window, a, is to be taken as the mean of the length of the longer sides. The value of b, the length of the shorter side, may be similarly determined.

7.9 Laminated glass thickness

7.9.1 Laminated toughened safety glass may be used having a thickness greater than the single plate toughened safety glass for the same size window, as given by:

$$t_s^2 = t_{i1}^2 + t_{i2}^2 + \ldots\ldots + t_{in}^2 \text{ mm}$$

where
n = number of laminates
t_i = thickness of laminate, in mm
t_s = thickness of equivalent single plate, in mm.

7.10 Other glazing materials

7.10.1 Materials other than glass may be used for windows, except for those in the wheelhouse, with the thickness obtained by multiplying the thickness for toughened safety glass by a factor of 1,3 for polycarbonate and 1,5 for acrylic. Consideration will be given to composite and multi-layer constructions where documented results of a pressure test confirm that the proposed construction, when fitted in its appropriate frame, is able to withstand a test pressure of four times the design pressure and remain watertight.

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7.11 Openings and framing requirements

7.11.1 The strength and dimensions of the frame section are to be appropriate to the size of the window, the type of glazing being used and its method of bedding. The glazing is to be secured to its frame in accordance with the Manufacturer's instructions and recommendations; metal to glass contact is to be avoided.

7.11.2 Rubber frames are not acceptable for windows in Positions 1 and 2, and are not generally acceptable in any other position in external casings. Any proposals to fit rubber frames are to be submitted for consideration. The proposed locations, frame dimensions, glass thicknesses and the results of any tests carried out, are to be forwarded.

7.12 Deadlights and storm covers

7.12.1 Portlights fitted to spaces below the weather deck, or to spaces within enclosed superstructures, are to be fitted with efficient, hinged, inside deadlights which are capable of being effectively closed and secured watertight below the weather deck and weathertight above the weather deck.

7.12.2 In service craft less than 24 m Rule length, L_R, and yachts, portlights in the hull in way of accommodation may have portable deadlights, provided that they are stored adjacent to the portlight and can be readily fitted. Also, in the case of these craft, portlights in superstructures or deckhouses do not require to have deadlights, unless on the weather deck in exposed positions or protecting direct access below, in which case, they are to be provided with deadlights or storm covers.

7.12.3 For craft in **Service Group G1**, storm covers or deadlights are generally not required for windows or portlights in superstructures or deckhouses.

7.12.4 For craft in **Service Group G2**, storm covers or deadlights are required for:

(a) 50 per cent of the windows and portlights in the front of the superstructure or deckhouse on the weather deck.
(b) The windows and portlights in the forward half of the superstructure or deckhouse side on the weather deck, except where these are interchangeable port and starboard, in which case a sufficient number to fit the forward half of one side is to be provided.
(c) Each different size of window and portlight.

7.12.5 For craft in **Service Group G3**, storm covers or deadlights are required for:

(a) All windows and portlights in the front of the superstructure or deckhouse on the weather deck.
(b) All windows and portlights in the sides of the superstructure or deckhouse on the weather deck, except where they are interchangeable port and starboard, in which case a sufficient number to fit any one side are to be provided.
(c) Each different size of window and portlight.

7.12.6 For craft in **Service Groups G4** and **G5**, storm covers or deadlights are required as follows:

(a) If fitted in a deckhouse in Position 1, windows are to be provided with strong, hinged, weathertight storm covers. However, if there is an opening leading below deck in this deckhouse, this opening is to be treated as being on an exposed deck and is to have weathertight protection.
(b) Portlights and windows at the shell in Position 2, protecting direct access below, are to be provided with strong permanently attached deadlights.
(c) Portlights and windows at the shell in Position 2, not protecting direct access below, are to be provided with strong portable steel covers for 50 per cent of each size, with means for securing at each window.
(d) Portlights and windows set inboard from the shell in Position 2, protecting direct access below, are either to be provided with strong permanently attached deadlights or, where they are accessible, strong permanently attached external storm covers instead or internal deadlights.
(e) Portlights and windows set inboard from the shell in Position 2, not protecting direct access below, do not require deadlights or storm covers.
(f) Windows in the shell above Position 2 are to be provided with strong portable internal storm covers for 25 per cent of each window, with means of securing being provided at each window.
(g) Where windows are permitted in an exposed bulkhead on the weather deck in the forward $0{,}25L_L$, strong external storm covers are to be provided, which may be portable and stored adjacent.

7.12.7 Deadlights and storm covers are not required for second tier portlights or windows in deckhouses without direct access below.

7.12.8 Where the wheelhouse is in Position 2, in lieu of storm covers being provided for the wheelhouse windows, a weathertight cover, fitted to a coaming of not less than 230 mm in height around the internal stairway opening within the wheelhouse, may be accepted. If this arrangement is accepted, adequate means of draining the wheelhouse are to be provided.

7.12.9 If necessary, for practical considerations, the storm covers may be in two parts.

7.12.10 Deckhouses situated on a raised quarter deck may be treated as being in Position 2 as far as the provision of deadlights is concerned, provided the height of the raised quarter deck is equal to, or greater than the standard height.

7.12.11 Sliding glass doors are to be provided with storm covers of strong construction, or, in the case of a 'glass wall', this may be protected by a strongly constructed roller shutter or equivalent, which can be readily lowered and secured to provide adequate protection. When necessary, additional portable supports are to be provided for the cover. The arrangements are to be in accordance with approved plans. Alternative arrangements will be specially considered. In lieu of a weathertight coaming for the cover, adequate drainage is to be provided between the cover and the glass which may be in the form of a sump drained overboard, with a grating over.

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7.12.12 Deadlights and storm covers are to be weathertight and of equivalent strength to the surrounding structure.

7.12.13 Portable deadlights and storm covers are to be clearly marked to indicate which portlights or windows they fit and stowed in such a way as to be readily fitted.

7.13 Emergency exits

7.13.1 Portlights or windows intended as emergency escapes are to be capable of being opened from both sides and have a minimum clear opening of 600 mm x 600 mm.

7.14 Skylights

7.14.1 Skylights, where fitted, are to be of substantial construction and securely attached to their coamings. The height of the lower edge of opening is to be as required by 5.2.1. The scantlings of the coaming are to be as required by 5.3.2. The thickness of glasses in fixed or opening skylights is to be appropriate to their size and position as required for portlights or windows. Glasses in any position are to be protected from mechanical damage, and where fitted in Positions 1 or 2 (as defined in Ch 1,6.10) are to be provided with robust deadlights or storm covers permanently attached.

7.15 Testing on completion and installation

7.15.1 In order to demonstrate that the requirements of this Section are met the closing arrangements are to be operated under working conditions to the satisfaction of the Surveyor.

7.15.2 The items listed in Table 1.7.1, in Chapter 1, are to be hose tested to the satisfaction of the Surveyor.

■ *Section 8*
Bulwarks, guard rails and other means for the protection of crew

8.1 General

8.1.1 Bulwarks or guard rails are to be provided at the boundaries of exposed freeboard and superstructure decks and first tier deckhouses. Bulwarks or guard rails are to be not less than 1,0 m in height measured above sheathing, and are to be constructed as required by 8.2 and 8.4 respectively. Special consideration will be given to cases where this height would interfere with the normal operation of the craft.

8.1.2 The freeing arrangements in bulwarks are to be in accordance with Section 9.

8.1.3 Where appropriate, special consideration will be given to the provision of guard-wires in lieu of bulwarks or guard rails.

8.1.4 Where wire ropes are fitted, adequate devices are to be provided to ensure their tautness.

8.1.5 Where stanchions are fitted, every third stanchion is to be supported by a bracket or stay.

8.1.6 A proper step arrangement is to be provided in way of obstructions such as pipe lines, etc.

8.2 Bulwark construction

8.2.1 Plate bulwarks are to be stiffened by a strong rail section and supported by stays from the deck. The spacing of these bulwark stays is not to be greater than 1,83 m. Where bulwarks are cut to form a gangway or other opening, stays of increased strength are to be fitted at the ends of the openings. Bulwarks are to be adequately strengthened in way of eyeplates for cargo gear, and in way of mooring pipes the plating is to be doubled or increased in thickness and adequately stiffened.

8.2.2 In the calculation of the section modulus, only the material connected to the deck is to be included. The bulb or flange of the stay may be taken into account where connected to the deck, and where, at the ends of the craft, the bulwark plating is connected to the sheerstrake, a width of plating not exceeding that considered effective (*see* Pt 6, Ch 3,1.10, Pt 7, Ch 3,1.11 and Pt 8, Ch 3,1.7 for steel, aluminium alloy and composite construction respectively) may also be included. The free edge of the stay is to be stiffened.

8.2.3 Bulwark stays are to be supported by, or to be in line with, suitable underdeck stiffening, which is to be connected by double continuous fillet welds in way of the bulwark stay connection.

8.2.4 The foregoing requirements do not allow for any loading from deck cargoes.

8.3 Openings in bulwarks

8.3.1 Bulwarks are not to be cut for gangway or other openings near the breaks of superstructures, and are also to be arranged to ensure their freedom from main structural stresses. *See* shell plating in appropriate Chapters.

8.4 Guard rails

8.4.1 The opening below the lowest course of guardrails is not to exceed 230 mm. The other courses are to be spaced not more than 380 mm apart. In the case of craft with rounded gunwales, the guard rail supports are to be placed on the flat of the deck.

8.4.2 Satisfactory means, in the form of guard rails, life-lines, handrails, gangways, underdeck passageways or other equivalent arrangements, are to be provided for the protection of the crew in getting to and from their quarters, the machinery space and all other parts used in the necessary work of the craft.

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8.4.3 Chains are only permitted in short lengths in way of access openings.

8.4.4 Where permitted by the National Authority, gangways or walkways may be omitted on craft operating within **Service Groups G1** or **G2.** However, lifelines are to be provided on flush deck craft, or where the cargo hatch coamings are less than 600 mm high.

Section 9
Deck drainage

9.1 General

9.1.1 Where bulwarks on the weather portions of freeboard or superstructure decks form wells, ample provision is to be made for rapidly freeing the decks of large quantities of water by means of freeing ports, and also for draining them.

9.2 Freeing port area

9.2.1 The minimum freeing area on each side of the craft for each well on the freeboard deck or raised quarter deck, where the sheer in the well is not less than the standard sheer required by the *International Convention on Load Lines*, 1966, is to be derived from the following formulae:

(a) where the length, l, of the bulwark in the well is 20 m or less:
area required = $0,7 + 0,035l$ m^2

(b) where the length, l, exceeds 20 m
area required = $0,07l$ m^2
l need not be taken greater than $0,7L_L$, where L_L is the length of the craft as defined in Ch 1,6.2.

9.2.2 If the average height of the bulwark exceeds 1,2 m or is less than 0,9 m, the freeing area is to be increased or decreased, respectively, by 0,004 m^2 per metre of length of well for each 0,1 m increase or decrease in height respectively.

9.2.3 The minimum freeing area for each well on a first tier superstructure is to be half the area calculated from 9.2.1.

9.2.4 Two-thirds of the freeing port area required is to be provided in the half of the well nearest to the lowest point of the sheer curve.

9.2.5 When the deck has no sheer, the minimum freeing area for each well calculated from 9.2.1 is to be increased by 50 per cent. Where the sheer is less than the standard the percentage shall be obtained by linear interpolation. The freeing area is to be spread along the length of the well.

9.2.6 Where the length of the well is less than 10 m, or where a deckhouse occupies most of the length, the freeing port area will be specially considered but in general need not exceed ten per cent of the bulwark area.

9.2.7 Where it is not practical to provide sufficient freeing port area in the bulwark, particularly in small craft, credit can be given for bollard and fairlead openings where these extend to the deck.

9.2.8 Where a craft fitted with bulwarks has a continuous trunk, or hatch side coamings that are continuous, or substantially continuous, the minimum freeing area is to be not less than 20 per cent of the total bulwark area where the width of trunk or hatchway is $0,4B$ or less, and not less than 10 per cent of the total bulwark area when the width of the trunk or hatch is $0,75B$ or greater. The freeing area required for an intermediate width of trunk or hatch is to be obtained by linear interpolation.

9.2.9 Where the trunk referred to in 9.2.8 or its equivalent is included in the calculation of freeboard, open rails are to be fitted for at least 50 per cent of the length of the exposed part of the weather deck. Alternatively, if a continuous bulwark is fitted, the minimum freeing area is to be at least 33 per cent of the bulwark area. The freeing area is to be placed in the lower part of the bulwark.

9.2.10 Where a deckhouse has a breadth less than 80 per cent of the beam of the craft, or the width of the side passageways exceed 1,5 m, the arrangement is considered as one well. Where a deckhouse has a breadth equal to or greater than 80 per cent of the beam of the craft, or the width of the side passageways does not exceed 1,5 m, or when a screen bulkhead is fitted across the full breadth of the craft, this arrangement is considered as two wells, before and abaft the deckhouse.

9.2.11 Adequate provision is to be made for freeing water from superstructures which are open at either or both ends and from all other decks within open or partially open spaces in which water may be shipped and contained.

9.2.12 Suitable provision is also to be made for the rapid freeing of water from recesses formed by superstructures, deckhouses and deck cargo arrangements, etc., in which water may be shipped and trapped. Deck gear, particularly on fishing craft, is not to be stowed in such a manner as to obstruct unduly the flow of water to freeing ports.

9.2.13 The lower edges of freeing ports are to be as near to the deck as practicable, and should not be more than 100 mm above the deck.

9.3 Free flow area

9.3.1 The effectiveness of the freeing port area in bulwarks of craft not fitted with a continuous deck obstruction, depends on the free flow across the deck.

9.3.2 The free flow area is the net total longitudinal area of the transverse passageways or gaps between hatchways and superstructures or deckhouses, due account being made for any obstructions such as equipment or other fittings. The height of passageways or gaps used in the calculation of the area is the height of the bulwark.

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9.3.3 The provision of freeing area in bulwarks is to be related to the net free flow area as follows:

(a) If the free flow area is equal to, or greater than the freeing port area calculated from 9.2.8 when the hatchway coamings are continuous, then the minimum freeing area calculated from 9.2.1 is sufficient.

(b) If the free flow area is less than the freeing port area calculated from 9.2.1, then the minimum freeing area is to be that calculated from 9.2.8.

(c) If the free flow area is less than the freeing port area derived from (a) but greater than that derived from (b), the minimum freeing area, F, in the bulwark is to be obtained from the following formula:

$$F = F_1 + F_2 - f_p \quad m^2$$

where

F_1 = minimum area from 9.2.1

F_2 = minimum area from 9.2.8

f_p = total net area of passages and gaps between hatchways, superstructures and deckhouses (the free flow area).

9.4 Scupper arrangements

9.4.1 Scuppers, sufficient in number and size to provide effective drainage, are to be fitted in all decks.

9.4.2 Scuppers draining weather decks and spaces within superstructures or deckhouses not fitted with efficient weathertight doors are to be led overboard.

9.4.3 Scuppers and discharges which drain spaces below the freeboard deck, or spaces within intact superstructures or deckhouses on the freeboard deck fitted with efficient weathertight doors, may be led to the bilges in the case of scuppers, or to suitable sanitary tanks in the case of sanitary discharges. Alternatively, they may be led overboard provided that:

(a) the freeboard is such that the deck edge is not immersed when the craft heels to 5°, and

(b) the scuppers are fitted with a positive control valve or automatic non-return valve at the shell preventing water from passing inboard.

9.4.4 In craft where an approved fixed pressure water spray fire-extinguishing system is fitted in vehicle or cargo spaces, deck scuppers of not less than 150 mm diameter are to be provided port and starboard, spaced about 9,0 m apart. The scupper area will require to be increased if the design capacity of the drencher system exceeds the Rule required capacity by 10 per cent or more. After installation, the two adjacent sections with the greatest aggregate drencher capacity are to be tested in operation to ensure that there is no build up of water on the deck. The scuppers are to be led inboard to tanks or, alternatively they may be led overboard providing they comply with 9.4.3(a) and (b). Inboard draining scuppers do not require valves but are to be led to suitable drain tanks (water contaminated with petrol or other flammable substance is not to be drained to machinery spaces or any other space where a source of ignition may be present) and the capacity of the tanks is to be sufficient to hold approximately 10 minutes of drenching water. The arrangements for emptying these tanks are to be approved and suitable high level alarms provided. The mouth of the scupper is to be protected by bars.

9.4.5 Scupper pipes from the weather decks discharging overboard below or near the waterline are to be provided with a non-return valve or positive control valve. Where the scupper pipes are of substantial construction, having a wall thickness of not less than that of the side shell plus 2 mm, the non-return valve or positive control valve may be omitted.

9.4.6 For the use of non-metallic pipe, *see* Pt 15, Ch 1,8.

9.5 Large freeing port openings

9.5.1 Where the height of freeing ports is greater than 230 mm, vertical bars spaced approximately 230 mm apart may be accepted, as an alternative to a horizontal rail, to limit the height of the freeing port. Other equivalent arrangements will be specially considered.

■ *Section 10* Cabin sole and lining

10.1 General

10.1.1 Cabin soles are to be fitted and secured in such a manner as to provide access to the structure and fittings below.

10.1.2 The cabin fittings and linings against the side of the craft are to be so fitted as to be capable of being removed when necessary. The method of attachment is not to impair the strength of the structural members.

10.1.3 For fire protection requirements for cabin fittings and linings, *see* Part 17.

10.2 Removal for access

10.2.1 It is recommended that the cabin fittings and linings against the side of the craft be so fitted as to be capable of being removed when necessary. The method of attachment is not to impair the strength of the structural members.

10.3 Fire aspects

10.3.1 For information and plans required, *see* Part 17.

■ *Section 11* Ventilators

11.1 General

11.1.1 This Section provides requirements for ventilators and the ventilation of all craft.

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11.1.2 The requirements conform, where relevant, with those of the *International Convention on Load Lines, 1966*. Reference is also to be made to any additional requirements of the National Authority of the country in which the craft is to be registered and to the relevant regulations of the *International Convention for the Safety of Life at Sea, 1974* and applicable amendments.

11.1.3 Special care is to be taken in the design and positioning of ventilator openings and coamings, particularly in the region of the forward end of superstructures and other points of high stress. The deck plating in way of the coamings is to be efficiently stiffened.

11.1.4 The scantlings of ventilators exposed to the weather are to be equivalent to those of the adjacent deck or bulkhead. Where the height of the ventilator exceeds that required by 11.5.1, the thickness may be gradually reduced above that height to a minimum which will be specially considered dependent on the material of construction. Ventilators are to be adequately stayed.

11.1.5 Ventilators from deep tanks and tunnels passing through 'tween decks are to have scantlings suitable for withstanding the pressures to which they may be subjected, and are to be made watertight.

11.1.6 For the requirements for fire precautions on cargo and passenger craft, *see* Part 17.

11.1.7 Adequate ventilation is to be provided throughout the craft.

11.1.8 For the requirements for yachts, *see also* Part 4.

11.2 Accommodation spaces

11.2.1 Accommodation spaces are to be protected from gas or vapour fumes from machinery, exhaust and fuel systems in accordance with Ch 2,4.7, *see also* Part 17.

11.3 Machinery spaces

11.3.1 In addition to the requirements of this Section, a filter coalescer is to be fitted to the machinery space air intakes to remove fine spray where:

- Intakes are fitted in exposed positions on the weather deck; or
- intakes are large; or
- coaming height is reduced; or
- as required by the engine manufacturer.

Special consideration will be given to alternative arrangements for craft operating within service groups G1–G3, *see also* Part 9.

11.3.2 In general, ventilators necessary to continuously supply the machinery space or the emergency generator room shall have coamings of sufficient height to comply with 11.4.1, without having to fit weathertight closing appliances.

11.3.3 Where it is not practical to comply with 11.3.2 due to ship size and arrangement, lesser heights for machinery space and emergency generator room ventilator coamings, fitted with weathertight closing may be permitted by the Administration in combination with other suitable arrangements to ensure an uninterrupted, adequate supply of ventilation to these spaces.

11.4 Closing appliances

11.4.1 All ventilator openings are to be provided with efficient weathertight closing appliances unless:

(a) The height of the coaming is greater than 4,5 m above the deck at Position 1.

(b) The height of the coaming is greater than 2,3 m above the deck at Position 2.

11.4.2 Closing appliances are to be permanently attached to the ventilator coaming.

11.4.3 Where, in ferries, ventilators are proposed to be led overboard in an enclosed 'tween deck, the closing arrangements are to be submitted for approval. If such ventilators are led overboard more than 4,5 m above the main vehicle deck, closing appliances may be omitted, provided that satisfactory baffles and drainage arrangements are provided, as in the case of air intakes or exhaust openings for machinery spaces, which may be arranged in the sides of the craft.

11.4.4 Mushroom ventilators closed by a head revolving on a centre spindle (screw down head) are acceptable in Position 2, and also in sheltered positions in Position 1, but the diameter is not to exceed 300 mm if situated within the forward $0{,}25L_L$.

11.4.5 Mushroom ventilators with a fixed head and closed by a screw down plate (screw down cover) may be accepted in exposed positions within the forward $0{,}25L_L$ up to a diameter of 750 mm.

11.4.6 Wall ventilators (jalousies) may be accepted provided they are capable of being closed weathertight by hinged gasketed covers secured by bolts or toggles. They are preferably to face aft or athwartships and are to be fitted with a suitable means of preventing ingress of water and spray when open in the form of louvres, baffles, screens or an equivalent arrangement.

11.4.7 Reference is to be made to Section 1 concerning down flooding through ventilators which do not require closing appliances due to their coaming height being in accordance with 11.4.1.

11.5 Effective coaming heights

11.5.1 The height of ventilator coamings exposed to the weather is to be as high as practicable, with a minimum height of 600 mm in Position 1 and 450 mm in Position 2. In particularly exposed positions, the height of coamings may be required to be increased or self closing devices may be required.

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11.5.2 Reduced coaming heights may be considered for ventilators which are not required for the operation of the craft at sea, provided that operational procedures are in place and a notice is fitted to the ventilator to ensure that the closing device is closed whilst the craft is at sea.

11.5.3 For gooseneck ventilators, the coaming height is to be measured to the underside of the bend, this being the lowest point through which water on deck could pass freely to spaces below.

11.5.4 Where wall ventilators are fitted with an internal baffle which rises above the lower edge of the exterior opening, the coaming height is measured to the top of the baffle.

11.6 Drainage arrangements

11.6.1 Ventilators are to be provided with suitable drainage arrangements, particularly where an internal baffle is fitted, *see* 11.5.4.

■ *Section 12*
Air and sounding pipes

12.1 General

12.1.1 Air and sounding pipes are to comply with the requirements of Pt 15, Ch 2,11.

12.1.2 The minimum wall thickness of steel and aluminium alloy air pipes in positions indicated in 12.2.1 is to be taken as:

$t_p = 0{,}03d_p + 3{,}6$ mm with a maximum of 8,5 mm

where

t_p = wall thickness of air pipe, in mm

d_p = external diameter of air pipe, in mm.

12.1.3 The pipe material is to be compatible with the craft construction material.

12.1.4 Composite pipes may be acceptable for use on composite craft and will be specially considered.

12.1.5 Striking plates of suitable thickness, or their equivalent, are to be fitted under all sounding pipes.

12.1.6 For the requirements for yachts, *see also* Part 4.

12.2 Height of air pipes

12.2.1 The height of air pipes from the upper surface of decks exposed to the weather, to the point where water may have access below is normally to be not less than:

- 450 mm on the freeboard deck;
- 300 mm on the superstructure deck;

these heights being measured above deck sheathing, where fitted.

12.2.2 Lower heights may be approved in cases where these are essential for the working of the craft, provided that the design and arrangements are otherwise satisfactory.

12.2.3 An increase in the height of air pipes may be required or recommended by individual Administrations when air pipes to fuel oil and settling tanks are situated in positions where sea water could be temporarily entrapped, e.g. in recesses in the sides and ends of superstructures or deckhouses, between hatch ends, behind high sections of bulwark, etc. This may entail an increase in tank scantlings and will be specially considered.

12.2.4 Air pipes are generally to be led to an exposed deck. Alternatively, air pipes from cofferdams or void spaces may terminate in the enclosed 'tween deck space on main vehicle decks, provided the space is adequately ventilated and the air pipes are provided with weathertight closing appliances.

12.2.5 Where air pipes are led through the side of superstructures, the opening is to be at least 2,3 m above the summer load waterline.

12.3 Closing appliances

12.3.1 All openings of air and sounding pipes are to be provided with permanently attached, satisfactory means of closing to prevent the free entry of water.

12.3.2 Exposed air pipes in positions 1 and 2 are to be provided with approved automatic closing appliances.

■ *Section 13*
Particular requirements for multi-hull craft

13.1 General

13.1.1 In addition to the general requirements given in this Chapter, this Section gives particular requirements for multi-hull craft.

13.2 Multi-hull craft escape hatches

13.2.1 Multi-hull craft are to be provided with a suitable means of escape from each accommodation compartment between watertight bulkheads in the event of inversion of the craft.

13.2.2 Where the requirement given in 13.2.1 is achieved by means of escape hatches in the hull, these are to be fitted in the inboard side of each hull, or in the transom, with the lowest side of the opening at a minimum of 600 mm above the waterline in both the upright and inverted conditions of the craft. Hatch openings are to be a minimum of 450 mm x 450 mm and a maximum of 600 mm x 600 mm.

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13.2.3 Escape hatch frames and covers may be of steel, aluminium alloy or FRP construction and are to be of equivalent strength to the unpierced hull side or transom in which they are fitted.

13.2.4 Hatch covers are to be weathertight when closed and the means of securing the hatch cover are to be such that weathertightness can be maintained in any sea condition.

13.2.5 Hydrostatic pressure tests are to be carried out to confirm that the proposed construction, when fitted in the hull, is able to withstand a pressure of four times the design pressure and remain watertight.

13.2.6 Hatch covers are to be flush with the hull and substantially hinged. Where fitted in the inboard side of the hull, the hinges are to be on the forward side.

13.2.7 Escape hatches are to be capable of being opened from both sides. Handles on the outside are to be suitably protected from damage or inadvertent opening.

13.3 Portlights

13.3.1 Where it is proposed to fit portlights in the hulls of wave-piercing and other non-conventional multi-hull craft, the arrangements will be specially considered.

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Section

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2 **Equipment Number**

3 **Service group factors**

4 **Craft type factors**

5 **Anchors**

6 **Anchor cable**

7 **Mooring ropes and towlines**

8 **Windlass design and testing**

9 **Structural details**

■ *Section 1* General

1.1 Application

1.1.1 The anchoring equipment specified in this Section is suitable only for use in reasonably sheltered conditions or in emergencies. If the equipment is intended to be used during operations in the open sea, or if the sea or weather conditions in the service area are subject to unusual hazards, e.g. typhoons, etc., the equipment will be specially considered in each case.

1.1.2 Where the Equipment Number exceeds 1140 the equipment is to be in accordance with Pt 3, Ch 13 of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships).

1.2 Definitions

1.2.1 The definitions for use throughout this Chapter are as indicated in the appropriate Section.

1.3 Symbols

1.3.1 The following symbols are used in this Chapter, unless otherwise stated:

b_i = mean breadth of deckhouse or superstructure tier, in metres

h_i = mean height of deckhouse or superstructure tier, in metres

A = area, in m^2, in profile view of the hull, superstructure and deckhouses above the design waterline. Deckhouses with breadth less than B/4 are to be ignored

B_o = the greatest moulded breadth, in metres, or for craft of composite construction, the extreme breadth excluding rubbing strakes or other projections

B_1 = the greatest breadth of the outer hulls of a multi-hull craft, in metres. It is to be measured between the points of intersection of the extension of the hull sides to the normal line of the wet deck

B_2 = the greatest breadth of the centre hull in trimaran type craft, in metres. It is to be measured between the points of intersection of the extension of the hull sides to the normal line of the wet deck

D_h = the sum of bi hi cos qi for all deckhouses and superstructures tiers

G_A = air gap, as defined in Pt 5, Ch 1

α_1 = for multi-hull craft is the distance in metres, from the underside of the cross-deck structure to the underside of the first tier of deckhouse or superstructure for mono-hull craft is the distance in metres, from the waterline to the underside of the first tier of deckhouse or superstructure

θ_i = angle of inclination aft, of tier of deckhouse front, with a line perpendicular to the static load waterline

Δ = loaded displacement, in tonnes.

1.4 Character of classification

1.4.1 To entitle a craft to the figure **1** in its character of classification, equipment in accordance with the requirements of this Chapter is to be provided. The regulations governing assignment of the character figure **1** for equipment are given in Pt 1, Ch 2,3.

1.4.2 For craft intended to be operated only in suitable areas or conditions which have been agreed by the Committee, as defined in Pt 1, Ch 2,3.5, equipment differing from these requirements may be approved if considered suitable for the particular service on which the craft is to be engaged.

1.4.3 Where the Committee has agreed that anchoring and mooring equipment need not be fitted in view of the particular service of the ship, the character letter **N** will be assigned, *see also* Pt 1, Ch 2,3.2.2.

1.4.4 Where the ship is intended to perform its primary designed service function only while it is anchored, moored, towed or linked, the character letter **T** will be assigned, *see also* Pt 1, Ch 2,3.2.2.

1.4.5 For classification purposes the character figure **1**, or either of the character letters **N** or **T**, are to be assigned.

■ *Section 2* Equipment Number

2.1 Equipment Number

2.1.1 The anchoring and mooring equipment is based on an Equipment Number, *EN*, which is to be calculated as given in 2.1.2 to 2.1.4.

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2.1.2 **Mono-hull craft**

$EN = \Delta^{2/3} + 2\,(D_h + B_o\,\alpha_1) + 0{,}1A$

2.1.3 **Catamaran, Swath, SES and other twin hull craft**

$EN = \Delta^{2/3} + 2\,(D_h + B_o\,\alpha_1 + 2G_a\,B_1) + 0{,}1A$

2.1.4 **Trimarans**

$EN = \Delta^{2/3} + 2\,(D_h + B_o\,\alpha_1 + G_a\,(2B_1 + B_2)) + 0{,}1A$

2.2 Novel craft

2.2.1 Where a craft is of unusual form and proportions the requirement for equipment will be individually considered on the basis of the Rules.

■ *Section 3* Service group factors

3.1 General

3.1.1 The masses of anchors and the diameters and lengths of chain cable required by Table 5.5.1 and Table 5.6.1 respectively are for craft in **Service Group G4**.

3.2 G1 craft

3.2.1 For craft in **Service Group G1**, the equipment is generally to be that required for craft in **Service Group G2**; proposals for further reductions will be specially considered.

3.3 G2, G3 and G4 craft

3.3.1 For craft in **Service Groups G2**, **G3**, and **G4**, the mass of the anchor required by Table 5.5.1 may be multiplied by the following factors:

Service Group G2	0,60
Service Group G3	0,73
Service Group G4	1,00

3.3.2 The length and diameter of chain cable are to be those required by Table 5.6.1 corresponding to the reduced anchor mass given in Table 5.5.1.

3.3.3 Towlines and mooring lines are to be those required by Table 5.7.1 corresponding to the equipment number as determined from Section 2.

3.3.4 For service craft on particular duties, a further reduction in the mass of the anchor may be given in accordance with Section 4.

3.4 G5 craft

3.4.1 Craft in **Service Group G5** are considered for the purposes of this Chapter to be unrestricted in their service, and the equipment is to be in accordance with Pt 3, Ch 13 of the Rules for Ships.

3.5 G6 craft

3.5.1 **Service Group G6** covers yachts and patrol craft having unrestricted service.

3.5.2 For yachts, the mass of the anchors required by Table 5.5.1 may be multiplied by the craft type factor indicated in Section 4. The length and diameter of chain cable are to be those required by Table 5.6.1 corresponding to the reduced anchor mass given in Section 4.

3.5.3 For patrol craft, the equipment is to be in accordance with Pt 3, Ch 13 of the Rules for Ships for unrestricted service.

■ *Section 4* Craft type factors

4.1 General

4.1.1 The mass of the anchors required by Table 5.5.1 and corrected for service group factors in accordance with Section 3 (where applicable), are to be corrected by the craft type factors indicated in this Section.

4.2 Craft type factors

4.2.1 **Yachts** with an Equipment Numeral, *EN*, of less than or equal to 220 as determined in 2.1, may have the mass of the anchors as required by Table 5.5.1 reduced by the craft type factor, k_y, in accordance with the following:

$$k_y = \frac{EN}{500} + 0{,}56$$

4.2.2 For yachts with an Equipment Numeral, *EN*, in excess of 220, the craft type factor, k_y, is to be taken as unity.

4.2.3 **Pilot and Patrol** craft operating within **Service Group G1**, and which do not normally anchor in the course of their duties, with an Equipment Numeral *EN* of less than or equal to 220 as determined in 2.1, may have the mass of the anchor as required by Section 3 reduced by the craft type factor, k_{p1}, in accordance with the following:

$$k_{p1} = \frac{EN}{980} + 0{,}28$$

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4.2.4 **Pilot and patrol** craft operating within **Service Group G2**, and which do not normally anchor in the course of their duties, with an Equipment Numeral *EN* of less than or equal to 100 as determined in 2.1.2, may have the mass of the anchor as required by Section 3 reduced by the craft type factor, k_{p2}, in accordance with Table 5.4.1.

Table 5.4.1 Craft type factor

Equipment Numeral, *EN*	Craft type factor, k_{p2}
$\geq 5 \leq 40$	0,8
$> 40 \leq 100$	0,9
> 100	1,0

■ *Section 5* Anchors

5.1 General

5.1.1 The Rules are based on the use of high holding power (HHP) type anchors.

5.1.2 When ordinary holding power anchors are used as bower anchors, the mass given in Table 5.5.1 is to be increased by 33 per cent.

5.1.3 Where it is proposed to fit other types of anchor, the mass will be specially considered.

5.1.4 Craft other than yachts are to be provided with a single anchor on board which must be ready for immediate use.

5.1.5 In addition, the craft is to be supplied with one spare anchor located at each of the ports on its regular scheduled service, or alternatively the spare anchor may be carried on board.

5.1.6 **Yachts** are to be provided with two anchors on board. Each anchor must have the rule length of chain cable attached. Only one anchor is required to be ready for immediate deployment, i.e. around the capstan. The masses of anchors may be of the following combinations:

(a) The mass of the first anchor is to be not less than 100 per cent of the Rule value for the type of anchor concerned. The mass of the second anchor is to be not less than 70 per cent of the Rule value for the type concerned.

(b) The mass of each anchor is to be not less than 90 per cent of the Rule value for the type of anchor concerned.

5.1.7 The fitting of a single anchor on board yachts will be specially considered. The mass of the single anchor is to be not less than 100 per cent of the Rule value for the type of anchor concerned.

Table 5.5.1 Anchors

Equipment number		High holding power bower anchors	
Exceeding	Not exceeding	Number of anchors	Mass of anchor, in kg
—	5	1	11
5	10	1	13
10	15	1	17
15	20	1	22
20	25	1	27
25	30	1	32
30	35	1	37
35	40	1	44
40	45	1	52
45	50	1	59
50	70	1	80
70	90	1	117
90	110	1	154
110	130	1	197
130	150	1	240
150	175	1	292
175	205	1	360
205	240	1	428
240	280	1	495
280	320	1	585
320	360	1	675
360	400	1	765
400	450	1	855
450	500	1	968
500	550	1	1080
550	600	1	1193
600	660	1	1305
660	720	1	1440
720	780	1	1575
780	840	1	1710
840	910	1	1845
910	980	1	1980
980	1060	1	2138
1060	1140	1	2295

5.1.8 Anchors which must be specially laid the right way up, or which require the fluke angle or profile to be adjusted for varying types of sea bed, will not generally be approved for normal craft use. In such cases suitable tests may be required.

5.1.9 Anchors are to be of an approved design. The design of all anchor heads is to be such as to minimise stress concentrations, and in particular, the radii on all parts of cast anchor heads are to be as large as possible, especially where there is considerable change of section.

5.2 Materials

5.2.1 The requirements for anchor materials are contained in the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

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5.2.2 Anchors made of stainless steels or aluminium alloy may be acceptable subject to special consideration.

5.2.3 Where aluminium alloy anchors are proposed, due consideration is to be given to the compatibility of such anchors with the materials of the chain cable, anchor shackle, etc., in order to avoid galvanic corrosion.

5.3 Testing

5.3.1 Testing of anchors is to be carried out in accordance with Chapter 10 of the Rules for Materials.

5.3.2 For holding power testing requirements relating to high holding power anchors, *see* Ch 10,1.7 of the Rules for Materials.

5.4 Anchor shackle

5.4.1 Steel anchor shackles are to be forged or cast steel of approved manufacturer.

5.5 Anchor stowage

5.5.1 Anchors are generally to be housed in suitable hawse pipes, or stowed in dedicated chocks on deck.

5.5.2 Hawse pipes and anchor pockets are to be in accordance with 9.3. Alternatively, roller fairleads of suitable design may be fitted. Where hawse pipes are not fitted, alternative arrangements will be specially considered.

5.6 Super high holding power (SHHP) type anchors

5.6.1 Proposals to use anchors of the SHHP type will be subject to special consideration.

5.6.2 Final acceptance will be dependent upon satisfactory strength and performance tests.

5.6.3 Anchors of designs for which approval is sought as super high holding power anchors are to be tested at sea to show that they have holding powers of at least four times those of approved standard stockless anchors of the same mass.

5.7 Tolerances

5.7.1 The mass of each high holding power anchor given in Table 5.5.1 is for anchors of equal mass. The masses of individual anchors may vary by ±7 per cent of the masses given in the Table, provided that the total mass of the anchors is not less than would have been required for anchors of equal mass.

5.8 Identification

5.8.1 Identification of anchors which have been tested is to be in accordance with Ch 10,1.4 of the Rules for Materials.

■ *Section 6* Anchor cable

6.1 General

6.1.1 Anchor cable may be of stud link chain, short link chain, wire rope or fibre rope, subject to the requirements of this Section.

6.1.2 For each anchor required to be carried on board, *see* 5.1.6, a length of anchor cable, as indicated in Table 5.6.1, is to be provided.

6.2 Chain cable

6.2.1 The diameter of stud link chain cable is to be as indicated in Table 5.6.1.

6.2.2 Short link chain cable may be accepted provided that the breaking load is not less than that of stud link chain cable of the diameter required by Table 5.6.1.

6.2.3 Chain cables may be of mild steel, special quality steel or extra quality steel in accordance with the requirements of Ch 10 of the the Rules for Materials, and are to be graded in accordance with Table 5.6.2.

6.2.4 Grade U1 material having a tensile strength of less than 400 N/mm^2 is not to be used in association with high holding power anchors. Grade U3 material is to be used only for chain 20,5 mm or more in diameter.

6.2.5 In addition to 6.2.3 special consideration will be given to the use of chain cable of stainless steel. Stainless steel is to be of a suitable type, details of which are to be submitted for consideration.

6.2.6 The form and proportion of links and shackles are to be in accordance with Chapter 10 of the Rules for Materials.

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Table 5.6.1 Chain cable

Mass of HHP bower anchor, in kg	Length of chain cable, in metres	Stud link chain cable diameter, in mm		
		Mild steel (Grade:1 or U1)	Special quality steel (Grade:U2)	Extra special quality steel (Grade:U3)
11	55	8	–	–
13	55	8	–	–
17	55	8	–	–
22	55	9	–	–
			–	–
27	55	9	–	–
32	82,5	9	–	–
37	82,5	11,2	–	–
			–	–
44	82,5	11,2	–	–
52	110	11,2	–	–
59	110	12,5	–	–
			–	–
80	110	12,5	–	–
117	110	14	12,5	–
154	110	16	14	–
				–
197	137,5	17,5	16	–
240	137,5	19	17,5	–
292	137,5	20,5	17,5	–
				–
360	137,5	22	19	–
428	165	24	20,5	–
495	165	26	22	20,5
585	165	28	24	22
675	192,5	30	26	24
765	192,5	32	28	24
855	192,5	34	30	26
968	192,5	36	32	28
1080	220	38	34	30
1193	220	40	34	30
1305	220	42	36	32
1440	220	44	38	34
1575	220	46	40	36
1710	247,5	48	42	36
1845	247,5	50	44	38
1980	247,5	52	46	40
2138	247,5	54	48	42
2295	247,5	56	50	44

Table 5.6.2 Grades of steel for use as chain cable

Grade	Material	Tensile strength (N/mm^2)
U1	Mild steel	300 – 490
U2 (a)	Special quality steel (wrought)	490 – 690
U2 (b)	Special quality steel (cast)	490 – 690
U3	Extra special quality steel	690 min

6.3 Testing

6.3.1 Chain cable with a diameter of 12,5 mm or above is to be certified by Lloyd's Register (hereinafter referred to as 'LR'). Chain cable with a diameter below 12,5 mm is to be certified by a recognised testing establishment.

6.3.2 All chain cables are to be tested at establishments and on machines recognised by the Committee and under the supervision of LR's Surveyors or other Officers recognised by the Committee, and in accordance with Chapter 10 of the Rules for Materials.

6.3.3 Test certificates showing particulars of size and weight of cable and of the test loads applied are to be furnished. These certificates are to be examined by the Surveyors when the cables are placed on board the craft.

6.4 Wire rope

6.4.1 When the Equipment Number does not exceed 500 for craft in **Service Groups G1**, **G2** and **G3**, steel wire rope may be accepted in lieu of chain cable under the following conditions:

(a) A length of chain of the diameter specified in Table 5.6.1 is to be fitted to the anchor. The total length of chain is to be not less than 10 per cent of the total required by Table 5.6.1. In no case is the length of chain attached to an anchor to be less than 9 metres.

(b) The wire rope used in lieu of chain cable is to have a breaking load of not less than that of the chain cable it replaces.

(c) The combined length of the chain cable specified in (a) and the wire is to be not less than the length of chain cable required by Table 5.6.1.

(d) Thimbles are to be fitted at both ends of the wire rope, as appropriate.

(e) Suitable precautions are to be taken to reduce the wear on the wire rope at fairleads, etc.

6.4.2 Steel wire ropes are to be manufactured, tested and certified as required by Chapter 10 of the Rules for Materials.

6.5 Fibre rope

6.5.1 When the Equipment Number does not exceed 100, polyamide (or other equivalent synthetic fibre) rope may be accepted in lieu of wire rope, subject to compliance with 6.4.1(a) to (d).

6.5.2 Fibre ropes are to be manufactured, tested and certified as required by Chapter 10 of the Rules for Materials.

6.5.3 Synthetic fibre ropes are to be ultra-violet inhibited as necessary, dependent upon their type.

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6.6 Cable clench

6.6.1 Provision is to be made for securing the inboard ends of the cables to the structure. This attachment is to have a working strength of not less than 10 per cent of the breaking strength of the chain cable, and the structure to which it is attached is to be adequate for this load. Attention is drawn to the advantages of arranging that the cable may be slipped from an accessible position outside the chain cable locker. The proposed arrangement for slipping the chain cable, if constructed outside the chain locker, must be made watertight.

6.7 Cable stopping and release arrangements

6.7.1 It is recommended that suitable bow chain stoppers be provided. The scantlings of these chain stoppers are outwith the scope of the Rules, however the structure in way is to be designed with due regard to the applied loading. Support under chain stopping arrangements is to be to the satisfaction of the Surveyor.

6.8 Cable locker

6.8.1 Adequate storage is to be provided to accommodate the full length of anchor cable.

6.8.2 The chain locker is to be of a capacity and depth adequate to provide an easy direct lead for the cable into the chain pipes, when the cable is fully stowed. Chain or spurling pipes are to be of suitable size and provided with chafing lips. The port and starboard cables are to be separated by a division in the locker.

6.8.3 Chain lockers fitted abaft the collision bulkhead are to be watertight and the space to be efficiently drained.

■ *Section 7* Mooring ropes and towlines

7.1 Mooring ropes

7.1.1 Craft under 90 m in length are to be equipped with mooring ropes in accordance with Table 5.7.1.

7.1.2 The lengths of individual mooring lines in Table 5.7.1 may be reduced by up to seven per cent of the Table length, provided that the total length of mooring lines is not less than would have resulted had all lines been of equal length. Proposals to fit individual mooring lines of reduced length to suit the particular service will be specially considered.

7.2 Materials

7.2.1 Mooring lines may be of steel wire rope, natural fibre or synthetic fibre. The diameter, construction and specification of wire or natural fibre mooring lines are to comply with the requirements of Chapter 10 of the Rules for Materials. Where it is proposed to use synthetic fibre ropes, the size and construction will be specially considered.

7.3 Testing and certification

7.3.1 Mooring ropes are to be tested and certified in accordance with Chapter 10 of the Rules for Materials.

7.4 Towlines

7.4.1 Towlines are not required for classification other than for craft which are required to comply with the *IMO Code of Safety for High Speed Craft*. The details given in Table 5.7.1 are for guidance purposes only.

7.5 Bollards, fairleads and bull rings

7.5.1 Means are to provided to enable mooring lines to be adequately secured on board the craft. It is recommended that the total number of suitably placed bollards on either side of the craft and/or the total brake holding power of mooring winches should be capable of holding not less than 1,5 times the sum of the maximum breaking strengths of the mooring lines required or recommended. Attention is drawn to the existence of a number of National Standards for bollards and fairleads, and to the importance of ensuring that their seating arrangements, including the supporting hull structure, are efficiently constructed and adequate for the intended loads.

7.6 Towing requirements

7.6.1 Craft which are to comply with the *IMO Code of Safety for High Speed Craft* are to be provided with adequate arrangements to enable the craft to be towed in the worst intended environmental conditions. It is recommended that other craft comply with this requirement.

7.7 Towing bitts

7.7.1 Where towage is to be from more than one point a suitable bridle is to be provided.

7.7.2 Details of the structural scantlings, arrangements, loadings and design assumptions for the towing bitts are to be submitted for consideration.

7.7.3 The towing arrangements should be such that damage to the towline or bridle from abrasion is minimised.

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Table 5.7.1 Towlines and mooring lines

Equipment Number		Towline, *see* Notes		Mooring lines		
Exceeding	Not exceeding	Minimum length, in metres	Minimum breaking strength, in kN	Number of lines	Minimum length of each line, in metres	Minimum breaking strength, in kN
–	5	90	19,9	2	55	13,9
5	10	90	22,5	2	55	17,6
10	15	90	27,7	2	55	21,5
15	20	90	32,9	2	55	24,5
20	25	110	38,1	2	55	26,6
25	30	110	43,3	2	55	28,2
30	35	110	48,5	2	55	29,6
35	40	135	53,7	2	55	30,8
40	45	135	58,9	2	70	31,8
45	50	135	64,1	2	85	32,7
50	70	180	71,0	2	100	35,5
70	90	180	82,1	2	100	39,3
90	110	180	93,2	2	110	43,1
110	130	180	104,3	2	110	46,6
130	150	180	115,3	2	120	50,2
150	175	180	127,8	2	120	54,4
175	205	180	143,0	2	120	58,8
205	240	180	161,1	2	120	64,2
240	280	180	181,8	3	120	71,1
280	320	180	204,0	3	140	78,5
320	360	180	226,1	3	140	85,8
360	400	180	248,3	3	140	93,2
400	450	180	273,2	3	140	100,5
450	500	180	300,9	3	140	107,9
500	550	180	328,6	4	160	112,8
550	600	180	356,3	4	160	117,7
600	660	180	386,8	4	160	122,6
660	720	180	420,1	4	160	127,5
720	780	180	453,3	4	170	132,4
780	840	180	486,5	4	170	137,3
840	910	180	522,5	4	170	142,2
910	980	180	561,3	4	170	147,1
980	1060	180	602,9	4	180	156,9
1060	1140	180	647,2	4	180	166,7

NOTES
1. Towline specified for guidance only, *see* 7.4.1.
2. Wire ropes used for towlines and mooring lines are generally to be of a flexible construction with not less than:
   144 wires in six strands with seven fibre cores for strengths up to 490 kN
   222 wires in six strands with one fibre core for strengths exceeding 490 kN
   The wires to be laid around the fibre centre of each strand are to be up in not less than two layers.
3. Wire ropes for towlines and mooring lines used in association with mooring winches (on which the rope is stored on the winch drum) are to be of suitable construction.
4. Irrespective of strength of requirements, no fibre rope is to be less than 12 mm diameter.

7.8 Mooring winches

7.8.1 Mooring winches where provided are to be suitable for the intended purpose. Supports under the winches are to be to the Surveyor's satisfaction.

7.8.2 Mooring winches are to be fitted with drum brakes, the strength of which is sufficient to prevent unreeling of the mooring line when the rope tension is equal to 80 per cent of the breaking strength of the rope as fitted on the first layer on the winch drum, *see also* 7.5.1.

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■ *Section 8*
Windlass design and testing

8.1 General

8.1.1 A windlass, capstan or winch of sufficient power and suitable for the size of anchor cable is to be fitted to the craft. Where Owners require equipment significantly in excess of Rule requirements, it is their responsibility to specify increased windlass power.

8.1.2 Windlasses may be hand or power operated, subject to the requirements of 8.2.3.

8.1.3 Where steel wire rope is used in lieu of chain cable, a suitable winch with sufficient drum capacity to store the length of wire rope fitted is to be provided.

8.1.4 The windlass, anchoring capstans and winches are to be of types approved by LR.

8.1.5 On craft equipped with anchors having a mass of over 50 kg windlass(es) of sufficient power and suitable for the type and size of chain cable are to be fitted. Arrangements with anchor davits will be specially considered.

8.2 Windlass design

8.2.1 The following performance criteria are to be used as a design basis for the windlass:

(a) The windlass is to have sufficient power to exert a continuous duty pull of:
$28{,}5\ d_c^2$ N – for Grade U1 chain, with $d_c < 14$ mm
$37{,}5\ d_c^2$ N – for Grade U1 chain, with $d_c \geq 14$ mm
$42{,}5\ d_c^2$ N – for Grade U2 chain
$47{,}5\ d_c^2$ N – for Grade U3 chain
over a period of $0{,}12L_c$ minutes. The test period need not be taken longer than 30 minutes
where
d_c is the chain diameter, in mm
L_c is the total length of chain cable on board, in metres, as given by Table 5.6.1.

(b) The windlass is to have sufficient power to exert, over a period of at least two minutes, a pull equal to the greater of:
(i) short-term pull:
1,5 times the continuous duty pull as defined in 8.2.1(a).
(ii) anchor breakout pull:
$12{,}18W_a + 7{,}0L_c\ d_c^2/100$ N
where
W_a is the mass of bower anchor(kg) as given in Table 5.5.1.

(c) In the absence of a chain stopper, the windlass, with its braking system in action and in conditions simulating those likely to occur in service, is to be able to withstand, without permanent deformation or brake slip, a load, applied to the cable, given by:
$K_b\ d_c^2\ (44 - 0{,}08d_c)$ N
where
K_b = 7,85 for Cable Grade U1
= 11,00 for Cable Grade U2
= 15,70 for Cable Grade U3.

(d) Where a chain stopper is fitted, the windlass braking system is to have sufficient brake capacity to ensure safe stopping when paying out the anchor and chain. It is the Master's responsibility to ensure that the chain stopper is in use when riding at anchor. At clearly visible locations on the bridge and adjacent to the windlass control position, the following notice is to be displayed adjacent to the windlass control position, and at clearly visible locations on the bridge if the windlass can be operated remotely:
'The brake is rated to permit controlled descent of the anchor and chain only. The chain stopper is to be used at all times whilst riding at anchor.'
The performance criteria are to be verified by means of shop tests in the case of windlasses manufactured on an individual basis. Windlasses manufactured under LR's Type Approval Scheme for Marine Engineering Equipment will not require shop testing on an individual basis.

8.2.2 Windlass performance characteristics specified in 8.2.1 and 8.3.2 are based on the following assumptions:
(a) one cable lifter only is connected to the drive shaft,
(b) continuous duty and short term pulls are measured at the cable lifter,
(c) brake tests are carried out with the brakes fully applied and the cable lifter declutched,
(d) the probability of declutching a cable lifter from the motor with its brake in the off position is minimised,
(e) hawse pipe efficiency assumed to be 70 per cent.

8.2.3 Calculations for torque transmitting components are to be based on 1500 hours of operation with a nominal load spectrum factor of 1,0. Alternatively, unlimited hours with a nominal load spectrum factor of 0,8 can be applied.

8.2.4 Where the available input torque exceeds the torque required for anchor breakout, torque overload protection is to be fitted.

8.2.5 An arrangement to release the anchor and chain in the event of windlass power failure is to be provided.

8.2.6 The maximum calculated stress from the load cases stated in Table 5.8.1 are not to exceed the permissible stress limits stated in Table 5.8.2.

8.2.7 The following criteria are to be used for gearing design:
(a) Torque is to be based on the performance criteria specified in 8.2.1.
(b) The use of an equivalent torque, T_{eq}, for dynamic strength calculations is acceptable but the derivation is to be submitted to LR for consideration.
(c) The application factor for dynamic strength calculation, K_A, is to be 1,15.
(d) Calculations are to be based on 1500 hours of operation.
(e) The static torque is to be 1,5 x T_n, where T_n is the nominal torque.

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(f) The minimum factors of safety for load capacity of spur and helical gears, as derived using ISO 6336 or a relevant National or International Standard acceptable to LR, are to be 1,5 for bending stress and 0,6 for contact stress.

8.2.8 Keyways are to be designed to a relevant National or International Standard acceptable to LR.

8.2.9 The maximum stress in brake components is not to exceed the permissible stress stated in Table 5.8.2.

8.2.10 Hand-operated winches are only acceptable if the effort required at the handle does not exceed 15 kgf for raising one anchor at a speed of not less than 2 m/min and making about thirty turns of the handle per minute.

8.2.11 Winches suitable for operation by hand as well as by external power are to be so constructed that the power drive cannot activate the hand drive.

8.3 Control arrangements

8.3.1 All control devices are to be capable of being controlled from readily accessible positions and protected against unintentional operation.

8.3.2 The maximum travel of the levers is not to exceed 600 mm if movable in one direction only, or 300 mm to either side from a central position if movable in both directions.

8.3.3 Wherever practical, the lever is to move in the direction of the intended movement. If this cannot be achieved, then it is to move towards the right when hauling and towards the left when paying out.

8.3.4 For lever-operated brakes, the brake is to engage when the lever is pulled and disengage when the lever is pushed. The physical effort on the brake for the operator is not to exceed 160 N.

Table 5.8.1 Design load cases for windlass and chainstopper

Load case	Condition	Note
1	Continuous pull	*See* 8.2.1 (a)
2	Overload pull	*See* 8.2.1 (b)
3	Brake holding load	*See* 8.2.1 (c)

Table 5.8.2 Permissible stress for design load cases

Stress	Load case	
	1 and 2	3
	Permissible stress	
Tension	0,8 *Y*	0,9*Y*
Compression or bending	0,8 *Y*	0,9*Y*
Shear	0,7 *Y*	0,7*Y*
Combined	0,85 *Y*	0,9*Y*

NOTES

1. Where a component is subjected to axial tensile, axial compressive, bending or shear stress, F_c is to be calculated in the normal manner.
2. Where a component is subjected to a combination of co-existent stresses, F_c is the combined stress which is to be calculated as follows:

Combined bending and tension

$F_c = 1{,}25f_c + f_{bt}$

Combined bending and compression

$F_c = f_c + f_{bc}$

Combined bending, tension and shear

$$F_c = \sqrt{(1{,}25\, f_t + f_{bt})^2 + 3\, f_q{}^2}$$

Combined bending, compression and shear

$$F_c = \sqrt{(f_c + f_{bc})^2 + 3\, f_q{}^2}$$

where

F_c is the calculated stress
f_t is the calculated axial tensile stress
f_c is the calculated axial compressive stress
f_{bt} is the calculated maximum tensile stress due to bending about both principal axes
f_{bc} is the calculated maximum compressive stress due to bending about both principal axes
f_q is the calculated shear stress
Y is the specified 0,2 per cent proof stress for the material

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8.3.5 For pedal-operated brakes, the maximum travel is not to exceed 250 mm and the physical effort for the operator is not to exceed 320 N.

8.3.6 The handwheel or crankhandle is to actuate the brake when turned clockwise and release it when turned counterclockwise. The physical effort for the operator is not to exceed 250 N for speed regulation and 500 N at any moment.

8.3.7 When not provided with automatic sequential control, separate push-buttons are to be provided for each direction of operation.

8.3.8 The push-buttons are to actuate the machinery when depressed, and stop and effectively brake the machinery when released.

8.3.9 The above-mentioned individual push-buttons may be replaced by two 'start' and 'stop' push-buttons.

8.3.10 Control systems, whether electric, pneumatic or hydraulic, are to comply with the general requirements of Pt 6, Ch 1,2.

8.4 Maintenance arrangements

8.4.1 Access is to be provided for inspection of reduction gears, bearings, brakes, etc.

8.4.2 Accessible manual lubrication points, including nipples, are to be provided for both oil and grease, as applicable.

8.4.3 Gear-boxes are to be provided with adequate access arrangements for monitoring and replacing oil.

8.5 Protection arrangements

8.5.1 Where applicable, moving parts of windlass machinery are to be provided with suitable railings and/or guards to prevent injury to personnel.

8.5.2 Protection is to be provided for preventing persons from coming into contact with surfaces having temperatures over 50°C.

8.5.3 Steel surfaces not protected by lubricant are to be protected by a coating in accordance with the requirements of a relevant National or International Standard acceptable to LR.

8.5.4 For arrangements of power transmission systems and relief requirements, *see* Pt 5, Ch 14,9.1 of the Rules for Ships.

8.6 Marking and identification

8.6.1 Controls are to be permanently marked for identification, unless their functions are readily apparent. If required, instructions are to be permanently marked and readily visible.

8.7 Tests and trials

8.7.1 Where shop testing is not possible and Type Approval has not been obtained, calculations demonstrating compliance with 8.2.1 are to be submitted together with detailed plans and an arrangement plan showing the following components:

- Shafting.
- Gearing.
- Brakes.
- Clutches.

8.7.2 During trials on board the craft the windlass should be shown to be capable of raising the anchor from a depth of 82,5 m to a depth of 27,5 m at a mean speed of 9 m/min. Where the depth of water in the trial area is inadequate, or the anchor cable is less than 82,5 m, suitable equivalent simulating conditions will be considered as an alternative.

8.8 Seatings

8.8.1 The windlass is to be efficiently bedded and secured to the deck. The thickness of the deck in way of the windlass is to be increased, and adequate stiffening is to be provided, to the Surveyor's satisfaction. The structural design integrity of the bedplate is the responsibility of the Builder and windlass manufacturer.

■ *Section 9* Structural details

9.1 General

9.1.1 An easy lead of the cables from the windlass to the anchors and chain lockers is to be arranged. Where cables pass over or through stoppers, these stoppers are to be manufactured from ductile material and be designed to minimise the probability of damage to, or snagging of, the cable. They are to be capable of withstanding without permanent deformation a load equal to 80 per cent of the Rule breaking load of the cable passing over them.

9.2 Bulbous bow and wave piercing bow arrangements

9.2.1 The shell plating is to be increased in thickness at the fore end of the bulb and in other areas likely to be damaged by the anchors and chain cables. The increased plate thickness is to be the same as that required for plated stems by Parts 6, 7 and 8 of the Rules for steel, aluminium alloy and composite materials respectively.

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9.3 Hawse pipes and anchor recesses

9.3.1 Hawse pipes, bow rollers and other deck gear, of adequate size and construction, are to be provided for handling and securing the anchors and are to be efficiently attached to the structure and arranged to give an easy lead to the cable.

9.3.2 The hawse pipes are to be of sufficient size and thickness, and arranged to give an easy lead for the cable to the windlass.

9.3.3 Hawse pipes and anchor pockets are to be of ample thickness and of a suitable size and form to house the anchors efficiently, preventing, as much as practicable, slackening of the cable or movements of the anchor being caused by wave action. The shell plating and framing in way of the hawse pipes are to be reinforced as necessary, *see* 9.5.1. Substantial chafing lips are to be provided at shell and deck. These are to have sufficiently large, radiused faces to minimise the probability of cable links being subjected to high bending stresses. Alternatively, roller fairleads of suitable design may be fitted. Where unpocketed rollers are used, it is recommended that the roller diameter be not less than eleven times the chain diameter. Where hawse pipes are not fitted, alternative arrangements will be specially considered.

9.4 Spurling pipes

9.4.1 Satisfactory means are to be provided to prevent inadvertent flooding of chain lockers. It is recommended that steel plates in halves, hooked over the spurling pipe tops, be provided on top of which cement may be laid before lashing a canvas cover. Suitable alternatives will be considered.

9.4.2 The design of the windlass is to be such that the following requirements or equivalent arrangements will minimise the probability of the chain locker or forecastle being flooded in bad weather:

(a) a weathertight connection can be made between the windlass bedplate, or its equivalent, and the upper end of the chain pipe, and

(b) access to the chain pipe is adequate to permit the fitting of a cover or seal, of sufficient strength and proper design, over the chain pipe while the craft is at sea.

9.5 Local reinforcement

9.5.1 The thickness of shell plating determined in accordance with the Rule requirements is to be increased locally by not less than 50 per cent in way of hawse pipes.

9.5.2 Supports under windlasses and winches are to be suitably reinforced.

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Section

1 **General requirements**

2 **Noise**

3 **Vibration**

4 **Testing**

5 **Noise and vibration survey reporting**

6 **Non periodical survey requirements**

7 **Referenced standards**

Section 1 General requirements

1.1 Scope

1.1.1 These Rules set down the criteria for the assessment of the noise and vibration on special service craft and are applied in addition to the other relevant requirements of these Rules.

1.1.2 For the purpose of these Rules, the term 'ship', unless otherwise stated, applies to Special Service Craft and Yachts.

1.1.3 Compliance with these Rules is optional.

1.1.4 These Rules provide for two alternatives:

(a) **Class Notations** which indicate that the ship has been assessed and complies with noise and vibration criteria of these Rules and that a periodic survey regime has been established for the lifetime of the ship.

(b) **Certificate of Compliance** which provides evidence that the ship has been assessed and found to comply with the noise and vibration criteria of these Rules.

1.1.5 These Rules recognise existing National and International Standards and specify levels of noise and vibration currently achievable using good engineering practice. Compliance with these requirements will be assessed by review of procedures, inspection and measurement of the relevant parameters and pre-survey reviews. Inspections and measurements are to be conducted, witnessed or assessed by Lloyd's Register's Surveyors unless otherwise agreed by Lloyd's Register (hereinafter referred to as 'LR').

1.1.6 Accommodation comfort is a function of ship type and layout. These Rules address two types of ship:

(a) High-speed (e.g. surface effect ships, wave piercing catamarans, hydrofoils).

(b) Yacht (e.g. sailing yachts, motorised pleasure craft).

1.1.7 These Rules include levels of noise and vibration which should be verified by measurements following completion of the ship. It is recommended that the Builders undertake calculations of noise and vibration characteristics so that any potential problem areas can be identified and control measures implemented.

1.1.8 The sound pressure levels for audible alarms and public address systems fitted in accordance with other Sections of the Rules are to satisfy IMO Resolution A.830(19), Code on Alarms and Indicators.

1.2 Definitions

1.2.1 **Passenger spaces** are defined as all areas intended for passenger use, and include the following:

(a) Passenger cabins.

(b) Public spaces (e.g. restaurants, hospitals, lounges, reading and games rooms, gymnasiums, corridors and/or shops).

(c) Open deck recreation areas.

1.2.2 **Crew spaces** are defined as all areas intended for crew use only, and include the following:

(a) Accommodation spaces (e.g. cabins, offices, mess rooms, recreation rooms).

(b) Work spaces.

(c) Navigation spaces.

1.2.3 **Noise level** is defined as the A-weighted sound pressure level measured in accordance with ISO 2923.

1.2.4 **Vibration level** is defined by the application of either of the two versions of the ISO 6954 Standard:

(a) Where ISO 6954:1984 is applied, the vibration level is defined as the single amplitude peak value of deck structure vibration during a period of steady state vibration, representative of maximum repetitive behaviour, in mm/s, over the frequency range 5 to 100 Hz. For frequencies below 5 Hz, the requirements for vibration levels follow constant acceleration curves corresponding to the acceleration at 5 Hz.

(b) Where ISO 6954:2000 is applied, the vibration level is defined as the overall frequency weighted r.m.s. value of vibration during a period of steady-state operation over the frequency range 1 to 80 Hz.

In general, ISO 6954-2000 is the preferred standard to be applied, however ISO 6954-1984 may be applied where there are practical difficulties in the application of ISO 6954-2000 and this has been agreed between the Owner and Builder.

1.3 Class notations

1.3.1 The class notations described in 1.3.2 to 1.3.6 provide standards for noise and vibration levels in different spaces at the time of delivery and during the ship's life if substantial changes to the machinery installation or interior arrangements are made.

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1.3.2 The **PAC** (Passenger Accommodation Comfort), **CAC** (Crew Accommodation Comfort) and **PCAC** (Passenger and Crew Accommodation Comfort) notations are optional and are primarily intended to apply to passenger ships. If requested, however, any ship can be assessed for compliance, using these requirements as the basis for the assessment and a LR Certificate of Compliance issued (*see* 1.1.4(b) and 1.4).

1.3.3 The **PAC** notation indicates that the passenger accommodation meets the acceptance criteria whilst the **CAC** notation indicates that the crew accommodation and work areas meet the acceptance criteria. The **PCAC** notation indicates that the passenger and crew spaces both meet the acceptance criteria.

1.3.4 For ships which achieve the noise and vibration comfort standards specified in these Rules, the notation **PAC**, **CAC** or **PCAC** will be assigned.

1.3.5 Following the **PAC** or **CAC** notation, numerals **1**, **2** or **3** will indicate the acceptance criteria to which the noise and vibration levels have been assessed. In the case of the **PCAC** notation, two numerals will be assigned. The first will indicate the acceptance criteria for passenger accommodation, whilst the second will indicate the crew comfort criteria.

1.3.6 For particular vessels, impact insulation and transient noise in accordance with 2.5 and 2.6 together with any additional or more stringent noise and vibration criteria may be assessed within the scope of the notations where agreed between the Owner, Builder and LR.

1.4 Certificate of Compliance

1.4.1 A Certificate of Compliance records that a ship has been designed and constructed to satisfy the noise and vibration criteria contained in these Rules. This is to be confirmed by measurements and reporting in accordance with Sections 4 and 5.

1.4.2 A Certificate of Compliance is optional and if requested, any ship can be assessed for compliance using the Rule requirements.

1.4.3 Where noise and vibration levels are at variance with those prescribed by these Rules, they will be added to the certificate for information purposes.

1.4.4 A Certificate of Compliance will be issued after the initial survey required by Section 6.

■ *Section 2* Noise

2.1 Assessment criteria

2.1.1 Where a space is occupied by both passengers and crew, the more stringent of the relevant requirements apply unless agreed between the Builder and Owner and advised to LR.

2.2 Passenger accommodation and public spaces

2.2.1 Under test conditions specified in 4.2, the applicable noise levels specified in Tables 6.2.1 and 6.2.2 should not generally be exceeded. *See* 2.2.3.

Table 6.2.1 High speed craft – Maximum noise levels in dB(A)

Location		Acceptance Numeral		
		1	2	3
Public spaces:	Excluding shops	60	65	70
	Shops	65	68	72

Table 6.2.2 Yachts – Maximum noise levels in dB(A)

Location		Acceptance Numeral		
		1	2	3
Passenger cabins:	Standard	53	55	58
	Superior	50	53	55
Lounges		55	58	60
Open deck recreation areas:	2nd deck from WL	72	75	79
	3rd deck from WL	63	66	70
Wheelhouse		60	62	75

NOTES
1. The levels may be exceeded by 5dB(A) within 3 m of a ventilation inlet/outlet or machinery intake/uptake on open decks.
2. The levels may be exceeded by 3dB(A) in accommodation above the propellers for three decks above the mooring deck.
3. The levels for open deck recreation areas refer to ship generated noise only. On open deck spaces the noise generated from the effects of wind and waves can be considered separately to limits agreed between the Builder and Owner and advised to LR for the trial conditions.

2.2.2 For cabins bordering discotheques and similar entertainment areas, the deck and bulkhead sound insulation is to be sufficient to ensure that the maximum cabin noise levels are not exceeded even when high external noise levels prevail.

2.2.3 Acceptance of noise levels greater than those specified in Tables 6.2.1 and 6.2.2 may be considered where agreed between the Owner and Builder. Not more than 20 per cent of the passenger cabins, 30 per cent of the public spaces and 20 per cent of the crew cabins should exceed the relevant noise criteria by more than 3 dB(A).

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2.2.4 Acoustic insulation of bulkheads and decks between passenger spaces is to be generally in accordance with the values of the weighted apparent sound reduction index, R_w, as given in Table 6.2.3, calculated using ISO 717/1. *See also* 2.2.6.

Table 6.2.3 Minimum air-borne sound insulation indices, R_w

Location		Acceptance Numeral		
		1	2	3
Passenger cabins:	Standard	40	38	37
	Superior	45	42	40
Cabin to corridor:	Standard	38	36	34
	Superior	42	40	37
Cabin to stairway:	Standard	47	45	43
	Superior	50	47	45
Cabin to public space (excluding corridoors/ stairwells and discotheques):	Standard	52	48	48
	Superior	55	50	50
Discotheques to cabins		60	60	60
Discotheques to stairwells and public spaces		52	52	52
Cabin to machinery rooms and engine casing		55	53	50

2.2.5 For the purpose of selecting acoustic sound insulation, the following sound noise levels may be used with the agreement of the Owner and Builder:

(a) Cabins – 80 dB(A).
(b) Dining Rooms – 85 dB(A).
(c) Corridors – 90 dB(A).
(d) Discotheques, Theatres, Entertainment Areas – 105 dB(A).

2.2.6 Acceptance of bulkhead and deck acoustic insulation values less than those specified in Table 6.2.3 may be considered where agreed between the Owner and Builder. Not more than 20 per cent of the interfaces tested should have airborne sound insulation indices, R_w, more than 3 dB(A) lower than the minimum specified values.

2.3 Crew accommodation and work areas

2.3.1 Under the applicable test conditions specified in 4.2, the noise levels specified in Tables 6.2.4 and 6.2.5 are not to be exceeded.

2.3.2 Crew space insulation is to comply with the requirements of IMO Resolution A.468(XII).

Table 6.2.4 Crew accommodation – Maximum noise levels in dB(A)

Location		Acceptance Numeral		
		1	2	3
Sleeping cabins, hospitals		52	55	60
Day cabins		55	60	60
Office conference rooms		55	60	65
Mess rooms, lounges, reception areas:	Within accommodation	57	60	65
	On open decks	65	70	75
Alleyways, changing rooms, bathrooms, lockers		70	75	75

NOTE
The levels may be exceeded by 5dB(A) within 3 m of a ventilation inlet/outlet or machinery intake/uptake on open decks.

Table 6.2.5 Crew work areas – maximum noise levels in dB(A)

Location	dB(A) level
Machinery space(continuously manned) e.g. stores	90
Machinery space(not continuously manned) e.g. pump, refrigeration, thrusters or fan rooms	110
Workshops	85
Machinery control rooms	75
Wheelhouse	65
Bridge wing, additional limits: • 250 Hz band • 500 Hz band	 68 63
Radio room	60
Galleys and pantries: • Equipment not working • Individual items at 1 metre	 75 80
Normally unoccupied spaces (e.g. holds, decks)	90
Ship's whistle, on bridge or forecastle	110

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2.4 Maximum noise levels

2.4.1 Where the measured noise level exceeds the specified criterion by 3 dB(A), or contains subjectively annoying low frequency or tonal components, the noise rating (NR) number is to be established in accordance with the graph shown in Fig. 6.2.1. This is achieved by plotting the linear octave band levels on the graph; the NR number is that NR curve to which the highest plotted octave band level is anywhere tangent. The specified criterion may be considered satisfied if the NR number does not exceed the specified A-weighted value minus 5 dB(A).

2.4.2 Guidance on maximum acceptable sound pressure levels and noise exposure limits for crew spaces is given in IMO Resolution A.468(XII).

2.5 Impact insulation

2.5.1 Where agreed between the Owner, Builder and LR, enhanced criteria for noise levels recognising the effects of impact sound pressures may be applied in accordance with 2.5.2 to 2.5.5.

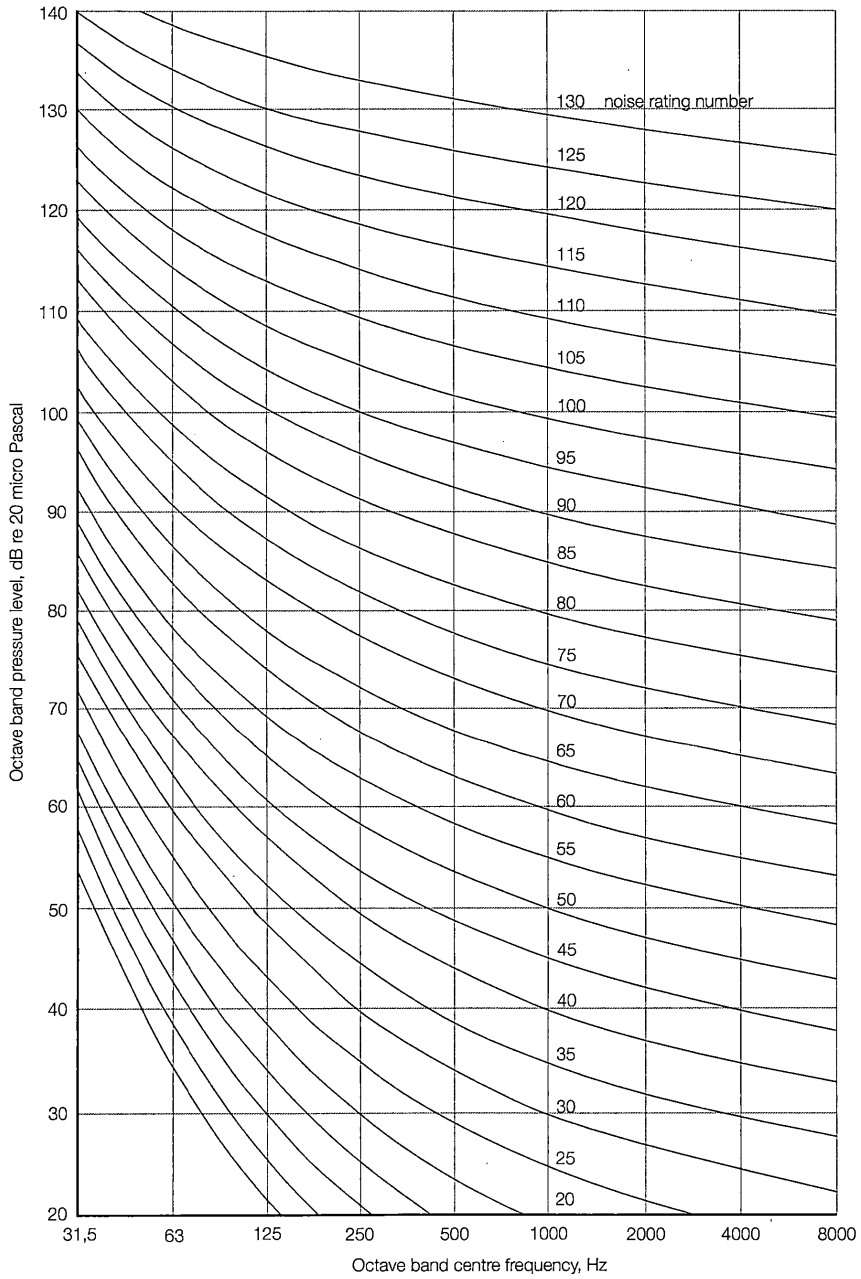

Fig. 6.2.1 Noise rating curves

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2.5.2 For passenger and crew cabins located below or adjacent to dance floors, stages, aerobics and gymnasium areas, jogging tracks or other areas where impact noise is generated, the normalised impact sound pressure level measured within the cabins is not to exceed 45 dB.

2.5.3 For public rooms under dance floors, stages, aerobics and gymnasium areas, jogging tracks or other areas where impact noise is generated, the normalised impact sound pressure level within the space is not to exceed 55 dB.

2.5.4 For passenger cabins, the normalised impact sound pressure level, $L_{n,w}$, calculated using ISO 717/2, is to be generally in accordance with the values stated in Table 6.2.6. *See also 2.5.5.*

Table 6.2.6 Passenger cabins normalised impact maximum sound pressure level $L_{n,w}$

Location	dB
Below decks covered with carpet and soft materials	50
Below decks covered with hard materials (such as wood, marble or similar	60
Below dance floors, theatre or sports rooms	47

2.5.5 Acceptance of normalised impact sound pressure levels greater than those specified in Table 6.2.6 may be considered for assignment of the applicable class notation where agreed between the Owner, Builder and LR. No more than 20 per cent of the passenger cabins tested should exceed the levels specified by more than 3 dB.

2.6 Transient noise

2.6.1 Where agreed between the Owner, Builder and LR, enhanced criteria for transient noise levels may be applied in accordance with 2.6.2.

2.6.2 The maximum sound pressure level (L_{max}) emanating from any machinery or system caused by a single event that produces a noise 'spike' compared to the reference condition sound level (such as vacuum systems or valve operations) is not to cause an increase in noise in comparison with the reference condition as below:

(a) Passenger cabins and public areas: +2 dB(A)
(b) Officer cabins: +2 dB(A)
(c) Crew cabins and public areas: +3 dB(A)

A tolerance of +1 dB(A) may be applied to 5 per cent of cabins and public areas in each fire zone on each deck. This criterion is generally applicable to the specified maximum noise levels for the space concerned.

■ *Section 3* Vibration

3.1 Assessment criteria

3.1.1 Where a space is occupied by both passengers and crew, the more stringent of the relevant requirements apply unless agreed between the Builder and Owner and this agreement advised to LR.

3.1.2 The limits apply to vertical, fore and aft and athwartship vibrations which are to be assessed separately.

3.1.3 Under test conditions specified in 4.2, the applicable vibration levels specified in Tables 6.3.1 to 6.3.3 should not be exceeded.

Table 6.3.1 High speed craft – Maximum vibration levels

Standard:	ISO 6954:1984			ISO 6954:2000		
Units:	Peak velocity (5 –100 Hz)			Frequency weighted (1–80 Hz) velocity mm/s rms		
	Acceptance Numeral					
Location	1	2	3	1	2	3
Public spaces	2,5	4,0	5,0	2,5	3,2	3,6

Table 6.3.2 Yacht – Maximum vibration levels

Standard:	ISO 6954:1984			ISO 6954:2000		
Units:	Peak velocity (5 –100 Hz)			Frequency weighted (1–80 Hz) velocity mm/s rms		
	Acceptance Numeral					
Location	1	2	3	1	2	3
Cabins and lounges	1,0	2,0	3,0	1,8	2,0	2,5
Public spaces	1,5	3,0	4,0	2,5	2,9	3,3
Open recreation decks	2,0	3,5	4,0	2,5	3,2	3,8
NOTE The vibration level may be exceeded by 0,3 mm/s in the yacht's aft body directly above the propellers.						

3.1.4 Acceptance of vibration levels greater than those specified in Tables 6.3.1 to 6.3.3 may be considered for assignment of the applicable class notation where agreed between the Owner, Builder and LR.

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Table 6.3.3 Crew spaces – Maximum vibration levels

Standard	ISO 6954:1984	ISO 6954:2000
Units	Peak velocity (5–100 Hz)	Frequency weighted (1–80 Hz) velocity mm/s rms
Location		
Accommodation and navigation spaces	5,0	3,5
Work spaces	6,0	5,0

3.1.5 The vibration levels for ISO 6954:1984 are stated as peak vibration velocity amplitude. If root mean square levels are measured, each frequency component may be converted to peak vibration velocity amplitude by application of a 1,41 multiplication factor where the ISO 6954:1984 is used for assessment against Tables 6.3.1 to 6.3.3. An approximation of maximum repetitive values may be obtained for direct comparison with the graph in ISO 6954-1984 by further application of the 1,8 conversion factor as stated in the 'Interim guidelines' note of the standard.

3.2 Passenger accommodation and public spaces

3.2.1 Passenger spaces are to comply with the overall vibration levels specified in Tables 6.3.1 and 6.3.2.

3.2.2 No more than 20 per cent of all passenger spaces/areas and public spaces should exceed the relevant vibration criteria specified in Tables 6.3.1 and 6.3.2 by more than 0,3 mm/s whether using ISO 6954:2000 or ISO 6954:1984.

3.3 Crew accommodation and work spaces

3.3.1 Crew spaces are to comply with the overall vibration levels specified in Table 6.3.3.

■ *Section 4* Testing

4.1 Measurement procedures

4.1.1 These requirements take precedence where quoted standards may differ.

4.1.2 The trial measurements may be undertaken by an approved technical organisation as defined in 4.7 or by LR. In the former case, the measurements are to be witnessed by an LR Surveyor.

4.1.3 Subject to agreement by LR and the Owner/Operator, the measurements may be undertaken by the Builder. In this case, the measurements are to be witnessed by an LR Surveyor.

4.2 Test conditions

4.2.1 Test conditions for the surveys are to be in accordance with those detailed in ISO 2923 and ISO 6954:1984 or ISO 6954:2000, as applicable.

4.2.2 The intended operating and loading conditions of the ship during assessment surveys are to be submitted to LR for agreement, prior to commencement of surveys.

4.2.3 Surveys are to be conducted when the ship is fully outfitted and all systems contributing to noise and vibration levels are operational.

4.2.4 The test conditions required for the vibration and noise measurements are to be in accordance with the following conditions:

(a) For high speed craft and yachts, prior to measurement surveys being carried out, the ship operating condition where the worst conditions are experienced between 0 and 85 per cent maximum continuous rating of the propulsion machinery is to be determined. To establish this condition, four measurement positions are to be defined with the agreement of LR and measurements taken of the parameters of interest at ship speeds corresponding to percentages of the maximum continuous rating of the propulsion machinery increasing up to 40 per cent MCR in 10 per cent intervals and from 40 per cent in 5 per cent intervals up to the 85 per cent maximum continuous rating of the propulsion machinery. If the 85 per cent maximum continuous rating condition is found to be the worst condition, then this will form the trial operating conditions. However, if a lower speed condition is found to be worse than the 85 per cent maximum continuous rating condition then both that condition and the 85 per cent maximum continuous rating condition will form the trial operating conditions. Where unavoidable, any barred range within the values required for the trial operating condition may be excluded on agreement between Owner and Builder subject to approval by LR.

(b) The power absorbed by the propeller(s) is to be that defined in 4.2.4(a). Alternatively, by special agreement, some lesser power could be accepted if it can be demonstrated by the Owner that this would correspond to a more representative normal service condition.

(c) Auxiliary machinery essential for the ship's operating conditions together with HVAC systems are to be running at their normal rated capacity during the noise and vibration trials. Combinations of auxiliary machinery operation may be necessary. In addition, the following equipment is to be running if appropriate: stabilisers, waste treatment equipment, swimming pool and jacuzzi equipment.

(d) For sea-going ships, measurements are to be taken with the ship proceeding ahead, at a constant speed and course, in a depth of water not less than five times the draught of the ship. For other ships, an appropriate water depth is to be agreed with LR prior to the trials.

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(e) Trials are to be conducted in sea conditions not greater than sea state 3 on the WMO sea state code. In addition, noise measurements should not be taken when the wind force exceeds 4 on the Beaufort scale.
(f) The ship is to be at a displacement and trim representative of an operating condition.
(g) Rudder angle variations are to be limited to ±2° of the midship position and rudder movements are to be kept to a minimum throughout the measurement periods.
(h) In addition, for ships which are designed to spend a considerable period of time in harbour, the noise and vibration, are to be measured for this condition, with the auxiliary machinery and HVAC systems running at their normal rated capacity.
(j) For passenger ships, intermittently run equipment such as transverse propulsion units are to be operated at 60 per cent of their rated power for additional measurements in surrounding ship areas.

4.2.5 Prior to survey, a test programme is to be submitted for approval by LR. This programme is to contain details of the following:
(a) Measurement locations indicated on a general arrangement of the ship.
(b) The ship's loading condition during survey.
(c) The machinery operating condition, including HVAC system, during survey.
(d) Noise and vibration measuring equipment.

4.3 Noise measurements

4.3.1 Noise measurements are to be conducted in accordance with ISO 2923 and IMO Resolution A.468(XII). Measurements of noise levels are to be carried out using precision grade sound level meters conforming to IEC 60651, Type 1 or 2. Subject to demonstration, equivalent Standards are acceptable.

4.3.2 Where the measured noise level exceeds the relevant criterion by 3 dB(A), or contains subjectively annoying low frequency noise or obvious tonal components, octave band readings are to be taken, with centre frequencies from 31,5 Hz to 8 kHz.

4.3.3 When outfitting is complete, and all soft furnishings are in place, sound insulation indices for passenger spaces are to be determined in accordance with ISO 140. Cabin to cabin indices are to be determined from a minimum of three locations within the passenger accommodation, the number of test locations being agreed with LR.

4.3.4 If required, impact sound measurements are to be carried out in accordance with ISO 140/7 and presented in accordance with ISO 717/2. *See* 4.4.4.

4.4 Noise measurement locations

4.4.1 Measurement locations are to be chosen so that the assessment represents the overall noise environment on board the ship. In addition to the requirements of IMO Resolution A.468(XII) for crew spaces, all public spaces and all passenger spaces are to be measured.

4.4.2 During measurement trials, recognised noise sources are to be operated at their normal level of noise output (e.g. machinery at design rating).

4.4.3 In larger sized spaces, where noise levels may vary considerably, such as restaurants, lounges, atria and open deck recreation areas, measurements are to be taken at locations not greater than 7 m apart.

4.4.4 For high speed craft having large passenger saloons, measurements are to be taken along the centreline and along both sides of the saloons at locations not greater than 7 m apart.

4.4.5 The number of and locations for impact noise measurements are to be agreed between the Builder, Owner and LR. The measurements are to be carried out when the ship is in harbour. The number and location of measurements are to take account of all different combinations of construction, areas of application, types of cabin and spaces below.

4.5 Vibration measurements

4.5.1 Vibration measurements are to be conducted in accordance with ISO 6954:1984 or ISO 6954:2000.

4.5.2 Measurements are to be made with instrumentation meeting the requirements of ISO 8041.

4.5.3 Vibration levels are to be given in terms of the velocity measurement appropriate to the version of the standard being used and should be measured over a period of not less than one minute.

4.6 Vibration measurement locations

4.6.1 Measurement locations are to be chosen so that the assessment represents the overall vibration environment onboard the ship. To minimise survey times, readings may be taken at the locations previously defined for the noise assessment part of the survey.

4.6.2 In cabins, vibration readings are to be taken in the centre of the floor area. The measurements are to indicate the vibration of the deck structure. In large spaces, such as restaurants, sufficient measurements are required to define the vibration profile.

4.6.3 Where deck coverings make transducer attachment impracticable, use of a small steel plate having a mass of at least 1 kg, with spikes as appropriate, is permissible.

4.6.4 At all locations, vibrations in the vertical direction are to be assessed. Sufficient measurements in the athwartships and fore and aft directions are to be taken to define global deck vibrations.

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4.7 Approved technical organisation

4.7.1 An approved technical organisation for the purposes of these Rules is one that is acceptable to the Owner and LR with proven capability in noise and vibration measurement and satisfies all the criteria set out below:

(a) Have instrumentation whose calibration, both before and after the measurements, can be traced back to National Standards and, hence, back to International Standards.

(b) Have analysis procedures capable of data reduction to the requirements and standards set out in these Rules.

(c) Be able to provide a written report in English with contents as defined by Section 5.

■ *Section 5* Noise and vibration survey reporting

5.1 General

5.1.1 Prior to survey, a noise and vibration measurement plan is to be agreed by the Owner, Builder and LR.

5.1.2 The survey report is to comprise the data and analysis for both noise and vibration and is to be submitted to LR for consideration.

5.1.3 The survey report is to be prepared by the organisation undertaking the trial measurements, which may be an approved technical organisation or LR.

5.1.4 The survey report is to be submitted to LR's London Office for evaluation and confirmation that the results are in accordance with the noise and vibration levels specified in these Rules and/or agreed between the Owner and Builder. The assignment of a Class Notation or the issue of a Statement of Compliance will be subject to confirmation by LR.

5.2 Noise

5.2.1 The reporting of results is to comply with ISO 2923, and is to include:

(a) Measurement locations indicated on a general arrangement plan including, where possible, the measured dB(A) level.

(b) Tabulated dB(A) noise levels, together with octave band analysis for positions where the level exceeds the specified criterion by 3 dB(A), or where subjectively annoying low frequency or tonal components were present. The Noise Rating number is also to be given where octave band analyses have been conducted.

(c) Ship and machinery details.

(d) Trial details:
- Loading condition.
- Machinery operating condition.
- Speed.
- Average water depth under keel.
- Weather conditions.
- Sea state.

(e) Details of measuring and analysis equipment (e.g. manufacturer, type and serial numbers), including frequency analysis parameters (e.g. resolution, averaging time, window function).

(f) Copies of the relevant instrument calibration certificates, together with the results of field calibration checks.

5.3 Vibration

5.3.1 The report is to contain the following information:

(a) Measurement positions indicated on a general arrangement plan.

(b) Where ISO 6964:2000 is used, the frequency-weighted overall r.m.s. vibration levels tabulated for all measurement locations calculated using the weighting functions and methodology stated in the standard.

(c) Where ISO 6954:1984 is used, the maximum peak vibration levels and their corresponding frequencies taken from the frequency spectra, tabulated for all measurement locations.

(d) Ship and machinery details.

(e) Trial details:
- Loading condition.
- Machinery operating condition.
- Speed.
- Average water depth under keel.
- Weather conditions.
- Sea state.

(f) Frequency analysis parameters (e.g. resolution, averaging time and window function), if the analysis is done in the frequency domain.

(g) Copies of the relevant instrument calibration certificates, together with the results of field calibration checks.

■ *Section 6* Non periodical survey requirements

6.1 Class notation assignment

6.1.1 Where the assignment of a Class Notation or a Statement of Compliance is requested, an Initial Survey is to comprise sea trial or initial in-service testing, reporting and assessment against the criteria set out in these Rules.

6.1.2 The sea trial or initial in-service testing requirements are set out in Section 4, and are to be reported in accordance with Section 5 and evaluated against the requirements of Sections 2 and 3.

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6.2 Maintenance of class notation through-life and following modifications

6.2.1 Where an Owner has requested assignment of a Class Notation, arrangements are to be agreed between LR and the Owner to record observations/ complaints of excessive noise and vibration that have been such as to disturb the comfort of passengers and crew. The records of the observations are to be made available to the attending LR Surveyor at each Annual Survey.

6.2.2 Where the observations indicate that the noise and/or vibration levels may exceed the criteria relating to the Class Notation requirements and those measured at the Initial Survey, a measurement programme is to be agreed between the Owner and LR and measurements taken in accordance with these Rules.

6.2.3 A Renewal Survey may be required following modifications, alterations or repairs including replacement of major machinery items. It is the responsibility of the Owner to advise LR of such modifications.

■ *Section 7* Referenced standards

7.1 Noise

7.1.1 The following National and International Standards for noise are referred to in these Rules:

- ISO 2923, *Acoustics – Measurement of noise on board vessels.*
- ISO 717/1, *Acoustics – Rating of sound insulation in buildings and of building elements; Part 1: Airborne sound insulation.*
- ISO 717/2, *Acoustics – Rating of sound insulation in buildings and of building elements: Part 2: Impact sound insulation.*
- IMO Resolution A.468(XII), *Code on noise levels on board ships.*
- *IEC Publication 651, Sound level meters.*
- ISO 140/4, *Acoustics – Measurement of sound insulation in buildings and of building elements; Part 4: Field measurements of airborne sound insulation between rooms.*
- ISO 140/7, *Acoustics – Measurement of sound insulation in buildings and of building elements; Part 7: Field measurements of impact sound insulation of floors.*

7.2 Vibration

7.2.1 The following National and International Standards for vibration are referred to in these Rules:

- ISO 6954:1984, *Mechanical vibration and shock – Guidelines for the overall evaluation of vibration in merchant ships.*
- ISO 6954:2000, *Mechanical vibration and shock – Guidelines for the measurement, reporting and evaluation of vibration with regard to habitability on passenger and merchant ships.*
- ISO 8041, *Human response to vibration. Measuring instrumentation.*

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Rules and Regulations for the Classification of Special Service Craft

Volume 3
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Section

1 **Introduction**

2 **International Rating Class (IRC) Yachts**

■ *Section 1* Introduction

1.1 General

1.1.1 This Part of the Rules contains the particular requirements for the construction and classification of yachts with an overall length, L_{OA} (as defined in Pt 3, Ch 1,6.2.4), of 24 m or greater, where these differ from the general Rule requirements indicated in Parts 1 to 17.

1.1.2 The regulations for the construction, classification and Periodical Survey of yachts are given in Part 1.

1.1.3 The minimum requirements in respect of intact stability for yachts are indicated in Pt 1, Ch 2,1.1.

1.1.4 Where a Load Line is to be assigned the yacht is to comply with the appropriate requirements of the National Authority or, in the absence of these, in accordance with the requirements of Chapter 2 and Pt 1, Ch 2,1.1.

1.1.5 The requirements for fire protection detection and extinction are to be in accordance with Part 17.

1.1.6 Yachts over 24 m overall length, L_{OA} (as defined in Pt 3, Ch 1,6.2.4), may be the subject of National or International regulations concerning construction, safety and manning and compliance with these regulations is the responsibility of the Owners and Builders. Lloyd's Register is able to advise on such matters and to issue applicable certificates where so authorised by the National Authority with which the yacht is registered.

1.1.7 A yacht may take any hull form and method of propulsion described in Parts 1 to 17 of these Rules. Other hull forms or methods of propulsion will be specially considered.

1.1.8 The scantling requirements for yachts constructed from steel, aluminium alloy and composite materials are given in Parts 6, 7 and 8 respectively. Where it is proposed to construct a yacht in wood or other material not specifically covered by the Rules, such proposals will be subject to special consideration on the basis of the Rules.

1.2 Definitions

1.2.1 **Freeboard deck** is as defined in Pt 3, Ch 1,6.3.1. When a lower continuous deck is designated as the freeboard deck, that part of the hull which extends above the freeboard deck is treated as superstructure so far as concerns the application of the conditions of assignment and the calculation of freeboard. It is from this lower continuous deck that the assigned freeboard is calculated.

1.2.2 **Virtual freeboard deck** is an imaginary continuous deck which, if fitted, would enable a freeboard, calculated in accordance with the Load Line requirements, and measured from the virtual freeboard deck, that would result in a draught not less than that corresponding to the assigned freeboard. That part of the enclosed hull which extends above the virtual freeboard deck may be treated as superstructure so far as concerns the application of the conditions of assignment provided it is not less than one standard superstructure height. (*See also* Pt 3, Ch 2,7.2).

■ *Section 2* International Rating Class (IRC) Yachts

2.1 General

2.1.1 The classification of International Rating Class Yachts will be specially considered on the basis of these Rules.

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Section

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6 **Protection of openings**

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8 **Navigation in first-year ice conditions**

■ *Section 1* General

1.1 Plans and data

1.1.1 Plans and data additional to those required by Pt 3, Ch 1,5 may be required to be submitted for appraisal, subject to the form of the yacht.

1.1.2 All plans are to be presented in a clear and unambiguous manner with sufficient details to avoid misinterpretation.

■ *Section 2* Ship side valves

2.1 General

2.1.1 Ship side valves are generally to be in accordance with Pt 15, Ch 2,3, but other materials may be considered.

2.1.2 Valves and sea chests are to be easily accessible and permanently marked. Valves not easily accessible are in addition to be fitted with remote control.

■ *Section 3* Anchor stowage

3.1 General

3.1.1 Where anchors are mounted on stemhead fittings, suitable local sheathing or protection is to be provided in areas where the anchor can make contact with the hull or deck, further precautions are to be taken to minimise hull damage in the event of a collision. The fittings are to be of substantial construction and well secured to the hull and deck.

3.1.2 Details of stemhead fittings incorporating forestay attachments are to be submitted for approval.

■ *Section 4* Bathing and watersport platforms and shell openings

4.1 General

4.1.1 Shell doors including bathing and watersport platforms, are generally to be fitted with a sill not less than 600 mm above the design waterline. All openings are to open into a watertight space with access into the yacht by watertight doors capable of being operated from both sides. The outer shell doors may be of a single or double leaf type with either hand or hand and hydraulic operated door clips to ensure watertightness when at sea. Any locking devices fitted are to 'fail safe' in the event of hydraulic failure. Provision is to be made for doors to be closed and locked by hand in the event of hydraulic failure, *see* Pt 3, Ch 4.

4.1.2 Shell openings with a sill height below, or less than 600 mm above, the design waterline are to be of equivalent structural integrity to the surrounding hull structure. Doors from this space providing internal access are to have a sill height at least 600 mm above the design waterline.

4.1.3 Drainage systems for the above shell openings are to be fitted with non-return valves.

4.1.4 Transom platforms are to be integral with the hull or be separate mechanically secured components.

4.1.5 Integral components are to have scantlings equivalent to the adjacent structure with care taken to ensure continuity of strength with no hard spots.

4.1.6 Separate mechanically secured components are to be of substantial construction and securely fastened to the main structure ensuring bolting and sealing arrangements are satisfactory with no hard spots.

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4.1.7 Recesses for passerelles, windlasses, platforms, cockpits, etc., are to be watertight and of equivalent strength to that of the surrounding hull and deck structure with care being taken to ensure continuity of strength. Electrical and hydraulic penetrations (where fitted) are to be through watertight glands. Direct overboard discharges are to be fitted to prevent any accumulation of water in the recess.

■ *Section 5* Deck safety equipment

5.1 General

5.1.1 Sailing yachts are, in general, to be fitted with a pulpit, pushpit and guard wires with hand rails inboard to assist personnel movement around the upper deck. Motor yachts are, in general, to be fitted with bulwarks and/or guard rails.

5.1.2 The size, height and position of bulwarks, pulpit, pushpit and guard rails or wires and the securing points for handrails and lifelines are to be in accordance with National or International Standards, *see also* 6.9. The scantlings and securing arrangements are to be designed to withstand the maximum load that could be exerted upon them in service, details of which are to be indicated in the relevant plans.

5.1.3 Doors fitted in bulwarks are to be of equal strength to the adjacent bulwarks and be capable of being secured closed at sea.

■ *Section 6* Protection of openings

6.1 General

6.1.1 Closing appliances for yachts are, in general, to provide weathertight integrity and safety equivalent to the requirements of Pt 3, Ch 4 taking into consideration reductions depending on the height of the lowest weatherdeck, relative to the design waterline.

6.1.2 The vertical distance between the freeboard deck and the weatherdeck may be used to reduce the Load Line requirements for closing appliances, coaming heights and openings in the hull, superstructure and deckhouses.

6.1.3 The vertical distance between the virtual freeboard deck and the weatherdeck may be used to reduce the Load Line requirements for closing appliances, coaming heights and openings in the hull, superstructure and deckhouses.

6.1.4 Where this vertical distance (as defined in 6.1.2 and 6.1.3) is at least one standard superstructure height then Load Line requirements for closing appliances, coaming heights and openings apply as if an additional tier of superstructure existed. *See also* Pt 3, Ch 2 7.2.2.

6.1.5 Where this vertical distance (defined in 6.1.2 and 6.1.3) is less than one standard superstructure height the coaming heights of doors, hatches, ventilators, air pipes, etc., may be reduced in proportion to the ratio of the actual distance and one standard superstructure height.

6.2 Hinged weathertight doors

6.2.1 Doors on the weather deck (first tier accommodation) protecting direct access to machinery spaces are to be of substantial construction in accordance with or equivalent to recognised National or International Standards. They are to be permanently attached to the casing, outward opening and gasketed weathertight with a minimum of six clips and have a coaming height of 460 mm with a minimum of 230 mm depending on the excess freeboard.

6.2.2 Doors on the weather deck to first tier accommodation or other spaces protecting access below are to be as required by 6.2.1 with a minimum of four clips. Provided access to the space(s) may be obtained from the deck above, the coaming height may be 230 mm with a minimum of 150 mm depending on the excess freeboard.

6.2.3 Where wood doors are proposed on the weather deck in lieu of doors in 6.2.2 above they are to be strongly constructed of hardwood not less than 50 mm thick, double gasketed with coamings as required by 6.2.2. For doors in exposed locations additional securing arrangements by slip bolts, clamps or equivalent are required. These doors are not to be the sole means of entry or exit from the space. Where these doors may be required to be used as a means of escape in an emergency situation, the additional securing arrangements are to be operable from both sides.

6.2.4 The use of FRP for doors on the weather deck other than to machinery spaces may be accepted, providing the doors are of substantial construction in accordance with 6.2.2.

6.2.5 Proposals to use FRP doors for access to machinery spaces are to comply with 6.2.4 in addition to Part 17, in respect of fire requirements and compliance with any National Authority requirements which may be applicable.

6.2.6 Doors in the second tier accommodation are to be as indicated in 6.2.1 with a minimum of four clips, or wood doors per 6.2.3 and have a coaming height of 100 mm with a minimum of 50 mm depending on the excess freeboard. Sliding doors with equivalent securing arrangements may be accepted.

6.3 Hatches (coamings and covers)

6.3.1 Hatches on the weather deck and deck above are to have a structural integrity of not less than the structure to which they are fitted and are to be weathertight when closed.

6.3.2 Hatches on the weather deck in the forward $0{,}25L_L$ or to machinery spaces are to be hinged on the forward side and have 460 mm coamings with a minimum of 230 mm depending on the excess freeboard.

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6.3.3 Elsewhere on the weather deck, hatches which are proposed to be open at sea and provide access to lower accommodation spaces are to have a coaming height of 230 mm with a minimum of 150 mm depending on the excess freeboard.

6.3.4 Hatches on the deck above the weather deck which are proposed to be open at sea, are to have a coaming height of 150 mm with a minimum of 50 mm depending on the excess freeboard.

6.3.5 Flush hatches that are not closed by gasketed covers and secured by close space bolts will be specially considered but should not, in general, be fitted on the weather deck. However, flush hatches fitted with double gasketed covers with drains led overboard that do not require to be opened at sea and that are in protection locations, will be considered.

6.3.6 Escape hatches are to be operable from both sides.

6.4 Ventilators and air pipes

6.4.1 Ventilators and air pipes are to have coamings complying with Pt 3, Ch 4,11 and Pt 15, Ch 2,11 respectively.

6.4.2 Where necessary for operational reasons, coamings on the weather deck protected by the bulwark, may be reduced to the bulwark height subject to a minimum coaming height of 450 mm for ventilators and 300 mm for air pipes.

6.5 Portlights and windows

6.5.1 The requirements for side scuttles and windows are indicated in Pt 3, Ch 4. Proposals to fit windows below freeboard deck will be specially considered.

6.5.2 Round, elliptical or elongated portlights are to have a structural integrity of not less than the structure to which they are fitted. If fitted below the weatherdeck they are to be provided with permanently attached deadlights. *See also* Pt 3, Ch 4,7.12.2.

6.5.3 Where internal covers are provided, they are to be gasketed and capable of being secured weathertight (with additional backing bars if necessary). Provision is to be made for the storm covers to be stored on board and their stowage location noted in the document 'For the information of the Master'. Internal storm blinds may be accepted subject to satisfactory tests being carried out.

6.5.4 Chemically toughened glass may be used in lieu of thermally toughened glass provided it can be demonstrated the strength of the arrangement is at least equivalent in strength to that of thermally toughened glass. The glazing system is to be of laminated construction and the method of testing will be specially considered.

6.5.5 Wheelhouse windows are to be of toughened safety glass, or where they are of laminated or sandwich construction, the surface layers are to be of toughened safety glass.

6.5.6 Details of the attachment of windows in their frames and of frames to the yacht structure are to be submitted for approval.

6.5.7 Storm covers or deadlights are required for all windows and portlights in the front of the deckhouse on the weather deck and also the sides, except where these are interchangeable port and starboard; in this case a sufficient number to fit any one side are to be provided. Additionally a storm cover or deadlight is to be provided for each different size of window or portlight respectively.

6.5.8 A glazing equivalent may be fitted in lieu of deadlights or stormcovers on the weather deck and above. The thicknesses and arrangements are to be acceptable to the National Authority with whom the craft is registered and/or by the Administration within whose jurisdiction the ship is intended to operate. For arrangements of glazing acceptable to Lloyd's Register (hereinafter referred to as LR), *see* Table 2.6.1. Alternative arrangements of glazing in lieu of deadlights or storm covers may be accepted provided details are submitted for consideration.

6.6 Sliding glass doors or glass walls

6.6.1 When sliding glass doors are provided, or a glass wall which includes an access, an alternative access, or exit from the space, is to be provided, and the arrangements are to be in accordance with approved plans and weathertight commensurate with their position. Coaming heights are, in general, to be in accordance with 6.2 and the use of portable coamings will be considered. Details are to be submitted.

6.6.2 The glass used in the above is to be toughened safety glass or equivalent in accordance with 6.5.

6.6.3 Storm covers of strong construction are to be provided and stored on board. Aft facing glass doors or walls in the second tier and above, are not required to be fitted with storm protection. The use of a virtual freeboard deck to determine storm cover requirements is not permitted. Additional portable supports are to be provided as necessary and full details are to be submitted for approval. Roller shutters or other alternatives will be specially considered.

6.6.4 In lieu of a weathertight coaming for the cover, adequate drainage is to be provided between the cover and the glass which may be in the form of a sump drained overboard, with a grating over, details of such proposals should be submitted for individual consideration.

6.7 Scuppers and sanitary discharges

6.7.1 Piping and valves are, in general, to comply with the requirements indicated in Pt 15, Ch 2,3.

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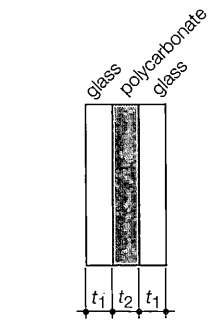
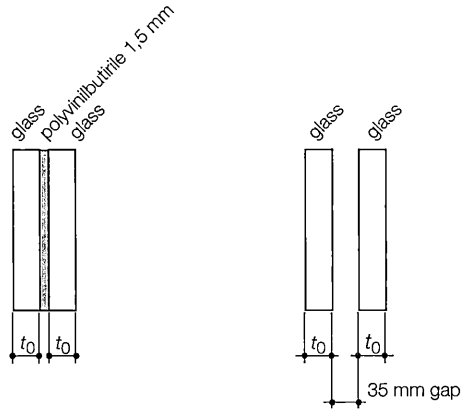
Table 2.6.1 Acceptable arrangements of glazing in lieu of portable storm covers/deadlights

In lieu of portable storm covers	In lieu of deadlights or storm covers
 $t_1^2 + (0{,}77t_2)^2 + t_1^2 = (1{,}2t_0)^2$	
Symbols	
t_0 = minimum thickness of toughened glass as calculated in Pt 3, Ch 4,7.8.1.	

6.8 Freeing ports

6.8.1 In general, freeing ports are to be in accordance with the requirements indicated in Pt 3, Ch 4, taking into consideration the position of the virtual freeboard deck indicated in 6.1.

6.9 Bulwarks, guard rails and wires

6.9.1 Bulwarks, guard rails and wires are in general, to comply with the requirements indicated in Pt 3, Ch 4,8.

6.9.2 Where a bulwark of reduced height is fitted, guard rails or wires are to be provided above the bulwark to a height of 1000 mm above the deck.

6.9.3 Where the proper working of a yacht may otherwise be impeded bulwarks, guard rails of wires of a reduced height may be considered. Details are to be submitted for approval.

6.9.4 Protection is to be provided in way of boats, liferafts, etc.

■ *Section 7* Corrosion protection

7.1 General

7.1.1 The design of the structure and methods of attachment of fittings are to take into consideration procedures to minimise corrosion of metal structures and fittings due to electro-chemical action. All exposed steel and aluminium alloy surfaces are to be protected by the application of a suitable paint and anti-fouling system and the fitting of a cathodic or impressed current protection system.

7.1.2 Sacrificial anodes are to be mounted equidistant between metals being protected, and their location and attachment is to be such as to obviate hard spots.

7.1.3 Anodes with cast-in galvanised steel straps are to be secured to the steel hull by welded studs or direct welding.

7.1.4 The design and performance characteristics of the cathodic protection system is the Builder's responsibility. Particular attention is to be given to the earth bonding system, to provide good electrical continuity.

7.1.5 Yachts fitted with a negatively grounded electrical system or fitted with a negatively grounded independent battery system may use the impressed current cathodic protection scheme.

7.2 Protection – Aluminium alloy yachts

7.2.1 Anti-fouling paints containing copper are not to be used.

7.2.2 Bilges and internal surfaces subject to salt laden air are to be coated with a waterproof mastic or equivalent.

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7.2.3 Particular attention is to be given to the design and selection of materials used for underwater fittings and the associated piping systems to limit the effect of bimetallic corrosion. Where materials other than aluminium are used they are, in general, to be electrically insulated from the hull and internal metal piping or cathodically protected separately by anodes attached directly to such fittings.

7.3 Protection – Composite yachts

7.3.1 Aluminium alloy or steel sterndrives, waterjet units and trim tabs are to be cathodically protected by anodes mounted on the hull, direct to the unit being protected or through the bonding system.

■ *Section 8*
Navigation in first-year ice conditions

8.1 General

8.1.1 Where additional strengthening is fitted in accordance with the requirements of Pt 6, Ch 5,7, Pt 7, Ch 5,7 and Pt 8, Ch 5,6 an appropriate special features notation will be assigned. It is the responsibility of the Owner to determine which notation is most suitable for their requirements.

8.1.2 When yachts may be expected to visit areas requiring them to navigate in light first year ice conditions other than the Northern Baltic corresponding to unbroken level ice of thickness not greater than 0,4 m, the hull is to meet the requirements necessary for the assignment of **Ice Class 1D**.

8.1.3 Yachts in Service Group G6, which have their own propulsion machinery, and which are built of steel but are not strengthened for navigation in ice, may be eligible for assignment of Finnish-Swedish Ice-Due Class II under the Finnish and Swedish Boards of Navigation *Finnish-Swedish Ice Class Rules*. Yachts in Service Groups G1–G4 inclusive, con-structed in any material, together with Yachts in Service Group G6 constructed in aluminium or composites are not eligible for this notation.

8.1.4 For Yachts requiring to navigate in areas of ice in excess of that specified in 8.1.2, the standard of construction is to comply with the requirements of Part 8 of the *Rules and Regulations for the Classification of Ships* as appropriate.

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Section

1 **Hull design and construction parameters**

2 **Hull construction**

3 **Chain plates**

4 **Deck planking**

5 **Deck fittings**

6 **Ballast keels**

7 **Rudder skegs and rudders**

8 **Open cockpits and companionways**

9 **Anchoring and mooring equipment**

■ *Section 1* Hull design and construction parameters

1.1 Plans and data

1.1.1 In addition to the general plans and data required by Pt 3, Ch 1,5 the following details of additional structural components, particular to sailing yachts, are to be submitted for appraisal:

- Sail plan.
- Mast loadings.
- Bowsprit loadings.
- Rigging loadings.
- Mast step.
- Mast partners.
- Ballast keel lines plan.
- Ballast keel securing arrangements.
- Rudder skeg construction and support details.
- Chainplates.
- Through deck fittings.

1.1.2 All plans are to be presented in a clear and unambiguous manner with sufficient details to avoid misinterpretation.

1.2 Mast and rigging support arrangements

1.2.1 Sailing yacht mast and standing rigging loadings and their support structure require special consideration as follows:

(a) Adequate hull and deck longitudinal structure to resist hull bending.

(b) Provision of adequate transverse structure in way of masts, chainplates, keels, skegs, etc.

(c) Provision of adequate bottom structure to support the mast and dissipate the mast loadings.

(d) Local reinforcement in way of chainplates, forestay and backstay fittings, etc.

(e) The deck and beams are to be suitably strengthened in way of masts, coachroof/deckhouse ends, windlass, cleats, sheet winches, sheet tracks, etc. Where a mast is stepped on the deck or coachroof/deckhouse the structural arrangements will be specially considered.

1.2.2 Details of the designer's/Builder's calculated maximum loads on the mast heel and the breaking loads of all standing rigging are to be submitted with the main structural plans for appraisal.

1.3 Bowsprits

1.3.1 The hull structure in way of the bowsprit is to be suitably reinforced with due account taken of the compressive loads along the bowsprit and bending moments due to rigging loads.

1.3.2 Details of the designer's/Builder's calculated maximum loads on the bowsprit and the breaking loads of all associated standing rigging are to be submitted with the structural plans for appraisal.

■ *Section 2* Hull construction

2.1 Hull scantlings (composite materials)

2.1.1 The basic structural scantlings are, unless specified within this Section, to be as indicated in Part 8.

2.1.2 The shell weight/thickness determined from Part 8, is to be maintained throughout the length of the craft, with the bottom shell weight extending to the chine line or 150 mm above the static load waterline, whichever is the greater.

2.1.3 The keel plate thickness for sailing yachts is to be 1,1 times the keel thickness for motor craft as determined in Part 8. In no case is the thickness of keel to be taken less than the thickness of the adjacent bottom shell or fin and tuck as appropriate.

2.1.4 The fin and tuck thickness is not to be less than 0,9 times the keel thickness for motor craft as determined in Part 8. In no case is the thickness of the fin and tuck to be taken less than the thickness of the adjacent bottom shell.

2.1.5 The construction of hull to deck connections is to be in accordance with Pt 8, Ch 2,5.

2.1.6 The hull laminate is to be strengthened in way of the attachment of chainplates, etc., *see* Pt 8, Ch 2,5.

2.1.7 The stern or transom is to be the same weight as the side shell and is to be adequately stiffened with special consideration being given to the transmission of backstay loadings.

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2.1.8 Where twin bilge keels are fitted, the bottom laminate in way of the bilge keels is to be formed by extending the keel reinforcement to a distance not less than 25 per cent the width of the keel, as required by Part 8, outside the line of the outboard edge of the bilge keels or to the supporting structure whichever is the greater, prior to being tapered in accordance with the Rules to the adjacent bottom shell laminate. *See also* 2.1.10.

2.1.9 The hull and deck are to be locally increased in thickness in way of fittings for rudder tubes, propeller brackets etc. The increase is not to be less than 50 per cent of the adjacent plate laminate. Details of such reinforced areas are to be submitted for consideration.

2.1.10 Local reinforcement is, in general, to extend under the adjacent supporting structure and then be tapered gradually to the base laminate thickness in accordance with Pt 8, Ch 3,3.14.

2.2 Transversely framed yachts

2.2.1 Sailing yachts with a conventional rig, are to be provided with suitably increased scantlings in floors, frames, beams and brackets adjacent to each mast.

2.2.2 In general, beams at the heads of web frames and four beams in way of each mast in sailing and auxiliary yachts are to have their scantlings increased by a factor of two. Where practicable, masts are to be located in way of transverse bulkheads or other primary stiffening.

2.2.3 Keel mounted masts are to be mounted on a suitable mast step secured to three floors at a height sufficient to provide the necessary structural integrity and to keep the heel of the mast clear of any bilge water.

2.2.4 Keel mounted masts are to be fitted with mast partners running fore and aft on either side of the mast to join the transverse beams. The strength of the mast partners are to be the same as for the beams.

2.2.5 Deck mounted masts are to be housed in a mast step positioned directly over a bulkhead or a web frame/deep beams with a pillar fitted under the mast.

2.3 Longitudinally framed yachts

2.3.1 Conventional masts mounted on mast steps as in 2.2.3 are to be fitted with heavy transverse web frames as required by 2.2.2.

2.4 Yachts fitted with non-conventional rigs

2.4.1 The structure in way of non-conventional mast configurations will be specially considered.

■ *Section 3* Chain plates

3.1 General

3.1.1 Chain plates and other securing arrangements to take the loads of all standing rigging for masts and bowsprits, are to be of substantial construction and well integrated with the hull and/or deck supporting structure. They are to be of sufficient strength that, in the event of failure of the standing rigging, the watertight integrity of the hull is not impaired.

3.1.2 The breaking loads of all mast and bowsprit standing rigging together with the actual loads imposed by the rigging are to be submitted.

3.2 Calculations

3.2.1 The strength of any part of chainplates or structure to which it is attached is not to be less than the breaking load of the rigging to which it is attached and subject to the following factors of safety (FOS).

Items:	Minimum FOS:
Rigging	1,0
Lug, eyebolt eye	1,2
Lug to baseplate	1,2
Eyebolt/base plate to foundation	2,0
Chainplate to foundation (below decks)	2,0
Chainplate foundation to hull structure	2,0

■ *Section 4* Deck planking

4.1 General

4.1.1 The construction of decks of steel, aluminium alloy or composite materials is to be in accordance with Pt 6, Ch 3,8, Pt 7, Ch 3,8 and Pt 8, Ch 3,8 respectively. Wood deck sheathing is in general to be treated as cosmetic and is outside the scope of these Rules. However, any wood sheathing fitted is not to be detrimental to the integrity of the main deck structure. Details of the means of attachment of such wood sheathing are to be submitted for consideration.

4.1.2 Decks constructed of wood will be specially considered on the basis of the Rules.

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Section 5
Deck fittings

5.1 General

5.1.1 Due consideration is to be given at the design stage to ensure that additional structural support, by way of pads, brackets etc., is provided in way of deck fittings such as mainsheet and genoa tracks, winches, eyebolts, sail-lead tracks, fairleads, anchor and chain cable handling and securing arrangements, grab rails, guard wires, hatch hinges, etc., which are subject to substantial loadings and or use.

5.1.2 Fittings which are subject to significant loads are, in general, to be through bolted, in single skin areas. The laminate is to be locally increased in thickness as necessary with due account taken of such loadings.

5.1.3 Details of inserts, local reinforcement and through bolting arrangements for yachts of composite construction are to be in accordance with Pt 8, Ch 2.

Section 6
Ballast keels

6.1 External ballast keel

6.1.1 The ballast keel may be of lead, cast iron or other suitable material. Cast iron or other ferrous metals are not to be used in wood or composite craft sheathed with copper or other non ferrous metal.

6.1.2 Prior to installation the ballast keel is to be 'Dry fitted' to the hull and the top is to be smooth, or slightly concave in all directions, and well coated with a suitable bedding compound.

6.1.3 In composite yachts care is to be taken to prevent crushing of GRP laminates through overtightening of keel bolts.

6.1.4 A substantial plate washer is to be fitted under the head of the keel bolt. The diameter and thickness are to be not less than 4,0 and 0,25 times the bolt diameter, respectively, but the thickness need not in general exceed 8 mm. The top of the bolt is to have sufficient thread to take double nuts or other suitable locking arrangement. *See also* 6.3.6.

6.1.5 The structure in way of the ballast keel is to be in accordance with the requirements of Parts 6, 7 and 8 for the respective material.

6.1.6 In steel/aluminium alloy yachts all bottom structure in way of the ballast keel(s) is to be welded by means of double continuous welding.

6.1.7 Ballast keels are to be fully supported by floors to distribute the keel loadings to the bottom structure, *see* Pt 8, Ch 3. The scantlings of the floors and frames will be specially considered in conjunction with the keel mass together with the size, material and position of the keel bolts.

6.1.8 Canards and lifting keels are outside the scope of the Rules but the structure in way will be specially considered with regard to maintenance of structural and watertight integrity. Full details are to be submitted for appraisal.

6.2 Internal ballast keel

6.2.1 Where ballast is to be incorporated in the keel, the internal surface is to be suitably coated prior to filling, and on completion the top surface is to be sealed.

6.2.2 For steel and aluminium alloy yachts the method of installing the internal ballast is not to be detrimental to the plating or internal structure. Details of the installation procedure are to be submitted for consideration prior to implementation.

6.2.3 Internal ballast is to be suitably supported and secured against movement. The supporting structure in way of internal ballast is to be suitably increased in strength.

6.2.4 In steel/aluminium yachts, the ballast is to be totally encapsulated by fully welded plating with a minimum thickness of 6 mm. Alternative arrangements will be specially considered.

6.2.5 In composite yachts, the internal ballast is to be encapsulated by a laminate equivalent in thickness to half the rule bottom shell laminate or 2400 g/m^2 CSM (or equivalent), whichever is the greater.

6.3 Keel bolts

6.3.1 The keel bolts are to be of a corrosion resistant material. The nuts, washers, etc., are to be of a material the same as, or compatible with, that of the keel bolts. The specifications of these materials are to be submitted for appraisal.

6.3.2 The diameter of keel bolts, d_k, is to be that determined from the following formula, or 14 mm, whichever is the greater:

$$d_k = 14{,}2\sqrt{\frac{w\, d_{cg}}{\sigma_u\, b_k}} \text{ mm}$$

where

b_k = breadth of top of ballast keel in way of bolt, in mm

d_{cg} = vertical distance of the centre of gravity of weight, w, below top of ballast keel, in mm

w = the portion of the weight of ballast keel supported by the bolt, in kg

σ_u = ultimate tensile strength of the bolt material, in N/mm^2

When determining w for the bolt at the ends of the keel, the weight of any overhang is to be included.

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6.3.3 Where double bolts are to be fitted, the total cross-sectional area of the bolts is to be not less than 1,2 times the cross-sectional area of the bolt determined in accordance with 6.3.2.

6.3.4 Keel bolts are to be fitted alternately on opposite sides of the middle line, and as close as is practicable to the bottom floor structure.

6.3.5 The ballast keel is to be secured by through bolting, but where this is not practicable, short keel bolts or studs may be fitted.

6.3.6 A substantial plate washer is to be fitted under the head of the keel bolt. The diameter and thickness are to be not less than 4,0 and 0,25 times the bolt diameter, respectively, but the thickness need not exceed 8 mm. Washer plates, where square or rectangular, are to have suitably radiused corners. In composite and wood craft the washer plates are to have all edges dressed smooth in addition to being suitably radiused.

6.3.7 The bottoms of short keel bolts are to be secured by nuts and washers fitted in pockets in the keel, or by square plate nuts cast in with the keel. Where cast in, the square plate nuts are to have a breadth and depth not less than 3,0 and 1,0 times the bolt diameter, respectively.

6.3.8 Where studs are fitted, the length of the threaded portion into the cast iron or steel keel is to be not less than 1,5 or 2,5 times the stud diameter where through tapped or blind tapped respectively.

6.3.9 It is recommended that the design of the keel bolt is such that it can be withdrawn for survey and is not cast permanently into the ballast keel.

6.3.10 Details of the proposed torque to be applied to the keel bolts is to be indicated on the relevant plans and submitted.

■ *Section 7*
Rudder skegs and rudders

7.1 Skegs

7.1.1 Skegs are to be effectively integrated into the adjacent structure and their design is to be such as to facilitate this.

7.1.2 The scantlings of skegs are to be sufficient to withstand any docking forces that they may be subjected to.

7.1.3 The thickness of the skeg plating is in no case to be taken as less than 1,5 times the thickness of the adjacent bottom shell or the fin and tuck laminate whichever is the greater.

7.1.4 Where metallic sub-frames are laminated into skegs, providing transverse stiffening to the skeg and support for the rudder pintle, such stiffening members are to be fully integrated with hull framing to ensure continuity of strength.

7.1.5 The scantlings of skegs of composite construction will be specially considered on the basis of the Rules, and in this respect are to be of equivalent strength and load carrying capability to that required for skegs of steel construction from Pt 3, Ch 3,3. Due account is to be taken of the differing material properties.

7.1.6 Direct calculations may be used as an alternative to the requirements of 7.1.5 to determine the scantlings of composite skegs. Such calculations are to be submitted for appraisal.

7.2 Rudder construction arrangements

7.2.1 Rudder construction for sailing yachts is generally to be in accordance with Pt 3, Ch 3.2.

7.2.2 For use in the determination of the rudder stock diameter, within Table 3.2.7 in Pt 3, Ch 3, the factor f_c may be taken as 70 for yachts with an overall length, L_{OA}, of 24 m varying up to 79 at a length of 50 m. Intermediate values are to be determined by linear interpolation. Yachts with a length, L_R, in excess of 50 m are to comply with Table 3.2.7.

7.2.3 The rudder stock diameter is to be based upon the maximum stated operational speed of the yacht, but in no case is this to be taken less than $2{,}536\sqrt{L_{WL}}$ knots. L_{WL} is as defined in Pt 3, Ch 1,6.2.5.

■ *Section 8*
Open cockpits and companionways

8.1 Cockpit construction

8.1.1 Cockpits are to be of watertight construction with scantlings equivalent to that of the upper deck.

8.1.2 Cockpit lockers and hatches where fitted, are to be of substantial construction and are to be tested weathertight.

8.1.3 Where engine removal or other hatches are fitted in the cockpit sole they are to be watertight and bolted down. Detailed plans are to be submitted for approval.

8.1.4 The height of the cockpit sole above the waterline is to be such that the water will effectively drain overboard under all normal conditions of heel and trim.

8.2 Companionways

8.2.1 Companionway openings, are to be sited on, or as close as possible to, the centreline. Sill heights are to be not less than as required by Pt 3, Ch 4.

8.2.2 Companionway hatches are to be of substantial construction capable of being opened from both sides and be tested weathertight.

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Section 9
Anchoring and mooring equipment

9.1 General

9.1.1 The requirements of Pt 3, Ch 5 apply to fore and aft rigged sailing yachts of all sizes.

9.1.2 Sailing yachts with three or more masts and fitted with a square rig are to be fitted with anchors 25 per cent heavier than those calculated in accordance with Pt 3, Ch 5. Chain cable, hawsers and warps are to be increased accordingly.

9.1.3 Square rigged yachts are to have a full length of chain cable on the main anchor but may have rope with a chain tail fitted to the second anchor. Kedge anchors may be fitted using the rule length and size of warp without a chain tail.

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Rules and Regulations for the Classification of Special Service Craft

Volume 3
Part 5
Design and Load Criteria
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Lloyd's Register
LIFE MATTERS

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Section

1 **Rule application**

2 **Direct calculations**

3 **Model experiments**

■ *Section 1* Rule application

1.1 General

1.1.1 The global and local load and design criteria detailed in this Part are to be used in conjunction with the formulae given in Parts 6, 7 and 8 to determine the scantlings of steel, aluminium alloy and composite craft respectively as defined in Part 1.

1.1.2 The global load and design criteria given in this Part are provided to enable the designer/Builder to check global hull strength against ductile failure modes involving gross deformation. The strength calculations are, in general, to be conducted using finite element analysis techniques with a three dimensional model.

1.1.3 Load and design criteria detailed in this Part are to be supplemented by direct calculation methods incorporating model test results and numerical analysis for novel designs. Full scale measurements may be required where considered necessary by Lloyd's Register (hereinafter referred to as LR).

1.1.4 Craft built and classed in accordance with the Rules will, in general, be assigned an operational envelope. This will be based on the allowable speeds, significant wave heights and corresponding displacements. It will form an appendix to the Classification Certificate and is to be incorporated in the craft's Operational Manual. The assigned operational envelope is to be clearly displayed in the wheelhouse. Installation of an accelerometer at LCG connected via a visual display in the wheelhouse may be required.

1.1.5 The operational envelope assigned is based on the assumption that the wave height can be visually observed. Where this is not the case, the speed of the craft is to be suitably reduced.

1.1.6 The design assessment is to include a range of speeds covering all modes of operation for which the craft is designed, i.e. speeds corresponding to displacement, semi planing and fully planing. A craft which is designed to operate in the planing mode will need to be assessed using the requirements of Chapter 3 at its design speed and required significant wave height, as well as the requirements of Chapter 4 when operating at reduced speed and a more severe wave height.

1.1.7 The load design criteria given in this Part are dependent on the operating mode of the craft as follows:

- Craft operating in the **non-displacement** mode:
  - Applies to craft operating in full planing or semi-planing modes.
  - Applies to HSC at design speed. HSC is defined in Pt 1, Ch 2,2.2.8.
  - Applies to LDC at design speed. LDC is defined in Pt 1, Ch 2,2.2.10.
  - Applies to craft in foil borne mode.
  - Applies to craft where other lifting devices are actively supporting some or all of the craft's weight.
  - Typically this applies to craft with a Taylor Quotient, Γ, greater than 3. Γ is defined in Ch 2,2.1.18. However, the following is to be noted:
    - Some craft are not designed to plane, but have Γ greater than 3, e.g. SWATHs and fast displacement yachts and, unless they are classified as HSC, then these craft are to be considered as only operating in the displacement mode.
    - Some craft are designed to plane with Γ less than 3 and these should be considered as operating in the non-displacement mode.
- Craft operating in the **displacement** mode:
  - Applies to craft designed to operate in the displacement mode.
  - Applies to all other craft where they are not operating in the non-displacement mode, e.g. at lower speed in severe weather.

■ *Section 2* Direct calculations

2.1 General

2.1.1 Direct calculations using hydrodynamic computer programs may be specifically required by the Rules. Also they may be required for craft having novel design features, or may be submitted in support of alternative load and design criteria. LR may, when requested, undertake calculations on behalf of designers and make recommendations in regard to suitability of any required model tests.

2.2 Special Service Craft Software

2.2.1 LR's direct calculation procedures and facilities are summarised in a publication entitled the LR *Software Guide*.

2.3 Submission of direct calculations

2.3.1 In cases where direct calculations have been carried out using procedures available in the LR *Software Guide* the following supporting information is to be submitted as applicable:

(a) Reference to the direct calculation procedure and technical program used.
(b) Input data.
(c) A description of the model.

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(d) A summary of analysis parameters including environmental conditions, speeds and headings.
(e) Details of the weight distributions.
(f) A comprehensive summary of calculation results. Sample calculations are to be submitted where appropriate.

2.3.2 In general, all input data and output results are required to be submitted. In such cases, magnetic media with agreed format may be used for submission.

2.3.3 The responsibility for error free specification and input of program data and the subsequent correct transposal of output rests with the designer/Builder.

■ *Section 3* Model experiments

3.1 General

3.1.1 Model experiments and theoretical calculations may be required to be carried out for new design concepts and the results are to be provided when plans are submitted for approval.

3.1.2 Where model testing is undertaken, the following details are to be submitted:
(a) A summary of the model construction and its instrumentation, including calibration of instruments.
(b) A summary of the testing arrangements and procedures.
(c) A summary of the tank facilities and test equipment.
(d) Details of the wave generation, response measurements, definitions and notations.
(e) Details of data recording, reduction and data analysis procedures.
(f) Details of calibration procedures with theoretical computations.
(g) Tabulated and plotted output.

3.2 Model test matrix

3.2.1 Where model testing is undertaken, the minimum test matrix shown in Table 1.3.1 is required to be carried out.

Table 1.3.1 Minimum test matrix

Item	Test matrix
Sea state	Regular and irregular seas
Heading	Beam, head, stern and quartering seas
Speed	Three speeds including zero and maximum service speeds
Wave frequency	Six frequencies

3.2.2 In addition to those quantities which are normally measured in a model experiment, the following data are to be obtained where practicable:
(a) Vertical accelerations at the LCG, bow and stern.
(b) Acceleration loads due to heave and pitch.
(c) Vertical bending moment.
(d) Bow impact pressures at full forward speed.
(e) Oblique sea loads inducing dynamic torque on the cross structure for multi-hull craft.
(f) Splitting loads due to beam seas and roll motion for multi-hull craft.
(g) Impact pressures in tunnel side and top for multi-hull craft.

3.2.3 The basis on which the parameters are chosen for investigation is to be submitted for approval.

3.2.4 Results from open water model experiments and full scale measurements may be accepted and full details are to be submitted for appraisal.

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Section

1 **Environmental conditions**

2 **Definitions and symbols**

3 **Motion response**

4 **Loads on shell envelope**

5 **Impact loads**

6 **Cross-deck structure for multi-hull craft**

7 **Component design loads**

■ *Section 1* Environmental conditions

1.1 General

1.1.1 This Chapter contains information regarding the derivation of load criteria which are to be used for the computation of local design criteria in Chapters 3 and 4.

1.1.2 Environmental conditions include natural phenomena such as wind, wave and currents from which design data are to be derived.

1.1.3 These environmental conditions are usually described by physical variables of statistical nature.

1.1.4 The load criteria used for design are to be based on environmental data for the specific area and operation of the craft.

1.1.5 The loads imposed by the environment are to be based on extreme conditions. These arise as the craft advances in a seaway and is loaded and stressed in a random manner by dynamic forces and moments.

1.1.6 The load criteria given here are derived from experimental and theoretical studies complemented with service experience.

1.1.7 Alternative methods of establishing the load criteria will be specially considered, provided that they are based on model tests, full scale measurements or generally accepted theories. In such cases, full details of the methods used are to be provided when plans are submitted for approval.

■ *Section 2* Definitions and symbols

2.1 Parameters to be used for the determination of load and design criteria

2.1.1 **Air gap.** The air gap, G_A, is the minimum vertical distance, in metres, from the static waterline to the point considered in an operational condition. In no case is G_A to be taken greater then $G_{A(max)}$ as indicated in Fig. 2.2.1.

2.1.2 **Allowable speed *V*.** The allowable speed used in the computation of environmental loads is the design speed, in knots, associated with a nominated operational environment in which the craft is certified at corresponding operational displacement.

2.1.3 **Beaufort Number.** Beaufort Number is a measure of wind strength.

2.1.4 **Bilge tangential point.** For craft with partially submerged hull(s), the bilge tangential point is defined as the tangential point of the bilge with an oblique line sloped at 50° to the horizontal at the LCG, *see* Fig. 2.2.2. For craft with fully submerged hull(s), the bilge tangential point is defined as the intersection points between the hull and the design waterline.

2.1.5 **Deadrise angle.** For craft with no clearly defined deadrise angle at the LCG, the angle, in degrees, to the horizontal of the line at the LCG formed by joining the lowest point of the hull or underside of keel and the bilge tangential point is to be taken as the deadrise angle θ_D, *see* Fig. 2.2.2. For craft with hulls of asymmetric section, where the inner and outer deadrise angles differ, the smaller of the two angles is to be used. For craft with fully submerged hull with circular sections, the deadrise angle is to be taken as 30°.

2.1.6 **Displacement mode.** Displacement mode means the regime, whether at rest or in motion, where the weight of the craft is fully or predominantly supported by hydrostatic forces.

2.1.7 **Froude Number F_n.** The Froude Number is a non-dimensional speed parameter and is defined as:

$$F_n = \frac{0{,}515 V_m}{\sqrt{g\, L_{WL}}}$$

where
g is the acceleration due to gravity and is taken to be 9,81 m/s^2.
L_{WL} is defined in 2.1.19.
V_m is the appropriate speed in knots.

2.1.8 **LCG.** The LCG is the longitudinal centre of gravity of the craft in the loading condition under consideration.

2.1.9 **Maximum wave height.** In general the maximum wave height, in metres, will be taken as 1,667 times the significant wave height. Where, for design purposes, a wave length is required this will be taken as the waterline length subject to any restriction resulting from limiting height to length ratio and wave profile angle.

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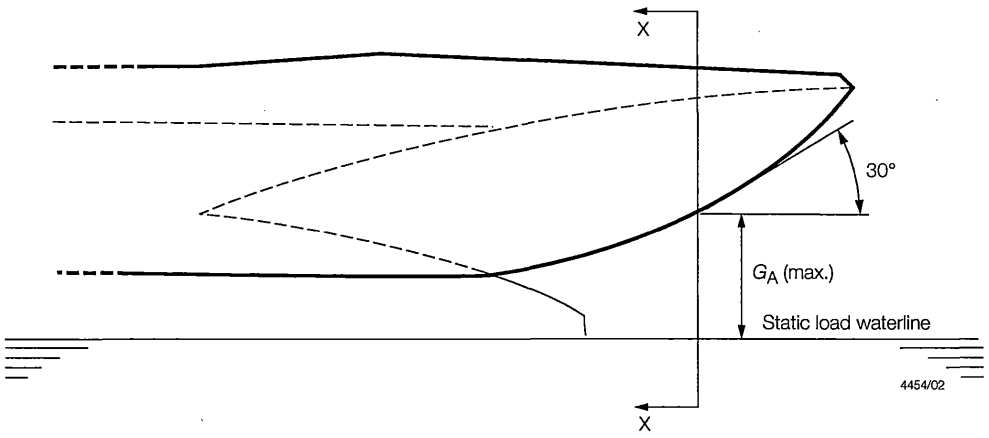
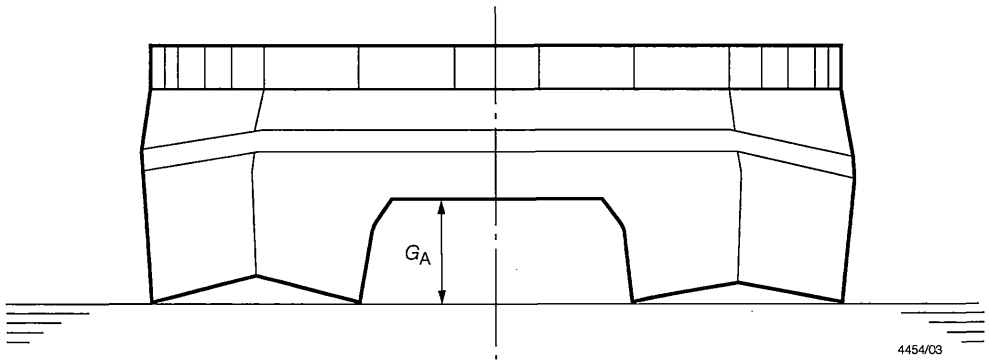
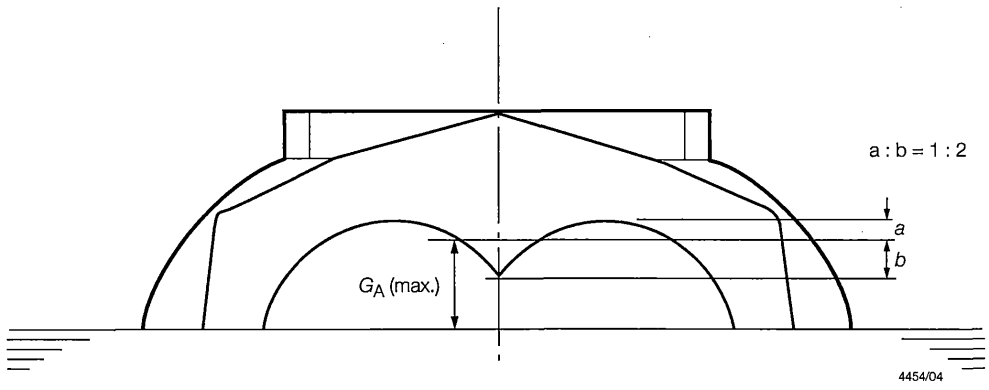


Elevation on Centreline



Section at X – X : Conventional Catamaran



Section at X – X : Wave Piercing Catamaran

Fig. 2.2.1 Definition of air gap

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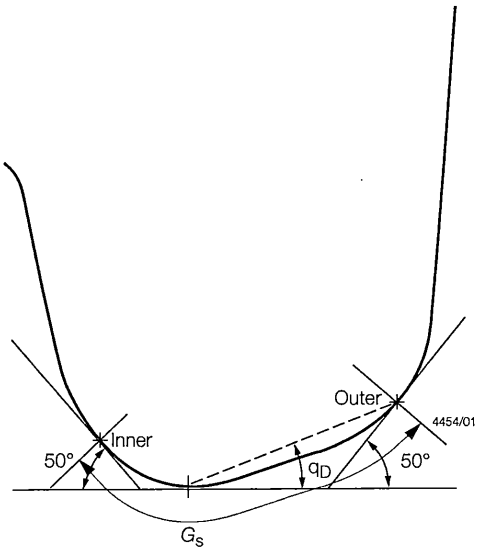

Fig. 2.2.2
Definition of bilge tangential point and G_s for craft with partially submerged hulls

2.1.10 **Non-displacement mode.** Non-displacement mode means the normal operational regime of a craft when non-hydrostatic forces substantially or predominantly support the weight of the craft.

2.1.11 **Operating waterline** is the waterline for the operating condition under consideration.

2.1.12 **Period.** The period is defined as the average time interval between upward crossings of the mean value.

2.1.13 **Sea state.** Sea state is an expression used to categorise wave conditions and is normally defined by sea spectrum, significant wave height and period distribution.

2.1.14 **Significant wave height $H_{1/3}$.** The wave height, in metres, used in the determination of craft motions and loads is a significant wave height, $H_{1/3}$, defined as the average of the one third highest waves in a short term wave measurement record.

2.1.15 **Support girth.** The support girth, G_s, is the girth distance, in metres, measured around the circumference of the shell plate between the tangential points or chines, as appropriate, of the hull for a mono-hull craft. For multi-hull craft it is to be taken between the inner and outer bilge tangential points or chines of the individual hulls. *See* 2.1.4 and Fig. 2.2.2.

2.1.16 **Surviving wave height H_{03}.** The wave height, in metres, used in the determination of the structural integrity of a craft and is defined as the wave height with three per cent probability of exceedance. If this value is unknown, the following equation is to be used to determine H_{03}:

$$H_{03} = 1{,}29H_{1/3}$$

2.1.17 **Taylor Quotient** Γ. The Taylor Quotient is defined as:

$$\Gamma = \frac{V}{\sqrt{L_{WL}}}$$

where V is defined in 2.1.2 and L_{WL} is defined in 2.1.19.

2.1.18 **Volumetric speed number F_v.** The Volumetric speed number is defined as:

$$F_v = 7{,}19\,\nabla^{1/6}$$

where ∇ is the moulded displacement, in m^3, of the craft corresponding to the design waterline.

2.1.19 **Waterline length.** Waterline length, L_{WL}, is as defined in Pt 3, Ch 1,6.2.

2.1.20 **Protected structure,** *see* Fig. 2.2.3. A protected structure is one in which the wet-deck component under consideration is enclosed by port and starboard side inboard structure, where 'side inboard' is as defined in Ch 4,1.5.6 of Parts 6, 7 and 8 for craft of steel, aluminium alloy and composite construction respectively.

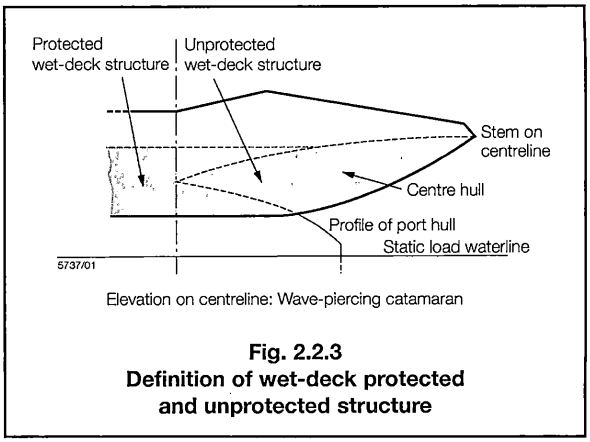

Fig. 2.2.3
Definition of wet-deck protected and unprotected structure

2.1.21 **Unprotected structure,** *see* Fig. 2.2.3. An unprotected structure is one in which the wet-deck component under consideration is not enclosed by port and starboard side inboard structure, where 'side inboard' is as defined in Ch 4,1.5.6 of Parts 6, 7 and 8 for craft of steel, aluminium alloy and composite construction respectively.

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2.2 Symbols

2.2.1 L_R, B, D, C_b, L_{WL} and T are as defined in Pt 3, Ch 1,6.2:

x_{wl} = longitudinal distance, in metres, measured forwards from the aft end of the L_{WL} to the position or centre of gravity of the item being considered

z = vertical distance, in metres, from the baseline to the position of centre of gravity of the item being considered. z is positive above the baseline

Normally the following definitions are to be applied:

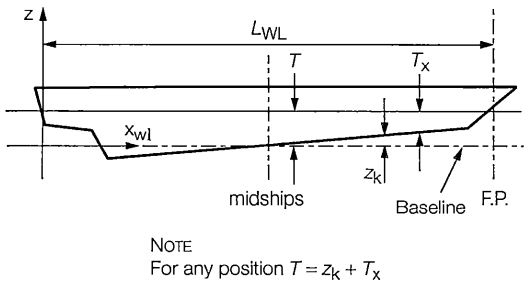
z is to be taken at one third of the panel or strake height

For short stiffener members: z is to be taken at the stiffener mid position

For long stiffener members: z is generally to be taken at the stiffener mid position, but may need to be specially considered, especially when there is a significant pressure variation along its length

z_k = vertical distance of the underside of the keel above the baseline, in metres, *see* Fig. 2.2.4

T_x = local draught to operating waterline at longitudinal position under consideration measured above the baseline is to be taken as the horizontal plane passing through the bottom of the moulded hull at midships, *see* Fig. 2.2.4.



NOTE
For any position $T = z_k + T_x$

Fig. 2.2.4 Definition of Symbols

2.2.2 The displacement, Δ, in tonnes, used in this Part is the mass of the craft in the loading condition under consideration.

2.3 Minimum significant wave height

2.3.1 The minimum value of significant wave height, $H_{1/3}$, *see* 2.1.14, in metres, used in the determination of accelerations and loads is, in general, not to be taken less than that given in Table 2.2.1 for the appropriate Service Groups defined in Pt 1, Ch 2,3.5.

2.3.2 The designer/Builder is to provide the value of significant wave height for use in the determination of the Rule loadings and, further, is to ensure that such a wave height is appropriate to the intended area of operation and/or service. In this respect the statistical wave data may be required to be submitted in support of the wave height nominated.

Table 2.2.1 Minimum significant wave height, $H_{1/3}$

Service Group	Minimum significant wave height, in metres
1	0,6
2	1,0
3	2,0
4	4,0
5	4,0
6	4,0

2.3.3 A reduction in the minimum value of significant wave height for a particular Service Group will be specially considered, provided that satisfactory statistical wave data for the intended service area are submitted for approval. *See also* 2.1.14.

■ *Section 3* Motion response

3.1 Relative vertical motion

3.1.1 The relative vertical motion is to be taken as:

$$H_{rm} = C_{w,min}\left(1 + \frac{k_r}{(C_b + 0{,}2)}\left(\frac{x_{wl}}{L_{WL}} - x_m\right)^2\right)$$

where

k_r = *see* Table 2.3.1

$$C_{w,min} = \frac{C_w}{k_m}$$

$$k_m = 1 + \frac{k_r\,(0{,}5 - x_m)^2}{(C_b + 0{,}2)}$$

x_m = $0{,}45 - 0{,}6F_n$ but not less than 0,2

C_w = wave head, in metres

$= 0{,}0771 L_{WL}\,(C_b + 0{,}2)^{0,3}\ e^{(-0{,}0044 L_{WL})}$

x_{wl} = distance from aft end of L_{WL}, in metres, *see* 2.2.1

L_{WL} = waterline length, in metres, *see* 2.1.19

C_b = block coefficient, *see* 2.2

F_n = Froude Number, *see* 2.1.7, where $V_m = {}^2/_3 V$

V as defined in 2.1.2.

Table 2.3.1 Hull form wave pressure factor

Craft type	k_r
Mono-hull craft in the non-displacement mode	2,25
Mono-hull craft in the displacement mode	1,95
Catamarans and multi-hull craft with partially submerged hulls	2,55
Swaths and multi-hull craft with fully submerged hulls	2,10
Craft supported by hydrodynamic lift provided by foils or other lifting devices	1,50

NOTE
Where multiple craft types apply, the higher value of k_r is to be used.

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3.2 Vertical acceleration

3.2.1 The instantaneous accelerations determined in accordance with the formulae in this Section are to be used to estimate the relationship between allowable speed, V, in knots, wave height, $H_{1/3}$, in metres, and displacement, Δ, in tonnes, and they will form the operational envelope which will be issued as an appendix to the Classification Certificate and be incorporated in the Operational Manual of the craft where such a manual is required by the Rules.

3.2.2 Where the Taylor Quotient, Γ, is greater than 10,8, the motion response criteria are to be specially considered.

3.2.3 The vertical acceleration at the LCG (longitudinal centre of gravity), a_v, is defined as the average of the 1/100 highest accelerations at the LCG.

3.2.4 The vertical acceleration in the non-displacement mode for mono-hull craft is to be taken as:

$$a_v = 1{,}5\theta_B L_1 (H_1 + 0{,}084)(5 - 0{,}1\theta_D)\,\Gamma^2 \times 10^{-3}$$

where

a_v is the vertical acceleration at the LCG in terms of g

g = acceleration due to gravity (9,81 m/sec^2)

$H_1 = \dfrac{H_{1/3}}{B_W}$, but is not to be taken as less than 0,2

$H_{1/3}$ = design significant wave height in metres

B_c = breadth of hull between the chines or bilge tangential points at LCG, as appropriate, in metres

B_W = breadth of hull at the LCG measured at the waterline, in metres

$L_1 = \dfrac{L_{WL} B_c^3}{B_W \Delta}$, but $\dfrac{L_{WL}}{B_W}$ is not to be taken as less than 3

L_{WL} = waterline length, in metres, *see* 2.1.19

θ_D = deadrise angle at the LCG, in degrees, but is not to be taken as greater than 30°

θ_B = running trim angle in degrees, but is not to be taken as less than 3°

Γ = Taylor Quotient, *see* 2.1.17

Δ = displacement, in tonnes, as defined in 2.2.2.

3.2.5 The vertical acceleration in the non-displacement mode for multi-hull craft is to be taken as:

$$a_v = \frac{f_a L_{WL}}{\Delta}(B_M H_{1/3} + 0{,}084 B_M^2)(5 - 0{,}1\theta_D)\,\Gamma^2 \times 10^{-3}$$

where

a_v is the vertical acceleration at the LCG in terms of g

f_a = hull form acceleration factor

= 2,7 for craft supported mainly by hydrodynamic lift provided by foils or other lifting devices

= 3,6 for Swaths and multi-hull craft with fully submerged hulls

= 4,5 for catamarans and multi-hull craft with partially submerged hulls

B_M = total breadth of hulls or struts at LCG at the waterline, in metres, excluding tunnels

$H_{1/3}$ = design significant wave height, in metres

L_{WL} = waterline length, in metres, *see* 2.1.19

θ_D = deadrise angle at the LCG, in degrees, but is not to be taken as greater than 30°, *see* 2.1.5

Γ = Taylor Quotient, *see* 2.1.17

Δ = displacement, in tonnes.

3.2.6 The vertical acceleration in the displacement mode for all craft is to be taken as:

$$a_v = 0{,}2\Gamma + \frac{34}{L_{WL}}$$

where

a_v is the vertical acceleration at the LCG in terms of g

L_{WL} = waterline length, in metres, *see* 2.1.19

Γ = Taylor Quotient, *see* 2.1.17.

3.2.7 The vertical acceleration, a_x, at any given location distance x_a from the AP along the hull may be taken as:

$$a_x = a_v \left(0{,}86 - 0{,}32\ \frac{x_a}{L_{WL}} + 1{,}76\ \left(\frac{x_a}{L_{WL}}\right)^2 + \xi_a\right)$$

where

a_v = vertical acceleration at LCG in terms of g, as appropriate

a_x = is the vertical acceleration at a distance x_a from AP on the static load waterline, in terms of g

x_a = distance from aft end of the static load waterline, in metres, to the point at which the vertical acceleration is calculated

x_{LCG} = distance from aft end of the static load waterline, in metres, to the LCG

L_{WL} = waterline length, in metres, *see* 2.1.19

$\xi_a = 0{,}14 + 0{,}32\ \dfrac{x_{LCG}}{L_{WL}} - 1{,}76\ \left(\dfrac{x_{LCG}}{L_{WL}}\right)^2$

■ *Section 4*
Loads on shell envelope

4.1 Pressures on the shell envelope

4.1.1 The design pressures for the shell envelope including exposed decks are to include the effects of combined static and dynamic load components. In addition, the effects of impact or slamming loads are also to be considered, but these are to be treated separately, *see* Section 5.

4.1.2 The individual pressure components are given in 4.3 to 4.5 and the combined pressure to be applied to the shell envelope is given in 4.2. The pressure to be applied to exposed and weather decks is given in 4.5.

4.2 Combined hydrostatic and hydrodynamic pressure on the shell plating

4.2.1 The total pressure distribution, P_s, in kN/m^2 acting on the shell plating envelope due to hydrostatic and hydrodynamic pressures is illustrated in Fig. 2.4.1 and is to be taken as specified in Table 2.4.1.

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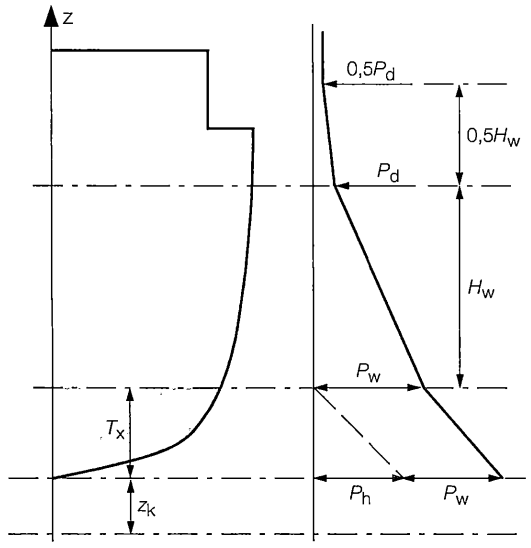

Fig. 2.4.1 Combined pressure distribution, P_s

Table 2.4.1 Combined pressure distribution, P_s

Vertical location i.e. z value	Shell envelope pressure, P_s kN/m^2
For $z \le T_x + z_k$ i.e. up to the operating waterline	$P_h + P_w$
At $z = T_x + z_k + H_w$	P_d
At $z \ge T_x + z_k + 1{,}5H_w$	$0{,}5P_d$
Symbols	
H_w is the nominal wave limit height, *see* 4.4.4 P_d is the weather deck pressure, *see* 4.5.1 P_h is the hydrostatic pressure, *see* 4.3 P_w is the hydrodynamic wave pressure, *see* 4.4 P_h and P_w are to be derived at the appropriate vertical position, z T_x, z and z_k are defined in 2.2	
NOTE Pressure values at other z values are to be derived by interpolation.	

4.3 Hydrostatic pressure on the shell plating

4.3.1 The pressure, P_h, acting on the shell plating up to the operating waterline due to hydrostatic pressure is to be taken as:

$$P_h = 10\,(T_x - (z - z_k))\ \text{kN/m}^2$$

where
T_x, z and z_k are defined in 2.2.

4.4 Hydrodynamic wave pressure

4.4.1 The hydrodynamic wave pressure distribution due to relative motion, P_w, around the shell envelope up to the operating waterline, i.e. $z \le T$, is to be taken as the greater of the following:

P_m kN/m^2
as defined in 4.4.2

P_p kN/m^2
as defined in 4.4.3.

4.4.2 The distribution of hydrodynamic pressure up to the operating waterline, P_m, is to be taken as:

$$P_m = 10 f_z H_{rm}\ \text{kN/m}^2$$

where

$$f_z = \text{the vertical distribution factor}$$
$$= k_z + (1 - k_z)\left(\frac{z - z_k}{T_x}\right)$$
$$k_z = e^{-u}$$
$$u = \left(\frac{2\pi\, T_x}{L_{WL}}\right)$$

H_{rm} is defined in 3.1.1
z, z_k, T_x and L_{WL} are defined in 2.2.

4.4.3 The distribution of hydrodynamic pressure up to the operating waterline, P_p, is to be taken as:

$$P_p = 10 H_{pm}\ \text{kN/m}^2$$

where

$$H_{pm} = 1{,}1\left(\frac{2x_{wl}}{L_{WL}} - 1\right)\sqrt{L_{WL}}$$

but not less than $f_L \sqrt{L_{WL}}$

f_L = 0,6 for $L_{WL} < 60$
= 1,5 - 0,015L_{WL} for $60 \le L_{WL} \le 80$
= 0,3 for $L_{WL} > 80$

L_{WL} = as defined in 2.1.19, but not greater than 150 m
x_{wl} is defined in 3.1.

4.4.4 The nominal wave limit height, H_w, above the design draft, T_x, is to be taken as:

$$H_w = 2H_{rm}\ \text{m}$$

where
H_{rm} is given in 3.1.1.

4.5 Pressure on weather and interior decks

4.5.1 The pressure acting on weather decks, P_d, is to be taken as specified in 4.5.2 or 4.5.3 as applicable.

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4.5.2 The pressure acting on weather and interior decks, P_{wh}, in the displacement mode is to be taken as:

$$P_{wh} = f_L (6 + 0{,}01L_{WL}) (1 + 0{,}05\Gamma) + E \quad kN/m^2$$

where

f_L = the location factor for weather decks
= 1,0 from aft end to $0{,}88L_R$
= 1,25 from $0{,}88L_R$ to $0{,}925L_R$
= 1,50 from $0{,}925L_R$ to forward end

f_L = 1,0 for interior decks

$E = \dfrac{0{,}7 + 0{,}08L_{WL}}{D - T}$ kN/m² for exposed decks but need not be taken greater than 3 kN/m²

E = 0,0 for sheltered decks

Γ = Taylor Quotient as defined in 2.1.17

Δ = the displacement as defined in 2.2

L_{WL} is as defined in 2.1.19.

4.5.3 The pressure acting on weather and interior decks, P_{wl}, in the non-displacement mode is to be taken as:

$$P_{wl} = f_L (5 + 0{,}01L_{WL}) (1 + 0{,}5a_v) + E \quad kN/m^2$$

where f_L and E are as defined in 4.5.2, and a_v is as defined in Section 3.

- a_v is not to be taken less than 1,0, but need not be taken greater than 4,0, for weather decks.
- a_v need not be taken greater than 1,0 for interior decks.

L_{WL} is as defined in 2.1.19.

Section 5
Impact loads

5.1 Impact pressure for displacement mode

5.1.1 The impact pressure, P_{dh}, for mono-hull and multi-hull craft is to be taken as specified in 5.1.2 and 5.1.3 as applicable.

5.1.2 The bottom shell impact pressure due to bottom slamming is given by the following expression:

$$P_{dh} = \Phi_{dh}\left(19 - 2720\left(\frac{T_x}{L_{WL}}\right)^2\right)\sqrt{L_{WL}V} \quad kN/m^2$$

$P_{dh} \geq P_m$

Φ_{dh} = 0,09 at L_{WL} from aft end of L_{WL}
= 0,18 at $0{,}9L_{WL}$ from aft end of L_{WL}
= 0,18 at $0{,}8L_{WL}$ from aft end of L_{WL}
= 0,0 between aft end of L_{WL} and $0{,}5L_{WL}$ from aft end of L_{WL}

L_{WL} = waterline length, in metres, *see* 2.1.19

V = allowable speed in knots, *see* 2.1.2.

Intermediate values to be determined by linear interpolation.

T_x is taken to be the draught T, as defined in Pt 3, Ch 1,6, but need not be taken greater than $0{,}08L_{WL}$.

P_{dh} at $0{,}9L_{WL}$ and $0{,}8L_{WL}$ from aft end of L_{WL} need not be taken greater than P_f at L_{WL} from aft end of L_{WL} as defined in 5.4.1.

5.1.3 The side shell impact pressure shall be taken as P_{dh} at the operating waterline, reducing to $0{,}4P_{dh}$ at the weather deck. Intermediate values between the weather deck at side and operating waterline, are to be determined by linear interpolation.

5.2 Impact pressure for non-displacement mode

5.2.1 The impact pressure, P_{dl}, for mono-hull and multi-hull craft is to be taken as specified in 5.2.2 and 5.2.3 as applicable.

5.2.2 The bottom impact pressure due to slamming, P_{dlb}, is given by the following expression:

$$P_{dlb} = \frac{f_d \Delta \Phi (1 + a_v)}{L_{WL} G_o} \quad kN/m^2$$

where

G_o = support girth or girth distance, in metres, as defined in Table 2.5.1

L_{WL} = waterline length, in metres, *see* 2.1.19

a_v = vertical acceleration as defined in 3.2

Δ = displacement, in tonnes, *see* 2.2.2

f_d = hull form pressure factor
= 54 for mono-hull craft
= $\dfrac{81}{N_H}$ for catamarans and multi-hull craft, where

N_H is the number of hulls, but it is not to be taken as greater than four

For craft in continuous contact with water:

Φ = 0,5 at L_{WL} from aft end of L_{WL}
= 1,0 at $0{,}75L_{WL}$ from aft end of L_{WL}
= 1,0 at $0{,}5L_{WL}$ from aft end of L_{WL}
= 0,5 at aft end of L_{WL}

Intermediate values to be determined by linear interpolation.

Otherwise, Φ = 1,0.

Table 2.5.1 Definition of G_o for the determination of bottom impact pressure, P_{dl}, for different regions of the hull

Bottom shell region	G_o	
	Craft with chines	Craft without chines
Between tangential points or chines	G_S	G_S
Between tangential points and design waterline	—	G_{WL}

NOTES
1. G_S = support girth, in metres, as defined in 2.1.15 at LCG.
2. G_{WL} = girth distance, in metres, measured between the waterlines on either side of a hull at the LCG.

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5.2.3 The side shell impact pressure due to slamming is to be taken as:

$$P_{dls} = P_{dlb} \frac{\tan(40 - \theta_B)}{\tan(\theta_S - 40)} \text{ kN/m}^2, \text{ but is not to be taken as greater than } P_{dlb}$$

where

θ_B = mean deadrise angle of bottom plating, in degrees at local section

θ_S = mean deadrise angle of side plating, in degrees at local section

$(40 - \theta_B)$ is not to be taken as less than 10 degrees

$(\theta_S - 40)$ is not to be taken as less than 10 degrees

P_{dls} is to be taken as constant from the chine or operating waterline to a point half G_o from this point, or the weather deck if this is reached first. Multiple chines will be subject to special consideration based on the above principle. *See* Fig. 2.5.1.

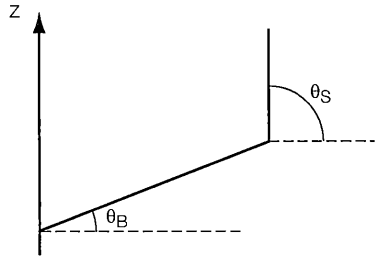

Fig. 2.5.1
Angles used in determination of side shell pressure for planing craft, P_{dls}

5.3 Impact pressure for craft with foils and lifting devices

5.3.1 The impact pressure, P_{fb}, for craft supported by hydrodynamic lift provided by foils or other lifting devices is to be taken as specified in 5.3.2 and 5.3.3, as applicable.

5.3.2 The bottom impact pressure is given by the greater of P_{fba} or P_{fbb}, where:

$$P_{fba} = \frac{16}{L_{WL}} \left(H_{03} + \sqrt{H_0 L_{WL}} \right)^2 \text{ kN/m}^2$$

$$P_{fbb} = \frac{1}{3} K_{po} V_R V \left(1 - \frac{H_0}{H_{03}} \right) \text{ kN/m}^2$$

where

K_{po} = longitudinal distribution factor
= 1,0 between the aft end of the L_{WL} and $0{,}75L_{WL}$
= 2,0 at L_{WL} from the aft end of L_{WL}, intermediate values to be determined by linear interpolation

H_0 = operational height of craft, in metres, measured from the waterline to the top of the keel at LCG

L_{WL} = waterline length, in metres, *see* 2.1.19

H_{03} = surviving waveheight as defined in 2.1.15 but is not taken as less than 1,0

V = allowable speed, in knots, *see* 2.1.2

P_{fbb} is not taken as less than zero.

V_R is the relative vertical speed of the craft at impact, in knots. If this value is unknown, then the following equation is to be used:

$$V_R = \frac{8H_{1/3}}{\sqrt{L_{WL}}} + 2 \text{ knots.}$$

5.3.3 The side shell impact pressure shall be taken as P_{fb} at the chine or at the operating waterline for round bilge hull-forms, as appropriate, reducing to $0{,}3P_{fb}$ at the weather deck. Intermediate values between the weather deck at side and the chine or operating waterline, as appropriate, are to be determined by linear interpolation.

5.4 Forebody impact pressure for displacement mode

5.4.1 Forebody and bow slamming pressure, P_f, at the load waterline due to relative motion is to be taken as:

$P_f = f_f L_{WL} (0{,}8 + 0{,}15\Gamma)^2$ kN/m^2 at FP

P_f = P_{dh} at $0{,}9L_{WL}$ from aft end of L_{WL}
= P_m at $0{,}75L_{WL}$ from aft end of L_{WL}
= 0,0 between aft end of L_{WL} and $0{,}75L_{WL}$ from aft end of L_{WL}

Intermediate values to be determined by linear interpolation where

f_f = forebody impact pressure factor as defined in Table 2.5.2

L_{WL} = waterline length, in metres, *see* 2.1.19

Γ = Taylor Quotient, *see* 2.1.17.

Table 2.5.2 Forebody impact pressure factor

Craft type	f_f
Mono-hull craft in non-displacement mode	0,94
Mono-hull craft in displacement mode	0,89
Catamarans and multi-hull craft with partially submerged hulls	1,0
Swaths and multi-hull craft with fully submerged hulls	0,91
Craft supported by hydrodynamic lift provided by foils or other lifting devices	0,81

NOTE
Where multiple craft types apply, the higher value of f_f is to be used.

5.4.2 The side shell impact pressure shall be taken as P_f at the chine or at the operating waterline for round bilge hull-forms, as appropriate, reducing to $0{,}4P_f$ at the weather deck. Intermediate values between the weather deck at side and the chine or operating waterline, as appropriate, are to be determined by linear interpolation.

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5.5 Forebody impact pressure for non-displacement mode

5.5.1 Forebody and bow slamming pressure, P_f, at the load waterline due to relative motion is to be taken as:

P_f = the greater of P_{dls} or $f_f L_{WL} (0,8 + 0,15\Gamma)^2$ kN/m^2 at FP
= P_{dls} at $0,75L_{WL}$ from aft end of L_{WL}
= P_m at $0,5L_{WL}$ from aft end of L_{WL}
= 0,0 between aft end of L_{WL} and $0,5L_{WL}$ from aft end of L_{WL}

Intermediate values to be determined by linear interpolation.

where

f_f = forebody impact pressure factor as defined in Table 2.5.2
L_{WL} = waterline length, in metres, *see* 2.1.19
Γ = Taylor Quotient, *see* 2.1.17.

5.5.2 The side shell impact pressure shall be taken as P_f at the chine or at the operating waterline for round bilge hull-forms, as appropriate, reducing to $0,3P_f$ at the weather deck. Intermediate values between the weather deck at side and the chine or operating waterline, as appropriate, are to be determined by linear interpretation.

Section 6
Cross-deck structure for multi-hull craft

6.1 Cross-deck structure clearance

6.1.1 For craft with multi-hulls linked by cross-deck structure, sufficient clearance is to be provided between the cross-deck structure and water surface to limit impact loads.

6.1.2 Where part or all of the cross-deck is intended to provide additional buoyancy to limit craft motion, the loading will be specially considered.

6.1.3 In the determination of the clearance, the following factors are to be considered:

(a) Relative motion in waves.
(b) The wave generated between the hulls when running.
(c) The bow sinkage.

6.1.4 The submitted clearance must be validated either by calculations according to accepted theories, model tests, full scale measurements or by documentary evidence if similar structures have proved to be satisfactory in service.

6.1.5 Where it is not possible to provide sufficient clearance to avoid slamming of the cross-deck structure, the equation given in 6.2 is to be used for the assessment of the impact pressures.

6.2 Impact pressure

6.2.1 The impact pressure, P_{pc}, acting on the underside of the cross deck ('wet deck') is to be taken as:

$$P_{pc} = \nabla_{pc} K_{pc} V_R V \left(1 - \frac{G_A}{H_{03}}\right) \text{ kN/m}^2$$

where

K_{pc} = longitudinal distribution factor
= 1,0 between the aft end of the L_{WL} and $0,75L_{WL}$
= 2,0 at the L_{WL} from the aft end of L_{WL}, intermediate values to be determined by linear interpolation
G_A = air gap, as defined in 2.1.1
H_{03} = surviving waveheight, as defined in 2.1.16
V = allowable speed, as defined in 2.1.2
∇_{pc} = cross-deck Impact Factor
= 1/6 for protected structures, as defined in 2.1.20
= 1/3 for unprotected structures, as defined in 2.1.21

V_R is the relative vertical speed of the craft at impact, in knots. If this value is unknown, then the following equation is to be used:

$$V_R = \frac{8H_{1/3}}{\sqrt{L_{WL}}} + 2 \text{ knots.}$$

Section 7
Component design loads

7.1 Deckhouses, bulwarks and superstructures

7.1.1 The design pressure, P_{dhp}, for the plating of deckhouses, bulwarks and first tier and above superstructures is given by:

$P_{dhp} = C_1 P_d$ kN/m^2

For structures other than windows:

C_1 = 1,25 for deckhouse and superstructure fronts on upper deck within the forward third of L_R
= 1,15 for deckhouse and superstructure fronts on upper deck outside the forward third of L_R and exposed machinery casings on the upper deck
= 1,0 for deckhouse and superstructure fronts above the lowest tier
= 0,8 for superstructure sides. A value of 0,64 may be used where the sides of the superstructure are stepped in from the sides of the craft by 1,0 m or more
= 0,5 elsewhere
L_R = Rule length in metres, *see* 2.2.1

For windows of toughened safety glass:

$C_1 = W_1 W_2 W_3$

In no case is the design pressure for windows of toughened safety glass to be taken less than $P_{dhp,min}$ as given by:

$P_{dhp,min} = W_1 G_f S_f (10 + 0,04L_{WL})$ kN/m^2

where

x_b = distance, in metres, from AP
y = vertical distance, in metres, from the static load waterline at the deepest design draught to the structural element considered
F = $(D - T)$ in metres

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L_{WL} = waterline length, in metres, *see* 2.1.19.
W_1 = 2,0 for the lowest tier of unprotected front
= 1,5 for superstructure fronts above the lowest tier
= 1,0 for superstructure sides. A value of 0,8 may be used where the sides of the superstructure are stepped in from the sides of the craft by 1,0 m or more
= 0,67 elsewhere
W_2 = 0,67 + 0,33 (x_b/L_{WL}) where $x_b > 0{,}5L_{WL}$ from AP
= 0,67 elsewhere
W_3 = $1 - (y - F)/y$
G_f and S_f are defined in Chapter 3 or Chapter 4 as appropriate.
P_d is defined in 4.5.
D and T are as defined in Pt 3, Ch 1,6.2.

7.2 Watertight and deep tank bulkheads

7.2.1 The design pressure, P_{bh}, on watertight and deep tank bulkheads is to be taken as:

P_{bh} = $11{,}2h_b$ kN/m^2 for deep tank bulkheads
= $7{,}2h_b$ kN/m^2 for watertight bulkheads

where
h_b = load head in metres, measured vertically as follows:

(a) Watertight bulkheads
(i) Plating: the distance from a point one-third of the height of the plate above its lower edge to the bulkhead deck at side.
(ii) Stiffeners: the distance from mid-point of stiffener span to the bulkhead deck at side.

(b) Deep tank bulkheads
For determination of head, the overflow is to be taken as not less than 1,8 m above the crown of the tank.
(i) Plating: the greater of:
- the distance from a point one-third of the height of the plate above its lower edge to the top of the tank
- half the distance from a point one third of the height of the plate above its lower edge to the top of the overflow.

(ii) Stiffeners: the greater of:
- the distance from mid-point of span to the top of the tank
- half the distance from mid point of span to the top of the overflow.

7.3 Pillars

7.3.1 The design load, P_{PI}, supported by a pillar is to be taken as:

P_{PI} = $S_{gt}\, b_{gt}\, P_c + P_a$ kN

where
b_{gt} = distance between centres of two adjacent spans of girders or transverses supported by the pillar, in metres
P_a = load, in kN, from pillar or pillars above, assumed zero if there are no pillars over
P_c = basic deck girder design pressure, as appropriate, plus any other loadings directly above the pillar, in kN/m^2
S_{gt} = spacing, or mean spacing, of girders or transverses, in metres

P_{PI} is not to be taken less than 5 kN.

7.4 Deck area designed for cargo, stores and equipment

7.4.1 The cargo deck design pressure, P_{cd}, for plating is to be taken as:

P_{cd} = $W_{CDP}\,(1 + 0{,}5a_x)$ kN/m^2

where a_x is given in Ch 2,3.1.7 and is not to be taken as less than 1,0.
W_{CDP} is the pressure exerted by the cargo on deck specified by the designer in kN/m^2.

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Local Design Criteria for Craft Operating in Non-Displacement Mode

Section

1 **General**

2 **Nomenclature and design factors**

3 **Hull envelope design criteria**

■ *Section 1* General

1.1 Application

1.1.1 The design criteria given in this Chapter are applicable to craft when operating in the non-displacement mode, *see* Ch 1,1.1.

1.1.2 Planing and semi-planing craft are craft with Taylor's Quotient, Γ, as defined in Ch 2,2.1.17, greater than or equal to 3,0.

1.1.3 Light displacement craft are craft with displacement, Δ, in tonnes, less than or equal to $0{,}04(L_R\,B)^{1,5}$, as defined in Pt 1, Ch 2,2.2.10.

1.1.4 The design criteria detailed in this Chapter are to be used in conjunction with the load criteria given in Chapter 2 together with the strength formulae given in Parts 6, 7 and 8 to determine the scantlings of steel, aluminium alloy and composite craft respectively as defined in Part 1.

1.1.5 Alternative methods of establishing the design criteria will be specially considered, provided that they are based on established Codes or Standards acceptable to LR. In such cases, full details of the methods used are to be provided when plans are submitted for approval.

■ *Section 2* Nomenclature and design factors

2.1 Nomenclature

2.1.1 The nomenclature used in this Chapter is given below:

P_p = pitching pressure, *see* Ch 2,4.4
P_{dl} = impact pressure, *see* Ch 2,5.2
P_{fb} = impact pressure for craft supported by hydrodynamic lift provided by foils or other lifting devices, *see* Ch 2,5.3
P_s = shell envelope pressure, *see* Ch 2,4.2
P_f = forebody impact pressure, *see* Ch 2,5.5
P_{cd} = cargo deck pressure, *see* Ch 2,7.4
P_{dhp} = deckhouse, bulwarks and superstructure pressure, *see* Ch 2,7.1
P_{bh} = watertight and deep tank bulkhead pressure, *see* Ch 2,7.2
P_{pc} = impact pressure acting on the cross-deck structure, *see* Ch 2,6.2
P_{wl} = pressure on weather deck, *see* Ch 2,4.5
P_{BP} = design pressure for bottom plating
P_{BF} = design pressure for bottom stiffening
P_{SP} = design pressure for side shell plating
P_{SF} = design pressure for side shell stiffening
P_{CP} = design pressure for cross-deck plating
P_{CF} = design pressure for cross-deck stiffening
P_h = hydrostatic pressure, *see* Ch 2,4.3
P_{WDP} = design pressure for weather deck plating
P_{WDF} = design pressure for weather deck stiffening
P_{CRP} = design pressure for coachroof plating
P_{CRF} = design pressure for coachroof stiffening
P_{IDP} = design pressure for interior deck plating
P_{IDF} = design pressure for interior deck stiffening
P_{IBP} = design pressure for inner bottom plating
P_{IBF} = design pressure for inner bottom stiffening
P_{DHP} = design pressure for deckhouse, bulwarks and superstructures plating and windows
P_{DHF} = design pressure for deckhouse, bulwarks and superstructure stiffening
P_{BHP} = design pressure for bulkheads
P_{CDP} = design pressure for cargo deck plating

Δ and Γ are defined in Ch 2,2.2.2 and Ch 2,2.1.17
T, L_R and B are as defined in Pt 3, Ch 1,6.2.

2.1.2 The unit for pressure is kN/m^2.

2.1.3 The design pressure, P, used in the scantling formulae given in Parts 3, 6, 7 and 8 is to be taken as equal to the appropriate value as defined in this Chapter.

2.2 Design factors

2.2.1 The design pressures on structural components are to be calculated taking into consideration the following factors:

(a) Hull notation assigned as defined in Pt 1, Ch 2,3.4.
(b) Service area restriction notation assigned as defined in Pt 1, Ch 2,3.5.
(c) Service type notation assigned as defined in Pt 1, Ch 2,3.6.
(d) Craft type notation assigned as defined in Pt 1, Ch 2,3.7.
(e) Type of stiffening members.

2.2.2 In general, the design pressure, in kN/m^2, for a particular structural component is to be determined as follows:

$$\text{Design pressure} = \delta_f H_f G_f S_f C_f \times \text{load criterion}$$

where

C_f = craft type notation factor given in Table 3.2.4
G_f = service area restriction notation factor given in Table 3.2.2
H_f = hull notation factor given in Table 3.2.1
S_f = service type factor notation given in Table 3.2.3
δ_f = stiffening type factor as given in Table 3.2.5.

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Table 3.2.1 Hull notation factor, H_f

Hull notation	Factor
HSC	1,0
LDC	0,95
NOTE For a craft eligible for both **HSC** and **LDC** notation, the higher value is to be used. H_f is to be taken as 1,0 for a craft not eligible for either the **HSC** or the **LDC** notation.	

Table 3.2.2 Service area notation factor, G_f

Service area restriction notation	Factor
G1	0,6
G2	0,75
G3	0,85
G4	1,0
G5	1,2
G6	1,25

Table 3.2.3 Service type notation factor, S_f

Service type notation	Factor
Cargo (A)	1,0
Cargo (B)	1,1
Passenger	1,0
Passenger (A)	1,0
Passenger (B)	1,1
Patrol	1,2
Pilot	1,25
Yacht	1,1
Workboat	1,25

Table 3.2.4 Craft type notation factor, C_f

Craft type notation	Factor
Catamaran	1,0
Hydrofoil	1,1
Mono	1,0
Multi	1,1
RIB	1,15
SES	1,0
SWATH	1,0

Table 3.2.5 Stiffening type factor, δ_f

Type	δ_f
Primary stiffening members and transverse frames	0,5
Secondary and local stiffening members Transverse beams	0,8

■ *Section 3* Hull envelope design criteria

3.1 Hull structures

3.1.1 The design pressures, in kN/m^2, to be used to determine the scantlings of structural elements are to be taken as specified in Table 3.3.1.

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Table 3.3.1 Design pressures for non-displacement craft

Category/location	Craft type	Symbol	Plating pressure	Min.	Symbol	Stiffener pressure	Min.
Mono-hull craft							
Bottom shell	Basic craft	P_{BP}	Greater of $H_f S_f P_s$ $H_f S_f C_f P_{dl}$ $H_f S_f G_f C_f P_f$		P_{BF}	Greater of $\delta_f H_f S_f P_s$ $\delta_f H_f S_f C_f P_{dl}$ $\delta_f H_f S_f G_f C_f P_f$	
	Craft with foils or other lifting devices	P_{BP}	Greater of $H_f S_f P_s$ $H_f S_f C_f P_{fb}$		P_{BF}	Greater of $\delta_f H_f S_f P_s$ $\delta_f H_f S_f C_f P_{fb}$	
Side shell		P_{SP}	P_{BP}		P_{SF}	$\delta_f P_{BP}$	
Multi-hull craft							
Bottom shell	Basic craft	P_{BP}	Greater of $H_f S_f P_s$ $H_f S_f C_f P_{dl}$ $H_f S_f G_f C_f P_f$		P_{BF}	Greater of $\delta_f H_f S_f P_s$ $\delta_f H_f S_f C_f P_{dl}$ $\delta_f H_f S_f G_f C_f P_f$	
	Craft with foils or other lifting devices	P_{BP}	Greater of $H_f S_f P_s$ $H_f S_f C_f P_{fb}$		P_{BF}	Greater of $\delta_f H_f S_f P_s$ $\delta_f H_f S_f C_f P_{fb}$	
	Fully submerged hulls	P_{BP}	Greater of $H_f S_f P_s$ $H_f S_f G_f P_f$		P_{BF}	Greater of $\delta_f H_f S_f P_s$ $\delta_f H_f S_f G_f P_f$	
Outboard side shell		P_{SP}	P_{BP}		P_{SF}	$\delta_f P_{BP}$	
Inboard side shell		P_{SP}	Greater of P_{BP} 1,6 P_{WDP} at wet deck		P_{SF}	Greater of $\delta_f P_{BP}$ 1,9 P_{WDP} at wet deck	
Wet deck		P_{CP}	Greater of $H_f S_f P_p$ $H_f S_f P_{pc}$		P_{CF}	Greater of $\delta_f H_f S_f P_p$ $\delta_f H_f S_f P_{pc}$	
Components							
Weather deck *see* Note 1		P_{WDP}	Greater of $H_f S_f G_f C_f P_{wl}$ P_{cd}	7	P_{WDF}	Greater of $\delta_f H_f S_f G_f C_f P_{wl}$ P_{cd}	7
Coachroof, *see* Note 1		P_{CRP}	$H_f S_f G_f C_f P_{wl}$	7	P_{CRF}	$\delta_f H_f S_f G_f C_f P_{wl}$	7
Interior deck		P_{IDP}	Greater of $H_f S_f C_f P_{wl}$ P_{cd}	3,5	P_{IDF}	Greater of $\delta_f H_f S_f C_f P_{wl}$ P_{cd}	3,5
Deckhouses, bulwarks and superstructure		P_{DHP}	$H_f S_f G_f C_f P_{dhp}$		P_{DHF}	$\delta_f H_f S_f G_f C_f P_{dhp}$	
Inner bottom		P_{IBP}	$H_f S_f P_m + P_h$	$10T$	P_{IBF}	$\delta_f (H_f S_f P_m + P_h)$	$10T$
Watertight and deep tank bulkheads		P_{BHP}	P_{bh}		P_{BHF}	P_{bh}	

NOTES
1. G_f is not to be taken less than 1,0.
2. The result of each row in each cell is found as the product of all items on that row in that cell.

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Local Design Criteria for Craft Operating in Displacement Mode

Section

1 **General**

2 **Nomenclature and design factors**

3 **Hull envelope design criteria**

Section 1 General

1.1 Application

1.1.1 The design criteria given in this Chapter are applicable to all craft when operating in the displacement mode.

1.1.2 Displacement craft are craft with Taylor's Quotient, Γ, as defined in Ch 2,2.1.17, less than 3,0 and with displacement, Δ, in tonnes, greater than $0{,}04(L_R B)^{1,5}$, as defined in Ch 2,2.2.2.

1.1.3 The design criteria detailed in this Chapter are to be used in conjunction with the load criteria given in Chapter 2 together with the strength formulae given in Parts 6, 7 and 8 to determine the scantlings of steel, aluminium alloy and composite craft as defined in Part 1.

1.1.4 Alternative methods of establishing the design criteria will be specially considered, provided that they are based on established Codes or Standards acceptable to LR. In such cases, full details of the methods used are to be provided when plans are submitted for approval.

Section 2 Nomenclature and design factors

2.1 Nomenclature

2.1.1 The nomenclature used in this Chapter is given below:

P_p = pitching pressure, *see* Ch 2,4.4
P_{dh} = impact pressure, *see* Ch 2,5.1
P_{dhp} = deckhouse, bulwarks and superstructure pressure, *see* Ch 2,7.1
P_s = shell envelope pressure, *see* Ch 2,4.1
P_f = forebody impact pressure, *see* Ch 2,5.4
P_{pc} = impact pressure acting on the cross-deck structure, *see* Ch 2,6.2
P_{wh} = pressure on weather deck, *see* Ch 2,4.5
P_{cd} = cargo deck pressure, *see* Ch 2,7.4
P_{bh} = watertight and deep tank bulkhead pressure, *see* Ch 2,7.2
P_{BP} = design pressure for bottom plating
P_{BF} = design pressure for bottom stiffening
P_h = hydrostatic pressure, *see* Ch 2,4.3
P_{SP} = design pressure for side shell plating
P_{SF} = design pressure for side shell stiffening
P_{CP} = design pressure for cross-deck plating
P_{CF} = design pressure for cross-deck stiffening
P_{WDP} = design pressure for weather deck plating
P_{WCDF} = design pressure for weather deck stiffening
P_{CRP} = design pressure for coachroof plating
P_{CRF} = design pressure for coachroof stiffening
P_{IDP} = design pressure for interior deck plating
P_{IDF} = design pressure for interior deck stiffening
P_{IBP} = design pressure for inner bottom plating
P_{IBF} = design pressure for inner bottom stiffening
P_{DHP} = design pressure for deckhouse, bulwarks and superstructures plating and windows
P_{DHF} = design pressure for deckhouse, bulwarks and superstructure stiffening
P_{BHP} = design pressure for bulkheads
P_{CDP} = design pressure for cargo deck plating

Δ and Γ are defined in Ch 2,2.2.2 and Ch 2,2.1.17
T, L_R and B are as defined in Pt 3, Ch 1,6.2.

2.1.2 The unit for pressure is kN/m^2.

2.1.3 The design pressure, P, used in the scantling formulae given in Parts 3, 6, 7 and 8 is to be taken as equal to the appropriate value as defined in this Chapter.

2.2 Design factors

2.2.1 The design pressures on structural components are to be calculated taking into consideration the following factors:

(a) Hull notation assigned as defined in Pt 1, Ch 2,3.4.
(b) Service area restriction notation assigned as defined in Pt 1, Ch 2,3.5.
(c) Service type notation assigned as defined in Pt 1, Ch 2,3.6.
(d) Type of stiffening members.

2.2.2 In general the design pressure, in kN/m^2, for a particular structural component is to be determined as follows:

$$\text{Design pressure} = \delta_f H_f G_f S_f \times \text{load criterion}$$

where

G_f = service area restriction notation factor given in Table 4.2.1
H_f = 1,05
S_f = service type factor notation given in Table 4.2.2
δ_f = stiffening type factor as given in Table 4.2.3.

Table 4.2.1 Service area restriction notation factor, G_f

Service area restriction notation	Factor
G1	0,6
G2	0,75
G3	0,85
G4	1,0
G5	1,2
G6	1,25

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Table 4.2.2 Service type notation factor, S_f

Service type notation factor	Factor
Cargo (A)	1,0
Cargo (B)	1,1
Passenger	1,0
Passenger (A)	1,0
Passenger (B)	1,1
Patrol	1,2
Pilot	1,25
Yacht	1,1
Workboat	1,25

Table 4.2.3 Stiffening type factor, δ_f

Type	δ_f
Primary stiffening members and transverse frames	0,5
Secondary and local stiffening members Transverse beams	0,8

■ *Section 3* Hull envelope design criteria

3.1 Hull structures

3.1.1 The design pressures, in kN/m^2, to be used to determine the scantlings of structural elements are to be taken as specified in Table 4.3.1.

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Table 4.3.1 Design pressures for displacement craft

Category/location	Craft type	Symbol	Plating pressure	Min.	Symbol	Stiffener pressure	Min.
Mono-hull craft							
Bottom shell	Basic craft	P_{BP}	Greater of $H_f S_f P_s$ $H_f S_f G_f P_{dh}$ $H_f S_f G_f P_f$		P_{BF}	Greater of $\delta_f H_f S_f P_s$ $\delta_f H_f S_f G_f P_{dh}$ $\delta_f H_f S_f G_f P_f$	
Side shell		P_{SP}	P_{BP}		P_{SF}	$\delta_f P_{BP}$	
Multi-hull craft							
Bottom shell	Partially submerged hulls	P_{BP}	Greater of $H_f S_f P_s$ $H_f S_f G_f P_{dh}$ $H_f S_f G_f P_f$		P_{BF}	Greater of $\delta_f H_f S_f P_s$ $\delta_f H_f S_f G_f P_{dh}$ $\delta_f H_f S_f G_f P_f$	
	Fully submerged hulls	P_{BP}	Greater of $H_f S_f P_s$ $H_f S_f G_f P_f$		P_{BF}	Greater of $\delta_f H_f S_f P_s$ $\delta_f H_f S_f G_f P_f$	
Outboard side shell		P_{SP}	P_{BP}		P_{SF}	$\delta_f P_{BP}$	
Inboard side shell		P_{SP}	Greater of P_{BP} 1,6 P_{WDP} at wet deck		P_{SF}	Greater of $\delta_f P_{BP}$ 1,9 P_{WDP} at wet deck	
Wet deck		P_{CP}	Greater of $H_f S_f P_p$ $H_f S_f P_{pc}$		P_{CF}	Greater of $\delta_f H_f S_f P_p$ $\delta_f H_f S_f P_{pc}$	
Components							
Weather deck *see* Note 1		P_{WDP}	Greater of $H_f S_f G_f P_{wl}$ P_{cd}	7	P_{WDF}	Greater of $\delta_f H_f S_f G_f P_{wh}$ P_{cd}	7
Coachroof, *see* Note 1		P_{CRP}	$H_f S_f G_f P_{wl}$	7	P_{CRF}	$\delta_f H_f S_f G_f P_{wh}$	7
Interior deck		P_{IDP}	Greater of $H_f S_f P_{wh}$ P_{cd}	3,5	P_{IDF}	Greater of $\delta_f H_f S_f P_{wh}$ P_{cd}	3,5
Deckhouses, bulwarks and superstructure		P_{DHP}	$H_f S_f G_f P_{dhp}$		P_{DHF}	$\delta_f H_f S_f G_f P_{dhp}$	
Inner bottom		P_{IBP}	$H_f S_f P_m + P_h$	$10T$	P_{IBF}	$\delta_f (H_f S_f P_m + P_h)$	$10T$
Watertight and deep tank bulkheads		P_{BHP}	P_{bh}		P_{BHF}	P_{bh}	

NOTES
1. G_f is not to be taken less than 1,0.
2. The result of each row in each cell is found as the product of all items on that row in that cell.

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Section

1 **General**

2 **Hull girder load criteria for mono-hull craft**

3 **Hull girder load criteria for multi-hull craft**

4 **Primary load criteria for multi-hull craft**

5 **Design criteria and load combinations**

6 **Loading guidance information**

Section 1 General

1.1 Introduction

1.1.1 The global load and design criteria detailed in this Chapter are to be used in conjunction with Parts 6, 7 and 8 to determine the global hull strength requirements for steel, aluminium alloys and composite craft respectively as defined in Pt 1, Ch 2,2.1.1.

1.1.2 The global load and design criteria given in this Chapter are also provided to enable the designer/Builder to check global hull strength against ductile failure modes involving gross deformation.

1.1.3 The global load criteria are divided into two categories:

(a) Hull girder loads

The types of hull girder loads which are to be considered for strength purposes are distinguished on the basis of their frequencies and they are defined as follows:

(i) Still water bending moments and associated shear forces arising from mass distribution and buoyancy forces.

(ii) Vertical wave bending moments and associated shear forces arising from low frequency hydrodynamic forces.

(iii) Dynamic bending moments and associated shear forces arising from high frequency bottom slamming.

(b) Primary loads for multi-hull craft

These loads arise from the interaction between the hulls and waves.

1.1.4 Alternative methods of establishing the global load and design criteria will be specially considered, provided that they are based on model tests, full scale measurements or other generally accepted theories. In such cases, full details of the methods used and the results are to be provided when plans are submitted for approval.

1.1.5 Longitudinal strength calculations are to be carried out and submitted for approval for craft as required in Parts 6, 7 and 8, as appropriate, covering the range of load and ballast conditions proposed, in order to determine the required hull girder strength. The calculations of still water shear forces and bending moments are to cover both departure and arrival conditions and any special mid-voyage conditions caused by changes in ballast distribution.

1.1.6 L_R, B, D, T and C_b are as defined in Pt 3, Ch 1,6.

1.1.7 The vertical acceleration at the LCG, a_v, in terms of g, as defined in Ch 2,3.2, as appropriate, is not to be taken less than 1,0 for the purpose of determining the global load and design criteria.

Section 2 Hull girder load criteria for mono-hull craft

2.1 General

2.1.1 The vertical bending moments specified here are applicable to all mono-hull craft as defined in Pt 1, Ch 2,2.2.12.

2.2 Vertical wave bending moments

2.2.1 For all craft except patrol craft in Service Group G6, the minimum value of vertical wave bending moment, M_W at any position along the craft may be taken as follows:

$M_W = F_f D_f M_o$ kNm

where

F_f = –1,1 for sagging (negative) moment

= $1{,}9C_b/(C_b + 0{,}7)$ for hogging (positive) moment

D_f = the longitudinal distribution factor

= 0 at aft end of L_R

= 1,0 between $0{,}4L_R$ and $0{,}65L_R$

= 0 at forward end of L_R

Intermediate values of D_f are to be determined by linear interpolation

$M_o = 0{,}1L_f G_f L_R^2 B (C_b + 0{,}7)$ kNm

$L_f = 0{,}0412L_R + 4{,}0$, for $L_R < 90$ m

$= 10{,}75 - (3 - 0{,}01L_R)^{1.5}$, for $L_R \geq 90$ m

G_f = Service group factor, *see* Pt 1, Ch 2,3.5.5

= 0,5 for G1 craft

= 0,6 for G2 craft

= 0,7 for G3 craft

= 0,8 for G4 craft

= 1,0 for G5 and G6 craft (yachts only)

L_R = Rule length, in metres, as defined in Pt 3, Ch 1,6

C_b to be taken not less than 0,60.

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2.2.2 For patrol craft in Service Group G6, the minimum value of vertical wave bending moment, M_W, at any position along the ship may be taken as follows:

$M_W = F_f D_f M_o$ kNm

where

F_f is the hogging, F_{fH}, or sagging, F_{fS}, correction factor based on the amount of bow flare, stern flare, length and effective buoyancy of the aft end of the craft above the waterline. F_{fS} is the sagging (negative) moment correction factor and is to be taken as:

$F_{fS} = -1{,}10 R_A^{0,3}$ for values of $R_A \geq 1{,}0$

$F_{fS} = -1{,}10$ for values of $R_A < 1{,}0$

R_A is an area ratio factor, *see* 2.2.3

An area ratio value of 1,0 results in a sagging correction factor of –1,10

F_{fH} is the hogging (positive) moment correction factor and is to be taken as

$F_{fH} = 1{,}9 C_b / (C_b + 0{,}7)$

D_f = the longitudinal distribution factor

= 0 at aft end of L_R

= 1,0 between $0{,}4L_R$ and $0{,}65L_R$

= 0 at forward end of L_R

Intermediate values of D_f are to be determined by linear interpolation

$M_o = 0{,}1 L_f L_R^2 B_{WL} (C_b + 0{,}7)$ kNm

$L_f = 0{,}0412 L_R + 4{,}0$, for $L_R < 90$ m

$= 10{,}75 - (3 - 0{,}01 L_R)^{1,5}$, for $L_R \geq 90$ m

B_{WL} = maximum breadth at the design waterline, in metres

C_b to be taken not less than 0,60.

2.2.3 The area ratio factor, R_A, for the combined stern and bow shape is to be derived as follows:

$$R_A = \frac{30 (A_{BF} + 0{,}5 A_{SF})}{L_R B_{WL}}$$

where

A_{BF} is the bow flare area, in m^2, *see* 2.2.4

A_{SF} is the stern flare area, in m^2, *see* 2.2.5.

2.2.4 The bow flare area, A_{BF}, is illustrated in Fig. 5.2.1 and may be derived as follows:

$A_{BF} = A_{UB} - A_{LB}$ m^2

where

A_{UB} = half the water plane area at a waterline of $T_{C,U}$ of the bow region of the hull forward of $0{,}8L_R$ from the AP.

A_{LB} = half the water plane area at the design waterline of the bow region of the hull forward of $0{,}8L_R$ from the AP.

Note the AP is to be taken at the aft end of the Rule length, L_R

The design waterline is to be taken at T, *see* Pt 3, Ch 1.

Alternatively the following formula may be used:

$A_{BF} = 0{,}05 L_R (b_0 + 2b_1 + b_2) + b_0 a/2$ m^2

where

b_0 = projection of $T_{C,U}$ waterline outboard of the design waterline at the FP, in metres, *see* Fig. 5.2.1

b_1 = projection of $T_{C,U}$ waterline outboard of the design waterline at $0{,}9L_R$ from the AP, in metres

b_2 = projection of $T_{C,U}$ waterline outboard of the design waterline at $0{,}8L_R$ from the AP, in metres

a = projection of $T_{C,U}$ waterline forward of the FP, in metres

$T_{C,U}$ is a waterline taken $L_f/2$ m above the design waterline

$T_{C,U} = T + L_f/2$ m

L_f is given in 2.2.2.

For ships with large bow flare angles above the $T_{C,U}$ waterline the bow flare area may need to be specially considered.

2.2.5 The stern flare area, A_{SF}, is illustrated in Fig. 5.2.1 and is to be derived as follows:

$A_{SF} = A_{US} - A_{LS}$ m^2

where

A_{US} = half the water plane area at a waterline of $T_{C,U}$ of the stern region of the hull from aft to $0{,}2L_R$ forward of the AP

A_{LS} = half the water plane area at a waterline of $T_{C,L}$ of the stern region of the hull from aft to $0{,}2L_R$ forward of the AP

$T_{C,L}$ is a waterline taken $L_f/2$ m below the design waterline

$T_{C,L} = T - L_f/2$ m

L_f is given in 2.2.2.

For craft with tumblehome in the stern region, the maximum breadth at any waterline less than $T_{C,U}$ is to be used in the calculation of A_{US}. The effects of appendages including bossings are to be ignored in the calculation of A_{LS}.

2.2.6 The sagging correction factor, F_{fS} , in the vertical wave bending moment formulation in 2.2.2 may be derived by direct calculation methods. Appropriate direct calculation methods may include a combination of long term ship motion analysis, non linear ship motion analysis and static balance on a wave crest or trough.

2.3 Still water bending moments

2.3.1 The still water bending moment, M_S, hogging and sagging is the maximum moment calculated from the loading conditions.

2.3.2 Still water bending moments are to be calculated along the craft length. For these calculations, downward loads are to be taken as positive values and are to be integrated in the forward direction from the aft end of L_R. Hogging bending moments are positive.

2.4 Wave shear force

2.4.1 The wave shear force, Q_W, at any position along the craft is given by:

$$Q_W = \frac{3 K_f M_o}{L_R} \text{ kN}$$

where K_f is to be taken as follows:

(a) Positive shear force:

K_f = 0 at aft end of L_R

= 1,589C_b/ (C_b + 0,7) between $0{,}2L_R$ and $0{,}3L_R$ from aft end of L_R

= 0,7 between $0{,}4L_R$ and $0{,}6L_R$ from aft end of L_R

= 1,0 between $0{,}7L_R$ and $0{,}85L_R$ from aft end of L_R

= 0 at forward end of L_R

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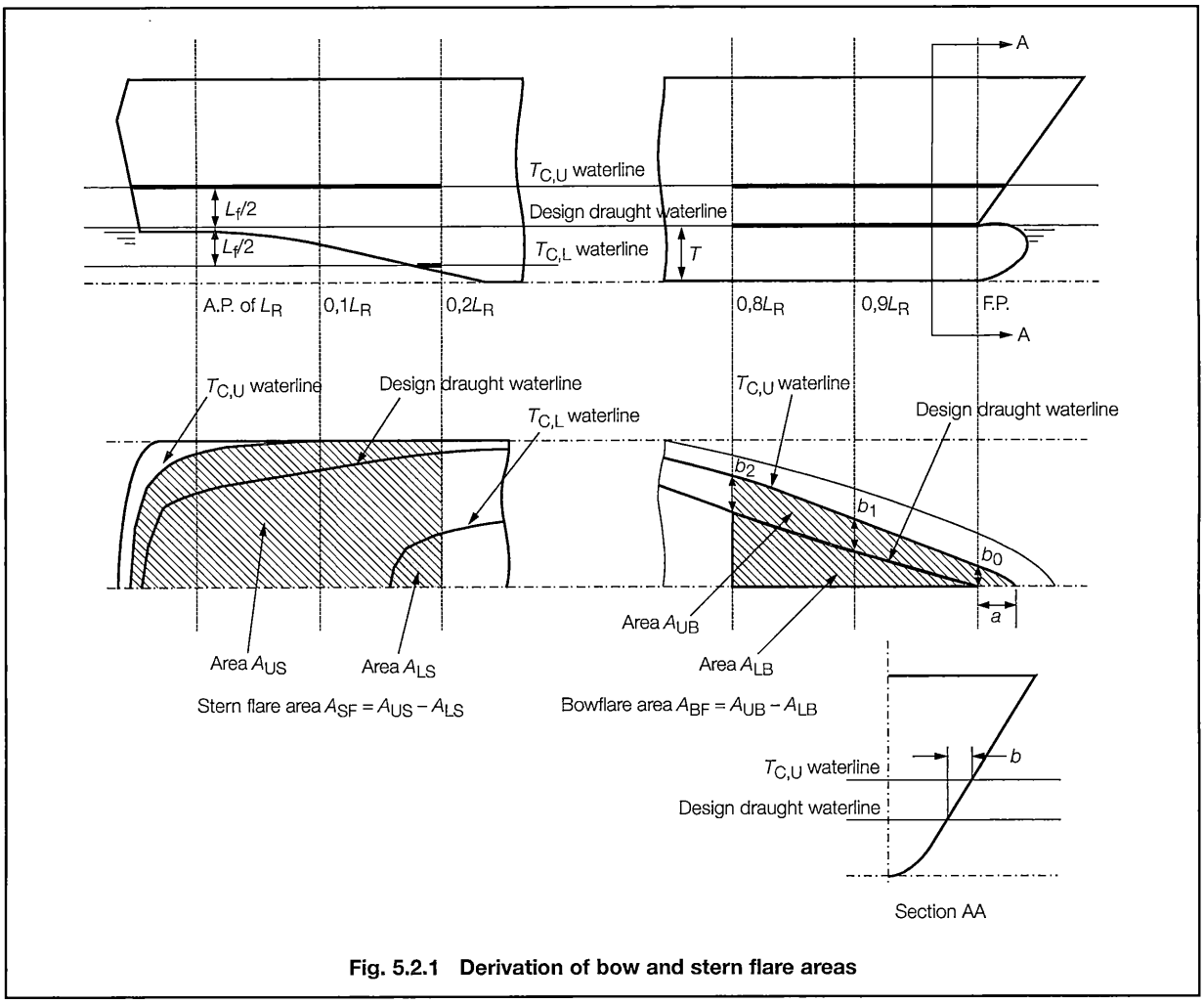

Fig. 5.2.1 Derivation of bow and stern flare areas

(b) Negative shear force:

K_f = 0 at aft end of L_R
= –0,92 between $0,2L_R$ and $0,3L_R$ from aft end of L_R
= –0,7 between $0,4L_R$ and $0,6L_R$ from aft end of L_R
= $-1,727C_b/(C_b + 0,7)$ between $0,7L_R$ and $0,85L_R$ from aft end of L_R
= 0 at forward end of L_R

Intermediate values to be determined by linear interpolation.

M_o, C_b are as defined in 2.2.1 and 2.2.2.

2.5 Still water shear force

2.5.1 The still water shear force, Q_s, at each transverse section along the hull is to be taken as the maximum positive and negative value found from the longitudinal strength calculations.

2.5.2 Still water shear forces are to be calculated at each section along the craft length. For these calculations, downward loads are to be taken as positive values and are to be integrated in a forward direction from the aft end of L_R. The shear force is positive when the algebraic sum of all vertical forces aft of the section is positive.

2.5.3 The actual shear force obtained from the longitudinal strength calculations may be corrected for the effect of local forces at the transverse bulkhead, if applicable.

2.6 Dynamic bending moments and associated shear forces

2.6.1 The dynamic bending moments, including wave and still water effects, specified here are applicable to all non-displacement mono-hull craft as defined in Pt 1, Ch 2,2.2.12.

2.6.2 The dynamic bending moment, due to slamming effects at amidships, is to be calculated using the following expression:

$M_{DW} = F_f D_f |M_D|$ kNm

where

$|M_D|$ is taken to be the absolute value of the function, irrespective of signs

$M_D = 51\Delta L_R (16a_v - 4a_b - 17a_s - 5)\ 10^{-3}$ kNm

Δ = displacement, in tonnes, as defined in Ch 2,2.2.2

F_f = –1,0 for sagging (negative) moment
= 1,0 for hogging (positive) moment

D_f = 0 at aft end of L_R

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= 1,0 between $0,4L_R$ and $0,65L_R$ from aft
= 0 at forward end of L_R

a_v = vertical acceleration at the LCG, in terms of g, as defined in Ch 2,3.2.4, *see also* 1.1.6

a_b = vertical acceleration at forward end of L_R, in terms of g

a_s = vertical acceleration at aft end of L_R, in terms of g

If the values of a_b and a_s are unknown, the distributions given in Ch 2,3.2.7 are applicable.

2.6.3 The bottom longitudinal amidships are additionally subjected to the following effective pressure, P_s:

$$P_s = 0,14P_{dl} + 8T \text{ kN/m}^2$$

where

P_{dl} is as defined in Ch 2,5.2.1. T is as defined in Pt 3, Ch 1,6.

2.6.4 The bottom plating amidships is subjected to the following additional effective pressure, P_t:

$$P_t = 0,175P_{dl} + 10T \text{ kN/m}^2$$

where

P_{dl} is as defined in Ch 2,5.2.1. T is as defined in Pt 3, Ch 1,6.

2.6.5 The dynamic shear force, Q_{DW}, at any position along the craft is given by:

$$Q_{DW} = \frac{4K_f M_D}{L_R} \text{ kN}$$

where M_D is as defined in 2.6.2 and K_f is as defined in 2.4.1.

Section 3
Hull girder load criteria for multi-hull craft

3.1 General

3.1.1 The vertical bending moments specified here are applicable to all multi-hull craft as defined in Pt 1, Ch 2,2.2.13.

3.1.2 L_R and T are as defined in Pt 3, Ch 1,6.

3.2 Vertical wave bending moments and associated shear forces

3.2.1 The vertical wave bending moments, M_{MW}, including wave and still water effects, at amidship is given by the following:

$$M_{MW} = F_f D_f M_M \text{ kNm}$$

where

$M_M = S_f G_f E_f C_{WP} L_S^{2,5} B_M$ kNm

C_{WP} = the waterplane area coefficient and is to be taken not less than 0,5

G_f = service group factor, *see* Pt 1, Ch 2,3.5.5
= 0,5 for G1 craft
= 0,6 for G2 craft
= 0,7 for G3 craft
= 0,8 for G4 craft
= 1,0 for G5 and G6 craft

S_f = 1,1 for passenger and cargo craft
= 1,15 for craft other than cargo and passenger craft

E_f = 0,125 for sagging moment
= 0,2 for hogging moment

F_f = –1,0 for sagging (negative) moment
= 1,0 for hogging (positive) moment

D_f = 0 at aft end of L_R
= 1,0 between $0,4L_R$ and $0,65L_R$ from aft end of L_R
= 0 at forward end of L_R

B_M = total breadth of hulls or struts at LCG at the waterline, in metres, excluding tunnels

L_S = Rule length, L_R, in metres, for partially submerged hulls
= strut length, in metres, for fully submerged hulls.

3.2.2 The wave shear force, Q_{MW}, at any position along the craft is given by:

$$Q_{MW} = \frac{3K_f M_M}{L_S} \text{ kN}$$

where M_M is as defined in 3.2.1 and K_f is as defined in 2.4.1.

3.3 Dynamic bending moments

3.3.1 The dynamic bending moments, including wave and still water effects, specified here are applicable to all non-displacement multi-hull craft as defined in Pt 1, Ch 2,2.2.13.

3.3.2 The dynamic bending moment, M_{MDW}, due to slamming effects at amidships is to be calculated using the following expression:

$$M_{MDW} = F_f D_f M_{MD} \text{ kNm}$$

where

$M_{MD} = 52\Delta L_S (20 a_v - 5) \times 10^{-3}$ kNm

F_f = –1,0 for sagging (negative) moment
= 1,0 for hogging (positive) moment

D_f = 0 at aft end of L_R
= 1,0 between $0,4L_R$ and $0,65L_R$ from aft
= 0 at forward end of L_R

a_v = vertical acceleration at the LCG, in terms of g, as defined in Ch 2,3.2.5 as appropriate, *see also* 1.1.6

Δ = displacement, in tonnes, as defined in Ch 2,2.2.2

L_S is as defined in 3.2.1.

3.3.3 The bottom longitudinals amidships are additionally subjected to the following effective pressure, P_s:

$$P_s = 0,14P_{dl} + 8T \text{ kN/m}^2$$

where

P_{dl} is as defined in Ch 2,5.2.1. T is as defined in Pt 3, Ch 1,6.

3.3.4 The bottom plating amidships is subjected to the following additional effective pressure, P_t:

$$P_t = 0,175P_{dl} + 10T \text{ kN/m}^2$$

where

P_{dl} is as defined in Ch 2,5.2.1. T is as defined in Pt 3, Ch 1,6.

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3.3.5 The dynamic shear force, Q_{MDW}, at any position along the craft is given by:

$$Q_{MDW} = \frac{4K_f M_{MD}}{L_S} \text{ kN}$$

where M_{MD} is as defined in 3.3.2. and K_f as defined in 2.4.1.

Section 4
Primary load criteria for multi-hull craft

4.1 General

4.1.1 For multi-hull craft, the strength of the cross deck structure is to be checked for the loadings specified in this Section, *see also* 5.3.

4.1.2 Other values may be used provided they are verified by model experiments, full scale measurements or any other generally accepted theories. Full details are to be submitted for appraisal.

4.1.3 L_R and T are as defined in Pt 3, Ch 1,6.

4.2 Global loads for multi-hull craft with partially submerged hulls

4.2.1 The twin hull transverse bending moment, M_B, about a longitudinal axis is given by:

$M_B = G_f b \Delta a_v$ kNm

where

a_v = the vertical acceleration as defined in Ch 2,3.2, *see also* 1.1.6

b = transverse distance, in metres, between the centre of the two hulls

G_f = service group factor, *see* Pt 1, Ch 2,3.5.5
= 1,25 for G1 and G2
= 1,50 for G3
= 2,00 for G4
= 2,50 for G5 and G6

Δ = displacement, in tonnes, as defined in Ch 2,2.2.2.

4.2.2 The twin hull torsional connecting moment, M_T, is given by:

$M_T = G_f \Delta L_R a_v$ kNm

where

G_f = service group factor, *see* Pt 1, Ch 2,3.5.5
= 0,63 for G1 and G2
= 0,75 for G3
= 1,00 for G4
= 1,25 for G5 and G6

Δ = displacement, in tonnes, as defined in Ch 2,2.2.2

L_R = Rule length, in metres, as defined in Pt 3, Ch 1,6

a_v = the vertical acceleration as defined in Ch 2,3.2, *see also* 1.1.6.

4.2.3 The vertical shear force, Q_T, at the centreline of the cross-deck structure between the twin hulls is given by:

$Q_T = G_f \Delta a_v$ kN

where

G_f = service group factor, *see* Pt 1, Ch 2,3.5.5
= 1,25 for G1 and G2
= 1,50 for G3
= 2,00 for G4
= 2,50 for G5 and G6

Δ = displacement, in tonnes, as defined in Ch 2,2.2.2

a_v = the vertical acceleration as defined in Ch 2,3.2, *see also* 1.1.6.

4.3 Global loads for multi-hull craft with fully submerged hulls

4.3.1 The design side force acting at mid-draught of the hull is given by:

$F_{FS} = G_f T \Delta^{2/3} \Psi_1 \Psi_2$ kN

where

G_f = service group factor, *see* Pt 1, Ch 2,3.5.5
= 8,5 for G1 and G2
= 10,2 for G3
= 13,6 for G4
= 17,0 for G5 and G6

Δ = displacement, in tonnes, as defined in Ch 2,2.2.2

$\Psi_1 = 1,55 - 0,75\tanh(\Delta/11000)$

$\Psi_2 = 0,75 + 0,35\tanh(1,64 L_S \Delta^{-1/3} - 6)$

L_S = strut length, in metres, at waterline.

4.3.2 The lateral pressure acting on the outboard hull may be assumed to be constant and is given by:

$$P_{FS} = \frac{F_{FS}}{A_{FS}} \text{ kN/m}^2$$

where A_{FS} is the projected area, in m^2, of the struts with length L_S at waterline at draught T.

4.3.3 The design transverse bending moment, M_B, due to the side force is given as:

$M_B = F_{FS}(F + 0,5T)$ kNm

where F is the distance, in metres, from the waterline to the top of cross structure.

4.3.4 The twin hull torsional connecting moment, M_T, is given by:

$M_T = G_f \Delta L_R a_v$ kNm

where

G_f = service group factor, *see* Pt 1, Ch 2,3.5.5
= 0,63 for G1 and G2
= 0,75 for G3
= 1,00 for G4
= 1,25 for G5 and G6

Δ = displacement, in tonnes, as defined in Ch 2,2.2.2

a_v = the vertical acceleration as defined in Ch 2,3.2, *see also* 1.1.6

L_R = Rule length, in metres, as defined in Pt 3, Ch 1,6

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4.3.5 The vertical shear force, Q_T, at the centreline of the cross-deck structure between the twin hulls is given by:

$Q_T = G_f \Delta a_v$ kN

where

G_f = service group factor, *see* Pt 1, Ch 2,3.5.5
= 1,25 for G1 and G2
= 1,50 for G3
= 2,00 for G4
= 2,50 for G5 and G6

Δ = displacement, in tonnes, as defined in Ch 2,2.2.2

a_v = the vertical acceleration as defined in Ch 2,3.2, *see also* 1.1.6.

■ *Section 5* Design criteria and load combinations

5.1 Hull girder design criteria for mono-hull craft

5.1.1 The Rule bending moment, M_R, and associated shear forces, Q_R, for non-displacement craft are to be determined as follows:

(a) The Rule bending moment, M_R, is to be taken as the greater of $(M_w + M_S)$, as defined in 2.2 and 2.3 and M_{DW}, as defined in 2.6, taking into account the hogging and sagging conditions.

(b) The Rule shear forces, Q_R, is to be taken as the greater of $(Q_w + Q_S)$, as defined in 2.4 and 2.5 and Q_{DW}, as defined in 2.6, taking into account of the hogging and sagging conditions.

5.1.2 The Rule bending moment, M_R, and associated shear forces, Q_R, for displacement craft are taken to be the greater of the following:

(a) The Rule bending moment, M_R, is to be taken as $(M_w + M_S)$, as defined in 2.2 and 2.3, taking into account the hogging and sagging conditions.

(b) The Rule shear forces, Q_R, are to be taken as $(Q_w + Q_S)$, as defined in 2.4 and 2.5, taking into account the hogging and sagging conditions.

5.1.3 L_R and B are as defined in Pt 3, Ch 1,6. Γ and Δ are defined in Ch 2,2.1.17 and Ch 2,2.2.2 respectively.

5.2 Hull girder design criteria for multi-hull craft

5.2.1 The Rule bending moment, M_R, and associated shear forces, Q_R, for non-displacement craft are to be determined as follows:

(a) The Rule bending moment, M_R, is to be taken as the greater of M_{MW}, as defined in 3.2 and M_{MDW}, as defined in 3.3, taking into account the hogging and sagging conditions.

(b) The Rule shear forces, Q_R, are to be taken as the greater of Q_{MW}, as defined in 3.2 and Q_{MDW}, as defined in 3.3, taking into account the hogging and sagging conditions.

5.2.2 The Rule bending moment, M_R, and associated shear forces, Q_R, for displacement craft are taken to be the greater of the following:

(a) The Rule bending moment, M_R, is to be taken as M_{MW}, as defined in 3.2, taking into account the hogging and sagging conditions.

(b) The Rule shear forces, Q_R, are to be taken as Q_{MW}, as defined in 3.2, taking into account the hogging and sagging conditions.

5.2.3 L_R and B are as defined in Pt 3, Ch 1,6. Γ and Δ are defined in Ch 2,2.1.17 and Ch 2,2.2.2 respectively.

5.3 Primary load combinations applicable to the cross-deck structure of multi-hull craft

5.3.1 If the global load criteria given in this Chapter are utilised to check cross-deck strength against ductile failure modes involving gross deformation, the following load combinations are to be considered depending on heading of the craft:

(a) Head sea
$0,1M_B + M_R + 0,1M_T$

(b) Beam sea
$M_B + 0,1M_R + 0,2M_T$

(c) Quartering sea
$0,1M_B + 0,4M_R + M_T$

M_B, M_T and M_R are to be taken from 4.2.1, 4.2.3 and 5.2 for multi-hull craft with partially submerged hulls.

M_B, M_T and M_R are to be taken from 4.3.1, 4.3.3 and 5.2 for multi-hull craft with fully submerged hulls.

5.3.2 The strength calculations are, in general, to be conducted using the finite element analysis techniques with a three dimensional model.

■ *Section 6* Loading guidance information

6.1 General

6.1.1 Sufficient information is to be supplied to every craft to enable the Master to arrange loading and ballasting in such a way as to avoid the creation of unacceptable stresses in the craft's structure.

6.1.2 This information is to be provided by means of a Loading Manual and in addition, where required, by means of an approved loading instrument.

6.1.3 An Operational manual which contains the craft's assigned operational envelope is to be provided on board, *see* Pt 1, Ch 2,2 and Ch 1,1.

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6.2 Loading Manuals

6.2.1 A Loading Manual is to be supplied to all craft where longitudinal strength calculations have been required, *see* Ch 5,1. The Manual is to be submitted for approval in respect of strength aspects. Where both Loading Manual and loading instrument are supplied the Loading Manual must nevertheless be approved from the strength aspect. In this case the Manual is to be endorsed to the effect that any departures from these conditions in service are to be arranged on the basis of the loading instrument and the allowable local loadings shown in the Manual.

6.2.2 The Loading Manual is to be based on the final data of the craft and is to include well-defined lightweight distribution and buoyancy data.

6.2.3 Details of the loading conditions are to be included in the manual as applicable.

6.2.4 The Loading Manual is also to contain the following:

(a) Values of actual and permissible still water bending moments and shear forces and where applicable limitations due to torsional loads.

(b) The allowable local loadings for the structure.

(c) Details of cargo carriage constraints imposed by the use of an accepted coating in association with a system of corrosion control.

(d) A note saying:
'Scantlings approved for minimum draught forward of ...m with ballast tanks No ... filled. In heavy weather conditions the forward draught is not to be less than this value. If, in the opinion of the Master, sea conditions are likely to cause regular slamming, then other appropriate measures such as change in speed, heading or an increase in draught forward may also need to be taken.'

6.2.5 Where alteration to structure, lightweight, cargo distribution or draught is proposed, revised information is to be submitted for approval.

6.3 Loading instrument

6.3.1 In addition to a Loading Manual, an approved type loading instrument is to be provided for craft when it is deemed necessary by Lloyd's Register (hereinafter referred to as LR).

6.3.2 The loading instrument is to be capable of calculating shear forces and bending moments, and where necessary cargo torque, in any load or ballast condition at specified readout points and is to indicate the permissible values. The instrument is to be certified in accordance with LR's *Approval of Longitudinal Strength and Stability Calculation Programs.*

6.3.3 The instrument readout points are usually selected at the position of the transverse bulkheads or other obvious boundaries. As many readout points as considered necessary by LR are to be included, e.g. between bulkheads.

6.3.4 A notice is to be displayed on the loading instrument stating:
'Scantlings approved for minimum draught forward of ... m with ballast tanks No ... filled. In heavy weather conditions the forward draught is not be to less than this value. If, in the opinion of the Master, sea conditions are likely to cause regular slamming, then other appropriate measures such as change in speed, heading or an increase in draught forward may also need to be taken.'

6.3.5 Where alteration to structure, lightweight or cargo distribution is proposed, the loading instrument is to be modified accordingly and details submitted for approval.

6.3.6 The operation of the loading instrument is to be verified by the Surveyor upon installation and at Annual and Periodical Surveys as required in Pt 1, Ch 3. An Operation Manual for the instrument is to be verified as being available on board.

6.3.7 Where an onboard computer system having a longitudinal strength or a stability computation capability is provided as an Owner's option, it is recommended that the system be certified in accordance with LR's document entitled *Approval of Longitudinal Strength and Stability Calculation Programs.* For systems having a stability computation capability and installed on a new ship, *see also* Pt 1, Ch 2,1.1.10. For systems having a stability computation capability and installed on an existing craft, it is recommended that the system be certified in accordance with LR's document entitled, *Approval of Longitudinal Strength and Stability Calculation Programs.*

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Rules and Regulations for the Classification of Special Service Craft

Volume 4
Part 6
Hull Construction in Ships
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Lloyd's Register
LIFE MATTERS

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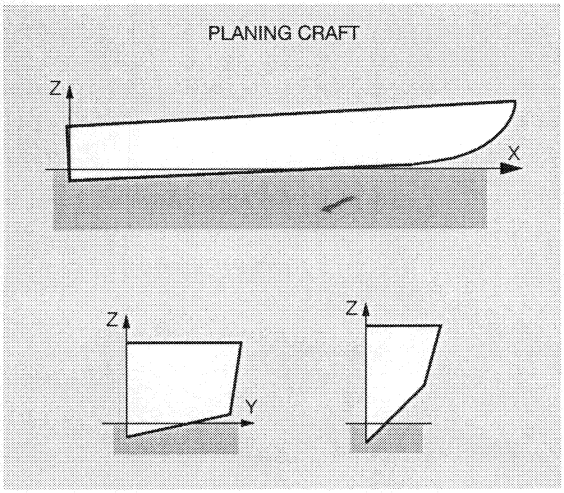
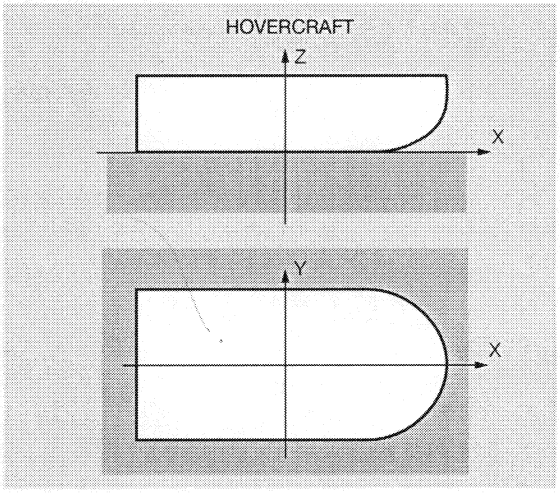
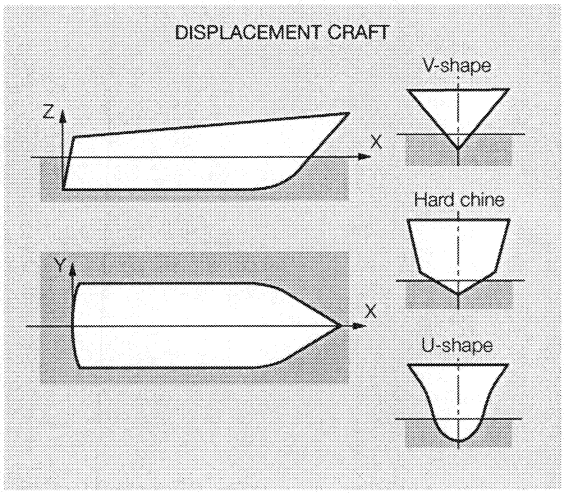
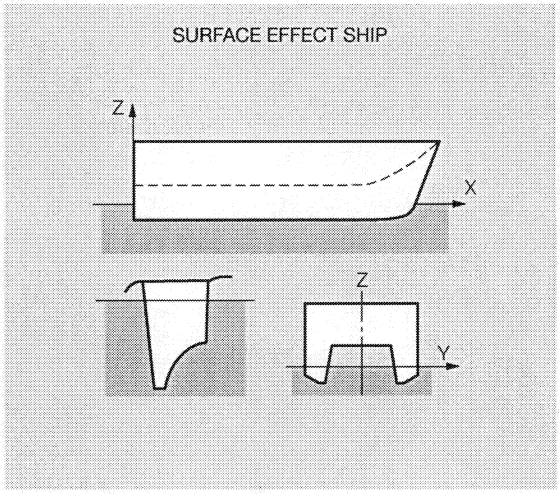
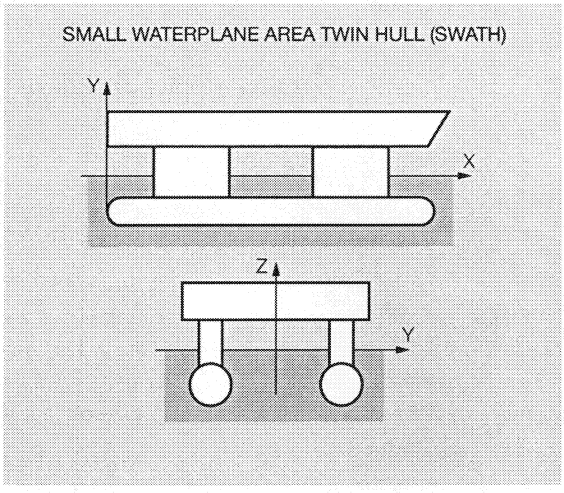
DIFFERENT TYPES OF HULL FORMS COVERED BY THE SPECIAL SERVICE CRAFT RULES

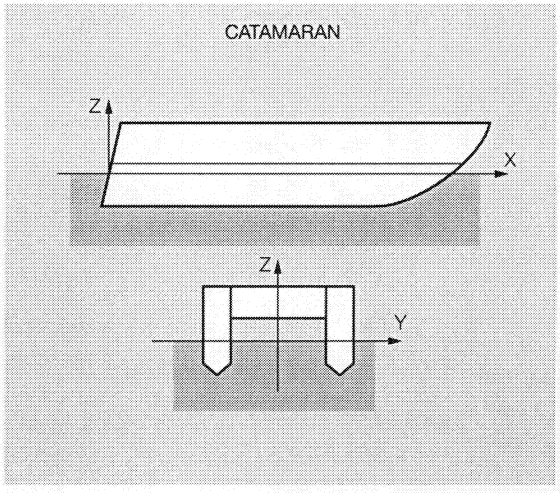












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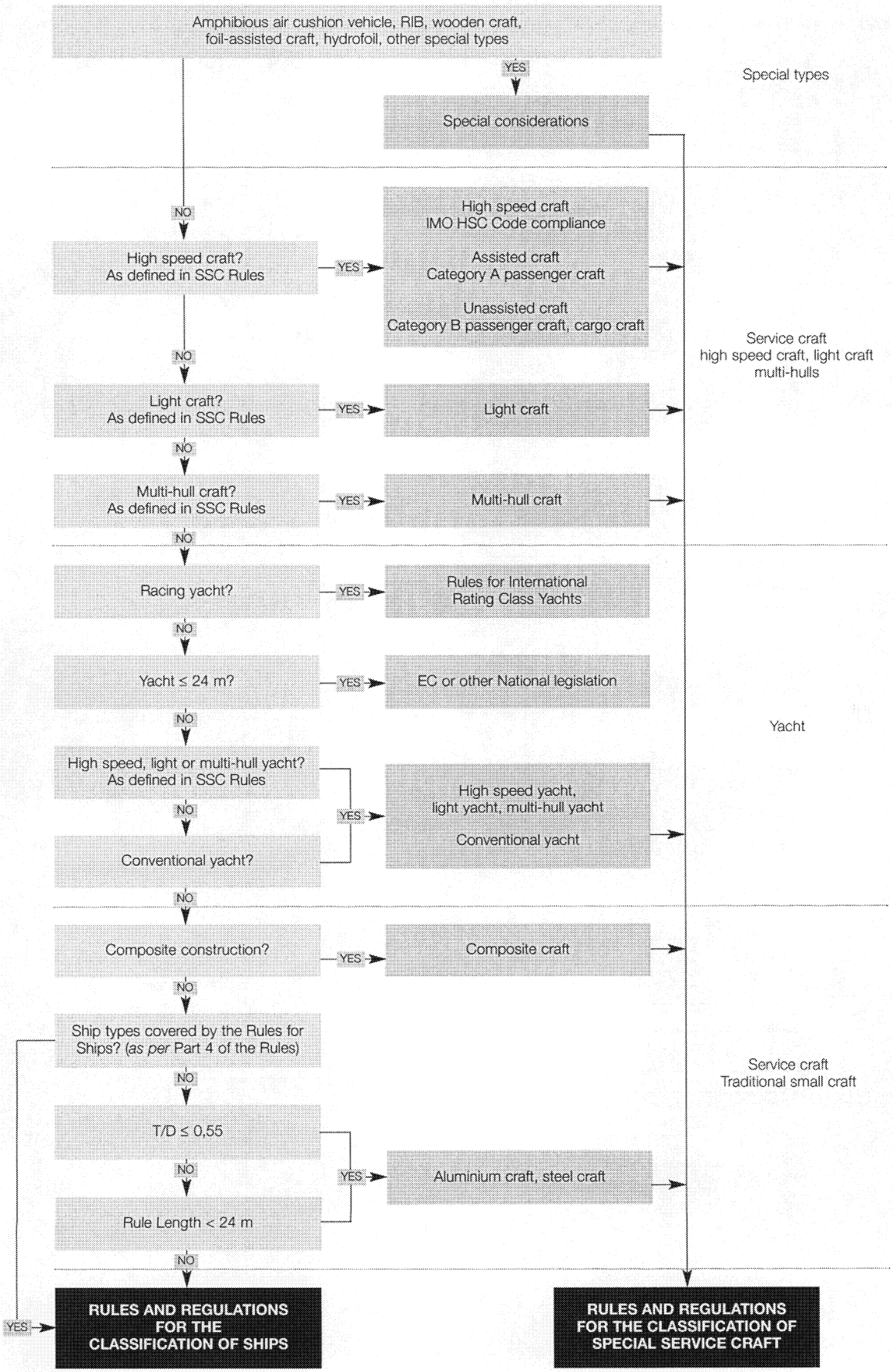

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Section

1 **Application**

2 **General requirements**

■ *Section 1* Application

1.1 General

1.1.1 The Rules apply to mono and multi-hull craft of normal form, proportions and speed. Although the Rules are, in general, for steel craft of all welded construction, other materials for use in hull construction will be specially considered on the basis of the Rules.

1.2 Interpretation

1.2.1 The interpretation of the Rules is the sole responsibility and at the sole discretion of Lloyd's Register (hereinafter referred to as 'LR'). Where there is any doubt regarding the interpretation of the Rules it is the Builders' and/or designers' responsibility to obtain clarification from LR prior to submission of plans and data for appraisal.

1.2.2 Where applicable, the Rules take into account unified requirements and interpretations established by the International Association of Classification Societies (IACS).

1.2.3 Attention is drawn to the fact that Codes of Practice issued by IMO contain requirements which are outside classification as defined in the Rules.

1.3 Equivalents

1.3.1 Alternative scantlings and arrangements may be accepted as equivalent to the Rule requirements. Details of such proposals are to be submitted for consideration in accordance with Pt 3, Ch 1,3.

1.4 Symbols and definitions

1.4.1 The symbols and definitions for use throughout this Part are as defined within the appropriate Chapters and Sections.

■ *Section 2* General requirements

2.1 General

2.1.1 Limitations with regard to the application of these Rules are indicated in the various Chapters for differing craft types.

2.2 Aesthetics

2.2.1 LR is not concerned with the general arrangement, layout and appearance of the craft; the responsibility for such matters remains with the Builders and/or designers to ensure that the agreed specification is complied with. LR is however concerned with the quality of workmanship, in this respect the acceptance criteria as required by Rules are to be complied with.

2.3 Constructional configuration

2.3.1 The Rules provide for the basic structural configurations for both single and multi-deck mono and multi-hull craft with multi-deck or a single deck hulls which include a double bottom, or a single bottom arrangement. The structural configuration may also include a single or multiple arrangement of cargo hatch openings, and side tanks.

2.3.2 The Rules provide for longitudinal and transverse framing systems.

2.3.3 Novel or other types of framing systems will be considered on the basis of the Rules.

2.4 Plans to be submitted

2.4.1 Plans covering the following items are to be submitted:

- Midship sections showing longitudinal and transverse material.
- Profile and decks.
- Shell expansion.
- Oiltight and watertight bulkheads.
- Propeller brackets.
- Double bottom construction.
- Pillars and girders.
- Aft end construction.
- Engine room construction.
- Engine and thrust seatings.
- Fore end construction.
- Hatch cover construction.
- Deckhouses and superstructures.
- Sternframe.
- Rudder, stock and tiller.
- Equipment.
- Loading Manuals, preliminary and final (where applicable).
- Scheme of corrosion control (where applicable).
- Ice strengthening.
- Welding schedule.

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- Hull penetration plans.
- Support structure for masts, derrick posts or cranes.
- Bilge keels showing material grades, welded connections and detail design.

2.4.2 The following supporting documents are to be submitted:

- General arrangement.
- Capacity plan.
- Lines plan or equivalent.
- Dry-docking plan.
- Towing and mooring arrangements.
- Sail/rigging plan, indicating loadings (as applicable to sailing craft).

2.4.3 The following supporting calculations are to be submitted:

- Equipment Number.
- Hull girder still water and dynamic bending moments and shear forces as applicable.
- Midship section modulus.
- Structural items in the aft end, midship and fore end regions of the craft.
- Preliminary freeboard calculation.

2.5 Novel features

2.5.1 Where the proposed construction of any part of the hull or machinery is of novel design, or involves the use of unusual material, or where experience, in the opinion of LR, has not sufficiently justified the principle or mode of application involved, special tests or examinations before and during service may be required. In such cases a suitable notation may be entered in the *Register Book*.

2.6 Enhanced scantlings

2.6.1 Where the Owner decides to increase the scantling of the bottom shell, side shell and deck plating of a newbuilding, then the craft will be eligible to be assigned the description note **ES**, *see* Pt 1, Ch 2,3.12. For example, the descriptive note **ES+1** would indicate that an extra 1 mm of steel has been fitted to bottom shell, side shell and deck plating.

2.7 Direct calculations

2.7.1 Direct calculations may be specifically required by the Rules and may be required for craft having novel design features or in support of alternative arrangements and scantlings. LR may, when requested, undertake calculations on behalf of designers and make recommendations with regard to suitability of any required model tests.

2.7.2 Where direct calculations are proposed then the requirements of Pt 3, Ch 1,2 are, in general, to be complied with.

2.8 Exceptions

2.8.1 Craft of unusual form, proportions or speed, intended for the carriage of special cargoes, or for special or restricted service, not covered specifically by the Rules, will receive individual consideration based on the general requirements of the Rules.

2.9 Advisory services

2.9.1 The Rules do not cover certain technical characteristics, such as stability, except as mentioned in Pt 1, Ch 2,1.1.11, 1.1.13 and 1.1.14, trim, vibration (other than local stiff end flat panels, *see* Ch 1,5), docking arrangements, etc. The Committee cannot assume responsibility for these matters but is willing to advise upon them on request.

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Section

1 **General**

2 **Materials**

3 **Procedures for welded construction**

4 **Joints and connections**

Section 1 General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull and multi-hull craft of steel construction as defined in Pt 1, Ch 1,1.

1.2 General

1.2.1 This Chapter contains the general Rule requirements for the construction of steel craft using electric arc welding processes. Where alternative methods of construction are proposed, details are to be submitted for consideration by Lloyd's Register (hereinafter referred to as 'LR').

1.3 Symbols and definitions

1.3.1 The symbols and definitions used in this Chapter are defined in the appropriate Section.

1.4 Builder's facilities

1.4.1 The buildings used for production and storage are to be of suitable construction and equipped to provide the required environment, and are also to comply with any local or National Authority requirements.

1.4.2 The Surveyor is to be allowed unrestricted access during working hours to such parts of the Builder's establishment as may be necessary to ensure that the requirements of the Rules are being complied with.

1.5 Works inspection

1.5.1 Prior to the commencement of construction, the facilities are to be inspected to the satisfaction of the attending Surveyor. This will include the minimum quality control arrangements outlined in 1.6.

1.5.2 The Surveyor is to be satisfied that the Builder has the organisation and capability to construct craft to the standards required by the Rules.

1.5.3 The Builder is to be advised of the result of the inspection and all deficiencies are to be rectified prior to the commencement of production.

1.5.4 Where structural components are to be assembled and welded by sub-contractors, the Surveyors are to inspect the sub-contractor's works to ensure that compliance with the requirements of this Chapter can be achieved.

1.6 Quality control

1.6.1 For compliance with 1.5.2, LR's methods of survey and inspection for hull construction and machinery installation are to include procedures involving the shipyard management, organisation and quality systems.

1.6.2 The extent and complexity of the quality systems will vary considerably depending on the size and type of craft and production output. LR will consider certification of the Builder in accordance with the requirements of one of the following systems:

(a) Quality Assurance System in accordance with an International or National Standard (i.e. ISO 9000 and BS ENISO 9001) with assessment and certification carried out by a nationally accredited body.

(b) LR's Quality Assurance Scheme for the Construction of Special Service Craft.

(c) LR's locally accepted Quality Control System – The Builder is implementing a documented Quality Control System which controls the following activities:
  (i) Receipt storage and issue of materials, equipment, etc.
  (ii) Fabrication environment.
  (iii) Weld procedures and welder performance.
  (iv) Production fabrication.
  (v) Inspection of production processes.
  (vi) Installation of machinery and essential systems.
  (vii) Fitting-out.
  (viii) Tests and trials.
  (ix) Drawings and document control.
  (x) Records.

1.6.3 LR's involvement is only in that part of the system which controls the standards required to meet the classification requirements.

1.6.4 The 'documented' quality control system will in general require the Builder to have written procedures that describe clearly and unambiguously how each of the activities specified in 1.6.2(c) is carried out, when it is carried out and by whom. These procedures will form part of the system manual which is also to contain a statement of management policy, organisation chart and statements of responsibilities. The manual is to be controlled in respect to the formal issue and revision.

1.6.5 Further details of LR's requirements are available on request from the local LR office.

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1.7 Building environment

1.7.1 The craft is to be suitably protected during the building period from adverse weather and climatic conditions.

1.8 Storage areas

1.8.1 All materials are to be stored safely and in accordance with the manufacturer's requirements. Storage arrangements are to be such as to prevent deterioration through contact with heat, sunlight, damp, cold and poor handling.

1.8.2 All storage spaces provided by the Builder for welding consumables are to be suitable for maintaining them in good condition and are to be in accordance with the manufacturer's recommendations.

1.8.3 All materials are to be fully identifiable in the storage areas, and identification is to be maintained during issue to production.

1.8.4 Material suspected of being non-conforming is to be segregated from acceptable materials.

1.9 Materials handling

1.9.1 The Builder is to maintain purchasing documents containing a clear description of the materials ordered for use in hull construction and the standards to which the material must conform, together with the identification and certification requirements.

1.9.2 The Builder is to be responsible for ensuring that all incoming plates, sections, castings, components, fabrications and consumables and other materials used in the hull construction are inspected or otherwise verified as conforming to purchase order requirements.

1.9.3 The Builder is to have procedures for the inspection, storage and maintenance of Owner supplied materials and equipment.

1.9.4 The Builder is to record, on receipt, the manufacturing date, or use-by date of critical materials. Any materials which have a shelf life are to be used in order of manufacturing date to ensure stock rotation.

1.9.5 The Builder is to establish and maintain a procedure to ensure that materials and consumables used in the hull construction process are identified (by colour-coding and/or marking as appropriate) from arrival in the yard through to fabrication in such a way as to enable the type and grade to be readily recognised.

1.9.6 Where materials are found to be defective they are to be rejected in accordance with the Builder's quality control procedure.

1.10 Faults

1.10.1 All identified faults are to be recorded under the requirements of the quality control systems. Faults are to be classified according to their severity and are to be monitored during Periodical Survey.

1.10.2 Production faults are to be discussed with the attending Surveyor and a rectification scheme agreed. Deviations from the approved plans are to be locally approved by the attending Surveyor and a copy forwarded to the plan approval office for record purpose.

1.11 Inspection

1.11.1 On acceptance of a 'Request for Services' the attending Surveyor is to inform the Builder of the key stages of the production that are to be inspected and the extent of the inspection to be carried out.

1.11.2 It is the Builder's responsibility to carry out required inspections in accordance with the accepted quality control system.

1.11.3 It is the Surveyor's responsibility to monitor the Builder's quality control records and carry out inspections at key stages and during periodic visits.

1.11.4 Adequate facilities are to be provided to enable the Surveyor to carry out a satisfactory inspection and to facilitate subsequent in-service maintenance. These are to include the provision of access holes in restricted spaces and removable deck head and shipside linings, cabin soles, etc.

1.11.5 During inspections all deviations are to be dealt with in accordance with 1.6.4.

1.12 Acceptance criteria

1.12.1 Classification is dependent upon the work being carried out in accordance with the approved plans and the requirements of an accepted quality control system.

1.12.2 The work is to be carried out to the satisfaction of the attending Surveyor. This will include the verification of the quality control documentation and the remedial action associated with all defects and deficiencies recorded.

1.12.3 Proposed deviations from the approved plans are subject to LR approval and in the first instance are to be discussed with the attending Surveyor. Where applicable, an amended plan is to be submitted to the plan appraisal office. Such deviations will be recorded as endorsements to the classification unless specifically agreed otherwise with the plan appraisal office.

1.12.4 Where the above requirements are met the attending Surveyor will arrange for the relevant certification to be issued.

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1.13 Repair

1.13.1 Minor repairs are to be agreed with the attending Surveyor and a rectification scheme agreed with the Builder. The Builder is to incorporate details of the agreed repair procedures in the quality control system in accordance with 1.6.4.

1.13.2 Repairs which affect the structural integrity are to be discussed with the Builder and the Builder's proposed rectification scheme is to be submitted to the plan appraisal office for consideration.

■ *Section 2* Materials

2.1 General

2.1.1 The materials used in the construction of the craft are to be manufactured and tested in accordance with the appropriate requirements of Chapter 3 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

2.1.2 All materials are to be manufactured at works which have been approved by LR for the type and, where appropriate, grade of steel which is being supplied and for the relevant steel production and processing route.

2.2 Grade of steel

2.2.1 The grade of steel, supply condition and its mechanical properties are to be indicated on the construction plans.

2.2.2 When plate material, intended for welded construction, will be subject to significant strains in a direction perpendicular to the rolled surfaces, it is recommended that consideration be given to the use of special plate material with specified through thickness properties, and tested in accordance with Ch 3,8 of the Rules for Materials.

2.3 Steel castings and forgings

2.3.1 Where steel castings or forgings are used for stern-frames, rudder frames, rudder stocks, propeller shaft brackets and other major structural items, they are to comply with Chapter 4 or Chapter 5, as appropriate.

2.4 Mechanical properties for design

2.4.1 The scantlings determined within this Part of the Rules assume that mild steel has the following mechanical properties:

	N/mm^2
Yield strength (minimum)	235
Tensile strength	400 – 490
Modulus of elasticity	200 x 10^3

2.4.2 Steel having a specified minimum yield stress of 235 N/mm^2 (24 kgf/mm^2) is regarded as mild steel. Steel having a higher specified minimum yield stress is regarded as higher tensile steel.

2.4.3 The requirements for global strength considerations in craft incorporating higher tensile steel materials are to be based on a material efficiency factor, η_{HTS}, as given in Table 2.2.1.

Table 2.2.1 Values of η_{HTS}

Specified minimum yield stress in N/mm^2	η_{HTS}
235	1,000
265	0,964
315	0,956
340	0,934
355	0,919
390	0,886
NOTE Intermediate values by interpolation.	

2.4.4 The local scantling requirements of higher tensile steel plating, longitudinals, stiffeners and girders may be based on a k_s factor determined as follows:

$$k_s = \frac{235}{\sigma_s}$$

or 0,66 whichever is the greater

where

σ_s = specified minimum yield strength of material, in N/mm^2.

2.4.5 For the application of the requirements of 2.4.3 and 2.4.4 special consideration will be given to steel where $\sigma_s \geq 390$ N/mm^2. Where such steel grades are used in areas which are subject to fatigue loading the structural details are to be verified using fatigue design assessment methods.

2.5 Corrosion protection

2.5.1 All steelwork, except inside integral fuel tanks, is to be suitably protected against corrosion. This may be by coating or, where applicable, by a system of cathodic protection.

2.5.2 Steelwork is to be suitably cleaned and cleared of millscale before the application of any coating. It is recommended that blast cleaning, or other equally effective means, be employed for this purpose.

2.5.3 Where an impressed current cathodic protection system is fitted, plans showing the proposed layout of anodes and hull penetrations are to be submitted.

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2.6 Paints and coatings

2.6.1 The hull is to be protected against corrosion by a suitable protective coating. All coatings are to be in accordance with the requirements of this Section.

2.6.2 Where a primer is used to coat steel after surface preparation and prior to fabrication, the composition of the coating is to be such that it will have no significant deleterious effect on subsequent welding work and that it is compatible with the paints or other coatings subsequently applied in association with an approved system of corrosion control.

2.6.3 Paints or other coatings are to be suitable for the intended purpose in the locations where they are to be used. Coatings are to be of adequate film thickness, applied in accordance with the paint manufacturer's specification.

2.6.4 Integral fuel tanks are to be cleaned and dried, after testing, and then treated with a suitable coating, in accordance with the manufacturer's recommendations.

2.6.5 Paints, varnishes and similar preparations having a nitro-cellulous or other highly flammable base are not to be used in accommodation or machinery spaces.

2.6.6 Protective coatings are generally to be hard coatings. Other coating systems (e.g. soft coatings) may be considered as alternatives provided they are applied and maintained in compliance with the manufacturer's specification.

2.6.7 The paint or coating is to be compatible with any previously applied primer, *see* 2.6.

2.7 Galvanic action

2.7.1 Where bimetallic connections are made, involving dissimilar metals, measures are to be incorporated to preclude galvanic corrosion. In order to prevent galvanic corrosion, special attention is to be given to the penetrations of, and connections to the hull, bulkheads and decks by piping and, equipment where dissimilar materials are involved.

2.8 Bimetallic connections

2.8.1 The design shall ensure that the location of all bimetallic connections allows for regular inspection and maintenance of the joints and penetrations during service.

2.9 External immersed areas

2.9.1 For the deferment of dry docking or where an **IWS** (In-water Survey) notation is to be assigned protection of the underwater portion of the hull is to be provided by means of a suitable high resistant paint applied in accordance with the manufacturer's requirements. Details of the high resistant paint are to be submitted for information.

2.10 External cathodic protection

2.10.1 Where an impressed current cathodic protection system is fitted, plans showing the proposed layout of anodes, reference cells, wiring diagram and the means of bonding-in of the rudder and propeller, are to be submitted.

2.10.2 The arrangement for glands, where cables pass through the shell, are to include a small cofferdam. Cables to anodes are not to be led through tanks containing low flash point oils.

2.11 Protection of ballast spaces

2.11.1 Cathodic protection may be used in association with coatings for the protection of ballast spaces.

2.11.2 The anodes are to be of approved design and sufficiently rigid to avoid resonance in the anode support. Steel cores are to be fitted, and these are to be so designed as to retain the anode even when the latter is wasted.

2.11.3 Anodes are to be attached to the structure in such a way that they remain secure both initially and during service. The following methods of attachment would be acceptable:

(a) Steel core connected to the structure by continuous welding of adequate section.

(b) Steel core bolted to separate supports, provided that a minimum of two bolts with lock nuts are used at each support. The separate supports are to be connected to the structure by continuous welding of adequate section.

(c) Approved means of mechanical clamping.

2.11.4 Anodes are to be attached to stiffeners, or may be aligned in way of stiffeners on plane bulkhead plating, but they are not to be attached to the shell. The two ends are not to be attached to separate members which are capable of relative movement.

2.11.5 Where cores or supports are welded to the main structure, they are to be kept clear of the toes of brackets and similar stress raisers. Where they are welded to asymmetrical stiffeners, they are to be connected to the web with the welding kept at least 25 mm away from the edge of the web. In the case of stiffeners or girders with symmetrical face plates, the connection may be made to the web or to the centreline of the face plate but well clear of the free edges. However, it is recommended that anodes are not fitted to face plates of higher tensile steel longitudinals.

2.12 Deck coverings

2.12.1 Where plated decks are sheathed with wood, the sheathing is to be efficiently attached to the deck, caulked and sealed, to the satisfaction of the Surveyor in accordance with the approved drawings.

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2.12.2 Deck coverings in the following positions are to be of a type which will not readily ignite when used on decks:

(a) Forming the crown of machinery or cargo spaces within accommodation spaces of cargo craft.

(b) Within accommodation spaces, control stations, stairways and corridors of passenger craft.

2.13 Corrosion margin

2.13.1 The scantlings determined from the formulae provided in the Rules assume that the materials used are selected, manufactured and protected in such a way that there is negligible loss in strength by corrosion.

2.13.2 Where steel is not protected against corrosion, by painting or other approved means, the scantlings may require to be further considered.

2.14 Fracture control

2.14.1 Construction procedures, materials and welding are to be in accordance with the requirements of this Chapter such that stress corrosion cracking is avoided.

2.14.2 High local stresses are to be avoided by the use of suitable design detail. *See also* LR's *Guidance Notes for Structural Details*.

2.14.3 The resistance to fracture is controlled, in part, by the notch toughness of the steel used in the structure. Steels with different levels of notch toughness are specified in the Rules for Materials. The grade of steel to be used is, in general, related to the thickness of the material and the stress pattern associated with its location.

2.14.4 Where tee or cruciform connections employ full penetration welds, and the plate material is subject to significant strains in a direction perpendicular to the rolled surfaces, it is recommended that consideration be given to the use of special plate material with specified through thickness properties, as detailed in Ch 3,8 of the Rules for Materials.

2.14.5 For craft operating for long periods in low air temperature the material of exposed structures will, in general, be specially considered.

■ *Section 3* Procedures for welded construction

3.1 General

3.1.1 All welded construction is to be conducted in accordance with the requirements specified in Chapter 13 of the Rules for Materials.

3.2 Information to be submitted

3.2.1 The plans and information submitted for approval are to clearly indicate details of the welded connections of the main structural members, including the type, disposition and size of welds.

3.3 Defined practices and welding sequence

3.3.1 Rudder, sterntubes, propeller brackets and jet units. The final boring out of propeller brackets and sterntubes and the fit-up and alignment of rudder bearings and jet units are to be carried out after the major part of the welding of the aft end of the craft is complete. The contacts between rudder stocks and propeller shafts with bearings are to be checked before the final mounting.

3.4 Structural arrangements and access

3.4.1 Ceilings, cabin sole, side and overhead linings are to be secured in such a manner as to be easily removed for the maintenance and inspection of the structure below.

3.5 Inspection

3.5.1 Inspection of welded construction is to be conducted in accordance with the requirements specified in Chapter 13 of the Rules for Materials.

3.5.2 Checkpoints examined at the pre-fabrication stage are to include ultrasonic testing on examples of the stop/start points of automatic welding and magnetic particle inspections of weld ends.

3.5.3 Typical locations for volumetric examination and number of checkpoints to be taken are shown in Table 2.3.1. A list of the proposed items to be examined is to be submitted for approval.

3.6 Acceptance criteria

3.6.1 All finished welds are to be sound and free from cracks and substantially free from lack of fusion, incomplete penetration, porosity and tungsten inclusions. The surfaces of welds are to be reasonably smooth and substantially free from undercut and overlap. Care is to be taken to ensure that the specified dimensions of welds have been achieved and that both excessive reinforcement and underfill of welds are avoided.

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Table 2.3.1 Non-destructive examinations of welds

Volumetric non-destructive examinations – Recommended extent of testing, *see* 3.5.3		
Item	Location	Checkpoints, *see* Note 1
Intersections of butts and seams of fabrication and section welds	Throughout: • hull envelope • longitudinal and transverse bulkheads • inner bottom and hopper bottom	The summation of checkpoint lengths, *see* Note 2, examined at intersections is to be *L*, where *L* is the overall length of the ship in metres
Butt welds in plating	Throughout	1 m in 25 m, *see* Note 3
Seam welds in plating	Throughout	1 m in 100 m
Butts in longitudinals	Hull envelope within 0,4*L* amidships Hull envelope outside 0,4*L* amidships	1 in 10 welds 1 in 20 welds
Bilge keel butts	Throughout	1 in 10 welds
Structural items when made with full penetration welding as follows: • connection of stool and bulkhead to lower stool shelf plating • vertical corrugations to an inner bottom • hopper knuckles • sheerstrake to deck stringer • hatchways coaming to deck	Throughout	1 m in 20 m

NOTES
1. The length of each checkpoint is to be between 0,3 m and 0,5 m.
2. For checkpoints at intersections the measured dimension of length is to be in the direction of the butt weld.
3. Checkpoints in butt welds and seam welds are in addition to those at intersections.
4. Agreed locations are not to be indicated on the blocks prior to the welding taking place, nor is any special treatment to be given at these locations.
5. Particular attention is to be given to repair rates in longitudinal butts. Additional welds are to be tested in the event that defects, such as lack of fusion or incomplete penetrations, are repeatedly observed.

■ *Section 4* Joints and connections

4.1 General

4.1.1 Requirements are given in this Chapter for welding connection details, aluminium/steel transition joints, steel/wood connection, riveting of light structure and chemical bonding.

4.1.2 Welded joints are to be detailed such that crevices or inaccessible pockets capable of retaining dirt or moisture are avoided. Where cavities are unavoidable, they are to be sealed by welding or protective compounds or made accessible for inspection and maintenance.

4.2 Weld symbols

4.2.1 Weld symbols, where used, are to conform to a recognised National or International Standard. Details of such Standards are to be indicated on the welding schedule, which is to be submitted for appraisal.

4.3 Welding schedule

4.3.1 A welding schedule containing not less than the following information is to be submitted:
(a) Weld throat thickness or leg lengths.
(b) Grades, tempers, and thicknesses of materials to be welded.
(c) Locations, types of joints and angles of abutting members.
(d) Reference to welding procedures to be used.
(e) Sequence of welding of assemblies and joining up of assemblies.

4.4 Butt welds

4.4.1 All structural butt joints are to be made by means of full penetration welds and, in general, the edges of plates to be joined by welding are to be bevelled on one or both sides of the plates. Full details of the proposed joint preparation are to be submitted for approval, *see also* 4.24.

4.4.2 Where butt welds form a T-junction, the leg of the T is, where practicable, to be completed first including any back run. During the welding operation special attention is to be given to the completion of the weld at the junction, which is to be chipped back to remove crater cracks, etc., before the table is welded.

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4.5 Fillet welds

4.5.1 The throat thickness of fillet welds is to be determined from:

$$\text{Throat thickness} = t_p \times \text{weld factor} \times \left(\frac{d}{s}\right) \text{ mm}$$

where

s = the length of correctly proportioned weld fillet, clear of end craters, in mm, and is to be 10 x plate thickness, t_p, or 75 mm, whichever is the lesser, but in no case to be taken less than 40 mm

d = the distance between successive weld fillet, in mm

t_p = plate thickness, in mm, on which weld fillet size is based, *see* 4.5.6

Weld factors are contained in Table 2.4.1.

NOTE

For double continuous fillet welding $\left(\frac{d}{s}\right)$ is to be taken as 1, *see* 4.8.1.

4.5.2 For ease of welding, it is recommended that the ratio of the web height to the flange breadth is greater than or equal to 1,5, *see* Fig. 2.4.1.

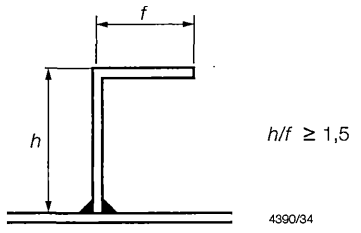

Fig. 2.4.1 Web height/flange breadth ratio

4.5.3 The leg length of the weld is to be not less than $\sqrt{2}$ times the specified throat thickness.

4.5.4 The plate thickness t_p to be used in 4.5.2 is generally to be that of the thinner of the two parts being joined. Where the difference in thickness is considerable, the size of fillet weld will be specially considered.

4.6 Throat thickness limits

4.6.1 The throat thickness limits given in Table 2.4.2 are to be complied with.

4.7 Double continuous fillet welding

4.7.1 Where double continuous fillet welding is proposed the throat thickness is to be in accordance with 4.5.2 taking $\left(\frac{d}{s}\right)$ equal to 1.

4.7.2 Double continuous fillet welding is to be adopted in the following locations and may be used elsewhere if desired:

(a) Boundaries of weathertight decks and erections, including hatch coamings, companionways and other openings.

(b) Boundaries of tank and watertight compartments.

(c) Main engine seatings.

(d) Bottom framing structure in machinery spaces of high speed craft.

(e) The side and bottom shell structure in the impact area of high speed motor craft.

(f) The underside of the cross-deck structure in the impact area of high speed multi-hull craft.

(g) Structure in way of ride control systems, stabilisers, thrusters, bilge keels, foundations and other areas subject to high stresses.

(h) The shell structure in the vicinity of the propeller blades.

(j) Stiffening members to plating in way of end connections scallops and of end brackets to plating in the case of lap connections.

(k) Primary and secondary members to plating in way of end connections, and end brackets to plating in the case of lap connections.

(l) Face flats to webs of built-up/fabricated stiffening members in way of knees/end brackets and for a distance beyond such knees/end brackets of not less than the web depth of stiffener in way.

4.8 Intermittent fillet welding (staggered)

4.8.1 Staggered intermittent welding may be used, outside of the impact area in the bottom shell or crossdeck structure of high speed craft.

4.9 Intermittent fillet welding (chain)

4.9.1 Chain intermittent welding may be used, outside of the impact area in the bottom shell or crossdeck structure of high speed craft.

4.10 Single sided fillet welding

4.10.1 Continuous single sided fillet welding may be used in lieu of intermittent fillet welding (staggered and chain), outside of the impact area in the bottom shell or crossdeck structure of high speed craft.

4.11 Connections of primary structure

4.11.1 Depending on the structural design of the joint and design loads on the primary member, full penetration welding of flanges and web plates may be required to attain full section properties in the end connections of primary members. *See also* Ch 3,1.22. Otherwise weld factors for the connections of primary structure are given in Table 2.4.1.

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Table 2.4.1 Weld factors (*see continuation*)

Item	Weld Factor	Remarks
(1) General application:		except as required below
Watertight plate boundaries	0,34	
Non-tight plate boundaries	0,13	
Longitudinals,frames,beams, and other secondary members to shell, deck or bulkhead plating	0,10 0,13 0,21	 in tanks in way of end connections
Panel stiffeners	0,10	
Overlap welds generally	0,27	
(2) Bottom construction:		
Non-tight centre girder: to keel to inner bottom	0,27 0,21	 no scallops
Non-tight boundaries of floors, girders and brackets	0,21 0,27	in way of 0,2 x span at ends in way of brackets at lower end of main frame
Inner bottom longitudinals, or face flat to floors reverse frames	0,13	
Connection of floors to inner bottom where bulkhead is supported on tank top. The supporting floors are to be continuously welded to the inner bottom	0,44	Weld size based on floor thickness Weld material compatible with floor material
(3) Hull framing:		
Webs of web frames and stringers: to shell to face plate	 0,16 0,13	
(4) Decks and supporting structure:		
Weather deck plating to shell	0,44	
Other decks to shell and bulkheads (except where forming tank boundaries)	0,21	generally continuous
Webs of cantilevers to deck and to shell in way of root bracket	0,44	
Webs of cantilevers to face plate	0,21	
Girder webs to deck clear of end brackets	0,10	
Girder webs to deck in way of end brackets	0,21	
Web of girder to face plate	0,10	
Pillars: fabricated end connections end connections (tubular)	0,10 0,34 full penetration	
Girder web connections and brackets in way of pillar heads and heels	0,21	continuous

4.11.2 The weld connection to shell, deck or bulkhead is to take account of the material lost in the notch where longitudinals or stiffeners pass through the member. Where the width of notch exceeds 15 per cent of the stiffener spacing, the weld factor is to be multiplied by:

$$\frac{0{,}85 \times \text{stiffener spacing}}{\text{length of web plating between notches}}$$

4.11.3 Where direct calculation procedures have been adopted, the weld factors for the 0,2 x overall length at the ends of the members will be considered in relation to the calculated loads.

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Table 2.4.1 Weld factors (*continued*)

Item	Weld Factor	Remarks
(5) Bulkheads and tank construction:		
Plane and corrugated watertight bulkhead boundary at bottom , bilge, inner bottom, deck and connection to shelf plate, where fitted	0,44	weld size to be based on thickness of bulkhead plating weld material to be compatible with bulkhead plating material
Secondary members, where acting as pillars	0,13	
Non-watertight pillar bulkhead boundaries	0,13	
Perforated flats and wash bulkhead boundaries	0,10	
Deep tank horizontal boundaries at vertical corrugations	full penetration	
(6) Structure in machinery space:		
Centre girder to keel and inner bottom	0,27	no scallops to inner bottom
Floors to centre girder in way of engine thrust bearers	0,27	
Floors and girders to shell and inner bottom	0,21	
Main engine foundation girders: to top plate to hull structure	 deep penetration to depend on design	 edge to be prepared with maximum root $0,33t_p$ deep penetration generally
Floors to main engine foundation girders	0,27	
Brackets, etc., to main engine foundation girders	0,21	
Transverse and longitudinal framing to shell	0,13	
(7) Superstructures and deckhouses:		
Connection of external bulkheads to deck	0,34 0,21	1st and 2nd tier erections elsewhere
Internal bulkheads	0,13	
(8) Steering control systems:		
Rudder: Fabricated mainpiece and mainpiece to side plates and webs	 0,44	
Slot welds inside plates	0,44	
Remaining construction	0,21	
Fixed and steering nozzles: Main structure Elsewhere	 0,44 0,21	
Fabricated housing and structure of thruster units, stabilisers, etc.: Main structure Elsewhere	 0,44 0,21	

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Table 2.4.1 Weld factors (*conclusion*)

Item	Weld Factor	Remarks
(9) Miscellaneous fittings and equipment:		
Rings for manhole type covers, to deck or bulkhead	0,34	
Frames of shell and weathertight bulkhead doors	0,34	
Stiffening of doors	0,21	
Ventilator, air pipes, etc., coamings to deck	0,34 0,21	Load Line Position 1 and 2 elsewhere
Ventilator, etc., fittings	0,21	
Scuppers and discharges, to deck	0,44	
Masts, crane pedestals, etc., to deck	0,44	full penetration welding may be required
Deck machinery seats to deck	0,21	generally
Mooring equipment seats	0,21	generally, but increased or full penetration may be required
Bulwark stays to deck	0,21	
Bulwark attachment to deck	0,34	
Guard rails, stanchions, etc., to deck	0,34	
Bilge keel ground bars to shell	0,34	continuous fillet weld, minimum throat thickness 4 mm
Bilge keels to ground bars	0,21	light continuous or staggered intermittent fillet weld, minimum throat thickness 3 mm
Fabricated anchors	full penetration	

Table 2.4.2 Throat thickness limits

Item	Throat thickness mm	
	Minimum	Maximum
(1) Double continuous welding	$0,21t_p$	$0,44t_p$
(2) Intermittent welding	$0,27t_p$	$0,44t_p$ or 4,5
(3) Overriding minimum:		
(a) Continuous welds	2,5	—
(b) Intermittent welds:		
(i) Plate thickness $t_p \leq 7,5$ mm		
Hand or automatic welding	3,0	—
Automatic deep penetration welding	3,0	—
(ii) Plate thickness $t_p \geq 7,5$ mm Hand or automatic welding	3,25	—
Automatic deep penetration welding	3,0	—

NOTES
1. *In all cases* the limiting value is to be taken as the greatest of the applicable values above.
2. The maximum throat thicknesses shown are intended only as a design limit for the approval of fillet welded joints. Any welding in excess of these limits is to be to the Surveyor's satisfaction.

4.12 Primary and secondary member end connection welds

4.12.1 Welding of end connections of primary members is to be such that the area of welding is not less than the cross-sectional area of the member, and the weld factor is to be not less than 0,34 in tanks or 0,27 elsewhere.

4.12.2 The welding of secondary member end connections is to be not less than as required by Table 2.4.3. Where two requirements are given the greater is to be complied with.

4.12.3 The area of weld, A_w, is to be applied to each arm of the bracket or lapped connection.

4.12.4 Where a longitudinal strength member is cut at a primary support and the continuity of strength is provided by brackets, the area of weld is to be not less than the cross-sectional area of the member.

4.13 Weld connection of strength deck plating to sheerstrake

4.13.1 The weld connection of strength deck plating to sheerstrake is to be by double continuous fillet welding with a weld factor of 0,44. The welding procedure, including joint preparation, is to be specified and the procedure qualified and approved for individual Builders.

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Table 2.4.3 Secondary member end connection welds

Connection	Weld area, A_w, in cm^2	Weld factor
(1) Stiffener welded direct to plating	$0{,}25A_s$ or 6,5 cm^2 whichever is the greater	0,34
(2) Bracketless connection of stiffeners or stiffener lapped to bracket or bracket lapped to stiffener:		
(a) in dry space	$1{,}2\sqrt{Z}$	0,27
(b) in tank	$1{,}4\sqrt{Z}$	0,34
(c) main frame to tank side bracket in $0{,}15L_R$ forward	as (a) or (b)	0,34
(3) Bracket welded to face of stiffener and bracket connection to plating	–	0,34
(4) Stiffener to plating for 0,1 x span at ends, or in way of the end bracket if that be greater	–	0,34

Symbols

A_s = cross section area of the stiffener, in cm^2
A_w = the area of the weld, in cm^2, and is calculated as total length of weld, in cm, x throat thickness, in cm
Z = the section modulus, in cm^3, of the stiffener on which the scantlings of the end bracket are based

NOTE
For maximum and minimum weld fillet sizes, *see* Table 10.2.2.

4.14 Air and drain holes

4.14.1 Air and drain holes are to be kept clear of the toes of brackets, etc. Openings are to be well rounded with smooth edges. *See also* LR's *Guidance Notes for Structural Details*.

4.15 Notches and scallops

4.15.1 Notches and scallops are to be kept clear of the toes of brackets, etc. Openings are to well rounded with smooth edges.

4.15.2 Scallops are to be of such a size, and in such a position that a satisfactory weld can be made around the ends of openings.

4.16 Watertight collars

4.16.1 Watertight collars are to be fitted, where stiffeners are continuous through watertight or oiltight boundaries. *See also* LR's *Guidance Notes for Structural Details*.

4.17 Lug connections

4.17.1 The area of the weld connecting secondary stiffeners to primary structure in the bottoms of the hulls and cross-deck structure in areas subjected to impact pressures is to be not less than the shear area from the Rules. This area is to be obtained by fitting two lugs or by other equivalent arrangements. Some typical lug connections are shown in Fig. 2.4.2 and Fig. 3.1.7 in Chapter 3.

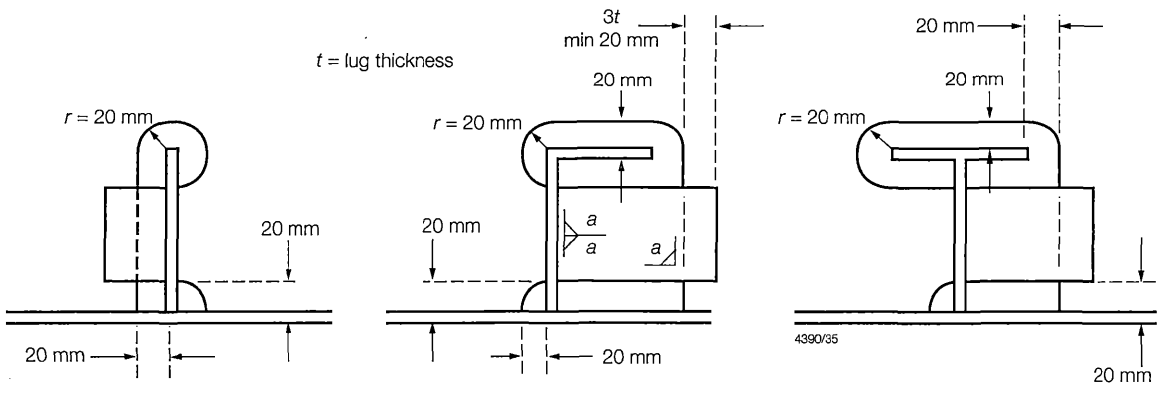

Fig. 2.4.2 Typical lug connections

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4.17.2 Lugs or tripping brackets are to be fitted where shell longitudinals are continuous through web frames in way of highly stressed areas of the side shell (e.g. in way of fenders, etc.).

4.17.3 Lugs or tripping brackets are also to be fitted where continuous secondary stiffeners are greater than half the depth of the primary stiffeners.

4.18 Insert plates

4.18.1 Where thick insert plates are butt welded to thin plates, the edge of the thick plate may require to be tapered. The slope of the taper is generally not to exceed one in three.

4.18.2 The corners of insert plates are to be suitably radiused.

4.19 Doubler plates

4.19.1 Doubler plates are to be avoided in areas where corrosion may be a problem and access for inspection and maintenance is limited.

4.19.2 Where doubler plates are fitted, they are to have well radiused corners and the perimeter is to be continuously welded. Large doubler plates are also to be suitably slot welded, the details of which are to be submitted for consideration.

4.20 Joint preparation

4.20.1 Typical butt joints are shown in LR's *Guidance Notes for Structural Details*.

4.21 Construction tolerances

4.21.1 The minimum requirements for construction tolerances are to be in accordance with Pt 3, Ch 1,8.

4.22 Riveting of light structure

4.22.1 Where it is proposed to adopt riveted construction, full details of the rivets or similar fastenings, including mechanical test results, are to be indicated on the construction plans submitted for approval or a separate riveting schedule is to be submitted.

4.22.2 Samples may be required of typical riveted joints made by the Builder under representative construction conditions and tested to destruction in the presence of the Surveyor in shear, tension, compression or peel at LR's discretion.

4.22.3 Where riveting strength data sheets have been issued by a recognised Authority, the values quoted in these sheets will normally be accepted for design purposes.

4.22.4 Where two dissimilar metals are to be joined by riveting, precautions are to be taken to eliminate electrolytic corrosion to LR's satisfaction, and where practicable, the arrangements are to be such as to enable the joint to be kept under observation at each survey without undue removal of lining and other items.

4.22.5 Where a sealing compound is used to obtain an airtight or watertight joint, details are to be submitted of its proposed use and of any tests made or experience gained in its use for similar applications.

4.22.6 Sealing paints or compounds are not to be used with hot driven rivets.

4.23 Chemical bonding of structure

4.23.1 Where chemical bonding of any load-bearing structure is proposed, details of the materials and the processes to be used are to be submitted for approval. These details are to include test results of samples manufactured under LR survey under workshop conditions to verify the strength, ageing effects and moisture resistance.

4.23.2 The adhesive manufacturer's recommendations in respect of the specified jointing system, comprising preparation of the surfaces to be adhered, the adhesive, bonding and curing processes, are to be strictly followed as variation of any step can severely affect the performance of the joint.

4.23.3 Meticulous preparation is essential where the joint is to be made by chemical bonding. The method of producing bonded joints is to be documented so that the process is repeatable after the procedure has been properly established.

4.23.4 Bonded joints are suitable for carrying shear loads, but are not, in general, to be used in tension or where the load causes peeling or other forces tending to open the joint. Loads are to be carried over as large an area as possible.

4.23.5 Bonded joints are to be suitably supported after assembly for the period necessary to allow the optimum bond strength of the adhesive to be to be developed. Entrained air pockets are to be avoided.

4.23.6 The use of adhesive for main structural joints is not to be contemplated unless considerable testing has established its validity, including environmental testing and fatigue testing where considered necessary by LR.

4.24 Triaxial stress considerations

4.24.1 Particular care is to be taken to avoid triaxial stresses which may result from poor joint design. Some recommendations in this respect are contained in LR's *Guidance Notes for Structural Details*.

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4.25 Aluminium/Steel transition joints

4.25.1 Provision is made in this Section for explosion bonded composite aluminium/steel transition joints used for connecting aluminium structures to steel plating. Such joints are to be used in accordance with the manufacturer's requirements, *see also* Ch 8,4 of the Rules for Materials.

4.25.2 Transition joints are to be manufactured by an approved producer in accordance with an approved specification which is to include the maximum temperature allowable at the interface during welding.

4.25.3 The steel material is to comply with the requirements of Section 2 and the aluminium is to be of an appropriate grade complying with the requirements of *Chapter 8 of the Rules for Materials*.

4.25.4 Alternative materials which comply with International, National or proprietary specifications may be accepted provided that they give equivalence to the requirements of 4.24.3 or are approved for a specific application.

4.25.5 Intermediate layers between the aluminium and steel may be used, in which case the material of any such layer is to be specified by the manufacturer and is to be recorded in the approval certificate. Any such intermediate layer is then to be used in all production transition joints.

4.25.6 Bimetallic joints where exposed to seawater or used internally within wet spaces are to be suitably protected to prevent galvanic corrosion.

4.26 Steel/Wood connection

4.26.1 To minimise corrosion of steel when in contact with wood in a damp or marine environment the timber is to be primed and painted in accordance with good practice. Alternatively the surface of the steel in contact with the timber is to be coated with a substantial thickness of a suitable sealant.

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Section

1 **General**

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■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull craft of steel construction as defined in Pt 1, Ch 2,2.

1.2 General

1.2.1 The formulae contained within this Chapter are to be used in conjunction with the design loadings from Part 5 to determine the Rule scantling requirements.

1.3 Direct calculations

1.3.1 Where the craft is of unusual design, form or proportions, or where the speed of the craft exceeds 60 knots the scantlings are to be determined by direct calculation.

1.3.2 The requirements of this Chapter may be modified where direct calculation procedures are adopted to analyse the stress distribution in the primary structure.

1.4 Equivalents

1.4.1 Lloyd's Register (hereinafter referred to as 'LR') will consider direct calculations for the derivation of scantlings as an alternative and equivalent to those derived by Rule requirements in accordance with Pt 3, Ch 1,3.

1.5 Symbols and definitions

1.5.1 The symbols used in this Chapter are defined below and in the appropriate Section:

L_R = Rule length of craft, in metres, as defined in Pt 3, Ch 1,6

B = moulded breadth of craft, in metres, as defined in Pt 3, Ch 1,6

Z = section modulus of stiffening member, in cm^3

I = moment of inertia, in cm^4

A_w = shear area of stiffener web, in cm^2

l = stiffener overall length, in metres

l_e = effective span length, in metres, as defined in 1.19

p = design pressure, in kN/m^2 as given in Part 5

s = stiffener spacing, in mm

t_p = plating thickness, in mm

β = panel aspect ratio correction factor as defined in 1.15

γ = convex curvature correction factor as defined in 1.14

k_s = high tensile steel factor
= $235/\sigma_s$, *see also* Ch 2,2.4

σ_s = guaranteed minimum yield strength of the material, in N/mm^2

$\tau_s = \frac{\sigma_s}{\sqrt{3}}$

E = modulus of elasticity, in N/mm^2.

1.6 Rounding policy for Rule plating thickness

1.6.1 Where plating thicknesses as determined by the Rules require to be rounded then this should be carried out to the nearest full or half millimetre, with thicknesses 0,75 and 0,25 being rounded up.

1.7 Dimensional tolerance

1.7.1 Dimensional tolerances for materials are to be in accordance with Chapter 8 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials), or an acceptable National or International Standard.

1.7.2 The under thickness tolerance acceptable for classification is to be considered as the lower limit of a range of thickness tolerance which could be found in the normal production of a conventional rolling mill manufacturing material, on average, to the nominal thickness.

1.7.3 The Shipowner and Shipbuilder may agree in individual cases whether they wish to specify a more stringent under thickness tolerance than that given in 1.7.2.

1.7.4 The minus tolerance on sections (except for wide flats) is to be in accordance with a National or International Standard.

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1.7.5 The thickness of plates and strip is to be measured at random locations whose distance from an edge is to be at least 25 mm. Local surface depressions resulting from imperfections and ground areas resulting from the elimination of defects may be disregarded provided that they are in accordance with the requirements of a National or International Standard.

1.7.6 The responsibility for maintaining the required tolerances and making the necessary measurements rests with the manufacturer/Builder. Occasional checking by the Surveyor does not absolve the manufacturer/Builder from the responsibility.

1.8 Material properties

1.8.1 The basic grade of steel used in the determination of the Rule scantling requirements is taken as mild steel with the following mechanical properties:

	N/mm^2
Yield strength (minimum)	235
Tensile strength	400 – 490
Modulus of elasticity	200×10^3.

1.9 Higher tensile steels

1.9.1 Steels having a yield stress not less than 265 N/mm^2 are regarded as higher tensile steels.

1.9.2 Where higher tensile steels are to be used, due allowance is given in the determination of the Rule requirement for plating thickness and stiffener section modulus, inertia and cross-sectional area by use of the following correction factors:

(a) Plating thickness factor = $\sqrt{k_s}$

(b) Section modulus and cross-sectional area factor = k_s

where

k_s is as defined in 1.5.1.

1.9.3 The minimum moment of inertia of higher tensile steel stiffening members is to be not less than that required for mild steel stiffening members.

1.9.4 For determination of hull girder section modulus in craft incorporating higher tensile steel materials, *see* Ch 6,2.2.1, 2.2.2 and Ch 2,2.4.3.

1.10 Effective width of attached plating

1.10.1 The effective geometric properties of rolled or built sections are to be calculated directly from the dimensions of the section and associated effective area of attached plating. Where the web of the section is not normal to the actual plating, and the angle exceeds 20°, the properties of the section are to be determined about an axis parallel to the attached plating.

1.10.2 For stiffening members, the geometric properties of rolled or built sections are to be calculated in association with an effective area of attached load bearing plating of thickness t_p, in mm and a breadth b_e in mm. b_e is as defined in 1.10.3 and 1.10.4.

1.10.3 The effective width of attached plating to secondary members b_e is to be taken as $2t_p\sqrt{E/\sigma_s}$ but not greater than s. σ_s is not to be taken as greater than 235 N/mm^2 for mild steel or 340 N/mm^2 for higher tensile steel. E, s and σ_s are as defined in 1.5.1.

1.10.4 The effective breadth of attached plating to primary support members (girders, transverses, webs etc.) b_e is to be taken as bf, where b and f are as defined in Pt 3, Ch 2, 3.2.1.

1.11 Other materials

1.11.1 Special consideration will be given to the use of materials other than steel. Details of the type of material, the specification to which it was manufactured and its mechanical properties are to be submitted for appraisal.

1.12 Aluminium alloys

1.12.1 The use of aluminium alloys in construction is to be in accordance with Part 7.

1.13 Fibre reinforced plastic (FRP)

1.13.1 The use of FRP in construction is to be in accordance with Part 8.

1.14 Convex curvature correction

1.14.1 The thickness of plating as determined by the Rules may be reduced where significant curvature exists between the supporting members. In such cases a plate curvature correction factor may be applied:

γ = plate curvature factor
= $1 - h/s$, and is not to be taken as less than 0,7,

h = the distance, in mm, measured perpendicularly from the chord length, s, (i.e. spacing) to the highest point of the curved plating arc between the two supports, *see* Fig. 3.1.1.

1.15 Aspect ratio correction

1.15.1 The thickness of plating as determined by the Rules may be reduced when the panel aspect ratio is taken into consideration. In such cases a panel aspect ratio correction factor may be applied:

β = aspect ratio correction factor
= $A_R(1 - 0{,}25A_R)$ for $A_R \leq 2$
= 1 for $A_R > 2$

A_R = panel aspect ratio
= panel length/panel breadth.

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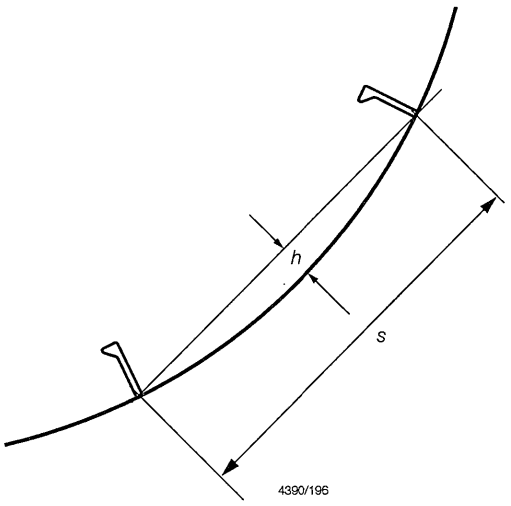

Fig. 3.1.1 Convex curvature

1.16 Plating general

1.16.1 The requirements for the thickness of plating, t_p, is, in general, to be in accordance with the following:

$$t_p = 22{,}4\, s\, \gamma\, \beta \sqrt{\frac{p}{f_\sigma\, \sigma_s}} \times 10^{-3} \text{ mm}$$

where

f_σ = limiting bending stress coefficient for the plating element under consideration given in Table 7.3.1 in Chapter 7.

s, γ, β, p, σ_s are as defined in 1.5.1.

1.17 Stiffening general

1.17.1 The requirements for section modulus, inertia and web area of stiffening members are, in general, to be in accordance with the following:

(a) Section modulus:

$$Z = \Phi_Z \frac{p\, s\, l_e^2}{f_\sigma\, \sigma_s} \text{ cm}^3$$

where

Φ_Z = section modulus coefficient dependent on the loading model assumption taken from Table 3.1.1

f_σ = limiting bending stress coefficient for stiffening member given in Table 7.3.1 in Chapter 7.

p, s, l_e, and σ_s are as defined in 1.5.1.

(b) Inertia:

$$I = \Phi_I\, f_\delta \frac{p\, s\, l_e^3}{E} \times 100 \text{ cm}^4$$

where

Φ_I = inertia coefficient dependent on the loading model assumption taken from Table 3.1.1

f_δ = limiting deflection coefficient for stiffener member given in Table 7.2.1 in Chapter 7.

p, s, l_e, and E are as defined in 1.5.1.

(c) Web area:

$$A_w = \Phi_A \frac{p\, s\, l_e}{100\, f_\tau\, \tau_s} \text{ cm}^2$$

where

Φ_A = web area coefficient dependent on the loading model assumption taken from Table 3.1.1

f_τ = limiting shear stress coefficient for stiffener member given in Table 7.3.1 in Chapter 7

p, s, l_e, and τ_s are as defined in 1.5.1.

1.18 Geometric properties and proportions of stiffener sections

1.18.1 From structural stability and local buckling considerations, the proportions of stiffening members are, in general, to be in accordance with Table 3.1.2.

1.19 Determination of span point

1.19.1 The effective span length, l_e, of a stiffening member is generally less than the overall length, l, by an amount which depends on the design of the end connections. The span points, between which the value of l_e is measured, are to be determined as follows:

(a) For rolled or built-up secondary stiffening members:
The span point is to be taken at the point where the depth of the end bracket, measured from the face of the secondary stiffening member, is equal to the depth of the member, *see* Fig. 3.1.2. Where there is no end bracket, the span point is to be measured between primary member webs.

(b) For primary support members:
The span point is to be taken at a point distant, b_e, from the end of the member

$$b_e = b_b \left(1 - \frac{d_w}{d_b}\right)$$

where

b_e, b_b, d_w and d_b are as shown in Fig. 3.1.2.

1.19.2 Where the stiffening member is inclined to a vertical or horizontal axis and the inclination exceeds 10°, the span is to be measured along the member.

1.19.3 Where the stiffening member is curved then the span is to be taken as the effective chord length between span points.

1.19.4 Where there is a pronounced turn of bilge, chine or the structure is significantly pitched, the span may be measured as in Fig. 3.1.2.

1.19.5 It is assumed that the ends of stiffening members are substantially fixed against rotation and displacement. If the arrangement of supporting structure is such that this condition is not achieved, consideration will be given to the effective span to be used for the stiffener.

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Table 3.1.1 Section modulus, inertia and web area coefficients

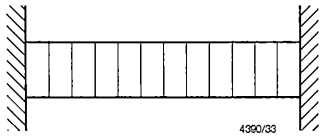
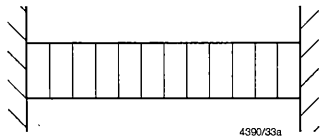
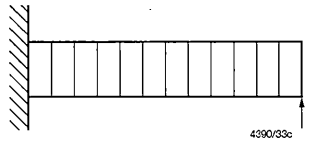
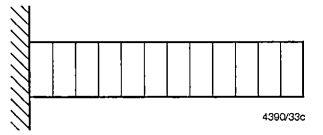
Load model	Position 1	Position 2	Position 3	Position	Web area coefficient Φ_A	Section modulus coefficient Φ_Z	Inertia coefficient Φ_I	Application
(a)	 4390/33			1 2 3	1/2 — 1/2	1/12 1/24 1/12	— 1/384 —	Primary and other members where the end fixity is considered encastre
(b)	 4390/33a			1 2 3	1/2 — 1/2	1/10 1/10 1/10	— 1/288 —	Local, secondary and other members where the end fixity is considered to be partial
(c)	 4390/33c			1 2 3	5/8 — 3/8	1/8 9/128 —	— 1/185 —	Various
(d)	 4390/33c			1 2 3	1 — —	1/2 — —	— — 1/8	Various
(e)	4390/33d			1 2 3	1/2 — 1/2	— 1/8 —	— 5/384 —	Hatch covers, glazing and other members where the ends are simply supported

Table 3.1.2 Stiffener proportions

Type of stiffener	Requirement
(1) Flat bar	Minimum web thickness: $t_w = d_w/18 \quad \geq 2{,}5$ mm
(2) Rolled or built sections	(a) Minimum web thickness: $t_w = d_w/65 \quad \geq 2{,}5$ mm (b) Maximum unsupported face plate (or flange) width: $b_f = 16t_f$
Symbols	
t_w = web thickness of stiffener with unstiffened webs, in mm d_w = web depth of stiffener, in mm b_f = face plate (or flange) unsupported width, in mm t_f = face plate (or flange) thickness, in mm	

1.20 Secondary member end connections

1.20.1 Secondary members, that is longitudinals, beams, frames and bulkhead stiffeners forming part of the hull structure, are to be effectively continuous and are to be suitably bracketed at their end connections. Where it is desired to adopt bracketless connections, the proposed arrangements will be individually considered, *see also* Ch 2,4.10 and Table 2.4.5 in Chapter 2.

1.20.2 Where bracketed end connections are fitted in accordance with these requirements, they may be taken into account in determining the effective span of the member.

1.20.3 The scantlings of secondary member end connections are to be in accordance with 1.21.

1.21 Scantlings of end brackets

1.21.1 Where a longitudinal strength member is cut at a primary support and the continuity of strength is provided by brackets, the scantlings of the brackets are to be such that their section modulus and effective cross-sectional area are not less than those of the member. Care is to be taken to ensure correct alignment of the brackets on each side of the primary member.

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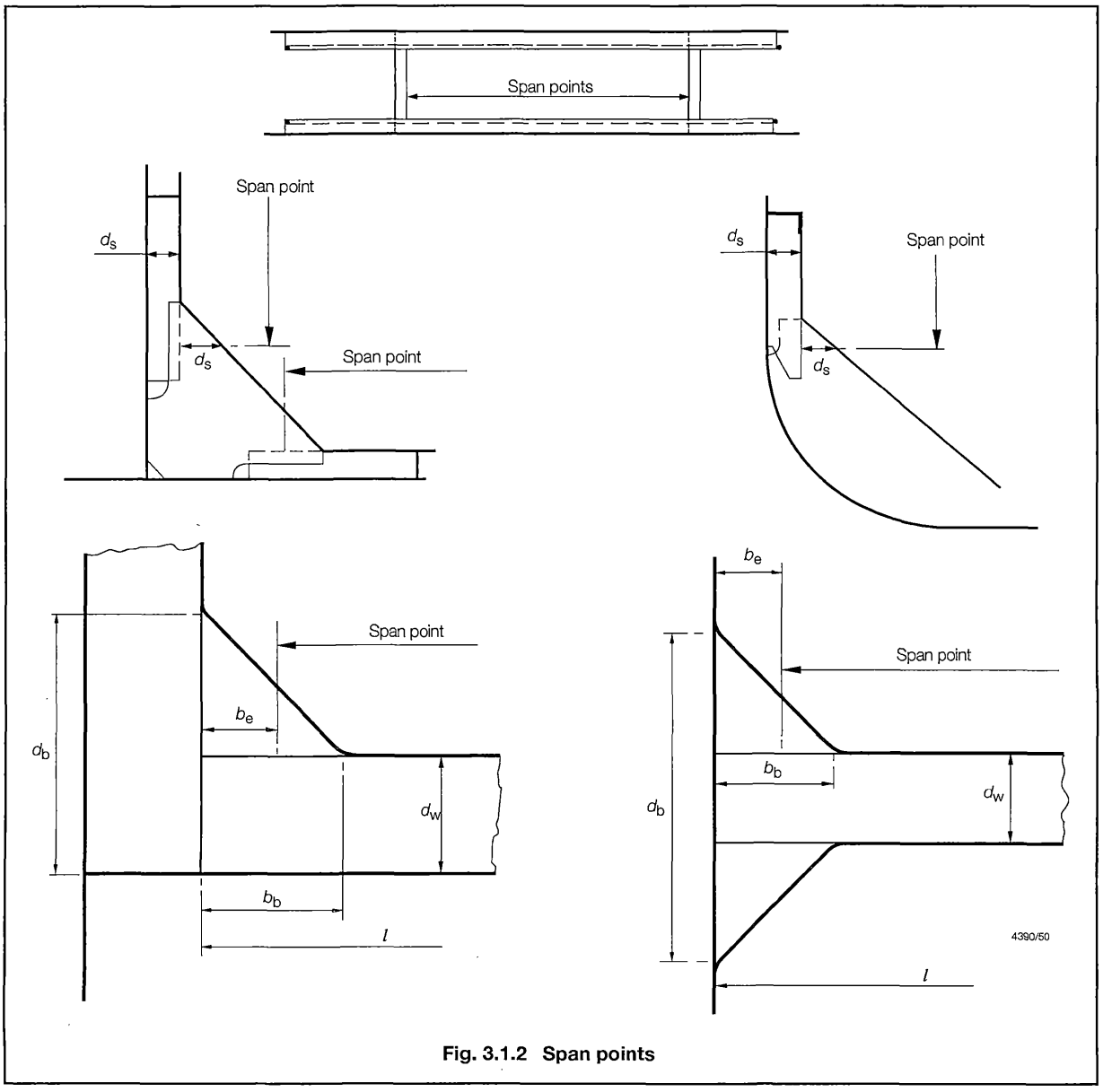

Fig. 3.1.2 Span points

1.21.2 In other cases the scantlings of the bracket are to be based on the modulus as follows:

(a) Bracket connecting stiffener to primary member – modulus of the stiffener.

(b) Bracket at the head of a main transverse frame where frame terminates – modulus of the frame.

(c) Brackets connecting lower deck beams or longitudinals to the main frame in the forward $0{,}5L_R$ – modulus of the frame.

(d) Elsewhere – the lesser modulus of the members being connected by the bracket.

1.21.3 The web thickness and face flat area of end brackets are not in general to be less than those of the connecting stiffeners. Additionally, the stiffener proportion requirements of 1.18 are to be satisfied.

1.21.4 Typical arrangements of stiffener end brackets are shown diagrammatically in Fig. 3.1.3.

1.21.5 The lengths, a and b, of the arms are to be measured from the plating to the toe of the bracket and are to be such that:

(a) $a + b \geq 2{,}0l_b$

(b) $a \geq 0{,}8l_b$

(c) $b \geq 0{,}8l_b$

where a and b are the actual lengths of the two arms of the bracket, in mm, measured from the plating to the toe of the bracket.

$$l_b = 90\left(2\sqrt{\frac{Z}{14+\sqrt{Z}}} - 1\right) \text{ mm}$$

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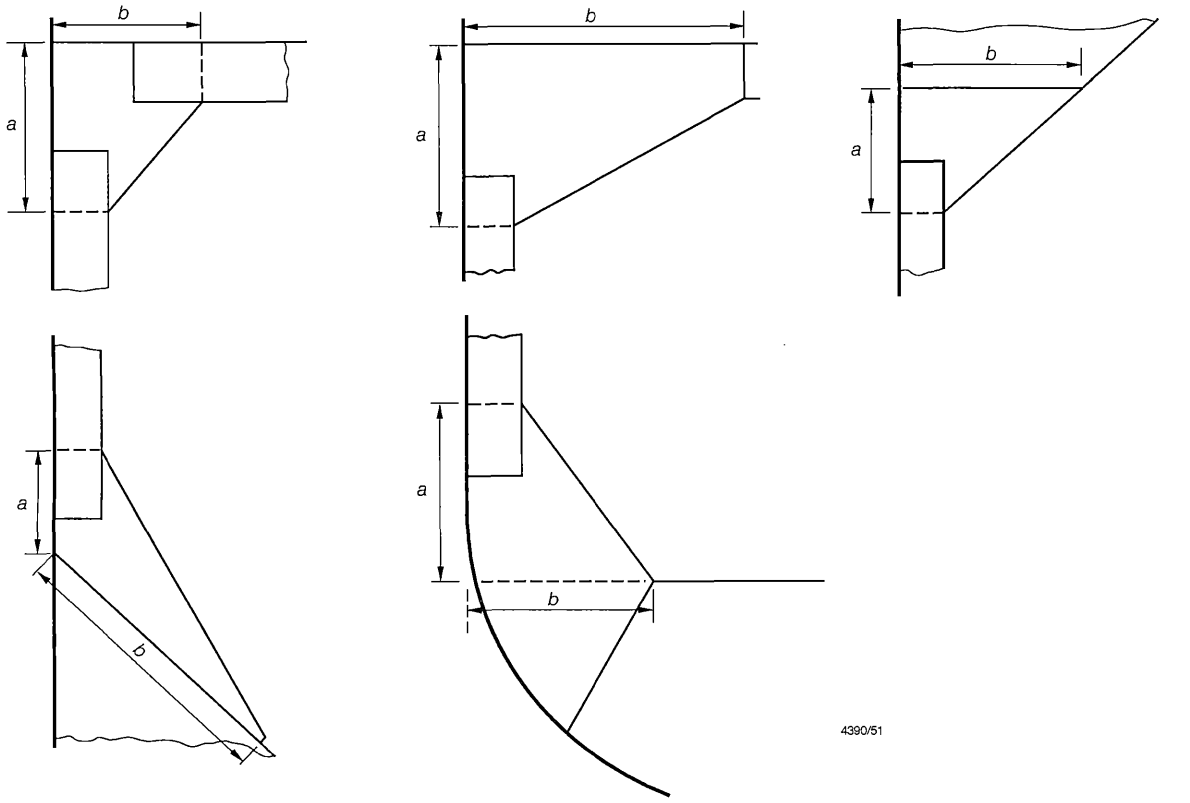

Fig. 3.1.3 Stiffener end brackets

Z = the section modulus of the secondary member, in cm^3
In no case is l_b to be taken as less than twice the web depth of the stiffener on which the bracket scantlings are to be based.

1.21.6 The free edge of the bracket is to be stiffened where any of the following apply:
(a) The section modulus, Z, exceeds 500 cm^3.
(b) The length of free edge exceeds 40 times the bracket thickness.
(c) The bracket is fitted at the lower end of main transverse side framing.

1.21.7 Where a face flat is fitted, its breadth, b_f, is to be not less than:

$$b_f = 40\left(1 + \frac{Z}{1000}\right) \text{ mm}$$

but not less than 50 mm

1.21.8 Where the edge is stiffened by a welded face flat, the cross-sectional area of the face flat is to be not less than:
(a) $0{,}009k_s\, b_f\, T_B$ cm^2 for offset edge stiffening.
(b) $0{,}014k_s\, b_f\, T_B$ cm^2 for symmetrically placed stiffening
where
b_f = breadth of face flat, in mm
T_B = the thickness of the bracket, in mm
k_s is as defined in 1.5.1.

1.21.9 Where the stiffening member is lapped on to the bracket, the length of overlap is to be adequate to provide for the required area of welding. In general, the length of overlap is not to be less than $10\sqrt{Z}$ mm, or the depth of stiffener, whichever is the greater.

1.21.10 Where the free edge of the bracket is hollowed out, it is to be stiffened or increased in size to ensure that the modulus of the bracket through the throat is not less than that of the required straight edged bracket.

1.21.11 The arrangement of the connection between the stiffener and the bracket is to be such that at no point in the connection is the actual modulus reduced to less than that of the stiffener with associated plating.

1.21.12 The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint.

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1.22 Primary member end connections

1.22.1 The requirements for section modulus and inertia (if applicable) of primary members are given in the appropriate Chapter. The scantling requirements for primary member end connections in dry spaces and in tanks of all craft types are generally to comply with the requirements of 1.21, taking Z as the section modulus of the primary member.

1.22.2 Primary members are to be so arranged as to ensure effective continuity of strength, and abrupt changes of depth or section are to be avoided. Where members abut on both sides of a bulkhead, or on other members, arrangements are to be made to ensure that they are in alignment. Primary members in tanks are to form a continuous line of support and wherever possible, a complete ring system.

1.22.3 The members are to have adequate lateral stability and web stiffening and the structure is to be arranged to minimise hard spots and other sources of stress concentration. Openings are to have well rounded corners and smooth edges and are to be located having regard to the stress distribution and buckling strength of the panel.

1.22.4 Primary members are to be provided with adequate end fixity by end brackets or equivalent structure. The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint and effective distribution of the load from the member.

1.22.5 Where the primary member is supported by structure which provides only a low degree of restraint against rotation, the member is generally to be extended beyond the point of support and thereafter tapered and/or scarfed into the adjacent structure over a distance generally not less than two frame spaces.

1.22.6 Where primary members are subject to concentrated loads, particularly if these are out of line with the member web, additional strengthening may be required.

1.22.7 The thickness of the bracket is to be not less than that of the primary member web. The free edge of the bracket is to be stiffened.

1.22.8 Where a deck girder or transverse is connected to a vertical member on the shell or bulkhead, the scantlings of the latter may be required to be increased to provide adequate stiffness to resist rotation of the joint.

1.22.9 Where a member is continued over a point of support, such as a pillar or pillar bulkhead stiffener, the design of the end connection is to be such as to ensure the effective distribution of the load into the support. Proposals to fit brackets of reduced scantlings, or alternative arrangements, will be considered.

1.22.10 Connections between primary members forming a ring system are to minimise stress concentrations at the junctions. Integral brackets are generally to be radiused or well rounded at their toes. The arm length of the bracket, measured from the face of the member, is to be not less than the depth of the smaller member forming the connection.

1.23 Tank boundary penetrations

1.23.1 Where structural members pass through the boundary of a tank, and leakage into the adjacent space could be hazardous or undesirable, full penetration welding is to be adopted for the members for at least 150 mm on each side of the boundary. Alternatively a small scallop of suitable shape may be cut in the member close to the boundary outside the compartment, and carefully welded all round.

1.24 Web stability

1.24.1 Primary members of asymmetrical section are to be supported by tripping brackets at alternate secondary members. If the section is symmetrical, the tripping brackets may be four spaces apart.

1.24.2 Tripping brackets are in general required to be fitted at the toes of end brackets and in way of heavy or concentrated loads such as the heels of pillars. *See also* LR's *Guidance Notes for Structural Details*.

1.25 Openings in the web

1.25.1 Where openings are cut in the web, the depth of opening is not to exceed 50 per cent of the web depth, and the opening is to be so located that the edges are not less than 25 per cent of the web depth from the face plate. The length of opening is not to exceed the web depth or 60 per cent of the secondary member spacing, whichever is the greater, and the ends of the openings are to be equidistant from the corners of cut-outs for secondary members. Where larger openings are proposed, the arrangements and compensation required will be specially considered.

1.25.2 Openings are to have smooth edges and well rounded corners.

1.26 Continuity and alignment

1.26.1 The arrangement of material is to be such as will ensure structural continuity. Abrupt changes of shape or section, sharp corners and points of stress concentration are to be avoided.

1.26.2 Where members abut on both sides of a bulkhead or similar structure, care is to be taken to ensure good alignment.

1.26.3 Pillars and pillar bulkheads are to be fitted in the same vertical line wherever possible, and elsewhere arrangements are to be made to transmit the out of line forces satisfactorily. The load at head and heel of pillars is to be effectively distributed and arrangements are to be made to ensure the adequacy and lateral stability of the supporting members.

1.26.4 Continuity is to be maintained where primary members intersect and where the members are of the same depth, a suitable gusset plate is to be fitted, *see* Fig. 3.1.4.

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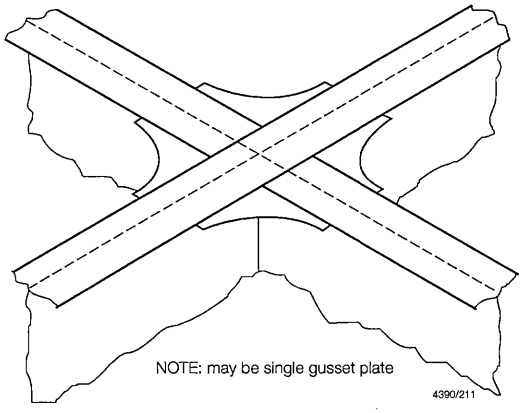

Fig. 3.1.4 Primary member intersection

1.26.5 End connections of structural members are to provide adequate end fixity and effective distribution of the load into the supporting structure.

1.26.6 The toes of brackets, etc., are not to land on unstiffened panels of plating. Special care is to be taken to avoid notch effects at the toes of brackets, by making the toe concave or otherwise tapering it off. *See also* LR's *Guidance Notes for Structural Details*.

1.26.7 Particular care is to be paid to the design of the end bracket toes in order to minimise stress concentrations. Sniped face plates which are welded onto the edge of primary member brackets are to be carried well around the radiuses bracket toe and are to incorporate a taper not exceeding one in three. Where sniped face plates are welded adjacent to the edge of primary member brackets, adequate cross sectional area is to be provided through the bracket toe at the end of the snipe. In general, this area measured perpendicular to the face plate, is to be not less than 60 per cent of the full cross-sectional area of the face plate, *see* Fig. 3.1.5.

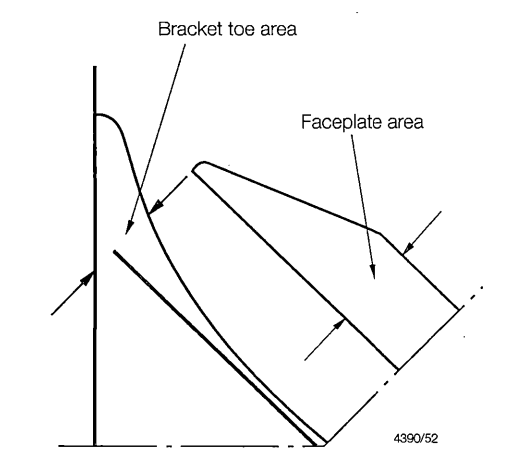

Fig. 3.1.5 Bracket toe construction

1.27 Arrangement with offset stiffener

1.27.1 Where the stiffeners of the double bottom floors and transverse bulkheads are unconnected to the secondary members and offset from them (*see* Fig. 3.1.6) the collar arrangement for the secondary members are to satisfy the requirements of 1.28. In addition, the fillet welds attaching the lugs to the secondary members are to be based on a weld factor of 0,44 for the throat thickness. To facilitate access for welding the offset stiffeners are to be located 50 mm from the slot edge furthest from the web of the secondary member. The ends of the offset stiffeners are to be suitably tapered and softened.

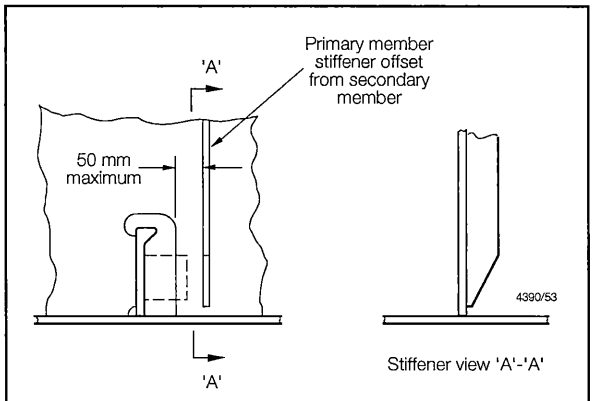

Fig. 3.1.6 Arrangement with offset stiffener

1.27.2 Alternative arrangements will be considered on the basis of their ability to transmit load with equivalent effectiveness. Details of the calculations made and testing procedures are to be submitted.

1.28 Arrangements at intersection of continuous secondary and primary members

1.28.1 Cut-outs for the passage of secondary members through the webs of primary members, and the related collaring arrangements, are to be designed to minimise stress concentrations around the perimeter of the opening and in the attached hull envelope or bulkhead plating. The critical shear buckling stress of the panel in which the cut-out is made is to be investigated. Cut-outs for longitudinals will be required to have double lugs in areas of high stress.

1.28.2 The breadth of cut-outs is to be as small as practicable, with the top edge suitably radiused. Cut-outs are to have smooth edges, and the corner radii are to be as large as practicable, with a minimum of 20 per cent of the breadth of the cut-out or 25 mm, whichever is the greater. It is recommended that the web plate connection to the hull envelope, or bulkhead, end in a smooth tapered 'soft toe'. Recommended shapes of cut-out are shown in Fig. 3.1.7, but consideration will be given to other shapes on the basis of maintaining equivalent strength and minimising stress concentration. *See also* LR's *Guidance Notes for Structural Details*.

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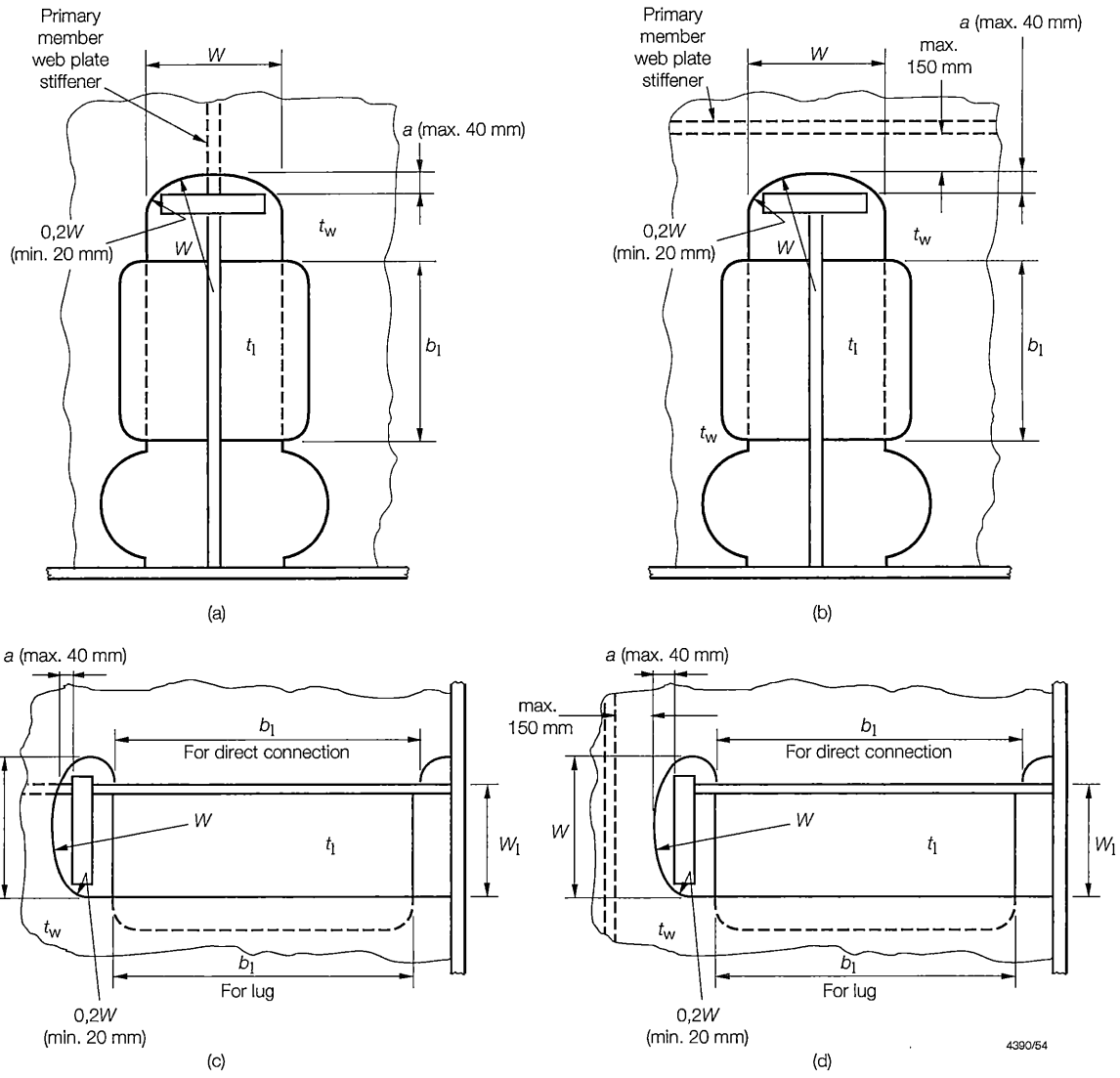

Fig. 3.1.7 Cut-outs and connections

1.28.3 Consideration is to be given to the provision of adequate drainage and unimpeded flow of air and water when designing the cut-outs and connection details.

1.28.4 Asymmetrical secondary members are to be connected on the heel side to the primary member web plate. Additional connection by lugs on the opposite side may be required.

1.28.5 Symmetrical secondary members are to be connected by lugs on one or both sides, as necessary.

1.28.6 Where the primary member stiffener is connected to the secondary member it is to be aligned with the web of the secondary member, except where the face plate of the latter is offset and abutted to the web, in which case the stiffener connection is to be lapped.

1.28.7 Fabricated longitudinals having the face plate welded to the underside of the web, leaving the edge of the web exposed, are not recommended for side shell and longitudinal bulkhead longitudinals. Where it is proposed to fit such sections, a symmetrical arrangement of connection to transverse members is to be incorporated. This can be achieved by fitting backing structure on the opposite side of the transverse web or bulkhead.

1.28.8 Where a bracket is fitted to the primary member web plate in addition to a connected stiffener it is to be arranged on the opposite side to, and in alignment with, the stiffener. The arm length of the bracket is to be not less than the depth of the stiffener, and its cross-sectional area through the throat of the bracket is to be included in the calculation of the area of the primary web stiffener in way of the connection.

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1.28.9 Alternative arrangements will be considered on the basis of their ability to transmit load with equivalent effectiveness. Details of the calculations made and testing procedures are to be submitted.

1.29 Openings

1.29.1 Manholes, lightening holes and other cut-outs are to be avoided in way of concentrated loads and areas of high shear. In particular, manholes and similar openings are not to be cut in vertical or horizontal diaphragm plates in narrow cofferdams or in floors and double bottom girders close to their span ends, or below the heels of pillars, unless the stresses in the plating and the panel buckling characteristics have been calculated and found satisfactory.

1.29.2 Manholes, lightening holes and other openings are to be suitably framed and stiffened where necessary.

1.29.3 Air and drain holes, notches and scallops are to be kept at least 200 mm clear of the toes of end brackets and other areas of high stress. Openings are to be well rounded with smooth edges. Closely spaced scallops are not permitted. Widely spaced air or drain holes may be accepted, provided that they are of elliptical shape, or equivalent, to minimise stress concentration and are, in general, cut clear of the weld connection.

1.30 Fittings and attachments, general

1.30.1 The quality of welding and general workmanship of fittings and attachments as given in 1.31 and 1.32 are to be in accordance with Chapter 13 of the Rules for Materials.

1.31 Bilge keels and ground bars

1.31.1 It is recommended that bilge keels are not fitted in the forward $0{,}3L_R$ region on ships intended to navigate in ice conditions.

1.31.2 Bilge keels are to be attached to a continuous ground bar as shown in Fig. 3.1.8. Butt welds in shell plating, ground bar and bilge keels are to be staggered.

1.31.3 The thickness of the ground bar is to be not less than the thickness of the bottom shell or 6 mm, whichever is the greater, but need not be taken as greater than 12 mm.

1.31.4 The material class, grade and quality of the ground bar are to be similar to those of the adjacent shell plating.

1.31.5 The ground bar is to be connected to the shell with a continuous fillet weld and the bilge keel to the ground bar with a light continuous fillet weld.

1.31.6 Direct connection between ground bar butt welds and shell plating, and between bilge keel butt welds and ground bar is to be avoided.

1.31.7 The end details of bilge keels and intermittent bilge keels, where adopted, are to be as shown in Fig. 3.1.9.

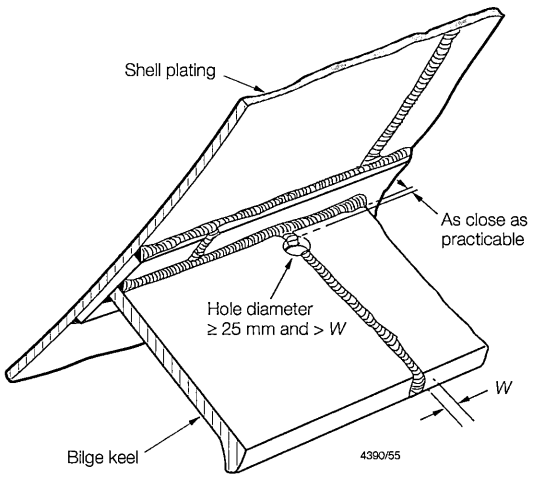

Fig. 3.1.8 Bilge keel construction

1.31.8 The ground bar and bilge keel ends are to be tapered or rounded. Where the ends are tapered, the tapers are to be gradual with ratios of at least 3:1, *see* Figs. 3.1.9(a) and (b). Where the ends are rounded, details are to be as shown in Fig. 3.1.9(c). Cut-outs on the bilge keel web within zone 'A' (*see* Fig. 3.1.9(b)) are not permitted.

1.31.9 The end of the bilge keel web is to be between 50 mm and 100 mm from the end of the ground bar, *see* Fig. 3.1.9(a).

1.31.10 An internal transverse support is to be positioned as close as possible to halfway between the end of the bilge keel web and the end of the ground bar, *see* Fig. 3.1.9(b).

1.31.11 Where an internal longitudinal stiffener is fitted in line with the bilge keel web, the longitudinal stiffener is to extend to at least the nearest transverse member outside zone 'A', *see* Fig. 3.1.9(b). In this case, the requirement of 1.31.10 does not apply.

1.31.12 For craft over 65 m in length, L_R, holes are to be drilled in the bilge keel butt welds. The size and position of these holes are to be as illustrated in Fig. 3.1.8. Where the butt weld has been subject to non-destructive examination the stop hole may be omitted.

1.31.13 Bilge keels of a different design from that shown in Fig. 3.1.8 and Fig. 3.1.9 will be specially considered.

1.31.14 Within zone 'B' (*see* Fig. 3.1.9(a)), welds at the ends of the ground bar and the bilge plating, and at the ends of the bilge keel web and ground bar, are to have weld factors of 0,44 and 0,34 respectively. These welds are to be ground and to blend smoothly with the base materials.

1.31.15 A plan of the bilge keels is to be submitted for approval of material grades, welded connections and detail design.

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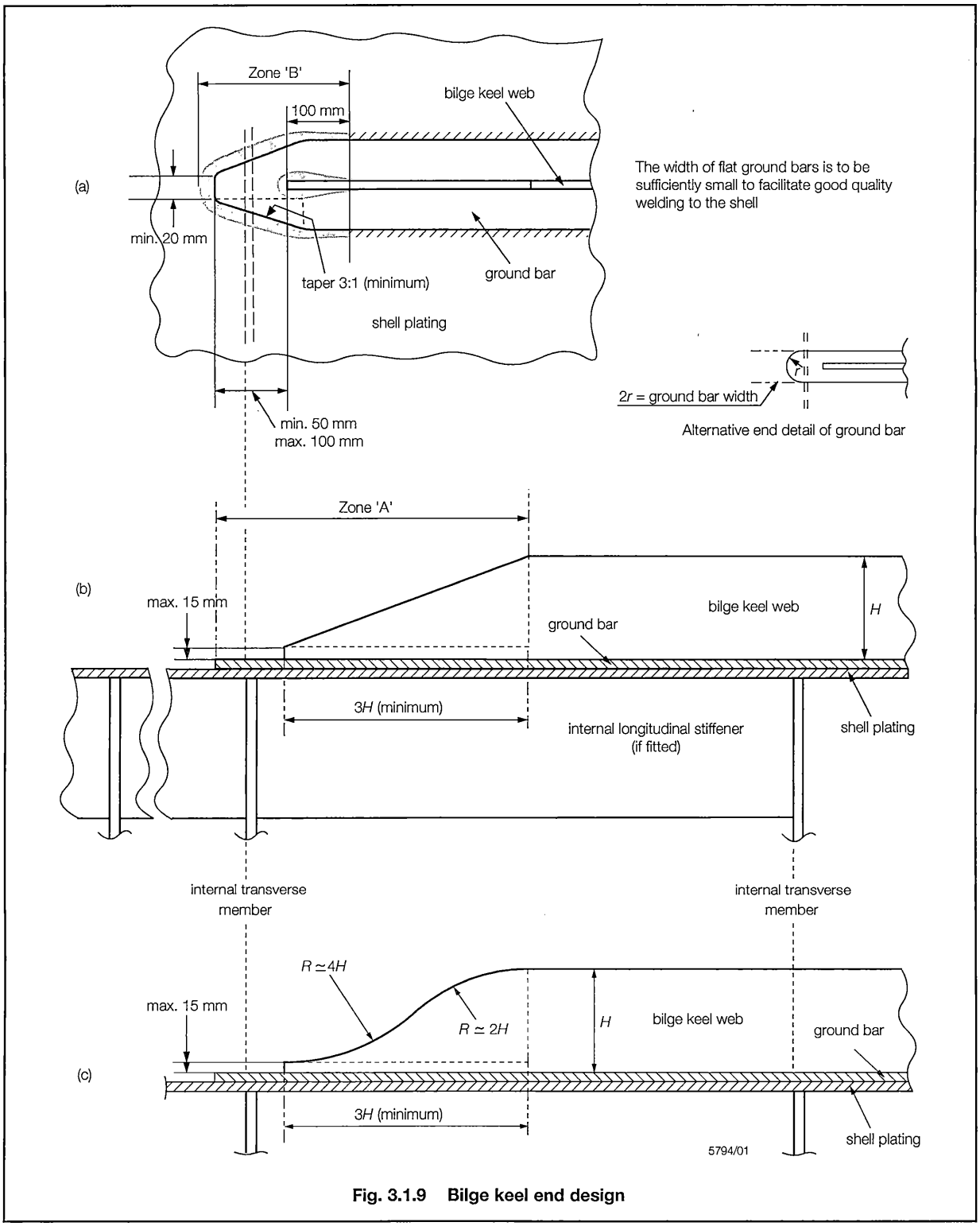

Fig. 3.1.9 Bilge keel end design

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1.32 Other fittings and attachments

1.32.1 Gutterway bars at the upper deck are to be so arranged that the effect of main hull stresses on them is minimised.

1.32.2 Minor attachments, such as pipe clips, staging lugs and supports, are generally to be kept clear of toes of end brackets, corners of openings and similar areas of high stress. Where connected to asymmetrical stiffeners, the attachments may be in line with the web provided the fillet weld leg length is clear of the offset face plate or flange edge. Where this cannot be achieved the attachments are to be connected to the web, and in the case of flanged stiffeners they are to be kept at least 25 mm clear of the flange edge. On symmetrical stiffeners, they may be connected to the web or to the centreline of the face plate in line with the web.

1.32.3 Where necessary in the construction of the craft, lifting lugs may be welded to the hull plating but they are not to be slotted through. Where they are subsequently removed, this is to be carried out by mechanical cutting close to the plate surface, and the remaining material and welding ground off. After removal the area is to be carefully examined to ensure freedom from cracks or other defects in the plate surface.

■ *Section 2* Minimum thickness requirements

2.1 General

2.1.1 The thickness of plating and stiffeners determined from the Rule scantling requirements is in no case to be less than that given in Table 3.2.1 for the craft type.

2.1.2 In addition, where plating contributes to the global strength of the craft, the thickness is to be not less than that required to satisfy the global strength requirements detailed in Chapter 6.

2.2 Corrosion margin

2.2.1 The minimum thicknesses given in Table 3.2.1 are based on the assumption that there is negligible loss in strength by corrosion. Where this is not the case the minimum thickness will be specially considered.

2.3 Impact consideration

2.3.1 Due consideration is to be given to the scantlings of all structure which may be subject to local impact loadings. Impact testing may be required to be carried out at the discretion of LR to demonstrate the suitability of the proposed scantlings for a particular application.

2.4 Sheathing

2.4.1 Areas of shell and deck which are subject to additional wear by abrasion, e.g. from passenger routes, working areas of fishing vessels, forefoot region, etc., are to be suitably protected by local reinforcement or sheathing. This sheathing may be of timber, rubber, steel, additional layers of reinforcement, etc., as appropriate. Details of such sheathing and the method of attachment are to be submitted for consideration.

2.4.2 The attachment of sheathing by mechanical means such as bolting or other methods is not to impair the watertight integrity of the craft. Through bolting of the hull is to be kept to a minimum and avoided where practicable. The design arrangements in way of any through bolting are to be such that damage to the sheathing will not impair the watertight integrity of the hull.

2.5 Operation in ice

2.5.1 The minimum plating thickness of craft intended for operation in ice conditions is to comply with Ch 5,7.

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Table 3.2.1 Minimum thickness requirements

Item	Minimum thickness (mm)		
	Mono-hull	Hydrofoil	Rigid inflatable boat (RIB)
Shell envelope Bottom shell plating	$\omega\sqrt{k_{ms}}\ (0,4\sqrt{L_R}+2,0) \geq 3,5\omega$	$\omega\sqrt{k_{ms}}\ (0,4\sqrt{L_R}+2,0) \geq 3,5\omega$	$\omega\sqrt{k_{ms}}\ (0,4\sqrt{L_R}+2,0) \geq 3,5\omega$
Side shell plating	$\omega\sqrt{k_{ms}}\ (0,38\sqrt{L_R}+1,2) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,38\sqrt{L_R}+1,2) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,38\sqrt{L_R}+1,2) \geq 3,0\omega$
Single bottom structure *Centre girder web*	$\omega\sqrt{k_{ms}}\ (0,8\sqrt{L_R}+1,0) \geq 4,0\omega$	$\omega\sqrt{k_{ms}}\ (0,8\sqrt{L_R}+1,0) \geq 4,0\omega$	$\omega\sqrt{k_{ms}}\ (0,8\sqrt{L_R}+1,0) \geq 4,0\omega$
Floor webs	$\omega\sqrt{k_{ms}}\ (0,6\sqrt{L_R}+0,8) \geq 3,5\omega$	$\omega\sqrt{k_{ms}}\ (0,6\sqrt{L_R}+0,8) \geq 3,5\omega$	$\omega\sqrt{k_{ms}}\ (0,6\sqrt{L_R}+0,8) \geq 3,5\omega$
Side girder webs	$\omega\sqrt{k_{ms}}\ (0,6\sqrt{L_R}+0,8) \geq 3,5\omega$	$\omega\sqrt{k_{ms}}\ (0,6\sqrt{L_R}+0,8) \geq 3,5\omega$	$\omega\sqrt{k_{ms}}\ (0,6\sqrt{L_R}+0,8) \geq 3,5\omega$
Double bottom structure Centre girder			
(1) Within $0,4L_R$ amidships	$\omega\sqrt{k_{ms}}\ (0,8\sqrt{L_R}+1,0) \geq 4,0\omega$	$\omega\sqrt{k_{ms}}\ (0,8\sqrt{L_R}+1,0) \geq 4,0\omega$	$\omega\sqrt{k_{ms}}\ (0,8\sqrt{L_R}+1,0) \geq 4,0\omega$
(2) Outside $0,4L_R$ amidships	$\omega\sqrt{k_{ms}}\ (0,7\sqrt{L_R}+1,0) \geq 4,0\omega$	$\omega\sqrt{k_{ms}}\ (0,7\sqrt{L_R}+1,0) \geq 4,0\omega$	$\omega\sqrt{k_{ms}}\ (0,7\sqrt{L_R}+1,0) \geq 4,0\omega$
Floors and side girders	$\omega\sqrt{k_{ms}}\ (0,6\sqrt{L_R}+0,8) \geq 3,5\omega$	$\omega\sqrt{k_{ms}}\ (0,6\sqrt{L_R}+0,8) \geq 3,5\omega$	$\omega\sqrt{k_{ms}}\ (0,6\sqrt{L_R}+0,8) \geq 3,5\omega$
Inner bottom plating	$\omega\sqrt{k_{ms}}\ (0,5\sqrt{L_R}+1,0) \geq 2,5\omega$	$\omega\sqrt{k_{ms}}\ (0,5\sqrt{L_R}+1,0) \geq 2,5\omega$	$\omega\sqrt{k_{ms}}\ (0,5\sqrt{L_R}+1,0) \geq 2,5\omega$
Bulkheads Watertight bulkhead plating	$\omega\sqrt{k_{ms}}\ (0,33\sqrt{L_R}+1,0) \geq 2,5\omega$	$\omega\sqrt{k_{ms}}\ (0,33\sqrt{L_R}+1,0) \geq 2,5\omega$	$\omega\sqrt{k_{ms}}\ (0,33\sqrt{L_R}+1,0) \geq 2,5\omega$
Deep tank bulkhead plating	$\omega\sqrt{k_{ms}}\ (0,38\sqrt{L_R}+1,2) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,38\sqrt{L_R}+1,2) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,38\sqrt{L_R}+1,2) \geq 3,0\omega$
Deck plating and stiffeners Strength/Main deck plating	$\omega\sqrt{k_{ms}}\ (0,38\sqrt{L_R}+1,2) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,38\sqrt{L_R}+1,2) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,38\sqrt{L_R}+1,2) \geq 3,0\omega$
Lower deck/inside deckhouse	$\omega\sqrt{k_{ms}}\ (0,18\sqrt{L_R}+1,7) \geq 2,0\omega$	$\omega\sqrt{k_{ms}}\ (0,18\sqrt{L_R}+1,7) \geq 2,0\omega$	$\omega\sqrt{k_{ms}}\ (0,18\sqrt{L_R}+1,7) \geq 2,0\omega$
Superstructures and deckhouses Superstructure side plating	$\omega\sqrt{k_{ms}}\ (0,3\sqrt{L_R}+1,0) \geq 2,0\omega$	$\omega\sqrt{k_{ms}}\ (0,3\sqrt{L_R}+1,0) \geq 2,0\omega$	$\omega\sqrt{k_{ms}}\ (0,3\sqrt{L_R}+1,0) \geq 2,0\omega$
Deckhouse front 1st tier	$\omega\sqrt{k_{ms}}\ (0,47\sqrt{L_R}+1,5) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,47\sqrt{L_R}+1,5) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,47\sqrt{L_R}+1,5) \geq 3,0\omega$
Deckhouse front upper tiers	$\omega\sqrt{k_{ms}}\ (0,42\sqrt{L_R}+1,3) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,42\sqrt{L_R}+1,3) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,42\sqrt{L_R}+1,3) \geq 3,0\omega$
Deckhouse aft	$\omega\sqrt{k_{ms}}\ (0,2\sqrt{L_R}+0,6) \geq 2,0\omega$	$\omega\sqrt{k_{ms}}\ (0,2\sqrt{L_R}+0,6) \geq 2,0\omega$	$\omega\sqrt{k_{ms}}\ (0,2\sqrt{L_R}+0,6) \geq 2,0\omega$
Pillars Wall thickness of tubular pillars	$\omega\sqrt{k_{ms}}\ 0,05d_p$	$\omega\sqrt{k_{ms}}\ 0,05d_p$	$\omega\sqrt{k_{ms}}\ 0,05d_p$
Wall thickness of rectangular pillars	$\omega\sqrt{k_{ms}}\ 0,05b_p$	$\omega\sqrt{k_{ms}}\ 0,05d_p$	$\omega\sqrt{k_{ms}}\ 0,05d_p$

Symbols

ω = service type correction factor as determined from Table 3.2.2

k_{ms} = $635/(\sigma_s + \sigma_u)$

σ_s = specified minimum yield strength of the material, in N/mm^2

σ_u = specified minimum ultimate tensile strength of the material, in N/mm^2

b_p = minimum breadth of cross section of hollow rectangle pillar, in mm

d_p = outside diameter of tubular pillar, in mm

L_R is as defined in 1.5.1.

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Table 3.2.2 Service type correction factor (ω)

Service type notation	ω
Cargo	1,1
Passenger	1,0
Patrol	1,0
Pilot	1,1
Yacht	1,0
Workboat MFV	1,2

■ *Section 3* Shell envelope plating

3.1 General

3.1.1 The requirements of this Section are applicable to longitudinally and transversely framed shell envelope plating.

3.1.2 The thickness of the shell envelope plating is in no case to be less than the appropriate minimum requirement given in Section 2.

3.2 Plate keel

3.2.1 The breadth, b_k, and thickness, t_k, of the plate keel are not to be taken as less than:

$$b_k = 7{,}0L_R + 340 \text{ mm}$$

$$t_k = \sqrt{k_s}\ 1{,}35L_R^{0,45} \text{ mm}$$

where

L_R and k_s are as defined in 1.5.1.

3.2.2 In no case is the thickness of the plate keel to be less than that of the adjacent bottom shell plating.

3.2.3 The width and thickness of the plate keel are to be maintained throughout the length of the craft from the transom to a point not less than 25 per cent of the freeboard (measured at the forward perpendicular) above the deepest load waterline on the stem. Thereafter the keel thickness may be reduced to that required by 3.3.1 for the stem.

3.2.4 For large or novel craft and for yachts with externally attached ballast keels, the scantlings of the keel will be specially considered.

3.2.5 For bar keels, *see* 5.2.2.

3.3 Plate stem

3.3.1 The thickness of plate stems, t_S, is not to be taken as less than:

$$t_s = \sqrt{k_s}\ (0{,}1L_R + 3) \text{ mm}$$

where

L_R and k_s are as defined in 1.5.1.

3.3.2 In no case is the thickness of the plate stem to be taken as less than the thickness of the adjacent shell plating.

3.3.3 Plate stems are to be supported by horizontal diaphragms, and where the stem radius is large, a centreline stiffener or web may be required. Where this is impracticable due to fabrication access considerations, alternative supporting arrangements will be specially considered

3.3.4 For large or novel craft the scantlings of the stem will be specially considered.

3.3.5 The breadth of plate stems is to be not less than the width of keel as required by 3.2.1.

3.4 Bottom shell plating

3.4.1 The thickness of the bottom shell plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.4.2 For all craft types the minimum thickness requirement for bottom shell plating, *see* Fig. 3.3.1, as detailed in Section 2, is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

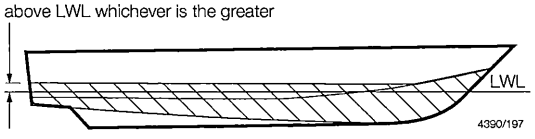

Fig. 3.3.1 Extent of bottom shell

3.5 Side shell plating

3.5.1 The thickness of the side shell plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

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3.6 Sheerstrake

3.6.1 The sheerstrake is generally to be taken as the side shell, locally reinforced in way of deck/hull connection and fender attachment. The amount of local reinforcement will be dependent upon the arrangement of structure and the proposed service.

3.6.2 The fendering arrangements for all craft types are the responsibility of the designers/Builders and are outside the scope of classification.

3.6.3 Where the pressure or impact loadings that a particular type of craft will experience in service are considered by the Builder, or subsequent Owner, to be not covered by or be greater than those indicated in Part 5 of the Rules, details of the loadings together with the calculations of how these will be satisfactorily distributed into the craft's structure, are to be submitted for consideration with the relevant construction plans.

3.6.4 The arrangements indicated in 3.6.5, 3.6.6, 4.18.2 and 4.18.3 for pilot and fishing craft are for the guidance of the Builder and subsequent Owners/operators of the craft. Where the intended service for either of these types of craft, or other types of craft which may be subject to loadings resulting from contact with other craft, jetties or similar loading or boarding facilities, is such that the loadings are greater than those that can be satisfactorily distributed into the craft's structure by the arrangements indicated, the strengthening arrangements are to be increased accordingly.

3.6.5 For pilot craft which may be subject to repeated impact loadings from contact with other craft etc., the sheerstrake plating is to be increased locally by not less than 50 per cent of the side shell thickness. The increased thickness is to extend from the bow aft over a distance of $0{,}33L_R$ or 500 mm aft of the point at which the deckline reaches its greatest breadth, whichever is the greater and forward of the quarter and over the transom for a distance of $0{,}075L_R$ or 1,0 m, whichever is the greater. It is in general to extend from the deck edge to below the first longitudinal stiffener, or a vertical distance equivalent to 1/3 the freeboard height whichever is the greater. The additional thickness is then to be tapered out to the side shell thickness in accordance with the Rules.

3.6.6 Fishing craft are in general to have their shell plating scantlings as required to satisfy the Rule loadings, increased by 20 per cent. Additionally the side shell is not to be taken less than as bottom shell thickness, and where there are gallows, gantries, nets, or lines etc., the plating in way is to be further increased locally and/or suitably protected by sheathing or other means.

3.6.7 Individual consideration will be given to lesser scantlings than those required by 3.6.3. for fishing craft used for pleasure, light duties, etc.; details of the service are to be submitted.

3.6.8 Where a rounded sheerstrake is adopted the radius is, in general, to be not less than 15 times the thickness.

3.6.9 The sheerstrake thickness is to be increased by 20 per cent at the ends of a bridge superstructure extending out to the craft's side. In the case of a bridge superstructure exceeding $0{,}15L_R$, the side plating at the ends of the superstructure is also to be increased by 25 per cent and tapered gradually into the upper deck sheerstrake.

3.6.10 In general, compensation will not be required for openings in the sheerstrake which are clear of the gunwale or deck openings and whose depth does not exceed 20 per cent of the depth of the sheerstrake. Openings are not to be cut in a rounded gunwale.

3.7 Chines

3.7.1 The chine plate thickness is to be equivalent to the bottom shell thickness required to satisfy the Rule pressure loading, increased by 20 per cent, or 6 mm, whichever is the greater.

3.7.2 Where tube is used in chine construction, the minimum wall thickness is to be not less than the thickness of the bottom shell plating increased by 20 per cent.

3.7.3 Full penetration welding of shell plating in way of chines is always to be maintained.

3.7.4 Chine details are to be such that the continuity of structural strength across the panel is maintained. Details of chines are to be submitted for consideration. *See also* LR's *Guidance Notes for Structural Details.*

3.8 Skegs

3.8.1 The thickness of the skeg plating is to be not less than the thickness of the adjacent bottom shell and additionally is to satisfy the requirements for solepieces given in Pt 3, Ch 3,3.

3.9 Transom

3.9.1 The thickness of the stern or transom is to be not less than that required for the side or bottom shell as appropriate. Where water jet or sterndrive units are fitted, the scantlings of the plating in way of the nozzles and connections will be specially considered.

3.10 Fin and tuck

3.10.1 The thickness of the plating is to be increased locally in way of the fin and tuck areas of yachts which have either internal fixed ballast or external attached ballast keels.

3.10.2 The plating thickness is to be not less than 1,25 times the thickness of the adjacent shell plating but need not be greater than the plate keel thickness as required by 3.2.

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3.11 Shell openings

3.11.1 Sea-inlets, or other openings, are to have well rounded corners and, so far as is practicable, are to be kept clear of the bilge radius, chine or radiused sheerstrake. Arrangements are to be made to maintain the strength in way of the openings.

3.11.2 Openings on or near the bilge radius may be accepted provided that they are of elliptical shape, or equivalent, to minimize stress concentrations and are, in general, to be cut clear of weld connections.

3.12 Sea inlet boxes

3.12.1 The thickness of the sea inlet box plating is to be 2 mm thicker than the adjacent shell plating, or 6 mm, whichever is the greater.

3.13 Local reinforcement/Insert plates

3.13.1 The thickness of the shell envelope plating determined in accordance with 3.4 and 3.5 is to be increased locally, by generally not less than 50 per cent in way of sternframe, propeller brackets, rudder horn, stabilisers, hawse pipes, anchor recess, etc. Details of such reinforcement are to be submitted for approval.

3.13.2 Insert plates are to extend outside the line of adjacent supporting structure and then be tapered over a distance of not less than three times the difference in thickness, *see also* Ch 2,4.22.

3.14 Appendages

3.14.1 The scantlings of appendages will be subject to special consideration on the basis of the Rules and the design loadings anticipated, but are, in no case, to be taken as less than that of the surrounding structure.

3.15 Fender attachment

3.15.1 Wood belting and fenders are to be bolted to lugs welded to a ground bar attached to the shell and not through-bolted to the shell plating.

3.16 Novel features

3.16.1 Where the Rules do not specifically define the requirements for novel features then the scantlings and arrangements are to be determined by direct calculation. Such calculations are to be carried out on the basis of the Rules or recognised standards. Details are to be submitted for consideration.

■ *Section 4* Shell envelope framing

4.1 General

4.1.1 The requirements in this Section apply to longitudinally and transversely framed shell envelopes.

4.1.2 For each stiffening member an assumed load model is stated. Where the proposed stiffener arrangement differs from that assumed, consideration will be given to an alternative load model.

4.1.3 The geometric properties of stiffener sections are to be in accordance with 1.18.

4.2 Bottom longitudinal stiffeners

4.2.1 Bottom longitudinal stiffeners are to be supported by bottom transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.2.2 Bottom longitudinals are to be continuous through the supporting structures.

4.2.3 Where it is impracticable to comply with the requirements of 4.2.2, or where it is proposed to terminate the bottom longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.2.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b).

4.3 Bottom longitudinal primary stiffeners

4.3.1 Bottom longitudinal primary stiffeners are to be supported by bottom deep transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 6 m apart.

4.3.2 Bottom longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

4.3.3 Where it is impracticable to comply with the requirements of 4.3.2, or where it is proposed to terminate the stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

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4.3.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

4.4 Bottom transverse stiffeners

4.4.1 Bottom transverse stiffeners are defined as local stiffening members which support the bottom shell, and which may be continuous or intercostal.

4.4.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b).

4.5 Bottom transverse frames

4.5.1 Bottom transverse frames are defined as stiffening members which support the bottom shell. They are to be effectively continuous and bracketed at their end connections to side frames and bottom floors as appropriate.

4.5.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

4.6 Bottom transverse web frames

4.6.1 Bottom transverse web frames are defined as primary stiffening members which support bottom shell longitudinals. They are to be continuous and substantially bracketed at their end connections to side web frames and bottom floors.

4.6.2 Where it is impracticable to comply with the requirements of 4.6.1, or where it is proposed to terminate the bottom transverse web frames in way of longitudinal primary girders, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.6.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

4.7 Side longitudinal stiffeners

4.7.1 The side longitudinal stiffeners are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.7.2 Side longitudinals are to be continuous through the supporting structures.

4.7.3 Where it is impracticable to comply with the requirements of 4.7.2, or where it is proposed to terminate the side longitudinal in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.7.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b).

4.8 Side longitudinal primary stiffeners

4.8.1 Side longitudinal primary stiffeners are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 6 m apart.

4.8.2 Side longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

4.8.3 Where it is impracticable to comply with the requirements of 4.8.2, or where it is proposed to terminate the side longitudinal in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.8.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

4.9 Side transverse stiffeners

4.9.1 Side transverse stiffeners are defined as local stiffening members supporting the side shell and may be continuous or intercostal.

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4.9.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b).

4.10 Side transverse frames

4.10.1 Side transverse frames are defined as stiffening members supporting the side shell and spanning continuously between bottom floors/frames and decks. They are to be effectively constrained against rotation at their end connections.

4.10.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

4.11 Side transverse web frames

4.11.1 Side transverse web frames are defined as primary stiffening members which support side shell longitudinals. They are to be continuous and substantially bracketed at their head and heel connections to deck transverses and bottom web frames respectively.

4.11.2 Where it is impracticable to comply with the requirements of 4.11.1, or where it is proposed to terminate the web frames in way of side longitudinal primary stiffeners, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.11.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

4.12 Grouped frames

4.12.1 For the purposes of satisfying Rule scantling requirements, frames may, subject to agreement by LR, be grouped. The number of frames in any group shall not in general exceed five. The summation of the section moduli and inertia for the group of frames is not to be less than the summation of the Rule requirement for the individual framing members. In addition, in no case is the proposed scantling of an individual framing member within the group to be less than ninety per cent of the Rule value for that member.

4.13 Grillage structures

4.13.1 For complex girder systems, a complete structural analysis using numerical methods may have to be performed to demonstrate that the stress levels are acceptable when subjected to the most severe and realistic combination of loading conditions intended.

4.13.2 General or special purpose computer programs or any other analytical techniques may be used provided that the effects of bending, shear, axial and torsion are properly accounted for and the theory and idealisation used can be justified.

4.13.3 In general, grillages consisting of slender girders may be idealised as frames based on beam theory provided proper account of the variations of geometric properties is taken. For cases where such an assumption is not applicable, finite element analysis or equivalent methods may have to be used.

4.14 Combined framing systems

4.14.1 Where longitudinal and transverse primary stiffeners form grillage structures the scantlings may be derived in accordance with 4.13.

4.15 Floating framing systems

4.15.1 Floating framing systems, where proposed, will be subject to special consideration.

4.16 Frame struts

4.16.1 Where struts are fitted to side shell transverse web frames or longitudinal primary stiffeners to carry axial loads, the strut cross-sectional area is to be derived as for pillars in Section 10. If fitted at the stiffener half span point, the stiffener section modulus may be taken as half the modulus derived above.

4.16.2 Design of end connections is to be such that the area of the welding is to be not less than the minimum cross-sectional area of the strut derived in 4.16.1. To achieve this, full penetration welding may be required. The weld connections between the face flats and webs of the pillar supporting structure are to be welded using double continuous welding of an equivalent area to that derived by 4.16.1.

4.17 Arrangements and details

4.17.1 The arrangement of the connection between the stiffener and the bracket is to be such that at no point in the connection are the section modulus and inertia reduced to less than that of the stiffener with associated plating.

4.17.2 The web stability, openings in the web and continuity and alignment are to be in accordance with 1.24, 1.25 and 1.26 respectively.

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4.17.3 Secondary and primary end connections and arrangements at intersection of continuous secondary and primary members are to be in accordance with 1.20, 1.22 and 1.28, respectively.

4.17.4 Stiffeners in slamming areas are to be lugged or bracketed.

4.18 Structure in way of fenders

4.18.1 **For craft**, including pilot boats and fishing vessels, which may be subject to repeated impact loadings from contact with other craft whilst in service, due consideration is to be given to increasing the scantlings of stiffening members in way of fenders. Details of anticipated loadings and calculations for the required increased scantlings are to be submitted, *see also* 3.6.3 and 3.6.4.

4.18.2 **Pilot craft** are to be fitted with large knees in way of the sheerstrake in areas as indicated in 3.6. The knees are to be aligned between the transverse frames and the deck beams. In the case of longitudinally framed craft, intermediate knees are to be fitted with a spacing in general not greater than 500 mm. Where such intermediate brackets are fitted they are to terminate on a side longitudinal with a section modulus of, in general, twice that of the Rule longitudinal for the web frame spacing, and a deck longitudinal. The side longitudinal is to be positioned below any fendering to carry the heel of the knee. Consideration will be given to the termination of such brackets by use of a 'soft-toe' in way of the deck. The thickness of the webs for these knees is to be twice that required by 1.21.

4.18.3 **Fishing craft** engaged in pair trawling and other modes of fishing, and which may be subject to repeated impact loading from contact with the other craft are to have additional stiffening fitted in way of the impact areas. This may be in the form of large knees, intermediate knees, substantial fendering/rubbing strakes.

4.19 Novel features

4.19.1 The scantlings are to be determined by direct calculation where the shell framing is of unusual design, form or proportions.

■ *Section 5*
Single bottom structure and appendages

5.1 General

5.1.1 The requirements of this Section provide for single bottom construction in association with transverse and longitudinal framing systems.

5.1.2 All girders are to extend as far forward and aft as practicable and care is to be taken to avoid any abrupt discontinuity. Where girders are cut at bulkheads, their longitudinal strength is to be maintained.

5.1.3 Particular care is to be taken to ensure that the continuity of structural strength in way of the intersection of transverse floors and longitudinal girders is maintained. The face flats of such stiffening members are to be effectively connected.

5.1.4 The single bottom structure in way of the keel and girders is to be sufficient to withstand the forces imposed by dry-docking the craft.

5.1.5 The scantlings of the single bottom structure are to comply with the appropriate minimum requirements given in Section 2.

5.2 Keel

5.2.1 The breadth, and thickness of plate keels are to comply with the requirements of 3.2.

5.2.2 The cross-sectional area, A_k, and thickness, t_k, of bar keels are not, in general, be taken as less than:

$$A_k = k_s (L_R + 1) \text{ cm}^2$$

$$t_k = \sqrt{k_s}\ (0{,}5L_R + 6) \text{ mm}$$

where

L_R and k_s are as defined in 1.5.1.

5.3 Centre girder

5.3.1 A centreline girder is, in general, to be fitted throughout the length of the hull in association with transverse frames, transverses supporting longitudinals or where the breadth of floors at the upper edge is greater than 1,5 m.

5.3.2 Centreline girders are to be formed of intercostal or continuous plate webs with a face flat welded to the upper edge. In all cases the face flat is to be continuous. Where girder webs are intercostal, additional bracketing and local reinforcement will be required to maintain the continuity of structural strength.

5.3.3 The web depth of the centre girder is in general to be equal to the depth of the floors at the centreline as specified in 5.5.3.

5.3.4 The web thickness, t_w, is to be taken not less than:

$$t_w = \sqrt{k_s}\ \left(\sqrt{L_R} + 1\right) \text{ mm}$$

where

L_R and k_s are as defined in 1.5.1.

5.3.5 The geometric properties of the centre girder are to be in accordance with 1.18.

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5.3.6 The face flat area of the centre girder, A_f, is to be not less than:

$$A_f = 0{,}3L_R k_s \text{ cm}^2$$

where

L_R and k_s are as defined in 1.5.1.

5.3.7 The face flat area of the centre girder outside $0{,}5L_R$ may be 80 per cent of the value given in 5.3.6.

5.3.8 The face flat thickness is to be not less than the thickness of the web.

5.3.9 The ratio of the width to thickness of the face flat is to be not less than 8 but is not to exceed 16.

5.3.10 Additionally, the requirements of 4.3 for bottom longitudinal primary stiffeners are to be complied with.

5.4 Side girders

5.4.1 Where the floor breadth at the upper edge exceeds 6,0 m side girders are to be fitted at each side of the centre girder such that the spacing between the side and centre girders or between the side girders themselves is not greater than 3 metres. Side girders where fitted are to extend as far forward and aft as practicable and are, in general, to terminate in way of bulkheads, deep floors or other primary transverse structure.

5.4.2 The web thickness of side girders is to be taken as not less than:

$$t_w = \sqrt{(k_s L_R)} \text{ mm}$$

where

L_R and k_s are as defined in 1.5.1.

5.4.3 The face flat area and thickness of side girders are to comply with the requirements for plate floors as defined in 5.5.6 and 5.5.7.

5.4.4 Watertight side girders and side girders forming the boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads and deeptanks as detailed in 7.3 and 7.5 respectively.

5.4.5 In the engineroom, additional side girders are generally to be fitted in way of main machinery seatings. Where fitted, they are to be integrated into the structure of the craft and extended forward and aft as far as practicable.

5.4.6 Additionally, the requirements of 4.3 for bottom longitudinal primary stiffeners are to be complied with.

5.5 Floors general

5.5.1 In transversely framed craft, plate floors are generally to be fitted at each frame.

5.5.2 In longitudinally framed craft, plate floors are to be fitted at every transverse web frame and generally at a spacing not exceeding 2 m. Additional transverse floors or webs are in general to be fitted at half web-frame spacing in way of engine seatings and thrust bearings, pillars, skegs, ballast/bilge keels and the bottom of the craft forward.

5.5.3 The overall depth, d_f, of plate floors at the centreline is not to be taken as less than:

when $B < 10$ m $\quad d_f = 40\,(B + 0{,}85D)$ mm

when $B \geq 10$ m $\quad d_f = 40\,(1{,}5B + 0{,}85D) - 200$ mm

where

D is defined in Pt 3, Ch 1,6.2.6

B is as defined in 1.5.1.

5.5.4 The web thickness, t_w, of plate floors, is to be accordance with 1.18 and is to be taken as not less than:

$$t_w = \sqrt{k_s}\left(\frac{3{,}4d_f}{1000} + 2{,}25\right)\left(\frac{s}{1000} + 0{,}5\right) \text{ mm}$$

where

d_f is to be determined from 5.5.3

k_s and s are as defined in 1.5.1.

5.5.5 If the side frames of the craft are attached to the floors by brackets, the depth of floor may be reduced by 15 per cent and the floor thickness determined using the reduced depth. The brackets are to be flanged and have the same thickness as the floors, and their arm lengths clear of the frame are to be the same as the reduced floor depth given above.

5.5.6 The face flat area of floors, A_f, is not to be taken as less than:

$$A_f = k_s\, 0{,}15L_R \text{ cm}^2$$

where

k_s and L_R are defined in 1.5.1.

5.5.7 The face flat thickness is to be not less than the thickness of the web and the ratio of the web to the thickness of the face flat is to be not less than 8 but is not to exceed 16.

5.5.8 Additionally the requirements of 4.6 for bottom transverse web frames are to be complied with.

5.5.9 Floors are generally to be continuous from side to side.

5.5.10 The tops of floors, in general, may be level from side to side. However, in craft having considerable rise of floor the depth of the floor plate may require to be increased to maintain the required section modulus.

5.5.11 The floors in the aft peak are to extend over and provide effective support to the stern tube(s) where applicable.

5.5.12 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deeptanks as detailed in 7.3 and 7.5.

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5.6 Floors in machinery spaces

5.6.1 The thickness, t_W, of the floors in machinery spaces is to be 1 mm greater than that required by 5.5.4.

5.6.2 The depth and section modulus of floors anywhere between engine or gearbox girders is to be not less than that required to maintain continuity of structural integrity or 50 per cent of the depth given in 5.5.3. The face flat area and web thickness for such reduced floor heights are to be increased appropriately in order to maintain continuity of structural strength, *see also* 4.12.

5.7 Machinery seatings

5.7.1 The general requirements for machinery seatings are given in Pt 3, Ch 2,6.9, *see also* Pt 9, Ch 1,5.

5.7.2 Engine holding-down bolts are to be arranged as near as practicable to floors and longitudinal girders. When this cannot be achieved, bracket floors are to be fitted.

5.7.3 Welding in way of machinery seatings is to be double continuous and/or full penetration where appropriate.

5.8 Drainholes in bottom structure

5.8.1 Sufficient limber holes are to be cut in the internal bottom structure to allow for the drainage of water from all parts of the bilge to the pump suctions.

5.8.2 Particular care is to be given to the positioning of limber holes to ensure adequate drainage and to avoid stress concentrations.

5.8.3 Suitable arrangements are to be made to provide free passage of air from all parts of tanks to the air pipes.

5.9 Rudder horns

5.9.1 The shell plating thickness in way of the rudder horn is to be increased locally, by generally not less than 50 per cent, but need not be taken as greater than the keel thickness required by 3.2.

5.9.2 The scantlings of the rudder horn are to be such that the section modulus against transverse bending, Z_r, at any horisontal section XX (*see* Fig. 3.5.1) is not less than:

$$Z_r = 1{,}5k_s R_A K_V (V+3)^2 \sqrt{a^2 + 0{,}5b^2} \quad \text{cm}^3$$

where

R_A = total rudder area, in m^2

V = maximum speed in the fully loaded condition, in knots

K_V = 1,0 for displacement craft with $V/\sqrt{L_{WL}} < 3{,}0$

= $(1{,}12 - 0{,}005V)^3$ for planing and semi-planing craft with $V/\sqrt{L_{WL}} \geq 3{,}0$

a, b = dimensions, in metres, as given in Fig. 3.5.1

L_{WL} is as defined in Pt 3, Ch 1,6.2.5.

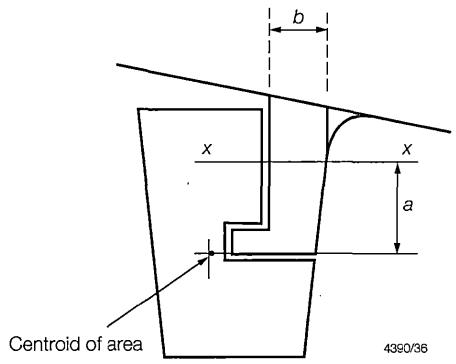

Fig. 3.5.1 Rudder horn

5.9.3 Rudder horns are to be effectively integrated into the adjacent structure and their design is to be such as to facilitate this.

5.10 Sternframes

5.10.1 The scantlings of fabricated and forged/solid sternframes are to comply with the requirements of Pt 3, Ch 3,3 modified for appropriate grade of steel in accordance with Pt 3, Ch 3,1.2.

5.11 Skeg construction

5.11.1 Skegs are to be effectively integrated into the adjacent structure and their design is to be such as to facilitate this.

5.11.2 The scantlings and arrangements for skegs (solepieces) are to be in accordance with Pt 3, Ch 3,3.14.

5.11.3 The scantlings of skegs are to be sufficient to withstand any docking forces that they may be subjected to.

5.12 Forefoot and stem

5.12.1 The thickness of plate stems at the waterline is to comply with the requirements for plate keels as given in 3.2.

5.12.2 The forefoot and stem is to be additionally reinforced with floors.

5.12.3 The cross-sectional area of bar stems, A_{bs}, is not to be taken as less than:

$$A_{bs} = 0{,}8k_s L_R \quad \text{cm}^2$$

where

L_R and k_s are as defined in 1.5.1.

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5.13 Transom knee

5.13.1 Centre and side girders are to be bracketed to the transom framing members by means of substantial knees. The face flat of the girders may be gradually reduced to that of the transom stiffening members in accordance with Fig. 3.5.2.

5.13.2 Hard spots are to be avoided in way of the end connections and care is to be taken to ensure that the stiffening member to which the transom knee is bracketed can satisfactorily carry the transmitted loads.

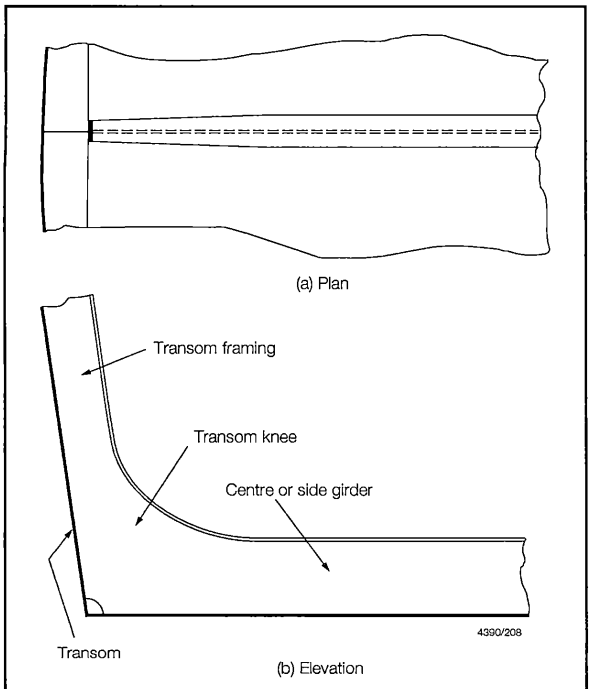

Fig. 3.5.2 Transom knee

■ *Section 6* Double bottom structure

6.1 General

6.1.1 The requirements given in this Section provide for double bottom construction of steel mono-hull craft in association with either transverse or longitudinal framing.

6.1.2 Double bottoms are generally to be fitted in accordance with Pt 3, Ch 2,6.6 and where fitted are to extend from the collision bulkhead to the after peak bulkhead, as far as this is practicable within the design and proper working of the craft. In addition, the inner bottom is to be continued to the craft's side in such a manner as to protect the bottom to the turn of bilge or chine.

6.1.3 The double bottom structure in way of girders and duct keels is to be sufficient to withstand the forces imposed by dry-docking the craft.

6.1.4 The centreline girder and side girders are to extend as far forward and aft as practicable and care is to be taken to avoid any abrupt discontinuity. Where girders are cut at bulkheads, their longitudinal strength is to be maintained.

6.1.5 The scantlings of the double bottom structure are to comply with the appropriate minimum requirements given in Section 2.

6.2 Keel

6.2.1 The scantlings of bar and plate keels are to comply with the requirements of 5.3.

6.2.2 Duct keels, where arranged, are to have a side plate thickness not less than:

$$t_p = \sqrt{k_s}\ (0{,}008 d_{DB} + 1)\ \text{mm}$$

but need not be taken as greater than 90 per cent of the centre girder thickness given in 6.3.

where

d_{DB} is the Rule centre girder depth given in 6.3.3

k_s as defined in 1.5.1.

6.2.3 Where a duct keel forms the boundary of a tank, the requirements of 7.4 and 7.5 for deep tanks are to be complied with.

6.2.4 The duct keel width is in general to be 15 per cent of the beam or 2 m, whichever is the lesser, but in no case is it to be taken as less than 630 mm. The inner bottom and bottom shell within the duct keel are to be suitably stiffened with primary stiffening in the transverse direction, whilst the continuity of the floors is maintained. Access to the duct keel is to be by means of watertight manholes or trunks.

6.3 Centre girder

6.3.1 A centre girder is to be fitted throughout the length of the craft. The web thickness, t_w, is not to be less than that required by:

$$t_w = \sqrt{k_s}\ (0{,}1 L_R + 3)\ \text{mm within } 0{,}4 L_R \text{ amidships}$$

$$= \sqrt{k_s}\ (0{,}1 L_R + 2)\ \text{mm at ends.}$$

where

k_s and L_R as defined in 1.5.1.

6.3.2 The geometric properties of the girder section are to be in accordance with 1.18.

6.3.3 The overall depth of the centre girder, d_{DB}, is to be taken as not less than 630 mm and is to be sufficient to give adequate access to all parts of the double bottom.

6.3.4 Additionally, the requirements of 4.3 for bottom longitudinal primary stiffeners are to be complied with.

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6.4 Side girders

6.4.1 Where the floor breadth does not exceed 6,0 m, side girders are not required. Vertical stiffeners are to be fitted to the floors on each side, the number and positions of these stiffeners being dependent on the arrangement of the double bottom structure.

6.4.2 Where the breadth of floor is greater than 6,0 m, additional side girders having the same thickness as the floors are to be fitted. The number of side girders is to be such that the distance between the side girders and centre girder and margin plate, or between the side girders themselves, does not exceed 3,0 m.

6.4.3 Side girders where fitted are to extend as far forward and aft as practicable and are in general to terminate in way of bulkheads, deep floors or other primary transverse structure.

6.4.4 Where additional side girders are fitted in way of main machinery seatings, they are to be integrated into the structure of the craft and extended forward and aft as far as practicable.

6.4.5 Under the main engine, girders extending from the bottom shell to the top plate of the engine seating are to be fitted. The height of the girders is to be not less than the height of the floor. Engine holding-down bolts are to be arranged as near as practicable to the girders and floors. Where this cannot be achieved, bracket floors and/or hanging brackets are to be fitted.

6.4.6 Additionally, the requirements of 4.3 for bottom longitudinal primary stiffeners are to be complied with.

6.5 Plate floors

6.5.1 The web thickness of non-watertight plate floors, t_w, is to be not less than:

$$t_w = \sqrt{k_s}\ (0{,}05L_R + 3{,}5)\ \text{mm}$$

where

k_s and L_R as defined in 1.5.1.

6.5.2 Additionally, the requirements of 4.6 for bottom transverse web frames stiffeners are to be complied with.

6.5.3 Plate floors are, in general, to be continuous between the centre girder and the margin plate.

6.5.4 In longitudinally framed craft, plate floors or equivalent structure are, in general, to be fitted in the following positions:

(a) At every half frame in way of the main engines, thrust bearings, and bottom of the craft forward.
(b) Outboard of the engine seatings, at every frame within the engine room.
(c) Underneath pillars and bulkheads.
(d) Outside of the engine room at a spacing not exceeding 2,0 m.

6.5.5 Vertical flat bar stiffeners are to be fitted to all plate floors at each longitudinal. Each stiffener is to have a depth of not less than $10t_w$ and a thickness of not less than t_w, where

t_w is the thickness of the plate floor as calculated in 6.5.1.

6.5.6 In transversely framed craft, plate floors are to be fitted at every frame in the engine room, under bulkheads, in way of change in depth of double bottom and elsewhere at a spacing not exceeding 2,0 m.

6.6 Bracket floors

6.6.1 Between plate floors, the shell and inner bottom plating is to be supported by bracket floors. The brackets are to have the same thickness as plate floors and are to be stiffened on the unsupported edge.

6.6.2 In longitudinally framed craft, the brackets are to extend from the centre girder and margin plate to the adjacent longitudinal, but in no case is the breadth of the bracket to be taken as not less than 75 per cent of the depth of the centre girder. They are to be fitted at every web frame at the margin plate, and those at the centre girder are to be spaced not more than 1,0 m apart.

6.6.3 In transversely framed craft, the breadth of the brackets, attaching the bottom and inner bottom frames to the centre girder and margin plate, is to be not less than 75 per cent of the depth of the centre girder.

6.7 Watertight floors

6.7.1 The scantlings of watertight floors are to comply with the requirements for plate floors as given in 6.5.

6.7.2 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deep tanks as detailed in 7.3 or 7.5 respectively.

6.8 Tankside brackets

6.8.1 The scantlings of tankside brackets are to comply with the requirements for plate floors given in 6.5.

6.9 Inner bottom plating

6.9.1 The thickness of the inner bottom plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

6.9.2 Inner bottom plating forming the boundaries of tank spaces is, in addition, to comply with the requirements for watertight bulkheads or deeptanks as detailed in 7.2 or 7.4 respectively. Where the plating forms vehicle, passenger or other decks the requirements of Section 8 are to be complied with.

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6.10 Inner bottom longitudinals

6.10.1 Inner bottom longitudinals are to be supported by inner bottom transverse web frames, floors, bulkheads or other primary structure, generally spaced not more than 2 m apart.

6.10.2 The inner bottom longitudinals are to be continuous through the supporting structure and are to be satisfactorily stiffened against buckling.

6.10.3 Where it is impracticable to comply with the requirements of 6.10.2, or where it is desired to terminate the inner bottom longitudinals in way of bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

6.10.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b).

6.11 Inner bottom transverse web framing

6.11.1 Inner bottom transverse web frames are defined as primary stiffening members which support inner bottom longitudinals. They are to be continuous and to be substantially bracketed at their end connections to bottom web frames, bottom floors and tankside brackets.

6.11.2 Where it is impracticable to comply with the requirements of 6.11.1, or where it is desired to terminate the inner bottom transverse web frames in way of centre or side girders, bulkheads or integral tank boundaries, etc., they are to be bracketed in way of their end connections, to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

6.11.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

6.12 Margin plates

6.12.1 A margin plate, if fitted, is to have a thickness as required for inner bottom plating.

6.13 Wells

6.13.1 Small wells constructed in the double bottom structure are not to extend in depth more than necessary. A well extending to the outer bottom may, however, be permitted at the after end of the shaft tunnel of the craft. Other well arrangements (e.g. for lubricating oil under main engines) may be considered provided they give protection equivalent to that afforded by the double bottom.

6.14 Transmission of pillar loads

6.14.1 In double bottoms under widely spaced pillars, the connections of the floors to the girders, and of the floors and girders to the inner bottom, are to be suitably increased. Where pillars are not directly above the intersection of plate floors and girders, partial floors and intercostals are to be fitted as necessary to support the pillars. Manholes are not to be cut in the floors and girders below the heels of pillars. Where longitudinal framing is adopted in the double bottom, equivalent stiffening under the heels of pillars is to be provided, and where the heels of pillars are carried on a tunnel, suitable arrangements are to be made to support the load.

6.15 Manholes

6.15.1 Sufficient manholes are to be cut in the inner bottom, floors and side girders to provide adequate access to, and ventilation of, all parts of the double bottom. The size of the manhole openings is not, in general, to exceed 50 per cent of the double bottom depth unless edge reinforcement is provided. Holes are not to be cut in the centre girder, except in tanks at the forward and after ends of the craft, and elsewhere where tank widths are reduced unless additional stiffening and/or compensation is fitted to maintain the structural integrity.

6.16 Pressure testing

6.16.1 Double bottoms are to be tested upon completion with a head of water representing the maximum internal pressure which could be experienced in service, but not less than a head of water equivalent to the level of the upper deck.

6.17 Drainholes in bottom structure

6.17.1 Sufficient limber holes are to be cut in the internal bottom structure to allow for the drainage of water from all parts of the bilge to the pump suctions.

6.17.2 Particular care is to be given to the positioning of limber holes to ensure adequate drainage and to avoid stress concentrations.

6.17.3 Suitable arrangements are to be made to provide free passage of air from all parts of tanks to the air pipes.

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Section 7
Bulkheads and deep tanks

7.1 General

7.1.1 The requirements of this Section apply to a vertical system of stiffening on bulkheads. They may also be applied to a horizontal system of stiffening provided that equivalent support and alignment are provided.

7.1.2 The number and disposition of transverse watertight bulkheads are to be in accordance with Pt 3, Ch 2,4.

7.1.3 Bulkheads, or part bulkheads, forming the boundary of tanks are to comply with the requirements of 7.5 and 7.6.

7.1.4 For bulkheads in way of partially filled holds or tanks, sloshing forces may be required to be taken into account. Where such forces are likely to be significant, the scantlings will be required to be verified by additional calculations.

7.1.5 A centreline bulkhead is, generally, to be fitted in deep tanks which extend from side to side. The bulkhead may be intact or perforated as desired. If intact, the scantlings are to comply with the requirements of 7.5 and 7.6 for tank boundary bulkheads. If perforated, they are to comply with the requirements of 7.13 for washplates.

7.1.6 The minimum requirements in Section 2 are to be complied with.

7.2 Watertight bulkhead plating

7.2.1 The thickness of the watertight bulkhead plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

7.3 Watertight bulkhead stiffening

7.3.1 The Rule requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 using the appropriate load model.

7.3.2 Bulkheads are to be suitably strengthened, if necessary, at the ends of deck girders and where subjected to concentrated loads.

7.4 Deep tank plating

7.4.1 The thickness of deep tank plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

7.5 Deep tank stiffening

7.5.1 Deep tank bulkhead stiffeners are to be bracketed at both ends. The thickness of the brackets is to be not less than the web thickness of the stiffener.

7.5.2 The Rule requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4, 3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for load model (b).

7.6 Double bottom tanks

7.6.1 The scantlings of double bottom tanks are to comply with the requirements for deep tanks given in 7.4 and 7.5.

7.6.2 Where the crown of a double bottom tank forms a vehicle, passenger or other deck, the requirements of Section 8 are to be complied with.

7.7 Collision bulkheads

7.7.1 The scantlings of collision bulkheads are to comply with the requirements of 7.2 and 7.3 except that the thickness of plating and modulus of stiffeners are not to be less than 12 and 25 per cent greater respectively, than required by 7.2 and 7.3. If the collision bulkhead forms the boundary of a deep tank or cofferdam then the requirements of 7.4 and 7.5 are also to be complied with.

7.8 Gastight bulkheads

7.8.1 Where gastight bulkheads are fitted, in accordance with Pt 3, Ch 2,4 the scantling requirements for watertight bulkheads are to be complied with.

7.8.2 Gastight bulkheads are to be fitted to protect accommodation spaces from gases and vapour fumes from machinery exhaust and fuel systems.

7.9 Non-watertight or partial bulkheads

7.9.1 Where a bulkhead is structural but non-watertight the scantlings are in general to be as for watertight bulkheads or equivalent in strength to web frames in the same position. Partial bulkheads that are non-structural are outside the scope of LR classification.

7.10 Transmission of pillar loads

7.10.1 Bulkheads that are required to act as pillars in way of underdeck girders and other structures subject to heavy loads are to comply with the requirements of Section 10.

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7.11 Corrugated bulkheads

7.11.1 The plating thickness and section modulus for symmetrical corrugated bulkheads are to be in accordance with watertight bulkheads or deep tank bulkheads as appropriate. The spacing, s, is to be taken as s_c, as defined in Fig. 2.3.1 in Pt 3, Ch 2.

7.11.2 In addition, the section geometric properties of 1.18 are to be complied with.

7.11.3 The actual section modulus may be derived in accordance with Pt 3, Ch 2,3.2.

7.12 Stiffeners passing through bulkheads

7.12.1 Primary longitudinal stiffening members are to be continuous through transverse bulkheads.

7.12.2 Pipe or cable runs through watertight bulkheads are to be fitted with suitable watertight glands.

7.13 Wash plates

7.13.1 Tanks are to be sub-divided as necessary by internal baffles or wash plates. Baffles or wash plates which support hull framing are to have scantlings equivalent to web frames in the same position.

7.13.2 Wash plates and wash bulkheads are, in general, to have an area of perforation not less than 10 per cent of the total area of the bulkhead. The perforations are to be so arranged that the efficiency of the bulkhead as a support is not impaired.

7.13.3 The plate thickness is to be not less than the structural element from which the wash bulkhead is formed.

7.13.4 The general stiffener requirements are to be in accordance with 7.5. However, the section modulus may be 50 per cent of that required by 7.5.

7.14 Cofferdams

7.14.1 A cofferdam is to be fitted between freshwater and oil fuel or sanitary tanks. The scantlings of cofferdams are to comply with the requirements of deep tank bulkheads or non-watertight bulkheads as appropriate.

7.15 Coatings

7.15.1 Integral freshwater and oil fuel tanks are to be cleaned and dried after testing and then treated with a suitable coating, in accordance with the manufacturer's recommendations.

7.16 Air pipes

7.16.1 Air pipes of sufficient number and area are to be fitted to each tank in accordance with Pt 15, Ch 2,11.

7.17 Fire protection

7.17.1 Fire protection requirements given in Part 17 are to be complied with.

7.18 Access

7.18.1 Compartments within the craft are to be sufficiently accessible to allow for maintenance and future structural surveys. Linings on craft sides, deckheads and bulkheads, etc., must be capable of being removed. Sufficient space is to be available below lower decks/soles to allow access to the bottom structure. An adequate number of manholes, removable panels, etc., are to provided.

7.18.2 Doors and hatches fitted through watertight bulkheads are to be of equivalent construction to the bulkhead in which they are fitted, be permanently attached and capable of being closed watertight from both sides of the bulkhead. They are to be tested watertight.

7.18.3 Doors and hatches are not to be fitted in collision bulkheads, except in craft of less than 21 metres Rule length, L_R, or in the case where it would be impracticable to arrange access to the forepeak other than through the collision bulkhead. Where fitted, the doors and hatches are to be watertight, as small as practicable and open into the forepeak compartment. Doors in collision bulkheads are to be kept closed at all times while the craft is at sea, *see* Pt 3, Ch 2,4.3.4.

7.18.4 Particular care is to be given to the design and workmanship of the tanks, and adequate access manholes are to be fitted, *see* Pt 3, Ch 1,7.

7.19 Testing

7.19.1 Deep tanks are to be tested on completion, with a head of water to the top of the overflow, or 1,8 m above the crown of the tank, whichever is the greater. The pressure to which the tanks will be subjected to in service is to be indicated on the plans submitted.

■ *Section 8*
Deck structures

8.1 General

8.1.1 The deck plating is to be supported by transverse beams with fore and aft girders or by longitudinals with deep transverse beams. The transverse and deep transverse beams are to align with side main frames and side web frames respectively.

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8.1.2 Beams are to be fitted at every frame and bracketed to the frames. Strong beams and deep transverse beams are to align with and be effectively connected to the side web frames. They are also to be fitted at the ends of large openings in the deck.

8.1.3 The deck plating and supporting structure are to be suitably reinforced in way of cranes, masts, derrick posts and deck machinery.

8.1.4 Primary stiffening members are to be continuous and substantially bracketed at their end connections to maintain continuity of structural strength.

8.1.5 Secondary stiffening members are to be effectively continuous and bracketed at their end connections as appropriate.

8.1.6 Primary and secondary stiffener end connection arrangements are, in general, to be in accordance with 1.22 and 1.20, respectively.

8.1.7 The ends of beams, longitudinals, girders and transverses are to be effectively built into the adjacent structure, or equivalent arrangements provided.

8.1.8 Tripping brackets are to be fitted on deep webs.

8.1.9 Deck structures subject to concentrated loads, are to be suitably reinforced. Where concentrations of loading on one side of a stiffening member may occur, such as pillars out of line, the member is to be adequately stiffened against torsion. Additional reinforcements may be required in way of localised areas of high stress.

8.1.10 The thickness of the deck plating is in no case to be less than the appropriate minimum requirement given in Section 2.

8.1.11 The geometric properties of stiffener sections are to be in accordance with 1.18.

8.2 Strength/Weather deck plating

8.2.1 The thickness of strength/weather deck plating is to be determined from the general plating equation given in 1.16 using the design pressure head from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

8.2.2 The scantlings of watertight cockpits are to be of equivalent strength to those of the strength/weather deck, *see also* Part 4.

8.2.3 It is recommended that the working areas of the weather deck have an anti-slip surface.

8.2.4 Where decks are sheathed with wood or other materials, details of the method of attachment are to be submitted, *see also* 2.4.

8.3 Lower deck/Inside deckhouse plating

8.3.1 The thickness of the lower deck/inside deckhouse plating is to be determined from the general plating equation given in 1.16 using the design pressure head from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

8.4 Accommodation deck plating

8.4.1 Accommodation decks are in general to be treated as lower deck/inside deckhouse decks, with their plating requirements determined in accordance with 8.3.

8.5 Cargo deck plating

8.5.1 The thickness of cargo deck plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

8.5.2 For vehicle decks, plating thickness requirements are to comply with the requirements of Ch 5,3.

8.6 Decks forming crowns of tanks

8.6.1 Decks forming the crown of tanks are to comply with the requirements for the appropriate deck, and are to be additionally examined for compliance with the requirements for deep tank plating given in 7.4.

8.7 Strength/Weather deck stiffening

8.7.1 The Rule requirements for section modulus, inertia and web area for the **strength/weather deck primary stiffening** are to be determined from the general equations given in 1.17, using the design pressure heads from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

8.7.2 The Rule requirements for section modulus, inertia and web area for the **strength/weather deck secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.7.3 Longitudinal framing is, in general, to be adopted at the strength deck outside line of openings, but special consideration will be given to proposals for transverse framing.

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8.8 Lower deck/Inside deckhouse stiffening

8.8.1 The Rule requirements for section modulus, inertia and web area for lower deck/inside deckhouse stiffening are to be determined from the general equations given in 1.17 using the design pressure head from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1. Primary members are assumed to be load model (a) and secondary members load model (b). However, special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.9 Accommodation deck stiffening

8.9.1 Accommodation decks are in general to be treated as lower deck/inside deckhouse decks, with their scantling requirements determined in accordance with 8.8.

8.10 Cargo deck stiffening

8.10.1 The Rule requirements for section modulus, inertia and web area for cargo deck stiffening are to be determined from the general equations given in 1.17 using the design pressure head from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1. Primary members are assumed to be load model (a) and secondary members load model (b). However, special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.10.2 In addition, where the cargo comprises wheeled vehicles, the requirements of Ch 5,3 are to be complied with.

8.11 Deck openings

8.11.1 All openings are to be supported by an adequate framing system, pillars or cantilevers. When cantilevers are used scantlings may be derived from direct calculations.

8.11.2 Where stiffening members terminate in way of an opening they are to be attached to carlings, girders, transverses or coaming plates.

8.11.3 The corners of large hatchways in the strength/weather deck within $0{,}5L_R$ amidships are to be elliptical, parabolic or rounded, with a radius generally not less than 1/24 of the breadth of the opening.

8.11.4 Where elliptical corners are arranged, the major axis is to be fore and aft, the ratio of the major to minor axis is to be not less than two to one nor greater than 2.5 to 1, and the minimum half-length of the major axis is to be defined by l_1 in Fig. 3.8.1. Where parabolic corners are arranged, the dimensions are also to be as shown in Fig. 3.8.1.

8.11.5 Where the corners are parabolic or elliptical, insert plates are not required.

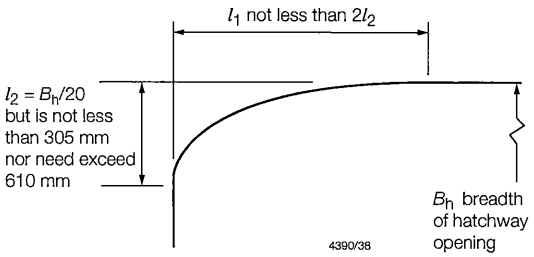

Fig. 3.8.1 Hatch opening geometry

8.11.6 For other shapes of corner, insert plates of the size and extent shown in Fig. 3.8.2 will, in general, be required. The required thickness of the insert plate is to be not less than 25 per cent greater than the adjacent deck thickness, outside line of openings.

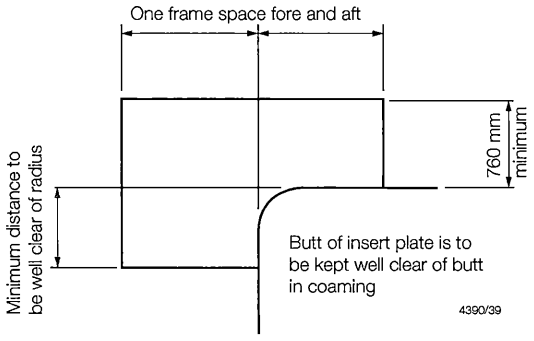

Fig. 3.8.2 Inserts in way of hatch opening

8.11.7 For lower decks the corners of large openings are to be rounded, with a radius generally not less than 1/24 of the breadth of the opening.

8.11.8 Insert plates will be required at lower decks in way of any rapid change in hull form to compensate for loss of deck cross-sectional area. Otherwise, insert plates will not normally be required.

8.11.9 Adequate transverse strength is to be provided in the deck area between large hatch openings, subjected to transverse and buckling loads.

8.11.10 The requirements for closing arrangements and outfit are given in Pt 3, Ch 4.

8.12 Sheathing

8.12.1 The requirements for deck sheathing given in 2.4 are to be complied with.

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8.13 Novel features

8.13.1 Where large or novel hatch openings are proposed, detailed calculations are to be submitted to demonstrate that the scantlings and arrangements in way of the openings are adequate to maintain continuity of structural strength.

■ *Section 9* Superstructures, deckhouses and bulwarks

9.1 General

9.1.1 Where practicable, superstructures and deckhouses are to be designed with well cambered decks and well radiused corners to build rigidity into the structure.

9.1.2 The plating and supporting structure are to be suitably reinforced in way of localised areas of high stress such as corners of openings, cranes, masts, derrick posts, machinery, fittings and other heavy or vibrating loads.

9.1.3 Primary stiffening members are to be continuous and substantially bracketed at their end connections to maintain continuity of structural strength.

9.1.4 Secondary stiffening members are to be effectively continuous and bracketed at their end connections as appropriate.

9.1.5 Structures subject to concentrated loads are to be suitably reinforced. Where concentrations of loading on one side of a stiffener may occur, such as pillars out of line, the stiffener is to be adequately stiffened against torsion.

9.1.6 The plating thickness of superstructures, deckhouses and bulwarks is no case to be less than the appropriate minimum requirement given in Section 2.

9.1.7 Stiffener sections and geometric properties are to be in accordance with 1.18.

9.2 Symbols and definitions

9.2.1 The term 'house' is used in this Section to include both superstructures and deckhouses.

9.2.2 The symbols applicable to this Section are defined in 1.5.1.

9.3 House side plating

9.3.1 The thickness of house side plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

9.4 House front plating

9.4.1 The thickness of the house front plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

9.5 House end plating

9.5.1 The thickness of the house end plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

9.6 House top plating

9.6.1 The thickness of the house top plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

9.7 Coachroof plating

9.7.1 The thickness of the coachroof plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

9.8 Machinery casing plating

9.8.1 The thickness of the plating of machinery casings is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

9.9 Forecastle requirements

9.9.1 The forecastle side plating may be a continuation of the hull side shell plating or fitted as a separate assembly. In both cases the plating thickness is to be the same as the side shell plating at deck edge. Where fitted as a separate assembly, suitable arrangements are to be made to ensure continuity of the effect of the sheerstrake at the break and at the upper edge of the forecastle side. Full penetration welding is to be used.

9.9.2 The side plating is to be stiffened by side frames effectively connected to the deck structure. Deep webs are to be fitted to ensure overall rigidity.

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9.9.3 The deck plating thickness is to be increased by 20 per cent in way of the end of the forecastle if this occurs at a position aft of $0{,}25L_R$ from the FP. No increase is required if the forecastle end bulkhead lies forward of $0{,}2L_R$ from the FP. The increase at intermediate positions of end bulkhead is to be obtained by interpolation.

9.10 House side stiffeners

9.10.1 The Rule requirements for section modulus, inertia and web area for the **house side primary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

9.10.2 The Rule requirements for section modulus, inertia and web area for **house side secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.11 House front stiffeners

9.11.1 The Rule requirements for section modulus, inertia and web area for **house front primary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

9.11.2 The Rule requirements for section modulus, inertia and web area for **house front secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.12 House aft end stiffeners

9.12.1 The Rule requirements for section modulus, inertia and web area for **house aft end primary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

9.12.2 The Rule requirements for section modulus, inertia and web area for **house aft end secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.13 House top stiffeners

9.13.1 The house top is to be effectively supported by a system of transverse or longitudinal beams and girders. The span of the beams is in general not to exceed 2,4 m and the beams are to be effectively connected to the house upper coamings and girders.

9.13.2 The Rule requirements for section modulus, inertia and web area for **house top primary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

9.13.3 The Rule requirements for section modulus, inertia and web area for **house top secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.14 Coachroof stiffeners

9.14.1 The Rule requirements for section modulus, inertia and web area for **coachroof primary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

9.14.2 The Rule requirements for section modulus, inertia and web area for **coachroof secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

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9.15 Machinery casing stiffeners

9.15.1 The Rule requirements for section modulus, inertia and web area for **machinery casing primary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

9.15.2 The Rule requirements for section modulus, inertia and web area for **machinery casing secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.15.3 Where casing sides act as girders supporting decks, care is to be taken that access openings do not seriously weaken the structure. Openings are to be effectively framed and reinforced if found necessary. Particular care is to be paid to stiffening where the casing supports the funnel or exhaust uptakes.

9.15.4 Where casing stiffeners carry loads from deck transverses, girders, etc., or where they are in line with pillars below, they are to be suitably reinforced.

9.16 Forecastle stiffeners

9.16.1 The scantlings of forecastle primary and secondary stiffening members are to be equivalent to those for the side shell envelope framing at the deck edge as required by Section 4.

9.17 Superstructures formed by extending side structures

9.17.1 Superstructure first tier sides formed by extending the hull side structure are to be in accordance with the requirements for house fronts given in 9.4 and 9.11 for plating and stiffeners respectively, but need not be taken as greater than the side structure requirements at the deck edge at the same longitudinal position.

9.18 Fire aspects

9.18.1 The requirements for fire detection, protection and extinction are given in Part 17.

9.19 Openings

9.19.1 All openings are to be substantially framed and have well rounded corners. Arrangements are to be made to minimise the effect of discontinuities in erections. Continuous coamings or girders are to be fitted below and above doors and similar openings.

9.19.2 Particular care is to be paid to the effectiveness of end bulkheads, and the upper deck stiffening in way, when large openings for doors and windows are fitted.

9.19.3 Special care is to be taken to minimise the size and number of openings in the side bulkheads in the region of the ends of erections within $0{,}5L_R$ amidships. Account is to be taken of the high vertical shear loading which can occur in these areas.

9.19.4 For closing arrangements and outfit the requirements are given in Pt 3, Ch 4.

9.20 Mullions

9.20.1 Window openings are to be suitably framed and mullions will in general be required.

9.20.2 The scantlings of mullions are to be not less than as required for a stiffener in the same position.

9.20.3 When determining the stiffener requirements, the width of effective plating is in no case to be taken as greater than the distance between adjacent window openings.

9.20.4 Where significant shear forces are to be vertically transmitted by the window frames, adequate shear rigidity is to be verified by direct calculation.

9.21 Global strength

9.21.1 Transverse rigidity is to be maintained throughout the length of the erection by means of web frames, bulkheads or partial bulkheads. Particular care is to be paid when an upper tier is wider than its supporting tier and when significant loads are carried on the house top.

9.21.2 Where practicable, web frames are to be arranged in line with bulkheads below.

9.21.3 Internal bulkheads are to be fitted in line with bulkheads or deep primary stiffeners below.

9.22 House/deck connection

9.22.1 Adequate support under the ends of erections is to be provided in the form of webs, pillars, diaphragms or bulkheads in conjunction with reinforced deck beams.

9.22.2 Special attention is to be given to the connection of the erection to the deck in order to provide an adequate load distribution and avoid stress concentrations.

9.22.3 Connections between the erection and the deck by means of bimetallic joints are to comply with Ch 2,4.24.

9.22.4 Typical design details of house/deck connections are given in LR's *Guidance Notes for Structural Details*.

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9.23 Sheathing

9.23.1 Sheathing arrangements are to comply with the requirements of 2.4.

9.24 Erections contributing to longitudinal strength

9.24.1 For craft above 40 m in length, L_R, or for designs where the superstructure is designed to absorb global loads the effectiveness of superstructures to carry these loads is to be determined. The effectiveness may be assessed in accordance with Ch 6,2.5.

9.24.2 Where 9.17 applies and the first or second tier is regarded as the strength deck according to Ch 6,2.5, the hull upper deck scantlings at the forward and aft ends of the superstructure may need to be increased due to the lesser efficiency of the superstructure tiers at their ends. The scantlings of the side structure in way of these areas may also be required to be increased.

9.24.3 When large openings or a large number of smaller openings are cut in the superstructure sides, reducing the capability to transmit shear force between decks, an assessment or structural efficiency may be required.

9.25 Novel features

9.25.1 Direct calculations may be required to determine the plating and stiffener requirements where the house is of unusual design, form or proportions.

9.26 Bulwarks

9.26.1 General requirements for bulwarks are given in Pt 3, Ch 4,8.

9.26.2 The thickness of the bulwark plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

9.26.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (d).

9.26.4 Bulwarks are not to be cut for gangway or other openings near the breaks of superstructures.

9.26.5 Attention is to be paid to avoid discontinuity of strength of the bulwark, particularly in way of local increases in stress and changes in height.

9.26.6 Welding of bulwark to the top edge of sheer-strake within $0{,}5L_R$ amidship, is generally to be avoided. However, if this arrangement is not practicable welding to the sheerstrake may be accepted if care is taken to minimise any notch effects.

9.26.7 **Fishing craft** are to have bulwarks fitted. The bulwark may be formed from a continuation of the side shell plating or connected as a separate assembly. Where the bulwark is considered to be stressed and contributing to the global strength of the craft, the plate thickness of the bulwark is not to be less than the sheer-strake thickness. In no case is the thickness of the bulwark plating to be taken as less than 80 per cent of the side shell thickness. The bulwark is to be supported by suitable stiffening members which may be formed from a continuation of the side frames, or from flanged plate stays of the same thickness as the bulwark. In general these frames are to be spaced not more than two side frame spacings apart.

9.26.8 In way of gantries, trawl gallows, mooring pipes etc., the plate thickness in way is to be increased by not less than 50 per cent.

9.26.9 **Pilot craft** are to be fitted with sufficient hand rails adjacent to the exposed areas of the working decks and platforms. In addition these areas are to have non-skid surfaces.

9.27 Freeing arrangements

9.27.1 Requirements for freeing arrangements are given in Pt 3, Ch 4,9.

9.28 Free flow area

9.28.1 The requirements for the free flow area are given in Pt 3, Ch 4,9.3.

9.29 Guard rails

9.29.1 The requirements for guard rails are given in Pt 3, Ch 4,8.4.

■ *Section 10* Pillars and pillar bulkheads

10.1 Application

10.1.1 Pillars are to be arranged to transmit loads from decks and superstructures into the bottom structure. Pillars are generally to be constructed from solid, tubular, or I beam section. A pillar may be a fabricated trunk or partial bulkhead.

10.2 Determination of span length

10.2.1 The effective span length of the pillar, l_{ep}, is in general the distance between the head and heel of the pillar. Where substantial brackets are fitted, l_{ep} may be reduced by 2/3 the depth of the bracket at each end.

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10.3 Head and heel connections

10.3.1 Pillars are to be attached at their heads to plates supported by efficient brackets, in order to transmit the load effectively. Doubling or insert plates are to be fitted to decks under large pillars and to the inner bottom under the heels of tubular or hollow square pillars. The pillars are to have a bearing fit and are to be attached to the head and heel plates by continuous welding. At the heads and heels of pillars built of rolled sections, the load is to be well distributed by means of longitudinal and transverse brackets.

10.4 Alignment and arrangement

10.4.1 Pillars are to be located on main structural members. They are in general to be fitted below windlasses, winches, capstans, the corners of deckhouses and elsewhere where considered necessary.

10.4.2 Wherever possible, deck pillars are to be fitted in the same vertical line as pillars above and below, and effective arrangements are to be made to distribute the load at the heads and heels of all pillars.

10.4.3 Where pillars support eccentric loads, or are subjected to lateral pressures, they are to be suitably strengthened for the additional bending moment imposed upon them.

10.4.4 Doublers are generally to be fitted on decks and inner bottoms, other than within tanks where doublers are not allowed. Brackets may be used instead of doublers.

10.5 Minimum thickness

10.5.1 The minimum wall thickness of hollow pillars is to be taken as not less than 1/20 of the external dimension of the pillar.

10.6 Design loads

10.6.1 The design loading, P_p, to be used in the determination of pillar scantlings is as follows:

$$P_p = S_{gt}\, b_{gt}\, P_c + P_a \text{ kN}$$

where

P_p = design load supported by the pillar, to be taken as not less than 5 kN

P_c = basic deck girder design pressure, as appropriate, plus any other loadings directly above the pillar, in kN/m^2

P_a = load, in kN, from pillar or pillars above, assumed zero if there are no pillars over

S_{gt} = spacing, or mean spacing, of girders or transverses, in metres

b_{gt} = distance between centres of two adjacent spans of girders or transverses supported by the pillar, in metres.

10.7 Scantlings determination

10.7.1 The cross-sectional area of the pillar, A_p, is not to be less than:

$$A_p = 10\,\frac{P_p}{\sigma_p} \text{ cm}^2$$

where

P_p = design load, in kN, supported by the pillar as determined from 10.6

σ_p = permissible compressive stress, in N/mm^2

$$= \frac{f_p\,\sigma_s}{1 + 0{,}0051\sigma_s\, k\left(\frac{l_{ep}}{r}\right)^2} \text{N/mm}^2$$

where

f_p = pillar location factor defined in Table 3.10.1

σ_s = specified minimum yield strength of the material, in N/mm^2

k_f = pillar end fixity factor
= 0,25 for full fixed/bracketed
= 0,50 for partially fixed
= 1,0 for free ended

r = least radius of gyration of pillar cross-section, in cm

$$= \sqrt{\frac{I_p}{A_p}} \text{ cm}$$

I_p = least moment of inertia of cross-section of pillar or stiffener/plate combination, in cm^4

l_{ep} = effective span of pillar, in metres, or bulkhead as defined in 10.2.

Table 3.10.1 Pillar location factors

Location	f_p
Supporting weather deck	0,50
Supporting vehicle deck	0,50
Supporting passenger deck	0,50
Supporting lower/inner deck	0,75
Supporting coachroof	0,75
Supporting deckhouse top	1,00

10.8 Maximum slenderness ratio

10.8.1 The slenderness ratio (l_{ep}/r) of pillars is not to be taken greater than 1,1. Where l_{ep} and r are as defined in 10.7.1. Pillars with slenderness ratio in excess of 1,1 may be accepted subject to special consideration on a case by case basis and provided that the remaining requirements of the Rules are complied with.

10.9 Pillars in tanks

10.9.1 In no circumstances are pillars to pass through tanks. Where loads are to be transmitted through tanks, pillars within the tanks are to be carefully aligned with the external pillars.

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10.9.2 Pillars within tanks are, in general, to be of solid cross section. Where it is proposed to use hollow section pillars each case will be subject to special consideration and the scantlings as determined from the Rules may require to be increased dependent upon the material to be used, the fluid contained and the arrangement of the pillars. Hollow pillars are to be adequately drained and vented.

10.9.3 Where pillars within tanks may be subjected to tensile stresses due to hydrostatic pressure, the design is to provide sufficient welding to withstand the tensile load imposed.

10.9.4 Doubling plates at ends of pillars within tanks are not acceptable.

10.10 Pillar bulkheads

10.10.1 The stiffener/plate combination used in the determination of pillar bulkhead scantlings is to be that of a stiffener with an effective width of attached plating as determined from 1.11.

10.10.2 The cross-sectional area of the pillar bulkhead, A_{pb}, is to be determined in accordance with 10.7 using the design loading, P_{pb}, as follows:

$$P_{pb} = S_{bs}\, b_{pb}\, P_c + P_a \text{ kN}$$

where

P_{pb} = design load supported by the stiffener plate combination of the pillar bulkhead

P_c = basic deck girder design pressure, as appropriate, plus any other loadings directly above the pillar, in kN/m^2

S_{bs} = spacing, or mean spacing, of bulkheads or effective transverses/longitudinal stiffeners, in metres

b_{pb} = distance between centres of two adjacent spans of girders or transverses supported by the pillar bulkhead, in metres, and can be taken as the distance between pillar bulkhead stiffeners where the stiffeners at the top of the bulkhead effectively distributes the load evenly into the stiffeners.

10.10.3 The thickness of the bulkhead plating is in no case to be taken as less than 4 mm.

10.11 Direct calculations

10.11.1 As an alternative to 10.6, pillars may be designed on the basis of direct calculation. The method adopted and the stress levels proposed for the material of construction are to be submitted together with the calculations for consideration.

10.12 Fire aspects

10.12.1 Pillars and pillar bulkheads are to be suitably protected against fire, and, where necessary, be self-extinguishing or capable of resisting fire damage. All pillars are to comply with the requirements of Part 17.

10.13 Novel features

10.13.1 Where unusual or novel pillar designs are proposed that are unable to comply with the requirements of this Section, their design together with the direct calculations are to be submitted for special consideration.

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Section

1 **General**

2 **Minimum thickness requirements**

3 **Shell envelope plating**

4 **Shell envelope framing**

5 **Single bottom structure and appendages**

6 **Double bottom structure**

7 **Bulkheads and deep tanks**

8 **Deck structures**

9 **Superstructures, deckhouses, pillars and bulwarks**

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to multi-hull craft of steel construction as defined in Pt 1, Ch 1,1.

1.2 General

1.2.1 Except as otherwise specified within this Chapter, the scantlings and arrangements of multi-hull craft are to be determined in accordance with the procedures described in, or required by Chapter 3 for mono-hull craft, using the pressures from Part 5 appropriate to multi-hulls.

1.3 Direct calculations

1.3.1 Where the craft is of unusual design, form or proportions, or where the speed of the craft exceeds 60 knots the scantlings are to be determined by direct calculation.

1.3.2 The requirements of this Chapter may be modified where direct calculation procedures are adopted to analyse the stress distribution in the primary structure.

1.4 Equivalents

1.4.1 Lloyd's Register (hereinafter referred to as 'LR') will consider direct calculations for the derivation of scantlings as an alternative and equivalent to those derived by Rule requirements in accordance with Pt 3, Ch 1,3.

1.5 Symbols and definitions

1.5.1 The symbols used in this Chapter are defined below and in the appropriate Section:

L_R = Rule length of craft, in metres
s = stiffener spacing, in mm
t_p = plating thickness, in mm
k_s = high tensile steel factor
= $235/\sigma_s$
σ_s = specified minimum yield strength of the material, in N/mm^2.

1.5.2 **Bottom outboard.** For high speed craft, where the scantlings of the bottom shell are governed by impact pressure considerations, the bottom outboard shell is defined as the area of the hull between the outboard edge of the keel and the outer bilge tangential point. For displacement and semi displacement type craft where the scantlings of the bottom shell are governed by either hydrostatic or pitching pressures the bottom outboard shell is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

1.5.3 **Bottom inboard.** For high speed craft, where the scantlings of the bottom shell are governed by impact pressure considerations, the bottom inboard shell is defined as the area of the hull between the inboard edge of the keel and the inner bilge tangential point. For displacement and semi displacement type craft where the scantlings of the bottom shell are governed by either hydrostatic or pitching pressures the bottom inboard shell is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

1.5.4 **Cross-deck.** The cross-deck is defined as the structure which forms the bridge connection between any two adjacent hulls.

1.5.5 **Haunch.** The haunch is defined as the transition area between the cross-deck and the inboard side shell plating.

1.5.6 **Side inboard.** The side inboard is defined as the area between the bottom inboard shell and the wet-deck (or lower edge of the haunches, where fitted).

1.5.7 **Side outboard.** The side outboard is defined as the area between bottom outboard shell and the deck at side.

1.5.8 **Wet-deck.** The wet-deck is defined as the area between the upper edges of the side inboard plating (or upper edges of the haunches, where fitted).

■ *Section 2* Minimum thickness requirements

2.1 General

2.1.1 Unless otherwise specified in this Section, the requirements of Ch 3,2 are to be complied with.

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2.1.2 The thickness of plating and stiffeners determined from the Rule requirements is in no case to be less than the appropriate minimum requirement given in Table 4.2.1 for craft type.

2.1.3 In addition, where plating contributes to the global strength of the craft, the thickness is to be not less than that required to satisfy global strength requirements.

Table 4.2.1 Minimum thickness requirements

Item	Minimum thickness (mm)		
	Catamaran	Multi-hull	Swath
Shell envelope Bottom shell plating	$\omega\sqrt{k_{ms}}\ (0,4\sqrt{L_R}+2,0) \geq 3,5\omega$	$\omega\sqrt{k_{ms}}\ (0,4\sqrt{L_R}+2,0) \geq 3,5\omega$	$\omega\sqrt{k_{ms}}\ (0,4\sqrt{L_R}+2,0) \geq 3,5\omega$
Side shell plating	$\omega\sqrt{k_{ms}}\ (0,38\sqrt{L_R}+1,2) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,38\sqrt{L_R}+1,2) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,38\sqrt{L_R}+1,2) \geq 3,0\omega$
Wet-deck plating	$\omega\sqrt{k_{ms}}\ (0,38\sqrt{L_R}+1,2) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,38\sqrt{L_R}+1,2) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,38\sqrt{L_R}+1,2) \geq 3,0\omega$
Single bottom structure Centre girder web	$\omega\sqrt{k_{ms}}\ (0,8\sqrt{L_R}+1,0) \geq 4,0\omega$	$\omega\sqrt{k_{ms}}\ (0,8\sqrt{L_R}+1,0) \geq 4,0\omega$	$\omega\sqrt{k_{ms}}\ (0,8\sqrt{L_R}+1,0) \geq 4,0\omega$
Floor webs	$\omega\sqrt{k_{ms}}\ (0,6\sqrt{L_R}+0,8) \geq 3,5\omega$	$\omega\sqrt{k_{ms}}\ (0,6\sqrt{L_R}+0,8) \geq 3,5\omega$	$\omega\sqrt{k_{ms}}\ (0,6\sqrt{L_R}+0,8) \geq 3,5\omega$
Side girder webs	$\omega\sqrt{k_{ms}}\ (0,6\sqrt{L_R}+0,8) \geq 3,5\omega$	$\omega\sqrt{k_{ms}}\ (0,6\sqrt{L_R}+0,8) \geq 3,5\omega$	$\omega\sqrt{k_{ms}}\ (0,6\sqrt{L_R}+0,8) \geq 3,5\omega$
Double bottom structure Centre girder:			
(1) Within $0,4L_R$ amidships	$\omega\sqrt{k_{ms}}\ (0,8\sqrt{L_R}+1,0) \geq 4,0\omega$	$\omega\sqrt{k_{ms}}\ (0,8\sqrt{L_R}+1,0) \geq 4,0\omega$	$\omega\sqrt{k_{ms}}\ (0,8\sqrt{L_R}+1,0) \geq 4,0\omega$
(2) Outside $0,4L_R$ amidships	$\omega\sqrt{k_{ms}}\ (0,7\sqrt{L_R}+1,0) \geq 4,0\omega$	$\omega\sqrt{k_{ms}}\ (0,7\sqrt{L_R}+1,0) \geq 4,0\omega$	$\omega\sqrt{k_{ms}}\ (0,7\sqrt{L_R}+1,0) \geq 4,0\omega$
Floors and side girders	$\omega\sqrt{k_{ms}}\ (0,6\sqrt{L_R}+0,8) \geq 3,5\omega$	$\omega\sqrt{k_{ms}}\ (0,6\sqrt{L_R}+0,8) \geq 3,5\omega$	$\omega\sqrt{k_{ms}}\ (0,6\sqrt{L_R}+0,8) \geq 3,5\omega$
Inner bottom plating	$\omega\sqrt{k_{ms}}\ (0,5\sqrt{L_R}+1,0) \geq 2,5\omega$	$\omega\sqrt{k_{ms}}\ (0,5\sqrt{L_R}+1,0) \geq 2,5\omega$	$\omega\sqrt{k_{ms}}\ (0,5\sqrt{L_R}+1,0) \geq 2,5\omega$
Bulkheads Watertight bulkhead plating	$\omega\sqrt{k_{ms}}\ (0,33\sqrt{L_R}+1,0) \geq 2,5\omega$	$\omega\sqrt{k_{ms}}\ (0,33\sqrt{L_R}+1,0) \geq 2,5\omega$	$\omega\sqrt{k_{ms}}\ (0,33\sqrt{L_R}+1,0) \geq 2,5\omega$
Deep tank bulkhead plating	$\omega\sqrt{k_{ms}}\ (0,38\sqrt{L_R}+1,2) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,38\sqrt{L_R}+1,2) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,38\sqrt{L_R}+1,2) \geq 3,0\omega$
Deck plating and stiffeners Strength/Main deck plating	$\omega\sqrt{k_{ms}}\ (0,38\sqrt{L_R}+1,2) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,38\sqrt{L_R}+1,2) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,38\sqrt{L_R}+1,2) \geq 3,0\omega$
Lower deck/Inside deckhouse	$\omega\sqrt{k_{ms}}\ (0,18\sqrt{L_R}+1,7) \geq 2,0\omega$	$\omega\sqrt{k_{ms}}\ (0,18\sqrt{L_R}+1,7) \geq 2,0\omega$	$\omega\sqrt{k_{ms}}\ (0,18\sqrt{L_R}+1,7) \geq 2,0\omega$
Superstructures and deckhouses Superstructure side plating	$\omega\sqrt{k_{ms}}\ (0,3\sqrt{L_R}+1,0) \geq 2,0\omega$	$\omega\sqrt{k_{ms}}\ (0,3\sqrt{L_R}+1,0) \geq 2,0\omega$	$\omega\sqrt{k_{ms}}\ (0,3\sqrt{L_R}+1,0) \geq 2,0\omega$
Deckhouse front 1st tier	$\omega\sqrt{k_{ms}}\ (0,47\sqrt{L_R}+1,5) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,47\sqrt{L_R}+1,5) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,47\sqrt{L_R}+1,5) \geq 3,0\omega$
Deckhouse front upper tiers	$\omega\sqrt{k_{ms}}\ (0,42\sqrt{L_R}+1,3) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,42\sqrt{L_R}+1,3) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,42\sqrt{L_R}+1,3) \geq 3,0\omega$
Deckhouse aft	$\omega\sqrt{k_{ms}}\ (0,2\sqrt{L_R}+0,6) \geq 2,0\omega$	$\omega\sqrt{k_{ms}}\ (0,2\sqrt{L_R}+0,6) \geq 2,0\omega$	$\omega\sqrt{k_{ms}}\ (0,2\sqrt{L_R}+0,6) \geq 2,0\omega$
Pillars Wall thickness of tubular pillars	$\omega\sqrt{k_{ms}}\ 0,05d_p$	$\omega\sqrt{k_{ms}}\ 0,05d_p$	$\omega\sqrt{k_{ms}}\ 0,05d_p$
Wall thickness of rectangular pillars	$\omega\sqrt{k_{ms}}\ 0,05b_p$	$\omega\sqrt{k_{ms}}\ 0,05b_p$	$\omega\sqrt{k_{ms}}\ 0,05b_p$

Symbols

ω = service type factor as determined from Table 3.2.2 in Chapter 3
k_{ms} = $635/(\sigma_s + \sigma_u)$
σ_s = specified minimum yield strength of the material, in N/mm^2
σ_u = specified minimum ultimate tensile strength of the material, in N/mm^2
b_p = minimum breadth of cross section of hollow rectangular pillar, in mm
d_p = outside diameter of tubular pillar, in mm

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■ *Section 3*
Shell envelope plating

3.1 General

3.1.1 Unless otherwise specified within this Section, the scantlings and arrangements for shell envelope plating are to be determined in accordance with the procedures described in, or as required by, Ch 3,3 for mono-hull craft using the pressures from Part 5 appropriate to multi-hulls.

3.1.2 The thickness of the shell envelope plating is in no case to be less than the appropriate minimum requirement given in Section 2.

3.2 Keel plates

3.2.1 The breadth, b_k, and thickness, t_k, of plate keels are not to be taken as less than:

$$b_k = 5{,}0L_R + 250 \text{ mm}$$

$$t_k = \sqrt{k_s}\ 1{,}35L_R^{0{,}45} \text{ mm}$$

where

L_R and k_s are as defined in 1.5.1.

3.2.2 In no case is the thickness of the keel to be less than that of the adjacent bottom shell plating.

3.2.3 The width and thickness of plate keels are to be maintained throughout the length of the craft from the transom to a point not less than 25 per cent of the freeboard (measured at the forward perpendicular) above the deepest load waterline on the stem. Thereafter the keel thickness may be reduced to that required by Ch 3,3.3.1 for the stem.

3.2.4 For large or novel craft and for yachts with externally attached ballast keels, the scantlings of the keel will be specially considered.

3.3 Bottom outboard

3.3.1 The thickness of the bottom outboard plating is to be determined from the general plating equation given in Ch 3,1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.3.2 For all craft types, the minimum bottom outboard shell thickness requirement given in Section 2 is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

3.4 Bottom inboard

3.4.1 The thickness of the bottom inboard plating is to be determined from the general plating equation given in Ch 3,1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.4.2 For all craft types, the minimum bottom inboard shell thickness requirement given in Section 2 is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

3.5 Side outboard

3.5.1 The thickness of the side outboard plating is to be determined from the general plating equation given in Ch 3,1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.6 Side inboard

3.6.1 The thickness of the side inboard plating is to be determined from the general plating equation given in Ch 3,1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.7 Wet-deck

3.7.1 The thickness of the wet-deck plating is to be determined from the general plating equation given in Ch 3,1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.7.2 Additionally, the thickness of the wet-deck plating is in no case to be less than the thickness of the side inboard shell plating determined from 3.6.

3.7.3 The wet-deck plating on the underside of the cross-deck structure may require to be additionally protected, particularly where the air gap is small and there is a high risk of localised impact due to collision with floating debris, ice, etc., in the service area. In such cases the sheathing requirements given in Ch 3,2.4 are to be complied with.

3.8 Transom

3.8.1 The scantlings and arrangements of the stern or transom are to be not less than that required for the adjacent bottom inboard or side outboard structure as appropriate. Where water jet or sterndrive units are fitted, the scantlings of the plating in way of the nozzles and connections will be specially considered.

3.9 Haunch reinforcement (SWATH)

3.9.1 For craft above 40 m in Rule length, L_R, the stresses in the haunch area are to be derived using a two dimensional fine mesh finite element analysis. The model is to extend horizontally into the box structure and vertically into the strut structure. All discontinuities and cut-outs are to be modelled in order to determine shear stresses at critical locations and stresses for the determination of fatigue strength.

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3.9.2 Due consideration is to be given to shear lag when determining the effective breadth of the attached plating.

3.10 Lower hull (SWATH)

3.10.1 Where the lower hull structure incorporates ring frames and attached shell plating fitted between bulkheads or diaphragms, the thickness of the lower hull shell plating may be derived from an established method for shell analysis or recognised standard for pressure vessels using the design pressure loading from Pt 5, Ch 3,3.1 or Ch 4,3.1 as appropriate. Other loads considered significant for the scantling determination are to be taken into account. Modes of failure to be considered are buckling, frame collapse, inter-frame shell collapse and overall frame shell collapse between bulkheads. A copy of the direct calculations are to be submitted for consideration.

3.11 Novel features

3.11.1 Where the Rules do not specifically define the requirements for plating elements with novel features then the scantlings and arrangements are to be determined by direct calculations. Such calculations are to be carried out on the basis of the Rules, Recognised Standards and good practice, and are to be submitted for consideration.

■ *Section 4*
Shell envelope framing

4.1 General

4.1.1 Unless otherwise specified in this Section, the scantlings and arrangements for shell envelope framing are to be determined in accordance with the procedures described in, or as required by, Ch 3,3 for mono-hull craft using the pressures from Part 3 appropriate to multi-hulls.

4.1.2 The requirements in this Section apply to longitudinally and transversely framed shell envelopes.

4.2 Bottom outboard longitudinal stiffeners

4.2.1 Bottom outboard longitudinal stiffeners are to be supported by transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.2.2 Bottom outboard longitudinals are to be continuous through the supporting structures.

4.2.3 Where it is impracticable to comply with the requirements of 4.2.2, or where it is proposed to terminate the bottom outboard longitudinals in way of the transom, bulkheads or integral tank boundaries, all longitudinals are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets.

4.2.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b).

4.3 Bottom outboard longitudinal primary stiffeners

4.3.1 Bottom outboard longitudinal primary stiffeners are to be supported by deep transverse web frames, floors, bulkheads, or other primary structures, generally spaced not more than 4 m apart.

4.3.2 Bottom outboard longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

4.3.3 Where it is impracticable to comply with the requirements of 4.3.2, or where it is proposed to terminate the stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.3.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.4 Bottom outboard transverse stiffeners

4.4.1 Bottom outboard transverse stiffeners are defined as local stiffening members which support the bottom shell and which may be continuous or intercostal.

4.4.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b).

4.5 Bottom outboard transverse frames

4.5.1 Bottom outboard transverse frames are defined as stiffening members which support the bottom shell. They are to be effectively continuous and bracketed at their end connections to side frames and bottom floors as appropriate.

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4.5.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.6 Bottom outboard transverse web frames

4.6.1 Bottom outboard transverse web frames are defined as primary stiffening members which support bottom shell longitudinals. They are to be continuous and substantially bracketed at their end connections to side web frames and bottom floors.

4.6.2 Where it is impracticable to comply with the requirements of 4.6.1, or where it is proposed to terminate the web frames in way of bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.6.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.7 Bottom inboard longitudinal stiffeners

4.7.1 The scantlings and arrangements for bottom inboard longitudinal stiffeners are to be determined in accordance with the procedures described in 4.2 using the bottom inboard stiffening member design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.8 Bottom inboard longitudinal primary stiffeners

4.8.1 The scantlings and arrangements for bottom inboard longitudinal primary stiffeners are to be determined in accordance with the procedures described in 4.3 using the bottom inboard stiffening member design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.9 Bottom inboard transverse stiffeners

4.9.1 The scantlings and arrangements for bottom inboard transverse stiffeners are to be determined in accordance with the procedures described in 4.4 using the bottom inboard stiffening member design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.10 Bottom inboard transverse frames

4.10.1 The scantlings and arrangements for bottom inboard transverse frames are to be determined in accordance with the procedures described in 4.5 using the bottom inboard stiffening member design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.11 Bottom inboard transverse web frames

4.11.1 The scantlings and arrangements for bottom inboard transverse frames are to be determined in accordance with the procedures described in 4.6 using the bottom inboard stiffening design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.12 Side outboard longitudinal stiffeners

4.12.1 The side outboard longitudinal stiffeners are to be supported by transverse web frames, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.12.2 Side outboard longitudinals are to be continuous through the supporting structures.

4.12.3 Where it is impracticable to comply with the requirements of 4.12.2, or where it is proposed to terminate the side outboard longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets.

4.12.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b).

4.13 Side outboard longitudinal primary stiffeners

4.13.1 Side outboard longitudinal primary stiffeners are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 4 m apart.

4.13.2 Side outboard longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

4.13.3 Where it is impracticable to comply with the requirements of 4.13.2, or where it is proposed to terminate the side outboard longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

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4.13.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.14 Side outboard transverse stiffeners

4.14.1 Side outboard transverse stiffeners are defined as local stiffening members supporting the side shell and may be continuous or intercostal.

4.14.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b).

4.15 Side outboard transverse frames

4.15.1 Side outboard transverse frames are defined as stiffening members supporting the side shell and spanning continuously between bottom floors/frames and decks. They are to be effectively constrained against rotation at their end connections.

4.15.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.16 Side outboard transverse web frames

4.16.1 Side outboard transverse web frames are defined as primary stiffening members which support side shell longitudinals. They are to be continuous and substantially bracketed at their head and heel connections to deck beams and bottom web frames respectively.

4.16.2 Where it is impracticable to comply with the requirements of 4.16.1, or where it is proposed to terminate the side outboard longitudinals in way of bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.16.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.17 Side inboard longitudinal stiffeners

4.17.1 The scantlings and arrangements for side inboard longitudinal stiffeners are to be determined in accordance with the procedures described in 4.12 using the side inboard design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.18 Side inboard longitudinal primary stiffeners

4.18.1 The scantlings and arrangements for side inboard longitudinal primary stiffeners are to be determined in accordance with the procedures described in 4.13 using the side inboard design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.19 Side inboard transverse stiffeners

4.19.1 The scantlings and arrangements for side inboard transverse stiffeners are to be determined in accordance with the procedures described in 4.14 using the side inboard design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.20 Side inboard transverse frames

4.20.1 The scantlings and arrangements for side inboard transverse frames are to be determined in accordance with the procedures described in 4.15 using the side inboard design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.21 Side inboard transverse web frames

4.21.1 The scantlings and arrangements for side inboard transverse web frames are to be determined in accordance with the procedures described in 4.16 using the side inboard design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.22 Wet-deck longitudinal stiffeners

4.22.1 The wet-deck longitudinal stiffeners are to be supported by transverse web frames, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.22.2 Wet-deck longitudinals are to be continuous through the supporting structures.

4.22.3 Where it is impracticable to comply with the requirements of 4.22.2, or where it is proposed to terminate the wet-deck longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

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4.22.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b).

4.22.5 In no case are the scantlings and arrangements for the wet-deck longitudinal stiffeners to be taken as less than those required for the side inboard longitudinal stiffeners detailed in 4.17.

4.23 Wet-deck longitudinal primary stiffeners

4.23.1 Wet-deck longitudinal primary stiffeners are to be supported by transverse web frames, bulkheads, or other primary structure, generally spaced not more than 4 m apart.

4.23.2 Wet-deck longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

4.23.3 Where it is impracticable to comply with the requirements of 4.23.2, or where it is proposed to terminate the wet-deck longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.23.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.23.5 In no case are the scantlings and arrangements for the wet-deck longitudinal primary stiffeners to be taken as less than those required for the side inboard longitudinal primary stiffeners detailed in 4.18.

4.23.6 Additionally the requirements of Chapter 6 relating to global strength are to be complied with.

4.24 Wet-deck transverse stiffeners

4.24.1 Wet-deck transverse stiffeners are defined as local stiffening members supporting the wet-deck and may be continuous or intercostal.

4.24.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b).

4.24.3 In no case are the scantlings and arrangements for the wet-deck transverse stiffeners to be taken as less than those required for the side inboard transverse stiffeners detailed in 4.19.

4.25 Wet-deck transverse frames

4.25.1 Wet-deck transverse frames are defined as stiffening members which support the wet-deck. They are to be effectively continuous and bracketed at their end connections to side frames.

4.25.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.25.3 In no case are the scantlings and arrangements for the wet-deck transverse frames to be taken as less than those required for the side inboard transverse frames detailed in 4.20.

4.26 Wet-deck transverse web frames

4.26.1 Wet-deck transverse web frames are defined as primary stiffening members which support wet-deck longitudinals. They are to be continuous and substantially bracketed at their end connections to side transverse web frames.

4.26.2 Where it is impracticable to comply with the requirements of 4.26.1, or where it is proposed to terminate the wet-deck longitudinals in way of the bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.26.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.26.4 In no case are the scantlings and arrangements for the wet-deck transverse web frames to be taken as less than those required for the side inboard transverse web frames detailed in 4.21.

4.26.5 Primary transverse web frames that link the strength deck to the wet-deck structure and which carry the transverse global loading are additionally to comply with Ch 6,3.4.

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4.26.6 Particular attention is to be taken to ensure that the continuity of transverse structural strength is maintained. All primary transverse members are to be continuous through the inboard side structure and integrated into transverse bulkheads or other primary structure within each hull (*see* Fig. 4.4.1). In the case of trimaran type craft the primary transverse members are to be continuous through the centre hull. Additionally the side inboard shell plating in way of the intersection is to be increased locally by not less than 50 per cent.

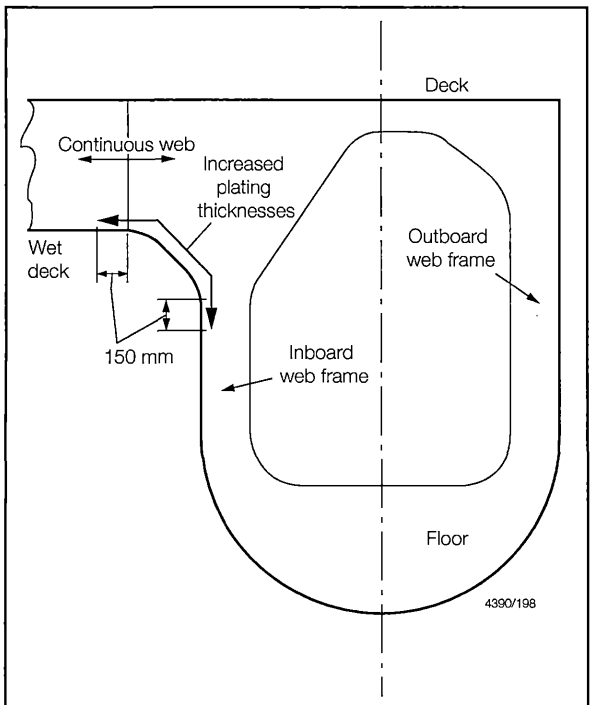

Fig. 4.4.1
End connection details, wet-deck structure

4.27 Lower hull (SWATH)

4.27.1 Where the lower hull structure incorporates ring frames and attached shell plating fitted between bulkheads or diaphragms, the scantlings of the lower hull shell stiffening may be derived from an established method for stiffening analysis or Recognised Standard for pressure vessels using the design loading from Pt 5, Ch 4,4.1. Modes of failure to be considered are buckling, frame collapse, inter frame shell collapse and overall frame shell collapse between bulkheads. A copy of the direct calculations is to be submitted for consideration.

4.28 Scantlings of end brackets

4.28.1 The scantlings of end brackets in way of transverse web frames/crossdeck primary structure which carry transverse global loading, are to be as large as practicable and be additionally reinforced as necessary. The webs of deep brackets are to be stiffened as necessary to resist buckling, *see also* Ch 6,3.5.

■ *Section 5*
Single bottom structure and appendages

5.1 General

5.1.1 Unless otherwise specified in this Section, the scantlings and arrangements for single bottom structure and appendages are to be determined in accordance with the procedures described in, or as required by, Ch 3,5 for mono-hull craft using the pressures from Part 5 appropriate to multi-hulls.

5.1.2 The thickness of single bottom structural members is in no case to be less than the appropriate minimum requirement given in Section 2.

5.2 Keel

5.2.1 The scantlings and arrangements of plate keels are to be in accordance with 3.2.

5.2.2 Where fitted, the cross-sectional area, A_{bk}, and thickness, t_{bk}, of bar keels are not, in general, be taken as less than:

$$A_{bk} = 0{,}75 L_R k_s \text{ cm}^2$$

$$t_{bk} = \sqrt{k_s}\,(0{,}5L_R + 2) \text{ mm}$$

where

L_R and k_s are as defined in 1.5.1.

5.3 Centre girder

5.3.1 Centreline girders are to be fitted throughout the length of each hull and are generally to be fitted in association with transverse frames, transverses supporting longitudinals or where the breadth of floors at the upper edge is greater than 1,5 m.

5.3.2 Centreline girders may be formed with intercostal or continuous plate webs. In all cases the face flat is to be continuous. Where girder webs are intercostal, additional bracketing and local reinforcement are to be provided to maintain the continuity of structural strength.

5.3.3 The web depth of the centre girder is, in general, to be equal to the depth of the floors at the centreline as specified in 5.5.3.

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5.3.4 The web thickness, t_w, of the centre girder is to be taken not less than:

$$t_w = \sqrt{k_s}\,(0{,}8\sqrt{L_R} + 1) \text{ mm}$$

where

L_R and k_s are as defined in 1.5.1.

5.3.5 The face flat area, A_f, of the centre girder is to be not less than:

$$A_f = k_s\, 0{,}22 L_R \text{ cm}^2$$

where

L_R and k_s are as defined in 1.5.1.

5.3.6 The geometric section properties of the centre girder are to be in accordance with Ch 3,1.18.

5.3.7 The face flat area of the centre girder outside $0{,}5L_R$ may be 80 per cent of the value given in 5.3.5.

5.3.8 The face flat thickness is to be not less than the thickness of the web, t_w, as determined from 5.3.4.

5.3.9 The ratio of the width to thickness of the face flat is to be not less than eight but is not to exceed 16.

5.3.10 Additionally, the requirements of 4.8 for bottom inboard longitudinal primary stiffeners are to be complied with.

5.4 Side girders

5.4.1 Where the floor breadth at the upper edge exceeds 4,0 m, side girders are to be fitted at each side of the centre girder such that the spacing between the side and centre girders or between the side girders themselves is not greater than 2 metres. Side girders where fitted are to extend as far forward and aft as practicable and are, in general, to be scarfed into the bottom structure forward and aft of the support at which they terminate, i.e. in way of bulkheads, deep floors or other primary transverse structure.

5.4.2 The web thickness, t_w, of side girder webs is to be taken as not less than:

$$t_w = \sqrt{(0{,}43 k_s L_R)} \text{ mm}$$

where

L_R and k_s are as defined in 1.5.1.

5.4.3 The face flat area and thickness of side girders are to comply with the requirements for plate floors as defined in 5.5.6 and 5.5.7.

5.4.4 Additionally, the requirements of 4.8 for bottom inboard longitudinal primary stiffeners are to be complied with.

5.4.5 Watertight side girders and side girders forming the boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads and deep tanks as detailed in Ch 3,7.2 and Ch 3,7.4 respectively.

5.4.6 In the engineroom, additional side girders are generally to be fitted in way of main machinery seatings. Where fitted they are to be integrated into the structure of the craft and extended forward and aft as far as practicable.

5.5 Floors

5.5.1 In transversely framed craft, floors are generally to be fitted at every frame and underneath each bulkhead.

5.5.2 In longitudinally framed craft, floors are in general to be fitted at every transverse web frame and bulkhead and generally at a spacing not exceeding 2 m. Additional transverse floors or webs are to be fitted at half web-frame spacing in way of engine seatings and thrust bearings, pillars, skegs, ballast/bilge keels and the bottom of the craft in the forefoot region.

5.5.3 The overall depth, d_f, of floors at the centreline, is not to be taken as less than:

$$d_f = 6{,}2 L_R + 50 \text{ mm}$$

where

L_R is as defined in 1.5.1.

5.5.4 The web thickness of plate floors, t_w, is to be in accordance with Ch 3,1.18 and not less than:

$$t_w = \sqrt{k_s}\left(\frac{3{,}4 d_f}{1000} + 2{,}25\right)\left(\frac{s}{1000} + 0{,}5\right) \text{ mm}$$

where

d_f is to be determined from 5.5.3

k_s and s are as defined in 1.5.1.

5.5.5 If the side frames of the craft are attached to the floors by brackets, the depth of floor may be reduced by 15 per cent and the floor thickness determined using the reduced depth. The brackets are to be flanged and have the same thickness as the floors, and their arm lengths clear of the frame are to be the same as the reduced floor depth given above.

5.5.6 The face flat area, A_f, of floors is not to be taken as less than:

$$A_f = 0{,}11 k_s L_R \text{ cm}^2$$

where

L_R and k_s are as defined in 1.5.1.

5.5.7 The face flat thickness, t_f, is to be not less than the thickness of the web and the ratio of the web to the thickness of the face flat is to be not less than eight but is not to exceed 16.

5.5.8 Additionally, the requirements of 4.11 for bottom inboard transverse web frames are to be complied with.

5.5.9 Floors are in general to be continuous from side to side.

5.5.10 The tops of floors, in general, may be level from side to side. However, in craft having considerable rise of floor the depth of the floor plate may require to be increased to maintain the required section modulus.

5.5.11 The floors in the aft peak are to extend over and provide efficient support to the stern tube(s) where applicable.

5.5.12 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deep tanks as detailed in Ch 3,7.3 and Ch 3,7.5.

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5.6 Floors in machinery space

5.6.1 The web thickness, t_w, of floors in machinery spaces is to be 1 mm greater than that required by 5.5.4.

5.6.2 The depth and mechanical strength properties of floors between engine or gearbox girders is to be not less than that required to maintain continuity of structural integrity or 50 per cent of the depth given in 5.5.3. The face flat area and web thickness of such reduced height floors are to be increased appropriately in order to maintain the continuity of structural strength, *see also* Ch 3,4.12.

5.7 Forefoot and stem

5.7.1 The thickness of plate stems at the waterline is to comply with the requirements for plate keels as given in 3.2.

5.7.2 The forefoot and stem is to be additionally reinforced with floors.

5.7.3 The cross-sectional area of bar stems, A_{bs}, is not to be taken as less than:

$$A_{bs} = 0{,}6k_s L_R \text{ cm}^2$$

where

k_s and L_R are as defined in 1.5.1.

■ *Section 6*
Double bottom structure

6.1 General

6.1.1 Unless otherwise specified in this Section, the scantlings and arrangements for the double bottom structure are to be determined in accordance with the procedures described in, or as required by, Ch 3,6 for mono-hull craft using the pressures from Part 5 appropriate to multi-hulls.

6.1.2 The thickness of double bottom structural members is in no case to be less than the appropriate minimum requirement given in Section 2.

6.2 Keel

6.2.1 The scantlings of plate and bar keels are to comply with the requirements of 5.2.

6.3 Centreline girder

6.3.1 A centre girder is to be fitted throughout the length of the craft. The web thickness, t_w, is not to be less than that required by:

$$t_w = \sqrt{k_s}\,(0{,}06L_R + 3) \text{ mm within } 0{,}4L_R \text{ amidships}$$

$$= \sqrt{k_s}\,(0{,}06L_R + 2) \text{ mm at ends}$$

where

k_s and L_R are as defined in 1.5.1.

6.3.2 The geometric properties of the girder section are to be in accordance with Ch 3,1.18.

6.3.3 The overall web depth, d_w, of the centre girder is to be taken as not less than 630 mm and is to be sufficient to give adequate access to all parts of the double bottom.

6.3.4 Additionally, the requirements of 4.8 for bottom inboard longitudinal primary stiffeners are to be complied with.

6.4 Side girders

6.4.1 Where the floor breadth does not exceed 4,0 m, side girders are not required. Vertical stiffeners are to be fitted to the floors on each side, the number and positions of these stiffeners being dependent on the arrangement of the double bottom structure.

6.4.2 Where the breadth of floor is greater than 4,0 m, additional side girders having the same thickness as the floors are to be fitted. The number of side girders is to be such that the distance between the side girders and centre girder and margin plate, or between the side girders themselves, does not exceed 2,0 m.

6.4.3 Side girders, where fitted, are to extend as far forward and aft as practicable and are in general to to be scarfed into the bottom structure forward and aft of the supporting bulkheads, deep floors or other primary transverse structure.

6.4.4 Where additional side girders are fitted in way of main machinery seatings, they are to be integrated into the structure of the craft and extended forward and aft as far as practicable.

6.4.5 Under the main engine, girders extending from the bottom shell to the top plate of the engine seating are to be fitted. The height of the girders is to be not less than the height of the floor. Engine holding-down bolts are to be arranged as near as practicable to the girders and floors. Where this cannot be achieved, bracket floors and/or hanging brackets are to be fitted.

6.4.6 The geometric properties of the girder section are to be in accordance with Ch 3,1.18.

6.4.7 Additionally, the requirements of 4.8 for bottom inboard longitudinal primary stiffeners are to be complied with.

6.5 Plate floors

6.5.1 The web thickness, t_w, of non-watertight plate floors is to be not less than:

$$t_w = \sqrt{k_s}\,(0{,}03L_R + 3{,}5) \text{ mm}$$

where

k_s and L_R are as defined in 1.5.1.

6.5.2 The geometric properties of the floor section are to be in accordance with Ch 3,1.18.

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6.5.3 Additionally, the requirements of 4.6 for bottom inboard transverse web frames are to be complied with.

6.5.4 Plate floors are, in general, to be continuous between the centre girder and the margin plate.

6.5.5 In longitudinally framed craft, plate floors are to be fitted in the following positions:

(a) At every half frame in way of the main engines, thrust bearings, and bottom of the craft forward.
(b) Outboard of the engine seatings, at every frame within the engineroom.
(c) Underneath pillars and bulkheads.
(d) Outside of the engine room at a spacing not exceeding 2,0 m.

6.5.6 Vertical flat bar stiffeners are to be fitted to all plate floors at each longitudinal. Each stiffener is to have a depth of not less than $10t_w$ and a thickness of not less than t_w, where t_w is thickness of the plate floor as calculated in 6.5.1.

6.5.7 In transversely framed craft, plate floors are to be fitted at every frame in the engineroom, under bulkheads, in way of change in depth of double bottom and elsewhere at a spacing not exceeding 2,0 m.

6.6 Additional requirements for watertight floors

6.6.1 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deep tanks as detailed in Ch 3,7.2 or Ch 3,7.4 respectively.

■ *Section 7*
Bulkheads and deep tanks

7.1 General

7.1.1 Unless otherwise specified in this Section, the scantlings and arrangements for bulkheads and deep tanks are to be determined in accordance with the procedures described in, or as required by Ch 3,3 for mono-hull craft using the pressures from Part 5 appropriate to multi-hulls.

7.2 Longitudinal bulkheads within the cross-deck structure

7.2.1 Longitudinal bulkheads are to be fitted within the cross-deck structure to prevent cross flooding and the spread of flame and smoke. The minimum number of such bulkheads is to be two for catamarans and four for trimarans. Quadrimarans and other craft of novel configuration will be specially considered.

7.2.2 The scantlings and arrangements for cross-deck longitudinal bulkheads are to be determined in accordance with the procedures described in Ch 3,7.2 and Ch 3,7.3 for bulkheads in mono-hull craft.

7.2.3 In addition the requirements of 7.4 with regard to global strength are to be complied with.

7.3 Transverse bulkheads within the cross-deck structure

7.3.1 The scantlings of cross-deck transverse bulkheads are to be determined in accordance with the procedures described in Ch 3,7.2 and Ch 3,7.3 for bulkheads in mono-hull craft.

7.3.2 In addition the requirements of 7.4 in respect of global strength are to be complied with.

7.4 Additional strength required for global loading

7.4.1 Where transverse bulkheads or deep tank bulkheads within the cross-deck structure are to assist in resisting torsional or bending loads between the hulls, then the watertight/deep tank bulkheads may be required to be additionally stiffened and the plating or skin thicknesses may require to be increased. For hull girder strength requirements, *see* Ch 6,3.

7.4.2 Longitudinal bulkheads within the cross-deck structure that are to assist in maintaining the longitudinal strength of the craft are to satisfy both bulkhead/deep tank and longitudinal strength requirements. This may require additional stiffening and increase in plate thickness requirements. For hull girder strength requirements, *see* Ch 6,3.

7.4.3 Where longitudinal or transverse cross-deck bulkheads/deep tanks are to carry global loads, detailed calculations are to be submitted.

7.4.4 For longitudinal or transverse cross-deck members carrying global loads, consideration is to be given to stiffener arrangement, alignment, and continuity in order to maximise the rigidity and stiffness of the structure, in resisting the torsional/bending loads. Discontinuity of structural bulkheads is to be avoided.

7.5 Access

7.5.1 Access through the cross-deck structure may be permitted, provided that the global strength requirements are satisfied. Cut outs through the bulkhead are not to exceed 50 per cent of its depth, *see also* Ch 3,7.18.

7.5.2 Where the cross-deck structure acts as a watertight bulkhead pipe or cable runs through the watertight bulkheads are to be fitted with suitable watertight glands.

7.6 Local reinforcement

7.6.1 Bulkheads forming the cross-deck structure are to be suitably strengthened, if necessary, in way of deck girders and where subjected to concentrated loads.

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7.7 Integral/deep tanks within cross-deck structure

7.7.1 Where the cross-deck structure forms the boundaries of deep tanks, the scantlings of these boundaries are to satisfy both deep tank and global strength requirements. For general and structural requirements for deep tanks, *see* Ch 3,7. For global considerations of strength, *see* Ch 6,3.

■ *Section 8* Deck structures

8.1 General

8.1.1 Unless otherwise specified in this Section, the scantlings and arrangements for deck structures are to be determined in accordance with the procedures described in, or as required by, Ch 3,8 for mono-hull craft using the pressures from Part 5 appropriate to multi-hulls.

8.2 Arrangements

8.2.1 Design loads to be applied for cross-deck scantling calculations are transverse vertical bending moment and shear force, twin hull torsional connecting moment, external pressure load and appropriate internal loads as defined in Part 3.

8.2.2 For craft up to 50 m in Rule length, L_R, where the cross-deck is formed by transverse primary stiffeners or bulkheads, and subjected to global transverse loads in accordance with 8.2.1 the scantling requirements to satisfy the global loading condition are given in Ch 6,3.5.

8.2.3 Superstructures fitted on the cross-deck structures, on craft up to 50 m in Rule length, L_R, will, in general, be considered as non load carrying and are not to be included in the strength of the cross-deck. For designs where the superstructure is designed to absorb global loads, the requirements are given in Ch 6,3.2.

8.2.4 For craft more than 50 m in Rule length, L_R, global analysis is required to determine the response of the deck and superstructure as a system. Deck scantlings may then be derived for compliance with the requirements of Ch 6,3.

8.3 Cross-deck plating

8.3.1 The thickness of the cross-deck plating is to be determined from the general plating equation given in Ch 3,1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

8.3.2 The thickness of the cross-deck plating is in no case to be less than the appropriate minimum requirement given in Section 2.

8.3.3 The scantlings of watertight cockpits are to be of equivalent strength to those of the strength/weather deck, *see also* Part 4.

8.3.4 It is recommended that the working areas of the weather deck have an anti-slip surface.

8.3.5 Where decks are sheathed with wood or other materials, details of the method of attachment are to be submitted, *see also* Ch 3,2.4.

8.4 Cross-deck stiffening

8.4.1 The Rule requirements for section modulus, inertia and web area for the cross-deck primary stiffeners are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

8.4.2 The Rule requirements for section modulus, inertia and web area of the strength/weather deck secondary stiffening are to be determined the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.4.3 The geometric properties of stiffener sections are to be in accordance with Ch 3,1.18.

8.4.4 For cases where there may be excessive rotations or deflections at supports or where the lateral pressure distribution is non-uniform, the above scantlings may require increasing appropriately.

8.4.5 Where stiffeners are subject to concentrated loads such as pillars, the concentrated loads are to be superimposed on the lateral pressure and strength calculations carried out to demonstrate compliance with the deflection and stress criteria given in Ch 7,2 and Ch 7,3.

8.4.6 Where stiffening members support plating of the extruded plank type, or the floating frame system is used, the plating is not to be included in the scantling derivation of the supporting structure.

8.4.7 Openings in the cross-deck for hatches, etc., are to comply with the requirements of Ch 3,8.11.

8.5 Novel features

8.5.1 Where the cross-deck structure is of unusual design, form or proportions, the scantlings are to be determined by direct calculation and a copy submitted for consideration.

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Section 9
Superstructures, deckhouses, pillars and bulwarks

9.1 General

9.1.1 The scantlings and arrangements for superstructures, deckhouses and bulwarks are to be determined in accordance with the procedures described in, or as required by, Ch 3,9 for mono-hull craft.

9.1.2 The scantlings and arrangements for pillars and pillar bulkheads are to be determined in accordance with the procedures described in, or as required by, Ch 3,10 for mono-hull craft.

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Section

1 **General**

2 **Special features**

3 **Vehicle decks**

4 **Bow doors**

5 **Movable decks**

6 **Helicopter landing areas**

7 **Strengthening requirements for navigation in ice conditions**

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull and multi-hull craft of steel construction as defined in Pt 1, Ch 1,1.

1.2 Symbols and definitions

1.2.1 The symbols and definitions used in this Chapter are defined below and in the appropriate Section:

s = stiffener spacing, in mm

k_s = higher tensile steel factor
= $235/\sigma_s$

σ_s = specified minimum yield strength of the material, in N/mm^2.

■ *Section 2* Special features

2.1 Water jet propulsion systems – Construction

2.1.1 The requirements for the construction and installation of water jet units apply irrespective of rated power.

2.1.2 Water jet ducts may be fabricated as an integral part of the hull structure, or as a bolted-in unit. In either case, detailed plans indicating dimensions, scantlings and materials of construction of the following are to be submitted in triplicate:

(a) Arrangement of the system including intended method of attachment to the hull and building-in, geometry of tunnel, shell opening, method of stiffening, reinforcement, etc.
(b) Shaft sealing arrangements.
(c) Details of any shafting support or guide vanes used in the water jet system.
(d) Details and arrangements of inspection ports, their closing appliances and sealing arrangement, etc.
(e) Details and arrangements of protection gratings and their attachments.

2.1.3 When submitting the plans requested in 2.1.2, details of the designers' loadings and their positions of application in the hull are to be submitted. These are to include maximum applied thrust, moments and tunnel pressures for which approval is sought.

2.1.4 All materials used in construction are to be manufactured and tested in accordance with the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

2.1.5 Steels are to be of suitable grades in accordance with the requirements of Ch 2,2.

2.1.6 Irrespective of the material used, the strength and supporting structure of all tunnels are to be examined by direct calculation procedures which are to be submitted. In no case are the scantlings to be taken as less than the Rule requirements for the surrounding structure. The strength of the hull structure in way of tunnels is to be maintained. The structure is to be adequately reinforced and compensated as necessary. All openings are to be suitably reinforced and have radiused corners.

2.1.7 Consideration is to be given to providing the inlet to the tunnel with a suitable guard to prevent the ingress of large objects into the rotodynamic machinery. The dimensions of the guard are to strike a balance between undue efficiency loss due to flow restriction and viscous losses, the size of object allowed to pass and susceptibility to clog with weed and other flow restricting matter.

2.1.8 The inlet profile of the tunnel is to be so designed as to provide a smooth uptake of water over the range of craft operating trims and avoid significant separation of the flow into the rotating machinery.

2.1.9 Single or multiple water jet unit installations having a total rated power in excess of 500 kW are to be contained within their own watertight compartment. Other arrangements for maintaining watertight integrity may be specially considered depending on the size and installation layout.

2.1.10 For details of machinery requirements, *see* Pt 12, Ch 2.

2.2 Water jet propulsion systems – Installation

2.2.1 Standard units built for 'off the shelf' supply and which include the duct are to be installed strictly in accordance with the manufacturer's instructions, *see also* 2.1.4.

2.2.2 Integral water jet ducts are to be constructed in accordance with the manufacturer's requirements and the relevant plans submitted as required by 2.1.

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2.2.3 Where load is transmitted into the transom and/or bottom shell, the thickness of the plating adjacent to the jet unit is to be increased. The increase in thickness is to be not less than 50 per cent of the calculated transom and bottom plating thicknesses respectively or 8 mm, whichever is the greater. Such reinforcement is to extend beyond the surrounding stiffening structure.

2.2.4 For 'bolted in' units, hull receiving rings are to be of a material compatible with the hull. Scantlings of the receiving rings are to be as required by the jet unit manufacturer and suitably edge prepared prior to welding in place. The receiving ring is to be installed using an approved welding procedure. Where a manufacturer's specification is not provided, full details are to be submitted.

2.2.5 Bolt sizes and spacings are to be specified by the manufacturer, and are to be of suitable marine grade, insulated as appropriate and locked by suitable means.

2.2.6 Where studs are proposed for the receiving ring(s), the remaining thickness below the depth of blind tap is to be not less than the bottom shell plating thickness plus 2 mm. Bottoms of all blind taps are to be free of sharp corners.

2.2.7 The use of approved alignment resins may be considered where accurate seating and faying surfaces are required. Details are to be submitted for consideration and approval.

2.2.8 Where a water jet unit forms an integral part of the hull structure, such units are to be installed using an approved weld procedure and in accordance with the manufacturer's instructions. Materials to be welded are to be of compatible specifications.

2.2.9 Water jet units transmitting thrust into the transom structure are to be supported by a system of radial, athwartship and vertical stiffening. Drawings are to be accompanied by a set of detailed structural calculations. Where complex installations are proposed, a finite element model may be submitted in lieu of direct calculations.

2.2.10 Water jet units transmitting thrust to a bottom shell connection or intermediate tunnel connection are to be supported by additional stiffening, the details of which are to be submitted.

2.3 Foil support arrangements

2.3.1 The materials and construction of the lifting surface will be considered on a case by case basis.

2.3.2 The design and performance of the lifting surface is outside the scope of classification. However, when submitting structural plans for the hull connection installation, the designer/Builder is to define:

(a) Operating mode, i.e. fully submerged or surface piercing.
(b) Maximum operational speed for which approval is sought.
(c) Maximum, direct, bending, shear and torque loads generated by the foil at the point of attachment(s).
(d) The type of profile or section used, e.g. N.A.C.A.
(e) Supply of lift/drag profile.
(f) If the foil is fixed, movable or retractable.
(g) If the foil is fitted with control surfaces.
(h) If the vertical leg(s) act as a rudder(s).
(j) If shaft liners are carried to the foils at which support arrangements are provided.
(k) If water intakes/scoops are fitted.
(l) If propulsion units are fitted.

2.3.3 The scantlings and arrangements of foils and their supporting structure will require to be specially considered in the following cases where:

(a) Propulsion units are incorporated within the foil.
(b) Foils carry shaft support arrangements.
(c) The foils are of novel design.

2.3.4 Where fully submerged foils are 'built-in' to the hull, the attachment area is to be contained within a watertight compartment the structural arrangements of 2.4 are to be complied with as appropriate.

2.3.5 Where foils are to be bolted to the structural foundation, calculations are to be submitted to demonstrate that the effect of loading arising from high speed impact, grounding, fouling, etc., is limited to failure of the bolted connection. In all cases the structural and watertight integrity of the craft is to be maintained.

2.3.6 Attachment points of foils are in all cases to be contained within a watertight compartment.

2.3.7 Foils attached by riveted means are in addition to comply with Ch 2,4.21.

2.3.8 Bow fairing doors fitted on forward retracting bow foils are to be weathertight and comply with Pt 3, Ch 4.

2.3.9 Aft bulkheads of bow foil compartments are to comply with the requirements for collision bulkheads as detailed in Ch 3,7.7.

2.3.10 Hydraulically operated retracting systems are to be equipped with low pressure and are to include a manual system of operation in the event of system failure.

2.3.11 A mechanical locking system is to be provided on retracting systems when the system is in both the operational and 'stowed' conditions.

2.4 Surface drive mountings

2.4.1 Transoms through which surface drive systems pass and which are required to carry thrust, significant weight, torque, moment, etc., are to be adequately reinforced.

2.4.2 The thickness of transom plating in way is to be not less than 1,5 times the thickness of the adjacent plating or as advised by the drive manufacturer, whichever is the greater.

2.4.3 Steering rams are to be mounted on suitably reinforced areas of plating supported by additional internal stiffening, details of which are to be submitted for consideration.

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2.5 Sea inlet scoops

2.5.1 Sea inlet scoops may be integral with or an appendage to the hull.

2.5.2 Scoops are to be suitably positioned to minimise ventilation.

2.5.3 Suitable protective arrangements are to be provided to minimise the ingress of debris. The net area through the proposed arrangement is to be not less than twice that of the valves connected to the scoop. Provision is to be made for clearing the scoops by the use of suitable means and proposals are to be submitted.

2.5.4 Scoops are to be contained within a watertight compartment.

2.5.5 The plating thickness in way of integral scoops is to be not less than 1,5 times the thickness of the adjacent shell plating, with additional reinforcement at the leading edge.

2.5.6 For craft navigating in ice, the arrangements will be specially considered on an individual basis.

2.6 Crane support arrangements

2.6.1 Crane pedestals are to be efficiently supported and in general, are to be carried through the deck and satisfactorily scarfed into the surrounding structure. Alternatively, crane pedestals may comprise a foundation, in which case the foundation and its supporting structure are to be of substantial construction. Proposals for other support arrangements will be specially considered.

2.6.2 The pedestal or proposed arrangement is to be designed with respect to the worst possible combinations of loads resulting from the crane self weight, live load, wind and crane accelerations together with those resulting from the craft's heel and trim.

2.6.3 Stowage arrangements are to be taken into account when calculating the loads applied to the pedestal.

2.6.4 When submitting plans for the proposed foundation, the designer is to include design calculations covering the parameters indicated in 2.6.2.

2.6.5 Insert plates are to be incorporated in the deck plating in way of crane foundations. The thickness of the insert plates is to be as required by the designer's calculations but is in no case to be taken as less than 1,5 times the thickness of the adjacent attached plating.

2.6.6 All inserts are to have well radiused corners and be suitably edge prepared prior to welding. All welding in way is to be double continuous and full penetration where necessary. Tapers are to be not less than three to one.

2.7 Skirt attachment

2.7.1 The design and scantlings of the skirt are outside the scope of classification, however the designer/builder is to submit their proposals in respect of the attachment detail. The following supporting information is to be submitted:

(a) cushion pressure,

(b) calculations demonstrating that the effect of damage to the flexible membrane and/or the retaining section arising from high speed impact, grounding, fouling, etc., will not compromise the structural and watertight integrity of the craft.

2.7.2 The skirt is to be securely attached around its periphery and is to be suitably reinforced by the use of backing plates.

2.7.3 Where the skirt is retained by bolting, the retaining bars are to be as long as practicable with a fastener spacing of not more than 50 mm.

2.7.4 Where the design of the skirt is such that the flexible edge is retained by the use of a pre-formed channel, only the bolted hull connection of the preform to the hull structure is considered.

2.8 Trim tab arrangements

2.8.1 The shape, design and scantlings of the trim tabs are outside the scope of classification, however Lloyd's Register (hereinafter referred to as 'LR') is concerned with their attachment to the hull structure.

2.8.1 The designer/Builder is to submit the following:

(a) Detailed calculations indicating the maximum lift force generated by the tab for which acceptance is sought together with the corresponding speed and displacement.

(b) Details and calculations of the hull attachment.

(c) Details and calculations of the local internal reinforcement in way of the attachment.

2.8.3 Bearing materials used are to be of an approved type.

2.8.4 Fully submerged retractable trim tabs will be specially considered on a case by case basis.

2.9 Spray rails

2.9.1 Spray rails may be integrated into the hull structure or added in the form of an appendage on completion of the hull shell.

2.9.2 Where spray rails are integrated, they are to have a plating thickness not less than the adjacent bottom shell and additionally have a section modulus and inertia equivalent to that required for a longitudinal stiffener in the same position.

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2.9.3 Where spray rails are added as an appendage, they are to be attached by double continuous welding and are additionally to comply with the strength requirements of 2.9.2.

2.9.4 Spray rails are to be supported by the internal stiffening arrangements and by additional local reinforcement as necessary.

2.9.5 In no case are the toes of spray rails to terminate on unsupported plating.

2.10 Other lifting surfaces

2.10.1 Other lifting surfaces not specifically covered by the Rules will be individually considered on the basis of submitted direct calculations.

2.10.2 Structure or hull shapes above the running waterline designed to generate aerodynamic lift may be individually considered on a case by case basis.

2.10.3 Aerodynamic, hydrodynamic and aero-hydrodynamic stability are outside the scope of classification and are subject to the approval of the National Administration concerned.

2.11 Propeller ducting

2.11.1 Where propellers are fitted within ducts/tunnels the plating thickness in way of the blades is to be increased by 50 per cent.

2.11.2 The tunnel wall in way of the propeller blades is to be additionally stiffened.

2.12 Ride control ducting and installation for Surface Effect Ships (SES)

2.12.1 Ducts penetrating the side inboard shell plating are to comply with the scantling requirements for side inboard structures, over their entire length in the appropriate material.

2.12.2 Ducts penetrating the wet-deck are to comply with the scantling requirements for wet-deck structures over their entire length in the appropriate material.

2.12.3 Open ends of ducts are to be fitted with a suitable protective grille.

2.12.4 The vent assembly, its design, construction and operation is outside the scope of classification and is the responsibility of the ride control system designer.

2.12.5 Details of the installation and securing arrangements of the vent valve assembly into the duct are to be submitted for approval.

■ *Section 3* Vehicle decks

3.1 General

3.1.1 These requirements are applicable to longitudinally or transversely framed craft intended for the carriage of wheeled vehicles, or where wheeled vehicles are to be used for cargo handling.

3.1.2 The deck and supporting structure are to be designed on the basis of the maximum loading to which they may be subjected in service. Where applicable, the hatch covers are to be similarly designed. In no case, however, are the scantlings to be less than would be required for a weather or cargo deck, or hatch cover, as applicable.

3.1.3 Details of the deck loading resulting from the proposed stowage or operation of vehicles are to be supplied by the Builder. These details are to include axle and wheel spacing, the wheel load, type of tyre and tyre print dimensions for the vehicles. The vehicle types and wheel loads for which the vehicle decks, including hatch covers where applicable, have been approved are to be included in the craft's documentation and contained in a notice displayed on each deck. For design purpose, the wheel loading is to be taken as not less than 3,0 kN.

3.1.4 The scantling requirements are based on structural strength and limitations on stress and deflection, with no allowance made for wear and tear. Local reinforcement is to be fitted as necessary, particularly in way of vehicle lanes and passenger routes.

3.1.5 The webs of vehicle deck stiffening members are in no cases to be scalloped.

3.2 Definitions

3.2.1 **Load Area.** The load area is defined as the footprint area of an individual wheel or the area enclosing a group of wheels when the distance between footprints is less than the smaller dimension of the individual prints.

3.3 Deck plating

3.3.1 The thickness, t_p, of vehicle deck plating is to be taken as not less than:

$$t_p = \frac{\alpha\, s}{1000\,\sqrt{k_s}} \text{ mm}$$

where

P_1 = corrected patch load, in tonnes, obtained from Table 5.3.1

α = thickness coefficient obtained from Fig. 5.3.1

s = secondary stiffener spacing, in mm

β_p = tyre print coefficient used in Fig. 5.3.1

$$= \log_{10}\left(\frac{P_1\, k_s^2}{s^2} \times 10^7\right)$$

s and k_s are as defined in 1.2.

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Table 5.3.1 Deck plate thickness calculation

Symbols	Expression	
a, s, u, and v as defined in Fig. 5.3.1 n = tyre correction factor as detailed in Table 5.3.2 P_1 = corrected patch load, in tonnes λ = dynamic magnification factor P_w = load, in tonnes, on the tyre print. For closely spaced wheels the shaded area shown in Fig. 5.3.1 may be taken as the combined print f_1 = patch aspect ratio correction factor f_2 = panel aspect ratio correction factor f_3 = wide patch load factor	$P_1 = \phi_1 \phi_2 \phi_3 \lambda P_w$	
	$\phi_1 = \dfrac{2v_1 + 1{,}1s}{u_1 + 1{,}1s}$	$v_1 = v$, but $\leq s$ $u_1 = u$, but $\leq a$
	$\phi_2 = 1{,}0$ $= \dfrac{1}{1{,}3 - \dfrac{0{,}3}{s}(a-u)}$ $= \dfrac{2v_1 + 1{,}1s}{u_1 + 1{,}1s}$	for $u \leq (a - s)$ for $a \geq u > (a - s)$ for $u > a$
	$\phi_3 = 1{,}0$ $= 0{,}6\,(s/v) + 0{,}4$ $= 1{,}2\,(s/v)$	for $v < s$ for $1{,}5 > (v/s) > 1{,}0$ for $(v/s) \geq 1{,}5$
	λ = 1,25 for craft operating in G1 = (1 + 0,35n) for craft operating in G2 = (1 + 0,42n) for craft operating in G3 = (1 + 0,49n) for craft operating in G4 = (1 + 0,56n) for craft operating in G5 = (1 + 0,70n) for craft operating in G6 G1, G2, G3, G4, G5 and G6 as defined in Pt 1, Ch 2,3.5.5.	

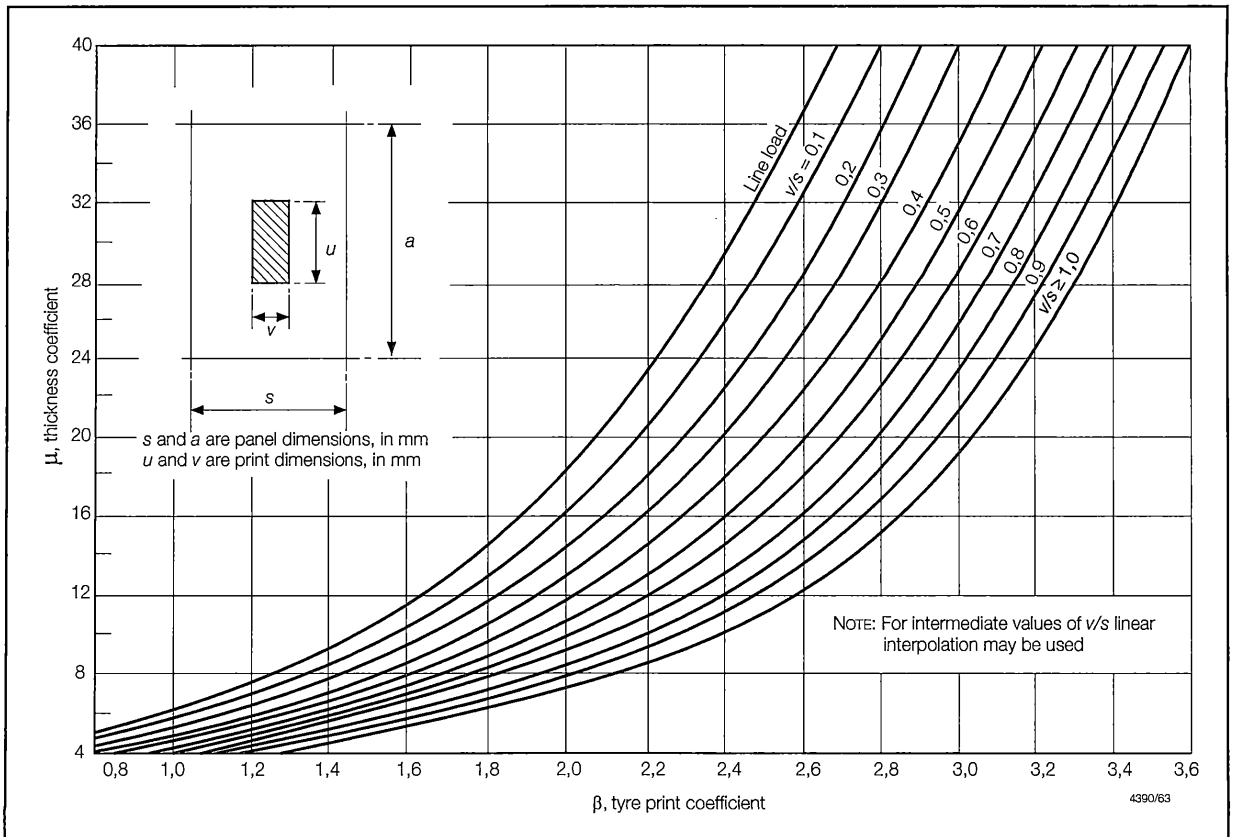

Fig. 5.3.1 Tyre print chart

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3.4 Secondary stiffening

3.4.1 The scantlings of vehicle deck stiffeners are to be as required to satisfy the most severe arrangement of print wheel loads in conjunction with the cargo/weather deck design head.

3.4.2 The minimum requirements for section modulus, inertia and web area of vehicle deck secondary stiffeners subject to wheel loading are to be calculated in accordance with Table 5.3.3, *see also* Fig. 5.3.1 and Table 5.3.2.

Table 5.3.2 Tyre correction factor, *n*

Number of wheels in idealised patch	Pneumatic tyres correction factor, *n*	Solid rubber tyres correction factor, *n*
1	0,6	0,8
2 or more	0,75	0,9

3.4.3 When two or more load areas are located simultaneously on the same stiffener span, the scantling requirements are to be specially considered on the basis of direct calculation.

3.4.4 Where continuous secondary stiffeners pass through the webs of primary members, they are to be fully collared or lugged in way. The shear stresses at the connections are to be in compliance with Table 7.3.1 in Chapter 7.

3.5 Primary stiffening

3.5.1 The scantlings of vehicle deck primary girders and transverse web frames are to be determined on the basis of direct calculation in association with the limiting permissible stress and deflection criteria contained in Chapter 7.

3.6 Securing arrangements

3.6.1 Details of the connections to the hull of vehicle securing arrangements are to be submitted for approval.

3.6.2 Deck fittings in way of vehicle lanes are to be recessed.

3.6.3 The vehicle deck structure is to be of adequate strength for the upward forces imposed at fixed securing points. Local reinforcement is to be fitted as necessary.

Table 5.3.3 Secondary stiffener requirements

Scantling requirement	Load case	
	$d \le l$	$d > l$
Section modulus (Z) (cm^3)	$Z = \left(\frac{P k_w (3l^2 - d^2)}{24 l f_\sigma \sigma_s} \right) \times 10^3 + Z_{dk}$	$Z = \left(\frac{k_w P l^2}{10 d f_\sigma \sigma_s} \right) \times 10^3 + Z_{dk}$
Inertia (I) (cm^4)	$I = \left(\frac{f_\delta P k_w (2l^3 - 2d^2 l + d^3)}{384 E l} \right) \times 10^5 + I_{dk}$	$I = \left(\frac{f_\delta k_w P l^3}{384 E d} \right) \times 10^5 + I_{dk}$
Web area (A_w) (cm^2)	$A_w = \frac{10 P k_w (m^3 - 2m^2 + 2)}{2 f_\tau \tau_s} + A_{dk}$ where $m = d/l$	$A_w = \frac{k_w P l}{2 d f_\tau \tau_s} + A_{dk}$

Symbols

P = maximum effective load per wheel or group of wheels, in kN
l = overall secondary stiffener length, in metres
s = stiffener spacing, in metres
d = dimension of load area parallel to stiffener axis, in metres
E = Young's Modulus of elasticity of material, in N/mm^2
w = dimension of load area perpendicular to stiffener axis, in metres
k_w = lateral loading factor
= 1 for $w \le s$
= s/w for $w > s$
f_σ = limiting bending stress coefficient taken from Table 7.3.1 in Chapter 7
f_τ = limiting shear stress coefficient taken from Table 7.3.1 in Chapter 7
f_δ = limiting deflection coefficient taken from Table 7.2.1 in Chapter 7
σ_s = specified minimum yield strength of the material, in N/mm^2
τ_s = shear stress of material, in N/mm^2
= $\frac{\sigma_s}{\sqrt{3}}$

Z_{dk}, I_{dk}, A_{dk} = stiffener requirements for weather/cargo decks to be determined in accordance with Ch 3,8.7 and Ch 3,8.10 using the appropriate design head for weather/cargo. In no case is the head to be taken as less than 2 kN/m^2.

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3.7 Access

3.7.1 Bow doors are to comply with the requirements of Section 4.

3.7.2 Where access to the vehicle deck is provided by side and stern doors, the doors are to have scantlings equivalent to the structure in which they are fitted, *see also* Pt 3, Ch 4,4.

3.7.3 Doors providing pedestrian access between vehicle decks and accommodation spaces are to be gastight, have scantlings equivalent to the surrounding structure and where applicable are to comply with the requirements of Part 17.

3.8 Hatch covers

3.8.1 The scantlings and arrangements of hatches and hatch covers located within vehicle decks are to be not less than that required by the Rules for the supporting structure in which such hatches are fitted. In general the end fixity of primary stiffening members is to be taken as simply supported. Local and secondary stiffening members may be either partially or fully fixed at their end connections dependent upon the proposed arrangement.

3.8.2 In no case, however, are the scantlings of plating and stiffeners to be less than would be required for a weather or cargo deck, or hatch cover, as applicable.

3.8.3 Where unusual arrangements of hatch cover stiffening are proposed, the scantlings of plating and stiffeners may be determined by direct calculations using a two dimensional grillage model. Copies of calculations are to be submitted.

3.9 Heavy and special loads

3.9.1 Where heavy or special loads are proposed to be carried, the scantlings and arrangements of the deck structure will be individually considered on the basis of submitted calculations.

3.9.2 Due account is to be taken of the acceleration levels due to craft motion as applicable to particular items of heavy mass such as vehicles, containers, pallets, etc.

3.10 Direct calculations

3.10.1 LR will consider direct calculations for the derivation of scantlings as an alternative to and equivalent to those derived by Rule requirements. The assumptions made and the calculation procedures used are to be submitted for appraisal in accordance with Pt 3, Ch 1,2.

■ *Section 4* Bow doors

4.1 Application

4.1.1 The requirements of this Section are applicable to the arrangement, strength and securing of bow doors, both the visor and the side opening type doors, and inner doors leading to a complete or long forward enclosed superstructure.

4.1.2 Other types of bow door will be specially considered.

4.2 General

4.2.1 The attention of Owners and Builders is drawn to the additional statutory regulations for bow doors that may be imposed by the National Authority.

4.2.2 Bow doors are to be situated above the freeboard deck. A watertight recess in the freeboard deck located forward of the collision bulkhead and above the deepest waterline fitted for arrangement of ramps or other related mechanical devices may be regarded as a part of the freeboard deck.

4.2.3 An inner door is to be fitted. The inner door is to be part of the collision bulkhead. The inner door need not be fitted directly above the bulkhead below, provided it is located within the limits specified for the position of the collision bulkhead, *see* Pt 3, Ch 2,4. A vehicle ramp may be arranged for this purpose, provided its position complies with Pt 3, Ch 2,4 and the ramp is weathertight over its complete length. In this case the upper part of the ramp higher than 2,3 m above the freeboard deck may extend forward of the limit specified in Pt 3, Ch 2,4. If this is not possible a separate inner weathertight door is to be installed, as far as practicable within the limits specified for the position of the collision bulkhead.

4.2.4 Bow doors are to be fitted as to ensure tightness consistent with operational conditions and to give effective protection to inner doors. Inner doors forming part of the collision bulkhead are to be weathertight over the full height of the cargo space and arranged with fixed sealing supports on the aft side of the doors.

4.2.5 Bow doors and inner doors are to be arranged so as to preclude the possibility of the bow door causing structural damage to the inner door or to the collision bulkhead in the case of damage to or detachment of the bow door. If this is not possible, a separate inner weathertight door is to be installed, as indicated in 4.2.3.

4.2.6 The requirements for inner doors are based on the assumption that vehicles are effectively lashed and secured against movement in the stowed position.

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4.3 Symbols and definitions

4.3.1 The symbols used in this Section are defined as follows:

A_s = area stiffener web, in cm^2

A_x = area, in m^2, of the transverse vertical projection of the door between the levels of the bottom of the door and the upper deck or between the bottom of the door and the top of the door, whichever is the lesser, as shown in Fig. 5.4.2

A_y = area, in m^2, of the longitudinal vertical projection of the door between the levels of the bottom of the door and the upper deck or between the bottom of the door and the top of the door, whichever is the lesser

A_z = area of the horizontal projection of the door between the levels of the bottom of the door and the upper deck or between the bottom of the door and the top of the door, in m^2, whichever is the lesser, as shown in Fig. 5.4.2

a_{bv} = vertical distance, in metres, from visor pivot to the centroid of the transverse vertical projected area of the visor door, as shown in Fig. 5.4.2

b_{bv} = horizontal distance, in metres, from visor pivot to the centroid of the horizontal projected area of the visor door, as shown in Fig. 5.4.2

c_{bv} = horizontal distance, in metres, from visor pivot to the centre of gravity of visor mass, as shown in Fig. 5.4.2

d_{bv} = Vertical distance, in metres, from bow door pivot to the centre of gravity of the bow door, as shown in Fig. 5.4.2

h = height of the door between the levels of the bottom of the door and the upper deck or between the bottom of the door and the top of the door, in metres, whichever is the lesser, as shown in Fig. 5.4.1

K_s = higher tensile steel factor
= $235/\sigma_s$

l_d = length of the door at a height $h/2$ above the bottom of the door, in metres, as shown in Fig. 5.4.2

Q_{bd} = shear force, in kN, in the stiffener calculated by using uniformly distributed external pressure P_e as given in 4.5.1

W_{bv} = mass of the visor door, in tonnes

W = breadth of the door at a height $h/2$ above the bottom of the door, in metres, as shown in Fig. 5.4.2

σ = bending stress, in N/mm^2

σ_{eq} = equivalent stress, in N/mm^2
= $\sqrt{\sigma^2 + 3\tau^2}$

σ_s = specified minimum yield strength of the material, in N/mm^2

τ = shear stress, in N/mm^2.

4.3.2 **Locking device**. A device that locks a securing device in the closed position.

4.3.3 **Securing device**. A device used to keep the door closed by preventing it from rotating about its hinges.

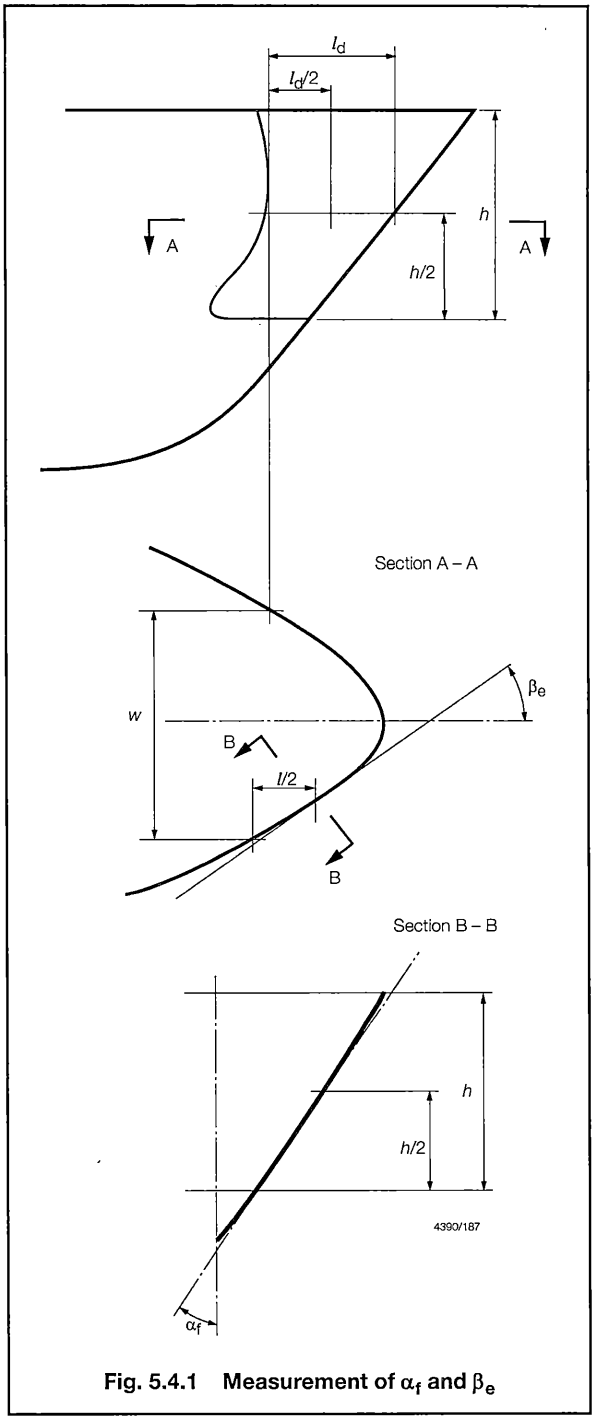

Fig. 5.4.1 Measurement of α_f and β_e

4.3.4 **Side-opening doors**. Side-opening doors are opened either by rotating outwards about a vertical axis through two or more hinges located near the outboard edges or by horizontal translation by means of linking arms arranged with pivoted attachments to the door and the craft. It is anticipated that side-opening doors are arranged in pairs.

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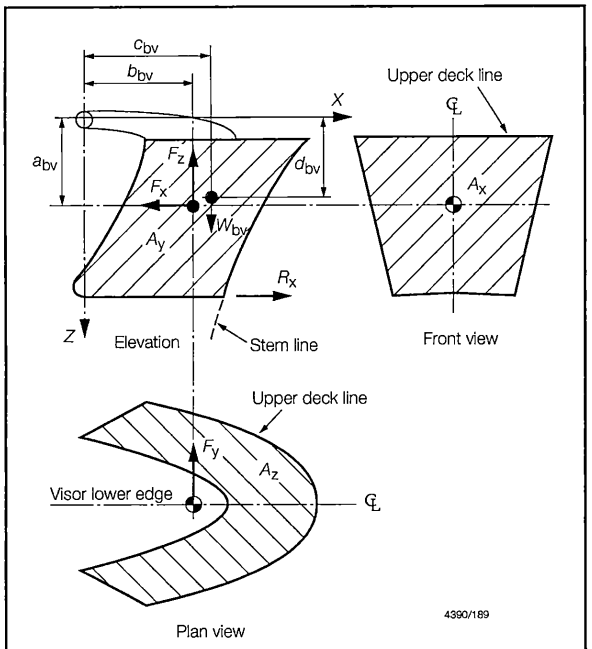

Fig. 5.4.2 Bow visor (upward hinging)

4.3.5 **Supporting device.** A device used to transmit external or internal loads from the door to a securing device and from the securing device to the craft's structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, that transmits loads from the door to the craft's structure.

4.3.6 **Visor doors.** Visor doors are opened by rotating upwards and outwards about a horizontal axis through two or more hinges located near the top of the door and connected to the primary structure of the door by longitudinally arranged lifting arms.

4.4 Strength criteria

4.4.1 Scantlings of the primary members, securing and supporting devices of bow doors and inner doors are to be able to withstand the design loads defined in 4.5. The shear, bending and equivalent stresses are not to exceed $80/k_s$ N/mm^2, $120/k_s$ N/mm^2 and $150/k_s$ N/mm^2 respectively.

4.4.2 The buckling strength of primary members is to be verified as being adequate, *see* Ch 7,4.

4.4.3 For steel to steel bearings in securing and supporting devices, the nominal bearing pressure calculated by dividing the design force by the projected bearing area is not to exceed 80 per cent of the yield stress of the bearing material. For other bearing materials, the permissible bearing pressure is to be determined according to the manufacturer's specification.

4.4.4 The arrangement of securing and supporting devices is to be such that threaded bolts do not carry support forces. The maximum tension in way of threads of steel bolts not carrying support forces is not to exceed $125/k_s$ N/mm^2.

4.5 Design loads

4.5.1 The design external pressure, P_e, for the determination of scantlings for primary members, securing and supporting devices of bow doors is to be taken not less than the following:

$$P_e = 2{,}75\lambda_G C_H (0{,}22 + 0{,}15\tan\alpha_f)(0{,}4V_{max}\sin\beta_e + 0{,}6L_R^{0,5})^2 \quad \text{kN/m}^2$$

where

V_{max} = maximum speed, in knots, as defined in Pt 1, Ch 2, 2.2.10

L_R = Rule length of craft, in metres, as defined in Pt 3, Ch 1,6

λ_G = Service group factor for mono-hull craft, *see* Pt 1, Ch 2
= 0,5 for Group 1 and Group 2
= 0,6 for Group 3
= 0,8 for Group 4
= 1,0 for Group 5 and Group 6
For multi-hull craft, λ_G will be specially considered and may be reduced where the freeboard is significant

C_H = $0{,}0125L_R$ for $L_R < 80$ m
= 1,0 for $L_R \geq 80$ m

α_f = flare angle, in degrees, at the point to be considered, defined as the angle between a vertical line and the tangent to the side shell plating, measured in a vertical plane normal to the horizontal tangent to the shell plating, *see* Fig. 5.4.1

β_e = entry angle, in degrees, at the point to be considered, defined as the angle between a longitudinal line parallel to the centreline and the tangent to the shell plating in a horizontal plane, *see* Fig. 5.4.1.

4.5.2 The design external forces, F_x, F_y and F_z, in kN, for the determination of scantlings of securing and supporting devices of bow doors are taken to be not less than $P_e A_x$, $P_e A_y$ and $P_e A_z$ respectively:

where

P_e is the external pressure, defined in 4.5.1, with the flare angle α_f, and the entry angle β_e, measured at the point on the bow door

$l_d/2$ aft of the stem line on the plane, and

$h/2$ above the bottom of the door, as shown in Fig. 5.4.1

A_x, A_y, A_z and h as defined in 4.3.1.

4.5.3 For bow doors, including bulwark, of unusual form or proportions, the areas used for the determination of the design values of external forces will be specially considered.

4.5.4 For visor doors the closing moment, M_y, under external loads, is to be taken as:

$$M_y = F_x a_{bv} + 10W_{bv} c_{bv} - F_z b_{bv} \quad \text{kNm}$$

where

W_{bv}, a_{bv}, b_{bv} and c_{bv} are as defined in 4.3.1,
F_x and F_z are as defined in 4.5.2.

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4.5.5 The lifting arms of a visor and its supports are to be dimensioned for the static and dynamic forces applied during the lifting and lowering operations, and a minimum wind pressure of 1,5 kN/m^2 is to be taken.

4.5.6 The design external pressure, in kN/m^2, for the determination of scantlings for primary members, securing and supporting devices and surrounding structure of inner doors is to be taken as the greater of $0{,}45L_R$ and $10h_2$, where h_2 is the distance, in m, from the load point to the top of the cargo space and L_R as defined in Pt 3, Ch 1,6.2.1.

4.5.7 The design internal pressure for the determination of scantlings for securing devices of inner doors is not to be taken less than 25 kN/m^2.

4.6 Scantlings of bow doors

4.6.1 The strength of bow doors is to be commensurate with that of the surrounding structure.

4.6.2 Bow doors are to be adequately stiffened and means are to be provided to prevent lateral or vertical movement of the doors when closed. For visor doors adequate strength for the opening and closing operations is to be provided in the connections of the lifting arms to the door structure and to the craft structure.

4.6.3 The thickness of the bow plating is not to be less than that required for the side shell plating, using bow door stiffener spacing, but in no case less than the minimum required thickness of fore end shell plating.

4.6.4 The section modulus of horizontal or vertical stiffeners is not to be less than that required for end framing. Consideration is to be given, where necessary, to differences in fixity between the craft's frames and bow doors stiffeners.

4.6.5 The stiffener webs are to have a net sectional area A_s, not less than:

$$A_s = \frac{23{,}5Q_{bd}}{\sigma_s} \text{ cm}^2$$

where

A_s, Q_{bd} and σ_s are as defined in 4.3.1.

4.6.6 The bow door secondary stiffeners are to be supported by primary members constituting the main stiffening of the door.

4.6.7 The primary members of the bow door and the hull structure in way are to have sufficient stiffness to ensure integrity of the boundary support of the door.

4.6.8 Scantlings of the primary members are generally to be supported by direct calculations in association with the external pressure given in 4.5.1 and permissible stresses given in 4.4.2.

4.7 Scantlings of inner doors

4.7.1 Scantlings of the primary members are generally to be supported by direct calculations in association with the external pressure and permissible stresses given in 4.4.1. In general, formulae for simple beam theory may be applied.

4.7.2 Where inner doors also serve as a vehicle ramps, the scantlings are not to be less than those required for vehicle decks.

4.7.3 The distribution of forces acting on the securing and supporting devices is, in general, to be supported by direct calculations taking into account the flexibility of the structure and actual position and stiffness of the supports.

4.8 Securing and supporting of bow doors

4.8.1 Bow doors are to be fitted with adequate means of securing and supporting so as to be commensurate with the strength and stiffness of the surrounding structure. The hull supporting structure in way of the bow doors is to be suitable for the same design loads and design stresses as the securing and supporting devices. Where packing is required, the packing material is to be of a comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be considered. Maximum design clearance between securing and supporting devices is, in general, not to exceed 3 mm. A means is to be provided for mechanically fixing the door in the open position.

4.8.2 Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be included and considered to calculate the reaction forces acting on the devices. Small and/or flexible devices such as cleats intended to provide load compression of the packing material are, in general, not to be included in the calculations called for in 4.8.8. The number of securing and supporting devices are, in general, to be the minimum practical whilst taking into account the requirements for redundant provision given in 4.8.9 and 4.8.10 and the available space for adequate support in the hull structure.

4.8.3 For opening outwards visor doors, the pivot arrangement is generally to be such that the visor is self-closing under external loads, that is $M_y > 0$. Moreover, the closing moment, M_y, as given in 4.5.4 is to be not less than:

$$M_y = 10W_{bv}\, c_{bv} + 0{,}1(a_{bv}^2 + b_{bv}^2)^{0,5}\ (F_x^2 + F_z^2)^{0,5}$$

where

W_{bv}, a_{bv}, b_{bv} and c_{bv} are as defined in 4.3.1, F_x and F_z are as defined in 4.5.2.

4.8.4 Securing and supporting devices are to be adequately designed so that they can withstand the reaction forces within the permissible stresses given in 4.4.1.

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4.8.5 For **visor doors** the reaction forces applied on the effective securing and supporting devices assuming the door as a rigid body are determined for the following combination of external loads acting simultaneously together with the self weight of the door.

Case 1 F_x and F_z
Case 2 $0,7F_y$ acting on each side separately together with $0,7F_x$ and $0,7F_z$.

where

F_x, F_y and F_z are to be determined as indicated in 4.5.2 and applied at the centroid of projected areas.

4.8.6 For **side-opening doors** the reaction forces applied on the effective securing and supporting devices assuming the door as a rigid body are determined for the following combination of external loads acting simultaneously together with the self weight of the door:

Case 1 F_x , F_y and F_z acting on both doors.
Case 2 $0,7F_x$ and $0,7F_z$ acting on both doors and $0,7F_y$ acting on each door separately.

where

F_x, F_y and F_z are to be determined as indicated in 4.5.2 and applied at the centroid of projected areas.

4.8.7 The support forces as determined according to 4.8.5 and 4.8.6 are generally to give rise to a zero moment about the transverse axis through the centroid of the area A_x. For visor doors, longitudinal reaction forces of pin and/or wedge supports at the door base contributing to this moment are not to be of the forward direction.

4.8.8 The distribution of the reaction forces acting on the securing and supporting devices may require to be supported by direct calculations taking into account the flexibility of the hull structure and the actual position and stiffness of the supports.

4.8.9 The arrangement of securing and supporting devices in way of these securing devices is to be designed with redundancy so that in the event of failure of any single securing or supporting device the remaining devices are capable to withstand the reaction forces without exceeding by more than 20 per cent the permissible stresses as given in 4.4.1.

4.8.10 For visor doors, two securing devices are to be provided at the lower part of the door, each capable of providing the full reaction force required to prevent opening of the door within the permissible stresses given in 4.4.1. The opening moment, M_o, to be balanced by this reaction force, is not to be taken less than:

$$M_o = 10W_{bv}\, d_{bv} + 5A_x\, a_{bv} \text{ kNm}$$

where

W_{bv}, A_x, d_{bv} and a_{bv} as defined in 4.3.1.

4.8.11 For visor doors, the securing and supporting devices excluding the hinges should be capable of resisting the vertical design force ($F_z - 10W_{bv}$), in kN, within the permissible stresses given in 4.4.1.

4.8.12 All load transmitting elements in the design load path, from door through securing and supporting devices into the craft structure, including welded connections, are to be the same strength.

4.8.13 For side-opening doors, thrust bearing has to be provided in way of girder ends at the closing of the two leaves to prevent one leaf to shift towards the other one under effect of unsymmetrical pressure, *see* Fig. 5.4.3. Each part of the thrust bearing has to be kept secured on the other part by means of securing devices. Any other arrangements serving the same purpose are to be submitted for appraisal.

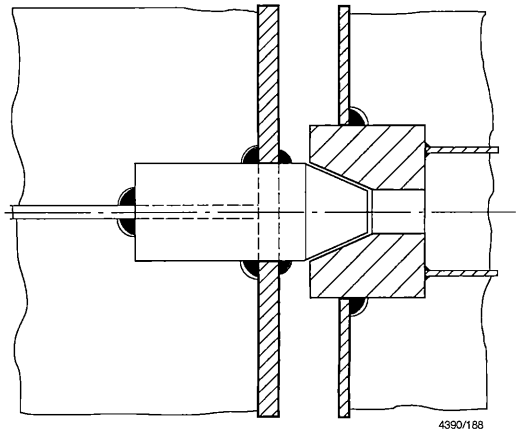

Fig. 5.4.3 Typical thrust bearing

4.9 Securing and locking arrangement

4.9.1 Securing devices are to be simple to operate and easily accessible. Securing devices are to be equipped with mechanical locking arrangements (self locking or separate arrangement), or be of the gravity type. The opening and closing systems as well as securing and locking devices are to be interlocked in such a way that they can only operate in the proper sequence.

4.9.2 Bow doors and inner doors giving access to vehicle decks are to be provided with an arrangement for remote control, from a position above the freeboard deck, of:

(a) the closing and opening of the doors; and

(b) associated securing and locking devices for every door.

Indication of the open/closed position of every door and every securing and locking device is to be provided at the remote control stations. The operating panels for operation of doors are to be inaccessible to unauthorised persons. A notice plate, giving instructions to the effect that all securing devices are to be closed and locked before leaving harbour, is to be placed at each operating panel and is to be supplemented by warning indicator lights.

4.9.3 Where hydraulic securing devices are applied, the system is to be mechanically lockable in closed position so that in the event of loss of the hydraulic fluid, the securing devices remain locked. The hydraulic system for securing and locking devices is to be isolated from other hydraulic circuits when in closed position.

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4.9.4 Separate indicator lights and audible alarms are to be provided on the navigation bridge and on the operating panel to show that the bow door and inner door are closed and that their securing and locking devices are properly positioned. The indication panel is to be provided with a lamp test function. The indicator lights are to be provided with a permanent power supply, and arrangements are to be such that it is not possible to turn off these lights in service.

4.9.5 The indicator system is to be designed on the fail-safe principle and is to show by visual alarms if the door is not fully closed and not fully locked and by audible alarms if securing devices become open or locking devices become unsecured. The power supply for the indicator system is to be independent of the power supply for operating and closing the doors. The sensors of the indicator system are to be protected from water, ice formation and mechanical damage.

4.9.6 The indication panel on the navigation bridge is to be equipped with a mode selection function 'harbour/sea voyage', so arranged that audible alarm is given if the craft leaves harbour with the bow door or inner door not closed and with any of the securing devices not in the correct position.

4.9.7 A water leakage detection system with audible alarm and television surveillance is to be arranged to provide an indication to the navigation bridge and to the engine control room of leakage through the inner door.

4.9.8 Between the bow door and the inner door a television surveillance system is to be fitted with a monitor on the navigation bridge and in the engine control room. The system is to be able to monitor the position of doors and a sufficient number of their securing devices. Special consideration is to be given for lighting and contrasting colour of objects under surveillance.

4.9.9 A drainage system is to be arranged in the area between bow door and ramp, as well as in the area between the ramp and inner door where fitted. The system is to be equipped with an audible alarm function to the navigation bridge for water level in these areas exceeding 0,5 m above the car deck level.

4.10 Operating and Maintenance Manual

4.10.1 An Operating and Maintenance Manual for the bow door and inner door is to be provided on board and contain necessary information on:

(a) main particulars and design drawings;
(b) service conditions, e.g. service area restrictions and acceptable clearances for supports;
(c) maintenance and function testing;
(d) register of inspections and repairs.

This manual is to be submitted for approval.

4.10.2 Documented operating procedures for closing and securing the bow door and inner door are to be kept on board and posted at an appropriate place.

■ *Section 5* Movable decks

5.1 Classification

5.1.1 Movable decks other than those described in 5.1.2 are not a classification item, although consideration must be given to associated supporting structure. Where movable decks are fitted, it is recommended that they be based on the requirements of this Section.

5.1.2 At the Owner's or Builder's request, however, movable decks will be included as a classification item, and the class notation **Movable decks** will be entered in the *Register Book*. In such cases, all movable decks on board the ship are to comply with the requirements of this Section.

5.2 Arrangements and designs

5.2.1 Movable decks are generally to be constructed as pontoons comprising a web structure with top decking. Other forms of construction will be individually considered.

5.2.2 Positive means of control are to be provided to secure decks in the lowered position.

5.2.3 The decks are to be efficiently supported, and hinges, pillars, chains or other means (or a combination of these) are to be designed on the basis of the imposed loads. Where supporting chains and fittings are required, they are to have a factor of safety of at least two on the proof load.

5.2.4 Plans showing the proposed scantlings and arrangements of the system are to be submitted.

5.2.5 Where it is proposed to stow the pontoons on deck, when not in use, details of the proposals for racks, fittings, etc., are to be submitted for consideration.

5.3 Loading

5.3.1 Details of the deck loading resulting from the proposed stowage arrangements of vehicles are to be supplied by the Shipbuilder. These details are to include the axle and wheel spacing, the wheel load, type of tyre and tyre print dimensions for the vehicles. For design purposes the wheel loading is to be taken as not less than 3,0 kN, *see* Section 3.

5.3.2 Where it is proposed also to use the decks for general cargo, the design loadings are to be submitted for consideration.

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5.4 Scantling requirements

5.4.1 The scantlings and arrangements of removable decks are to be not less than those required by the Rules for the supporting structure in which the movable decks are fitted. In general the end fixity of primary stiffening members is to be taken as simply supported. Local and secondary stiffening members may be either partially or fully fixed at their end connections dependent upon the proposed arrangement.

5.5 Deflection

5.5.1 Where wheeled vehicles are to be used, the supporting arrangements are to be such that the movement at the edge of one pontoon relative to the next does not exceed 50 mm during loading or unloading operations.

■ *Section 6* Helicopter landing areas

6.1 General

6.1.1 The landing area may be located on an appropriate area of the weather deck or on a platform specifically designed for this purpose and permanently connected to the craft structure.

6.1.2 The structure is to be designed to accommodate the largest helicopter type which it is intended to use. In general, the diameter of the landing area is to be not less than 1,25 times the rotor diameter.

6.1.3 Attention is drawn to the requirements of National and other Authorities concerning the construction of helicopter landing platforms and the operation of helicopters as they affect the craft.

6.1.4 Plans are to be submitted showing the proposed scantlings and arrangements of the structure. The type, size and weight of helicopters to be used are also to be indicated. Details of the helicopter types to be used are to be included in the craft's documentation, and be contained in a notice displayed on the helicopter landing deck.

6.1.5 Where the landing area forms part of a weather or erection deck, the scantlings are to be not less than those required for decks in the same position.

6.1.6 The requirements for fire protection, detection and extinction for yachts are to comply with Part 17. The requirements for other types of craft are outside the scope of classification and are therefore to comply with the requirements of the National Authority. Special consideration is to be given to the insulation standard if the space below the helicopter deck is a high fire-risk space.

6.2 Arrangements

6.2.1 The landing area is to be sufficiently large to allow for the landing and manoeuvring of the helicopter, and is to be approached by a clear landing and take-off sector complying in extent with the applicable regulations.

6.2.2 The landing area is to be free of any projections above the level of the deck. Projections in the zone surrounding the landing area are to be kept below the heights permitted by the regulations.

6.2.3 Suitable arrangements are to be made to minimise the risk of personnel or machinery sliding off the landing area. A non-slip surface and anchoring devices, and in the case of independent platforms, safety nets, are to be provided.

6.2.4 Arrangements are to be made for drainage of the platform, including drainage of spilt fuel.

6.2.5 Details of arrangements for securing the helicopter to the deck are to be submitted for approval.

6.3 Landing area plating

6.3.1 The deck plate thickness, t_p, within the landing area is to be not less than:

$$t_p = \frac{\alpha\, s}{1000\sqrt{k_s}}$$

α = thickness coefficient obtained from Fig. 5.3.1

β_p = tyre print coefficient used in Fig. 5.3.1

$$= \log_{10}\left(\frac{P_1\, k_s^2}{s^2} \times 10^7\right)$$

where

s and k_s are defined in 1.2.

The plating is to be designed for the emergency landing case taking

P_1 = $2{,}5\, \phi_1\, \phi_2\, \phi_3\, f\, \gamma\, P_w$ tonnes

where

ϕ_1, ϕ_2, ϕ_3 are to be determined from Table 5.3.1

f = 1,15 for landing decks over manned spaces, e.g. deckhouses, bridges, control rooms, etc.
= 1,0 elsewhere

P_h = the maximum all up weight of the helicopter, in tonnes

P_w = landing load, on the tyre print, in tonnes; P_w is to be taken as P_h divided equally between the two main undercarriages (for helicopters with single main rotor)

γ = a location factor given in Table 5.6.1

k_s is as defined in 1.2.

The tyre print dimensions specified by the manufacturer are to be used for the calculation. Where these are unknown it may be assumed that the print area is 300 mm x 300 mm and this assumption is to be indicated on the submitted plan.

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Table 5.6.1 Location factor, γ

Location	γ
On decks forming part of the hull girder:	
(a) within $0,4L_R$ amidships	0,71 Values for intermediate locations are to be determined by interpolation
(b) at the F.P. or A.P.	0,6
Elsewhere	0,6

6.3.2 For helicopters fitted with landing gear consisting of skids, the print dimensions specified by the manufacturer are to be used. Where these are unknown it may be assumed that the print consists of a 300 mm line load at each end of each skid, when applying Fig. 5.3.1.

6.4 Deck stiffening

6.4.1 The helicopter deck stiffening is to be designed for the load cases given in Table 5.6.2 with the helicopter being positioned so as to produce the most severe loading condition for each structural member under consideration.

6.4.2 The minimum requirements for section modulus, inertia and web area of secondary stiffeners are to be in accordance with Table 5.3.3.

6.4.3 For primary stiffening, and where a grillage arrangement is adopted, it is recommended that direct calculation procedures be used to determine the scantling requirements, in association with the limiting permissible stress criteria given in Chapter 7. A copy of the calculations is to be submitted for consideration.

■ *Section 7*
Strengthening requirements for navigation in ice conditions

7.1 General

7.1.1 The strengthening requirements detailed in this Section are applicable to craft, other than those assigned the notation **HSC** and/or **LDC** (*see* Pt 1, Ch 2), intended for operation in light first year ice conditions in areas other than the northern Baltic corresponding to unbroken level ice of thickness not greater than 0,4 m.

7.1.2 Craft complying with the requirements of this Section, in addition to the requirements for sea-going service where applicable, will be eligible for the special features notation **Ice Class 1D**. Alternatively, a Special Duties Notation may be assigned indicating that the craft has been additionally strengthened for duties in ice, *see* Pt 1, Ch 2,3.8.

7.1.3 Craft designed to operate in ice conditions other than those detailed in 7.1.1 are to comply with Part 8 of the *Rules and Regulations for the Classification of Ships*.

7.1.4 The requirements of this Section are applicable to both longitudinally and transversely framed craft and concern the shell plating and framing in the forward region, the stem, sternframe, rudder and the steering gear.

7.1.5 The vertical extent of the ice strengthening is related to the ice light and load waterlines, which are defined in 7.2. The maximum and minimum Ice Class draughts at both the fore and aft ends will be stated on the Class Certificate.

7.1.6 The requirements of this Section assume that when approaching ice infested waters the craft's speed will be reduced appropriately. The vertical extent of ice strengthening for craft intended to operate in ice conditions at speeds exceeding 15 knots will be specially considered.

Table 5.6.2 Design load cases for deck stiffening and supporting structure

Loadcase	Loads (tonnes)			
	Landing area		Supporting structure, *see* Note 1	
	UDL	Helicopter *see* Note 2	Self weight	Horizontal load *see* Note 2
(1) Overall distributed loading	2	–	–	–
(2) Helicopter emergency landing	0,2	$2,5P_h f$	W_h	$0,5P_h$
(3) Normal Usage	0,5	$1,5P_h$	W_h	$0,5P_h + 0,5W_h$

Symbols

P_h and f are as defined in 5.4.1.
UDL = Uniformly distributed vertical load over entire landing area, kN/m^2
W_h = structural weight of helicopter platform, in tonnes

NOTES
1. For the design of the supporting structure for helicopter platforms applicable self weight and horizontal loads are to be added to the landing area loads.
2. The helicopter is to be so positioned as to produce the most severe loading condition for each structural member under consideration.

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7.1.7 The ballast capacity of propeller-driven craft is to be sufficient to give adequate propeller immersion in all ice navigating conditions without trimming the craft in such a manner that the actual waterline at the bow is below the ice light waterline. Ballast tanks situated above the ice light waterline and adjacent to the shell, which are intended to be used in ice navigating conditions, are to be provided with heating pipes.

7.2 Definitions

7.2.1 The Ice Load Waterline is that corresponding to the Fresh Water Summer Loadline.

7.2.2 The Ice Light Waterline is that corresponding to the lightest condition in which the craft is expected to navigate in ice.

7.2.3 The Ice Load Waterline and the Ice Light Waterline are to be indicated on the plans. For navigation in certain geographical areas, the relevant National Authority may require the maximum Ice Class draught to be marked on the craft in a specified manner.

7.2.4 The Main Ice Belt Zone extends vertically from 500 mm below the Ice Light Waterline to 400 mm above the Ice Load waterline and horizontally from the stem to $0{,}02L_R$ m aft of the point at which the deepest load waterline reaches its greatest breadth.

7.3 Powering of ice strengthened craft

7.3.1 Ice strengthened craft are assumed to be capable of developing sufficient thrust to permit continuous mode ice-breaking at a speed of at least five knots in ice having a thickness of 0,4 m and a snow cover of at least 0,3 m.

7.4 Shell plating

7.4.1 In way of the main ice belt zone, the thickness of the shell plating is to be determined by direct calculation. A copy of these calculations is to be submitted for consideration.

7.4.2 Changes in plating thicknesses in the longitudinal direction are to take place gradually.

7.4.3 Side scuttles are not to be situated in the ice belt.

7.4.4 If the weather deck in any part of the craft is situated below the upper limit of the ice belt, the bulwark is to be reinforced to the same degree as the shell plating in the main ice belt.

7.4.5 In general all welded seams and butts in way of the main ice belt are to be dressed smooth.

7.5 Shell framing requirements

7.5.1 Ice framing is to extend a minimum distance of 1000 mm above the Ice Load Waterline and 1600 mm below the Ice Light Waterline between the stem and $0{,}02L_R$ m aft of the point at which the deepest load waterline reaches its greatest breadth.

7.5.2 The web thickness of ice framing is not, in general, to be less than half that of the attached shell plating.

7.5.3 Ice frames are to be attached to the shell plating by double continuous welding and are not to be scalloped except at shell plating seams or butts. Air and drain holes are to be kept to a minimum.

7.5.4 Main and intermediate frames within the minimum extent of ice framing are to be efficiently supported to prevent tripping. The distance between anti-tripping supports is not to exceed 1000 mm.

7.5.5 The section modulus of an ice framing stiffening member is to be determined by direct calculation. A copy of these calculations is to be submitted for consideration.

7.5.6 Where transverse framing is adopted, ice stringers (primary longitudinal members supporting ice framing) are to be spaced not more than 1000 mm apart and are to have a section modulus not less than four times the section modulus of the transverse framing.

7.5.7 Where longitudinal framing is adopted, ice stringers need not be fitted.

7.6 Stem construction

7.6.1 Where a plate stem is fitted, the plate thickness is to be not less than 1,3 times that determined by Ch 3,3.3.

7.6.2 Where a bar stem is fitted, its cross-sectional area is to be not less than 1,25 times that determined by Ch 3,5.12.

7.7 Stern construction

7.7.1 A transom stern is not normally to extend below the ice load waterline. Where this cannot be avoided, the transom is to be kept as narrow as possible and the scantlings of plating and stiffeners are to be as required for the midcraft region.

7.8 Bossings and shaft struts

7.8.1 For craft with two or more propellers, shafting and sterntubes are generally to be enclosed within plated bossings. If detached supporting struts are necessary, their design, strengthening and attachment to the hull will be specially considered.

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7.9 Rudder and steering arrangements

7.9.1 Rudder posts, rudder horns, sole pieces, rudder stocks and pintles are to be dimensioned in accordance with Pt 3, Ch 3,2. The speed used in the calculations is to be the service speed or 14 knots, whichever is the greater.

7.9.2 The thickness of rudder plating and webs is to be increased by 10 per cent over the requirements of Pt 3, Ch 3,2.

7.9.3 Due regard is to be paid to the method of securing the rudder in the centreline position when backing into ice. Where possible, rudder stoppers working on the blade or rudder head are to be fitted.

7.9.4 Where steering nozzles are fitted, the thickness of the shroud plating is to include an abrasion allowance of 2 mm.

7.9.5 The scantlings of the stock, pintles, gudgeon and sole pieces associated with the nozzle are to be increased on the basis given in 7.9.1. However, the diameter of the nozzle stock is to be not less than that calculated in the astern condition taking the astern speed as seven knots or the actual astern speed, whichever is the greater.

7.9.6 Nozzles with articulated flaps will be subject to special consideration.

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Section

1 **General**

2 **Hull girder strength for mono-hull craft**

3 **Additional hull girder strength requirements for multi-hull craft**

Section 1 General

1.1 Application

1.1.1 The requirements for longitudinal and transverse global strength for mono-hull and multi-hull craft of steel construction, are contained within this Chapter. Due consideration is taken of the dynamic effects, where appropriate, in both the crest and trough wave landing conditions.

1.2 Symbols and definitions

1.2.1 The symbols and definitions applicable to this Chapter are defined below or in the appropriate sub-Section.

L_R = Rule length of the craft, in metres

B = *moulded breadth of craft, see* Pt 3, *Ch* 1,6.2.1, *in* metres (to be taken as the breadth of a single hull for multi-hull craft)

l = overall span length of stiffening member, in metres

l_e = effective span length of stiffening member, in metres

p = design pressure as appropriately given in Part 3, in kN/m^2

s = spacing of stiffener, in mm

t_p = thickness of plating, in mm

σ_s = specified minimum yield strength of the material, in N/mm^2

β = panel aspect ratio correction, see Ch 3,1.15

$$\tau_s = \frac{\sigma_s}{\sqrt{3}}$$

1.2.2 The strength deck is to be taken as follows:

(a) Where there is a complete upper deck the strength deck is the upper deck.

(b) Where the upper deck is stepped, as in the case of raised quarterdeck craft, the strength deck is stepped as shown in Fig. 6.1.1.

1.3 General

1.3.1 The additional pressures arising from the influence of the global loading are considered in the determination of the longitudinal strength requirements for local and secondary stiffening and bottom shell plating.

1.3.2 In general, the effective sectional area of continuous longitudinal strength members, after deduction of openings, is to be used for the calculation of midship section modulus.

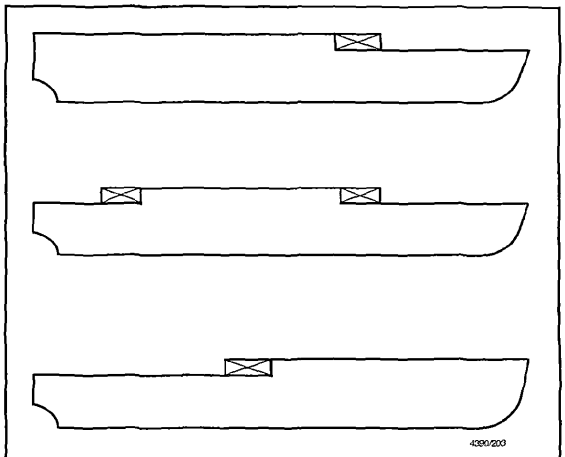

Fig. 6.1.1 Strength deck

1.3.3 Structural members which contribute to the overall hull girder strength are to be carefully aligned so as to avoid discontinuities resulting in abrupt variations of stresses and are to be kept clear of any form of openings which may affect their structural performances.

1.3.4 In general, superstructures or deckhouses will not be accepted as contributing to the global longitudinal or transverse strength of the craft. However, where it is proposed to include substantial, continuous stiffening members, special consideration will be given to their inclusion on submission of the designer's/Builder's calculations.

1.3.5 Where continuous deck longitudinals or deck girders are arranged above the strength deck, special consideration may be given to the inclusion of their sectional area in the calculation of the hull section modulus (Z). The lever is to be taken to a position corresponding to the depth of the longitudinal member above the moulded deckline at side amidships. Each such case will be individually considered.

1.3.6 Adequate transition brackets are to be fitted at the ends of effective continuous longitudinal strength members in the deck and bottom structures.

1.3.7 Scantlings of all continuous longitudinal members of the hull girder based on the minimum section stiffness requirements determined from 2.2 are to be maintained within $0{,}4L_R$ amidships. However, in special cases, based on consideration of type of ship, hull form and loading conditions, the scantlings may be gradually reduced towards the ends of the $0{,}4L_R$ part, bearing in mind the desire not to inhibit the craft's loading and operational flexibility.

1.4 Openings

1.4.1 Deck openings having a length in the fore and aft directions exceeding $0{,}1B$ m or a breadth exceeding $0{,}05B$ m are in all cases to be deducted from the sectional areas used in the section modulus calculation.

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1.4.2 Deck openings smaller than stated in 1.4.1, including manholes, need not be deducted provided they are isolated and the sum of their breadths or shadow area breadths (*see* 1.4.3) in one transverse section does not exceed 0,06 ($B_o - \Sigma b_o$).

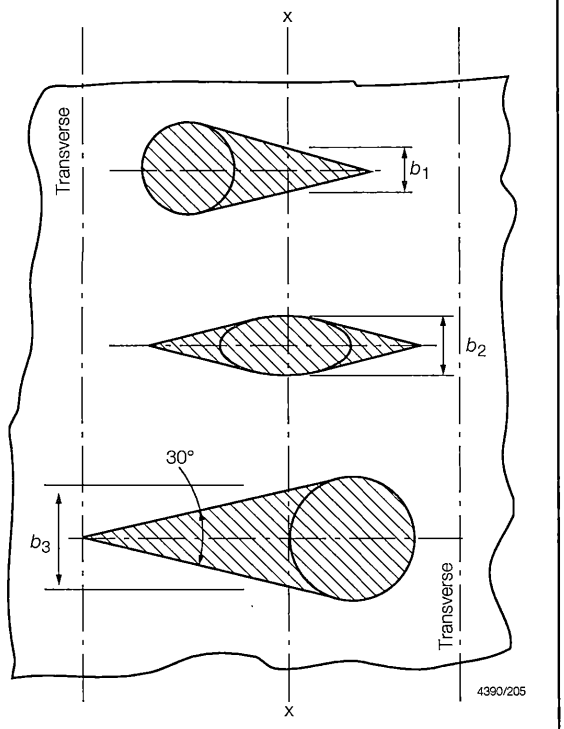
where

B_o = breadth of craft, in metres, at section considered

Σb_o = sum of breadths, in metres, of deductible openings

Where a large number of deck openings are proposed in any transverse space, special consideration will be required.

1.4.3 Where calculating deduction-free openings, the openings are assumed to have longitudinal extensions as shown by the shaded areas in Fig. 6.1.2. The shadow area is obtained by drawing two tangent lines to an opening angle of 30°. The section to be considered is to be perpendicular to the centreline of the ship and is to result in the maximum deduction in each transverse space.



Total equivalent breadth of small openings at xx = $b_1 + b_2 + b_3$

Fig. 6.1.2 Isolated openings

1.4.4 Isolated openings in longitudinals or longitudinal girders need not be deducted if their depth does not exceed 25 per cent of the web depth or 75 mm, whichever is the lesser.

1.4.5 Openings are considered isolated if they are spaced not less than 1 m apart.

1.4.6 A reduction for drainage holes and scallops in beams and girders, etc., is not necessary so long as the original section stiffness at deck or keel is reduced by no more than 3,0 per cent.

1.5 Direct calculation procedure

1.5.1 In direct calculation procedures capable of deriving the wave induced loads on the craft, and hence the required modulus, account is to be taken of the craft's actual form and weight distribution.

1.5.2 Lloyd's Register's (hereinafter referred to as 'LR') direct calculation method involves derivation of response to regular waves by strip theory, short-term response to irregular waves using the sea spectrum concept, and long-term response predictions using statistical distributions of sea states. Other direct calculation methods submitted for approval are normally to contain these three elements and produce similar and consistent results when compared with LR's methods.

1.6 Approved calculation systems

1.6.1 Where the assumptions, method and procedures of a longitudinal strength calculation system have received general approval from LR, calculations using the system for a particular craft may be submitted.

1.7 Information required

1.7.1 In order that an assessment of the longitudinal strength requirements can be made, the following information is to be submitted, in LR's standard format where appropriate:

(a) General arrangement and capacity plan or list, showing details of the volume and position of centre of gravity of all tanks and compartments.

(b) Bonjean data, in the form of tables or curves, for at least 21 equally spaced stations along the hull. A lines plan and/or tables of offsets may also be required.

(c) Details of the calculated lightweight and its distribution.

(d) Details of the weights and centres of gravity of all deadweight items for each of the main loading conditions. It is recommended that this information be submitted in the form of a preliminary Loading Manual, to include the calculated still water and dynamic bending moments and shear forces.

1.8 Loading guidance information

1.8.1 Sufficient information is to be supplied to the Master of every craft to enable him to arrange loading in such a way as to avoid the creation of unacceptable stresses in the craft's structure.

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■ *Section 2*
Hull girder strength for mono-hull craft

2.1 General

2.1.1 Longitudinal strength calculations are to be submitted for all craft with a Rule length, L_R, exceeding 50 m covering the range of load and ballast conditions proposed, in order to determine the required hull girder strength. Still water, static wave and dynamic bending moments and shear forces are to be calculated for both departure and arrival conditions.

2.1.2 For craft of ordinary hull form with a Rule length, L_R, less than 50 m, the minimum hull girder strength requirements are generally satisfied by scantlings obtained from local strength requirements. However longitudinal strength calculations may be required at LR's discretion, dependent upon the form, constructional arrangement and proposed loading.

2.1.3 Where the Rule length, L_R, of the craft exceeds 75 m, or for new designs of large, structurally complicated craft, the design loads and scantling determination formulae in this Chapter are to be supplemented by direct calculation and structural analysis by 3-D finite element methods. These supplementary calculations are to include the results of model tests and full scale measurement where available or required by LR. Full details of such methods and all assumptions and calculations, which are to be based on generally accepted theories, are to be submitted for appraisal.

2.2 Bending strength

2.2.1 The effective geometric properties of the midship section are to be calculated directly from the dimensions of the section using only the effective material elements which contribute to the global longitudinal strength irrespective of the grades of steel incorporated in the construction. For the purposes of this analysis an element may be of deck plating, longitudinal girder, inner bottom, etc., or other continuous member.

2.2.2 The contribution that higher tensile steel makes to the global strength is based upon the strain in that material in relation to the allowable strain in mild steel. Therefore, the maximum permissible hull vertical bending stress, σ_p, for the design analysis is not to be taken greater than that determined from the following:

$$\sigma_{p\,(HTS)} = \sigma_{p\,(MS)} \frac{\overline{y}_{(HTS)}}{\overline{y}_{(MS)}}$$

where

σ_p is as defined in 2.2.3

$\overline{y}_{(HTS)}$ = the maximum distance, in metres, above or below the neutral axis of the hull cross-section to any effective higher tensile steel element contributing to global longitudinal strength

$\overline{y}_{(MS)}$ = the maximum distance, in metres, above or below the neutral axis of the hull cross-section to any effective mild steel element contributing to global longitudinal strength.

2.2.3 The longitudinal strength of craft with $\frac{V}{\sqrt{L_{WL}}} \geq 3{,}0$ is to satisfy both the following criteria:

$$\sigma_k + \sigma_l + \sigma_t < 1{,}2\sigma_P \text{ and}$$
$$\sigma_d < \sigma_P$$

where

σ_P = maximum permissible hull vertical bending stress, in N/mm^2 and is not to be taken greater than that determined from 2.2.2

= $f_{\sigma gH}$, σ_s or the value determined from 2.2.2, whichever is the lesser

$f_{\sigma gH}$ = limiting hull bending stress coefficient taken from Table 7.3.2 in Chapter 7

L_{WL} is as defined in Pt 3, Ch 1,6.2.5

σ_k, σ_l, σ_t and σ_d are given in Table 6.2.1

σ_s is as defined in 1.2.1.

Table 6.2.1 Longitudinal component stresses

Component stress type	Nominal stress (N/mm^2)
Hull girder bending stress at strength deck amidships	$\sigma_d = \frac{M_R}{1000Z_d}$
Hull girder bending stress at keel amidships	$\sigma_k = \frac{M_R}{1000Z_k}$
Actual stress in bottom longitudinals amidships due to design pressure load	$\sigma_l = \frac{p_s s l_e^2}{12Z_l}$
Actual stress in bottom plating amidships due to design pressure load	$\sigma_t = 0{,}34P_t\left(\frac{\beta s}{t_p}\right)^2 \times 10^{-3}$
Symbols and definitions	
M_R = design longitudinal midship bending moment, in kNm, given in Pt 5, Ch 5,5 p_s = additional effective pressure loading, in kN/m^2, on bottom longitudinals from global dynamic load model, given in Pt 5, Ch 5,2.6.3 P_t = additional effective pressure loading, in kN/m^2, on bottom plating from global dynamic load model, given in Pt 5, Ch 5,2.6.4 Z_d = actual section modulus at deck, in m^3 Z_k = actual section modulus at keel, in m^3 Z_l = maximum section modulus of bottom longitudinal stiffener, associated with plating, amidships, in cm^3 s, l_e, β and t_p are as defined in 1.2.	

2.2.4 The longitudinal strength of craft with $\frac{V}{\sqrt{L_{WL}}} < 3{,}0$ is to satisfy both the following criteria:

$$\sigma_k < \sigma_P$$
$$\sigma_d < \sigma_P$$

where

σ_P is as defined in 2.2.3

σ_k and σ_d are given in Table 6.2.1

L_{WL} is as defined in Pt 3, Ch 1,6.2.5.

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2.3 Minimum hull section modulus

2.3.1 For patrol craft in Service Group G6, the hull midship modulus about the transverse neutral axis, at the deck or the keel, is to be not less than:

$$Z_{min} = \eta_{HTS} L_f L_R^2 B_{WL} (C_b + 0{,}7) \times 10^{-6} \quad m^3$$

where

η_{HTS} is as defined in Ch 2,2.4.3
L_R and C_b are as given in Pt 5, Ch 2,2.2.2
C_b to be taken not less than 0,6
L_f is as given in Pt 5, Ch 5,2.2.2
B_{WL} = maximum breadth at the design waterline, in metres.

2.4 Shear strength

2.4.1 The shear strength of the craft at any position along its length is to satisfy the following criterion:

$$\frac{Q_R}{A_\tau} 10^{-3} \leq \tau_p$$

where

Q_R = design hull shear force at any section along the Rule length, L_R, in kN determined from Pt 5, Ch 5,5
A_τ = shear area of transverse section, in m^2, is to be taken as the effective net sectional area of the shell plating and longitudinal bulkheads after deductions for openings. For longitudinal strength members which are inclined to the vertical, the area of the member to be included in the calculation is to be based on the area projected onto the vertical plane, *see* Fig. 6.2.1
τ_p = maximum permissible mean shear stress, in N/mm^2
= $f_{\tau gH} \tau_s$
$f_{\tau gH}$ = limiting hull shear stress coefficient taken from Table 7.3.2 in Chapter 7

τ_s is as defined in 1.2.1.

2.5 Torsional strength

2.5.1 Torsional stresses are typically small for mono hulls of ordinary form of Rule length, L_R, less than 75 m and can generally be ignored.

2.5.2 The calculation of torsional stresses and/or deflections may be required when considering craft with large deck openings, unusual form or proportions. Calculations may in general be required to be carried out using a direct calculation procedure. Such calculations are to be submitted in accordance with 1.5.

2.6 Superstructures global strength

2.6.1 The effectiveness of the superstructure in absorbing hull girder bending loads is to be established where the first tier of the superstructure extends within 0,4*L* amidships and where:

$$l_1 > b_1 + 3h_1$$

where

l_1 = length of first tier, in metres
b_1 = breadth of first tier, in metres
h_1 = 'tween deck height of first tier, in metres.

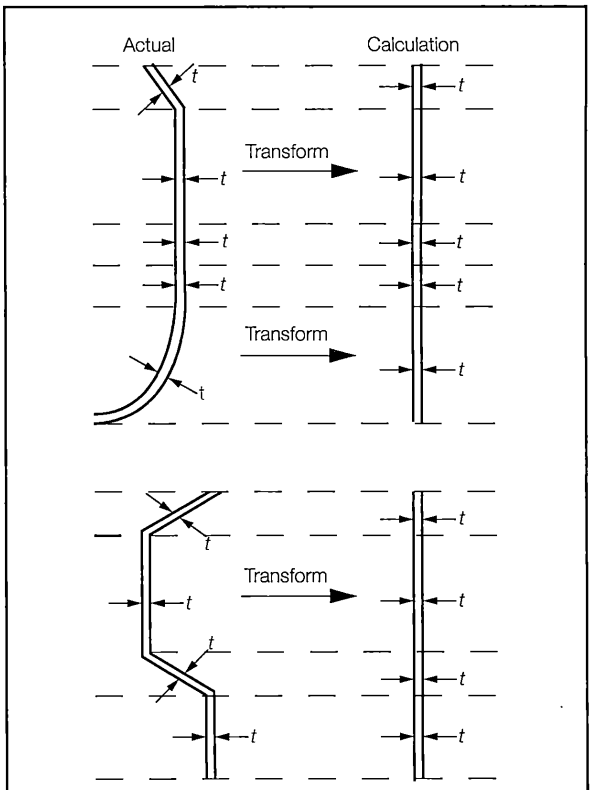

Fig 6.2.1 Effective shear area

2.6.2 For superstructures with one or two tiers extending outboard to the craft's side shell, the effectiveness in absorbing hull girder bending loads in the uppermost effective tier may be assessed by the following factor:

$$\eta_s = 7 [(\varepsilon - 5) \gamma^4 + 94 (5 - \varepsilon) \gamma^3 + 2800 (\varepsilon - 5{,}8) \gamma^2 + 27660 (9 - \varepsilon) \gamma] f(\lambda, N) \times 10^{-7}$$

where

$f(\lambda, N = 1) = 1$
$f(\lambda, N = 2) = 0{,}90\lambda^3 - 2{,}17\lambda^2 + 1{,}73\lambda + 0{,}50$

and

N = 1 if $l_2 < 0{,}7 l_1$
= 2 if $l_2 \geq 0{,}7 l_1$

$\lambda = \frac{l_w}{L_R}$ or 1, whichever is less

$\varepsilon = \frac{b_1}{h_1}$ or 5, whichever is less

$\gamma = \frac{l_w}{h_1}$ or 25, whichever is less

l_w = l_1 for $N = 1$
= $\frac{(2l_1 + l_2)}{3}$ for $N = 2$

L_R = as defined in 1.2.1, in metres
l_1, b_1, h_1 = as defined in 2.5.1, in metres
l_2 = length of second tier, in metres.

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2.6.3 The hull girder compressive bending stress σ_L, in the uppermost effective tier at side may be derived according to the following formula:

$$\sigma_L = \eta_s \frac{M_R}{1000 Z_{100}} \text{ N/mm}^2$$

where

M_R = hull girder bending moment at midships due to sagging as determined in Pt 5, Ch 5,5, in kNm

Z_{100} = section modulus at uppermost effective tier of hull and effective tiers, assuming tiers to be 100 per cent effective, in m^3

η_s = as defined in 2.6.2.

2.6.4 The compressive stress, σ_L, in the uppermost effective tier at side is to be checked against buckling in accordance with Ch 7,4.

2.6.5 The uppermost effective tier may need to fulfil the requirements for strength deck when the following applies:

$$\eta_s > \left(1 + \frac{Z_0 h}{I_{100}}\right)^{-1}$$

where

η_s = as defined in 2.6.2

Z_0 = section modulus of hull only at hull upper deck, in m^3

I_{100} = moment of inertia of hull and effective tiers, assuming tiers to be 100 per cent effective, in m^4

h = height from hull upper deck to uppermost effective tier, in metres.

■ *Section 3*
Additional hull girder strength requirements for multi-hull craft

3.1 General

3.1.1 Except as otherwise specified within this Section, the global strength requirements for multi-hull craft are to comply with Section 2.

3.1.2 Longitudinal strength calculations are to be submitted for all craft with a length, L_R, exceeding 40 m covering the range of load and ballast conditions proposed, in order to determine the required hull girder strength. Still water, static wave and dynamic bending moments and shear forces are to be calculated for both departure and arrival conditions.

3.1.3 For craft of ordinary hull form length with a Rule length, L_R, less than 40 m, the minimum hull girder strength requirements are generally satisfied by scantlings obtained from local strength requirements. However longitudinal strength calculations may be required at LR's discretion, dependent upon the proposed loading.

3.1.4 Where the length, L_R, of the craft exceeds 60 m, or for new designs of large, structurally complicated craft, the design loads and scantling determination formulae in this Chapter are to be supplemented by direct calculation and structural analysis by 3-D finite element methods. These supplementary calculations are to include the results of model tests and full scale measurement where available or required by LR. Full details of such methods and all assumptions and calculations, which are to be based on generally accepted theories, are to be submitted for appraisal.

3.1.5 The strength deck plating in way of the cross-deck structure, the wet-deck plating, longitudinal bulkheads and girders, and other continuous members may be included in the determination of the midship section stiffness.

3.1.6 Special consideration will be given to the global strength requirements for craft with more than two hulls linked by cross-deck structure.

3.2 Hull longitudinal bending strength

3.2.1 The requirements of 2.2 are in general to be complied with, using the appropriate design bending moment and effective pressure loadings applicable to multi-hull craft, as determined from Pt 5, Ch 5,5.

3.3 Hull shear strength

3.3.1 The requirements of 2.3 are to be complied with so far as they are applicable.

3.4 Torsional strength

3.4.1 Where a craft is of unusual form or novel construction, or at the discretion of LR, the torsional stress is to be determined by direct calculation methods using the twin hull torsional connecting moment as defined in Pt 5, Ch 5,5. Such calculations are to be submitted in accordance with 1.5.

3.5 Strength of cross-deck structures

3.5.1 Design loads to be applied for scantling calculations are transverse vertical bending moment and shear force, twin hull torsional connecting moment, external pressure load and appropriate internal loads as defined in Part 5.

3.5.2 The primary stiffening members of the cross-deck structure are to provide sufficient strength to satisfy the stress criteria given in Table 6.3.1.

3.5.3 The component nominal stresses may be determined in accordance with Table 6.3.2 in the case where the cross-deck is formed by transverse primary stiffeners or bulkheads and the following assumptions are taken:

(a) The cross-deck is symmetrical forward and aft of a transverse axis at its half length.

(b) Primary stiffeners having the same scantlings and spacing.

3.5.4 Other cross-deck designs subjected to global transverse loads will require a two-dimensional grillage analysis to be performed to demonstrate compliance with 3.5.2.

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Table 6.3.1 Primary member stress criteria

Stress type	Component stresses	Allowable stress level (N/mm^2)
Total direct stress, σ_P	$\sigma_P = \sigma_{MB} + \sigma_{MT} + \sigma_d$	$f_{\sigma gV}\,\sigma_s$
Total shear stress, τ_P	$\tau_P = \tau_T + \tau_{MBT} + \tau_{MT}$	$f_{\tau gV}\,\tau_s$
Equivalent stress, σ_{eq}	$\sigma_{eq} = \sqrt{\sigma^2 + 3\tau^2}$	$1{,}2 f_{\sigma eg}\,\sigma_s$
Symbols and definitions		
σ_{MB}, σ_{MT}, τ_T, τ_{MBT} σ_d, and τ_{MT} are component stresses, in N/mm^2, to be taken from Table 6.3.2 $f_{\sigma gV}$, $f_{\tau gV}$ and $f_{\sigma eg}$ are limiting stress coefficients for cross-deck structures to be taken from Table 7.3.2 in Chapter 7 σ_s and τ_s are defined in 1.2		

Table 6.3.2 Cross-deck component stresses for designs complying with 3.5.3

Component stress type	Nominal stress (N/mm^2)
Hull girder bending stress at strength deck amidships, *see* Table 6.2.1	$\sigma_d = f_{MR}\,\dfrac{M_R}{1000 Z_d}$
Stress induced by the transverse bending moment M_B, as defined in Pt 5, Ch 5,5	$\sigma_{MB} = f_{MB}\,\dfrac{M_B}{nZ}\,10^3$
Stress induced by the torsional moment M_T, as defined in Pt 5, Ch 5,5	$\sigma_{MT} = f_{MT}\,\dfrac{3x_H M_T}{n(n+1)s_p Z}\,10^3$
Shear stress induced by the vertical shear force Q_T, as defined in Pt 5, Ch 5,5	$\tau_T = f_{MB}\,\dfrac{5Q_T}{n A_w}$
Bending shear stress induced by the torsional moment M_T, as defined in Pt 5, Ch 5,5	$\tau_{MBT} = f_{MT}\,\dfrac{60 M_T}{n(n+1)s_p A_w}$
Shear stress induced by the torsional moment M_T, as defined in Pt 5, Ch 5,5	$\tau_{MT} = f_{MT}\,\dfrac{46\kappa x_H^2 M_T}{n(n^2+1)s_p^2 I_y}\,10^3$
Symbols and definitions	

Q_T = vertical shear force, in kN, as determined from Pt 5, Ch 5,5
M_B = transverse bending moment in kNm, as determined from Pt 5, Ch 5,5
M_T = torsional moment in kNm, as determined from Pt 5, Ch 5,5
n = total number of transverse primary stiffeners or bulkheads
A_W = stiffener web area, cm^2
Z = primary stiffeners section modulus, in cm^3
s_p = stiffener spacing, in metres
I_y = moment of inertia of stiffener, cm^4
x_H = transverse distance between the centre of the two hulls, in metres
κ = t_f, for symmetrical I-section, in mm
= $b_b\,h/(b_b + h)$, for constant thickness box sections, in mm
σ_{MB} = stress induced by the transverse bending moment M_B, as defined in Pt 5, Ch 5,5, in N/mm^2
σ_{MT} = stress induced by the torsional moment M_T, as defined in Pt 5, Ch 5,5, in N/mm^2
τ_T = shear stress induced by the vertical shear force Q_T, as defined in Pt 5, Ch 5,5, in N/mm^2
τ_{MBT} = bending shear stress induced by the torsional moment M_T, as defined in Pt 5, Ch 5,5, in N/mm^2
τ_{MT} = shear stress induced by the torsional moment M_T, as defined in Pt 5, Ch 5,5, in N/mm^2
t_f = face plate thickness, in mm
b_b = breadth of box section, in mm
h_b = height of box section, in mm

f_{MR}, f_{MB} and f_{MT} are load combination factors reflecting the portions of each component global design load, M_R, Q_T, M_B and M_T, corresponding to the most severe load combinations, The most severe load combinations are the combinations of loads resulting in the maximum bending, shear and effective stress, respectively. The assessment of these load combinations need to take due consideration for the component load magnitude variation with wave heading and also the phasing in time between them. Generally, f_{MR}, f_{MB}, and f_{MT} are to be taken as indicated in Table 6.3.3.

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Table 6.3.3 Load combination factors

Heading	Factors		
	f_{MB}	f_{MR}	f_{MT}
Head sea	0,1	1,0	0,1
Beam sea	1,0	0,1	0,2
Quartering sea	0,1	0,4	1,0

3.5.5 Section properties are to be calculated using an effective breadth of plating to be determined in accordance with Ch 3,1.11.

3.5.6 Where primary stiffening members support areas of plating of the extruded plank type, or the floating frame system is used, the effect of the plating attached to the secondary stiffening members is to be ignored when determining the global section modulus requirements.

3.6 Grillage structures

3.6.1 For complex girder systems, a complete structural analysis using numerical methods may be required to be performed to demonstrate that the stress levels are acceptable when subjected to the most severe and realistic combination of loading conditions intended.

3.6.2 In general, the transverse and vertical girders, bottom and side structures, bridge structure, deck structures and any other parts of the craft which LR considers critical to the craft's structural integrity are to be included in the numerical modelling of the craft.

3.7 Analysis techniques

3.7.1 General or special purpose computer programs or any other analytical techniques may be used provided that the effects of bending, shear, axial and torsion are properly accounted for and the theory and idealisation used can be justified.

3.7.2 In general, grillages consisting of slender girders may be idealised as frames based on beam theory provided proper account of the variations of geometric properties is taken. For cases where such an assumption is not applicable, finite element analysis or equivalent methods may have to be used.

3.7.3 Analysis of the cross-deck structures with regard to impact loads due to slamming may have to be carried out using advanced structural analysis techniques.

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Section

1 **General**

2 **Deflection control**

3 **Stress control**

4 **Buckling control**

5 **Vibration control**

Section 1 General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull and multi-hull craft of steel construction as defined in Ch 1,1.1.

1.2 General

1.2.1 The failure modes criteria contained within this Chapter are to be used in the formulae from the preceding Chapters to determine the scantling requirements. In addition, they are to be used when direct calculation methods are proposed as an alternative.

1.3 Symbols and definitions

1.3.1 The symbols and definitions applicable to this Chapter are defined below or in the appropriate Section.

1.4 Direct calculations

1.4.1 Where direct calculations are proposed, the requirements of Pt 3, Ch 1,2 are to be complied with.

1.4.2 In addition, with the agreement of Lloyd's Register (hereinafter referred to as 'LR'), tests may be conducted to demonstrate the actual response of the structure and the results verified against the failure mode criteria in this Chapter.

Section 2 Deflection control

2.1 General

2.1.1 The limiting deflection requirements for plate panels and stiffening members are given in terms of limiting deflection coefficient, *see* Table 7.2.1. The coefficient equates to a span/deflection ratio, f_δ, in consistent units.

Table 7.2.1 Limiting deflection ratio

Item	Deflection ratio, f_δ
Bottom structure:	
• secondary stiffening	800
• primary girders and web frames	1000
Side structure:	
• secondary stiffening	800
• primary girders and web frames	1000
Main/strength deck structures:	
• secondary stiffening	1000
• primary girders and web frames	1250
• hatch covers	1250
Superstructures/deckhouses stiffeners:	
(a) Generally: • secondary	600
• primary	750
(b) Coachroof: • secondary	800
• primary	1000
(c) House top: • secondary	600
• primary	600
Lower/inner decks and house top subject to personnel loading:	
• secondary members	800
• primary members	1000
Deep tank stiffeners:	
• secondary members	1000
• primary members	1250
Watertight bulkhead stiffeners:	
• secondary members	600
• primary members	750
Multi-hull cross-deck stiffeners:	
• secondary members	800
• primary members	1000
Vehicle deck stiffeners:	
• secondary members	1000
• primary members	1250
Helicopter/flight decks stiffeners:	
• secondary members	1000
• primary members	1250
NOTE Where significant curvature exists over the span of the stiffener or breadth of the panel, the allowable deflections will be specially considered.	

Section 3 Stress control

3.1 General

3.1.1 The nominal limiting stress requirements for plating and primary and secondary stiffening members subject to local loading conditions are given in terms of limiting stress coefficients, *see* Table 7.3.1. The coefficients are expressed as a proportion of the yield stress of the material.

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3.1.2 The limiting stress coefficients for structural elements subject to global loading conditions are given in Table 7.3.2.

3.1.3 In the determination of the magnitude of the equivalent stress, σ_{eq}, it is assumed that the stresses are combined using the following formula:

$$\sigma_{eq} = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x \sigma_y + 3\tau^2}$$

where

σ_x = direct stress in the x direction
σ_y = direct stress in the y direction
τ = shear stress in the xy plane

Table 7.3.1 Limiting stress coefficients for local loading (*see continuation*)

Item	Limiting stress coefficient		
	Bending f_σ	Shear f_τ	Equivalent f_e
Shell envelope:			
(a) Bottom shell plating: • slamming zone	0,85	—	—
• elsewhere	0,75	—	—
(b) Side shell plating: • slamming zone	0,85	—	—
• elsewhere	0,75	—	—
(c) Keel	0,75	—	—
Bottom structure:			
(a) Secondary stiffening: • slamming zone	0,75	0,75	—
• elsewhere	0,65	0,65	—
(b) Primary girders and web frames	0,65	0,65	0,75
(c) Engine girders	0,55	0,55	0,75
Side structure:			
(a) Secondary stiffening: • slamming zone	0,75	0,75	—
• elsewhere	0,65	0,65	—
(b) Primary girders and web frames	0,65	0,65	0,75
Bow doors:			
(a) Plating	0,65	—	—
(b) Secondary stiffening	0,51	0,433	—
(c) Primary stiffening	0,51	0,34	0,64
Main/strength deck plating and stiffeners:			
(a) Plating	0,75	—	—
(b) Secondary stiffening	0,65	0,65	—
(c) Primary girders and web frame	0,65	0,65	0,75
(d) Hatch covers	0,55	0,55	0,64
Superstructures/deckhouses:			
(a) Deckhouse front, 1st tier: • plating	0,65	—	—
• stiffening	0,60	0,60	—
(b) Deckhouse front upper tiers: • plating	0,75	—	—
• stiffening	0,65	0,65	—
(c) Deckhouse aft and sides: • plating	0,75	—	—
• stiffening	0,75	0,75	—
(d) Coachroof: • plating	0,65	—	—
• stiffening	0,65	0,65	—
(e) House top: • plating	0,75	—	—
• stiffening	0,75	0,75	—
(f) Lower/inner decks and house top subject to personnel loading:			
• plating	0,75	—	—
• stiffening	0,60	0,60	—

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Table 7.3.1 Limiting stress coefficients for local loading (*conclusion*)

Item		Limiting stress coefficient		
		Bending f_σ	Shear f_τ	Equivalent f_e
Bulkheads:				
(a) Watertight bulkhead:	• plating	1,0	—	—
	• secondary stiffening	0,95	0,95	—
	• primary stiffening	0,90	0,90	1,0
(b) Watertight bulkhead doors		0,825	0,825	—
(c) Structure supporting watertight doors		0,80	0,80	
(d) Minor bulkheads:	• plating	0,65	—	—
	• secondary stiffening	0,65	0,65	—
	• primary stiffening	0,65	0,65	0,75
(e) Deep tank bulkheads:	• plating	0,65	—	—
	• secondary stiffening	0,65	0,65	—
	• primary stiffening	0,75	0,75	—
Multi-hull cross-deck structure:				
(a) Plating:	• slamming zone	0,85	—	—
	• elsewhere	0,75	—	—
(b) Secondary stiffening:	• slamming zone	0,75	0,75	—
	• elsewhere	0,65	0,65	—
(c) Primary stiffening		0,65	0,65	0,75
Vehicle deck:				
(a) Plating		0,6	—	—
(b) Secondary stiffening		0,425	0,425	—
(c) Primary stiffening		0,525	0,525	0,75
Helicopter/flight decks:				
(a) Normal usage:	• plating	0,65	—	—
	• secondary stiffening	0,75	0,75	—
	• primary stiffening	0,625	0,625	0,6
(b) Emergency landing:	• plating	0,75	—	—
	• secondary stiffening	1,0	1,00	—
	• primary stiffening	0,825	0,825	0,9
(c) Crane pedestal/foundation structural elements		0,7	0,70	0,75

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Table 7.3.2 Limiting stress coefficients for global loading

Operational mode of craft	Limiting stress coefficient					
	Hull girder			Cross-deck		
	Bending $f_{\sigma gH}$	Shear $f_{\tau gH}$	Equivalent $f_{\sigma eg}$	Bending $f_{\sigma gV}$	Shear $f_{\tau gV}$	Equivalent $f_{\sigma eg}$
$\Gamma \geq 3,0$ or $\Delta \leq 0,04(L_R B)^{1,5}$	0,80 η_{HTS}	0,80 η_{HTS}	0,825 η_{HTS}	0,80 η_{HTS}	0,80 η_{HTS}	0,825 η_{HTS}
$\Gamma < 3,0$ and $\Delta > 0,04(L_R B)^{1,5}$	0,72 η_{HTS}	0,72 η_{HTS}	0,75 η_{HTS}	0,72 η_{HTS}	0,72 η_{HTS}	0,75 η_{HTS}

NOTES
$f_{\sigma gH}$ = limiting hull bending stress coefficient
$f_{\tau gH}$ = limiting hull shear stress coefficient
$f_{\sigma gV}$ = limiting cross-deck bending stress coefficient
$f_{\tau gV}$ = limiting cross-deck shear stress coefficient
$f_{\sigma eg}$ = limiting equivalent stress coefficient
Δ is the displacement as defined in Pt 5, Ch 2,2
Γ is the Taylor Quotient as defined in Pt 5, Ch 2,2.1.16
L_R and B are as defined in Pt 3, Ch 1,6.2
η_{HTS} is as defined in Ch 2,2.4.3

■ *Section 4* Buckling control

4.1 General

4.1.1 This Section contains the requirements for buckling control of plate panels subject to in-plane compressive and/or shear stresses and buckling control of primary and secondary stiffening members subject to axial compressive and shear stresses.

4.1.2 The requirements for buckling control of plate panels are contained in 4.3 to 4.6. The requirements for secondary stiffening members are contained in 4.7 to 4.8. The requirements for primary members are contained in 4.9 and 4.10.

4.1.3 In general all areas of the structure are to meet the buckling strength requirements for the design stresses. The design stresses are to be taken as follows:

(a) Global hull girder bending and shear stresses given in Chapter 6, but not including stresses σ_l and σ_t as defined in Table 6.2.1 in Chapter 6.

(b) Stresses from local compressive loads.

4.1.4 The buckling requirements are to be met using the net scantlings, hence any additional thickness for corrosion margin or Owners extra is not included in scantlings used to assess the buckling performance.

4.2 Symbols

4.2.1 The symbols used in this Section are defined below and in the appropriate sub-Section:

t_p = thickness of plating, in mm

A_R = panel aspect ratio

$$= \frac{a}{b}$$

a = panel length, i.e. parallel to direction of compressive stress being considered, in mm

b = panel breadth, i.e. perpendicular to direction of compressive stress being considered, in mm

S_p = span of primary members, in metres

σ_o = specified minimum yield strength of the material, in N/mm^2

σ_e = elastic compressive buckling stress, in N/mm^2

σ_c = critical compressive buckling stress, including the effects of plasticity where appropriate, in N/mm^2

τ_o = specified minimum yield shear stress of the material, in N/mm^2

$$= \frac{\sigma_o}{\sqrt{3}} \text{ N/mm}^2$$

E = modulus of elasticity of material in N/mm^2

τ_e = elastic shear buckling stress, in N/mm^2

τ_c = critical shear buckling stress, in N/mm^2

b_{eb} = lesser of $1,9t_p\sqrt{\frac{E}{\sigma_o}}$ or $0,8b$ mm

A_{te} = cross-sectional area of secondary stiffener, in cm^2, including an effective breadth of attached plating, b_{eb}

s = length of shorter edge of plate panel, in mm (typically the spacing of secondary stiffeners)

l = length of longer edge of plate panel, in metres.

S = spacing of primary member, in metres (measured in direction of compression).

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4.3 Plate panel buckling requirements

4.3.1 This Section gives methods for evaluating the buckling strength of plate panels subjected to the following load fields:

(a) uni-axial compressive loads;
(b) shear loads;
(c) bi-axial compressive loads;
(d) uni-axial compressive loads and shear loads;
(e) bi-axial compressive loads and shear loads.

4.3.2 The plate panel buckling requirements will be satisfied if the buckling interaction equations given in Table 7.4.2 for the above load fields are complied with.

4.3.3 The critical compressive buckling stresses and critical shear buckling stresses required for Table 7.4.2 are to be derived in accordance with 4.4.

4.3.4 The buckling factors of safety λ_σ and λ_τ required by Table 7.4.2 are given in Table 7.4.4 for the structural member concerned.

4.3.5 For all structural members which contribute to the hull girder strength, the plate panel buckling requirements for uni-axial compressive loads, Table 7.4.2(a), and shear loads, Table 7.4.2(b) are to be complied with.

4.3.6 In addition to 4.3.5, structural members which are subjected to local compressive loads and/or shear loads are to be verified using the plate panel buckling requirements in Table 7.4.2(c) to (e).

4.3.7 However, where some members of the structure have been designed such that elastic buckling of the plate panel between the stiffeners is allowable, then the requirements of 4.5 must be applied to the buckling analysis of the stiffeners supporting the plating. In addition, panels which do not satisfy the panel buckling requirements must be indicated on the appropriate drawing and the effect of these panels not being effective in transmitting compressive loads taken into account for the hull girder strength calculation.

4.3.8 In general the plate panel buckling requirements for more complex load fields, *see* 4.3.1(c), (d) and (e), are to be complied with. Where this is not possible, due to elastic buckling of the panel, then the critical buckling stress, σ_c, may be based on the ultimate collapse strength of the plating, σ_u from 4.5.4, instead of the elastic buckling stress, σ_e, derived in 4.3.5. In addition, the requirements of 4.5 are to be met for the supporting secondary stiffeners and primary members.

4.4 Derivation of the buckling stress for plate panels

4.4.1 The critical compressive buckling stress, σ_c, for a plate panel subjected to uni-axial in-plane compressive loads is to be derived in accordance with Table 7.4.1(a).

4.4.2 The critical shear buckling stress, τ_c, for a plate panel subjected to pure in-plane shear load is to be derived in accordance with Table 7.4.1(b).

4.4.3 For welded plate panels with plating thicknesses below 8 mm the critical compressive buckling stress is to be reduced to account for the presence of residual welding stresses. The critical buckling stress is to be taken as the minimum of:

$\sigma_{cr} = \sigma_e - \sigma_r$

or σ_c as derived using 4.4.1

where

σ_r = reduction in compressive buckling stress due to residual welding stresses

$$= \frac{2\beta_{RS}\sigma_o}{b/t_p}$$

β_{RS} = residual stress coefficient dependent on type of weld (average value of β_{RS} to be taken as 3)

b, t_p and σ_o are defined in 4.2.1.

4.4.4 In general the effect of lateral loading on plate panels (for example hydrostatic pressure on bottom shell plating) may be neglected and the critical buckling stresses calculated considering the in-plane stresses only.

4.4.5 Unless indicated otherwise, the effect of initial deflection on the buckling strength of plate panels may be ignored.

4.5 Additional requirements for plate panels which buckle elastically

4.5.1 Elastic buckling of plate panels between stiffeners occurs when both the following conditions are satisfied:

(a) The design compressive stress, σ_d, is greater than the elastic buckling stress of the plating, σ_e,

$\sigma_d > \sigma_e$

(b) The elastic buckling stress is less than half the yield stress

$$\sigma_e \leq \frac{\sigma_o}{2}$$

4.5.2 Elastic buckling of local plating between stiffeners, including girders or floors, etc., may be allowed if all of the following conditions are satisfied:

(a) The critical buckling stress of the stiffeners in all buckling modes is greater than the axial stress in the stiffeners after redistribution of the load from the elastically buckled plating into the stiffeners, hence

$$\frac{\sigma_{de}}{\sigma_{c(i)}} \leq \frac{1}{\lambda_\sigma}$$

(b) Maximum predicted loadings are used in the calculations.

(c) Functional requirements will allow a degree of plating deformation.

where

σ_{de} is the stiffener axial stress given in 4.5.5

$\sigma_{c(i)}$ is given by Table 7.4.3

where

i = a, t, w or f depending on the mode of buckling.

λ_σ is the buckling factor of safety
= 1,25.

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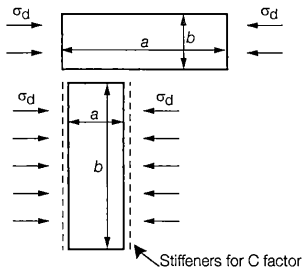
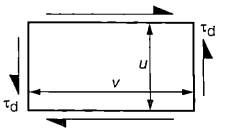
Table 7.4.1 Buckling stress of plate panels

Mode	Elastic buckling stress, N/mm^2, *see* Note 1	
(a) Uni-axial compression: (i) Long narrow panels, loaded on the narrow edge	$A_R \geq 1$ $\sigma_e = 3{,}62\varphi E \left(\frac{t_p}{b}\right)^2$	
(ii) Short broad panels, loaded on the broad edge	$A_R < 1$ $\sigma_e = 0{,}9C\varphi \left(\frac{b}{a} + \frac{a}{b}\right)^2 E\left(\frac{t_p}{b}\right)^2$	
(b) Pure shear:	$\tau_e = 3{,}62\left(1{,}335 + \left(\frac{u}{v}\right)^2\right) E\left(\frac{t_p}{u}\right)^2$ *See* Note 2	

NOTES

1. The critical buckling stresses, in N/mm^2, are to be derived from the elastic buckling stresses as follows:

$\sigma_c = \sigma_e$ when $\sigma_e < \frac{\sigma_o}{2}$

$= \sigma_o\left(1 - \frac{\sigma_o}{4\sigma_e}\right)$ when $\sigma_e \geq \frac{\sigma_o}{2}$

σ_c is defined in 4.2.1
σ_o is defined in 4.2.1

$\tau_c = \tau_e$ when $\tau_e < \frac{\tau_o}{2}$

$= \tau_o\left(1 - \frac{\tau_o}{4\tau_e}\right)$ when $\tau_e \geq \frac{\tau_o}{2}$

τ_c is defined in 4.2.1
τ_o is defined in 4.2.1

2. u is to be the minimum dimension

Symbols and definitions

A_R = panel aspect ratio, *see* 4.2.1
σ_e = elastic compressive buckling stress, in N/mm^2
τ_e = elastic shear buckling stress, in N/mm^2
a and b are the panel dimensions in mm, *see* figures above
t_p = thickness of plating, in mm
φ = stress distribution factor for linearly varying compressive stress across plate width
= $0{,}47\mu^2 - 1{,}4\mu + 1{,}93$ for $\mu \geq 0$
= 1 for constant stress

$\mu = \frac{\sigma_{d1}}{\sigma_{d2}}$ where σ_{d1} and σ_{d2} are the smaller and larger average compressive stresses respectively

E = Young's Modulus of elasticity of material, in N/mm^2
C = stiffener influence factor for panels with stiffeners perpendicular to compressive stress
= 1,3 when plating stiffened by floors or deep girders
= 1,21 when stiffeners are built up profiles or rolled angles
= 1,10 when stiffeners are bulb flats
= 1,05 when stiffeners are flat bars
σ_d and τ_d are the design compressive and design shear stresses in the direction illustrated in the figures. With linearly varying stress across the plate panel, σ_d is to be taken as σ_{d2}

4.5.3 The effective breadth of attached plating for stiffeners, girder or beams that is to be used for the determination of the critical buckling stress of the stiffeners attached to plating which buckles elastically is to be taken as follows:

$$b_{eu} = \frac{b\sigma_u}{\sigma_o} \text{ mm}$$

where

σ_u = ultimate buckling strength of plating as given in 4.5.4
b_{eu} = effective panel breadth perpendicular to direction of compressive stress being considered

b is given in 4.2.1.

4.5.4 The ultimate buckling strength of plating, σ_u, which buckles elastically, may be determined as follows:

(a) shortest edge loaded, i.e. $A_R \geq 1$:

$$\sigma_u = \sigma_o\left(\frac{1{,}9}{\Omega} - \frac{0{,}8}{\Omega^2}\right) \text{ N/mm}^2$$

(b) longest edge loaded, i.e. $A_R < 1$:

$$\sigma_u = \frac{1{,}77\sigma_o A_R^{0{,}78}}{\Omega} \text{ N/mm}^2$$

where

$$\Omega = \frac{s}{t_p}\sqrt{\frac{\sigma_o}{E}}$$

A_R and s are defined in 4.2.1.
t_p, E and σ_o are defined in 4.2.1.

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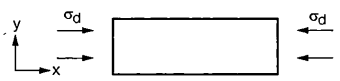
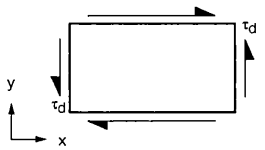
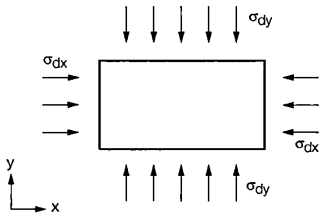
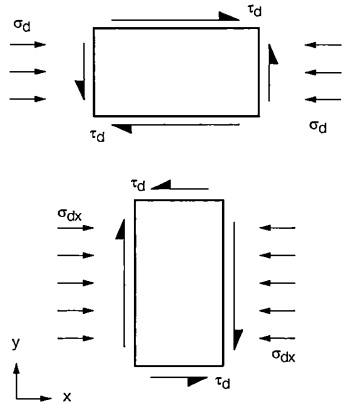
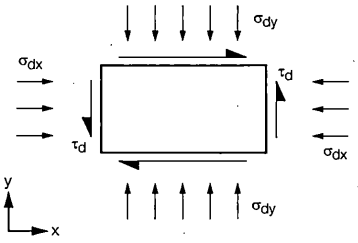
Table 7.4.2 Plate panel buckling requirements

	Stress field	Buckling interaction formula	
(a)	uni-axial compressive loads	$\frac{\sigma_d}{\sigma_c} \le \frac{1}{\lambda_\sigma}$	
(b)	shear loads	$\frac{\tau_d}{\tau_c} \le \frac{1}{\lambda_\tau}$	
(c)	bi-axial compressive loads	for $A_R = 1,0$ $\frac{\sigma_{dx}}{\sigma_{cx}} + \frac{\sigma_{dy}}{\sigma_{cy}} \le 1,0$ for other aspect ratios, i.e. $A_R \neq 1,0$ $\frac{\sigma_{dx}}{\sigma_{cx}} + \frac{\sigma_{dy}}{\sigma_{cy}} \le G$ where G is taken from Fig. 7.4.3	
(d)	uni-axial compressive loads plus shear load	for $A_R > 1$ $\left(\frac{\sigma_d}{\sigma_c}\right) + \left(\frac{\tau_d}{\tau_c}\right)^2 \le 1$ for $A_R \le 1$ $\left(\frac{1 + 0,6A_R}{1,6}\right)\left(\frac{\sigma_d}{\sigma_c}\right) + \left(\frac{\tau_d}{\tau_c}\right)^2 \le 1$	
(e)	bi-axial compressive loads plus shear loads	$\frac{0,625\left(1 + \frac{0,6}{A_R}\right)\left(\frac{\sigma_{dy}}{\sigma_{cy}}\right)}{1 - 0.625\left(\frac{\sigma_{dx}}{\sigma_{cx}}\right)} + \frac{\left(\frac{\tau_d}{\tau_c}\right)^2}{1 - \left(\frac{\sigma_{dx}}{\sigma_{cx}}\right)} \le 1$	

Symbols

σ_d = design compressive stress, *see* 4.1.3
σ_c = critical compressive buckling stress, in N/mm^2, for uniaxial compressive load acting independently, *see* 4.3.5
σ_{dx} = design compressive stress in x direction
σ_{dy} = design compressive stress in the y direction
σ_{cx} = critical compressive buckling stress in x direction, *see* 4.3.5
σ_{cy} = critical compressive buckling stress in y direction, *see* 4.3.5
λ_σ = buckling factor of safety for compressive stresses, *see* 4.3.4
λ_τ = buckling factor of safety for shear stresses, *see* 4.3.4
τ_d = design shear stress, in N/mm^2
τ_c = critical shear buckling stress, in N/mm^2, acting independently, *see* 4.3.5

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Table 7.4.3 Buckling stress of secondary stiffeners (*see continuation*)

Mode	Elastic buckling stress, N/mm^2	Critical buckling stress, N/mm^2 *see* Note 1
(a) Overall buckling (perpendicular to plane of plating without rotation of cross-section)	$\sigma_{e(a)} = C_f\, 0{,}001\, E\, \frac{I_a}{A_{te}\, l_e^2}$	$\sigma_{c(a)}$
(b) Torsional buckling	$\sigma_{e(t)} = \frac{0{,}001 E\, I_w}{I_p\, l_e^2}\left(m^2 + \frac{K}{m^2}\right) + 0{,}385E\, \frac{I_t}{I_p}$	$\sigma_{c(t)}$
(c) Web buckling (excluding flat bar stiffeners)	$\sigma_{e(w)} = 3{,}8\, E \left(\frac{t_w}{d_w}\right)^2$	$\sigma_{c(w)}$
(d) Flange buckling	$\sigma_{e(f)} = 0{,}39\, E \left(\frac{t_f}{b_f}\right)^2$	$\sigma_{c(f)}$

Symbols

d_w = web depth, in mm, (excluding flange thickness for rolled sections), *see* Fig. 7.4.4

t_w = web thickness, in mm

b_f = flange width, in mm (including web thickness)

t_f = flange thickness, in mm. For bulb plates, the mean thickness of the bulb may be used, *see* Fig. 7.4.4

l_e = effective span length of stiffener, in metres

C_f = end constraint factor

= 1 where both ends are pinned

= 2 where one end is pinned and the other end is fixed

= 4 where both ends are fixed

E = Young's Modulus of elasticity of the material, in N/mm^2

I_a = moment of inertia, in cm^4, of longitudinal, including attached plating of effective width b_{eb}, *see* Note 2

t_p and σ_o are given in 4.2.1

A_{te} and b_{eb} are given in 4.2.1

I_t = St.Venant's moment of inertia, in cm^4, of longitudinal (without attached plating)

$= \frac{d_w\, t_w^3}{3}\, 10^{-4}$ for flat bars

$= \frac{1}{3}\left[d_w\, t_w^3 + b_f\, t_f^3 \left(1 - \frac{0{,}63\, t_f}{b_f}\right)\right] 10^{-4}$ for built up profiles, rolled angles and bulb plates

I_p = polar moment of inertia, in cm^4, of profile about connection of stiffener to plating

$= \frac{d_w^3\, t_w}{3}\, 10^{-4}$ for flat bars

$= \left(\frac{d_w^3\, t_w}{3} + d_w^2\, b_f\, t_f\right) 10^{-4}$ for built up profiles, rolled angles and bulb plates

I_w = sectorial moment of inertia, in cm^6, of profile and connection of stiffener to plating

$= \frac{d_w^3\, t_w^3}{36}\, 10^{-6}$ for flat bars

$= \frac{t_f\, b_f^3\, d_w^2}{12}\, 10^{-6}$ for 'Tee' profiles

$= \frac{b_f^3\, d_w^2}{12\,(b_f + d_w)^2}\left(t_f\,(b_f^2 + 2b_f\, d_w + 4d_w^2) + 3t_w\, b_f\, d_w\right) 10^{-6}$ for 'L' profiles, rolled angles and bulb plates

C = spring stiffness exerted by supporting plate panel

$= \frac{k_p\, E\, t_p^3}{3b\left(1 + \frac{1{,}33 k_p\, d_w\, t_p^3}{b\, t_w^3}\right)}$

k_p = $1 - \eta_p$, and is not to be taken as less than zero. For built up profiles, rolled angles and bulb plates, k_p need not be taken less than 0,1

$\eta_p = \frac{\sigma_d}{\sigma_{ep}}$

σ_{ep} = elastic critical buckling stress, in N/mm^2, of the supporting plate derived from Table 7.4.1

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Table 7.4.3 Buckling stress of secondary stiffeners (*conclusion*)

m is determined as follows; e.g. $m = 2$ for $K = 25$

K	0 to 4	4 to 36	36 to 144	144 to 400	400 to 900	900 to 1764	$(m-1)^2 m^2$ to $m^2 (m+1)^2$
m	1	2	3	4	5	6	m

$$K = \frac{1{,}03CS^4}{E I_w} 10^4$$

σ_d is the design stress, in N/mm^2
all other symbols are as defined in 4.2.1.

NOTES

1. The critical buckling stresses are to be derived from the elastic buckling stresses as follows:

$$\sigma_c = \sigma_e \text{ when } \sigma_e < \frac{\sigma_o}{2}$$

$$= \sigma_o\left(1 - \frac{\sigma_o}{4\sigma_e}\right) \text{ when } \sigma_e \geq \frac{\sigma_o}{2}$$

2. For stiffeners attached to plating which buckles elastically, *see* 4.5, the effective width of plating is to be taken as b_{eu}.

4.5.5 The axial stress in stiffeners attached to plating which is likely to buckle elastically is to be derived as follows:

$$\sigma_{de} = \sigma_d \frac{A_t}{A_{tb}}$$

where

σ_d is the axial stress in the stiffener when the plating can be considered fully effective

$$A_t = A_s + \frac{bt}{100} \text{ cm}^2$$

$$A_{tb} = A_s + \frac{b_{eu}\, t}{100} \text{ cm}^2$$

where

b and b_{eu} are given in 4.5.3
t is the plating thickness, in mm
A_s is the stiffener area in cm^2.

4.6 Shear buckling of stiffened panels

4.6.1 The shear buckling capability of longitudinally stiffened panels between primary members is to satisfy the following condition:

$$\frac{\tau_d}{\tau_c} \leq \frac{1}{\lambda_\tau}$$

where

τ_c is derived from 4.6.3
τ_d is the design shear stress
λ_τ is given in Table 7.4.4.

Table 7.4.4 Buckling factor of safety

Structural item	Buckling factor of safety (2) Compressive stresses, λ_σ	Buckling factor of safety (3) Shear stresses, λ_τ
Bottom shell plating	1,0	—
Inner bottom plating	1,0	—
Deck plating	1,0	—
Side shell plating	1,0	1,1
Longitudinal bulkhead plating	1,0	1,1
Double bottom girders	1,0	1,1
Longitudinal girders	1,0	1,1
Superstructures/deckhouses (partially longitudinally effective)	1,0	—
Longitudinal secondary stiffeners	1,1(1)	—
Girder and floor web plating subject to local loads	1,1	1,2

NOTES

1. The buckling factor of safety for stiffeners attached to plating which is allowed to buckle in the elastic mode due to the applied loads is to be taken as 1,25, *see also* 4.5.
2. Buckling factor of safety to be applied to the compressive stress due to global longitudinal stresses.
3. Buckling factor of safety to be applied to the shear stress.

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4.6.2 The elastic shear buckling stress of longitudinally stiffened panels between primary members may be taken as:

$$\tau_e = K_s E \left(\frac{t}{s}\right)^2 \quad \text{for } A_R \geq 1$$

where

$$K_s = 4{,}5\left(\left(\frac{s}{1000l}\right)^2 + \frac{1}{N^2} + \left(\frac{N^2-1}{N^2}\right)\left(\frac{\omega}{1+\omega}\right)^r\right)$$

N = number of subpanels

$$= \frac{1000S_p}{s}$$

$$\omega = \frac{10I_{se}}{l\,t^3}$$

I_{se} = moment of inertia of a section, in cm^4, consisting of the longitudinal stiffener and a plate flange of effective width $s/2$

$$r = 1 - 0{,}75\left(\frac{s}{1000l}\right)$$

s, l, E and S_p are as defined in 4.2.1, *see also* Fig. 7.4.1.

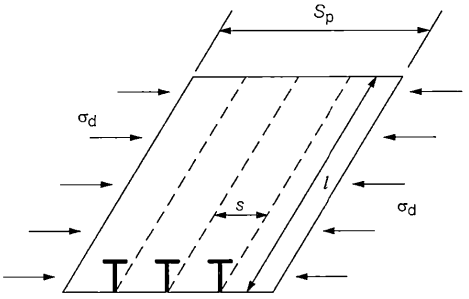

Fig. 7.4.1 Shear buckling of stiffened panels

4.6.3 The critical shear buckling stress, τ_c, may be determined from τ_e, *see* Note 2 in Table 7.4.1.

4.7 Secondary stiffening in direction of compression

4.7.1 The buckling performance of stiffeners will be considered satisfactory if the following conditions are satisfied:

$$\frac{\sigma_d}{\sigma_{c(a)}} \leq \frac{1}{\lambda_\sigma} \qquad \frac{\sigma_d}{\sigma_{c(t)}} \leq \frac{1}{\lambda_\sigma}$$

$$\frac{\sigma_d}{\sigma_{c(w)}} \leq \frac{1}{\lambda_\sigma} \qquad \frac{\sigma_d}{\sigma_{c(f)}} \leq \frac{1}{\lambda_\sigma}$$

where

$\sigma_{c(a)}$, $\sigma_{c(t)}$, $\sigma_{c(w)}$ and $\sigma_{c(f)}$ are the critical buckling stress of the stiffener for each mode of failure, *see* 4.7.2

σ_d is the design compressive stress, *see also* 4.5 and 4.1.3

λ_σ is the buckling factor of safety given in Table 7.4.4. The value of λ_σ to be chosen depends on the buckling assessment of the attached plating, *see* Note 1, Table 7.4.4.

4.7.2 The critical buckling stresses for the overall, torsional, web and flange buckling modes of longitudinals and secondary stiffening members under axial compressive loads are to be determined in accordance with Table 7.4.3.

4.7.3 To prevent torsional buckling of secondary stiffeners from occurring before buckling of the plating, the critical torsional buckling stress, $\sigma_{c(t)}$, is to be greater than the critical buckling stress of the attached plating as detailed in 4.4.1.

4.7.4 The critical buckling stresses of the stiffener web, $\sigma_{c(w)}$, and flange, $\sigma_{c(f)}$, are to be greater than the critical torsional buckling stress, hence:

$\sigma_{c(w)} > \sigma_{c(t)}$

$\sigma_{c(f)} > \sigma_{c(t)}$

4.7.5 To ensure that overall buckling of the stiffened panel cannot occur before local buckling of the secondary stiffener, the critical overall buckling stress $\sigma_{c(a)}$, is to be greater than the critical torsional buckling stress, hence:

$\sigma_{c(a)} > \sigma_{c(t)}$

4.8 Secondary stiffening perpendicular to direction of compression

4.8.1 Where a stiffened panel of plating is subjected to a compressive load perpendicular to the direction of the stiffeners, *see* Fig. 7.4.2, e.g. a transversely stiffened panel subject to longitudinal compressive load, the requirements of this Section are to be applied.

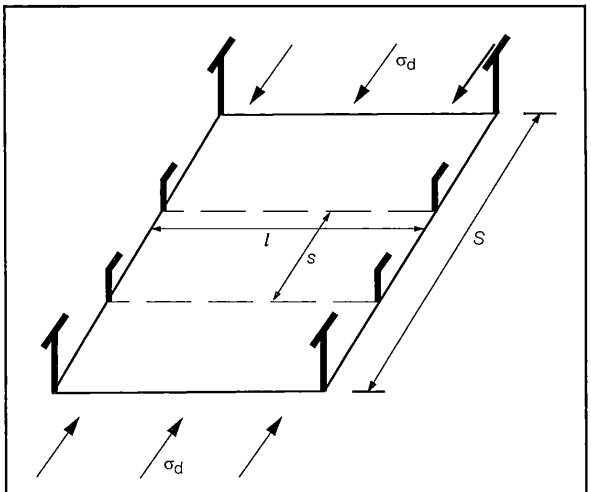

Fig. 7.4.2
Secondary stiffening perpendicular to direction of compression

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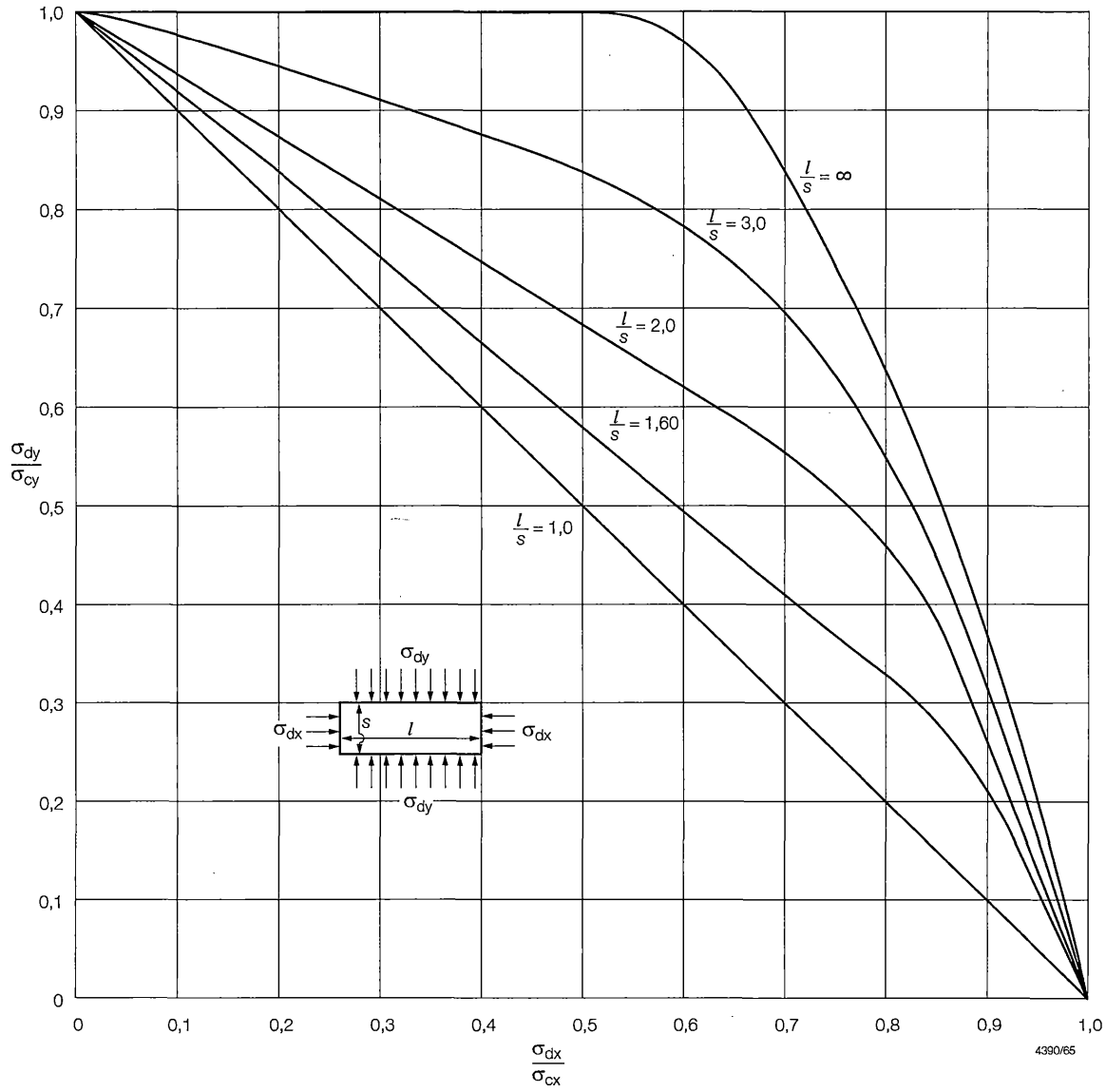

Fig. 7.4.3
Interaction limiting stress curves of G for plate panels subject to bi-axial compression, *see* Table 7.4.2(c)

4.8.2 The minimum area moment of inertia of each stiffener including attached plating of width, s, to ensure that overall panel buckling does not precede plate buckling is to be taken as:

$$I_s = \frac{D\,s\,(4N_L^2 - 1)((N_L^2 - 1)^2 - 2\,(N_L^2 + 1)\,\kappa + \kappa^2)}{2\,(5N_L^2 + 1 - \kappa)\,\Pi^4\,E} \text{ mm}^4$$

where

$$D = \frac{E\,t_p^3}{12\,(1 - \upsilon^2)}$$

$\kappa = A_R^2\,\Pi^2$

A_R = plate panel aspect ratio

$$= \frac{s}{1000l}$$

$$\Pi = \frac{S}{l}$$

N_L = number of plate panels

$N_L - 1$ = number of stiffeners

υ = 0,3

s, l and S are defined in 4.2.1 and shown in Fig. 7.4.2.

t_p and E are defined in 4.2.1.

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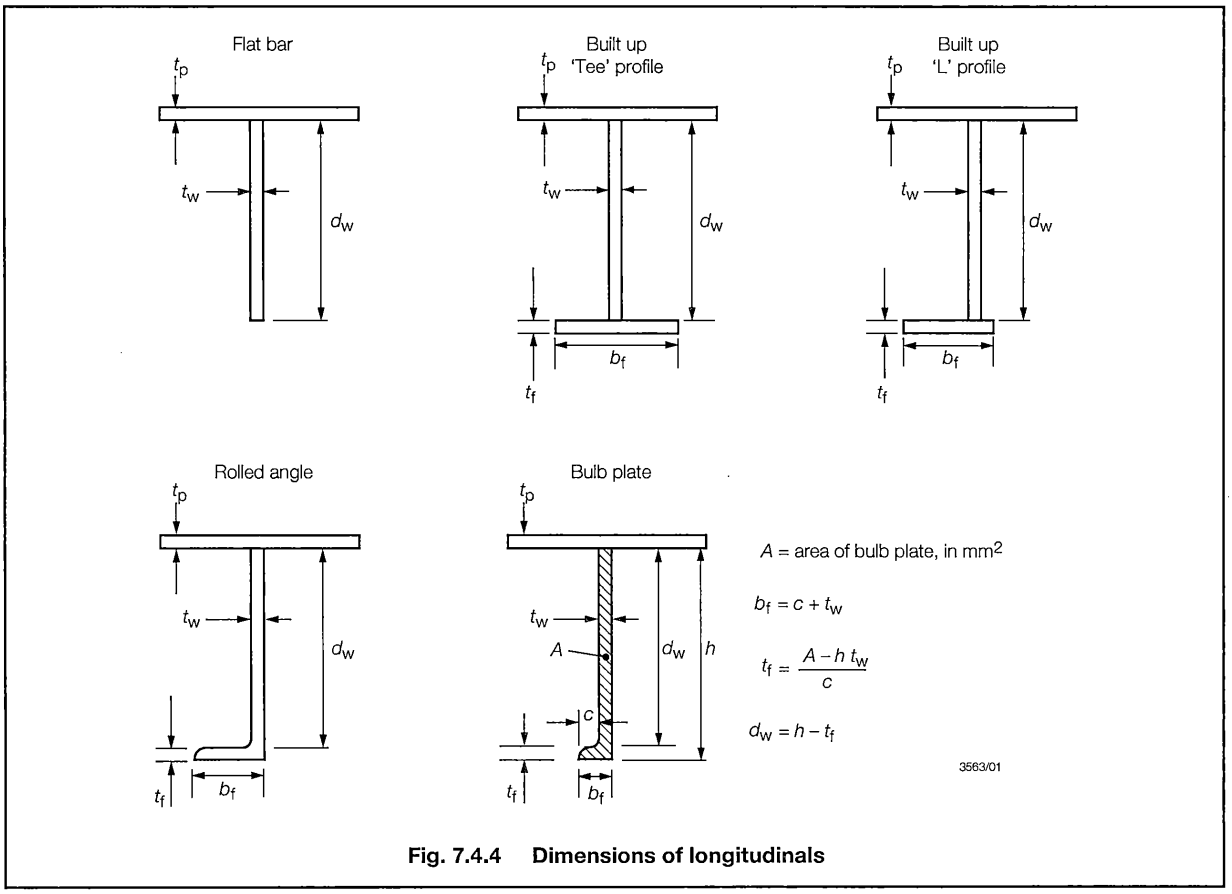

Fig. 7.4.4 Dimensions of longitudinals

4.9 Buckling of primary members

4.9.1 Where primary girders are subject to axial compressive loading, the buckling requirements for lateral, torsional, web and flange buckling modes detailed in 4.7 are to be satisfied.

4.9.2 To prevent global buckling from occurring before local panel buckling, transverse primary girders supporting axially loaded longitudinal stiffeners are to have a sectional moment of inertia, including attached plating, of not less than the following:

$$I_g = \frac{0{,}35 S_p^4 I_s}{l^3 s} \times 10^3 \quad \text{cm}^4$$

S_p and s are as defined in 4.2.1, *see also* Fig. 7.4.1

I_g = sectional moment of inertia including attached plating

I_s = moment of inertia of secondary stiffeners, in cm⁴, required to satisfy the overall elastic column buckling mode requirement specified in Table 7.4.3

$$= \frac{\sigma_{ep} A_{te} l_e^2}{0{,}001E}$$

where

$$\sigma_{ep} = 1{,}2\sigma_d \text{ N/mm}^2 \text{ for } \sigma_{e(a)} < \frac{\sigma_o}{2}$$

$$= \frac{\sigma_o^2}{4(\sigma_o - 1{,}2\sigma_d)} \text{ for } \sigma_{e(a)} \geq \frac{\sigma_o}{2}$$

σ_d is design stress, in N/mm²

σ_o and A_{te} are as defined in 4.2.1

$\sigma_{e(a)}$ is the elastic column buckling stress, *see* 4.7.2

E is defined in 4.2.1.

l_e is defined in Table 7.4.3.

4.10 Shear buckling of girder webs

4.10.1 Local panels in girder webs subject to in-plane shear loads are to satisfy the shear buckling requirements in Table 7.4.2, item (b).

4.10.2 The critical shear buckling stress, τ_c, is to be determined using the following formula for τ_e and Note 1 in Table 7.4.1.

$$\tau_e = 3{,}62\left(1{,}335 + \left(\frac{d_w}{1000\, l_p}\right)^2\right) E \left(\frac{t_w}{d_w}\right)^2 \text{ N/mm}^2$$

where

d_w = web height, in mm

t_w = web thickness, in mm

l_p = unsupported length of web, in metres

E is defined in 4.2.1.

4.11 Pillars and pillar bulkheads

4.11.1 Pillars and pillar bulkheads are to comply with the requirements of Ch 3,10.

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Section 5
Vibration control

5.1 General

5.1.1 Natural frequencies are to be investigated for local unstiffened and stiffened panels expected to be exposed to excessive structural vibrations being induced from machinery, propulsion unit or other potential excitation sources.

5.1.2 Where the structural configurations are such that basic structural elements may be modelled individually the natural frequencies may be derived in accordance with 5.3, 5.4 and 5.5, as appropriate. Under other circumstances finite element analysis is to be employed to evaluate the vibration characteristics of the structure considered.

5.2 Frequency band

5.2.1 The natural frequency of panels is generally not to lie within a band of ±20 per cent of a significant excitation frequency.

5.3 Natural frequency of plate

5.3.1 The natural frequency of a clamped plate in air is given by the following:

$$f_{air} = 5{,}544 \frac{t_p}{ab} \sqrt{\left(\frac{a}{b}\right)^2 + \left(\frac{b}{a}\right)^2 + 0{,}6045} \text{ Hz}$$

where

a = panel length, in metres
b = panel breadth, in metres
t_p = panel thickness, in mm

5.4 Natural frequency of plate stiffener

5.4.1 The natural frequency of a plate stiffener in air is given by the following:

$$f_{air,i} = \frac{K_i}{2\pi L_b^2} \sqrt{\frac{EI}{m\left(1 + \frac{\pi^2 EI}{L_b^2 GA}\right)}} \text{ Hz}$$

where

EI = flexural rigidity of plate stiffener combination, in Nm^2
GA = shear rigidity of plate stiffener combination, in N
L_b = beam length, in metres
m = mass per unit length of the stiffener and associated plating, in kg/m
K_i = constant where i refers to the mode of vibration as given in Table 7.5.1.

Table 7.5.1 Vibration mode constant K_i

Mode	1	2	3	4	5
K_i	22,40	61,70	121,0	200,0	299,0

5.5 Effect of submergence

5.5.1 To obtain the frequency, f_{water}, of a plate with one side exposed to air and the other side exposed to a liquid, the frequency calculated in air, f_{air}, may be modified by the following formula:

$$f_{water} = \psi f_{air}$$

where

$$\psi = \sqrt{\frac{\kappa_p}{\kappa_p + \frac{\rho_l}{\rho_p}}}$$

ρ_l = density of the liquid, in kg/m^3
ρ_p = density of the plate, in kg/m^3

$$\kappa_p = \frac{\pi t_p}{1000 a b} \sqrt{a^2 + b^2}$$

where

a, b and t_p are as defined in 5.3.1.

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Rules and Regulations for the Classification of Special Service Craft

Volume 5
Part 7
Hull Construction in Aluminium
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Lloyd's Register
LIFE MATTERS

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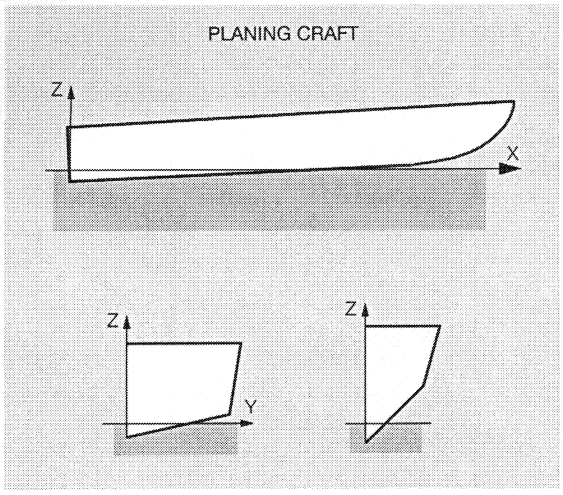

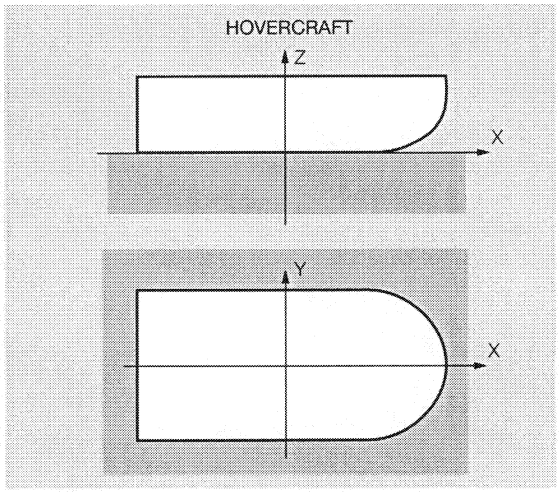

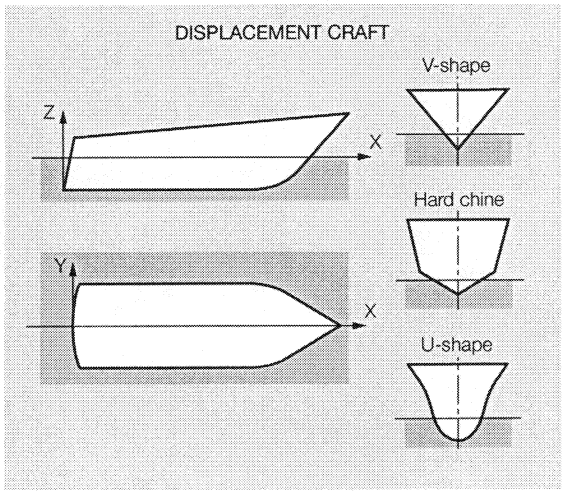

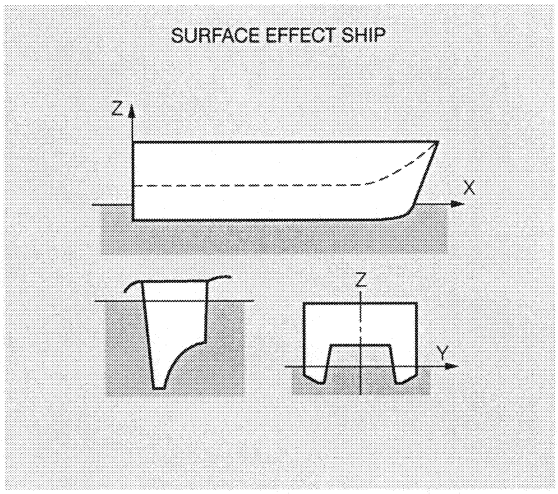

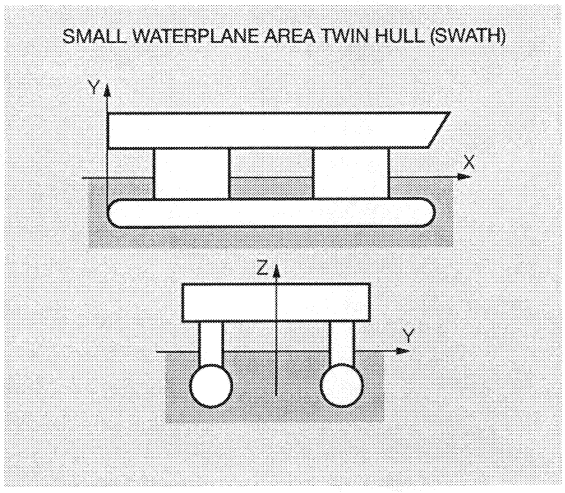

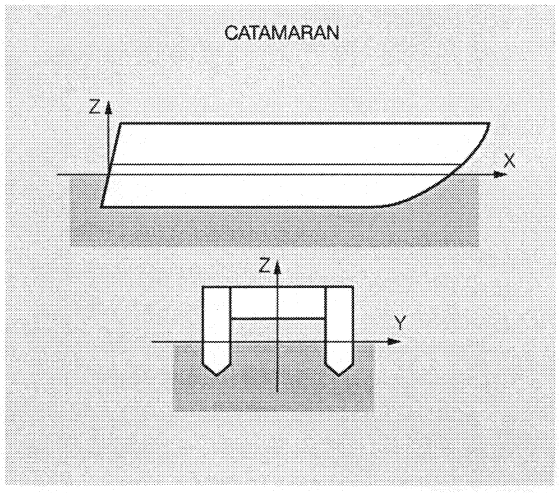

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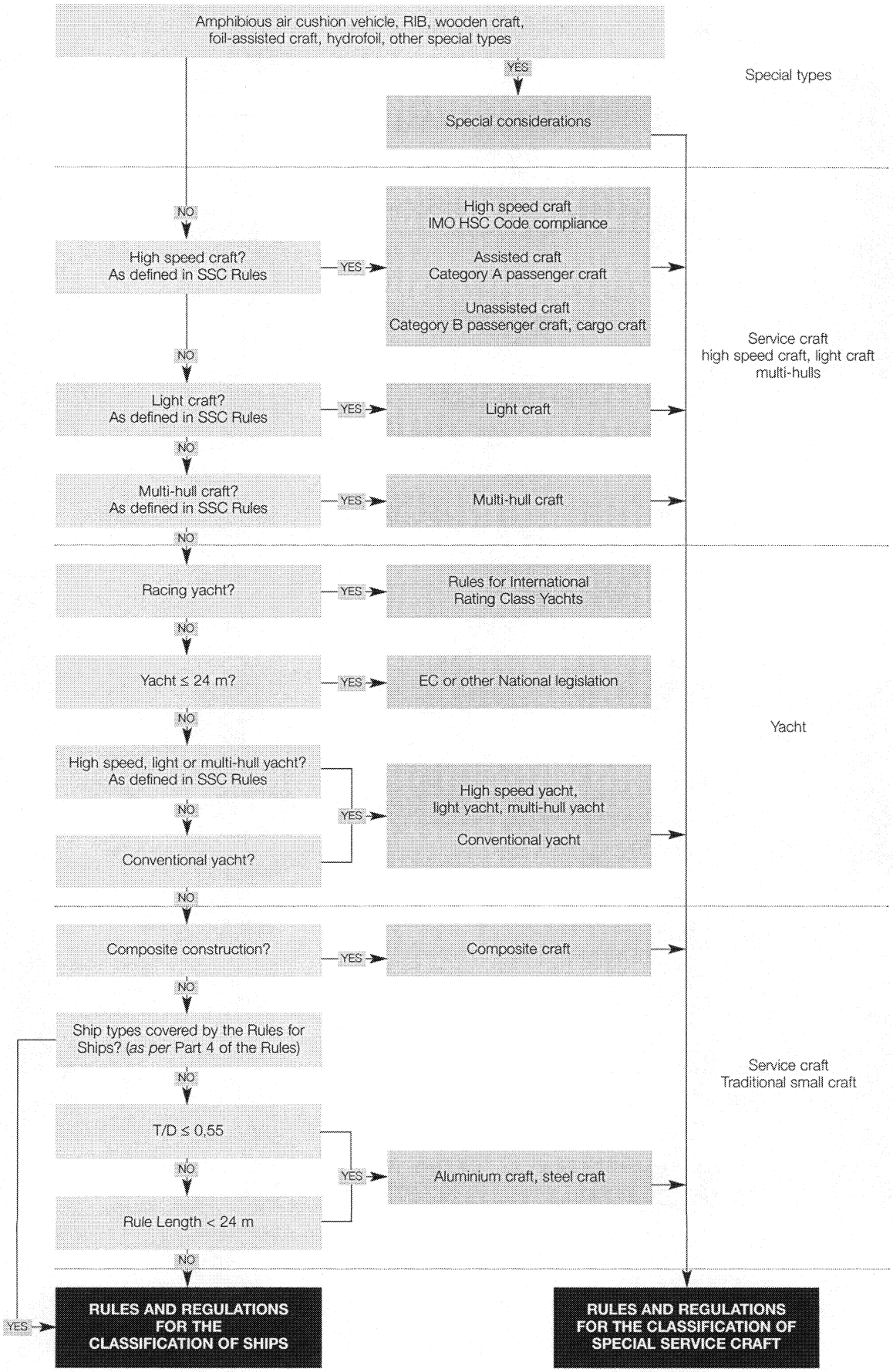

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Section

1 **Application**

2 **General requirements**

Section 1 Application

1.1 General

1.1.1 The Rules apply to mono and multi-hull craft of normal form, proportions and speed. Although the Rules are, in general, for aluminium craft of all welded construction, other materials for use in hull construction will be specially considered on the basis of the Rules.

1.2 Interpretation

1.2.1 The interpretation of the Rules is the sole responsibility and at the sole discretion of Lloyd's Register (hereinafter referred to as 'LR'). Where there is any doubt, regarding the interpretation of the Rules it is the Builder's and/or designer's responsibility to obtain clarification from LR prior to submission of plans and data for appraisal.

1.2.2 Where applicable, the Rules take into account unified requirements and interpretations established by the International Association of Classification Societies (IACS).

1.2.3 Attention is drawn to the fact that Codes of Practice issued by IMO contain requirements which are outside classification as defined in the Rules.

1.3 Equivalents

1.3.1 Alternative scantlings and arrangements may be accepted as equivalent to the Rule requirements. Details of such proposals are to be submitted for consideration in accordance with Pt 3, Ch 1,3.

1.4 Symbols and definitions

1.4.1 The symbols and definitions for use throughout this Part are as defined within the appropriate Chapters and Sections.

Section 2 General requirements

2.1 General

2.1.1 Limitations with regard to the application of these Rules are indicated in the various Chapters for differing craft types.

2.2 Aesthetics

2.2.1 LR is not concerned with the general arrangement, layout and appearance of the craft; the responsibility for such matters remains with the Builders and/or designers to ensure that the agreed specification is complied with. LR is however concerned with the quality of workmanship, in this respect the acceptance criteria as required by the Rules are to be complied with.

2.3 Constructional configuration

2.3.1 The Rules provide for the basic structural configurations for both single and multi-deck mono and multi-hull craft with multi-deck or single deck hulls which include a double bottom, or a single bottom arrangement. The structural configuration may also include a single or multiple arrangement of cargo hatch openings and side tanks.

2.3.2 The Rules provide for longitudinal and transverse framing systems.

2.3.3 Novel or other types of framing systems will be considered on the basis of the Rules.

2.4 Plans to be submitted

2.4.1 Plans covering the following items are to be submitted:

- Midship sections showing longitudinal and transverse material.
- Profile and decks.
- Shell expansion.
- Oiltight and watertight bulkheads.
- Propeller brackets.
- Double bottom construction.
- Pillars and girders.
- Aft end construction.
- Engine room construction.
- Engine and thrust seatings.
- Fore end construction.
- Hatch cover construction.
- Deckhouses and superstructures.
- Sternframe.
- Rudder, stock and tiller.
- Equipment.
- Loading Manuals, preliminary and final (where applicable).
- Scheme of corrosion control (where applicable).
- Ice strengthening.
- Welding schedule.
- Hull penetration plans.
- Support structure for masts, derrick posts or cranes.
- Bilge keels showing material grades, welded connections and detail design.

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2.4.2 The following supporting documents are to be submitted:

- General arrangement.
- Capacity plan.
- Lines plan or equivalent.
- Dry-docking plan.
- Towing and mooring arrangements.
- Sail/rigging plan, indicating loadings (as applicable to sailing craft).

2.4.3 The following supporting calculations are to be submitted:

- Equipment Number.
- Hull girder still water and dynamic bending moments and shear forces as applicable.
- Midship section modulus.
- Structural items in the aft end, midship and fore end regions of the craft.
- Preliminary freeboard calculation.

2.5 Novel features

2.5.1 Where the proposed construction of any part of the hull or machinery is of novel design, or involves the use of unusual material, or where experience, in the opinion of LR, has not sufficiently justified the principle or mode of application involved, special tests or examinations before and during service may be required. In such cases a suitable notation may be entered in the *Register Book*.

2.6 Enhanced scantlings

2.6.1 Where the Owner decides to increase the scantling of the bottom shell, side shell and deck plating of a newbuilding, then the craft will be eligible to be assigned the description note **ES**, *see* Pt 1, Ch 2,3.12. For example, the descriptive note **ES+1** would indicate that an extra 1 mm of aluminium has been fitted to bottom shell, side shell and deck plating.

2.7 Direct calculations

2.7.1 Direct calculations may be specifically required by the Rules and may be required for craft having novel design features or in support of alternative arrangements and scantlings. LR may, when requested, undertake calculations on behalf of designers and make recommendations with regard to suitability of any required model tests.

2.7.2 Where direct calculations are proposed then the requirements of Pt 3, Ch 1,2 of the Rules are, in general, to be complied with.

2.8 Exceptions

2.8.1 Craft of unusual form, proportions or speed, intended for the carriage of special cargoes, or for special or restricted service, not covered specifically by the Rules, will receive individual consideration based on the general requirements of the Rules.

2.9 Advisory services

2.9.1 The Rules do not cover certain technical characteristics, such as stability except as mentioned in Pt 1, Ch 2,1.1.11, 1.1.13 and 1.1.14, trim, vibration (other than local stiffened flat panels, *see* Ch 7,5), docking arrangements, etc. The Committee cannot assume responsibility for these matters but is willing to advise upon them on request.

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Section

1 **General**

2 **Materials**

3 **Procedures for welded construction**

4 **Joints and connections**

Section 1 General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull and multi-hull craft of aluminium construction as defined in Pt 1, Ch 1,1.

1.2 General

1.2.1 This Chapter contains the general Rule requirements for the construction of aluminium craft using the metal inert gas (MIG) and tungsten inert gas (TIG) welding processes. Where alternative methods of construction are proposed, details are to be submitted for consideration by Lloyd's Register (hereinafter referred to as 'LR').

1.3 Symbols and definitions

1.3.1 The symbols and definitions used in this Chapter are defined in the appropriate Section.

1.4 Builder's facilities

1.4.1 The buildings used for production and storage are to be of suitable construction and equipped to provide the required environment, and also to comply with any local or National Authority requirements.

1.4.2 The Surveyor is to be allowed unrestricted access during working hours to such parts of the Builder's establishment as may be necessary to ensure that the requirements of the Rules are being complied with.

1.5 Works inspection

1.5.1 Prior to the commencement of construction, the facilities are to be inspected to the satisfaction of the attending Surveyor. This will include the minimum quality control arrangements outlined in 1.6.

1.5.2 The Surveyor is to be satisfied that the Builder has the organisation and capability to construct craft to the standards required by the Rules.

1.5.3 The Builder is to be advised of the result of the inspection and all deficiencies are to be rectified prior to the commencement of production.

1.5.4 Where structural components are to be assembled and welded by sub-contractors, the Surveyors are to inspect the sub-contractor's works to ensure that compliance with the requirements of this Chapter can be achieved.

1.6 Quality control

1.6.1 For compliance with 1.5.2, LR's methods of survey and inspection for hull construction and machinery installation are to include procedures involving the shipyard management, organisation and quality systems.

1.6.2 The extent and complexity of the quality systems, will vary considerably depending on the size and type of craft and production output. LR will consider certification of the Builder in accordance with the requirements of one of the following systems:

(a) Quality Assurance System in accordance with an International or National Standard (i.e. ISO 9000 and BS ENISO 9001) with assessment and certification carried out by a nationally accredited body.

(b) LR's *Quality Assurance Scheme for the Construction of Special Service Craft*.

(c) LR's locally accepted Quality Control System – The Builder is required to implement a documented Quality Control System which controls the following activities:
  (i) Receipt storage and issue of materials, equipment, etc.
  (ii) Fabrication environment.
  (iii) Weld procedures and welder performance.
  (iv) Production fabrication.
  (v) Inspection of production processes.
  (vi) Installation of machinery and essential systems.
  (vii) Fitting-out.
  (viii) Tests and trials.
  (ix) Drawings and document control.
  (x) Records.

1.6.3 LR's involvement is only in that part of the system which controls the standards required to meet the classification requirements.

1.6.4 The 'documented' quality control system will in general require the Builder to have written procedures that describe clearly and unambiguously how each of the activities specified in 1.6.2(c) is carried out, when it is carried out and by whom. These procedures will form part of the system manual which is also to contain a statement of management policy, organisation chart and statements of responsibilities. The manual is to be controlled in respect to the formal issue and revision.

1.6.5 Further details of LR's requirements are available on request from the local LR office.

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1.7 Building environment

1.7.1 The craft is to be suitably protected during the building period from adverse weather and climatic conditions.

1.8 Storage areas

1.8.1 All materials are to be stored safely and in accordance with the manufacturer's requirements. Storage arrangements are to be such as to prevent deterioration through contact with heat, sunlight, damp, cold and poor handling.

1.8.2 Aluminium is to be stored in dry places, clear of the ground. Contact with other metals and with materials such as cement and damp timber is to be avoided. Aluminium sheet and plate are to be stacked, in general, on end in racks to avoid distortion.

1.8.3 All storage spaces provided by the Builder for welding consumables are to be suitable for maintaining them in good condition and are to be in accordance with the manufacturer's recommendations.

1.8.4 All materials are to be fully identifiable in the storage areas, and identification is to be maintained during issue to production.

1.8.5 Material suspected of being non-conforming is to be segregated from acceptable materials.

1.9 Materials handling

1.9.1 The Builder is to maintain purchasing documents containing a clear description of the materials ordered for use in hull construction and the standards to which the material must conform, together with the identification and certification requirements.

1.9.2 The Builder is to be responsible for ensuring that all incoming plates, sections, castings, components, fabrications and consumables and other materials used in the hull construction are inspected or otherwise verified as conforming to purchase order requirements.

1.9.3 The Builder is to have procedures for the inspection, storage and maintenance of Owner supplied materials and equipment.

1.9.4 The Builder is to record on receipt the manufacturing date, or use-by date of critical materials. Any materials which have a shelf life are to be used in order of manufacturing date to ensure stock rotation.

1.9.5 The Builder is to establish and maintain a procedure to ensure that materials and consumables used in the hull construction process are identified (by colour-coding and/or marking as appropriate) from arrival in the yard through to fabrication in such a way as to enable the type and grade to be readily recognised.

1.9.6 Where materials are found to be defective they are to be rejected in accordance with the Builder's quality control procedure.

1.10 Faults

1.10.1 All identified faults are to be recorded under the requirements of the quality control systems. Faults are to be classified according to their severity and are to be monitored during periodical survey.

1.10.2 Production faults are to be discussed with the attending Surveyor and a rectification scheme agreed. Deviations from the approved plans are to be locally approved by the attending Surveyor and a copy forwarded to the plan approval office for record purpose.

1.11 Inspection

1.11.1 On acceptance of a 'Request for Services' the attending Surveyor is to inform the Builder of the key stages of the production that are to be inspected and the extent of the inspection to be carried out.

1.11.2 It is the Builder's responsibility to carry out required inspections in accordance with the accepted quality control system.

1.11.3 It is the Surveyor's responsibility to monitor the Builder's quality control records and carry out inspections at key stages and during periodic visits.

1.11.4 Adequate facilities are to be provided to enable the Surveyor to carry out a satisfactory inspection and to facilitate subsequent in-service maintenance. These are to include the provision of access holes in restricted spaces and removable deckhead and shipside linings, cabin soles, etc.

1.11.5 During inspections all deviations are to be dealt with in accordance with 1.6.4.

1.12 Acceptance criteria

1.12.1 Classification is dependent upon the work being carried out in accordance with the approved plans and the requirements of an accepted quality control system.

1.12.2 The work is to be carried out to the satisfaction of the attending Surveyor. This will include the verification of the quality control documentation and the remedial action associated with all defects and deficiencies recorded.

1.12.3 Proposed deviations from the approved plans are subject to LR approval and in the first instance are to be discussed with the attending Surveyor. Where applicable, an amended plan is to be submitted to the plan appraisal office. Such deviations will be recorded as endorsements to the certification unless specifically agreed otherwise with the plan appraisal office.

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1.12.4 Where the above requirements are met the attending Surveyor will arrange for the relevant certification to be issued.

1.13 Repair

1.13.1 Minor repairs are to be agreed with the attending Surveyor and a rectification scheme agreed with the Builder. The Builder is to incorporate details of the agreed repair procedures in the quality control system in accordance with 1.6.4.

1.13.2 Repairs which affect the structural integrity are to be discussed with the Builder and the Builder's proposed rectification scheme is to be submitted to the plan appraisal office for consideration.

■ *Section 2* Materials

2.1 General

2.1.1 The materials used in the construction of the craft are to be manufactured and tested in accordance with the appropriate requirements of Chapter 8 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

2.1.2 As an alternative to 2.1.1, materials may be accepted for specific applications, provided they are manufactured and tested in accordance with the requirements of national or proprietary specifications which give reasonable equivalence to the requirements of the Rules for Materials. Additional tests may be required to prove that the materials are suitable for the intended purpose in respect of mechanical properties, weldability and corrosion resistance.

2.1.3 All materials are to be manufactured at works which have been approved by LR for the type and, where appropriate, grade of aluminium which is being supplied and for the relevant aluminium production and processing route.

2.2 Aluminium alloy plates, bars and sections

2.2.1 Materials are, in general, to be limited to the supply conditions detailed in Ch 8,1.6 of the Rules for Materials. Other supply conditions may be accepted but, as materials in a condition other than annealed are subject to a loss of mechanical strength in the vicinity of welded joints, the strength used in design calculations are to be as given in 2.4.

2.2.2 For applications where the material will be subject to high local stresses, it is recommended that the scantlings, when using higher strength materials, be determined on the basis of the mechanical properties of the material in the as-welded annealed condition.

2.3 Aluminium alloy castings

2.3.1 All structural castings are to be manufactured and tested in accordance with the appropriate requirements of Ch 8,3 of the Rules for Materials.

2.4 Mechanical properties for design

2.4.1 The minimum tensile strength properties of aluminium alloys approved for structural use are given in Table 2.2.1. Other alloys and conditions of temper may be accepted in accordance with 2.1.3.

2.4.2 In general, for welded structure, the maximum value for the strength of the material, σ_a, to be used in the scantling derivation is that of the aluminium alloy in the welded condition, where σ_a is defined as the 0,2 per cent butt welded proof stress or 70 per cent of the ultimate strength of the material in the welded condition in N/mm^2, whichever is the lesser.

2.4.3 The tensile modulus of elasticity to be used in scantling calculations is 69×10^3 N/mm^2 for all aluminium alloy materials.

2.4.4 The type of material, specification to which it is manufactured (including grade and temper) and minimum guaranteed mechanical properties are to be indicated on the construction drawings.

2.5 Cathodic protection

2.5.1 The potential of the aluminium-magnesium (5000 Series) and the aluminium-magnesium-silicon (6000 Series) alloys is generally in the range –0,7 to –0,9 Volts with reference to a silver/silver chloride sea-water reference electrode. A negative potential swing of at least 0,1 Volts from the corrosion potential is necessary to provide cathodic protection in sea-water (i.e. –0,8 to –1,0 Volts). The limit of negative potential is, however, not to exceed –1,1 Volts with reference to a silver/silver chloride sea-water reference electrode. Zinc or aluminium-zinc-indium or aluminium-zinc-tin anodes may be used for cathodic protection but aluminium anodes containing mercury are not acceptable.

2.5.2 Where an impressed current cathodic protection system is fitted, plans showing the proposed layout of anodes and hull penetrations are to be submitted.

2.6 Paints and coatings

2.6.1 The hull, deck, deckhouse and superstructure and other structure which is exposed to the marine environment is to be protected against corrosion by a suitable protective coating. All coatings are to be in accordance with the requirements of this Section. Internal structure need not in general be coated provided that they are built of aluminium alloy grades shown in Chapter 8 of the Rules for Materials.

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Table 2.2.1 Minimum mechanical properties for aluminium alloys

Alloy	Condition		0,2% proof stress N/mm^2		Ultimate tensile strength N/mm^2	
			Unwelded	Welded *see* Note 4	Unwelded	Welded *see* Note 4
5083	O/H111		125	125	275	275
5083	H112		125	125	275	275
5083	H116/H321		215	125	305	275
5383	O/H111		145	145	290	290
5383	H116/H321		220	145	305	290
5086	O/H111		100	95	240	240
5086	H112		125 *see* Note 2	95	250 *see* Note 2	240
5086	H116/H321		195	95	275	240
5059	O/H111		160	160	330	330
5059	H116/H321		260	160	360	300
5456	O		125	125	285	285
5456	H116		200 *see* Note 5	125	290 *see* Note 5	285
5456	H321		215 *see* Note 5	125	305 *see* Note 5	285
5754	O/H111		80	80	190	190
6005A *see* Note 1	T5/T6	Extruded: Open Profile Extruded: Closed Profile	215 215	100 100	260 250	160 160
6061 *see* Note 1	T5/T6	Rolled Extruded: Open Profile Extruded: Closed Profile	240 240 205	125 125 125	290 260 245	160 160 160
6082	T5/T6	Rolled Extruded: Open Profile Extruded: Closed Profile	240 260 240	125 125 125	280 310 290	190 190 190

NOTES
1. These alloys are not normally acceptable for application in direct contact with sea-water.
2. *See also* Tables 8.1.3 or 8.1.4 in Chapter 8 of the Rules for Materials.
3. The mechanical properties to be used to determine scantlings in other types and grades of aluminium alloy manufactured to National or proprietary Standards and specifications are to be individually agreed with LR, *see also* Ch 8,1.1.5 of the Rules for Materials.
4. Where detail structural analysis is carried out, 'Unwelded' stress values may be used away from heat-affected zones and weld lines, *see also* Ch 3,1.9.1 and 1.10.1 to 1.10.3.
5. For thickness less than 12,5 mm the minimum unwelded 0,2% proof stress is to be taken as 230 N/mm^2 and the minimum tensile strength is to be taken as 315 N/mm^2.

2.6.2 Aluminium alloy is to be suitably cleaned, cleared of oxide and degreased before the application of any protective coating.

2.6.3 Paints or other coatings are to be suitable for the intended purpose in the locations where they are to be used. Coatings are to be of adequate film thickness, applied in accordance with the paint manufacturer's specification. The paint or coating is to be compatible with any previously applied primer.

2.6.4 Paints containing lead, mercury or copper are not to be used in conjunction with aluminium alloys.

2.6.5 Paints, varnishes and similar preparations having a nitro-cellulose or other highly flammable base are not to be used in accommodation or machinery spaces.

2.7 Galvanic action

2.7.1 Where bimetallic connections are made, involving dissimilar metals, measures are to be incorporated to preclude galvanic corrosion. In order to prevent galvanic corrosion, special attention is to be given to the penetrations of and connections to the hull, bulkheads and decks by piping and equipment where dissimilar materials are involved.

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2.8 Bimetallic connections

2.8.1 The design is to ensure that the location of all bimetallic connections allows for regular inspection and maintenance of the joints and penetrations during service.

2.9 Deck coverings

2.9.1 Where plated decks are sheathed with wood, the sheathing is to be efficiently attached to the deck, caulked and sealed, to the satisfaction of the Surveyor in accordance with the approved drawings.

2.9.2 Deck coverings in the following positions are to be of a type which will not readily ignite where used on decks:

(a) Forming the crown of machinery or cargo spaces within accommodation spaces of cargo craft.

(b) Within accommodation spaces, control stations, stairways and corridors of passenger craft.

2.10 Corrosion margin

2.10.1 The scantlings determined from the formulae provided in the Rules assume that the materials used are selected, manufactured and protected in such a way that there is negligible loss in strength by corrosion.

2.10.2 Where aluminium alloy is not protected against corrosion, by painting or other approved means, the scantlings may require to be further considered.

2.11 Fracture control

2.11.1 Aluminium alloys in commercial use are in general not subject to unstable crack growth in an elastic stress field because fracture toughness is high. However, for alloys with higher strength and/or temper, special tests may be required to provide information on fracture toughness.

2.11.2 Construction procedures, materials and welding are to be in accordance with the requirements of this Chapter such that stress corrosion cracking is avoided.

2.11.3 High local stresses are to be avoided by the use of suitable design detail, *see also* LR's *Guidance Notes for Structural Details*.

■ *Section 3* Procedures for welded construction

3.1 General

3.1.1 Except as otherwise indicated below, all welded construction is to be conducted in accordance with the requirements specified in Chapter 13 of the Rules for Materials.

3.1.2 The requirements of this Section are applicable to aluminium alloys welded using the metal inert gas (MIG) or tungsten inert gas (TIG) processes. Where it is proposed to use alternative welding processes, details are to be submitted for approval, prior to the start of fabrication.

3.2 Information to be submitted

3.2.1 The plans and information submitted for approval are to clearly indicate details of the welded connections of the main structural members, including the type, disposition and size of welds.

3.3 Welding consumables

3.3.1 All welding consumables are to be approved by LR and are to be suitable for the type of joint and grade of material, *see* Ch 11,9 of the Rules for Materials.

3.3.2 The 5083 and 5086 alloys are normally welded using the 5356, 5556 or 5183 consumables and the 6061 and 6082 alloys are normally welded using the 4043 consumables.

3.3.3 Only approved filler wires are to be used. Testing requirements for welding consumables are contained in the Rules for Materials.

3.3.4 Cast aluminium alloys are not in general to be welded directly to wrought high magnesium alloys unless the welding is carried out in accordance with an agreed procedure.

3.3.5 Special care is to be taken in the distribution, storage and handling of all welding consumables. Aluminium filler metals are to be kept in a heated dry storage area with a relatively uniform temperature. Condensation on the metal surface during storage and use is to be avoided. Other welding consumables such as bare wire and welding studs are to be stored under dry conditions to prevent corrosion. Effective facilities for protecting consumables are to be provided close to working areas.

3.4 Defined practices and welding sequence

3.4.1 Details of the welding procedures and the sequence of welding assemblies and joining up of assemblies are to be submitted.

3.4.2 The proposed sequence of welding is to be agreed with the Surveyor prior to construction.

3.4.3 The type and disposition of connections and sequences of welding are to be so planned that any restraint during welding operations is reduced to a minimum.

3.4.4 Special attention is to be given to the examination of plating in way of all lifting eye plate positions to ensure freedom from cracks. This examination is not restricted to the positions where eye plates have been removed but includes the positions where lifting eye plates are permanent fixtures.

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3.4.5 Careful consideration is to be given to assembly sequence and overall shrinkage of plate panels, assemblies, etc., resulting from welding processes employed. Welding is to proceed systematically with each welded joint being completed in correct sequence without undue interruption. Where practicable, welding is to commence at the centre of a joint and proceed outwards or at the centre of an assembly and progress outwards towards the perimeter so that each part has freedom to move in one or more directions. Generally, the welding of stiffener members including transverses, frames, girders, etc., to welded plate panels by automatic processes is to be carried out in such a way as to minimise angular distortion of the stiffener.

3.4.6 Butt welds are to be finished full at the ends and cut back before welding the seams. Seams are generally not to be welded within 300 mm of an unwelded butt weld or welded across an unwelded butt joint.

3.4.7 The final boring out of propeller brackets and sterntubes and the fit-up and alignment of rudder bearings and jet units are to be carried out after the major part of the welding of the aft end of the craft is complete. The contacts between rudder stocks and propeller shafts with bearings are to be checked before the final mounting.

3.4.8 Precautions are to be taken to screen and pre-warm the general and local weld areas as necessary. Surfaces are to be dry.

3.5 Structural arrangements and access

3.5.1 Ceilings, cabin sole, side and overhead linings are to be secured in such a manner as to be easily removed for the maintenance and inspection of the structure below.

3.5.2 Structural arrangements are to be such as will allow adequate ventilation and access for preheating, where required, and for the satisfactory completion of all welding operations. Welded joints are to be so arranged as to facilitate the use of downhand welding wherever possible.

3.6 Heat treatment

3.6.1 Pre-heating is to be applied in accordance with the requirements specified in Chapter 13 of the Rules for Materials.

3.6.2 For aluminium-magnesium alloys, the preheating temperature is to be limited to 60°C to avoid the risk of stress corrosion cracking.

3.6.3 With the 6000 series heat-treatable alloys, it is sometimes beneficial to apply a post-weld heat treatment in the form of artificial ageing. The procedure to be used depends on the alloy and, in order to quantify the benefits, tests are required using representative specimens which accurately simulate the true situation in terms of metal thickness, geometry, filler metal and welding parameters, as well as the post-weld treatment employed.

3.7 Testing

3.7.1 Inspection of welded construction is to be conducted in accordance with the requirements specified in Chapter 13 of the Rules for Materials.

3.7.2 Checkpoints for volumetric examination are to be selected so that a representative sample of welding is examined.

3.7.3 Typical locations for volumetric examination and number of checkpoints to be taken are shown in Table 2.3.1. A list of the proposed items to be examined is to be submitted for approval.

3.8 Acceptance criteria

3.8.1 All finished welds are to be sound and free from cracks and substantially free from lack of fusion, incomplete penetration, porosity and tungsten inclusions. The surfaces of welds are to be reasonably smooth and substantially free from undercut and overlap. Care is to be taken to ensure that the specified dimensions of welds have been achieved and that both excessive reinforcement and underfill of welds are avoided.

3.8.2 The quality and workmanship of welding of all fittings and attachments to main structure, both permanent and temporary, are to be equivalent to those of the main hull structure.

3.8.3 Visual examination of all welds is to be supplemented by non-destructive testing as considered necessary by the Surveyor.

3.8.4 Fairing, by linear or spot heating, to correct distortions due to welding is, in general, not to be carried out unless procedures have been approved to ensure that the properties of the material are not adversely affected. Visual examination of all heat affected areas and welds in the vicinity is to be carried out to ensure freedom from defects.

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Table 2.3.1 Non-destructive examinations of welds

Volumetric non-destructive examinations – Recommended extent of testing, *see* 3.7.3		
Item	Location	Checkpoints, *see* Note 1
Intersections of butts and seams of fabrication and section welds	Throughout: hull envelope longitudinal and transverse bulkheads inner bottom and hopper bottom	The summation of checkpoint lengths (*see* Note 2) examined at intersections is to be *L*, where *L* is the overall length of the ship in metres
Butt welds in plating	Throughout	1 m in 25 m, *see* Note 3
Seam welds in plating	Throughout	1 m in 100 m
Butts in longitudinals	Hull envelope within 0,4*L* amidships Hull envelope outside 0,4*L* amidships	1 in 10 welds 1 in 20 welds
Bilge keel butts	Throughout	1 in 10 welds
Structural items when made with full penetration welding as follows: connection of stool and bulkhead to lower stool shelf plating vertical corrugations to an inner bottom hopper knuckles sheerstrake to deck stringer hatchways coaming to deck	Throughout	1 m in 20 m

NOTES
1. The length of each checkpoint is to be between 0,3 m and 0,5 m.
2. For checkpoints at intersections the measured dimension of length is to be in the direction of the butt weld.
3. Checkpoints in butt welds and seam welds are in addition to those at intersections.
4. Agreed locations are not to be indicated on the blocks prior to the welding taking place, nor is any special treatment to be given at these locations.
5. Particular attention is to be given to repair rates in longitudinal butts. Additional welds are to be tested in the event that defects, such as lack of fusion or incomplete penetrations, are repeatedly observed.

■ *Section 4*
Joints and connections

4.1 General

4.1.1 Requirements are given in this Chapter for welding connection details, aluminium/steel transition joints, aluminium/wood connection, riveting of light structure and chemical bonding.

4.1.2 Welded joints are to be detailed such that crevices or inaccessible pockets capable of retaining dirt or moisture are avoided. Where cavities are unavoidable, they are to be sealed by welding or protective compounds or made accessible for inspection and maintenance.

4.2 Weld symbols

4.2.1 Weld symbols, where used, are to conform to a recognised National or International Standard. Details of such Standards are to be indicated on the welding schedule, which is to be submitted for appraisal.

4.3 Welding schedule

4.3.1 A welding schedule containing not less than the following information is to be submitted:
(a) Weld throat thickness or leg lengths.
(b) Grades, tempers, and thicknesses of materials to be welded.
(c) Locations, types of joints and angles of abutting members.
(d) Reference to welding procedures to be used.
(e) Sequence of welding of assemblies and joining up of assemblies.

4.4 Butt welds

4.4.1 All structural butt joints are to be made by means of full penetration welds and, in general, the edges of plates to be joined by welding are to be bevelled on one or both sides of the plates. Full details of the proposed joint preparation are to be submitted for approval, *see also* 4.20.

4.4.2 Where butt welds form a T-junction, the leg of the T is, where practicable, to be completed first including any back run. During the welding operation special attention is to be given to the completion of the weld at the junction, which is to be chipped back to remove crater cracks, etc., before the table is welded.

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4.4.3 For guidance purposes, a number of typical joint preparations for TIG and MIG welding are shown in Tables 2.4.1 and 2.4.2 respectively.

4.5 Fillet welds

4.5.1 The throat thickness of fillet welds is to be determined from:

$$\text{Throat thickness} = t_p \times \text{Weld factor} \times \left(\frac{d}{s}\right) \text{ mm}$$

where

s = the length of correctly proportioned weld fillet, clear of end craters, in mm, and is to be 10 x plate thickness, t_p, or 75 mm, whichever is the lesser, but in no case to be taken less than 40 mm

d = the distance between successive weld fillets, in mm

t_p = plate thickness, in mm, on which weld fillet size is based, *see* 4.5.4.

Weld factors are contained in Table 2.4.3.

NOTE:

for double continuous fillet welding $\left(\frac{d}{s}\right)$ is to be taken as 1

(*see* 4.8.1).

4.5.2 For ease of welding, it is recommended that the ratio of the web height to the flange breadth be greater than or equal to 1,5, *see* Fig. 13.2.1 in Chapter 13 of the Rules for Materials.

4.5.3 The leg length of the weld is to be not less than $\sqrt{2}$ times the specified throat thickness.

4.5.4 The plate thickness t_p to be used in 4.5.1 is generally to be that of the thinner of the two parts being joined. Where the difference in thickness is considerable, the size of fillet will be specially considered.

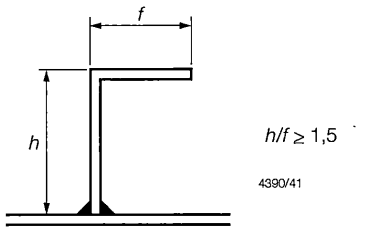


Fig. 2.4.1 Web height/flange breadth ratio

4.6 Throat thickness limits

4.6.1 The throat thickness limits given in Table 2.4.4 are to be complied with.

4.7 Single sided welding

4.7.1 Temporary backing bars for single sided welding may be austenitic stainless steel, glass tape, ceramic, or anodised aluminium of the same material as the base metal. Backing bars are not to be made of copper to avoid weld contamination and corrosion problems.

4.7.2 Temporary backing bars are to be suitably grooved in way of the weld to ensure full penetration.

Table 2.4.1 Typical joint preparations for TIG welding of aluminium alloys

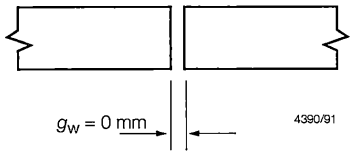
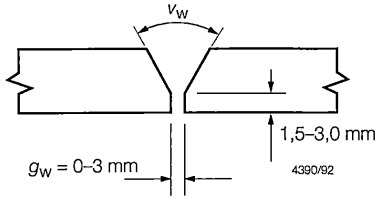
Thickness (mm)	Joint design	Welding position/comments
2,5 – 3,0		Flat Horizontal Vertical Overhead
3,0 – 10,0		Flat and Vertical V = 60° Horizontal and Overhead V = 90° – 110°
Symbols and definitions		
g_w = weld gap, in mm V_w = weld preparation angle, in degrees		

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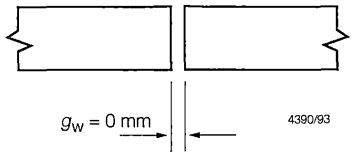
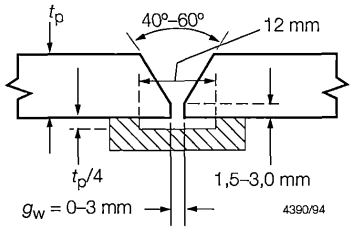
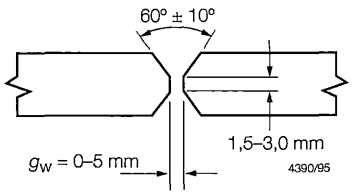
Table 2.4.2 Typical joint preparations for semi-automatic MIG welding

Thickness (mm)	Joint design	Welding position/comments
5,0 – 6,5		Flat
7,0 – 15,0		Flat Horizontal Vertical Overhead One sided welding with temporary backing
12,0 – 25,0		All positions
Symbols and definitions		
t_p = plate thickness, in mm g_w = weld gap, in mm		

4.8 Double continuous welding

4.8.1 Where double continuous fillet welding is proposed the throat thickness is to be in accordance with 4.5.1 taking $\left(\frac{d}{s}\right)$ equal to 1.

4.8.2 Double continuous welding is to be adopted in the following locations and may be used elsewhere if desired:

(a) Boundaries of weathertight decks and erections, including hatch coamings, companionways and other openings.
(b) Boundaries of tank and watertight compartments.
(c) Main engine seatings.
(d) Bottom framing structure of high speed craft in way of machinery and jet room spaces as appropriate.
(e) The side and bottom shell structure in the impact area of high speed motor craft.
(f) The underside of the cross-deck structure in the impact area of high speed multi-hull craft.
(g) Structure in way of ride control systems, stabilisers, thrusters, bilge keels, foundations and other areas subject to high stresses.
(h) The shell structure in the vicinity of the propeller blades.
(j) Stiffening members to plating in way of end connections scallops and of end brackets to plating in the case of lap connections.
(k) Primary and secondary members to plating in way of end connections, and end brackets to plating in the case of lap connections.
(l) Face flats to webs of built-up/fabricated stiffening members in way of knees/end brackets and for a distance beyond such knees/end brackets of not less than the web depth of stiffener in way.

4.9 Intermittent welding (staggered)

4.9.1 Staggered intermittent welding may be used, outside of the impact area in the bottom shell or crossdeck structure of high speed craft.

4.10 Intermittent welding (chain)

4.10.1 Chain intermittent welding may be used, outside of the impact area in the bottom shell or crossdeck structure of high speed craft.

4.11 Connections of primary structure

4.11.1 Depending on the structural design of the joint and design loads on the primary member, full penetration welding of flanges and web plates may be required to attain full section properties in the end connections of primary members. *See also* Pt 6, Ch 3,1.22. Otherwise weld factors for the connections of primary structure are given in Table 2.4.3.

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Table 2.4.3 Weld factors (*see continuation*)

Item	Weld Factor	Remarks
(1) General application:		except as required below
(a) Watertight plate boundaries	0,34	
(b) Non-tight plate boundaries	0,13	
(c) Longitudinals, frames, beams, and other secondary members to shell, deck, or bulkhead plating	0,10 0,13 0,21	 in tanks in way of end connections
(d) Panel stiffeners	0,10	
(e) Overlap welds generally	0,27	
(f) Longitudinals of the flat-bar type to plating		*see* 4.8.2
(2) Bottom construction:		
(a) Non-tight centre girder: • to keel • to inner bottom	 0,27 0,21	 no scallops
(b) Non-tight boundaries of: • floors, girders and • brackets	 0,21 0,27	 in way of 0,2 x span at ends in way of brackets at lower end of main frame
(c) Inner bottom longitudinals, or face flat to floors reverse frames	0,13	
(d) Connection of floors to inner bottom where bulkhead supported on tank top. The supporting floors are to be continuously welded to the inner bottom	0,44	Weld size based on floor thickness Weld material compatible with floor material
(3) Hull framing:		
(a) Webs of web frames and stringers: • to shell • to face plate	 0,16 0,13	
(4) Decks and supporting structure:		
(a) Weather deck plating to shell Other decks to shell and bulkheads (except where forming tank boundaries)	0,44 0,21	 generally continuous
(b) Webs of cantilevers to deck and to shell in way of root bracket	0,44	
(c) Webs of cantilevers to face plate	0,21	
(d) Girder webs to deck clear of end brackets	0,10	
(e) Girder webs to deck in way of end brackets	0,21	
(f) Web of girder to face plate	0,10	
(g) Pillars: • fabricated • end connections • end connections (tubular)	 0,10 0,34 full penetration	
(h) Girder web connections and brackets in way of pillar heads and heels	0,21	continuous

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Table 2.4.3 Weld factors (*see continuation*)

Item	Weld Factor	Remarks
(5) Bulkheads and tank construction:		
(a) Plane and corrugated watertight bulkhead boundary at bottom, bilge, inner bottom, deck and connection to shelf plate, where fitted	0,44	Weld size to be based on thickness of bulkhead plating Weld material to be compatible with bulkhead plating material
(b) Secondary members where acting as pillars	0,13	
(c) Non-watertight pillar bulkhead boundaries	0,13	
(d) Perforated flats and wash bulkhead boundaries	0,10	
(e) Deep tank horizontal boundaries at vertical corrugations	full penetration	
(6) Structure in machinery space:		
(a) Centre girder to keel and inner bottom	0,27	no scallops to inner bottom
(b) Floors to centre girder in way of engine thrust bearers	0,27	
(c) Floors and girders to shell and inner bottom	0,21	
(d) Main engine foundation girders: • to top plate • to hull structure	deep penetration to depend on design	edge to be prepared with maximum root $0,33t_p$ deep penetration, generally
(e) Floors to main engine foundation girders	0,27	
(f) Brackets, etc., to main engine foundation girders	0,21	
(g) Transverse and longitudinal framing to shell	0,13	
(7) Superstructures and deckhouses:		
(a) Connection of external bulkheads to deck	0,34 0,21	1st and 2nd tier erections elsewhere
(b) Internal bulkheads	0,13	
(8) Steering control systems:		
(a) Rudder: • Fabricated mainpiece and • mainpiece to side plates and webs	0,44	
(b) Slot welds inside plates	0,44	
(c) Remaining construction	0,21	
(d) Fixed and steering nozzles: • Main structure • Elsewhere	0,44 0,21	
(e) Fabricated housing and structure of thruster units, stabilisers, etc.: • Main structure • Elsewhere	0,44 0,21	

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Table 2.4.3 Weld factors (*conclusion*)

Item	Weld Factor	Remarks
(9) Miscellaneous fittings and equipment:		
(a) Rings for manhole type covers, to deck or bulkhead	0,34	
(b) Frames of shell and weathertight bulkhead doors	0,34	
(c) Stiffening of doors	0,21	
(d) Ventilator, air pipes, etc., coamings to deck	0,34 0,21	Load Line Positions 1 and 2 elsewhere
(e) Ventilator, etc., fittings	0,21	
(f) Scuppers and discharges, to deck	0,44	
(g) Masts, crane pedestals, etc., to deck	0,44	full penetration welding may be required
(h) Deck machinery seats to deck	0,21	generally
(j) Mooring equipment seats	0,21	generally, but increased or full penetration may be required
(k) Bulwark stays to deck	0,21	
(l) Bulwark attachment to deck	0,34	
(m) Guard rails, stanchions, etc., to deck	0,34	
(n) Bilge keel ground bars to shell	0,34	continuous fillet weld, minimum throat thickness 4 mm
(o) Bilge keels to ground bars	0,21	light continuous or staggered intermittent fillet weld, minimum throat thickness 3 mm
(p) Fabricated anchors		full penetration

4.11.2 The weld connection to shell, deck or bulkhead is to take account of the material lost in the notch where longitudinals or stiffeners pass through the member. Where the width of notch exceeds 15 per cent of the stiffener spacing, the weld factor is to be multiplied by:

$$\frac{0{,}85 \times \text{stiffener spacing}}{\text{length of web plating between notches}}$$

4.11.3 Where direct calculation procedures have been adopted, the weld factors for the 0,2 x overall length at the ends of the members will be considered in relation to the calculated loads.

4.12 Primary and secondary member end connection welds

4.12.1 Welding of end connections of primary members is to be such that the area of welding is not less than the cross-sectional area of the member, and the weld factor is to be not less than 0,34 in tanks or 0,27 elsewhere.

4.12.2 The welding of secondary member end connections is to be not less than as required by Table 2.4.5. Where two requirements are given the greater is to be complied with.

4.12.3 The area of weld, A_w, is to be applied to each arm of the bracket or lapped connection.

4.12.4 Where a longitudinal strength member is cut at a primary support and the continuity of strength is provided by brackets, the area of weld is to be not less than the cross-sectional area of the member.

4.13 Weld connection of strength deck plating to sheerstrake

4.13.1 The weld connection of strength deck plating to sheerstrake is to be by double continuous fillet welding with a weld factor of 0,44. The welding procedure, including joint preparation, is to be specified and the procedure qualified and approved for individual Builders.

4.14 Air and drain holes

4.14.1 Air and drain holes are to be kept clear of the toes of brackets, etc. Openings are to be well rounded with smooth edges, *see also* LR's *Guidance Notes for Structural Details*.

4.15 Notches and scallops

4.15.1 Notches and scallops are to be kept clear of the toes of brackets, etc. Openings are to be well rounded with smooth edges. Details of scallops are shown in Fig. 2.4.1.

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Table 2.4.4 Throat thickness limits

Item	Throat thickness mm	
	Minimum	Maximum
(1) Double continuous welding	$0,21t_p$	$0,44t_p$
(2) Intermittent welding	$0,27t_p$	$0,44t_p$ or 4,5
(3) Overriding minimum:		
(a) Continuous welds	2,5	
(b) Intermittent welds:		
(i) Plate thickness $t_p \leq 7,5$ mm Hand or automatic welding	3,0	
Automatic deep penetration welding	3,0	
(ii) Plate thickness $t_p \geq 7,5$ mm Hand or automatic welding	3,25	
Automatic deep penetration welding	3,0	

NOTES
1. In all cases the limiting maximum value is to be taken as the greatest of the applicable values above.
2. The maximum throat thicknesses shown are intended only as a design limit for the approval of fillet welded joints. Any welding in excess of these limits is to be to the Surveyor's satisfaction.

4.15.2 Scallops are to be of such a size, and in such a position that a satisfactory weld can be made around the ends of openings.

4.16 Watertight collars

4.16.1 Watertight collars are to be fitted, where stiffeners are continuous through watertight or oiltight boundaries, *see also* LR's *Guidance Notes for Structural Details*.

4.17 Lug connections

4.17.1 The area of the weld connecting secondary stiffeners to primary structure in the bottoms of the hulls and cross-deck structure in areas subjected to impact pressures is to be not less than the shear area from the Rules. This area is to be obtained by fitting two lugs or by other equivalent arrangements. Some typical lug connections are shown in Fig. 2.4.2 and Fig. 3.1.7 in Chapter 3.

4.17.2 Lugs or tripping brackets are to be fitted where shell longitudinals are continuous through web frames in way of highly stressed areas of the side shell (e.g. in way of fenders, etc.).

4.17.3 Lugs or tripping brackets are also to be fitted where continuous secondary stiffeners are greater than half the depth of the primary stiffeners.

4.18 Insert plates

4.18.1 Where thick insert plates are butt welded to thin plates, the edge of the thick plate may require to be tapered. The slope of the taper is generally not to exceed one in three.

4.18.2 The corners of insert plates are to be suitably radiused.

Table 2.4.5 Secondary member end connection welds

Connection	Weld area, A_w, in cm^2	Weld factor
(1) Stiffener welded direct to plating	$0,25A_s$ or 6,5 cm^2 whichever is the greater	0,34
(2) Bracketless connection of stiffeners or stiffener lapped to bracket or bracket lapped to stiffener:		
(a) in dry space	$1,2\sqrt{Z}$	0,27
(b) in tank	$1,4\sqrt{Z}$	0,34
(c) main frame to tank side bracket in $0,15L_R$ forward	as (a) or (b)	0,34
(3) Bracket welded to face of stiffener and bracket connection to plating	—	0,34
(4) Stiffener to plating for 0,1 x span at ends, or in way of the end bracket if that be greater	—	0,34

Symbols

A_s = cross section area of the stiffener, in cm^2
A_w = the area of the weld, in cm^2, and is calculated as total length of weld, in cm, x throat thickness, in cm
Z = the section modulus, in cm^3, of the stiffener on which the scantlings of the end bracket are based.

NOTE
For maximum and minimum weld fillet sizes, *see* Table 2.4.4.

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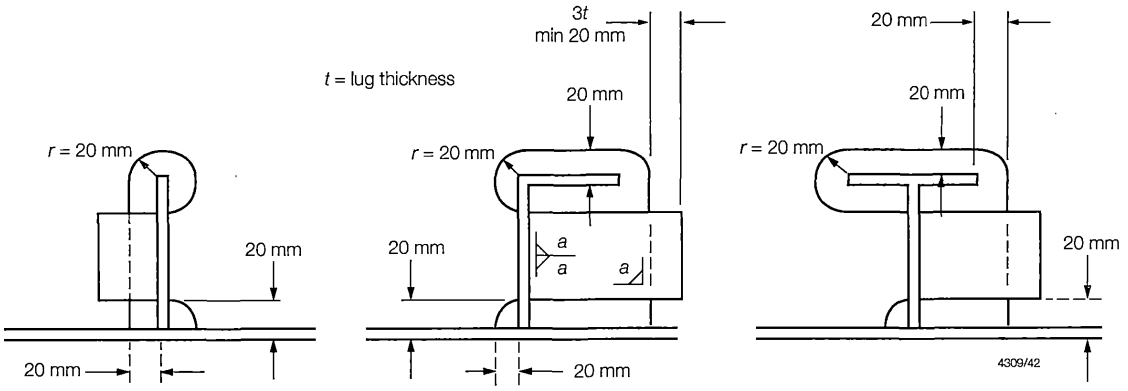

Fig. 2.4.3 Typical lug connections

4.19 Doubler plates

4.19.1 Doubler plates are to be avoided in areas where corrosion may be a problem and access for inspection and maintenance is limited.

4.19.2 Where doubler plates are fitted, they are to have well radiused corners and the perimeter is to be continuously welded. Large doubler plates are also to be suitably slot welded, the details of which are to be submitted for consideration.

4.20 Joint preparation

4.20.1 Typical butt joints are shown in Tables 2.4.1 and 2.4.2, *see also* LR's *Guidance Notes for Structural Details*.

4.21 Construction tolerances

4.21.1 The minimum requirements for construction tolerances are to be in accordance with Pt 3, Ch 1,8.

4.22 Riveting of light structure

4.22.1 Where it is proposed to adopt riveted construction, full details of the rivets or similar fastenings, including mechanical test results, are to be indicated on the construction plans submitted for approval or a separate riveting schedule is to be submitted.

4.22.2 Samples may be required of typical riveted joints made by the Builder under representative construction conditions and tested to destruction in the presence of the Surveyor in shear, tension, compression or peel at LR's discretion.

4.22.3 Where riveting strength data sheets have been issued by a recognised Authority, the values quoted in these sheets will normally be accepted for design purposes.

4.22.4 Where two dissimilar metals are to be joined by riveting, precautions are to be taken to eliminate electrolytic corrosion to LR's satisfaction, and where practicable, the arrangements should be such as to enable the joint to be kept under observation at each survey without undue removal of lining and other items.

4.22.5 Where a sealing compound is used to obtain an airtight or watertight joint, details are to be submitted of its proposed use and of any tests made or experience gained in its use for similar applications.

4.22.6 Aluminium alloy rivets in accordance with Ch 8,2 of the Rules for Materials are to be used where practicable. However, in the case of composite structures, including steel and GRP, consideration will be given to the use of steel rivets. In such cases, the mating surfaces are to be coated with a sealing paint.

4.22.7 Sealing paints or compounds are not to be used with hot driven rivets.

4.23 Chemical bonding of structure

4.23.1 Where chemical bonding of aluminium alloy of any load-bearing structure is proposed, details of the materials and the processes to be used are to be submitted for approval. These details are to include test results of samples manufactured under LR survey under workshop conditions to verify the strength, ageing effects and moisture resistance.

4.23.2 The adhesive manufacturer's recommendations in respect of the specified jointing system, comprising preparation of the surfaces to be adhered, the adhesive, bonding and curing processes, are to be strictly followed as variation of any step can severely affect the performance of the joint.

4.23.3 Meticulous preparation is essential where the joint is to be made by chemical bonding. The method of producing bonded joints is to be documented so that the process is repeatable after the procedure has been properly established.

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4.23.4 Bonded joints are suitable for carrying shear loads, but are not in general to be used in tension or where the load causes peeling or other forces tending to open the joint. Loads are to be carried over as large an area as possible.

4.23.5 Bonded joints are to be suitably supported after assembly for the period necessary to allow the optimum bond strength of the adhesive to be to be developed. Entrained air pockets are to be avoided.

4.23.6 The use of adhesives for main structural joints is not to be contemplated unless considerable testing has established its validity, including environmental testing and fatigue testing where considered necessary by LR.

4.24 Triaxial stress considerations

4.24.1 Particular care is to be taken to avoid triaxial stresses which may result from poor joint design. Detailed joint design is of particular importance in aluminium structures more so than many other materials. Some recommendations in this respect are contained in LR's *Guidance Notes for Structural Details*.

4.25 Butt straps

4.25.1 In general, the scantling derivation of welded structures are to be determined using the mechanical properties of the aluminium alloy in the welded condition in accordance with 2.4. However, where stiffeners are butt welded, special consideration will be given to the use of suitable butt straps on the flanges which sufficiently reinforce the area of the weld to allow the scantlings to be determined using the unwelded mechanical properties. The butt weld is to be completed and generally made flush with the flange of the stiffening member before the butt strap is fitted and the butt strap weld is to be continuous. Where this jointing method is proposed, the scantlings, arrangements and locations of all joints and butt straps are to be submitted. Additionally, LR may require mechanical tests to be carried out to demonstrate the effectiveness of such arrangements.

4.26 Extruded 'planking'

4.26.1 Joints between adjacent extruded aluminium alloy planking, and the attachment of the planking to the supporting structure is in general to be by means of continuous welding.

4.26.2 The planking is generally not to be included in the determination of the section properties for both section modulus and inertia. However, special consideration will be given to the inclusion of such materials on the basis of the efficiency of the connection to the supporting structure.

4.27 Aluminium/steel transition joints

4.27.1 Provision is made in this Section for explosion bonded composite aluminium/steel transition joints used for connecting aluminium structures to steel plating. Such joints are to be used in accordance with the manufacturer's requirements, *see also* Ch 8,4 of the Rules for Materials.

4.27.2 Transition joints are to be manufactured by an approved producer in accordance with an approved specification which is to include the maximum temperature allowable at the interface during welding.

4.27.3 The aluminium material is to comply with the requirements of Section 2 and the steel is to be of an appropriate grade complying with the requirements of Ch 3,2 of the Rules for Materials.

4.27.4 Alternative materials which comply with International, National or proprietary specifications may be accepted provided that they give equivalence to the requirements of 4.31.3 or are approved for a specific application.

4.27.5 Intermediate layers between the aluminium and steel may be used, in which case the material of any such layer is to be specified by the manufacturer and is to be recorded in the approval certificate. Any such intermediate layer is then to be used in all production transition joints.

4.27.6 Bimetallic joints where exposed to seawater or used internally within wet spaces are to be suitably protected to prevent galvanic corrosion.

4.28 Aluminium/wood connection

4.28.1 To minimise corrosion of aluminium when in contact with wood in a damp or marine environment the timber is to be primed and painted in accordance with good practice. Alternatively the surface of the aluminium in contact with the timber is to be coated with a substantial thickness of a suitable sealant.

4.28.2 Timbers such as western red cedar, oak and chestnut are not, unless well seasoned, to be directly in contact with aluminium.

4.28.3 Timber preservatives of the following types should be avoided: copper napthanate, copper-chrome-arsenate, borax-boric acid.

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Section

1 **General**

2 **Minimum thickness requirements**

3 **Shell envelope plating**

4 **Shell envelope framing**

5 **Single bottom structure and appendages**

6 **Double bottom structure**

7 **Bulkheads**

8 **Deck structures**

9 **Superstructures, deckhouses and bulwarks**

10 **Pillars and pillar bulkheads**

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull craft of aluminium construction as defined in Pt 1, Ch 2,2.

1.2 General

1.2.1 The formulae contained within this Chapter are to be used in conjunction with the design loadings from Part 5 to determine the Rule scantling requirements.

1.3 Direct calculations

1.3.1 Where the craft is of unusual design, form or proportions, or where the speed of the craft exceeds 60 knots the scantlings are to be determined by direct calculation.

1.3.2 The requirements of this Chapter may be modified where direct calculation procedures are adopted to analyse the stress distribution in the primary structure.

1.4 Equivalents

1.4.1 Lloyd's Register (hereinafter referred to as 'LR') will consider direct calculations for the derivation of scantlings as an alternative and equivalent to those derived by Rule requirements in accordance with Pt 3, Ch 1,3.

1.5 Symbols and definitions

1.5.1 The symbols used in this Chapter are defined below and in the appropriate Section:

k_a = alloy factor
= $125/\sigma_a$
l = stiffener overall length, in metres
l_e = effective span length, in metres, as defined in 1.19
p = design pressure, in kN/m^2, as given in Part 5
s = stiffener spacing, in mm
t_p = plating thickness, in mm
A_w = shear area of stiffener web, in cm^2
B = moulded breadth of craft, in metres, as defined in Pt 3, Ch 1,6
E = modulus of elasticity, in N/mm^2
I = moment of inertia, in cm^4
L_R = Rule length of craft, in metres, as defined in Pt 3, Ch 1,6
Z = section modulus of the stiffening member, in cm^3
β = panel aspect ratio correction factor as defined in 1.15
γ = convex curvature correction factor as defined in 1.14
σ_a = guaranteed minimum 0,2 per cent proof stress of the alloy in the welded condition, in N/mm^2, *see also* Ch 2,2.4.2

$$\tau_a = \frac{\sigma_a}{\sqrt{3}}$$

1.6 Rounding policy for Rule plating thickness

1.6.1 Where plating thicknesses as determined by the Rules require to be rounded then this is to be carried out to the nearest full or half millimetre, with thicknesses 0,75 and 0,25 being rounded up.

1.7 Dimensional tolerance

1.7.1 Dimensional tolerances for materials are to be in accordance with Chapter 8 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials), or an acceptable National or International Standard.

1.7.2 The under thickness tolerance acceptable for classification is to be considered as the lower limit of a range of thickness tolerance which could be found in the normal production of a conventional rolling mill manufacturing material, on average, to the nominal thickness.

1.7.3 The Owners and Builders may agree in individual cases whether they wish to specify a more stringent under thickness tolerance than that given in 1.7.2.

1.7.4 The minus tolerance on sections (except for wide flats) is to be in accordance with a National or International Standard.

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1.7.5 The thickness of plates and strip is to be measured at random locations whose distance from an edge is to be at least 25 mm. Local surface depressions resulting from imperfections and ground areas resulting from the elimination of defects may be disregarded provided that they are in accordance with the requirements of a National or International Standard.

1.7.6 The responsibility for maintaining the required tolerances and making the necessary measurements rests with the manufacturer/Builder. Occasional checking by the Surveyor does not absolve the manufacturer/Builder from the responsibility.

1.8 Material properties

1.8.1 The basic grade of aluminium alloy is taken as marine grade 5083-0 with the following mechanical properties:

	N/mm^2
0,2 per cent proof stress (minimum)	125
Tensile strength	260
Modulus of elasticity	69×10^3

1.8.2 Where other alloy grades with differing mechanical properties are to be used, due allowance is given in the determination of the Rule requirement for plating thickness, section modulus, inertia and cross-sectional area by use of the following correction factors:

(a) Plating thickness factor = $\sqrt{k_a}$

(b) Section modulus and cross section area factor = k_a where k_a is as defined in 1.5.1.

1.9 High strength sheet and plate

1.9.1 Particular attention is to be given to the welding procedures for the welding of high strength sheet and plate. The 0,2 per cent yield strength values in the welded condition will, in general, be significantly less than in the unwelded condition. These reduced values are to be used in the determination of the Rule scantlings.

1.10 High strength extrusions

1.10.1 The requirements of 1.9 are to be complied with. However, special consideration will be given to the use of un-welded strength properties for use in the determination of the Rule scantlings provided that suitable compensation is provided in way of welding on the face of the stiffener. This compensation can be provided by butt-straps or other acceptable arrangements, *see also* Ch 2,4.28.

1.10.2 The application of high strength extrusions is in general limited to superstructures, deckhouses, decks and bulkheads. Special consideration will be given to their use in other areas.

1.10.3 Butt welds and seams are to be carefully positioned clear of areas of high stress and where practicable are to be orientated parallel to the direction of the main stresses.

1.11 Effective width of attached plating

1.11.1 The effective geometric properties of rolled or built sections are to be calculated directly from the dimensions of the section and associated effective area of attached plating. Where the web of the section is not normal to the actual plating, and the angle exceeds 20°, the properties of the section are to be determined about an axis parallel to the attached plating.

1.11.2 For stiffening members, the geometric properties of rolled or built sections are to be calculated in association with an effective area of attached load bearing plating of thickness t_p, in mm and a breadth b_e, in mm, b_e is as defined in 1.11.3 and 1.11.4.

1.11.3 The effective width of attached plating to secondary members b_e is to be taken as $2t_p\sqrt{E/\sigma_a}$ but not greater than s. σ_a is not to be taken as greater than 169 N/mm^2 for aluminium alloy. E, s and σ_a are as defined in 1.5.1.

1.11.4 The effective breadth of attached plating to primary support members (girders, transverses, webs, etc.) b_e is to be taken as bf, where b and f are as defined in Pt 3, Ch 2,3.2.1.

1.11.5 Where primary stiffening members support areas of plating of the extruded plank type, or the floating frame system is used, the effect of the plating attached to the secondary stiffening members is to be ignored when calculating the actual section modulus and inertia of the primary stiffening members, i.e. the full section modulus and inertia are to be provided by the primary stiffening member only, *see also* Ch 2,4.27.

1.12 Other materials

1.12.1 Special consideration will be given to the use of materials other than aluminium alloy. Details of the type of material, the specification to which it was manufactured and its mechanical properties are to be submitted for appraisal.

1.13 Fibre reinforced plastic (FRP)

1.13.1 The use of FRP in construction is to be in accordance with Part 8.

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1.14 Convex curvature correction

1.14.1 The thickness of plating as determined by the Rules may be reduced where significant curvature exists between the supporting members. In such cases a plate curvature correction factor may be applied:

γ = plate curvature factor
= $1 - h/s$, and is not to be taken as less than 0,7

h = the distance, in mm, measured perpendicularly from the chord length s (i.e. spacing) to the highest point of the curved plating arc between the two supports

See Fig. 3.1.1.

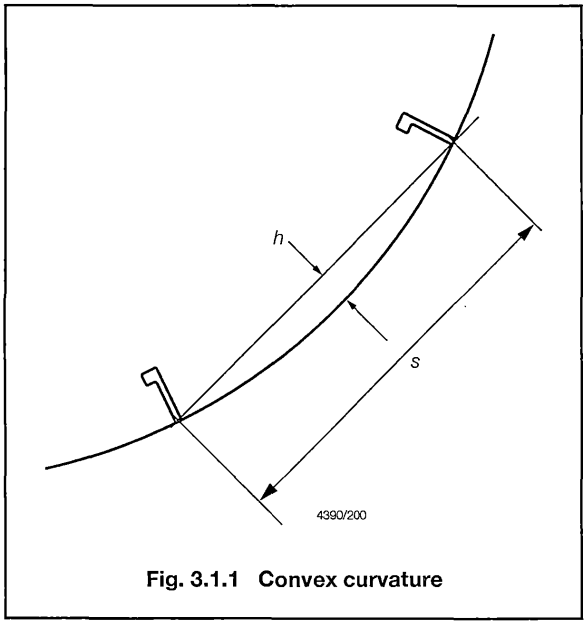

Fig. 3.1.1 Convex curvature

1.15 Aspect ratio correction

1.15.1 The thickness of plating as determined by the Rules may be reduced when the panel aspect ratio is taken into consideration. In such cases a panel aspect ratio correction factor may be applied:

β = aspect ratio correction factor
= $A_R (1 - 0{,}25A_R)$ for $A_R \leq 2$
= 1 for $A_R > 2$

where

A_R = panel aspect ratio
= panel length/panel breadth.

1.16 Plating general

1.16.1 The requirements for the thickness of plating, t_p, is, in general, to be in accordance with the following:

$$t_p = 22{,}4s\,\gamma\,\beta\sqrt{\frac{p}{f_\sigma\,\sigma_a}} \times 10^{-3} \text{ mm}$$

where

f_σ = limiting bending stress coefficient for the plating element under consideration is given in Table 7.3.1 in Chapter 7.

s, γ, β, p, σ_a are as defined in 1.5.1.

1.17 Stiffening general

1.17.1 The requirements for section modulus, inertia and web area of stiffening members are in general to be in accordance with the following:

(a) Section modulus:

$$Z = \Phi_Z \frac{p\,s\,l_e^2}{f_\sigma\,\sigma_a} \text{ cm}^3$$

where

Φ_z = section modulus coefficient dependent on the loading model assumption taken from Table 3.1.1

f_σ = limiting bending stress coefficient for stiffening member given in Table 7.3.1 in Chapter 7.

p, s, l_e and σ_a are as defined in 1.5.

(b) Inertia:

$$I = \Phi_I f_\delta \frac{p\,s\,l_e^3}{E} \times 100 \text{ cm}^4$$

where

Φ_I = inertia coefficient dependent on the loading model assumption taken from Table 3.1.1

f_δ = limiting deflection coefficient for stiffener member given in Table 7.2.1 in Chapter 7.

p, s, l_e and E are as defined in 1.5.1.

(c) Web area:

$$A_w = \Phi_A \frac{p\,s\,l_e}{100 f_\tau\,\tau_a} \text{ cm}^2$$

where

Φ_A = web area coefficient dependent on the loading model assumption taken from Table 3.1.1

f_τ = limiting shear stress coefficient for stiffener member given in Table 7.3.1 in Chapter 7

p, s, l_e and τ_a are as defined in 1.5.1.

1.18 Geometric properties and proportions of stiffener sections

1.18.1 From structural stability and local buckling considerations, the proportions of stiffening members are, in general, to be in accordance with Table 3.1.2.

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Table 3.1.1 Section modulus, inertia and web area coefficients

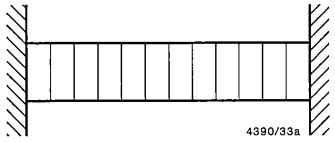
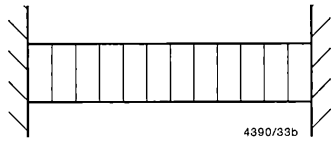
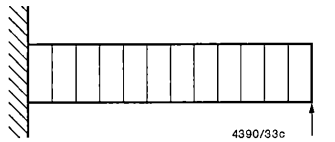
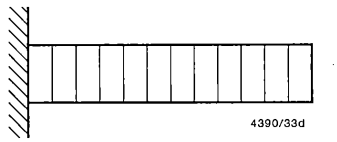
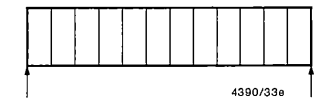
Load model	Position 1	Position 2	Position 3	Position	Web area coefficient Φ_A	Section modulus coefficient Φ_Z	Inertia coefficient Φ_I	Application
(a)	 4390/33a			1 2 3	1/2 — 1/2	1/12 1/24 1/12	— 1/384 —	Primary and other members where the end fixity is considered encastre
(b)	 4390/33b			1 2 3	1/2 — 1/2	1/10 1/10 1/10	— 1/288 —	Local, secondary and other members where the end fixity is considered to be partial
(c)	 4390/33c			1 2 3	5/8 — 3/8	1/8 9/128 —	— 1/185 —	Various
(d)	 4390/33d			1 2 3	1 — —	1/2 — —	— — 1/8	Various
(e)	 4390/33e			1 2 3	1/2 — 1/2	— 1/8 —	— 5/384 —	Hatch covers, glazing and other members where the ends are simply supported

Table 3.1.2 Stiffener proportions

Type of stiffener	Requirement
(1) Flat bar	Minimum web thickness: $t_w = d_w/15$ ≥ 3 mm
(2) Rolled or built sections	(a) Minimum web thickness: $t_w = d_w/50$ ≥ 3 mm (b) Maximum unsupported face plate (or flange) width: $b_f = 16\ t_f$
Symbols	
t_w = web thickness of stiffener with unstiffened webs, in mm d_w = web depth of stiffener, in mm b_f = face plate (or flange) unsupported width, in mm t_f = face plate (or flange) thickness, in mm	

1.19 Determination of span point

1.19.1 The effective length of span, l_e, of a stiffening member is generally less than the overall length, l, by an amount which depends on the design of the end connections. The span points, between which the value of l_e is measured, are to be determined as follows:

(a) For rolled or built-up secondary stiffening members:
The span point is to be taken at the point where the depth of the end bracket, measured from the face of the secondary stiffening member, is equal to the depth of the member, *see* Fig. 3.1.2. Where there is no end bracket, the span point is to be measured between primary member webs.

(b) For primary support members:
The span point is to be taken at a point distant, b_e from the end of the member, where

$$b_e = b_b\left(1 - \frac{d_w}{d_b}\right)$$

where b_e, b_b, d_w and d_B are as shown in Fig. 3.1.2.

1.19.2 Where the stiffener member is inclined to a vertical or horizontal axis and the inclination exceeds 10°, the span is to be measured along the member.

1.19.3 Where the stiffening member is curved then the span is to be taken as the effective chord length between span points.

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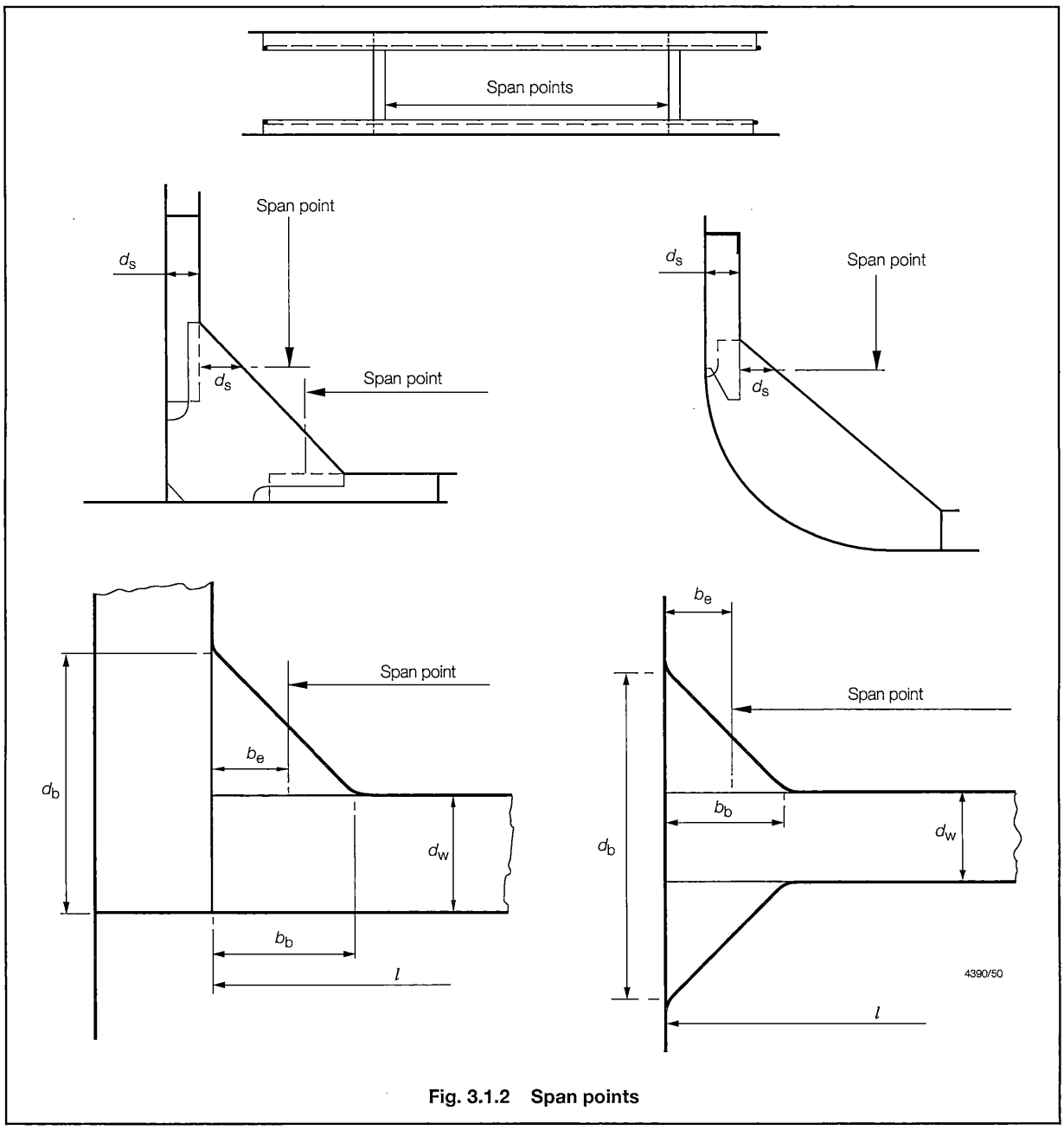

Fig. 3.1.2 Span points

1.19.4 Where there is a pronounced turn of bilge, chine or the structure is significantly pitched, the span may be measured as in Fig. 3.1.2.

1.19.5 It is assumed that the ends of stiffening members are substantially fixed against rotation and displacement. If the arrangement of supporting structure is such that this condition is not achieved, consideration will be given to the effective span to be used for the stiffener.

1.20 Secondary member end connections

1.20.1 Secondary members, that is longitudinals, beams, frames and bulkhead stiffeners forming part of the hull structure, are to be effectively continuous and are to be suitably bracketed at their end connections. Where it is desired to adopt bracketless connections, the proposed arrangements will be individually considered, *see also* Ch 2,4.15 and Table 2.4.5 in Chapter 2.

1.20.2 Where bracketed end connections are fitted in accordance with these requirements, they may be taken into account in determining the effective span of the member.

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1.20.3 The scantlings of secondary member end connections are to be in accordance with 1.21.

1.21 Scantlings of end brackets

1.21.1 Where a longitudinal strength member is cut at a primary support and the continuity of strength is provided by brackets, the scantlings of the end brackets are to be such that their section modulus and effective cross-sectional area are not less than those of the member. Care is to be taken to ensure correct alignment of the brackets on each side of the primary member.

1.21.2 In other cases the scantlings of the bracket are to be based on the modulus as follows:

(a) Bracket connecting stiffener to primary member – modulus of the stiffener.

(b) Bracket at the head of a main transverse frame where frame terminates – modulus of the frame.

(c) Brackets connecting lower deck beams or longitudinals to the main frame in the forward $0{,}5L_R$ – modulus of the frame.

(d) Elsewhere – the lesser modulus of the members being connected by the bracket.

1.21.3 The web thickness and face flat area of end brackets are not in general to be less than those of the connecting stiffeners. Additionally, the stiffener proportion requirements of 1.18 are to be satisfied.

1.21.4 Typical arrangements of stiffener end brackets are shown diagrammatically in Fig. 3.1.3.

1.21.5 The lengths, *a* and *b* of the arms are to be measured from the plating to the toe of the bracket and are to be such that:

(a) $a + b \geq 2{,}0l_b$

(b) $a \geq 0{,}8l_b$

(c) $b \geq 0{,}8l_b$

where *a* and *b* are the actual lengths of the two arms of the bracket, in mm, measured from the plating to the toe of the bracket.

$$l_b = 90\left(2\sqrt{\frac{Z}{14+\sqrt{Z}}} - 1\right) \text{ mm}$$

Z = the section modulus of the secondary member, in cm^3

In no case is l_b to be taken as less than twice the web depth of the stiffener on which the bracket scantlings are to be based.

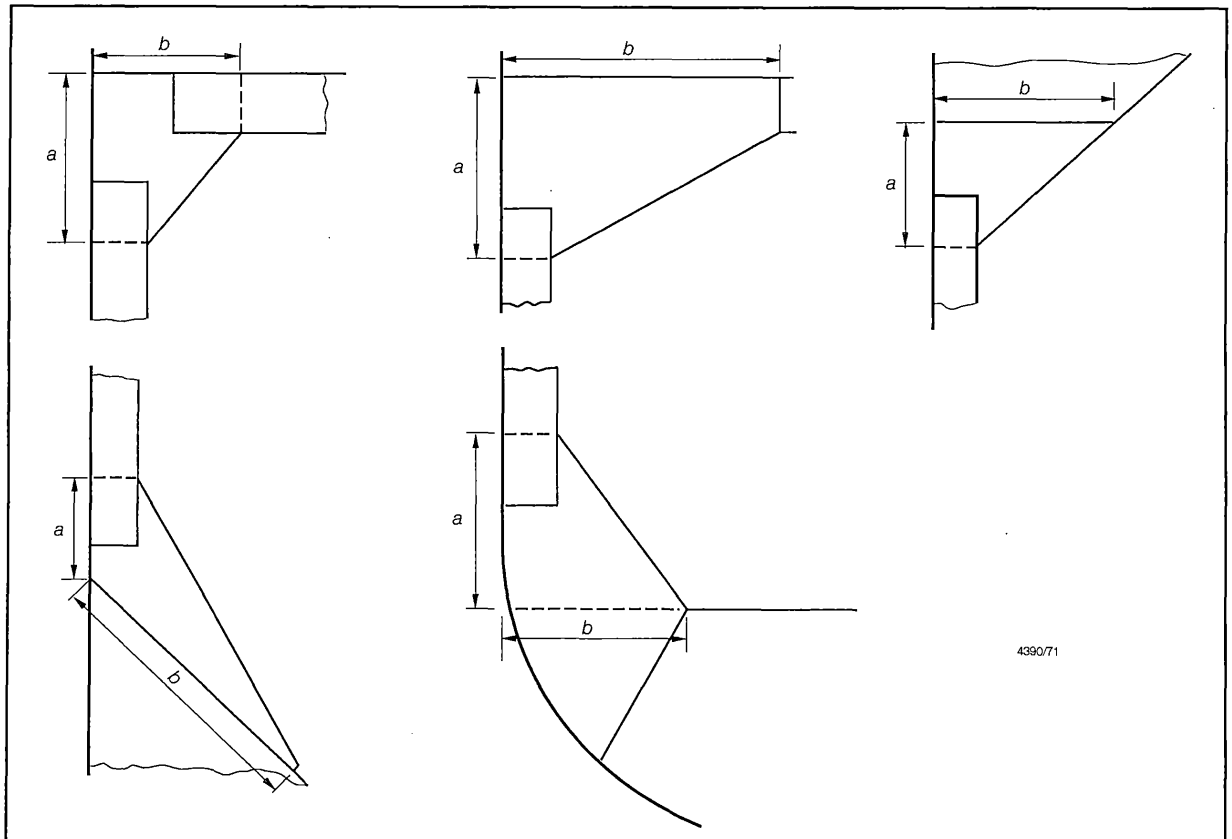

Fig. 3.1.3 Stiffener end brackets

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1.21.6 The free edge of the bracket is to be stiffened where any of the following apply:

(a) The section modulus, Z, exceeds 500 cm^3.

(b) The length of free edge exceeds 40 times the bracket thickness.

(c) The bracket is fitted at the lower end of main transverse side framing.

1.21.7 Where a face flat is fitted, its breadth, b_f, is to be not less than:

$$b_f = 30\left(1 + \frac{Z}{1000}\right) \text{ mm}$$

but not less than 40 mm.

1.21.8 Where the edge is stiffened by a welded face flat, the cross-sectional area of the face flat is to be not less than:

(a) $0{,}017 k_a b_f T_B$ cm^2 for offset edge stiffening.

(b) $0{,}014 k_a b_f T_B$ cm^2 for symmetrically placed stiffening.

b_f = breadth of face flat, in mm

T_B = the thickness of the bracket, in mm

k_a is as defined in 1.5.1.

1.21.9 Where the stiffening member is lapped onto the bracket, the length of overlap is to be adequate to provide for the required area of welding. In general, the length of overlap is not to be less than $10\sqrt{Z}$, or the depth of stiffener, whichever is the greater.

1.21.10 Where the free edge of the bracket is hollowed out, it is to be stiffened or increased in size to ensure that the modulus of the bracket through the throat is not less than that of the required straight edged bracket.

1.21.11 The arrangement of the connection between the stiffener and the bracket is to be such that at no point in the connection is the actual modulus reduced to less than that of the stiffener with associated plating.

1.21.12 The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint.

1.22 Primary member end connections

1.22.1 The requirements for section modulus and inertia (if applicable) of primary members are given in the appropriate Chapter. The scantling requirements for primary member end connections in dry spaces and in tanks of all craft types are generally to comply with the requirements of 1.21, taking Z as the section modulus of the primary member.

1.22.2 Primary members are to be so arranged as to ensure effective continuity of strength, and abrupt changes of depth or section are to be avoided. Where members abut on both sides of a bulkhead, or on other members, arrangements are to be made to ensure that they are in alignment. Primary members in tanks are to form a continuous line of support and wherever possible, a complete ring system.

1.22.3 The members are to have adequate lateral stability and web stiffening and the structure is to be arranged to minimise hard spots and other sources of stress concentration. Openings are to have well rounded corners and smooth edges and are to be located having regard to the stress distribution and buckling strength of the panel.

1.22.4 Primary members are to be provided with adequate end fixity by end brackets or equivalent structure. The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint and effective distribution of the load from the member.

1.22.5 Where the primary member is supported by structure which provides only a low degree of restraint against rotation, the member is generally to be extended beyond the point of support and thereafter tapered and/or scarfed into the adjacent structure over a distance generally not less than two frame spaces.

1.22.6 Where primary members are subject to concentrated loads, particularly if these are out of line with the member web, additional strengthening may be required.

1.22.7 The thickness of the bracket is to be not less than that of the primary member web. The free edge of the bracket is to be stiffened.

1.22.8 Where a deck girder or transverse is connected to a vertical member on the shell or bulkhead, the scantlings of the latter may be required to be increased to provide adequate stiffness to resist rotation of the joint.

1.22.9 Where a member is continued over a point of support, such as a pillar or pillar bulkhead stiffener, the design of the end connection is to be such as to ensure the effective distribution of the load into the support. Proposals to fit brackets of reduced scantlings, or alternative arrangements, will be considered.

1.22.10 Connections between primary members forming a ring system are to minimise stress concentrations at the junctions. Integral brackets are generally to be radiused or well rounded at their toes. The arm length of the bracket, measured from the face of the member, is to be not less than the depth of the smaller member forming the connection.

1.23 Tank boundary penetrations

1.23.1 Where structural members pass through the boundary of a tank, and leakage into the adjacent space could be hazardous or undesirable, full penetration welding is to be adopted for the members for at least 150 mm on each side of the boundary. Alternatively a small scallop of suitable shape may be cut in the member close to the boundary outside the compartment, and carefully welded all round.

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1.24 Web stability

1.24.1 Primary members of asymmetrical section are to be supported by tripping brackets at alternate secondary members. If the section is symmetrical, the tripping brackets may be four spaces apart.

1.24.2 Tripping brackets are in general required to be fitted at the toes of end brackets and in way of heavy or concentrated loads such as the heels of pillars. *See also* LR's *Guidance Notes for Structural Details*.

1.25 Openings in the web

1.25.1 Where openings are cut in the web, the depth of opening is not to exceed 50 per cent of the web depth, and the opening is to be so located that the edges are not less than 25 per cent of the web depth from the face plate. The length of opening is not to exceed the web depth or 60 per cent of the secondary member spacing, whichever is the greater, and the ends of the openings are to be equidistant from the corners of cut-outs for secondary members. Where larger openings are proposed, the arrangements and compensation required will be specially considered.

1.25.2 Openings are to have smooth edges and well rounded corners.

1.26 Continuity and alignment

1.26.1 The arrangement of material is to be such as will ensure structural continuity. Abrupt changes of shape or section, sharp corners and points of stress concentration are to be avoided.

1.26.2 Where members abut on both sides of a bulkhead or similar structure, care is to be taken to ensure good alignment.

1.26.3 Pillars and pillar bulkheads are to be fitted in the same vertical line wherever possible, and elsewhere arrangements are to be made to transmit the out of line forces satisfactorily. The load at head and heel of pillars is to be effectively distributed and arrangements are to be made to ensure the adequacy and lateral stability of the supporting members.

1.26.4 Continuity is to be maintained where primary members intersect and where the members are of the same depth, a suitable gusset plate is to be fitted, *see* Fig. 3.1.4.

1.26.5 End connections of structural members are to provide adequate end fixity and effective distribution of the load into the supporting structure.

1.26.6 The toes of brackets, etc., are not to land on unstiffened panels of plating. Special care is to be taken to avoid notch effects at the toes of brackets, by making the toe concave or otherwise tapering it off, *see also* LR's *Guidance Notes for Structural Details*.

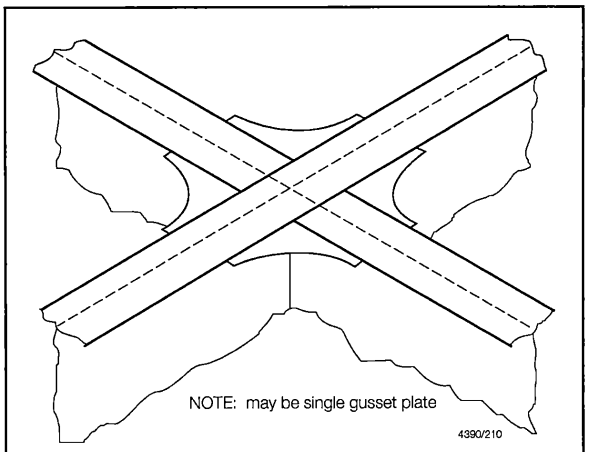

Fig. 3.1.4 Primary member intersection

1.26.7 Particular attention is to be paid to the design of the end bracket toes in order to minimise stress concentrations. Sniped face plates which are welded onto the edge of primary member brackets are to be carried well around the radiused part of the bracket toe and are to incorporate a taper not exceeding one in three. Where sniped face plates are welded adjacent to the edge of primary member brackets, adequate cross sectional area is to be provided through the bracket toe at the end of the snipe. In general, this area measured perpendicular to the face plate, is to be not less than 60 per cent of the full cross-sectional area of the face plate, *see* Fig. 3.1.5.

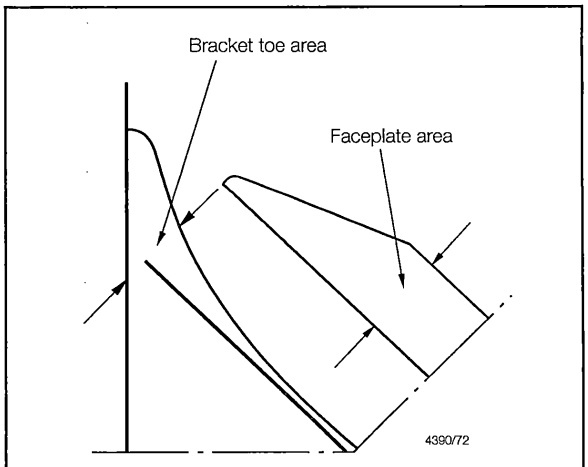

Fig. 3.1.5 Bracket toe construction

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1.27 Arrangement with offset stiffener

1.27.1 Where the stiffeners of the double bottom floors and transverse bulkheads are unconnected to the secondary members and offset from them, *see* Fig. 3.1.6, the collar arrangement for the secondary members are to satisfy the requirements of 1.28. In addition, the fillet welds attaching the lugs to the secondary members are to be based on a weld factor of 0,44 for the throat thickness. To facilitate access for welding the offset stiffeners are to be located 50 mm from the slot edge furthest from the web of the secondary member. The ends of the offset stiffeners are to be suitably tapered and softened.

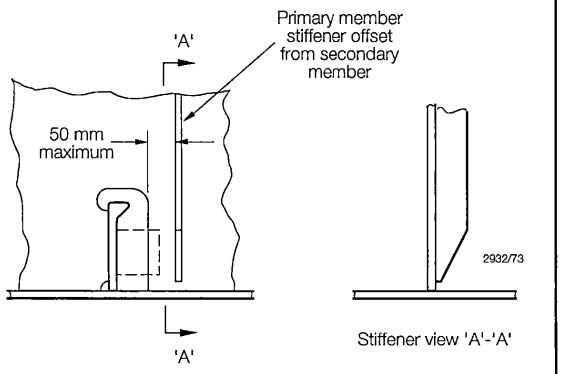

Fig. 3.1.6 Arrangement with offset stiffener

1.27.2 Alternative arrangements will be considered on the basis of their ability to transmit load with equivalent effectiveness. Details of the calculations made and testing procedures are to be submitted.

1.28 Arrangements at intersection of continuous secondary and primary members

1.28.1 Cut-outs for the passage of secondary members through the webs of primary members, and the related collaring arrangements, are to be designed to minimise stress concentrations around the perimeter of the opening and in the attached hull envelope or bulkhead plating. The critical shear buckling stress of the panel in which the cut-out is made is to be investigated. Cut-outs for longitudinals will be required to have double lugs in areas of high stress.

1.28.2 The breadth of cut-outs is to be as small as practicable, with the top edge suitably radiused. Cut-outs are to have smooth edges, and the corner radii are to be as large as practicable, with a minimum of 20 per cent of the breadth of the cut-out or 25 mm, whichever is the greater. It is recommended that the web plate connection to the hull envelope, or bulkhead, end in a smooth tapered 'soft toe'. Recommended shapes of cut-out are shown in Fig. 3.1.7, but consideration will be given to other shapes on the basis of maintaining equivalent strength and minimising stress concentration, *see also* LR's *Guidance Notes for Structural Details*.

1.28.3 Consideration is to be given to the provision of adequate drainage and unimpeded flow of air and water when designing the cut-outs and connection details.

1.28.4 Asymmetrical secondary members are to be connected on the heel side to the primary member web plate. Additional connection by lugs on the opposite side may be required.

1.28.5 Symmetrical secondary members are to be connected by lugs on one or both sides, as necessary.

1.28.6 Where the primary member stiffener is connected to the secondary member it is to be aligned with the web of the secondary member, except where the face plate of the latter is offset and abutted to the web, in which case the stiffener connection is to be lapped.

1.28.7 Fabricated longitudinals having the face plate welded to the underside of the web, leaving the edge of the web exposed, are not recommended for side shell and longitudinal bulkhead longitudinals. Where it is proposed to fit such sections, a symmetrical arrangement of connection to transverse members is to be incorporated. This can be achieved by fitting backing structure on the opposite side of the transverse web or bulkhead.

1.28.8 Where a bracket is fitted to the primary member web plate in addition to a connected stiffener it is to be arranged on the opposite side to, and in alignment with the stiffener. The arm length of the bracket is to be not less than the depth of the stiffener, and its cross-sectional area through the throat of the bracket is to be included in the calculation of the area of the primary web stiffener in way of the connection.

1.28.9 Alternative arrangements will be considered on the basis of their ability to transmit load with equivalent effectiveness. Details of the calculations made and testing procedures are to be submitted.

1.29 Openings

1.29.1 Manholes, lightening holes and other cut-outs are to be avoided in way of concentrated loads and areas of high shear. In particular, manholes and similar openings are not to be cut in vertical or horizontal diaphragm plates in narrow cofferdams or in floors and double bottom girders close to their span ends, or below the heels of pillars, unless the stresses in the plating and the panel buckling characteristics have been calculated and found satisfactory.

1.29.2 Manholes, lightening holes and other openings are to be suitably framed and stiffened where necessary.

1.29.3 Air and drain holes, notches and scallops are to be kept at least 200 mm clear of the toes of end brackets and other areas of high stress. Openings are to be well rounded with smooth edges. Closely spaced scallops are not permitted. Widely spaced air or drain holes may be accepted, provided that they are of elliptical shape, or equivalent, to minimise stress concentration and are, in general, cut clear of the weld connection.

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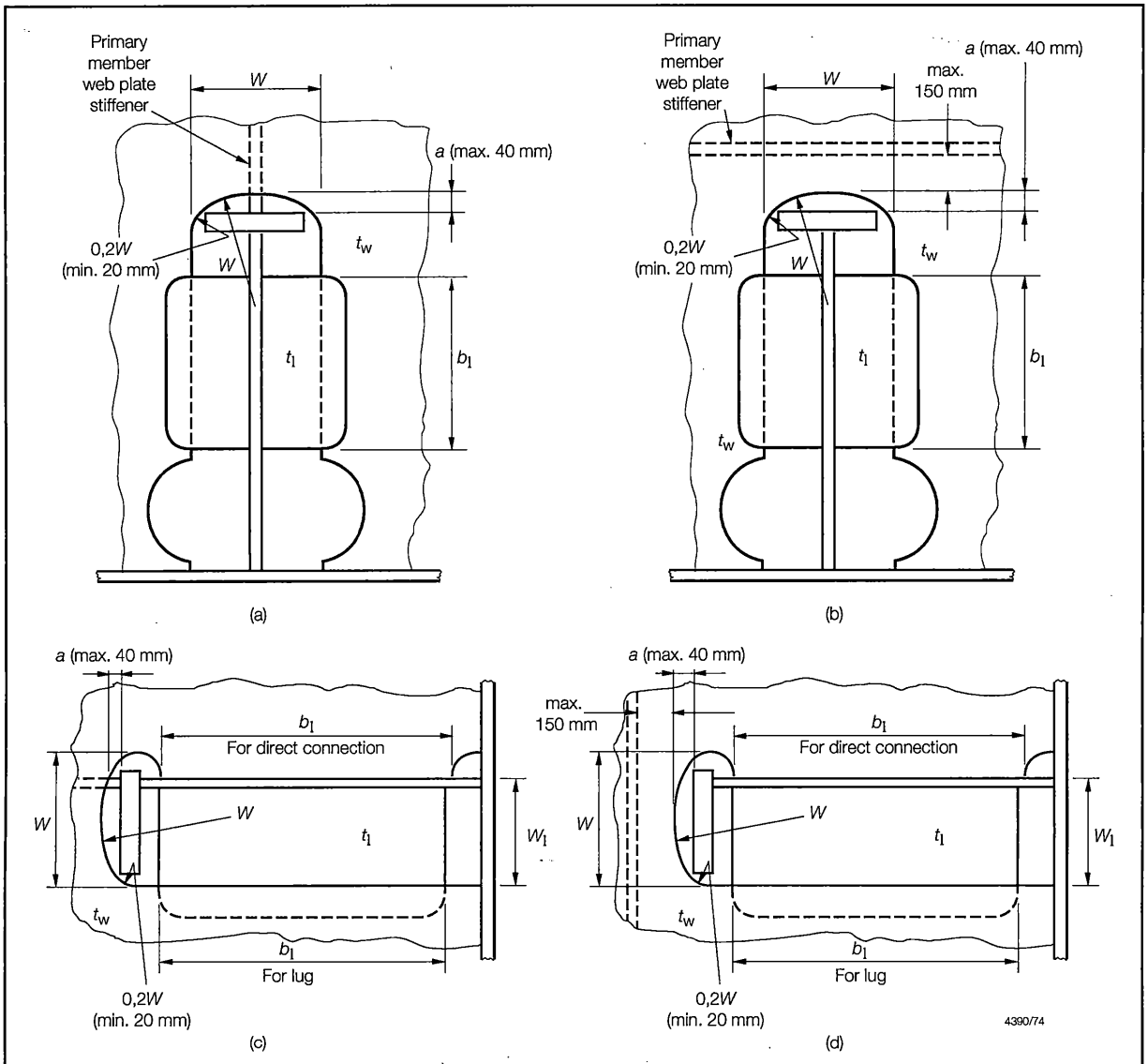

Fig. 3.1.7 Cut-outs and connections

1.30 Fittings and attachments, general

1.30.1 The quality of welding and general workmanship of fittings and attachments as given in 1.31 and 1.32 are to be in accordance with Ch 2,3.8.

1.31 Bilge keels and ground bars

1.31.1 It is recommended that bilge keels are not to be fitted in the forward $0,3L_R$ region on ships intended to navigate in ice conditions.

1.31.2 Bilge keels are to be attached to a continuous ground bar as shown in Fig. 3.1.8. Butt welds in shell plating, ground bar and bilge keels are to be staggered.

1.31.3 The thickness of the ground bar is to be not less than the thickness of the bottom shell or 8 mm, whichever is the greater, but need not be taken as greater than 15 mm.

1.31.4 The material class, grade and quality of the ground bar are to be similar to those of the adjacent shell plating.

1.31.5 The ground bar is to be connected to the shell with a continuous fillet weld and the bilge keel to the ground bar with a light continuous fillet weld.

1.31.6 Direct connection between ground bar butt welds and shell plating, and between bilge keel butt welds and ground bar is to be avoided.

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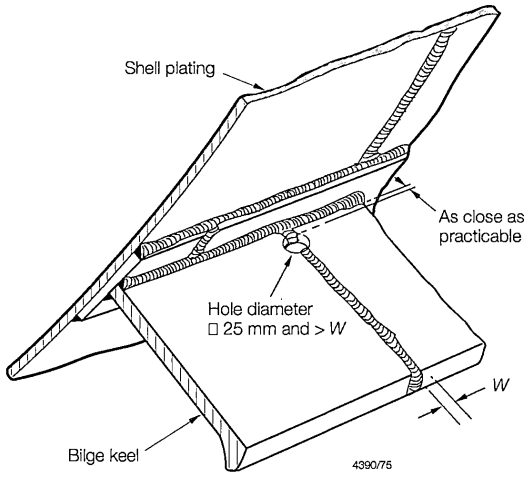

Fig. 3.1.8 Bilge keel construction

1.31.7 The end details of bilge keels and intermittent bilge keels, where adopted, are to be as shown in Fig. 3.1.9.

1.31.8 The ground bar and bilge keel ends are to be tapered or rounded. Where the ends are tapered, the tapers are to be gradual with ratios of at least 3:1, *see* Figs. 3.1.9(a) and (b). Where the ends are rounded, details are to be as shown in Fig. 3.1.9(c). Cut-outs on the bilge keel web within zone 'A' (*see* Fig. 3.1.9(b)) are not permitted.

1.31.9 The end of the bilge keel web is to be between 50 mm and 100 mm from the end of the ground bar, *see* Fig. 3.1.9(a).

1.31.10 An internal transverse support is to be positioned as close as possible to halfway between the end of the bilge keel web and the end of the ground bar, *see* Fig. 3.1.9(b).

1.31.11 Where an internal longitudinal stiffener is fitted in line with the bilge keel web, the longitudinal stiffener is to extend to at least the nearest transverse member outside zone 'A', *see* Fig. 3.1.9(b). In this case, the requirement of 1.31.10 does not apply.

1.31.12 For craft over 65 m in length, L_R, holes are to be drilled in the bilge keel butt welds. The size and position of these holes are to be as illustrated in Fig. 3.1.8. Where the butt weld has been subject to non-destructive examination the stop hole may be omitted.

1.31.13 Bilge keels of a different design from that shown in Fig. 3.1.8 and Fig. 3.1.9 will be specially considered.

1.31.14 Within zone 'B' (*see* Fig. 3.1.9(a)), welds at the ends of the ground bar and the bilge plating, and at the ends of the bilge keel web and ground bar, are to have weld factors of 0,44 and 0,34 respectively. These welds are to be ground and to blend smoothly with the base materials.

1.31.15 A plan of the bilge keels is to be submitted for approval of material grades, welded connections and detail design.

1.32 Other fittings and attachments

1.32.1 Gutterway bars at the upper deck are to be so arranged that the effect of main hull stresses on them is minimised.

1.32.2 Minor attachments, such as pipe clips, staging lugs and supports, are generally to be kept clear of toes of end brackets, corners of openings and similar areas of high stress. Where connected to asymmetrical stiffeners, the attachments may be in line with the web providing the fillet weld leg length is clear of the offset face plate or flange edge. Where this cannot be achieved the attachments are to be connected to the web, and in the case of flanged stiffeners they are to be kept at least 25 mm clear of the flange edge. On symmetrical stiffeners, they may be connected to the web or to the centre-line of the face plate in line with the web.

1.32.3 Where necessary in the construction of the craft, lifting lugs may be welded to the hull plating but they are not to be slotted through. Where they are subsequently removed, this is to be carried out by mechanical cutting close to the plate surface, and the remaining material and welding ground off. After removal the area is to be carefully examined to ensure freedom from cracks or other defects in the plate surface.

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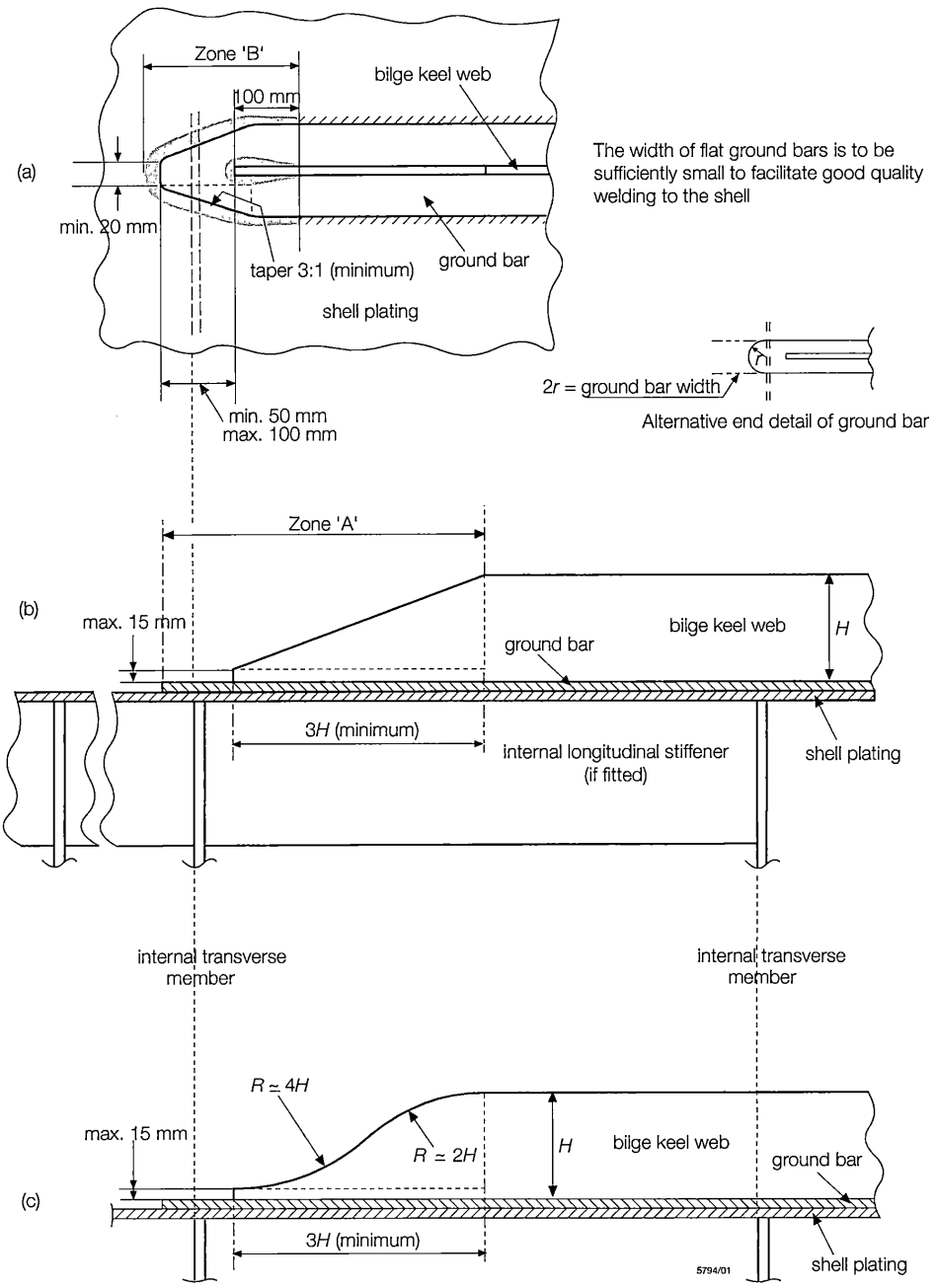

Fig. 3.1.9 Bilge keel end design

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Section 2
Minimum thickness requirements

2.1 General

2.1.1 The thickness of plating and stiffeners determined from the Rule scantling requirements is in no case to be less than that given in Table 3.2.1 for the craft type.

2.1.2 In addition, where plating contributes to the global strength of the craft, the thickness is to be not less than that required to satisfy the global strength requirements detailed in Chapter 6.

2.2 Corrosion margin

2.2.1 The minimum thicknesses given in Table 3.2.1 are based on the assumption that there is negligible loss in strength by corrosion. Where this is not the case the minimum thickness will be specially considered.

Table 3.2.1 Minimum thickness requirements

Item	Minimum thickness (mm)		
	Mono-hull	Hydrofoil	Rigid inflatable boat (RIB)
Shell envelope			
Bottom shell plating	$\omega\ \sqrt{k_m}\,(0{,}7\sqrt{L_R} + 1{,}0) \geq 4{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}7\sqrt{L_R} + 1{,}0) \geq 4{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}7\sqrt{L_R} + 1{,}0) \geq 4{,}0\ \omega$
Side shell plating	$\omega\ \sqrt{k_m}\,(0{,}5\sqrt{L_R} + 1{,}4) \geq 3{,}5\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}5\sqrt{L_R} + 1{,}4) \geq 3{,}5\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}5\sqrt{L_R} + 1{,}4) \geq 3{,}5\ \omega$
Single bottom structure			
Centre girder web	$\omega\ \sqrt{k_m}\,(1{,}1\sqrt{L_R} + 1{,}4) \geq 5{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(1{,}1\sqrt{L_R} + 1{,}4) \geq 5{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(1{,}1\sqrt{L_R} + 1{,}4) \geq 5{,}0\ \omega$
Floor webs	$\omega\ \sqrt{k_m}\,(0{,}8\sqrt{L_R} + 1{,}1) \geq 4{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}8\sqrt{L_R} + 1{,}1) \geq 4{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}8\sqrt{L_R} + 1{,}1) \geq 4{,}0\ \omega$
Side girder webs	$\omega\ \sqrt{k_m}\,(0{,}8\sqrt{L_R} + 1{,}1) \geq 4{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}8\sqrt{L_R} + 1{,}1) \geq 4{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}8\sqrt{L_R} + 1{,}1) \geq 4{,}0\ \omega$
Double bottom structure			
Centre girder			
(1) Within $0{,}4L_R$ amidships	$\omega\ \sqrt{k_m}\,(1{,}1\sqrt{L_R} + 1{,}4) \geq 5{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(1{,}1\sqrt{L_R} + 1{,}4) \geq 5{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(1{,}1\sqrt{L_R} + 1{,}4) \geq 5{,}0\ \omega$
(2) Outside $0{,}4L_R$ amidships	$\omega\ \sqrt{k_m}\,(0{,}95\sqrt{L_R} + 1{,}4) \geq 5{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}95\sqrt{L_R} + 1{,}4) \geq 5{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}95\sqrt{L_R} + 1{,}4) \geq 5{,}0\ \omega$
Floors and side girders	$\omega\ \sqrt{k_m}\,(0{,}8\sqrt{L_R} + 1{,}1) \geq 4{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}8\sqrt{L_R} + 1{,}1) \geq 4{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}8\sqrt{L_R} + 1{,}1) \geq 4{,}0\ \omega$
Inner bottom plating	$\omega\ \sqrt{k_m}\,(0{,}7\sqrt{L_R} + 1{,}3) \geq 3{,}5\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}7\sqrt{L_R} + 1{,}3) \geq 3{,}5\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}7\sqrt{L_R} + 1{,}3) \geq 3{,}5\ \omega$
Bulkheads			
Watertight bulkhead plating	$\omega\ \sqrt{k_m}\,(0{,}43\sqrt{L_R} + 1{,}2) \geq 3{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}43\sqrt{L_R} + 1{,}2) \geq 3{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}43\sqrt{L_R} + 1{,}2) \geq 3{,}0\ \omega$
Deep tank bulkhead plating	$\omega\ \sqrt{k_m}\,(0{,}5\sqrt{L_R} + 1{,}4) \geq 3{,}5\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}5\sqrt{L_R} + 1{,}4) \geq 3{,}5\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}5\sqrt{L_R} + 1{,}4) \geq 3{,}5\ \omega$
Deck plating and stiffeners			
Strength/Main deck plating	$\omega\ \sqrt{k_m}\,(0{,}5\sqrt{L_R} + 1{,}4) \geq 3{,}5\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}5\sqrt{L_R} + 1{,}4) \geq 3{,}5\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}5\sqrt{L_R} + 1{,}4) \geq 3{,}5\ \omega$
Lower deck/Inside deckhouse	$\omega\ \sqrt{k_m}\,(0{,}3\sqrt{L_R} + 1{,}3) \geq 3{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}3\sqrt{L_R} + 1{,}3) \geq 3{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}3\sqrt{L_R} + 1{,}3) \geq 3{,}0\ \omega$
Superstructures and deckhouses			
Superstructure side plating	$\omega\ \sqrt{k_m}\,(0{,}4\sqrt{L_R} + 1{,}1) \geq 3{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}4\sqrt{L_R} + 1{,}1) \geq 3{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}4\sqrt{L_R} + 1{,}1) \geq 3{,}0\ \omega$
Deckhouse front 1st tier	$\omega\ \sqrt{k_m}\,(0{,}62\sqrt{L_R} + 1{,}8) \geq 3{,}5\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}62\sqrt{L_R} + 1{,}8) \geq 3{,}5\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}62\sqrt{L_R} + 1{,}8) \geq 3{,}5\ \omega$
Deckhouse front upper tiers	$\omega\ \sqrt{k_m}\,(0{,}55\sqrt{L_R} + 1{,}5) \geq 3{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}55\sqrt{L_R} + 1{,}5) \geq 3{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}55\sqrt{L_R} + 1{,}5) \geq 3{,}0\ \omega$
Deckhouse aft	$\omega\ \sqrt{k_m}\,(0{,}25\sqrt{L_R} + 0{,}7) \geq 2{,}5\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}25\sqrt{L_R} + 0{,}7) \geq 2{,}5\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}25\sqrt{L_R} + 0{,}7) \geq 2{,}5\ \omega$
Pillars			
Wall thickness of tubular pillars	$\omega\ \sqrt{k_m}\ 0{,}07d_p$	$\omega\ \sqrt{k_m}\ 0{,}07d_p$	$\omega\ \sqrt{k_m}\ 0{,}07d_p$
Wall thickness of rectangular pillars	$\omega\ \sqrt{k_m}\ 0{,}07b_p$	$\omega\ \sqrt{k_m}\ 0{,}07b_p$	$\omega\ \sqrt{k_m}\ 0{,}07b_p$

Symbols

ω = service type correction factor as determined from Table 3.2.2
k_m = $385/(\sigma_A + \sigma_u)$
σ_A = specified minimum yield stress or 0,2% proof stress of the alloy in unwelded condition, in N/mm^2
σ_u = specified minimum ultimate tensile strength of the alloy in unwelded condition, in N/mm^2
b_p = minimum breadth of cross section of hollow rectangle pillar, in mm
d_p = outside diameter of tubular pillar, in mm
L_R is as defined in 1.5.1.

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Table 3.2.2 Service type correction factors (ω)

Service type notation	ω
Cargo	1,1
Passenger	1,0
Patrol	1,0
Pilot	1,1
Yacht	1,0
Workboat MFV	1,2

2.3 Impact considerations

2.3.1 Due consideration is to be given to the scantlings of all structure which may be subject to local impact loadings. Impact testing may be required to be carried out at the discretion of LR to demonstrate the suitability of the proposed scantlings for a particular application.

2.4 Sheathing

2.4.1 Areas of shell and deck which are subject to additional wear by abrasion e.g. passenger routes, working areas of fishing craft, forefoot region etc, are to suitably protected by local reinforcement or sheathing. This sheathing may be of timber, rubber, steel, additional layers of reinforcement, etc., as appropriate. Details of such sheathing and the method of attachment are to be submitted for consideration.

2.4.2 The attachment of sheathing by mechanical means such as bolting or other methods is not to impair the watertight integrity of the craft. Through bolting of the hull is to be kept to a minimum and avoided where practicable. The design arrangements in way of any through bolting are to be such that damage to the sheathing will not impair the watertight integrity of the hull.

2.5 Operation in ice

2.5.1 The minimum plating thickness of craft intended for operation in ice conditions is to comply with Ch 5,7.

■ *Section 3* Shell envelope plating

3.1 General

3.1.1 The requirements of this Section are applicable to longitudinally and transversely framed shell envelopes.

3.1.2 The thickness of the shell envelope plating is in no case to be less than the appropriate minimum requirement given in Section 2.

3.2 Plate keel

3.2.1 The breadth, b_k, and thickness, t_k, of the plate keel are not to be taken as less than:

$$b_k = 7{,}0L_R + 340 \text{ mm}$$

$$t_k = 1{,}85\sqrt{k_a}\,L_R^{0,45} \text{ mm}$$

where L_R and k_a are as defined in 1.5.1.

3.2.2 In no case is the thickness of the plate keel to be less than that of the adjacent bottom shell plating.

3.2.3 The width and thickness of the plate keel are to be maintained throughout the length of the craft from the transom to a point not less than 25 per cent of the freeboard (measured at the forward perpendicular) above the deepest load waterline on the stem. Thereafter the keel thickness may be reduced to that required by 3.3.1 for the stem.

3.2.4 For large or novel craft and for yachts with externally attached ballast keels, the scantlings of the keel will be specially considered.

3.2.5 For bar keels, *see* 5.2.2.

3.3 Plate stem

3.3.1 The thickness of plate stems, t_s, is not to be taken as less than:

$$t_s = \sqrt{k_a}\,(0{,}14L_R + 4) \text{ mm}$$

L_R and k_a are as defined in 1.5.1.

3.3.2 In no case is the thickness of the plate stem to be taken as less than the thickness of the adjacent shell plating.

3.3.3 Plate stems are to be supported by horizontal diaphragms, and where the stem radius is large, a centreline stiffener or web may be required. Where this is impracticable due to fabrication access considerations, alternative supporting arrangements will be specially considered

3.3.4 For large or novel craft the scantlings of the stem will be specially considered.

3.3.5 The breadth of plate stems is to be not less than the width of keel as required by 3.2.1.

3.4 Bottom shell plating

3.4.1 The thickness of the bottom shell plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.4.2 For all craft types the minimum thickness requirement for bottom shell plating as, detailed in Section 2, is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater. See Fig. 3.3.1.

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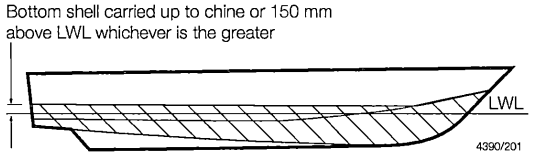

Fig. 3.3.1 Extent of bottom shell

3.5 Side shell plating

3.5.1 The thickness of the side shell plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.6 Sheerstrake

3.6.1 The sheerstrake is generally to be taken as the side shell, locally reinforced in way of deck/hull connection and fender attachment. The amount of local reinforcement will be dependent upon the arrangement of structure and the proposed service.

3.6.2 The fendering arrangements for all craft types are the responsibility of the designers/Builders and are outside the scope of classification.

3.6.3 Where the pressure or impact loadings that a particular type of craft will experience in service are considered by the Builder, or subsequent Owner, to be not covered by or be greater than those indicated in Part 5 of the Rules, details of the loadings together with the calculations of how these will be satisfactorily distributed into the craft's structure, are to be submitted for consideration with the relevant construction plans.

3.6.4 The arrangements indicated in 3.6.5, 3.6.6, 4.18.2 and 4.18.3 for pilot and fishing craft are for the guidance of the Builder and subsequent Owners/operators of the craft. Where the intended service for either of these types of craft, or other types of craft which may be subject to loadings resulting from contact with other craft, jetties or similar loading or boarding facilities, is such that the loadings are greater than those that can be satisfactorily distributed into the craft's structure by the arrangements indicated, then the strengthening arrangements are to be increased accordingly.

3.6.5 For pilot craft which may be subject to repeated impact loadings from contact with other craft etc., the sheerstrake plating is to be increased locally by not less than 50 per cent of the side shell thickness. The increased thickness is to extend from the bow aft over a distance of $0{,}33L_R$ or 500 mm aft of the point which the deckline reaches its greatest breadth whichever is the greater and forward of the quarter and over the transom for a distance of $0{,}075L_R$ or 1,0 m, whichever is the greater. It is in general to extend from the deck edge to below the first longitudinal stiffener, or a vertical distance equivalent to 1/3 the freeboard height whichever is the greater. The additional thickness is then to be tapered out to the side shell thickness in accordance with the Rules.

3.6.6 Fishing craft are in general to have their shell plating scantling as required to satisfy the Rule loadings, increased by 20 per cent. Additionally the side shell is not to be taken less than as bottom shell thickness, and where there are gallows, gantries, nets, or lines etc. the plating in way is to be further increased locally and/or suitably protected by sheathing or other means.

3.6.7 Individual consideration will be given to lesser scantlings than those required by 3.6.3. for fishing craft used for pleasure, light duties, etc. Details of the service are to be submitted.

3.6.8 Where a rounded sheerstrake is adopted the radius, in general, is to be not less than 15 times the thickness.

3.6.9 The sheerstrake thickness is to be increased by 20 per cent at the ends of a bridge superstructure extending out to the craft's side. In the case of a bridge superstructure exceeding $0{,}15L_R$, the side plating at the ends of the superstructure is also to be increased by 25 per cent and tapered gradually into the upper deck sheerstrake.

3.6.10 In general, compensation will not be required for openings in the sheerstrake which are clear of the gunwale or deck openings and whose depth does not exceed 20 per cent of the depth of the sheerstrake. Openings are not to be cut in a rounded gunwale.

3.7 Chines

3.7.1 The chine plate thickness is to be equivalent to the bottom shell thickness required to satisfy the Rule pressure loading, increased by 20 per cent, or 6 mm, whichever is the greater.

3.7.2 Where tube is used in chine construction, the minimum wall thickness is to be not less than the thickness of the bottom shell plating increased by 20 per cent.

3.7.3 Full penetration welding of shell plating in way of chines is always to be maintained.

3.7.4 Chine details are to be such that the continuity of structural strength across the panel is maintained. Details of chines are to be submitted for consideration. *See also* LR's *Guidance Notes for Structural Details*.

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3.8 Skegs

3.8.1 The thickness of the skeg plating is to be not less than the thickness of the adjacent bottom shell and additionally is to satisfy the requirements for sole pieces given in Ch 3,3 of the Rules for Materials.

3.9 Transom

3.9.1 The thickness of the stern or transom is to be not less than that required for the side or bottom shell as appropriate. Where water jet or sterndrive units are fitted, the scantlings of the plating in way of the nozzles and connections will be specially considered.

3.10 Fin and tuck

3.10.1 The thickness of the plating is to be increased locally in way of the fin and tuck areas of yachts which have either internal fixed ballast or external attached ballast keels.

3.10.2 The plating thickness is to be not less than 1,25 times the thickness of the adjacent shell plating but need not be greater than the plate keel thickness as required by 3.2.

3.11 Shell openings

3.11.1 Sea-inlets, or other openings, are to have well rounded corners and, so far as is practicable, are to be kept clear of the bilge radius, chine or radiused sheerstrake. Arrangements are to be made to maintain the strength in way of the openings.

3.11.2 Openings on or near the bilge radius may be accepted provided that they are of elliptical shape, or equivalent, to minimise stress concentrations and are, in general, to be cut clear of weld connections.

3.12 Sea inlet boxes

3.12.1 The thickness of the sea inlet box plating is to be 1 mm thicker than the adjacent shell plating, or 8 mm, whichever is the greater.

3.13 Local reinforcement/insert plates

3.13.1 The thickness of the shell envelope plating determined in accordance with 3.4 and 3.5 is to be increased locally, by generally not less than 50 per cent in way of sternframe, propeller brackets, rudder horn, stabilisers, hawse pipes and anchor recess. Details of such reinforcement are to be submitted for approval.

3.13.2 Insert plates are to extend outside the line of adjacent supporting structure and then be tapered over a distance of not less than three times the difference in thickness, *see also* Ch 2,4.21.

3.14 Appendages

3.14.1 The scantlings of appendages will be subject to special consideration on the basis of the Rules and the design loadings anticipated, but in no case are to be taken as less than that of the surrounding structure.

3.15 Fender attachment

3.15.1 Wood belting and fenders are to be bolted to lugs welded to a ground bar attached to the shell and not through-bolted to the shell plating.

3.16 Novel features

3.16.1 Where the Rules do not specifically define the requirements for novel features then the scantlings and arrangements are to be determined by direct calculation. Such calculations are to be carried out on the basis of the Rules or recognised standards. Details are to be submitted for consideration.

■ *Section 4* Shell envelope framing

4.1 General

4.1.1 The requirements in this Section apply to longitudinally and transversely framed shell envelopes.

4.1.2 For each stiffening member an assumed load model is stated. Where the proposed stiffener arrangement differs from that assumed, consideration will be given to an alternative load model.

4.1.3 The geometric properties of stiffener sections are to be in accordance with 1.18.

4.2 Bottom longitudinal stiffeners

4.2.1 Bottom longitudinal stiffeners are to be supported by bottom transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.2.2 Bottom longitudinals are to be continuous through the supporting structures.

4.2.3 Where it is impracticable to comply with the requirements of 4.2.2, or where it is proposed to terminate the bottom longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets.

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4.2.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b).

4.3 Bottom longitudinal primary stiffeners

4.3.1 Bottom longitudinal primary stiffeners are to be supported by bottom deep transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 6 m apart.

4.3.2 Bottom longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

4.3.3 Where it is impracticable to comply with the requirements of 4.3.2, or where it is proposed to terminate the stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.3.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

4.4 Bottom transverse stiffeners

4.4.1 Bottom transverse stiffeners are defined as local stiffening members which support the bottom shell, and which may be continuous or intercostal.

4.4.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b).

4.5 Bottom transverse frames

4.5.1 Bottom transverse frames are defined as stiffening members which support the bottom shell. They are to be effectively continuous and bracketed at their end connections to side frames and bottom floors as appropriate.

4.5.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

4.6 Bottom transverse web frames

4.6.1 Bottom transverse web frames are defined as primary stiffening members which support bottom shell longitudinals. They are to be continuous and substantially bracketed at their end connections to side web frames and bottom floors.

4.6.2 Where it is impracticable to comply with the requirements of 4.6.1, or where it is proposed to terminate the bottom transverse web frames in way of longitudinal primary girders bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.6.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

4.7 Side longitudinal stiffeners

4.7.1 The side longitudinal stiffeners are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.7.2 Side longitudinals are to be continuous through the supporting structures.

4.7.3 Where it is impracticable to comply with the requirements of 4.7.2, or where it is proposed to terminate the side longitudinal in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.7.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b).

4.8 Side longitudinal primary stiffeners

4.8.1 Side longitudinal primary stiffeners are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 6 m apart.

4.8.2 Side longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

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4.8.3 Where it is impracticable to comply with the requirements of 4.8.2, or where it is proposed to terminate the side longitudinally in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.8.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

4.9 Side transverse stiffeners

4.9.1 Side transverse stiffeners are defined as local stiffening members supporting the side shell and may be continuous or intercostal.

4.9.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b).

4.10 Side transverse frames

4.10.1 Side transverse frames are defined as stiffening members supporting the side shell and spanning continuously between bottom floors/frames and decks. They are to be effectively constrained against rotation at their end connections.

4.10.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

4.11 Side transverse web frames

4.11.1 Side transverse web frames are defined as primary stiffening members which support side shell longitudinally. They are to be continuous and substantially bracketed at their head and heel connections to deck transverses and bottom web frames respectively.

4.11.2 Where it is impracticable to comply with the requirements of 4.11.1, or where it is proposed to terminate the web frames in way of side longitudinal primary stiffeners bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.11.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

4.12 Grouped frames

4.12.1 For the purposes of satisfying Rule scantling requirements, frames may, subject to agreement by LR, be grouped. The number of frames in any group shall not in general exceed five. The summation of the section moduli and inertia for the group of frames is not to be less than the summation of the Rule requirement for the individual framing members. In addition, in no case is the proposed scantling of an individual framing member within the group to be less than ninety per cent of the Rule value for that member.

4.13 Grillage structures

4.13.1 For complex girder systems, a complete structural analysis using numerical methods may have to be performed to demonstrate that the stress levels are acceptable when subjected to the most severe and realistic combination of loading conditions intended.

4.13.2 General or special purpose computer programs or any other analytical techniques may be used provided that the effects of bending, shear, axial and torsion are properly accounted for and the theory and idealisation used can be justified.

4.13.3 In general, grillages consisting of slender girders may be idealised as frames based on beam theory provided proper account of the variations of geometric properties is taken. For cases where such an assumption is not applicable, finite element analysis or equivalent methods may have to be used.

4.14 Combined framing systems

4.14.1 Where longitudinal and transverse primary stiffeners form grillage structures the scantlings may be derived in accordance with 4.13.

4.15 Floating framing systems

4.15.1 Floating framing systems, where proposed, will be subject to special consideration.

4.16 Frame struts

4.16.1 Where struts are fitted to side shell transverse web frames or longitudinal primary stiffeners to carry axial loads, the strut cross-sectional area is to be derived as for pillars in Section 10. If fitted at the stiffener half span point the stiffener section modulus may be taken as half the modulus derived above.

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4.16.2 Design of end connections is to be such that the area of the welding is to be not less than the minimum cross-sectional area of the strut derived in 4.16.1. To achieve this full penetration welding may be required. The weld connections between the face flats and webs of the pillar supporting structure are to be welded using double continuous welding of an equivalent area to that derived by 4.16.1.

4.17 Arrangements and details

4.17.1 The arrangement of the connection between the stiffener and the bracket is to be such that at no point in the connection are the section modulus and inertia reduced to less than that of the stiffener with associated plating.

4.17.2 The web stability, openings in the web and continuity and alignment are to be in accordance with 1.24, 1.25 and 1.26 respectively.

4.17.3 Secondary and primary end connections and arrangements at intersection of continuous secondary and primary members are to be in accordance with 1.20, 1.22 and 1.28 respectively.

4.17.4 Stiffeners in slamming areas are to be lugged or bracketed.

4.18 Structure in way of fenders

4.18.1 For craft, including pilot craft and fishing craft, which may be subject to repeated impact loadings from contact with other craft whilst in service, due consideration is to be given to increasing the scantlings of stiffening members in way of fenders. Details of anticipated loadings and calculations for the required increased scantlings are to be submitted, *see also* 3.6.3 and 3.6.4.

4.18.2 **Pilot craft** are to be fitted with large knees in way of the sheerstrake in areas as indicated in 3.6. The knees are to be aligned between the transverse frames and the deck beams. In the case of longitudinally framed craft, intermediate knees are to be fitted with a spacing in general not greater than 500 mm. Where such intermediate brackets are fitted they are to terminate on a side longitudinal with a section modulus of, in general, twice that of the Rule longitudinal for the web frame spacing, and a deck longitudinal. The side longitudinal is to be positioned below any fendering to carry the heel of the knee. Consideration will given to the termination of such brackets by use of a 'soft-toe' in way of the deck. The thickness of the webs for these knees is to be twice that required by 1.21.

4.18.3 **Fishing craft** engaged in pair trawling and other modes of fishing, and which may be subject to repeated impact loading from contact with the other craft are to have additional stiffening fitted in way of the impact areas. This may be in the form of large knees, intermediate knees, substantial fendering/ rubbing strakes.

4.19 Novel features

4.19.1 The scantlings are to be determined by direct calculation where the shell framing is of unusual design, form or proportions.

■ *Section 5*
Single bottom structure and appendages

5.1 General

5.1.1 The requirements of this Section provide for single bottom construction in association with transverse and longitudinal framing systems.

5.1.2 All girders are to extend as far forward and aft as practicable and care is to be taken to avoid any abrupt discontinuity. Where girders are cut at bulkheads, their longitudinal strength is to be maintained.

5.1.3 Particular attention is to be taken to ensure that the continuity of structural strength in way of the intersection of transverse floors and longitudinal girders is maintained. The face flats of such stiffening members are to be effectively connected.

5.1.4 The single bottom structure in way of the keel and girders is to be sufficient to withstand the forces imposed by dry-docking the craft.

5.1.5 The scantlings of the single bottom structure are to comply with the appropriate minimum requirements given in Section 2.

5.2 Keel

5.2.1 The breadth, and thickness of plate keels are to comply with the requirements of 3.2.

5.2.2 The cross-sectional area, A_k, and thickness, t_k, of bar keels are not, in general, be taken as less than:

$$A_k = k_a (1{,}85L_R + 2) \text{ cm}^2$$

$$t_k = \sqrt{k_a}\ (0{,}7L_R + 8{,}25) \text{ mm}$$

where

L_R and k_a are as defined in 1.5.1.

5.3 Centre girder

5.3.1 A centreline girder is, in general, to be fitted throughout the length of the hull in association with transverse frames, transverses supporting longitudinals or where the breadth of floors at the upper edge is greater than 1,5 m.

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5.3.2 Centreline girders are to be formed of intercostal or continuous plate webs with a face flat welded to the upper edge. In all cases the face flat is to be continuous. Where girder webs are intercostal, additional bracketing and local reinforcement will be required to maintain the continuity of structural strength.

5.3.3 The web depth of the centre girder is, in general, to be equal to the depth of the floors at the centreline as specified in 5.5.3.

5.3.4 The web thickness, t_w, is to be taken not less than:

$$t_w = 1{,}4\sqrt{k_a}\ (\sqrt{L_R} + 1)\ \text{mm}$$

where

L_R and k_a are as defined in 1.5.1.

5.3.5 The geometric properties of the centre girder are to be in accordance with 1.18.

5.3.6 The face flat area of the centre girder, A_f, is to be not less than:

$$A_f = 0{,}56 L_R k_a\ \text{cm}^2.$$

5.3.7 The face flat area of the centre girder outside $0{,}5L_R$ amidships may be 80 per cent of the value given in 5.3.6.

5.3.8 The face flat thickness is to be not less than the thickness of the web.

5.3.9 The ratio of the width to thickness of the face flat is to be not less than eight but should not exceed 16.

5.3.10 Additionally, the requirements of 4.3 for bottom longitudinal primary stiffeners are to be complied with.

5.4 Side girders

5.4.1 Where the floor breadth at the upper edge exceeds 6,0 m side girders are to be fitted at each side of the centre girder such that the spacing between the side and centre girders or between the side girders themselves is not greater than 3 m. Side girders where fitted are to extend as far forward and aft as practicable and are, in general, to terminate in way of bulkheads, deep floors or other primary transverse structure.

5.4.2 The web thickness of side girders is to be taken as not less than:

$$t_w = 1{,}4\sqrt{k_a L_R}\ \text{mm}$$

where

L_R and k_a are as defined in 1.5.1.

5.4.3 The face flat area and thickness of side girders are to comply with the requirements for plate floors as defined in 5.5.6 and 5.5.7.

5.4.4 Watertight side girders, and side girders forming the boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads and deeptanks as detailed in 7.3 and 7.5 respectively.

5.4.5 In the engineroom, additional side girders are generally to be fitted in way of main machinery seatings. Where fitted, they are to be integrated into the structure of the craft and extended forward and aft as far as practicable.

5.4.6 Additionally, the requirements of 4.3 for bottom longitudinal primary stiffeners are to be complied with.

5.5 Floors general

5.5.1 In transversely framed craft, plate floors are generally to be fitted at each frame.

5.5.2 In longitudinally framed craft, plate floors are to be fitted at every transverse web and generally at a spacing not exceeding 2 m. Additional transverse floors or webs are in general to be fitted at half web-frame spacing in way of engine seatings and thrust bearings, pillars, skegs, ballast/bilge keels and the bottom of the craft forward.

5.5.3 The overall depth, d_f, of plate floors at the centreline is not to be taken as less than:

when $B < 10$ m $\quad d_f = 40(B + 0{,}85D)$ mm

when $B \geq 10$ m $\quad d_f = 40(1{,}5B + 0{,}85D) - 200$ mm

where

D is defined in Pt 3, Ch 1,6.2.8.

5.5.4 The web thickness, t_w, of plate floors, is to be accordance with 1.18 and is to be taken as not less than:

$$t_w = \sqrt{k_a}\left(\frac{4{,}7 d_f}{1000} + 3{,}1\right)\left(\frac{s}{1000} + 0{,}5\right)\ \text{mm}$$

where

d_f is to be determined from 5.5.3

k_a and s are as defined in 1.5.1.

5.5.5 If the side frames of the craft are attached to the floors by brackets, the depth of floor may be reduced by 15 per cent and the floor thickness determined using the reduced depth. The brackets are to be flanged and have the same thickness as the floors, and their arm lengths clear of the frame are to be the same as the reduced floor depth given above.

5.5.6 The face flat area of floors, A_f, is not to be taken as less than:

$$A_f = 0{,}28 k_a L_R\ \text{cm}^2$$

where

k_a and L_R are defined in 1.5.1.

5.5.7 The face flat thickness is to be not less than the thickness of the web and the ratio of the web to the thickness of the face flat is to be not less than eight but is not to exceed 16.

5.5.8 Additionally the requirements of 4.6 for bottom transverse web frames are to be complied with.

5.5.9 Floors are generally to be continuous from side to side.

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5.5.10 The tops of floors, in general, may be level from side to side. However, in craft having considerable rise of floor the depth of the floor plate may require to be increased to maintain the required section modulus.

5.5.11 The floors in the aft peak are to extend over and provide effective support to the stern tube(s) where applicable.

5.5.12 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deeptanks as detailed in 7.3 and 7.5.

5.6 Floors in machinery spaces

5.6.1 The thickness, t_w, of the floors in machinery spaces is to be 1 mm greater than that required by 5.5.4.

5.6.2 The depth and section modulus of floors anywhere between engine or gearbox girders is to be not less than that required to maintain continuity of structural integrity or 50 per cent of the depth given in 5.5.3. The face flat area and web thickness for such reduced floor heights are to be increased appropriately in order to maintain continuity of structural strength, *see also* 4.12.

5.7 Machinery seatings

5.7.1 The general requirements for machinery seatings are given in Pt 3, Ch 2,6.9, *see also* Pt 9, Ch 1,5.

5.7.2 Engine holding-down bolts are to be arranged as near as practicable to floors and longitudinal girders. When this cannot be achieved, bracket floors are to be fitted.

5.7.3 Welding in way of machinery seatings is to be double continuous and/or full penetration where appropriate.

5.8 Drainholes in bottom structure

5.8.1 Sufficient limber holes are to be cut in the internal bottom structure to allow for the drainage of water from all parts of the bilge to the pump suctions.

5.8.2 Particular attention is to be given to the positioning of limber holes to ensure adequate drainage and to avoid stress concentrations.

5.8.3 Suitable arrangements are to be made to provide free passage of air from all parts of tanks to the air pipes.

5.9 Rudder horns

5.9.1 The shell plating thickness in way of the rudder horn is to be increased locally, by generally not less than 50 per cent but need not to be taken as greater than the keel thickness required by 3.2.

5.9.2 The scantlings of the rudder horn are to be such that the section modulus against transverse bending at any horizontal section XX (*see* Fig. 3.5.1) is not less than:

$$Z = 2{,}8 k_a R_A K_V (V + 3)^2 \sqrt{a^2 + 0{,}5b^2} \quad \text{cm}^3$$

where

R_A = total rudder area, in m^2

V = Maximum speed in the fully loaded condition, in knots

K_V = 1,0 for displacement craft with $\frac{V}{\sqrt{L_{WL}}} < 3{,}0$

= $(1{,}12 - 0{,}005V)^3$ for planing and semi-planing craft with $\frac{V}{\sqrt{L_{WL}}} \geq 3{,}0$

a, b = dimensions, in metres, as given in Fig. 3.5.1

L_{WL} = waterline length as defined in Pt 3, Ch 1,6.2.5.

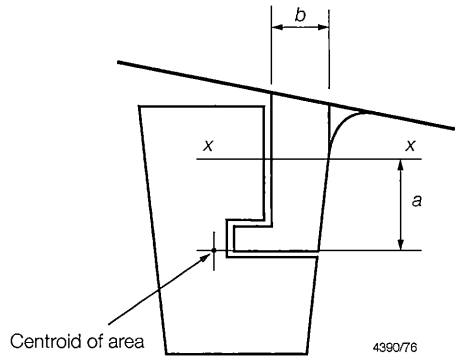

Fig. 3.5.1 Rudder horn

5.9.3 Rudder horns are to be effectively integrated into the adjacent structure and their design is to be such as to facilitate this.

5.10 Sternframes

5.10.1 The scantlings of fabricated and forged/solid sternframes are to comply with the requirements of Pt 3, Ch 3,3 modified for appropriate grade of aluminium in accordance with Pt 3, Ch 3,1.2.

5.11 Skeg construction

5.11.1 Skegs are to be effectively integrated into the adjacent structure and their design is to be such as to facilitate this.

5.11.2 The scantlings and arrangements for skegs (solepieces) are to be in accordance with Pt 3, Ch 3,3.14.

5.11.3 The scantlings of skegs are to be sufficient to withstand any docking forces that they may be subjected to.

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5.12 Forefoot and stem

5.12.1 The thickness of plate stems at the waterline is to comply with the requirements for plate keels as given in 3.2.

5.12.2 The forefoot and stem is to be additionally reinforced with floors.

5.12.3 The cross-sectional area of bar stems, A_{bs}, is not to be taken as less than:

$$A_{bs} = 1{,}5k_a L_R \text{ cm}^2$$

where

L_R and k_a are as defined in 1.5.1.

5.13 Transom knee

5.13.1 Centre and side girders are to be bracketed to the transom framing members by means of substantial knees. The face flat of the girders may be gradually reduced to that of the transom stiffening members in accordance with Fig. 3.5.2.

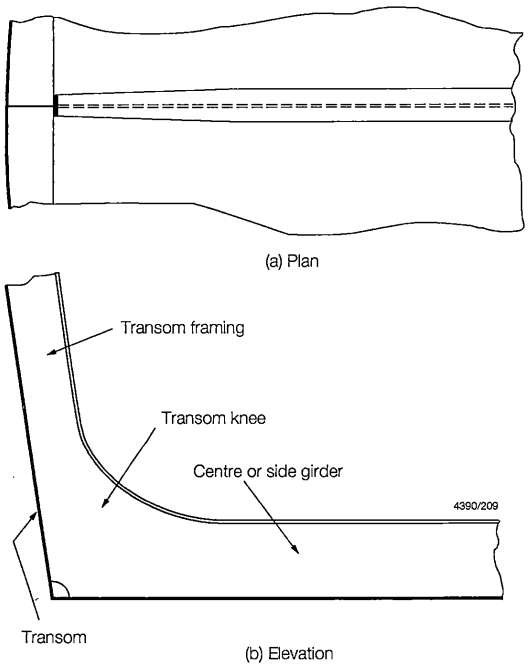

Fig. 3.5.2 Transom knee

5.13.2 Hard spots are to be avoided in way of the end connections and care is to be taken to ensure that the stiffening member to which the transom knee is bracketed can satisfactorily carry the transmitted loads.

Section 6
Double bottom structure

6.1 General

6.1.1 The requirements given in this Section provide for double bottom construction of aluminium mono-hull craft in association with either transverse or longitudinal framing.

6.1.2 Double bottoms are generally to be fitted in accordance with Pt 3, Ch 2,6.6 and where fitted are to extend from the collision bulkhead to the after peak bulkhead, as far as this is practicable within the design and proper working of the craft. In addition, the inner bottom is to be continued to the craft's side in such a manner as to protect the bottom to the turn of bilge or chine.

6.1.3 The double bottom structure in way of girders and duct keels is to be sufficient to withstand the forces imposed by dry-docking the craft.

6.1.4 The centreline girder and side girders are to extend as far forward and aft as practicable and care is to be taken to avoid any abrupt discontinuity. Where girders are cut at bulkheads, their longitudinal strength is to be maintained.

6.1.5 The scantlings of the double bottom structure are to comply with the appropriate minimum requirements given in Section 2.

6.2 Keel

6.2.1 The scantlings of bar and plate keels are to comply with the requirements of 5.3.

6.2.2 Duct keels, where arranged, are to have a side plate thickness not less than:

$$t = \sqrt{k_a}\ (0{,}01d_{DB} + 2) \text{ mm}$$

but need not be taken as greater than 90 per cent of the centre girder thickness given in 6.3.

d_{DB} is the Rule centre girder depth given in 6.3.3

k_a is as defined in 1.5.1.

6.2.3 Where a duct keel forms the boundary of a tank, the requirements of 7.4 and 7.5 for deep tanks are to be complied with.

6.2.4 The duct keel width is in general to be 15 per cent of the beam or 2 m, whichever is the lesser, but in no case is it to be taken as less than 630 mm. The inner bottom and bottom shell within the duct keel are to be suitably stiffened with primary stiffening in the transverse direction, whilst the continuity of the floors is maintained. Access to the duct keel is to be by means of watertight manholes or trunks.

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6.3 Centre girder

6.3.1 A centre girder is to be fitted throughout the length of the craft. The web thickness, t_w, is not to be less than that required by:

$t_w = \sqrt{k_a}\ (0{,}14L_R + 4)$ mm within $0{,}4L_R$ amidships

$= \sqrt{k_a}\ (0{,}14\ L_R + 2{,}75)$ mm at ends.

where

k_a and L_R are as defined in 1.5.1.

6.3.2 The geometric properties of the girder section are to be in accordance with 1.18.

6.3.3 The overall depth of the centre girder, d_{DB}, is to be taken as not less than 630 mm and is to be sufficient to give adequate access to all parts of the double bottom.

6.3.4 Additionally, the requirements of 4.3 for bottom longitudinal primary stiffeners are to be complied with.

6.4 Side girders

6.4.1 Where the floor breadth does not exceed 6,0 m, side girders are not required. Vertical stiffeners are to be fitted to the floors on each side, the number and positions of these stiffeners being dependent on the arrangement of the double bottom structure.

6.4.2 Where the breadth of floor is greater than 6,0 m, additional side girders having the same thickness as the floors are to be fitted. The number of side girders is to be such that the distance between the side girders and centre girder and margin plate, or between the side girders themselves, does not exceed 3,0 m.

6.4.3 Side girders where fitted are to extend as far forward and aft as practicable and are in general to terminate in way of bulkheads, deep floors or other primary transverse structure.

6.4.4 Where additional side girders are fitted in way of main machinery seatings, they are to be integrated into the structure of the craft and extended forward and aft as far as practicable.

6.4.5 Under the main engine, girders extending from the bottom shell to the top plate of the engine seating are to be fitted. The height of the girders is to be not less than the height of the floor. Engine holding-down bolts are to be arranged as near as practicable to the girders and floors. Where this cannot be achieved, bracket floors and/or hanging brackets are to be fitted.

6.4.6 Additionally, the requirements of 4.3 for bottom longitudinal primary stiffeners are to be complied with.

6.5 Plate floors

6.5.1 The web thickness of non-watertight plate floors, t_w, is to be not less than:

$t_w = \sqrt{k_a}\ (0{,}07L_R + 4{,}75)$ mm

where

k_a and L are as defined in 1.5.1.

6.5.2 Additionally, the requirements of 4.6 for bottom transverse web frames stiffeners are to be complied with.

6.5.3 Plate floors are, in general, to be continuous between the centre girder and the margin plate.

6.5.4 In longitudinally framed craft, plate floors or equivalent structure are in general to be fitted in the following positions:

(a) At every half frame in way of the main engines, thrust bearings and bottom of the craft forward.
(b) Outboard of the engine seatings, at every frame within the engine room.
(c) Underneath pillars and bulkheads.
(d) Outside of the engine room at a spacing not exceeding 2,0 m.

6.5.5 Vertical flat bar stiffeners are to be fitted to all plate floors at each longitudinal. Each stiffener is to have a depth of not less than $10t_w$ and a thickness of not less than t_w, where t_w is thickness of the plate floor as calculated in 6.5.1.

6.5.6 In transversely framed craft, plate floors are to be fitted at every frame in the engine room, under bulkheads, in way of change in depth of double bottom and elsewhere at a spacing not exceeding 2,0 m.

6.6 Bracket floors

6.6.1 Between plate floors, the shell and inner bottom plating is to be supported by bracket floors. The brackets are to have the same thickness as plate floors and are to be stiffened on the unsupported edge.

6.6.2 In longitudinally framed craft, the brackets are to extend from the centre girder and margin plate to the adjacent longitudinal, but in no case is the breadth of the bracket to be taken as not less than 75 per cent of the depth of the centre girder. They are to be fitted at every web frame at the margin plate, and those at the centre girder are to be spaced not more than 1,0 m apart.

6.6.3 In transversely framed craft, the breadth of the brackets, attaching the bottom and inner bottom frames to the centre girder and margin plate, is to be not less than 75 per cent of the depth of the centre girder.

6.7 Watertight floors

6.7.1 The scantlings of watertight floors are to comply with the requirements for plate floors as given in 6.5.

6.7.2 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deep tanks as detailed in 7.3 or 7.5 respectively.

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6.8 Tankside brackets

6.8.1 The scantlings of tankside brackets are to comply with the requirements for plate floors given in 6.5.

6.9 Inner bottom plating

6.9.1 The thickness of the inner bottom plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

6.9.2 Inner bottom plating forming the boundaries of tank spaces is, in addition, to comply with the requirements for watertight bulkheads or deeptanks as detailed in 7.2 or 7.4 respectively. Where the plating forms vehicle, passenger or other decks the requirements of Section 8 are to be complied with.

6.9.3 Inner bottom longitudinals are to be supported by inner bottom transverse web frames, floors, bulkheads or other primary structure, generally spaced not more than 2 m apart.

6.9.4 The inner bottom longitudinals are to be continuous through the supporting structure and are to be satisfactorily stiffened against buckling.

6.9.5 Where it is impracticable to comply with the requirements of 6.9.4, or where it is desired to terminate the inner bottom longitudinals in way of bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

6.9.6 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b).

6.10 Inner bottom transverse web framing

6.10.1 Inner bottom transverse web frames are defined as primary stiffening members which support inner bottom longitudinals. They are to be continuous and to be substantially bracketed at their end connections to bottom web frames, bottom floors and tankside brackets.

6.10.2 Where it is impracticable to comply with the requirements of 6.10.1, or where it is desired to terminate the inner bottom transverse web frames in way of centre or side girders, bulkheads or integral tank boundaries, etc., they are to be bracketed in way of their end connections, to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

6.10.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

6.11 Margin plates

6.11.1 A margin plate, if fitted, is to have a thickness as required for inner bottom plating.

6.12 Wells

6.12.1 Small wells constructed in the double bottom structure are not to extend in depth more than necessary. A well extending to the outer bottom may, however, be permitted at the after end of the shaft tunnel of the craft. Other well arrangements (e.g. for lubricating oil under main engines) may be considered provided they give protection equivalent to that afforded by the double bottom.

6.13 Transmission of pillar loads

6.13.1 In double bottoms under widely spaced pillars, the connections of the floors to the girders, and of the floors and girders to the inner bottom, are to be suitably increased. Where pillars are not directly above the intersection of plate floors and girders, partial floors and intercostals are to be fitted as necessary to support the pillars. Manholes are not to be cut in the floors and girders below the heels of pillars. Where longitudinal framing is adopted in the double bottom, equivalent stiffening under the heels of pillars is to be provided, and where the heels of pillars are carried on a tunnel, suitable arrangements are to be made to support the load.

6.14 Manholes

6.14.1 Sufficient manholes are to be cut in the inner bottom, floors and side girders to provide adequate access to, and ventilation of, all parts of the double bottom. The size of the manhole openings is not, in general, to exceed 50 per cent of the double bottom depth unless edge reinforcement is provided. Holes are not to be cut in the centre girder, except in tanks at the forward and after ends of the craft, and elsewhere where tank widths are reduced unless additional stiffening and/or compensation is fitted to maintain the structural integrity.

6.15 Pressure testing

6.15.1 Double bottoms are to be tested upon completion with a head of water representing the maximum internal pressure which could be experienced in service, but not less than a head of water equivalent to the level of the upper deck.

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6.16 Drainholes in bottom structure

6.16.1 Sufficient limber holes are to be cut in the internal bottom structure to allow for the drainage of water from all parts of the bilge to the pump suctions.

6.16.2 Particular care is to be given to the positioning of limber holes to ensure adequate drainage and to avoid stress concentrations.

6.16.3 Suitable arrangements are to be made to provide free passage of air from all parts of tanks to the air pipes.

■ *Section 7* Bulkheads

7.1 General

7.1.1 The requirements of this Section apply to a vertical system of stiffening on bulkheads. They may also be applied to a horizontal system of stiffening provided that equivalent support and alignment are provided.

7.1.2 The number and disposition of transverse watertight bulkheads are to be in accordance with Pt 3, Ch 2,4.

7.1.3 Bulkheads, or part bulkheads, forming the boundary of tanks are to comply with the requirements of 7.5 and 7.6.

7.1.4 For bulkheads in way of partially filled holds or tanks, sloshing forces may be required to be taken into account. Where such forces are likely to be significant, the scantlings will be required to be verified by additional calculations.

7.1.5 A centreline bulkhead is, generally, to be fitted in deep tanks which extend from side to side. The bulkhead may be intact or perforated as desired. If intact, the scantlings are to comply with the requirements of 7.5 and 7.6 for tank boundary bulkheads. If perforated, they are to comply with the requirements of 7.13 for washplates.

7.1.6 The minimum requirements in Section 2 are to be complied with.

7.2 Watertight bulkhead plating

7.2.1 The thickness of the watertight bulkhead plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5 Ch 4,3.1 for non-displacement or displacement craft as appropriate.

7.3 Watertight bulkhead stiffening

7.3.1 The Rule requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 using the appropriate load model.

7.3.2 Bulkheads are to be suitably strengthened, if necessary, at the ends of deck girders and where subjected to concentrated loads.

7.4 Deep tank plating

7.4.1 The thickness of deep tank plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

7.5 Deep tank stiffening

7.5.1 Deep tank bulkhead stiffeners are to be bracketed at both ends. The thickness of the brackets is to be not less than the web thickness of the stiffener.

7.5.2 The Rule requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for load model (b).

7.6 Double bottom tanks

7.6.1 The scantlings of double bottom tanks are to comply with the requirements for deep tanks given in 7.4 and 7.5.

7.6.2 Where the crown of a double bottom tank forms a vehicle, passenger or other deck, the requirements of Section 8 are to be complied with.

7.7 Collision bulkheads

7.7.1 The scantlings of collision bulkheads are to comply with the requirements of 7.2 and 7.3 except that the thickness of plating and modulus of stiffeners are not to be less than 12 and 25 per cent greater respectively, than required by 7.2 and 7.3. If the collision bulkhead forms the boundary of a deep tank or cofferdam then the requirements of 7.4 and 7.5 are also to be complied with.

7.8 Gastight bulkheads

7.8.1 Where gastight bulkheads are fitted, in accordance with Pt 3, Ch 2,4 the scantling requirements for watertight bulkheads are to be complied with.

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7.8.2 Gastight bulkheads are to be fitted to protect accommodation spaces from gases and vapour fumes from machinery exhaust and fuel systems.

7.9 Non-watertight or partial bulkheads

7.9.1 Where a bulkhead is structural but non-watertight the scantlings are in general to be as for watertight bulkheads or equivalent in strength to web frames in the same position. Partial bulkheads that are non-structural are outside the scope of classification.

7.10 Transmission of pillar loads

7.10.1 Bulkheads that are required to act as pillars in way of underdeck girders and other structures subject to heavy loads are to comply with the requirements of Section 10.

7.11 Corrugated bulkheads

7.11.1 The plating thickness and section modulus for symmetrical corrugated bulkheads are to be in accordance with watertight bulkheads or deep tank bulkheads as appropriate. The spacing, s, is to be taken as s_c, as defined in Fig. 2.3.1 in Pt 3, Ch 2.

7.11.2 In addition, the section geometric properties of 1.18 are to be complied with.

7.11.3 The actual section modulus may be derived in accordance with Pt 3, Ch 2,3.2.

7.12 Stiffeners passing through bulkheads

7.12.1 Primary longitudinal stiffening members are to be continuous through transverse bulkheads.

7.12.2 Pipe or cable runs through watertight bulkheads are to be fitted with suitable watertight glands.

7.13 Wash plates

7.13.1 Tanks are to be subdivided as necessary by internal baffles or wash plates. Baffles or wash plates which support hull framing are to have scantlings equivalent to web frames in the same position.

7.13.2 Wash plates and wash bulkheads are, in general, to have an area of perforation not less than 10 per cent of the total area of the bulkhead. The perforations are to be so arranged that the efficiency of the bulkhead as a support is not impaired.

7.13.3 The plate thickness is to be not less than the structural element from which the wash bulkhead is formed.

7.13.4 The general stiffener requirements are to be in accordance with 7.5. However, the section modulus may be 50 per cent of that required by 7.5.

7.14 Cofferdams

7.14.1 A cofferdam is to be fitted between freshwater and oil fuel or sanitary tanks. The scantlings of cofferdams are to comply with the requirements of deep tank bulkheads or non-watertight bulkheads as appropriate.

7.15 Coatings

7.15.1 Integral freshwater and oil fuel tanks need not in general be coated provided they are constructed from suitable marine grade aluminium alloys in accordance with Chapter 8 of the Rules for Materials. Where tanks are to be coated, then all surfaces are to be cleaned and dried after testing and then treated with a suitable coating in accordance with the coating manufacturer's recommendations. *See* Ch 2,2.6.

7.16 Air pipes

7.16.1 Air pipes of sufficient number and area are to be fitted to each tank in accordance with Pt 15, Ch 2,11.

7.17 Fire protection

7.17.1 Fire protection requirements given in Part 17 are to be complied with.

7.18 Access

7.18.1 Compartments within the craft are to be accessible in order to facilitate proper maintenance and future structural surveys. Linings on craft sides, deckheads and bulkheads, etc., must be capable of being removed. Similarly sufficient space must be available below lower decks/soles to provide proper access to the bottom structure. An adequate number of manholes, removable panels etc. are to be provided.

7.18.2 Doors and hatches fitted through watertight bulkheads are to be of equivalent construction to the bulkhead in which they are fitted, to be permanently attached and capable of being closed watertight from both sides of the bulkhead. They are to be tested watertight.

7.18.3 Doors and hatches are not to be fitted in collision bulkheads, except in craft of less than 21 m Rule length or where it would be impracticable to arrange access to the forepeak other than through the collision bulkhead. Where fitted, the doors and hatches are to be watertight, as small as practicable and open into the forepaw compartment. Doors in collision bulkheads are to be kept closed at all times while the craft is at sea, *see* Pt 3, Ch 2,4.3.4.

7.18.4 Particular attention is to be given to the design and workmanship of the tanks, and adequate access manholes are to be fitted, *see* Pt 3, Ch 1,7.

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7.19 Testing

7.19.1 Deep tanks are to be tested on completion, with a head of water to the top of the overflow, or 1,8 m above the crown of the tank, whichever is the greater, The pressure to which the tanks will be subjected in service is to be indicated on the plans submitted.

■ *Section 8*
Deck structures

8.1 General

8.1.1 The deck plating is to be supported by transverse beams with fore and aft girders or by longitudinals with deep transverse beams. The transverse and deep transverse beams are to align with side main frames and side web frames respectively.

8.1.2 Beams are to be fitted at every frame and bracketed to the frames. Strong beams and deep transverse beams are to align with and be effectively connected to the side web frames. They are also to be fitted at the ends of large openings in the deck.

8.1.3 The deck plating and supporting structure are to be suitably reinforced in way of cranes, masts, derrick posts and deck machinery.

8.1.4 Primary stiffening members are to be continuous and substantially bracketed at their end connections to maintain continuity of structural strength.

8.1.5 Secondary stiffening members are to be effectively continuous and bracketed at their end connections as appropriate.

8.1.6 Primary and secondary stiffener end connection arrangements are, in general, to be in accordance with 1.22 and 1.20, respectively.

8.1.7 The ends of beams, longitudinals, girders and transverses are to be effectively built into the adjacent structure, or equivalent arrangements provided.

8.1.8 Tripping brackets are to be fitted on deep webs.

8.1.9 Deck structures subject to concentrated loads, are to be suitably reinforced. Where concentrations of loading on one side of a stiffening member may occur, such as pillars out of line, the member is to be adequately stiffened against torsion. Additional reinforcements may be required in way of localised areas of high stress.

8.1.10 The thickness of the deck plating is in no case to be less than the appropriate minimum requirement given in Section 2.

8.1.11 The geometric properties of stiffener sections are to be in accordance with 1.18.

8.2 Strength/weather deck plating

8.2.1 The thickness of strength/weather deck plating is to be determined from the general plating equation given in 1.16 using the design pressure head from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

8.2.2 The scantlings of watertight cockpits are to be of equivalent strength to those of the strength/weather deck. *See also* Part 4.

8.2.3 It is recommended that the working areas of the weather deck have an anti-slip surface.

8.2.4 Where decks are sheathed with wood or other materials, details of the method of attachment are to be submitted. *See also* 2.4.

8.3 Lower deck/inside deckhouse plating

8.3.1 The thickness of the lower deck/inside deckhouse plating is to be determined from the general plating equation given in 1.16 using the design pressure head from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

8.4 Accommodation deck plating

8.4.1 Accommodation decks are in general to be treated as lower deck/inside deckhouse decks, with their plating requirements determined in accordance with 8.3.

8.5 Cargo deck plating

8.5.1 The thickness of cargo deck plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

8.5.2 For vehicle decks, the plating thickness is to comply with the requirements of Ch 5,3.

8.6 Decks forming crowns of tanks

8.6.1 Decks forming the crown of tanks are to comply with the requirements for the appropriate deck, and are to be additionally examined for compliance with the requirements for deep tank plating given in 7.4.

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8.7 Strength/weather deck stiffening

8.7.1 The Rule requirements for section modulus, inertia and web area for the **strength/weather deck primary stiffening** are to be determined from the general equations given in 1.17, using the design pressure heads from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

8.7.2 The Rule requirements for section modulus, inertia and web area for the **strength/weather deck secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.7.3 Longitudinal framing is, in general, to be adopted at the strength deck outside line of openings, but special consideration will be given to proposals for transverse framing.

8.8 Lower deck/inside deckhouse stiffening

8.8.1 The Rule requirements for section modulus, inertia and web area for lower deck/inside deckhouse stiffening are to be determined from the general equations given in 1.17 using the design pressure head from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1. Primary members are assumed to be load model (a) and secondary members load model (b). However, special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.9 Accommodation deck stiffening

8.9.1 Accommodation decks are in general to be treated as lower deck/inside deckhouse decks, with their scantling requirements determined in accordance with 8.8.

8.10 Cargo deck stiffening

8.10.1 The Rule requirements for section modulus, inertia and web area for cargo deck stiffening are to be determined from the general equations given in 1.17 using the design pressure head from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1. Primary members are assumed to be load model (a) and secondary members load model (b). However, special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.10.2 In addition, where the cargo comprises wheeled vehicles, the requirements of Ch 5,3 are to be complied with.

8.11 Deck openings

8.11.1 All openings are to be supported by an adequate framing system, pillars or cantilevers. When cantilevers are used scantlings may be derived from direct calculations.

8.11.2 Where stiffening members terminate in way of an opening they are to be attached to carlings, girders, transverses or coaming plates.

8.11.3 The corners of large hatchways in the strength/weather deck within $0{,}5L_R$ amidships are to be elliptical, parabolic or rounded, with a radius generally not less than 1/24 of the breadth of the opening.

8.11.4 Where elliptical corners are arranged, the major axis is to be fore and aft, the ratio of the major to minor axis is to be not less than two to one nor greater than 2,5 to one, and the minimum half-length of the major axis is to be defined by l_1 in Fig. 3.8.1. Where parabolic corners are arranged, the dimensions are also to be as shown in Fig. 3.8.1.

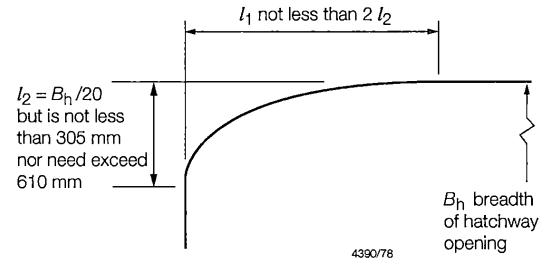

Fig. 3.8.1 Hatch opening geometry

8.11.5 Where the corners are parabolic or elliptical, insert plates are not required.

8.11.6 For other shapes of corner, insert plates of the size and extent shown in Fig. 3.8.2 will, in general, be required. The required thickness of the insert plate is to be not less than 25 per cent greater than the adjacent deck thickness, outside line of openings.

8.11.7 For lower decks the corners of large openings are to be rounded, with a radius generally not less than 1/24 of the breadth of the opening.

8.11.8 Insert plates will be required at lower decks in way of any rapid change in hull form to compensate for loss of deck cross-sectional area. Otherwise, insert plates will not normally be required.

8.11.9 Adequate transverse strength is to be provided in the deck area between large hatch openings, subjected to transverse and buckling loads.

8.11.10 The requirements for closing arrangements and outfit are given in Pt 3, Ch 4.

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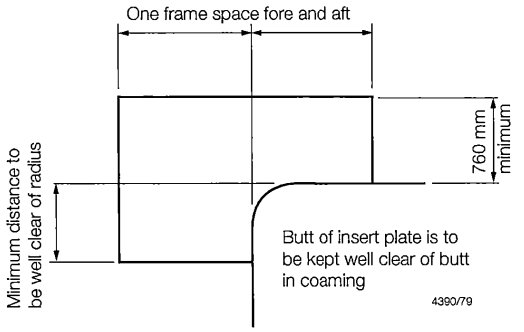

Fig. 3.8.2 Inserts in way of hatch opening

8.12 Sheathing

8.12.1 The requirements for deck sheathing given in 2.4 are to be complied with.

8.13 Novel features

8.13.1 Where large or novel hatch openings are proposed, detailed calculations are to be submitted to demonstrate that the scantlings and arrangements in way of the openings are adequate to maintain continuity of structural strength.

■ *Section 9* Superstructures, deckhouses and bulwarks

9.1 General

9.1.1 Where practicable, superstructures and deckhouses are to be designed with well cambered decks and well radiused corners to build rigidity into the structure.

9.1.2 The plating and supporting structure are to be suitably reinforced in way of localised areas of high stress such as corners of openings, cranes, masts, derrick posts, machinery, fittings and other heavy or vibrating loads.

9.1.3 Primary stiffening members are to be continuous and substantially bracketed at their end connections to maintain continuity of structural strength.

9.1.4 Secondary stiffening members are to be effectively continuous and bracketed at their end connections as appropriate.

9.1.5 Structures subject to concentrated loads are to be suitably reinforced. Where concentrations of loading on one side of a stiffener may occur, such as pillars out of line, the stiffener is to be adequately stiffened against torsion.

9.1.6 The plating thickness of superstructures, deckhouses and bulwarks is in no case to be less than the appropriate minimum requirement given in Section 2.

9.1.7 Stiffener sections and geometric properties are to be in accordance with 1.18.

9.2 Symbols and definitions

9.2.1 The term 'house' is used in this Section to include both superstructures and deckhouses.

9.2.2 The symbols applicable to this Section are defined in 1.5.1.

9.3 House side plating

9.3.1 The thickness of house side plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

9.4 House front plating

9.4.1 The thickness of the house front plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4, 3.1 for non-displacement or displacement craft as appropriate.

9.5 House end plating

9.5.1 The thickness of the house end plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

9.6 House top plating

9.6.1 The thickness of the house top plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

9.7 Coachroof plating

9.7.1 The thickness of the coachroof plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

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9.8 Machinery casing plating

9.8.1 The thickness of the plating of machinery casings is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

9.9 Forecastle requirements

9.9.1 The forecastle side plating may be a continuation of the hull side shell plating or fitted as a separate assembly. In both cases the plating thickness is to be the same as the side shell plating at deck edge. Where fitted as a separate assembly, suitable arrangements are to be made to ensure continuity of the effect of the sheerstrake at the break and at the upper edge of the forecastle side. Full penetration welding is to be used.

9.9.2 The side plating is to be stiffened by side frames effectively connected to the deck structure. Deep webs are to be fitted to ensure overall rigidity.

9.9.3 The deck plating thickness is to be increased by 20 per cent in way of the end of the forecastle if this occurs at a position aft of $0{,}25L_R$ from the F.P. No increase is required if the forecastle end bulkhead lies forward of $0{,}2L_R$ from the F.P. The increase at intermediate positions of end bulkhead is to be obtained by interpolation.

9.10 House side stiffeners

9.10.1 The Rule requirements for section modulus, inertia and web area for the **house side primary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

9.10.2 The Rule requirements for section modulus, inertia and web area for **house side secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.11 House front stiffeners

9.11.1 The Rule requirements for section modulus, inertia and web area for **house front primary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

9.11.2 The Rule requirements for section modulus, inertia and web area for **house front secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.12 House aft end stiffeners

9.12.1 The Rule requirements for section modulus, inertia and web area for **house aft end primary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

9.12.2 The Rule requirements for section modulus, inertia and web area for **house aft end secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.13 House top stiffeners

9.13.1 The house top is to be effectively supported by a system of transverse or longitudinal beams and girders. The span of the beams is in general not to exceed 2,4 m and the beams are to be effectively connected to the house upper coamings and girders.

9.13.2 The Rule requirements for section modulus, inertia and web area for **house top primary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

9.13.3 The Rule requirements for section modulus, inertia and web area for house top **secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

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9.14 Coachroof stiffeners

9.14.1 The Rule requirements for section modulus, inertia and web area for coachroof **primary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

9.14.2 The Rule requirements for section modulus, inertia and web area for coachroof **secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.15 Machinery casing stiffeners

9.15.1 The Rule requirements for section modulus, inertia and web area for machinery casing **primary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

9.15.2 The Rule requirements for section modulus, inertia and web area for machinery casing **secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.15.3 Where casing stiffeners carry loads from deck transverses, girders, etc., or where they are in line with pillars below, they are to be suitably reinforced.

9.15.4 Where casing sides act as girders supporting decks over, care is to be taken that access openings do not seriously weaken the structure. Openings are to be effectively framed and reinforced if found necessary. Particular attention is to be paid to stiffening where the casing supports the funnel or exhaust uptakes.

9.16 Forecastle stiffeners

9.16.1 The scantlings of forecastle primary and secondary stiffening members are to be equivalent to those for the side shell envelope framing at the deck edge as required by Section 4.

9.17 Superstructures formed by extending side structures

9.17.1 Superstructure first tier sides formed by extending the hull side structure are to be in accordance with the requirements for house fronts given in 9.4 and 9.11 for plating and stiffeners respectively, but need not be taken as greater than the side structure requirements at the deck edge at the same longitudinal position.

9.18 Fire aspects

9.18.1 The requirements for fire detection, protection and extinction are given in Part 17.

9.19 Openings

9.19.1 All openings are to be substantially framed and have well rounded corners. Arrangements are to be made to minimise the effect of discontinuities in erections. Continuous coamings or girders are to be fitted below and above doors and similar openings.

9.19.2 Particular attention is to be paid to the effectiveness of end bulkheads, and the upper deck stiffening in way, when large openings for doors and windows are fitted.

9.19.3 Special care is to be taken to minimise the size and number of openings in the side bulkheads in the region of the ends of erections within $0{,}5L_R$ amidships. Account is to be taken of the high vertical shear loading which can occur in these areas.

9.19.4 For closing arrangements and outfit the requirements are given in Pt 3, Ch 4.

9.20 Mullions

9.20.1 Window openings are to be suitably framed and mullions will in general be required.

9.20.2 The scantlings of mullions are to be not less than as required for a stiffener in the same position.

9.20.3 When determining the stiffener requirements, the width of effective plating is in no case to be taken as greater than the distance between adjacent window openings.

9.20.4 Where significant shear forces are to be vertically transmitted by the window frames, adequate shear rigidity is to be verified by direct calculation.

9.21 Global strength

9.21.1 Transverse rigidity is to be maintained throughout the length of the erection by means of web frames, bulkheads or partial bulkheads. Particular attention is to be paid when an upper tier is wider than its supporting tier and when significant loads are carried on the house top.

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9.21.2 Where practicable, web frames are to be arranged in line with bulkheads below.

9.21.3 Internal bulkheads are to be fitted in line with bulkheads or deep primary stiffeners below.

9.22 House/deck connection

9.22.1 Adequate support under the ends of erections is to be provided in the form of webs, pillars, diaphragms or bulkheads in conjunction with reinforced deck beams.

9.22.2 Special attention is to be given to the connection of the erection to the deck in order to provide an adequate load distribution and avoid stress concentrations.

9.22.3 Connections between the erection and the deck by means of bimetallic joints are to comply with Ch 2,4.28.

9.22.4 Typical design details of house/deck connections are given in LR's *Guidance Notes for Structural Details*.

9.23 Sheathing

9.23.1 Sheathing arrangements are to comply with the requirements of 2.4.

9.24 Erections contributing to longitudinal strength

9.24.1 For craft above 40 m in length, L_R, or for designs where the superstructure is designed to absorb global loads the effectiveness of superstructures to carry these loads is to be determined. The effectiveness may be assessed in accordance with Ch 6,2.5.

9.24.2 Where 9.17 applies and the first or second tier is regarded as the strength deck according to Ch 6,2.5, the hull upper deck scantlings at the forward and aft ends of the superstructure may need to be increased due to the lesser efficiency of the superstructure tiers at their ends. The scantlings of the side structure in way of these areas may also need to be increased.

9.24.3 When large openings or a large number of smaller openings are cut in the superstructure sides, reducing the capability to transmit shear force between decks, an assessment or structural efficiency may be required.

9.25 Novel features

9.25.1 Direct calculations may be required to determine the plating and stiffener requirements where the house is of unusual design, form or proportions.

9.26 Bulwarks

9.26.1 General requirements for bulwarks are given in Pt 3, Ch 4,8.

9.26.2 The thickness of the bulwark plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

9.26.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (d).

9.26.4 Bulwarks are not to be cut for gangway or other openings near the breaks of superstructures.

9.26.5 Attention is to be paid to avoid discontinuity of strength of the bulwark, particularly in way of local increases in stress and changes in height.

9.26.6 Welding of bulwark to the top edge of sheer strake within $0{,}5L_R$ amidship, is generally to be avoided. However, if this arrangement is not practicable welding to the sheerstrake may be accepted if care is taken to minimise any notch effects.

9.26.7 **Fishing craft** are to have bulwarks fitted. The bulwark may be formed from a continuation of the side shell plating or connected as a separate assembly. Where the bulwark is considered to be stressed and contributing to the global strength of the craft, the plate thickness of the bulwark is not to be less than the sheerstrake plating thickness. In no case is the thickness of the bulwark plating to be taken as less than 80 per cent of the side shell thickness. The bulwark is to be supported by suitable stiffening members which may be formed from a continuation of the side frames, or from flanged plate stays of the same thickness as the bulwark. In general these frames are to be spaced not more than two side frame spacings apart.

9.26.8 In way of gantries, trawl gallows, mooring pipes, etc., the plate thickness in way is to be increased by not less than 50 per cent.

9.26.9 **Pilot craft** are to be fitted with sufficient hand rails adjacent to the exposed areas of the working decks and platforms. In addition these areas are to have non-skid surfaces.

9.27 Freeing arrangements

9.27.1 Requirements for freeing arrangements are given in Pt 3, Ch 4,9.

9.28 Free flow area

9.28.1 The requirements for the free flow area are given in Pt 3, Ch 4,9.3.

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9.29 Guard rails

9.29.1 The requirements for guard rails are given in Pt 3, Ch 4,8.4.

■ *Section 10*
Pillars and pillar bulkheads

10.1 Application

10.1.1 Pillars are to be arranged to transmit loads from decks and superstructures into the bottom structure. Pillars are generally to be constructed from solid, tubular, or *I* beam section. A pillar may be a fabricated trunk or partial bulkhead.

10.2 Determination of span length

10.2.1 The effective span length of the pillar, l_{ep}, is in general the distance between the head and heel of the pillar. Where substantial brackets are fitted, l_{ep} may be reduced by 2/3 the depth of the bracket at each end.

10.3 Head and heel connections

10.3.1 Pillars are to be attached at their heads to plates supported by efficient brackets, in order to transmit the load effectively. Doubling or insert plates are to be fitted to decks under large pillars and to the inner bottom under the heels of tubular or hollow square pillars. The pillars are to have a bearing fit and are to be attached to the head and heel plates by continuous welding. At the heads and heels of pillars built of rolled sections, the load is to be well distributed by means of longitudinal and transverse brackets.

10.4 Alignment and arrangement

10.4.1 Pillars are to be located on main structural members. They are in general to be fitted below windlasses, winches, capstans, the corners of deckhouses and elsewhere where considered necessary.

10.4.2 Wherever possible, deck pillars are to be fitted in the same vertical line as pillars above and below, and effective arrangements are to be made to distribute the load at the heads and heels of all pillars.

10.4.3 Where pillars support eccentric loads, or are subjected to lateral pressures, they are to be suitably strengthened for the additional bending moment imposed upon them.

10.4.4 Doublers are generally to be fitted on decks and inner bottoms, other than within tanks where doublers are not allowed. Brackets may be used instead of doublers.

10.5 Minimum thickness

10.5.1 The minimum wall thickness of hollow pillars is to be taken as not less than 1/20 of the external dimension of the pillar.

10.6 Design loads

10.6.1 The design loading, P_p, is not to be less than:

$$P_p = S_{gt}\, b_{gt}\, P_c + P_a \text{ kN}$$

where

P_p = design load supported by the pillar, to be taken as not less than 5 kN

P_c = basic deck girder design pressure, as appropriate, plus any other loadings directly above the pillar, in kN/m^2

P_a = load, in kN, from pillar or pillars above, assumed zero if there are no pillars over

S_{gt} = spacing, or mean spacing, of girders or transverses, in metres

b_{gt} = distance between centres of two adjacent spans of girders or transverses supported by the pillar, in metres.

10.7 Scantlings determination

10.7.1 The cross-sectional area of the pillar, A_p, is not to be less than:

$$A_p = 10\,\frac{P_p}{\sigma_p} \text{ cm}^2$$

where

P_p = design load, in kN, supported by the pillar as determined from 10.6

σ_p = permissible compressive stress, in N/mm^2

$$= \frac{f_p\,\sigma_A}{1 + 0{,}015\sigma_A\, k_f \left(\frac{l_{ep}}{r}\right)^2} \text{ N/mm}^2$$

where

f_p = pillar location factor defined in Table 3.10.1

σ_A = 0,2 per cent proof stress of the alloy in the unwelded condition, in N/mm^2

k_f = pillar end fixity factor
= 0,25 for full fixed/bracketed
= 0,50 for partially fixed
= 1,0 for free ended

r = least radius of gyration of pillar cross-section, in cm, and may be taken as:

$$r = \sqrt{\frac{I_p}{A_p}} \text{ cm}$$

I_p = least moment of inertia of cross-section of pillar or stiffener/plate combination, in cm^4

l_{ep} = effective span of pillar or bulkhead, in metres, as defined in 10.2.

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Table 3.10.1 Pillar location factors

Location	f_p
Supporting weather deck	0,50
Supporting vehicle deck	0,50
Supporting passenger deck	0,50
Supporting lower/inner deck	0,75
Supporting coachroof	0,75
Supporting deckhouse top	1,00

10.8 Maximum slenderness ratio

10.8.1 The slenderness ratio (l_{ep}/r) of pillars is not to be taken greater than 1,1, where l_{ep} and r are as defined in 10.7.1. Pillars with slenderness ratio in excess of 1,1 may be accepted subject to special consideration on a case by case basis and provided that the remaining requirements of the Rules are complied with.

10.9 Pillars in tanks

10.9.1 In no circumstances are pillars to pass through tanks. Where loads are to be transmitted through tanks, pillars within the tanks are to be carefully aligned with the external pillars.

10.9.2 Pillars within tanks are, in general, to be of solid cross section. Where it is proposed to use hollow section pillars each case will be subject to special consideration and the scantlings as determined from the Rules may require to be increased dependent upon the material to be used, the fluid contained and the arrangement of the pillars. Hollow pillars are to be adequately drained and vented.

10.9.3 Where pillars within tanks may be subjected to tensile stresses due to hydrostatic pressure, the design is to provide sufficient welding to withstand the tensile load imposed.

10.9.4 Doubling plates at ends of pillars within tanks are not acceptable.

10.10 Pillar bulkheads

10.10.1 The stiffener/plate combination used in the determination of pillar bulkhead scantlings is to be that of a stiffener with an effective width of attached plating as determined from 1.11.

10.10.2 The cross-sectional area of the pillar bulkhead, A_{pb}, is to be determined in accordance with 10.7 using the design loading, P_{pb}, as follows:

$$P_{pb} = S_{bs}\, b_{pb}\, P_c + P_a \text{ kN}$$

where

P_{pb} = design load supported by the stiffener plate combination of the pillar bulkhead

P_c = basic deck girder design pressure, as appropriate, plus any other loadings directly above the pillar, in kN/m^2

S_{bs} = spacing, or mean spacing, of bulkheads or effective transverses/longitudinal stiffeners, in metres

b_{pb} = distance between centres of two adjacent spans of girders or transverses supported by the pillar bulkhead, in metres, and can be taken as the distance between pillar bulkhead stiffeners where the stiffeners at the top of the bulkhead effectively distributes the load evenly into the stiffeners.

10.10.3 The thickness of the bulkhead plating is in no case to be taken less than 4 mm.

10.11 Direct calculations

10.11.1 As an alternative to 10.6, pillars may be designed on the basis of direct calculation. The method adopted and the stress levels proposed for the material of construction are to be submitted together with the calculations for consideration.

10.12 Fire aspects

10.12.1 Pillars and pillar bulkheads are to be suitably protected against fire, and, where necessary, be self-extinguishing or capable of resisting fire damage. All pillars are to comply with the requirements of Part 17.

10.13 Novel features

10.13.1 Where unusual or novel pillar designs are proposed that are unable to comply with the requirements of this Section, their design together with the direct calculations are to be submitted for special consideration.

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Section

1 **General**

2 **Minimum thickness requirements**

3 **Shell envelope plating**

4 **Shell envelope framing**

5 **Single bottom structure and appendages**

6 **Double bottom structure**

7 **Bulkheads and deep tanks**

8 **Deck structures**

9 **Superstructures, deckhouses, pillars and bulwarks**

Section 1 General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to multi-hull craft of aluminium construction as defined in Pt 1, Ch 1,1.

1.2 General

1.2.1 Except as otherwise specified within this Chapter, the scantlings and arrangements of multi-hull craft are to be determined in accordance with the procedures described in, or required by Chapter 3 for mono-hull craft, using the pressures from Part 5 appropriate to multi-hulls.

1.3 Direct calculations

1.3.1 Where the craft is of unusual design, form or proportions, or where the speed of the craft exceeds 60 knots the scantlings are to be determined by direct calculation.

1.3.2 The requirements of this Chapter may be modified where direct calculation procedures are adopted to analyse the stress distribution in the primary structure.

1.4 Equivalents

1.4.1 Lloyd's Register (hereinafter referred to as 'LR') will consider direct calculations for the derivation of scantlings as an alternative and equivalent to those derived by Rule requirements in accordance with Pt 3, Ch 1,3.

1.5 Symbols and definitions

1.5.1 The symbols used in this Chapter are defined below and in the appropriate Section:

k_a = alloy factor
= $125/\sigma_a$
s = stiffener spacing, in mm
t_p = plating thickness, in mm
L_R = Rule length of craft, in metres
σ_a = 0,2 per cent proof stress of the alloy in the welded condition, in N/mm^2.

1.5.2 **Bottom outboard.** For high speed craft, where the scantlings of the bottom shell are governed by impact pressure considerations, the bottom outboard shell is defined as the area of the hull between the outboard edge of the keel and the outer bilge tangential point. For displacement and semi displacement type craft where the scantlings of the bottom shell are governed by either hydrostatic or pitching pressures the bottom outboard shell is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

1.5.3 **Bottom inboard.** For high speed craft, where the scantlings of the bottom shell are governed by impact pressure considerations, the bottom inboard shell is defined as the area of the hull between the inboard edge of the keel and the inner bilge tangential point. For displacement and semi displacement type craft where the scantlings of the bottom shell are governed by either hydrostatic or pitching pressures the bottom inboard shell is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

1.5.4 **Cross-deck.** The cross-deck is defined as the structure which forms the bridge connection between any two adjacent hulls.

1.5.5 **Haunch.** The haunch is defined as the transition area between the cross-deck and the inboard side shell plating.

1.5.6 **Side inboard.** The side inboard is defined as the area between the bottom inboard shell and the wet-deck (or lower edge of the haunches, where fitted).

1.5.7 **Side outboard.** The side outboard is defined as the area between bottom outboard shell and the deck at side.

1.5.8 **Wet-deck.** The wet-deck is defined as the area between the upper edges of the side inboard plating (or upper edges of the haunches, where fitted).

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Section 2
Minimum thickness requirements

2.1 General

2.1.1 Unless otherwise specified in this Section, the requirements of Ch 3,2 are to be complied with.

2.1.2 The thickness of plating and stiffeners determined from the Rule requirements is in no case to be less than the appropriate minimum requirement given in Table 4.2.1 for craft type.

2.1.3 In addition, where plating contributes to the global strength of the craft, the thickness is to be not less than that required to satisfy global strength requirements.

Table 4.2.1 Minimum thickness requirements

Item	Minimum thickness (mm)		
	Catamaran	Multi-hull	Swath
Shell envelope Bottom shell plating	$\omega\sqrt{k_m}\,(0,7\sqrt{L_R}+1,0) \geq 4,0\,\omega$	$\omega\sqrt{k_m}\,(0,7\sqrt{L_R}+1,0) \geq 4,0\,\omega$	$\omega\sqrt{k_m}\,(0,7\sqrt{L_R}+1,0) \geq 4,0\,\omega$
Side shell plating	$\omega\sqrt{k_m}\,(0,5\sqrt{L_R}+1,4) \geq 3,5\,\omega$	$\omega\sqrt{k_m}\,(0,5\sqrt{L_R}+1,4) \geq 3,5\,\omega$	$\omega\sqrt{k_m}\,(0,5\sqrt{L_R}+1,4) \geq 3,5\,\omega$
Wet-deck plating	$\omega\sqrt{k_m}\,(0,5\sqrt{L_R}+1,4) \geq 3,5\,\omega$	$\omega\sqrt{k_m}\,(0,5\sqrt{L_R}+1,4) \geq 3,5\,\omega$	$\omega\sqrt{k_m}\,(0,5\sqrt{L_R}+1,4) \geq 3,5\,\omega$
Single bottom structure Centre girder web	$\omega\sqrt{k_m}\,(1,1\sqrt{L_R}+1,4) \geq 5,0\,\omega$	$\omega\sqrt{k_m}\,(1,1\sqrt{L_R}+1,4) \geq 5,0\,\omega$	$\omega\sqrt{k_m}\,(1,1\sqrt{L_R}+1,4) \geq 5,0\,\omega$
Floor webs	$\omega\sqrt{k_m}\,(0,8\sqrt{L_R}+1,1) \geq 4,0\,\omega$	$\omega\sqrt{k_m}\,(0,8\sqrt{L_R}+1,1) \geq 4,0\,\omega$	$\omega\sqrt{k_m}\,(0,8\sqrt{L_R}+1,1) \geq 4,0\,\omega$
Side girder webs	$\omega\sqrt{k_m}\,(0,8\sqrt{L_R}+1,1) \geq 4,0\,\omega$	$\omega\sqrt{k_m}\,(0,8\sqrt{L_R}+1,1) \geq 4,0\,\omega$	$\omega\sqrt{k_m}\,(0,8\sqrt{L_R}+1,1) \geq 4,0\,\omega$
Double bottom structure Centre girder			
(1) Within 0,4*L* amidships	$\omega\sqrt{k_m}\,(1,1\sqrt{L_R}+1,4) \geq 5,0\,\omega$	$\omega\sqrt{k_m}\,(1,1\sqrt{L_R}+1,4) \geq 5,0\,\omega$	$\omega\sqrt{k_m}\,(1,1\sqrt{L_R}+1,4) \geq 5,0\,\omega$
(2) Outside 0,4*L* amidships	$\omega\sqrt{k_m}\,(0,95\sqrt{L_R}+1,4) \geq 5,0\,\omega$	$\omega\sqrt{k_m}\,(0,95\sqrt{L_R}+1,4) \geq 5,0\,\omega$	$\omega\sqrt{k_m}\,(0,95\sqrt{L_R}+1,4) \geq 5,0\,\omega$
Floors and side girders	$\omega\sqrt{k_m}\,(0,8\sqrt{L_R}+1,1) \geq 4,0\,\omega$	$\omega\sqrt{k_m}\,(0,8\sqrt{L_R}+1,1) \geq 4,0\,\omega$	$\omega\sqrt{k_m}\,(0,8\sqrt{L_R}+1,1) \geq 4,0\,\omega$
Inner bottom plating	$\omega\sqrt{k_m}\,(0,7\sqrt{L_R}+1,3) \geq 3,5\,\omega$	$\omega\sqrt{k_m}\,(0,7\sqrt{L_R}+1,3) \geq 3,5\,\omega$	$\omega\sqrt{k_m}\,(0,7\sqrt{L_R}+1,3) \geq 3,5\,\omega$
Bulkheads Watertight bulkhead plating	$\omega\sqrt{k_m}\,(0,43\sqrt{L_R}+1,2) \geq 3,0\,\omega$	$\omega\sqrt{k_m}\,(0,43\sqrt{L_R}+1,2) \geq 3,0\,\omega$	$\omega\sqrt{k_m}\,(0,43\sqrt{L_R}+1,2) \geq 3,0\,\omega$
Deep tank bulkhead plating	$\omega\sqrt{k_m}\,(0,5\sqrt{L_R}+1,4) \geq 3,5\,\omega$	$\omega\sqrt{k_m}\,(0,5\sqrt{L_R}+1,4) \geq 3,5\,\omega$	$\omega\sqrt{k_m}\,(0,5\sqrt{L_R}+1,4) \geq 3,5\,\omega$
Deck plating and stiffeners Strength/Main deck plating	$\omega\sqrt{k_m}\,(0,5\sqrt{L_R}+1,4) \geq 3,5\,\omega$	$\omega\sqrt{k_m}\,(0,5\sqrt{L_R}+1,4) \geq 3,5\,\omega$	$\omega\sqrt{k_m}\,(0,5\sqrt{L_R}+1,4) \geq 3,5\,\omega$
Lower deck/Inside deckhouse	$\omega\sqrt{k_m}\,(0,3\sqrt{L_R}+1,3) \geq 3,0\,\omega$	$\omega\sqrt{k_m}\,(0,3\sqrt{L_R}+1,3) \geq 3,0\,\omega$	$\omega\sqrt{k_m}\,(0,3\sqrt{L_R}+1,3) \geq 3,0\,\omega$
Superstructures and deckhouses Superstructure side plating	$\omega\sqrt{k_m}\,(0,4\sqrt{L_R}+1,1) \geq 3,0\,\omega$	$\omega\sqrt{k_m}\,(0,4\sqrt{L_R}+1,1) \geq 3,0\,\omega$	$\omega\sqrt{k_m}\,(0,4\sqrt{L_R}+1,1) \geq 3,0\,\omega$
Deckhouse front 1st tier	$\omega\sqrt{k_m}\,(0,62\sqrt{L_R}+1,8) \geq 3,5\,\omega$	$\omega\sqrt{k_m}\,(0,62\sqrt{L_R}+1,8) \geq 3,5\,\omega$	$\omega\sqrt{k_m}\,(0,62\sqrt{L_R}+1,8) \geq 3,5\,\omega$
Deckhouse front upper tiers	$\omega\sqrt{k_m}\,(0,55\sqrt{L_R}+1,5) \geq 3,0\,\omega$	$\omega\sqrt{k_m}\,(0,55\sqrt{L_R}+1,5) \geq 3,0\,\omega$	$\omega\sqrt{k_m}\,(0,55\sqrt{L_R}+1,5) \geq 3,0\,\omega$
Deckhouse aft	$\omega\sqrt{k_m}\,(0,25\sqrt{L_R}+0,7) \geq 2,5\,\omega$	$\omega\sqrt{k_m}\,(0,25\sqrt{L_R}+0,7) \geq 2,5\,\omega$	$\omega\sqrt{k_m}\,(0,25\sqrt{L_R}+0,7) \geq 2,5\,\omega$
Pillars Wall thickness of tubular pillars	$\omega\sqrt{k_m}\,0,07d_p$	$\omega\sqrt{k_m}\,0,07d_p$	$\omega\sqrt{k_m}\,0,07d_p$
Wall thickness of rectangular pillars	$\omega\sqrt{k_m}\,0,07b_p$	$\omega\sqrt{k_m}\,0,07b_p$	$\omega\sqrt{k_m}\,0,07b_p$

Symbols

ω = service type factor as determined from Table 4.2.2
k_m = $385/(\sigma_A + \sigma_u)$
σ_A = specified minimum yield stress or 0,2% proof stress of the alloy in unwelded condition, in N/mm^2
σ_u = specified minimum ultimate tensile strength of the alloy in unwelded condition, in N/mm^2
b_p = minimum breadth of cross section of hollow rectangle pillar, in mm
d_p = outside diameter of tubular pillar, in mm
L_R = as defined in 1.5.1

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Table 4.2.2 Service type correction factors (ω)

Service type notation	ω
Cargo	1,1
Passenger	1,0
Patrol	1,0
Pilot	1,1
Yacht	1,0
Workboat MFV	1,2

■ *Section 3* Shell envelope plating

3.1 General

3.1.1 Unless otherwise specified within this Section, the scantlings and arrangements for shell envelope plating are to be determined in accordance with the procedures described in, or as required by, Ch 3,3 for mono-hull craft using the pressures from Part 5 appropriate to multi-hulls.

3.1.2 The thickness of the shell envelope plating is in no case to be less than the appropriate minimum requirement given in Section 2.

3.2 Keel plates

3.2.1 The breadth, b_k, and thickness, t_k, of plate keels are not to be taken as less than:

$$b_k = 5{,}0L_R + 250 \text{ mm}$$

$$t_k = \sqrt{k_a}\ 1{,}85L_R^{0,45} \text{ mm}$$

where

L_R and k_a are as defined in 1.5.1.

3.2.2 In no case is the thickness of the keel to be less than that of the adjacent bottom shell plating.

3.2.3 The width and thickness of plate keels are to be maintained throughout the length of the craft from the transom to a point not less than 25 per cent of the freeboard (measured at the forward perpendicular) above the deepest load waterline on the stem. Thereafter the keel thickness may be reduced to that required by Ch 3,3.3.1 for the stem.

3.2.4 For large or novel craft and for yachts with externally attached ballast keels, the scantlings of the keel will be specially considered.

3.3 Bottom outboard

3.3.1 The thickness of the bottom outboard plating is to be determined from the general plating equation given in Ch 3,1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.3.2 For all craft types, the minimum bottom outboard shell thickness requirement given in Section 2 is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

3.4 Bottom inboard

3.4.1 The thickness of the bottom inboard plating is to be determined from the general plating equation given in Ch 3,1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.4.2 For all craft types, the minimum bottom inboard shell thickness requirement given in Section 2 is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

3.5 Side outboard

3.5.1 The thickness of the side outboard plating is to be determined from the general plating equation given in Ch 3,1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.6 Side inboard

3.6.1 The thickness of the side inboard plating is to be determined from the general plating equation given in Ch 3,1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.7 Wet-deck

3.7.1 The thickness of the wet-deck plating is to be determined from the general plating equation given in Ch 3,1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.7.2 Additionally, the thickness of the wet-deck plating is in no case to be less than the thickness of the side inboard shell plating determined from 3.6.

3.7.3 The wet-deck plating on the underside of the cross-deck structure may require to be additionally protected, particularly where the air gap is small and there is a high risk of localised impact due to collision with floating debris, ice, etc., in the service area. In such cases the sheathing requirements given in Ch 3,2.4 are to be complied with.

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3.8 Transom

3.8.1 The scantlings and arrangements of the stern or transom are to be not less than that required for the adjacent bottom inboard or side outboard structure as appropriate. Where water jet or sterndrive units are fitted, the scantlings of the plating in way of the nozzles and connections will be specially considered.

3.9 Haunch reinforcement (SWATH)

3.9.1 For craft above 40 m in Rule length, L_R, the stresses in the haunch area are to be derived using a two dimensional fine mesh finite element analysis. The model is to extend horizontally into the box structure and vertically into the strut structure. All discontinuities and cut-outs are to be modelled in order to determine shear stresses at critical locations and stresses for the determination of fatigue strength.

3.9.2 Due consideration is to be given to shear lag when determining the effective breadth of the attached plating.

3.10 Lower hull (SWATH)

3.10.1 Where the lower hull structure incorporates ring frames and attached shell plating fitted between bulkheads or diaphragms, the thickness of the lower hull shell plating may be derived from an established method for shell analysis or recognised standard for pressure vessels using the design pressure loading from Pt 5, Ch 4,3.1. Other loads considered significant for the scantling determination are to be taken into account. Modes of failure to be considered are buckling, frame collapse, inter-frame shell collapse and overall frame shell collapse between bulkheads. A copy of the direct calculations is to be submitted for consideration.

3.11 Novel features

3.11.1 Where the Rules do not specifically define the requirements for plating elements with novel features then the scantlings and arrangements are to be determined by direct calculations. Such calculations are to be carried out on the basis of the Rules, Recognised Standards and good practice, and are to be submitted for consideration.

■ *Section 4* Shell envelope framing

4.1 General

4.1.1 Unless otherwise specified in this Section, the scantlings and arrangements for shell envelope framing are to be determined in accordance with the procedures described in, or as required by, Ch 3,3 for mono-hull craft using the pressures from Part 5 appropriate to multi-hulls.

4.1.2 The requirements in this Section apply to longitudinally and transversely framed shell envelopes.

4.2 Bottom outboard longitudinal stiffeners

4.2.1 Bottom outboard longitudinal stiffeners are to be supported by transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.2.2 Bottom outboard longitudinals are to be continuous through the supporting structures.

4.2.3 Where it is impracticable to comply with the requirements of 4.2.2, or where it is proposed to terminate the bottom outboard longitudinals in way of the transom, bulkheads or integral tank boundaries, all longitudinals are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets.

4.2.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b).

4.3 Bottom outboard longitudinal primary stiffeners

4.3.1 Bottom outboard longitudinal primary stiffeners are to be supported by deep transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 4 m apart.

4.3.2 Bottom outboard longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

4.3.3 Where it is impracticable to comply with the requirements of 4.3.2, or where it is proposed to terminate the stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.3.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

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4.4 Bottom outboard transverse stiffeners

4.4.1 Bottom outboard transverse stiffeners are defined as local stiffening members which support the bottom shell and which may be continuous or intercostal.

4.4.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b).

4.5 Bottom outboard transverse frames

4.5.1 Bottom outboard transverse frames are defined as stiffening members which support the bottom shell. They are to be effectively continuous and bracketed at their end connections to side frames and bottom floors as appropriate.

4.5.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.6 Bottom outboard transverse web frames

4.6.1 Bottom outboard transverse web frames are defined as primary stiffening members which support bottom shell longitudinals. They are to be continuous and substantially bracketed at their end connections to side web frames and bottom floors.

4.6.2 Where it is impracticable to comply with the requirements of 4.6.1, or where it is proposed to terminate the web frames in way of bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.6.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.7 Bottom inboard longitudinal stiffeners

4.7.1 The scantlings and arrangements for bottom inboard longitudinal stiffeners are to be determined in accordance with the procedures described in 4.2 using the bottom inboard stiffening member design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.8 Bottom inboard longitudinal primary stiffeners

4.8.1 The scantlings and arrangements for bottom inboard longitudinal primary stiffeners are to be determined in accordance with the procedures described in 4.3 using the bottom inboard stiffening member design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.9 Bottom inboard transverse stiffeners

4.9.1 The scantlings and arrangements for bottom inboard transverse stiffeners are to be determined in accordance with the procedures described in 4.4 using the bottom inboard stiffening member design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.10 Bottom inboard transverse frames

4.10.1 The scantlings and arrangements for bottom inboard transverse frames are to be determined in accordance with the procedures described in 4.5 using the bottom inboard stiffening member design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.11 Bottom inboard transverse web frames

4.11.1 The scantlings and arrangements for bottom inboard transverse frames are to be determined in accordance with the procedures described in 4.6 using the bottom inboard stiffening design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.12 Side outboard longitudinal stiffeners

4.12.1 The side outboard longitudinal stiffeners are to be supported by transverse web frames, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.12.2 Side outboard longitudinals are to be continuous through the supporting structures.

4.12.3 Where it is impracticable to comply with the requirements of 4.12.2, or where it is proposed to terminate the side outboard longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.12.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b).

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4.13 Side outboard longitudinal primary stiffeners

4.13.1 Side outboard longitudinal primary stiffeners are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 4 m apart.

4.13.2 Side outboard longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

4.13.3 Where it is impracticable to comply with the requirements of 4.13.2, or where it is proposed to terminate the side outboard longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.13.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.14 Side outboard transverse stiffeners

4.14.1 Side outboard transverse stiffeners are defined as local stiffening members supporting the side shell and may be continuous or intercostal.

4.14.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b).

4.15 Side outboard transverse frames

4.15.1 Side outboard transverse frames are defined as stiffening members supporting the side shell and spanning continuously between bottom floors/frames and decks. They are to be effectively constrained against rotation at their end connections.

4.15.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.16 Side outboard transverse web frames

4.16.1 Side outboard transverse web frames are defined as primary stiffening members which support side shell longitudinals. They are to be continuous and substantially bracketed at their head and heel connections to deck beams and bottom web frames respectively.

4.16.2 Where it is impracticable to comply with the requirements of 4.16.1, or where it is proposed to terminate the side outboard longitudinals in way of bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.16.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.17 Side inboard longitudinal stiffeners

4.17.1 The scantlings and arrangements for side inboard longitudinal stiffeners are to be determined in accordance with the procedures described in 4.12 using the side inboard design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.18 Side inboard longitudinal primary stiffeners

4.18.1 The scantlings and arrangements for side inboard longitudinal primary stiffeners are to be determined in accordance with the procedures described in 4.13 using the side inboard design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.19 Side inboard transverse stiffeners

4.19.1 The scantlings and arrangements for side inboard transverse stiffeners are to be determined in accordance with the procedures described in 4.14 using the side inboard design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.20 Side inboard transverse frames

4.20.1 The scantlings and arrangements for side inboard transverse frames are to be determined in accordance with the procedures described in 4.15 using the side inboard design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

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4.21 Side inboard transverse web frames

4.21.1 The scantlings and arrangements for side inboard transverse web frames are to be determined in accordance with the procedures described in 4.16 using the side inboard design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.22 Wet-deck longitudinal stiffeners

4.22.1 The wet-deck longitudinal stiffeners are to be supported by transverse web frames, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.22.2 Wet-deck longitudinals are to be continuous through the supporting structures.

4.22.3 Where it is impracticable to comply with the requirements of 4.22.2, or where it is proposed to terminate the wet-deck longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.22.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b).

4.22.5 In no case are the scantlings and arrangements for the wet-deck longitudinal stiffeners to be taken as less than those required for the side inboard longitudinal stiffeners detailed in 4.17.

4.23 Wet-deck longitudinal primary stiffeners

4.23.1 Wet-deck longitudinal primary stiffeners are to be supported by transverse web frames, bulkheads, or other primary structure, generally spaced not more than 4 m apart.

4.23.2 Wet-deck longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

4.23.3 Where it is impracticable to comply with the requirements of 4.23.2, or where it is proposed to terminate the wet-deck longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.23.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.23.5 In no case are the scantlings and arrangements for the wet-deck longitudinal primary stiffeners to be taken as less than those required for the side inboard longitudinal primary stiffeners detailed in 4.18.

4.23.6 Additionally the requirements of Chapter 6 relating to global strength are to be complied with.

4.24 Wet-deck transverse stiffeners

4.24.1 Wet-deck transverse stiffeners are defined as local stiffening members supporting the wet-deck and may be continuous or intercostal.

4.24.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b).

4.24.3 In no case are the scantlings and arrangements for the wet-deck transverse stiffeners to be taken as less than those required for the side inboard transverse stiffeners detailed in 4.19.

4.25 Wet-deck transverse frames

4.25.1 Wet-deck transverse frames are defined as stiffening members which support the wet-deck. They are to be effectively continuous and bracketed at their end connections to side frames.

4.25.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.25.3 In no case are the scantlings and arrangements for the wet-deck transverse frames to be taken as less than those required for the side inboard transverse frames detailed in 4.20.

4.26 Wet-deck transverse web frames

4.26.1 Wet-deck transverse web frames are defined as primary stiffening members which support wet-deck longitudinals. They are to be continuous and substantially bracketed at their end connections to side transverse web frames.

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4.26.2 Where it is impracticable to comply with the requirements of 4.26.1, or where it is proposed to terminate the wet-deck longitudinals in way of the bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.26.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.26.4 In no case are the scantlings and arrangements for the wet-deck transverse web frames to be taken as less than those required for the side inboard transverse web frames detailed in 4.21.

4.26.5 Primary transverse web frames that link the strength deck to the wet-deck structure and which carry the transverse global loading are additionally to comply with Ch 6,3.4.

4.26.6 Particular care is to be taken to ensure that the continuity of transverse structural strength is maintained. All primary transverse members are to be continuous through the inboard side structure and integrated into transverse bulkheads or other primary structure within each hull (*see* Fig. 4.4.1). In the case of trimaran type craft the primary transverse members are to be continuous through the centre hull. Additionally the side inboard shell plating in way of the intersection is to be increased locally by not less than 50 per cent.

4.27 Lower hull (SWATH)

4.27.1 Where the lower hull structure incorporates ring frames and attached shell plating fitted between bulkheads or diaphragms, the scantlings of the lower hull shell stiffening may be derived from an established method for stiffening analysis or recognised standard for pressure vessels using the design loading from Pt 5, Ch 4,3.1 Modes of failure to be considered are buckling, frame collapse, inter frame shell collapse and overall frame shell collapse between bulkheads. A copy of the direct calculations is to be submitted for consideration.

4.28 Scantlings of end brackets

4.28.1 The scantlings of end brackets in way of transverse web frames/crossdeck primary structure which carry transverse global loading, are to be as large as practicable and be additionally reinforced as necessary. The webs of deep brackets are to be stiffened as necessary to resist buckling, *see also* Ch 6,3.5.

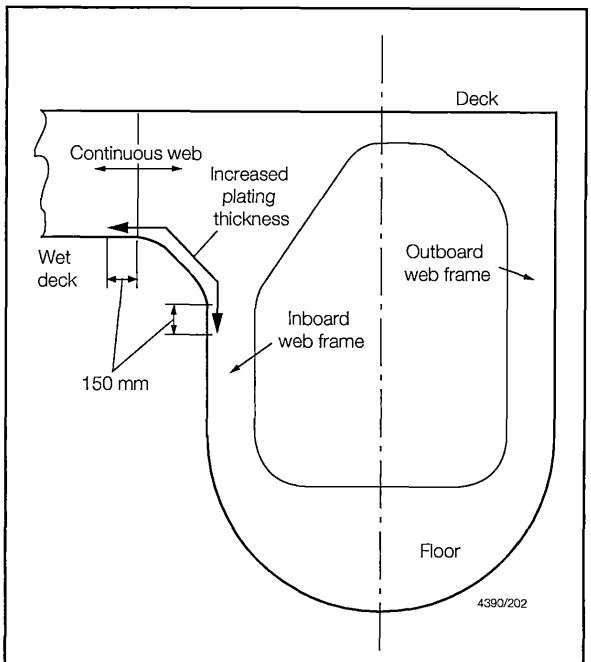

Fig. 4.4.1
End connection details, wet-deck structure

■ *Section 5*
Single bottom structure and appendages

5.1 General

5.1.1 Unless otherwise specified in this Section, the scantlings and arrangements for single bottom structure and appendages are to be determined in accordance with the procedures described in, or as required by, Ch 3,5 for mono-hull craft using the pressures from Part 5 appropriate to multi-hulls.

5.1.2 The thickness of single bottom structural members is in no case to be less than the appropriate minimum requirement given in Section 2.

5.2 Keel

5.2.1 The scantlings and arrangements of plate keels are to be in accordance with 3.2.

5.2.2 Where fitted, the cross-sectional area, A_{bk}, and thickness, t_{bk}, of bar keels should not, in general, be taken as less than:

$$A_{bk} = k_a(1{,}85L_R + 2) \text{ cm}^2$$

$$t_{bk} = \sqrt{k_a}\,(0{,}7L_R + 8{,}25) \text{ mm}$$

where

L_R and k_a are as defined in 1.5.1.

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5.3 Centre girder

5.3.1 Centreline girders are to be fitted throughout the length of each hull and are generally to be fitted in association with transverse frames, transverses supporting longitudinals or where the breadth of floors at the upper edge is greater than 1,5 m.

5.3.2 Centreline girders may be formed with intercostal or continuous plate webs. In all cases the face flat is to be continuous. Where girder webs are intercostal, additional bracketing and local reinforcement are to be provided to maintain the continuity of structural strength.

5.3.3 The web depth of the centre girder is, in general, to be equal to the depth of the floors at the centreline as specified in 5.5.3.

5.3.4 The web thickness, t_w, of the centre girder is to be taken as not less than:

$$t_w = \sqrt{k_a}\left(\sqrt{1{,}9L_R} + 1{,}3\right) \text{ mm}$$

where

k_a and L_R are as defined in 1.5.1.

5.3.5 The face flat area, A_f, of the centre girder is to be not less than:

$$A_f = 0{,}42k_a L_R \text{ cm}^2$$

where

k_a and L_R are as defined in 1.5.1.

5.3.6 The geometric section properties of the centre girder are to be in accordance with Ch 3,1.18.

5.3.7 The face flat area of the centre girder outside $0{,}5L_R$ may be 80 per cent of the value given in 5.3.5.

5.3.8 The face flat thickness, t_w, is to be not less than the thickness of the web.

5.3.9 The ratio of the width to thickness of the face flat is to be not less than eight but is not to exceed 16.

5.3.10 Additionally, the requirements of 4.8 for bottom inboard longitudinal primary stiffeners are to be complied with.

5.4 Side girders

5.4.1 Where the floor breadth at the upper edge exceeds 4,0 m side girders are to be fitted at each side of the centre girder such that the spacing between the side and centre girders or between the side girders themselves is not greater than 2 m. Side girders where fitted are to extend as far forward and aft as practicable and are, in general, to be scarfed into the bottom structure forward and aft of the support at which they terminate, i.e. terminate in way of bulkheads, deep floors or other primary transverse structure.

5.4.2 The web thickness, t_w, of side girders is to be taken as not less than:

$$t_w = \sqrt{0{,}83k_a L_R} \text{ mm}$$

where

k_a and L_R are as defined in 1.5.1.

5.4.3 The face flat area and thickness of side girders are to comply with the requirements for plate floors as defined in 5.5.6 and 5.5.7.

5.4.4 Additionally, the requirements of 4.8 for bottom inboard longitudinal primary stiffeners are to be complied with.

5.4.5 Watertight side girders, and side girders forming the boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads and deeptanks as detailed in Ch 3,7.2 and Ch 3,7.4 respectively.

5.4.6 In the engine room, additional side girders are generally to be fitted in way of main machinery seatings. Where fitted they are to be integrated into the structure of the craft and extended forward and aft as far as practicable.

5.5 Floors general

5.5.1 In transversely framed craft, floors are generally to be fitted at every frame and underneath each bulkhead.

5.5.2 In longitudinally framed craft, floors are, in general, to be fitted at every transverse web frame and bulkhead and generally at a spacing not exceeding 2 m. Additional transverse floors or webs are to be fitted at half web-frame spacing in way of engine seatings and thrust bearings, pillars, skegs, ballast/bilge keels and the bottom of the craft in the forefoot region.

5.5.3 The overall web depth, d_w, of floors at the centreline, is not to be taken as less than:

$$d_w = 6{,}2L_R + 50 \text{ mm}$$

where

L_R is as defined in 1.5.1.

5.5.4 The web thickness of plate floors, t_w, is to be in accordance with Ch 3,1.18 and not less than:

$$t_w = \sqrt{k_a}\left(\frac{4{,}7d_f}{1000} + 3{,}1\right)\left(\frac{s}{1000} + 0{,}5\right) \text{ mm}$$

where

d_f is determined from 5.5.3 and

k_a and s are as defined in 1.5.1.

5.5.5 If the side frames of the craft are attached to the floors by brackets, the depth of floor may be reduced by 15 per cent and the floor thickness determined using the reduced depth. The brackets are to be flanged and have the same thickness as the floors, and their arm lengths clear of the frame are to be the same as the reduced floor depth given above.

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5.5.6 The face flat area, A_f, of floors is not to be taken as less than:

$$A_f = k_a 0{,}21 L_R \text{ cm}^2$$

where

k_a and L_R are defined in 1.5.1.

5.5.7 The face flat thickness, t_f, is to be not less than the thickness of the web and the ratio of the web to the thickness of the face flat is to be not less than eight but is not to exceed 16.

5.5.8 Additionally, the requirements of 4.11 for bottom inboard transverse web frames are to be complied with.

5.5.9 Floors are in general to be continuous from side to side.

5.5.10 The tops of floors, in general, may be level from side to side. However, in craft having considerable rise of floor the depth of the floor plate may require to be increased to maintain the required section modulus.

5.5.11 The floors in the aft peak are to extend over and provide efficient support to the stern tube(s) where applicable.

5.5.12 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deeptanks as detailed in Ch 3,7.2 and Ch 3,7.4.

5.6 Floors in machinery space

5.6.1 The web thickness, t_w, of floors in machinery spaces is to be 1 mm greater than that required by 5.5.4.

5.6.2 The depth and mechanical strength properties of floors between engine or gearbox girders is to be not less than that required to maintain continuity of structural integrity or 50 per cent of the depth given in 5.5.3. The face flat area and web thickness of such reduced height floors are to be increased appropriately in order to maintain the continuity of structural strength, *see also* Ch 3,4.12.

5.7 Forefoot and stem

5.7.1 The thickness of plate stems at the waterline is to comply with the requirements for plate keels as given in 3.2.

5.7.2 The forefoot and stem are to be additionally reinforced with floors.

5.7.3 The cross-sectional area of bar stems, A_{bs}, is not to be taken as less than :

$$A_{bs} = 1{,}1 k_a L_R \text{ cm}^2$$

where

k_a and L_R are as defined in 1.5.1.

■ *Section 6* Double bottom structure

6.1 General

6.1.1 Unless otherwise specified in this Section, the scantlings and arrangements for the double bottom structure are to be determined in accordance with the procedures described in, or as required by, Ch 3,6 for mono-hull craft using the pressures from Part 5 appropriate to multi-hulls.

6.1.2 The thickness of double bottom structural members is in no case to be less than the appropriate minimum requirement given in Section 2.

6.2 Keel

6.2.1 The scantlings of plate and bar keels are to comply with the requirements of 5.2.

6.3 Centreline girder

6.3.1 A centreline girder is to be fitted throughout the length of the craft. The web thickness, t_w, is to be not less than that required by:

$$t_w = \sqrt{k_a}\ (0{,}082 L_R + 4{,}1) \text{ mm within } 0{,}4L \text{ amidships}$$

$$= \sqrt{k_a}\ (0{,}082 L_R + 2{,}7) \text{ mm at ends}$$

where

k_a and L_R are as defined in 1.5.

6.3.2 The geometric properties of the girder section are to be in accordance with Ch 3,1.18.

6.3.3 The overall web depth, d_w, of the centre girder is to be taken as not less than 630 mm and is to be sufficient to give adequate access to all parts of the double bottom.

6.3.4 Additionally, the requirements of 4.8 for bottom inboard longitudinal primary stiffeners are to be complied with.

6.4 Side girders

6.4.1 Where the floor breadth does not exceed 4,0 m, side girders are not required. Vertical stiffeners are to be fitted to the floors on each side, the number and positions of these stiffeners being dependent on the arrangement of the double bottom structure.

6.4.2 Where the breadth of floor is greater than 4,0 m, additional side girders having the same thickness as the floors are to be fitted. The number of side girders is to be such that the distance between the side girders and centre girder and margin plate, or between the side girders themselves, does not exceed 2,0 m.

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6.4.3 Side girders, where fitted, are to extend as far forward and aft as practicable and are in general to be scarfed into the bottom structure forward and aft of the supporting bulkheads, deep floors or other primary transverse structure.

6.4.4 Where additional side girders are fitted in way of main machinery seatings, they are to be integrated into the structure of the craft and extended forward and aft as far as practicable.

6.4.5 Under the main engine, girders extending from the bottom shell to the top plate of the engine seating are to be fitted. The height of the girders is to be not less than the height of the floor. Engine holding-down bolts are to be arranged as near as practicable to the girders and floors. Where this cannot be achieved, bracket floors and/or hanging brackets are to be fitted.

6.4.6 The geometric properties of the girder section are to be in accordance with Ch 3,1.18.

6.4.7 Additionally, the requirements of 4.8 for bottom inboard longitudinal primary stiffeners are to be complied with.

6.5 Plate floors

6.5.1 The web thickness, t_w, of non-watertight plate floor is to be not less than:

$$t = \sqrt{k_a}\ (0{,}41L_R + 4{,}8)\ \text{mm}$$

where

k_a and L_R are as defined in 1.5.

6.5.2 The geometric properties of the floor section are to be in accordance with Ch 3,1.18.

6.5.3 Additionally, the requirements of 4.11 for bottom inboard transverse web frames are to be complied with.

6.5.4 Plate floors are, in general, to be continuous between the centre girder and the margin plate.

6.5.5 In longitudinally framed craft, plate floors are to be fitted in the following positions:

(a) At every half frame in way of the main engines, thrust bearings, and bottom of the craft forward.
(b) Outboard of the engine seatings, at every frame within the engine room.
(c) Underneath pillars and bulkheads.
(d) Outside of the engine room at a spacing not exceeding 2,0 m.

6.5.6 Vertical flat bar stiffeners are to be fitted to all plate floors at each longitudinal. Each stiffener is to have a depth of not less than $10t_w$ and a thickness of not less than t_w, where t_w is thickness of the plate floor as calculated in 6.5.1.

6.5.7 In transversely framed craft, plate floors are to be fitted at every frame in the engineroom, under bulkheads, in way of change in depth of double bottom and elsewhere at a spacing not exceeding 2,0 m.

6.6 Additional requirements for watertight floors

6.6.1 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deeptanks as detailed in Ch 3,7.2 or Ch 3,7.4 respectively.

■ *Section 7*
Bulkheads and deep tanks

7.1 General

7.1.1 Unless otherwise specified in this Section, the scantlings and arrangements for bulkheads and deep tanks are to be determined in accordance with the procedures described in, or as required by Ch 3,3 for mono-hull craft using the pressures from Part 5 appropriate to multi-hulls.

7.2 Longitudinal bulkheads within the cross-deck structure

7.2.1 Longitudinal bulkheads are to be fitted within the cross-deck structure to prevent cross flooding and the spread of flame and smoke. The minimum number of such bulkheads is to be two for catamarans and four for trimarans. Quadrimarans and other craft of novel configuration will be specially considered.

7.2.2 The scantlings and arrangements for cross deck longitudinal bulkheads are to be determined in accordance with the procedures described in Ch 3,7.2 and Ch 3,7.3 for bulkheads in mono-hull craft.

7.2.3 In addition the requirements of 7.4 with regard to global strength are to be complied with.

7.3 Transverse bulkheads within the cross-deck structure

7.3.1 The scantlings of cross deck transverse bulkheads are to be determined in accordance with the procedures described in Ch 3,7.2 and Ch 3,7.3 for bulkheads in mono-hull craft.

7.3.2 In addition the requirements of 7.4 in respect of global strength are to be complied with.

7.4 Additional strength required for global loadings

7.4.1 Where transverse bulkheads or deep tank bulkheads within the cross deck structure are to assist in resisting torsional or bending loads between the hulls, then the watertight/deep tank bulkheads may be required to be additionally stiffened and the plating or skin thicknesses may require to be increased. For hull girder strength requirements, *see* Ch 6,3.

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7.4.2 Longitudinal bulkheads within the cross deck structure that are to assist in maintaining the longitudinal strength of the vessel are to satisfy both bulkhead/deep tank and longitudinal strength requirements. This may require additional stiffening and increase in plate thickness requirements. For hull girder strength requirements, *see* Ch 6,3.

7.4.3 Where longitudinal or transverse cross deck bulkheads/deep tanks are to carry global loads, detailed calculations are to be submitted.

7.4.4 For longitudinal or transverse cross deck members carrying global loads, consideration is to be given to stiffener arrangement, alignment, and continuity in order to maximise the rigidity and stiffness of the structure, in resisting the torsional/bending loads. Discontinuity of structural bulkheads is to be avoided.

7.5 Access

7.5.1 Access through the cross deck structure may be permitted, provided that the global strength requirements are satisfied. Cut outs through the bulkhead are not to exceed 50 per cent of its depth, *see also* Ch 3,7.18.

7.5.2 Where the cross deck structure acts as a watertight bulkhead pipe or cable runs through, the watertight bulkheads are to be fitted with suitable watertight glands.

7.6 Local reinforcement

7.6.1 Bulkheads forming the cross deck structure are to be suitably strengthened, if necessary, in way of deck girders and where subjected to concentrated loads.

7.7 Integral/deep tanks within the cross-deck structure

7.7.1 Where the cross deck structure forms the boundaries of deep tanks, the scantlings of these boundaries are to satisfy both deep tank and global strength requirements. For general and structural requirements for deep tanks, *see* Ch 3,7. For global considerations of strength, *see* Ch 6,3.

■ *Section 8* Deck structures

8.1 General

8.1.1 Unless otherwise specified in this Section, the scantlings and arrangements for deck structures are to be determined in accordance with the procedures described in, or as required by, Ch 3,8 for mono-hull craft using the pressures from Part 5 appropriate to multi-hulls.

8.2 Arrangements

8.2.1 Design loads to be applied for cross-deck scantling calculations are transverse vertical bending moment and shear force, twin hull torsional connecting moment, external pressure load and appropriate internal loads as defined in Part 5.

8.2.2 For craft up to 50 m in Rule length, L_R, where the cross-deck is formed by transverse primary stiffeners or bulkheads, and subjected to global transverse loads in accordance with 8.2.1 the scantling requirements to satisfy the global loading condition are given in Ch 6,3.5.

8.2.3 Superstructures fitted on the cross-deck structures, on craft up to 50 m in Rule length, L_R, will, in general, be considered as non-load carrying and are not to be included in the strength of the cross-deck. For designs where the superstructure is designed to absorb global loads, the requirements are given in Ch 6,3.2.

8.2.4 For craft more than 50 m in Rule length, L_R, global analysis is required to determine the response of the deck and superstructure as a system. Deck scantlings may then be derived for compliance with the requirements of Ch 6,3.

8.3 Cross-deck plating

8.3.1 The thickness of the cross-deck plating is to be determined from the general plating equation given in Ch 3,1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

8.3.2 The thickness of the cross-deck plating is in no case to be less than the appropriate minimum requirement given in Section 2.

8.3.3 The scantlings of watertight cockpits are to be of equivalent strength to those of the strength/weather deck, *see also* Part 4.

8.3.4 It is recommended that the working areas of the weather deck have an anti-slip surface.

8.3.5 Where decks are sheathed with wood or other materials, details of the method of attachment are to be submitted, *see also* Ch 3,2.4.

8.4 Cross-deck stiffening

8.4.1 The Rule requirements for section modulus, inertia and web area for the cross-deck primary stiffeners are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

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8.4.2 The Rule requirements for section modulus, inertia and web area of the strength/weather deck secondary stiffening are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.4.3 The geometric properties of stiffener sections are to be in accordance with Ch 3,1.18.

8.4.4 For cases where there may be excessive rotations or deflections at supports or where the lateral pressure distribution is non-uniform, the above scantlings may require increasing appropriately.

8.4.5 Where stiffeners are subject to concentrated loads such as pillars, the concentrated loads are to be superimposed on the lateral pressure and strength calculations carried out to demonstrate compliance with the deflection and stress criteria given in Ch 7,2 and Ch 7,3.

8.4.6 Where stiffening members support plating of the extruded plank type, or the floating frame system is used, the plating is not to be included in the scantling derivation of the supporting structure.

8.4.7 Openings in the cross-deck for hatches, etc., are to comply with the requirements of Ch 3,8.11.

8.5 Novel features

8.5.1 Where the cross-deck structure is of unusual design, form or proportions, the scantlings are to be determined by direct calculation and a copy is to be submitted for consideration.

■ *Section 9* Superstructures, deckhouses, pillars and bulwarks

9.1 General

9.1.1 The scantlings and arrangements for superstructures, deckhouses and bulwarks are to be determined in accordance with the procedures described in, or as required by, Ch 3,9 for mono-hull craft.

9.1.2 The scantlings and arrangements for pillars and pillar bulkheads are to be determined in accordance with the procedures described in, or as required by, Ch 3,10 for mono-hull craft.

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Section

1 **General**

2 **Special features**

3 **Vehicle decks**

4 **Bow doors**

5 **Movable decks**

6 **Helicopter landing areas**

7 **Strengthening requirements for navigation in ice conditions**

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull and multi-hull craft of aluminium construction as defined in Pt 1, Ch 1,1.

1.2 Symbols and definitions

1.2.1 The symbols and definitions used in this Chapter are defined below and in the appropriate Section:

k_a = alloy factor
= $125/\sigma_a$
s = stiffener spacing, in mm
σ_a = 0,2 per cent proof stress of the alloy in the welded condition, in N/mm^2.

■ *Section 2* Special features

2.1 Water jet propulsion systems – Construction

2.1.1 The requirements for the construction and installation of water jet units apply irrespective of rated power.

2.1.2 Water jet ducts may be fabricated as an integral part of the hull structure, or as a bolted-in unit. In either case, detailed plans indicating dimensions, scantlings and materials of construction of the following are to be submitted in triplicate:

(a) Arrangement of the system including intended method of attachment to the hull and building-in, geometry of tunnel, shell opening, method of stiffening, reinforcement, etc.
(b) Shaft sealing arrangements.
(c) Details of any shafting support or guide vanes used in the water jet system.
(d) Details and arrangements of inspection ports, their closing appliances and sealing arrangement, etc.
(e) Details and arrangements of protection gratings and their attachments.

2.1.3 When submitting the plans requested in 2.1.2, details of the designers' loadings and their positions of application in the hull are to be submitted. These are to include maximum applied thrust, moments and tunnel pressures for which approval is sought.

2.1.4 All materials used in construction are to be manufactured and tested in accordance with the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

2.1.5 Aluminium alloys are to be of suitable marine grades in accordance with the requirements of Ch 2,2.

2.1.6 Irrespective of the material used, the strength and supporting structure of all tunnels are to be examined by direct calculation procedures which are to be submitted. In no case are the scantlings to be taken as less than the Rule requirements for the surrounding structure. The strength of the hull structure in way of tunnels is to be maintained. The structure is to be adequately reinforced and compensated as necessary. All openings are to be suitably reinforced and have radiused corners.

2.1.7 Consideration is to be given to providing the inlet to the tunnel with a suitable guard to prevent the ingress of large objects into the rotodynamic machinery. The dimensions of the guard are to strike a balance between undue efficiency loss due to flow restriction and viscous losses, the size of object allowed to pass and susceptibility to clog with weed and other flow restricting matter.

2.1.8 The inlet profile of the tunnel is to be so designed as to provide a smooth uptake of water over the range of craft operating trims and avoid significant separation of the flow into the rotating machinery.

2.1.9 Single or multiple water jet unit installations having a total rated power in excess of 500 kW are to be contained within their own watertight compartment. Other arrangements for maintaining watertight integrity may be specially considered depending on the size and installation layout.

2.1.10 For details of machinery requirements, *see* Pt 12, Ch 2.

2.2 Water jet propulsion systems – Installation

2.2.1 Standard units built for 'off the shelf' supply and which include the duct are to be installed strictly in accordance with the manufacturer's instructions, *see also* 2.1.4.

2.2.2 Integral water jet ducts are to be constructed in accordance with the manufacturer's requirements and the relevant plans submitted as required by 2.1.

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2.2.3 Where load is transmitted into the transom and/or bottom shell, the thickness of the plating adjacent to the jet unit is to be increased. The increase in thickness is to be not less than 50 per cent of the calculated transom and bottom plating thicknesses respectively or 8 mm, whichever is the greater. Such reinforcement is to extend beyond the surrounding stiffening structure.

2.2.4 For 'bolted in' units, hull receiving rings are to be of a material compatible with the hull. Scantlings of the receiving rings are to be as required by the jet unit manufacturer and suitably edge prepared prior to welding in place. The receiving ring is to be installed using an approved welding procedure. Where a manufacturer's specification is not provided, full details are to be submitted.

2.2.5 Bolt sizes and spacings are to be specified by the manufacturer, and are to be of suitable marine grade, insulated as appropriate and locked by suitable means.

2.2.6 Where studs are proposed for the receiving ring(s), the remaining thickness below the depth of blind tap is to be not less than the bottom shell plating thickness plus 2 mm. Bottoms of all blind taps are to be free of sharp corners.

2.2.7 The use of approved alignment resins may be considered where accurate seating and faying surfaces are required. Details are to be submitted for consideration and approval.

2.2.8 Where a water jet unit forms an integral part of the hull structure, such units are to be installed using an approved weld procedure and in accordance with the manufacturer's instructions. Materials to be welded are to be of compatible specifications.

2.2.9 Water jet units transmitting thrust into the transom structure are to be supported by a system of radial, athwartship and vertical stiffening. Drawings are to be accompanied by a set of detailed structural calculations. Where complex installations are proposed, a finite element model may be submitted in lieu of direct calculations.

2.2.10 Water jet units transmitting thrust to a bottom shell connection or intermediate tunnel connection are to be supported by additional stiffening, the details of which are to be submitted.

2.3 Foil support arrangements

2.3.1 The materials and construction of the lifting surface will be considered on a case by case basis.

2.3.2 The design and performance of the lifting surface is outside the scope of classification. However, when submitting structural plans for the hull connection installation, the designer/Builder is to define:

(a) Operating mode, i.e. fully submerged or surface piercing.
(b) Maximum operational speed for which approval is sought.
(c) Maximum, direct, bending, shear and torque loads generated by the foil at the point of attachment(s).
(d) The type of profile or section used, e.g. N.A.C.A.
(e) Supply of lift/drag profile.
(f) If the foil is fixed, movable or retractable.
(g) If the foil is fitted with control surfaces.
(h) If the vertical leg(s) act as a rudder(s).
(j) If shaft liners are carried to the foils at which support arrangements are provided.
(k) If water intakes/scoops are fitted.
(l) If propulsion units are fitted.

2.3.3 The scantlings and arrangements of foils and their supporting structure will require to be specially considered in the following cases where:

(a) Propulsion units are incorporated within the foil.
(b) Foils carry shaft support arrangements.
(c) The foils are of novel design.

2.3.4 Where fully submerged foils are 'built-in' to the hull, the attachment area is to be contained within a watertight compartment and the structural arrangements of 2.4 are to be complied with as appropriate.

2.3.5 Where foils are to be bolted to the structural foundation calculations are to be submitted to demonstrate that the effect of loading arising from high speed impact, grounding, fouling, etc., is limited to failure of the bolted connection. In all cases the structural and watertight integrity of the craft is to be maintained.

2.3.6 Attachment points of foils are to be contained within a watertight compartment.

2.3.7 Foils attached by riveted means are in addition to comply with Ch 2,4.25.

2.3.8 Bow fairing doors fitted on forward retracting bow foils are to be weathertight and comply with Pt 3, Ch 4.

2.3.9 Aft bulkheads of bow foil compartments are to comply with the requirements for collision bulkheads as detailed in Ch 3,7.7.

2.3.10 Hydraulically operated retracting systems are to be equipped with low pressure and are to include a manual system of operation in the event of system failure.

2.3.11 A mechanical locking system is to be provided on retracting systems when the system is in both the operational and 'stowed' conditions.

2.4 Surface drive mountings

2.4.1 Transoms through which surface drive systems pass and which are required to carry thrust, significant weight, torque, moment, etc., are to be adequately reinforced.

2.4.2 The thickness of transom plating in way is to be not less than 1,5 times the thickness of the adjacent plating or as advised by the drive manufacturer, whichever is the greater.

2.4.3 Steering rams are to be mounted on suitably reinforced areas of plating supported by additional internal stiffening, details of which are to be submitted for consideration.

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2.5 Sea inlet scoops

2.5.1 Sea inlet scoops may be integral with or an appendage to the hull.

2.5.2 Scoops are to be suitably positioned to minimise ventilation.

2.5.3 Suitable protective arrangements are to be provided to minimise the ingress of debris. The net area through the proposed arrangement is to be not less than twice that of the valves connected to the scoop. Provision is to be made for clearing the scoops by the use of suitable means and proposals are to be submitted.

2.5.4 Scoops are to be contained within a watertight compartment.

2.5.5 The plating thickness in way of integral scoops is to be not less than 1,5 times the thickness of the adjacent shell plating, with additional reinforcement at the leading edge.

2.5.6 For craft navigating in ice, the arrangements will be specially considered on an individual basis.

2.6 Crane support arrangements

2.6.1 Crane pedestals are to be efficiently supported and in general, are to be carried through the deck and satisfactorily scarfed into the surrounding structure. Alternatively, crane pedestals may comprise a foundation, in which case the foundation and its supporting structure are to be of substantial construction. Proposals for other support arrangements will be specially considered.

2.6.2 The pedestal or proposed arrangement is to be designed with respect to the worst possible combinations of loads resulting from the crane self weight, live load, wind and crane accelerations together with those resulting from the craft's heel and trim.

2.6.3 Stowage arrangements are to be taken into account when calculating the loads applied to the pedestal.

2.6.4 When submitting plans for the proposed foundation, the designer is to include design calculations covering the parameters indicated in 2.6.2.

2.6.5 Insert plates are to be incorporated in the deck plating in way of crane foundations. The thickness of the insert plates is to be as required by the designer's calculations but is in no case is to be taken as less than 1,5 times the thickness of the adjacent attached plating.

2.6.6 All inserts are to have well radiused corners and be suitably edge prepared prior to welding. All welding in way is to be double continuous and full penetration where necessary. Tapers are to be not less than three to one.

2.7 Skirt attachment

2.7.1 The design and scantlings of the skirt are outside the scope of classification, however the designers/builders are to submit their proposals in respect of the attachment detail. The following supporting information is to be submitted:

(a) cushion pressure;

(b) calculations demonstrating that the effect of damage to the flexible membrane and/or the retaining section arising from high speed impact, grounding, fouling, etc., will not compromise the structural and watertight integrity of the craft.

2.7.2 The skirt is to be securely attached around its periphery and is to be suitably reinforced by the use of backing plates.

2.7.3 Where the skirt is retained by bolting the retaining bars are to be as long as practicable with a fastener spacing of not more than 50 mm.

2.7.4 Where the design of the skirt is such that the flexible edge is retained by the use of a pre-formed channel, only the bolted hull connection of the preform to the hull structure is considered.

2.8 Trim tab arrangements

2.8.1 The shape, design and scantlings of the trim tabs are outside the scope of classification, however Lloyd's Register (hereinafter referred to as 'LR') is concerned with their attachment to the hull structure.

2.8.2 The designer/Builder is to submit the following:

(a) Detailed calculations indicating the maximum lift force generated by the tab for which acceptance is sought together with the corresponding speed and displacement.

(b) Details and calculations of the hull attachment.

(c) Details and calculations of the local internal reinforcement in way of the attachment.

2.8.3 Bearing materials used are to be of an approved type.

2.8.4 Fully submerged retractable trim tabs will be specially considered on a case by case basis.

2.9 Spray rails

2.9.1 Spray rails may be integrated into the hull structure or added in the form of an appendage on completion of the hull shell.

2.9.2 Where spray rails are integrated, they are to have a plating thickness not less than the adjacent bottom shell and additionally have a section modulus and inertia equivalent to that required for a longitudinal stiffener in the same position.

2.9.3 Where spray rails are added as an appendage, they are to be attached by double continuous welding and are additionally to comply with the strength requirements of 2.9.2.

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2.9.4 Spray rails are to be supported by the internal stiffening arrangements and by additional local reinforcement as necessary.

2.9.5 In no case are the toes of spray rails to terminate on unsupported plating.

2.10 Other lifting surfaces

2.10.1 Other lifting surfaces not specifically covered by the Rules will be individually considered on the basis of submitted direct calculations.

2.10.2 Structure or hull shapes above the running waterline designed to generate aerodynamic lift may be individually considered on a case by case basis.

2.10.3 Aerodynamic, hydrodynamic and aero-hydrodynamic stability are outside the scope of classification and are subject to the approval of the National Administration concerned.

2.11 Propeller ducting

2.11.1 Where propellers are fitted within ducts/tunnels the plating thickness in way of the blades is to be increased by 50 per cent.

2.11.2 The tunnel wall in way of the propeller blades is to be additionally stiffened.

2.12 Ride control ducting and installation for Surface Effect Ships (SES)

2.12.1 Ducts penetrating the side inboard shell plating are to comply with the scantling requirements for side inboard structures, over their entire length in the appropriate material.

2.12.2 Ducts penetrating the wet-deck are to comply with the scantling requirements for wet-deck structures over their entire length in the appropriate material.

2.12.3 Open ends of ducts are to be fitted with a suitable protective grille.

2.12.4 The vent assembly, its design, construction and operation are outside the scope of classification and is the responsibility of the ride control system designer.

2.12.5 Details of the installation and securing arrangements of the vent valve assembly into the duct are to be submitted for approval.

■ *Section 3* Vehicle decks

3.1 General

3.1.1 These requirements are applicable to longitudinally or transversely framed craft intended for the carriage of wheeled vehicles, or where wheeled vehicles are to be used for cargo handling.

3.1.2 The deck and supporting structure are to be designed on the basis of the maximum loading to which they may be subjected in service. Where applicable, the hatch covers are to be similarly designed. In no case, however, are the scantlings to be less than would be required for a weather or cargo deck, or hatch cover, as applicable.

3.1.3 Details of the deck loading resulting from the proposed stowage or operation of vehicles are to be supplied by the Builder. These details are to include axle and wheel spacing, the wheel load, type of tyre and tyre print dimensions for the vehicles. The vehicle types and wheel loads for which the vehicle decks, including hatch covers where applicable, have been approved are to be included in the craft's documentation and contained in a notice displayed on each deck. For design purposes, the wheel loading is to be taken as not less than 3,0 kN.

3.1.4 The scantling requirements are based on structural strength and limitations on stress and deflection, with no allowance made for wear and tear. Local reinforcement is to be fitted as necessary, particularly in way of vehicle lanes and passenger routes.

3.1.5 The webs of vehicle deck stiffening members are in no cases to be scalloped.

3.2 Definitions

3.2.1 **Load area.** The load area is defined as the footprint area of an individual wheel or the area enclosing a group of wheels when the distance between footprints is less than the smaller dimension of the individual prints.

3.3 Deck plating

3.3.1 The thickness, t_p, of vehicle deck plating is to be taken as not less than:

$$t_p = \frac{\alpha\, s}{1370\sqrt{k_a}} \text{ mm}$$

where

P_1 = corrected patch load, in tonnes, obtained from Table 5.3.1

α = thickness coefficient obtained from Fig. 5.3.1

s = secondary stiffener spacing, in mm

β_p = tyre print coefficient used in Fig. 5.3.1

$$= \log_{10}\left(\frac{3{,}5 P_1 k_a^2}{s^2} \times 10^7\right)$$

s and k_a are as defined in 1.2.

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Table 5.3.1 Deck plate thickness calculation

Symbols	Expression	
a, *s*, *u*, and *v* as defined in Fig. 5.3.1 *n* = tyre correction factor as detailed in Table 5.3.2 P_1 = corrected patch load, in tonnes λ = dynamic magnification factor P_w = load, in tonnes, on the tyre print. For closely spaced wheels the shaded area shown in Fig. 5.3.1 may be taken as the combined print λ = dynamic magnification factor ϕ_1 = patch aspect ratio correction factor ϕ_2 = panel aspect ratio correction factor ϕ_3 = wide patch load factor	$P_1 = \phi_1\,\phi_2\,\phi_3\,\lambda\,P_w$	
	$\phi_1 = \dfrac{2v_1 + 1{,}1s}{u_1 + 1{,}1s}$	$v_1 = v$, but $\le s$ $u_1 = u$, but $\le a$
	$\phi_2 = 1{,}0$ $= \dfrac{1}{1{,}3 - \dfrac{0{,}3}{s}(a-u)}$ $= 0{,}77\,\dfrac{a}{u}$	for $u \le (a-s)$ for $a \ge u > (a-s)$ for $u > a$
	$\phi_3 = 1{,}0$ $= 0{,}6\,(s/v) + 0{,}4$ $= 1{,}2\,(s/v)$	for $v < s$ for $1{,}5 > (v/s) > 1{,}0$ for $(v/s) \ge 1{,}5$
	$\lambda = 1{,}25$ for craft operating in G1 $= (1 + 0{,}35n)$ for craft operating in G2 $= (1 + 0{,}42n)$ for craft operating in G3 $= (1 + 0{,}49n)$ for craft operating in G4 $= (1 + 0{,}56n)$ for craft operating in G5 $= (1 + 0{,}70n)$ for craft operating in G6 G1, G2, G3, G4, G5 and G6 as defined in Pt 1, Ch 2,3.5.5	

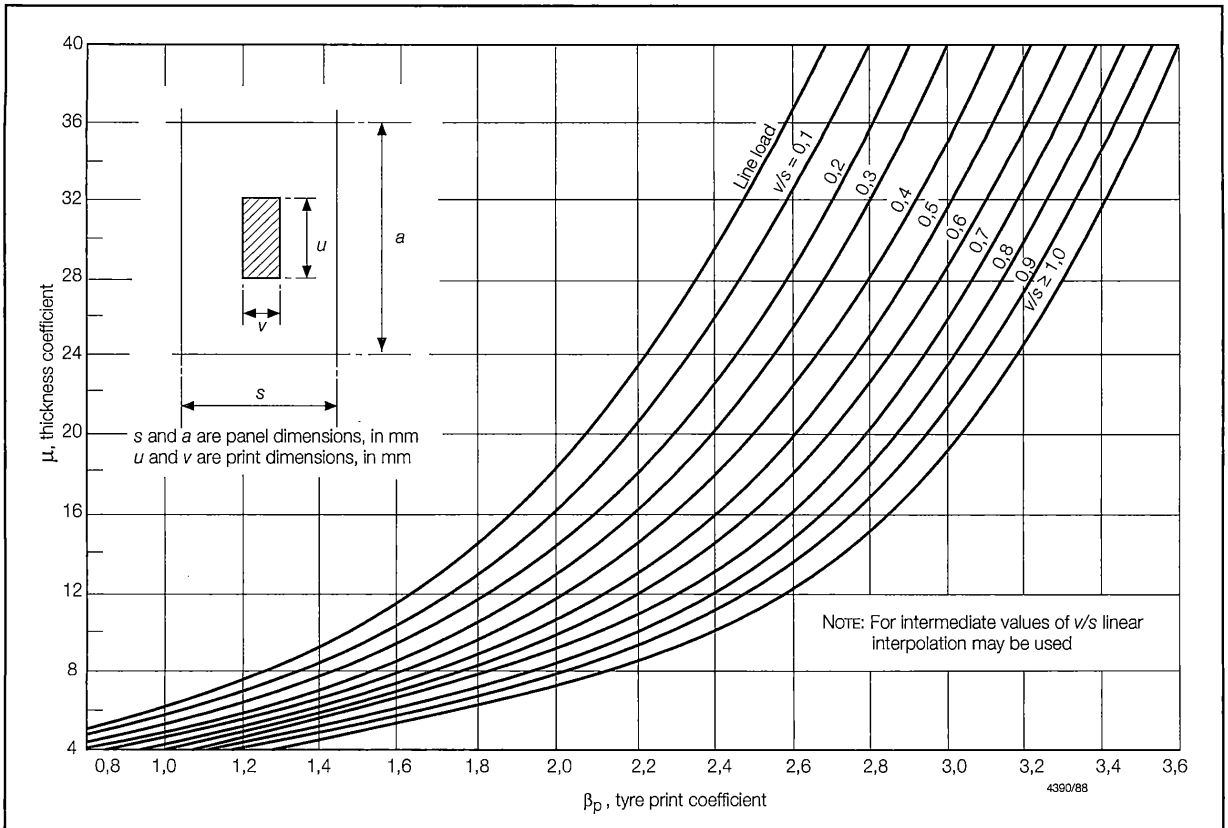

Fig. 5.3.1 Tyre print chart

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3.4 Secondary stiffening

3.4.1 The scantlings of vehicle deck stiffeners are to be as required to satisfy the most severe arrangement of print wheel loads in conjunction with the cargo/weather deck design head.

3.4.2 The minimum requirements for section modulus, inertia and web area of vehicle deck secondary stiffeners subject to wheel loading are to be calculated in accordance with Table 5.3.3, *see also* Fig. 5.3.1 and Table 5.3.2.

Table 5.3.2 Tyre correction factor, *n*

Number of wheels in idealised patch	Pneumatic tyres correction factor, *n*	Solid rubber tyres correction factor, *n*
1	0,6	0,8
2 or more	0,75	0,9

3.4.3 When two or more load areas are located simultaneously on the same stiffener span, the scantling requirements are to be specially considered on the basis of direct calculation.

3.4.4 Where continuous secondary stiffeners pass through the webs of primary members, they are to be fully collared or lugged in way. The shear stresses at the connections are to be in compliance with Table 7.3.1 in Chapter 7.

3.5 Primary stiffening

3.5.1 The scantlings of vehicle deck primary girders and transverse web frames are to be determined on the basis of direct calculation in association with the limiting permissible stress and deflection criteria contained in Chapter 7.

3.6 Securing arrangements

3.6.1 Details of the connections to the hull of vehicle securing arrangements are to be submitted for approval.

3.6.2 Deck fittings in way of vehicle lanes are to be recessed.

3.6.3 The vehicle deck structure is to be of adequate strength for the upward forces imposed at fixed securing points. Local reinforcement is to be fitted as necessary.

Table 5.3.3 Secondary stiffener requirements

Scantling requirement	Load case	
	$d \le l$	$d > l$
Section modulus (Z) (cm^3)	$Z = \left(\frac{P\ k_w\ (3l^2 - d^2)}{24\ l\ f_\sigma\ \sigma_a}\right) \times 10^3 + Z_{dk}$	$Z = \left(\frac{k_w\ P\ l^2}{10\ d\ f_\sigma\ \sigma_a}\right) \times 10^3 + Z_{dk}$
Inertia (I) (cm^4)	$I = \left(\frac{f_\delta\ P\ k_w\ (2l^3 - 2d^2\ l + d^3)}{384\ E\ l}\right) \times 10^5 + I_{dk}$	$I = \left(\frac{f_\delta\ k_w\ P\ l^3}{384\ E\ d}\right) \times 10^5 + I_{dk}$
Web area (A_w) (cm^2)	$A_W = \frac{10P\ k_w\ (m^3 - 2m^2 + 2)}{2\ f_\tau\ \tau_a} + A_{dk}$ where $m = d/l$	$A_W = \frac{k_w\ P\ l}{2\ d\ f_\tau\ \tau_a} + A_{dk}$

Symbols

P = maximum effective load per wheel or group of wheels, in kN
l = overall secondary stiffener length, in metres
s = stiffener spacing, in metres
d = dimension of load area parallel to stiffener axis, in metres
E = Young's modulus of elasticity of material, in N/mm^2
w = dimension of load area perpendicular to stiffener axis, in metres
k_w = lateral loading factor
= 1 for $w \le s$
= s/w for $w > s$
f_σ = limiting bending stress coefficient taken from Table 7.3.1 in Chapter 7
f_τ = limiting shear stress coefficient taken from Table 7.3.1 in Chapter 7
f_δ = limiting deflection coefficient taken from Table 7.2.1 in Chapter 7
σ_a = 0,2% proof stress of material, in N/mm^2
τ_a = shear stress of the alloy, in N/mm^2
= $\frac{\sigma_a}{\sqrt{3}}$
Z_{dk}, I_{dk}, A_{dk} = stiffener requirements for weather/cargo decks to be determined in accordance with Ch 3,8.7 and Ch 3,8.10 using the appropriate design head for weather/cargo. In no case is the head to be taken as less than 2 kN/m^2

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3.7 Access

3.7.1 Bow doors are to comply with the requirements of Section 4.

3.7.2 Where access to the vehicle deck is provided by side and stern doors the doors are to have scantlings equivalent to the structure in which they are fitted, *see also* Pt 3, Ch 4,4.

3.7.3 Doors providing pedestrian access between vehicle decks and accommodation spaces are to be gastight, have scantlings equivalent to the surrounding structure and where applicable are to comply with the requirements of Part 17.

3.8 Hatch covers

3.8.1 The scantlings and arrangements of hatches and hatch covers located within vehicle decks are to be not less than that required by the Rules for the supporting structure in which such hatches are fitted. In general the end fixity of primary stiffening members is to be taken as simply supported. Local and secondary stiffening members may be either partially or fully fixed at their end connections dependent upon the proposed arrangement.

3.8.2 In no case, however, are the scantlings of plating and stiffeners to be less than would be required for a weather or cargo deck, or hatch cover, as applicable.

3.8.3 Where unusual arrangements of hatch cover stiffening are proposed, the scantlings of plating and stiffeners may be determined by direct calculations using a two-dimensional grillage model. A copy of the calculations is to be submitted.

3.9 Heavy and special loads

3.9.1 Where heavy or special loads are proposed to be carried, the scantlings and arrangements of the deck structure will be individually considered on the basis of submitted calculations.

3.9.2 Due account is to be taken of the acceleration levels due to craft motion as applicable to particular items of heavy mass such as vehicles, containers, pallets, etc.

3.10 Direct calculations

3.10.1 LR will consider direct calculations for the derivation of scantlings as an alternative to and equivalent to those derived by Rule requirements. The assumptions made and the calculation procedures used are to be submitted for appraisal in accordance with Pt 3, Ch 1,2.

■ *Section 4* Bow doors

4.1 Application

4.1.1 The requirements of this Section are applicable to the arrangement, strength and securing of bow doors, both the visor and the side opening type doors, and inner doors leading to a complete or long forward enclosed superstructure.

4.1.2 Other types of bow door will be specially considered.

4.2 General

4.2.1 The attention of Owners and Builders is drawn to the additional statutory regulations for bow doors that may be imposed by the National Authority.

4.2.2 Bow doors are to be situated above the freeboard deck. A watertight recess in the freeboard deck located forward of the collision bulkhead and above the deepest waterline fitted for arrangement of ramps or other related mechanical devices may be regarded as a part of the freeboard deck.

4.2.3 An inner door is to be fitted. The inner door is to be part of the collision bulkhead. The inner door need not be fitted directly above the bulkhead below, provided it is located within the limits specified for the position of the collision bulkhead, *see* Pt 3, Ch 2,4. A vehicle ramp may be arranged for this purpose, provided its position complies with Pt 3, Ch 2,4 and the ramp is weathertight over its complete length. In this case the upper part of the ramp higher than 2,3 m above the freeboard deck may extend forward of the limit specified in Pt 3, Ch 2,4. If this is not possible a separate inner weathertight door is to be installed, as far as practicable within the limits specified for the position of the collision bulkhead.

4.2.4 Bow doors are to be fitted as to ensure tightness consistent with operational conditions and to give effective protection to inner doors. Inner doors forming part of the collision bulkhead are to be weathertight over the full height of the cargo space and arranged with fixed sealing supports on the aft side of the doors.

4.2.5 Bow doors and inner doors are to be arranged so as to preclude the possibility of the bow door causing structural damage to the inner door or to the collision bulkhead in the case of damage to or detachment of the bow door. If this is not possible, a separate inner weathertight door is to be installed, as indicated in 4.2.3.

4.2.6 The requirements for inner doors are based on the assumption that vehicles are effectively lashed and secured against movement in the stowed position.

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4.3 Symbols and definitions

4.3.1 The symbols used in this Section are defined as follows:

a_{bv} = vertical distance, in m, from visor pivot to the centroid of the transverse vertical projected area of the visor door, as shown in Fig. 5.4.2

b_{bv} = horizontal distance, in m, from visor pivot to the centroid of the horizontal projected are of the visor door, as shown in Fig. 5.4.2

c_{bv} = horizontal distance, in m, from visor pivot to the centre of gravity of visor mass, as shown in Fig. 5.4.2

h = height of the door between the levels of the bottom of the door and the upper deck or between the bottom of the door and the top of the door, in metres, whichever is the lesser, as shown in Fig. 5.4.1

k_a = alloy factor
= $125/\sigma_a$

l_d = length of the door at a height $h/2$ above the bottom of the door, in metres, as shown in Fig. 5.4.2

A_s = area stiffener web in cm^2

A_x = area, in m^2, of the transverse vertical projection of the door between the levels of the bottom of the door and the upper deck or between the bottom of the door and the top of the door, whichever is the lesser, as shown in Fig. 5.4.2

A_y = area, in m^2, of the longitudinal vertical projection of the door between the levels of the bottom of the door and the upper deck or between the bottom of the door and the top of the door, whichever is the lesser

A_z = area of the horizontal projection of the door between the levels of the bottom of the door and the upper deck or between the bottom of the door and the top of the door, in m^2, whichever is the lesser, as shown in Fig. 5.4.2

Q_{bd} = shear force, in kN, in the stiffener calculated by using uniformly distributed external pressure P_e as given in 4.5.1

W = breadth of the door at a height $h/2$ above the bottom of the door, in metres, as shown in Fig. 5.4.1

W_{bv} = mass of the visor door, in tonnes

σ = bending stress, in N/mm^2

σ_a = material yield stress, in N/mm^2

σ_{eq} = equivalent stress, in N/mm^2
= $\sqrt{\sigma^2 + 3\tau^2}$

τ = shear stress, in N/mm^2.

4.3.2 **Locking device.** A device that locks a securing device in the closed position.

4.3.3 **Securing device.** A device used to keep the door closed by preventing it from rotating about its hinges.

4.3.4 **Side-opening doors.** Side-opening doors are opened either by rotating outwards about a vertical axis through two or more hinges located near the outboard edges or by horizontal translation by means of linking arms arranged with pivoted attachments to the door and the craft. It is anticipated that side-opening doors are arranged in pairs.

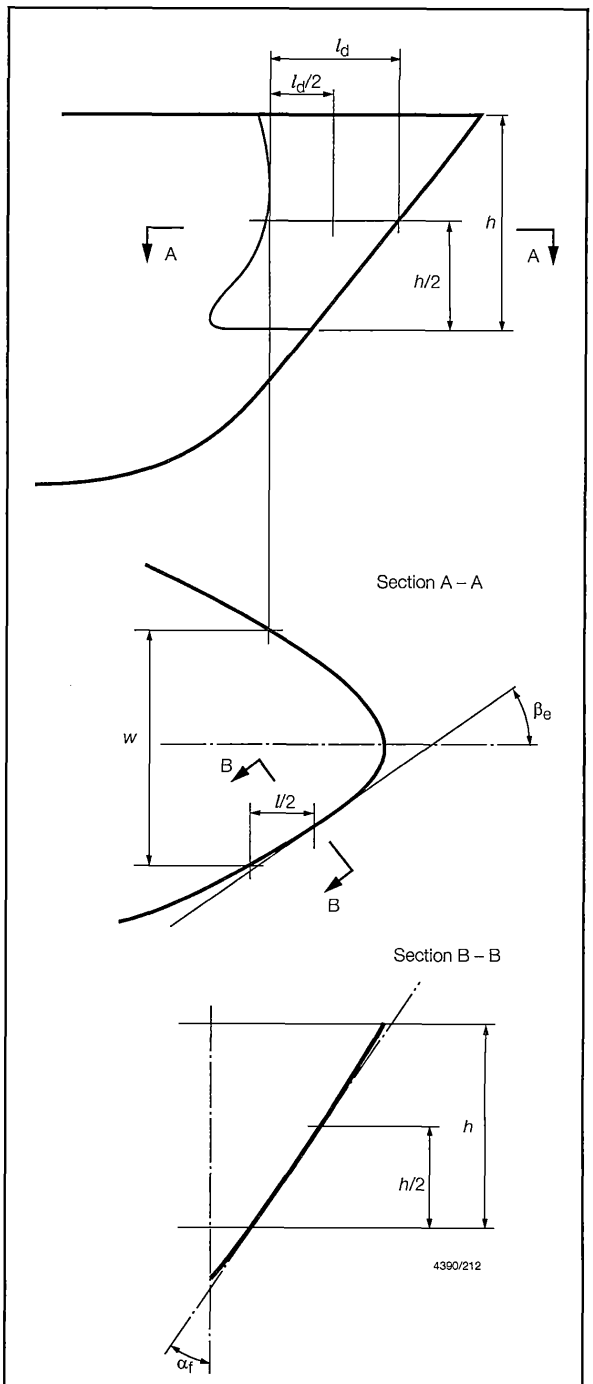

Fig. 5.4.1 Measurement of α_f and β_e

4.3.5 **Supporting device**. A device used to transmit external or internal loads from the door to a securing device and from the securing device to the craft's structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, that transmits loads from the door to the craft's structure.

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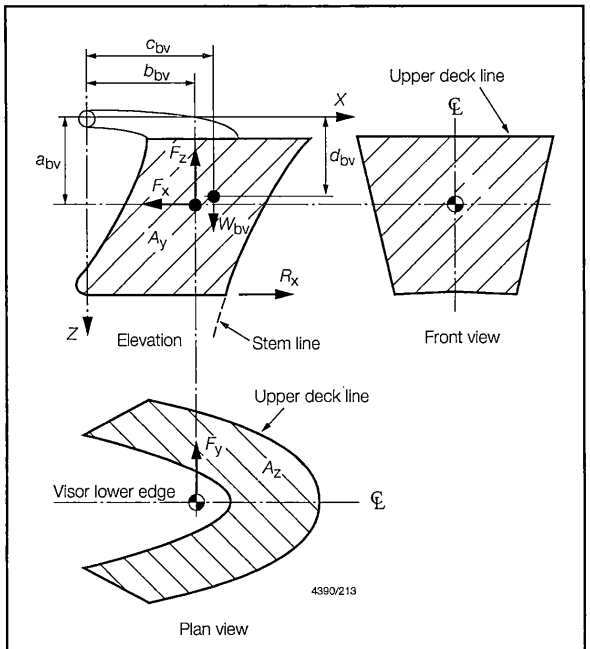

Fig. 5.4.2 Bow visor (upward hinging)

4.3.6 **Visor doors.** Visor doors are opened by rotating upwards and outwards about a horizontal axis through two or more hinges located near the top of the door and connected to the primary structure of the door by longitudinally arranged lifting arms.

4.4 Strength criteria

4.4.1 Scantlings of the primary members, securing and supporting devices of bow doors and inner doors are to be able to withstand the design loads defined in 4.5. The shear, bending and equivalent stresses are not to exceed $43/k_a$ N/mm^2, $64/k_a$ N/mm^2 and $80/k_a$ N/mm^2 respectively.

4.4.2 The buckling strength of primary members is to be verified as being adequate, *see* Ch 7,4.

4.4.3 For metal to metal bearings in securing and supporting devices, the nominal bearing pressure calculated by dividing the design force by the projected bearing area is not to exceed 80 per cent of the yield stress of the bearing material. For other bearing materials, the permissible bearing pressure is to be determined according to the manufacturer's specification.

4.4.4 The arrangement of securing and supporting devices is to be such that threaded bolts do not carry support forces. The maximum tension in way of threads of steel bolts not carrying support forces is not to exceed $125/k_s$ N/mm^2.

4.5 Design loads

4.5.1 The design external pressure, P_e, for the determination of scantlings for primary members, securing and supporting devices of bow doors is taken to be not less than the following:

$$P_e = 2{,}75\lambda_G C_H (0{,}22 + 0{,}15\tan\alpha_f)(0{,}4V_{max}\sin\beta_e + 0{,}6L_R^{0{,}5})^2 \quad \text{kN/m}^2$$

where

C_H = $0{,}0125L_R$ for $L_R < 80$ m
= 1,0 for $L_R \geq 80$ m

L_R = Rule length of craft, in m as defined in Pt 3, Ch 1,6

V_{max} = maximum speed in knots as defined in Pt 1, Ch 2, 2.2.10.

λ_G = Service group factor for mono-hull craft, *see* Pt 1, Ch 2
= 0,5 for Group 1 and 2
= 0,6 for Group 3
= 0,8 for Group 4
= 1,0 for Group 5 and 6
For multi-hull craft, λ_G will be specially considered and may be reduced where the freeboard is significant

α_f = flare angle at the point to be considered, defined as the angle between a vertical line and the tangent to the side shell plating, measured in a vertical plane normal to the horizontal tangent to the shell plating, *see* Fig. 5.4.1

β_e = entry angle at the point to be considered, defined as the angle between a longitudinal line parallel to the centreline and the tangent to the shell plating in a horizontal plane, *see* Fig. 5.4.1.

4.5.2 The design external forces, F_x, F_y and F_z, in kN, for the determination of scantlings of securing and supporting devices of bow doors are taken to be not less than $P_e A_x$, $P_e A_y$ and $P_e A_z$ respectively.
where
P_e is the external pressure, defined in 4.5.1, with the flare angle, α_f, and the entry angle, β_e, measured at the point on the bow door, $l_d/2$ aft of the stem line on the plane $h/2$ above the bottom of the door, as shown in Fig. 5.4.1.
A_x, A_y, A_z and h as defined in 4.3.1.

4.5.3 For bow doors, including bulwark, of unusual form or proportions, the areas used for the determination of the design values of external forces will be specially considered.

4.5.4 For visor doors the closing moment, M_y, under external loads, is to be taken as:

$$M_y = F_x a_{bv} + 10W_{bv} c_{bv} - F_z b_{bv} \quad \text{kNm}$$

where
W_{bv}, a_{bv}, b_{bv} and c_{bv} are as defined in 4.3.1
F_x and F_z are as defined in 4.5.2.

4.5.5 The lifting arms of a visor and its supports are to be dimensioned for the static and dynamic forces applied during the lifting and lowering operations, and a minimum wind pressure of 1,5 kN/m^2 is to be taken.

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4.5.6 The design external pressure, in kN/m^2, for the determination of scantlings for primary members, securing and supporting devices and surrounding structure of inner doors is to be taken as the greater of $0{,}45L_R$ and $10h_2$, where h_2 is the distance, in m, from the load point to the top of the cargo space and L_R is as defined in Pt 3, Ch 1,6.2.1.

4.5.7 The design internal pressure for the determination of scantlings for securing devices of inner doors is not to be taken less than 25 kN/m^2.

4.6 Scantlings of bow doors

4.6.1 The strength of bow doors is to be commensurate with that of the surrounding structure.

4.6.2 Bow doors are to be adequately stiffened and means are to be provided to prevent lateral or vertical movement of the doors when closed. For visor doors adequate strength for the opening and closing operations is to be provided in the connections of the lifting arms to the door structure and to the craft structure.

4.6.3 The thickness of the bow plating is not to be less than that required for the side shell plating, using bow door stiffener spacing, but in no case less than the minimum required thickness of fore end shell plating.

4.6.4 The section modulus of horizontal or vertical stiffeners is not to be less than that required for end framing. Consideration is to be given, where necessary, to differences in fixity between craft's frames and bow doors stiffeners.

4.6.5 The stiffener webs are to have a net sectional area A_s, not less than:

$$A_s = \frac{12{,}5Q_{bd}}{\sigma_a} \text{ cm}^2$$

where

A_s, Q_{bd} and σ_a are as defined in 4.3.1.

4.6.6 The bow door secondary stiffeners are to be supported by primary members constituting the main stiffening of the door.

4.6.7 The primary members of the bow door and the hull structure in way are to have sufficient stiffness to ensure integrity of the boundary support of the door.

4.6.8 Scantlings of the primary members are generally to be supported by direct calculations in association with the external pressure given in 4.5.1 and permissible stresses given in 4.4.2.

4.7 Scantlings of inner doors

4.7.1 Scantlings of the primary members are generally to be supported by direct calculations in association with the external pressure given in and permissible stresses given in 4.4.1. In general, formulae for simple beam theory may be applied.

4.7.2 Where inner doors also serve as a vehicle ramps, the scantlings are not to be less than those required for vehicle decks.

4.7.3 The distribution of the forces acting on the securing and supporting devices is, in general, to be supported by direct calculations taking into account the flexibility of the structure and actual position and stiffness of the supports.

4.8 Securing and supporting of bow doors

4.8.1 Bow doors are to be fitted with adequate means of securing and supporting so as to be commensurate with the strength and stiffness of the surrounding structure. The hull supporting structure in way of the bow doors is to be suitable for the same design loads and design stresses as the securing and supporting devices. Where packing is required, the packing material is to be of a comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be considered. Maximum design clearance between securing and supporting devices is, in general, not to exceed 3 mm. A means is to be provided for mechanically fixing the door in the open position.

4.8.2 Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be included and considered to calculate the reaction forces acting on the devices. Small and/or flexible devices such as cleats intended to provide load compression of the packing material are, in general, not to be included in the calculations called for in 4.8.8. The number of securing and supporting devices are, in general, to be the minimum practical whilst taking into account the requirements for redundant provision given in 4.8.9 and 4.8.10 and the available space for adequate support in the hull structure.

4.8.3 For opening outwards visor doors, the pivot arrangement is generally to be such that the visor is self closing under external loads, that is $M_y > 0$. Moreover, the closing moment, M_y, as given in 4.5.4 is to be not less than:

$$M_{ya} = 10W_{bv}\, c_{bv} + 0{,}1(a_{bv}^2 + b_{bv}^2)^{0{,}5}\, (F_x^2 + F_z^2)^{0{,}5}$$

where

W_{bv}, a_{bv}, b_{bv} and c_{bv} are as defined in 4.3.1

F_x and F_z are as defined in 4.5.2.

4.8.4 Securing and supporting devices are to be adequately designed so that they can withstand the reaction forces within the permissible stresses given in 4.4.1.

4.8.5 For **visor doors** the reaction forces applied on the effective securing and supporting devices assuming the door as a rigid body are determined for the following combination of external loads acting simultaneously together with the self weight of the door.

Case 1 F_x and F_z.

Case 2 $0{,}7F_y$ acting on each side separately together with $0{,}7F_x$ and $0{,}7F_z$

where

F_x, F_y and F_z are to be determined as indicated in 4.5.2 and applied at the centroid of projected areas.

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4.8.6 For **side-opening doors** the reaction forces applied on the effective securing and supporting devices assuming the door as a rigid body are determined for the following combination of external loads acting simultaneously together with the self weight of the door:

Case 1 F_x , F_y and F_z acting on both doors.

Case 2 $0,7F_x$ and $0,7F_z$ acting on both doors and $0,7F_y$ acting on each door separately.

where

F_x, F_y and F_z are to be determined as indicated in 4.5.2 and applied at the centroid of projected areas.

4.8.7 The support forces as determined according to 4.8.5 and 4.8.6 are to generally give rise to a zero moment about the transverse axis through the centroid of the area A_x. For visor doors, longitudinal reaction forces of pin and/or wedge supports at the door base contributing to this moment are not to be of the forward direction.

4.8.8 The distribution of the reaction forces acting on the securing and supporting devices may require to be supported by direct calculations taking into account the flexibility of the hull structure and the actual position and stiffness of the supports.

4.8.9 The arrangement of securing and supporting devices in way of these securing devices is to be designed with redundancy so that in the event of failure of any single securing or supporting device the remaining devices are capable of withstanding the reaction forces without exceeding by more than 20 per cent the permissible stresses as given in 4.4.1.

4.8.10 For **visor doors**, two securing devices are to be provided at the lower part of the door, each capable of providing the full reaction force required to prevent opening of the door within the permissible stresses given in 4.4.1. The opening moment, M_o, to be balanced by this reaction force, is not to be taken less than:

$$M_o = 10W_{bv}\, d_{bv} + 5A_x\, a_{bv} \text{ kNm}$$

where

W_{bv}, A_x, d_{bv} and a_{bv} are as defined in 4.3.1.

4.8.11 For **visor doors**, the securing and supporting devices excluding the hinges should be capable of resisting the vertical design force ($F_z - 10W_{bv}$), in kN, within the permissible stresses given in 4.4.1.

4.8.12 All load transmitting elements in the design load path, from door through securing and supporting devices into the craft structure, including welded connections, are to be the same strength.

4.8.13 For **side-opening doors**, thrust bearing has to be provided in way of girder ends at the closing of the two leaves to prevent one leaf to shift towards the other one under effect of unsymmetrical pressure, *see* Fig. 5.4.3. Each part of the thrust bearing has to be kept secured on the other part by means of securing devices. Any other arrangements serving the same purpose are to be submitted for appraisal.

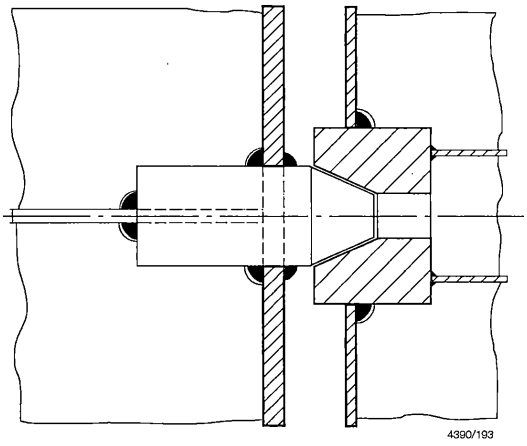

Fig. 5.4.3 Typical thrust bearing

4.9 Securing and locking arrangement

4.9.1 Securing devices are to be simple to operate and easily accessible. Securing devices are to be equipped with mechanical locking arrangement (self locking or separate arrangement), or be of the gravity type. The opening and closing systems as well as securing and locking devices are to be interlocked in such a way that they can only operate in the proper sequence.

4.9.2 Bow doors and inner doors giving access to vehicle decks are to be provided with an arrangement for remote control, from a position above the freeboard deck, of:

(a) the closing and opening of the doors; and

(b) associated securing and locking devices for every door.

Indication of the open/closed position of every door and every securing and locking device is to be provided at the remote control stations. The operating panels for operation of doors are to be inaccessible to unauthorised persons. A notice plate, giving instructions to the effect that all securing devices are to be closed and locked before leaving harbour, is to be placed at each operating panel and is to be supplemented by warning indicator lights.

4.9.3 Where hydraulic securing devices are applied, the system is to be mechanically lockable in the closed position so that in the event of loss of the hydraulic fluid, the securing devices remain locked. The hydraulic system for securing and locking devices is to be isolated from other hydraulic circuits when in the closed position.

4.9.4 Separate indicator lights and audible alarms are to be provided on the navigation bridge and on the operating panel to show that the bow door and inner door are closed and that their securing and locking devices are properly positioned. The indication panel is to be provided with a lamp test function. The indicator lights are to be provided with a permanent power supply, further, arrangements are to be such that it is not possible to turn off these lights in service.

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4.9.5 The indicator system is to be designed on the fail-safe principle and is to show by visual alarms if the door is not fully closed and not fully locked and by audible alarms if securing devices become open or locking devices become unsecured. The power supply for the indicator system is to be independent of the power supply for operating and closing the doors. The sensors of the indicator system are to be protected from water, ice formation and mechanical damages.

4.9.6 The indication panel on the navigation bridge is to be equipped with a mode selection function 'harbour/sea voyage', so arranged that audible alarm is given if the craft leaves harbour with the bow door or inner door not closed and with any of the securing devices not in the correct position.

4.9.7 A water leakage detection system with audible alarm and television surveillance are to be arranged to provide an indication to the navigation bridge and to the engine control room of leakage through the inner door.

4.9.8 Between the bow door and the inner door a television surveillance system is to be fitted with a monitor on the navigation bridge and in the engine control room. The system is to be able to monitor the position of doors and a sufficient number of their securing devices. Special consideration is to be given for lighting and contrasting colour of objects under surveillance.

4.9.9 A drainage system is to be arranged in the area between bow door and ramp, as well as in the area between the ramp and inner door where fitted. The system is to be equipped with an audible alarm function to the navigation bridge for water level in these areas exceeding 0,5 m above the car deck level.

4.10 Operating and Maintenance Manual

4.10.1 An Operating and Maintenance Manual for the bow door and inner door is to be provided on board and contain necessary information on:

(a) main particulars and design drawings,
(b) service conditions, e.g. service area restrictions, acceptable clearances for supports,
(c) maintenance and function testing,
(d) register of inspections and repairs.

This manual is to be submitted for approval.

4.10.2 Documented operating procedures for closing and securing the bow door and inner door are to be kept on board and posted at an appropriate place.

■ *Section 5* Movable decks

5.1 Classification

5.1.1 Movable decks other than those described in 5.1.2 are not a classification item, although consideration must be given to associated supporting structure. Where movable decks are fitted, it is recommended that they be based on the requirements of this Section.

5.1.2 At the Owner's or Builder's request, however, movable decks will be included as a classification item, and the class notation **Movable decks** will be entered in the *Register Book*. In such cases, all movable decks on board the ship are to comply with the requirements of this Section.

5.2 Arrangements and designs

5.2.1 Movable decks are generally to be constructed as pontoons comprising a web structure with top decking. Other forms of construction will be individually considered.

5.2.2 Positive means of control are to be provided to secure decks in the lowered position.

5.2.3 The decks are to be efficiently supported, and hinges, pillars, chains or other means (or a combination of these) are to be designed on the basis of the imposed loads. Where supporting chains and fittings are required, they are to have a factor of safety of at least two on the proof load.

5.2.4 Plans showing the proposed scantlings and arrangements of the system are to be submitted.

5.2.5 Where it is proposed to stow the pontoons on deck, when not in use, details of the proposals for racks, fittings, etc., are to be submitted for consideration.

5.3 Loading

5.3.1 Details of the deck loading resulting from the proposed stowage arrangements of vehicles are to be supplied by the Shipbuilder. These details are to include the axle and wheel spacing, the wheel load, type of tyre and tyre print dimensions for the vehicles. For design purposes the wheel loading is to be taken as not less than 3,0 kN, *see* Section 3.

5.3.2 Where it is proposed also to use the decks for general cargo, the design loadings are to be submitted for consideration.

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5.4 Scantling requirements

5.4.1 The scantlings and arrangements of removable decks are to be not less than those required by the Rules for the supporting structure in which the movable decks are fitted. In general the end fixity of primary stiffening members is to be taken as simply supported. Local and secondary stiffening members may be either partially or fully fixed at their end connections dependent upon the proposed arrangement.

5.5 Deflection

5.5.1 Where wheeled vehicles are to be used, the supporting arrangements are to be such that the movement at the edge of one pontoon relative to the next does not exceed 50 mm during loading or unloading operations.

■ *Section 6* Helicopter landing areas

6.1 General

6.1.1 The landing area may be located on an appropriate area of the weather deck or on a platform specifically designed for this purpose and permanently connected to the craft structure.

6.1.2 The structure is to be designed to accommodate the largest helicopter type which it is intended to use. In general, the diameter of the landing area is to be not less than 1,25 times the rotor diameter.

6.1.3 Attention is drawn to the requirements of National and other Authorities concerning the construction of helicopter landing platforms and the operation of helicopters as they affect the craft.

6.1.4 Plans are to be submitted showing the proposed scantlings and arrangements of the structure. The type, size and weight of helicopters to be used are also to be indicated. Details of the helicopter types to be used are to be included in the craft's documentation, and be contained in a notice displayed on the helicopter landing deck.

6.1.5 Where the landing area forms part of a weather or erection deck, the scantlings are to be not less than those required for decks in the same position.

6.1.6 The requirements for fire protection, detection and extinction for yachts are to comply with Part 17. The requirements for other types of craft are outside the scope of classification and are therefore to comply with the requirements for the National Authority. Special consideration is to be given to the insulation standard if the space below the helicopter deck is a high fire-risk space.

6.2 Arrangements

6.2.1 The landing area is to be sufficiently large to allow for the landing and manoeuvring of the helicopter, and is to be approached by a clear landing and take-off sector complying in extent with the applicable regulations.

6.2.2 The landing area is to be free of any projections above the level of the deck. Projections in the zone surrounding the landing area are to be kept below the heights permitted by the Regulations.

6.2.3 Suitable arrangements are to be made to minimise the risk of personnel or machinery sliding off the landing area. A non-slip surface and anchoring devices, and in the case of independent platforms, safety nets, are to be provided.

6.2.4 Arrangements are to be made for drainage of the platform, including drainage of spilt fuel.

6.2.5 Details of arrangements for securing the helicopter to the deck are to be submitted for approval.

6.3 Landing area plating

6.3.1 The deck plate thickness, t_p, within the landing area is to be not less than:

$$t_p = \frac{\alpha s}{1370\sqrt{k_a}}$$

α = thickness coefficient obtained from Fig. 5.3.1

β_p = tyre print coefficient used in Fig. 5.3.1

$$= \log_{10}\left(\frac{3{,}5\, P_1\, k_a^2}{s^2} \times 10^7\right)$$

where

s and k_a are as defined in 1.2.

The plating is to be designed for the emergency landing case taking:

$$P_1 = 2{,}5\phi_1\, \phi_2\, \phi_3\, f\, \gamma\, P_w \text{ tonnes}$$

where

ϕ_1, ϕ_2, ϕ_3 are to be determined from Table 5.3.1

f = 1,15 for landing decks over manned spaces, e.g. deckhouses, bridges, control rooms, etc.
= 1,0 elsewhere

P_h = the maximum all up weight of the helicopter, in tonnes

P_w = landing load, on the tyre print, in tonnes
P_w is to be taken as P_h divided equally between the two main undercarriages (for helicopters with single main rotor)

γ = a location factor given in Table 5.6.1

k_a is as defined in 1.2.

The tyre print dimensions specified by the manufacturer are to be used for the calculation. Where these are unknown it may be assumed that the print area is 300 x 300 mm and this assumption is to be indicated on the submitted plan.

6.3.2 For helicopters fitted with landing gear consisting of skids, the print dimensions specified by the manufacturer are to be used. Where these are unknown it may be assumed that the print consists of a 300 mm line load at each end of each skid, when applying Fig. 5.3.1.

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Table 5.6.1 Location factor, γ

Location	γ
On decks forming part of the hull girder: (a) within $0,4L_R$ amidships (b) at the F.P. or A.P.	0,71 Values for intermediate locations are to be 0,6 determined by interpolation
Elsewhere	0,6

6.4 Deck stiffening

6.4.1 The helicopter deck stiffening is to be designed for the load cases given in Table 5.6.2 with the helicopter being positioned so as to produce the most severe loading condition for each structural member under consideration.

6.4.2 The minimum requirements for section modulus, inertia and web area of secondary stiffeners are to be in accordance with Table 5.3.3.

6.4.3 For primary stiffening, and where a grillage arrangement is adopted, it is recommended that direct calculation procedures be used to determine the scantling requirements, in association with the limiting permissible stress criteria given in Chapter 7. A copy of the calculations is to be submitted for consideration.

■ *Section 7*
Strengthening requirements for navigation in ice conditions

7.1 General

7.1.1 The strengthening requirements detailed in this Section are applicable to craft, other than those assigned the notation **HSC** and/or **LDC** (*see* Pt 1, Ch 2), intended for operation in light first year ice conditions in areas other than the northern Baltic corresponding to unbroken level ice of thickness not greater than 0,4 m.

7.1.2 Craft complying with the requirements of this Section, in addition to the requirements for sea-going service where applicable, will be eligible for the special features notation **Ice Class 1D**. Alternatively, a Special Duties Notation may be assigned indicating that the craft has been additionally strengthened for duties in ice, *see* Pt 1, Ch 2,3.8.

7.1.3 Craft designed to operate in ice conditions other than those detailed in 7.1.1 are to comply with Part 8 of the *Rules and Regulations for the Classification of Ships*.

7.1.4 The requirements of this Section are applicable to both longitudinally and transversely framed craft and concern the shell plating and framing in the forward region, the stem, sternframe, rudder and the steering gear.

7.1.5 The vertical extent of the ice strengthening is related to the ice light and ice load waterlines, which are defined in 7.2. The maximum and minimum Ice Class draughts at both the fore and aft ends will be stated on the Class Certificate.

Table 5.6.2 Design load cases for deck stiffening and supporting structure

Loadcase	Loads (tonnes)			
	Landing area		Supporting structure, *see* Note 1	
	UDL	Helicopter, *see* Note 2	Self weight	Horizontal load, *see* Note 2
(1) Overall distributed loading	2	—	—	—
(2) Helicopter emergency landing	0,2	$2,5P_h f$	W_h	$0,5P_h$
(3) Normal Usage	0,5	$1,5P_h$	W_h	$0,5P_h + 0,5W_h$
Symbols				
P_h and f are as defined in 6.3.1 *UDL* = Uniformly distributed vertical load over entire landing area, kN/m^2 W_h = structural weight of helicopter platform, in tonnes				
NOTES 1. For the design of the supporting structure for helicopter platforms applicable self weight and horizontal loads are to be added to the landing area loads. 2. The helicopter is to be so positioned as to produce the most severe loading condition for each structural member under consideration.				

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7.1.6 The requirements of this Section assume that when approaching ice infested waters the craft's speed will be reduced appropriately. The vertical extent of ice strengthening for craft intended to operate in ice conditions at speeds exceeding 15 knots will be specially considered.

7.1.7 The ballast capacity of propeller-driven craft is to be sufficient to give adequate propeller immersion in all ice navigating conditions without trimming the craft in such a manner that the actual waterline at the bow is below the ice light waterline. Ballast tanks situated above the ice light waterline and adjacent to the shell, which are intended to be used in ice navigating conditions, are to be provided with heating pipes.

7.2 Definitions

7.2.1 The Ice Load Waterline is that corresponding to the Fresh Water Summer Loadline.

7.2.2 The Ice Light Waterline is that corresponding to the lightest condition in which the craft is expected to navigate in ice.

7.2.3 The Ice Load Waterline and the Ice Light Waterline are to be indicated on the plans. For navigation in certain geographical areas, the relevant National Authority may require the maximum Ice Class draught to be marked on the craft in a specified manner.

7.2.4 The Main Ice Belt Zone extends vertically from 500 mm below the Ice Light Waterline to 400 mm above the Ice Load Waterline and horizontally from the stem to 0,02*L* m aft of the point at which the deepest load waterline reaches its greatest breadth.

7.3 Powering of ice strengthened craft

7.3.1 Ice strengthened craft are assumed to be capable of developing sufficient thrust to permit continuous mode icebreaking at a speed of at least five knots in ice having a thickness of 0,4 m and a snow cover of at least 0,3 m.

7.4 Shell plating

7.4.1 In way of the main ice belt zone, the thickness of the shell plating is to be determined by direct calculation. A copy of these direct calculations are to be submitted for consideration.

7.4.2 Changes in plating thicknesses in the longitudinal direction are to take place gradually.

7.4.3 Side scuttles are not to be situated in the ice belt.

7.4.4 If the weather deck in any part of the craft is situated below the upper limit of the ice belt, the bulwark is to be reinforced to the same degree as the shell plating in the main ice belt.

7.4.5 In general all welded seams and butts in way of the main ice belt are to be dressed smooth.

7.5 Shell framing requirements

7.5.1 Ice framing is to extend a minimum distance of 1000 mm above the Ice Load Waterline and 1600 mm below the Ice Light Waterline between the stem and $0{,}02L_R$ m aft of the point at which the deepest load waterline reaches its greatest breadth.

7.5.2 The web thickness of ice framing is not, in general, to be less than half that of the attached shell plating.

7.5.3 Ice frames are to be attached to the shell plating by double continuous welding and are not to be scalloped except at shell plating seams or butts. Air and drain holes are to be kept to a minimum.

7.5.4 Main and intermediate frames within the minimum extent of ice framing are to be efficiently supported to prevent tripping. The distance between anti-tripping supports is not to exceed 1000 mm.

7.5.5 The section modulus of an ice framing stiffening member is to be determined by direct calculation. A copy of these direct calculations is to be submitted for consideration.

7.5.6 Where transverse framing is adopted, ice stringers (primary longitudinal members supporting ice framing) are to be spaced not more than 1000 mm apart and are to have a section modulus not less than four times the section modulus of the transverse framing.

7.5.7 Where longitudinal framing is adopted, ice stringers need not be fitted.

7.6 Stem construction

7.6.1 Where a plate stem is fitted, the plate thickness is to be not less than 1,3 times that determined by Ch 3,3.3.

7.6.2 Where a bar stem is fitted, its cross-sectional area is to be not less than 1,25 times that determined by Ch 3,5.12.

7.7 Stern construction

7.7.1 A transom stern is not normally to extend below the ice load waterline. Where this cannot be avoided, the transom is to be kept as narrow as possible and the scantlings of plating and stiffeners are to be as required for the midcraft region.

7.8 Bossings and shaft struts

7.8.1 For craft with two or more propellers, shafting and sterntubes are generally to be enclosed within plated bossings. If detached supporting struts are necessary, their design, strengthening and attachment to the hull will be specially considered.

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7.9 Rudder and steering arrangements

7.9.1 Rudder posts, rudder horns, solepieces, rudder stocks and pintles are to be dimensioned in accordance with Pt 3, Ch 3,2. The speed used in the calculations is to be the service speed or 14 knots, whichever is the greater.

7.9.2 The thickness of rudder plating and webs is to be increased by 10 per cent over the requirements of Pt 3, Ch 3,2.

7.9.3 Due regard is to be paid to the method of securing the rudder in the centreline position when backing into ice. Where possible, rudder stoppers working on the blade or rudder head are to be fitted.

7.9.4 Where steering nozzles are fitted, the thickness of the shroud plating is to include an abrasion allowance of 2 mm.

7.9.5 The scantlings of the stock, pintles, gudgeon and sole pieces associated with the nozzle are to be increased on the basis given in 7.9.1. However, the diameter of the nozzle stock is to be not less than that calculated in the astern condition taking the astern speed as seven knots or the actual astern speed, whichever is the greater.

7.9.6 Nozzles with articulated flaps will be subject to special consideration.

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Section

1 **General**

2 **Hull girder strength for mono-hull craft**

3 **Additional hull girder strength requirements for multi-hull craft**

■ *Section 1* General

1.1 Application

1.1.1 The requirements for longitudinal and transverse global strength for mono-hull and multi-hull craft of aluminium construction, are contained within this Chapter. Due consideration is taken of the dynamic effects, where appropriate, in both the crest and trough wave loading conditions.

1.2 Symbols and definitions

1.2.1 The symbols and definitions applicable to this Chapter are defined below or in the appropriate sub-Section:

l = length of stiffening member, in metres
l_e = effective span length of stiffening member, in metres
p = design pressure as appropriately given in Part 3, in kN/m^2
s = spacing of stiffener, in mm
t_p = thickness of plating, in mm
B = moulded breadth of craft, in metres (to be taken as the breadth of a single hull for multi-hull craft)
L_R = Rule length of the craft, in metres
β = panel aspect ratio correction, *see* Ch 3,1.15
σ_a = 0,2 per cent proof stress of the alloy in the welded condition, in N/mm^2

$$\tau_a = \frac{\sigma_a}{\sqrt{3}}$$

1.2.2 The strength deck is to be taken as follows:

(a) Where there is a complete upper deck the strength deck is the upper deck.

(b) Where the upper deck is stepped, as in the case of raised quarterdeck craft, the strength deck is stepped as shown in Fig. 6.1.1.

1.3 General

1.3.1 The additional pressures arising from the influence of the global loading are considered in the determination of the longitudinal strength requirements for local and secondary stiffening and bottom shell plating.

1.3.2 In general, the effective sectional area of continuous longitudinal strength members, after deduction of openings, is to be used for the calculation of midship section modulus.

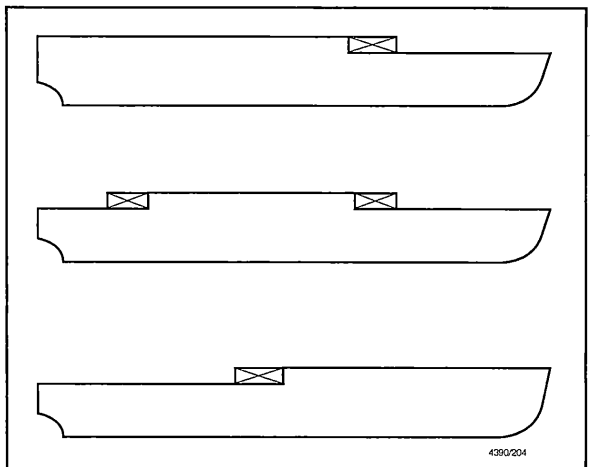

Fig. 6.1.1 Strength deck

1.3.3 Structural members which contribute to the overall hull girder strength are to be carefully aligned so as to avoid discontinuities resulting in abrupt variations of stresses and are to be kept clear of any form of openings which may affect their structural performances.

1.3.4 In general, superstructures or deckhouses will not be accepted as contributing to the global longitudinal or transverse strength of the craft. However, where it is proposed to include substantial, continuous stiffening members, special consideration will be given to their inclusion on submission of the designer's/Builder's calculations.

1.3.5 Where continuous deck longitudinals or deck girders are arranged above the strength deck, special consideration may be given to the inclusion of their sectional area in the calculation of the hull section modulus (Z). The lever is to be taken to a position corresponding to the depth of the longitudinal member above the moulded deckline at side amidships. Each such case will be individually considered.

1.3.6 Adequate transition brackets are to be fitted at the ends of effective continuous longitudinal strength members in the deck and bottom structures.

1.3.7 Scantlings of all continuous longitudinal members of the hull girder based on the minimum section stiffness requirements determined from 2.2 are to be maintained within $0{,}4L_R$ amidships. However, in special cases, based on consideration of type of craft, hull form and loading conditions, the scantlings may be gradually reduced towards the ends of the $0{,}4L_R$ part, bearing in mind the desire not to inhibit the craft's loading and operational flexibility.

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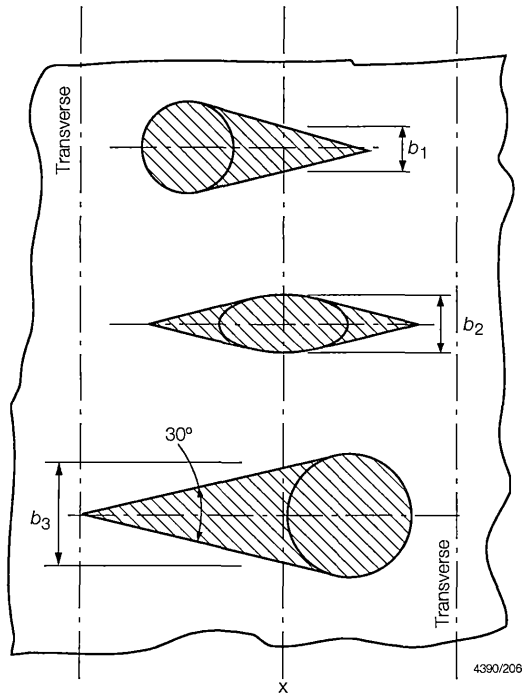
1.4 Openings

1.4.1 Deck openings having a length in the fore and aft directions exceeding 0,1*B* m or a breadth exceeding 0,05*B* m are in all cases to be deducted from the sectional areas used in the section modulus calculation.

1.4.2 Deck openings smaller than stated in 1.4.1, including manholes, need not be deducted provided they are isolated and the sum of their breadths or shadow area breadths (*see* 1.4.3) in one transverse section does not exceed 0,06 ($B_o - \Sigma b_o$):
where
B_o = breadth of craft, in metres, at section considered
Σb_o = sum of breadths, in metres, of deductible openings
Where a large number of deck openings are proposed in any transverse space, special consideration will be required.

1.4.3 Where calculating deduction-free openings, the openings are assumed to have longitudinal extensions as shown by the shaded areas in Fig. 6.1.2. The shadow area is obtained by drawing two tangent lines to an opening angle of 30°. The section to be considered is to be perpendicular to the centreline of the ship and is to result in the maximum deduction in each transverse space.



Total equivalent breadth of small openings at xx = $b_1 + b_2 + b_3$

Fig. 6.1.2 Isolated openings

1.4.4 Isolated openings in longitudinals or longitudinal girders need not be deducted if their depth does not exceed 25 per cent of the web depth or 75 mm, whichever is the lesser.

1.4.5 Openings are considered isolated if they are spaced not less than 1 m apart.

1.4.6 A reduction for drainage holes and scallops in beams and girders, etc., is not necessary so long as the original section stiffness at deck or keel is reduced by no more than three per cent.

1.5 Direct calculation procedure

1.5.1 In direct calculation procedures capable of deriving the wave induced loads on the craft, and hence the required modulus, account is to be taken of the craft's actual form and weight distribution.

1.5.2 Lloyd's Register's (hereinafter referred to as 'LR') direct calculation method involves derivation of response to regular waves by strip theory, short-term response to irregular waves using the sea spectrum concept, and long-term response predictions using statistical distributions of sea states. Other direct calculation methods submitted for approval are normally to contain these three elements and produce similar and consistent results when compared with LR's methods.

1.6 Approved calculation systems

1.6.1 Where the assumptions, method and procedures of a longitudinal strength calculation system have received general approval from LR, calculations using the system for a particular craft may be submitted.

1.7 Information required

1.7.1 In order that an assessment of the longitudinal strength requirements can be made, the following information is to be submitted, in LR's standard format where appropriate:

(a) General arrangement and capacity plan or list, showing details of the volume and position of centre of gravity of all tanks and compartments.
(b) Bonjean data, in the form of tables or curves, for at least 21 equally spaced stations along the hull. A lines plan and/or tables of offsets may also be required.
(c) Details of the calculated lightweight and its distribution.
(d) Details of the weights and centres of gravity of all deadweight items for each of the main loading conditions. It is recommended that this information be submitted in the form of a preliminary Loading Manual, to include the calculated still water and dynamic bending moments and shear forces.

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1.8 Loading guidance information

1.8.1 Sufficient information is to be supplied to the Master of every craft to enable him to arrange loading in such a way as to avoid the creation of unacceptable stresses in the craft's structure.

■ *Section 2*
Hull girder strength for mono-hull craft

2.1 General

2.1.1 Longitudinal strength calculations are to be submitted for all craft with a Rule length, L_R, exceeding 45 m covering the range of load and ballast conditions proposed, in order to determine the required hull girder strength. Still water, static wave and dynamic bending moments and shear forces are to be calculated for both departure and arrival conditions.

2.1.2 For craft of ordinary hull form with a Rule length, L_R, less than 45 m, the minimum hull girder strength requirements are generally satisfied by scantlings obtained from local strength requirements. However longitudinal strength calculations may be required at LR's discretion, dependent upon the form, constructional arrangement and proposed loading.

2.1.3 Where the Rule length, L_R, of the craft exceeds 75 m, or for new designs of large, structurally complicated craft, the design loads and scantling determination formulae in this Chapter are to be supplemented by direct calculation and structural analysis by 3-D finite element methods. These supplementary calculations are to include the results of model tests and full scale measurement where available or required by LR. Full details of such methods and all assumptions and calculations, which are to be based on generally accepted theories, are to be submitted for appraisal.

2.2 Bending strength

2.2.1 The effective geometric properties of the midship section are to be calculated directly from the dimensions of the section using only the effective material elements which contribute to the global longitudinal strength. For the purposes of this analysis an element may be of deck plating, longitudinal girder, inner bottom, etc., or other continuous member.

2.2.2 The longitudinal strength of craft with $\frac{V}{\sqrt{L_{WL}}} \geq 3{,}0$ is to satisfy both the following criteria:

$\sigma_k + \sigma_l + \sigma_t < 1{,}2\sigma_P$

$\sigma_d < \sigma_P$

where

σ_P = maximum permissible hull vertical bending stress, in N/mm^2
= $f_{\sigma gH}\,\sigma_a$

$f_{\sigma gH}$ = limiting hull bending stress coefficient taken from Table 7.3.2 in Chapter 7

L_{WL} is as defined in Pt 3, Ch 1,6.2.5

σ_k, σ_l, σ_t and σ_d are given in Table 6.2.1

σ_a is as defined in 1.2.1.

Table 6.2.1 Longitudinal component stresses

Component stress type	Nominal stress (N/mm^2)
Hull girder bending stress at strength deck amidships	$\sigma_d = \frac{M_R}{1000Z_d}$
Hull girder bending stress at keel amidships	$\sigma_k = \frac{M_R}{1000Z_k}$
Actual stress in bottom longitudinals amidships due to design pressure load	$\sigma_l = \frac{p_s\, s\, l_e^2}{12Z_l}$
Actual stress in bottom plating amidships due to design pressure load	$\sigma_t = 0{,}34p_t\left(\frac{\beta s}{t_p}\right)^2 \times 10^{-3}$
Symbols and definitions	
M_R = design longitudinal midship bending moment, in kNm given in Pt 5, Ch 5,5 p_s = additional effective pressure loading, in kN/m^2, on bottom longitudinals from global dynamic load model, given in Pt 5, Ch 5,2.6.3 p_t = additional effective pressure loading, in kN/m^2, on bottom plating from global dynamic load model, given in Pt 5, Ch 5,2.6.4 Z_d = actual section modulus at deck, in m^3 Z_k = actual section modulus at keel, in m^3 Z_l = maximum section modulus of bottom longitudinal stiffener, associated with plating, amidships, in cm^3 s, l_e, β and t_p are as defined in 1.2.	

2.2.3 The longitudinal strength of craft with $\frac{V}{\sqrt{L_{WL}}} < 3{,}0$ is to satisfy both the following criteria:

$\sigma_k < \sigma_P$

$\sigma_d < \sigma_P$

where

σ_P is as defined in 2.2.2

σ_k and σ_d, are given in Table 6.2.1

L_{WL} is as defined in Pt 3, Ch 1,6.2.5.

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2.3 Shear strength

2.3.1 The shear strength of the craft at any position along its length is to satisfy the following criterion:

$$\frac{Q_R}{A_\tau} 10^{-3} \leq \tau_p$$

where

Q_R = design hull shear force at any section along the hull length, L_R, in kN determined from Pt 5, Ch 5,5

A_τ = shear area of transverse section, in m^2, is to be taken as the effective net sectional area of the shell plating and longitudinal bulkheads after deductions for openings. For longitudinal strength members which are inclined to the vertical, the area of the member to be included in the calculation is to be based on the area projected onto the vertical plane, *see* Fig. 6.2.1

τ_p = maximum permissible mean shear stress, in N/mm^2 = $f_{\sigma g}\,\tau_a$

$f_{\sigma g}$ = limiting hull shear stress coefficient taken from Table 7.3.2 in Chapter 7

τ_a is as defined in 1.2.1.

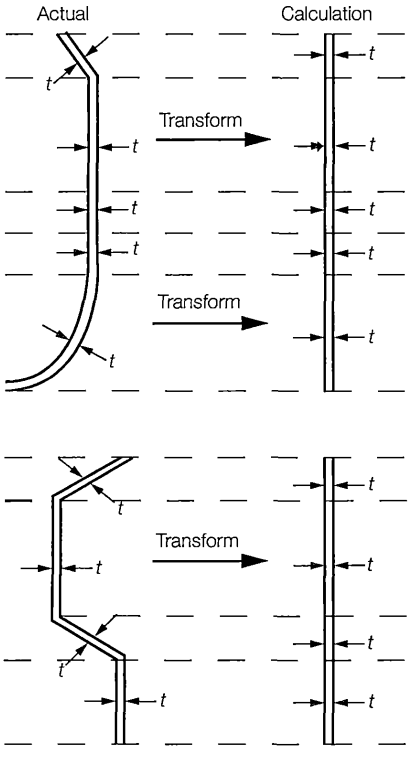

Fig. 6.2.1 Effective shear area

2.4 Torsional strength

2.4.1 Torsional stresses are typically small for mono-hulls of ordinary form of Rule length, L_R, less than 75 m and can generally be ignored.

2.4.2 The calculation of torsional stresses and/or deflections may be required when considering craft with large deck openings, unusual form or proportions. Calculations may in general be required to be carried out using a direct calculation procedure. Such calculations are to be submitted in accordance with 1.5.

2.5 Superstructures global strength

2.5.1 The effectiveness of the superstructure in absorbing hull girder bending loads is to be established where the first tier of the superstructure extends within 0,4*L* amidship and where:

$$l_d > b_d + 3h_d$$

where

l_d = length of first tier, in metres

b_d = breadth of first tier, in metres

h_d = 'tween deck height of first tier, in metres.

2.5.2 For superstructures with one or two tiers extending outboard to the craft's side shell, the effectiveness in absorbing hull girder bending loads in the uppermost effective tier may be assessed by the following factor:

$$\eta_s = 7\left[(\varepsilon - 5)\gamma^4 + 94(5 - \varepsilon)\gamma^3 + 2800(\varepsilon - 5{,}8)\gamma^2 + 27660(9 - \varepsilon)\gamma\right] f(\lambda, N) \times 10^{-7}$$

where

$f(\lambda, N = 1) = 1$

$f(\lambda, N = 2) = 0{,}90\lambda^3 - 2{,}17\lambda^2 + 1{,}73\lambda + 0{,}50$

and

N = 1 if $l_2 < 0{,}7l_1$

= 2 if $l_2 \geq 0{,}7l_1$

$\lambda = \frac{l_w}{L_R}$ or 1, whichever is less

$\varepsilon = \frac{b_1}{h_1}$ or 5, whichever is less

$\gamma = \frac{l_w}{h_1}$ or 25, whichever is less

$l_w = l_1$ for $N = 1$

$= \frac{(2l_1 + l_2)}{3}$ for $N = 2$

L_R = is as defined in 1.2.1, in metres

l_1, b_1, h_1 = is as defined in 2.5.1, in metres

l_2 = length of second tier, in metres.

2.5.3 The hull girder compressive bending stress σ_L, in the uppermost effective tier at side may be derived according to the following formula:

$$\sigma_L = \eta_s \frac{M_R}{1000 Z_{100}} \ N/mm^2$$

where

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M_R = hull girder bending moment at midships due to sagging as determined in Pt 5, Ch 5,5, in kNm
Z_{100} = section modulus at uppermost effective tier of hull and effective tiers, assuming tiers to be 100 per cent effective, in m^3
η_s = as defined in 2.5.2.

2.5.4 The compressive stress, σ_L, in the uppermost effective tier at side is to be checked against buckling in accordance with Ch 7,4.

2.5.5 The uppermost effective tier may need to fulfil the requirements for strength deck when the following applies:

$$\eta_s = \left(1 + \frac{Z_0 h}{I_{100}}\right)^{-1}$$

where
η_s = as defined in 2.5.2
Z_0 = section modulus of hull only at hull upper deck, in m^3
I_{100} = moment of inertia of hull and effective tiers, assuming tiers to be 100 per cent effective, in m^4
h = height from hull upper deck to uppermost effective tier, in metres.

Section 3
Additional hull girder strength requirements for multi-hull craft

3.1 General

3.1.1 Except as otherwise specified within this Section, the global strength requirements for multi-hull craft are to comply with Section 2.

3.1.2 Longitudinal strength calculations are to be submitted for all craft with a Rule length, L_R, exceeding 40 m covering the range of load and ballast conditions proposed, in order to determine the required hull girder strength. Still water, static wave and dynamic bending moments and shear forces are to be calculated for both departure and arrival conditions.

3.1.3 For craft of ordinary hull form length with a Rule length, L_R, less than 40 m, the minimum hull girder strength requirements are generally satisfied by scantlings obtained from local strength requirements. However longitudinal strength calculations may be required at LR's discretion, dependent upon the proposed loading.

3.1.4 Where the Rule length, L_R, of the craft exceeds 60 m, or for new designs of large, structurally complicated craft, the design loads and scantling determination formulae in this Chapter are to be supplemented by direct calculation and structural analysis by 3-D finite element methods. These supplementary calculations are to include the results of model tests and full scale measurement where available or required by LR. Full details of such methods and all assumptions and calculations, which are to be based on generally accepted theories, are to be submitted for appraisal.

3.1.5 The strength deck plating in way of the cross-deck structure, the wet-deck plating, longitudinal bulkheads and girders, and other continuous members may be included in the determination of the midship section stiffness.

3.1.6 Special consideration will be given to the global strength requirements for craft with more than two hulls linked by cross-deck structure.

3.2 Hull longitudinal bending strength

3.2.1 The requirements of 2.2 are in general to be complied with, using the appropriate design bending moment and effective pressure loadings applicable to multi-hull craft, as determined from Pt 5, Ch 5,5.

3.3 Hull shear strength

3.3.1 The requirements of 2.3 are to be complied with so far as they are applicable.

3.4 Torsional strength

3.4.1 Where a craft is of unusual form or novel construction, or at the discretion of LR, the torsional stress is to be determined by direct calculation methods using the twin hull torsional connecting moment as defined in Pt 5, Ch 5,5. Such calculations are to be submitted in accordance with 1.5.

3.5 Strength of cross-deck structures

3.5.1 Design loads to be applied for scantling calculations are transverse vertical bending moment and shear force, twin hull torsional connecting moment, external pressure load and appropriate internal loads as defined in Part 5.

3.5.2 The primary stiffening members of the cross-deck structure are to provide sufficient strength to satisfy the stress criteria given in Table 6.3.1.

3.5.3 The component nominal stresses may be determined in accordance with Table 6.3.2 in the case where the cross-deck is formed by transverse primary stiffeners or bulkheads and the following assumptions are taken:
(a) The cross-deck is symmetrical forward and aft of a transverse axis at its half length.
(b) Primary stiffeners having the same scantlings and spacing.

3.5.4 Other cross-deck designs subjected to global transverse loads will require a two-dimensional grillage analysis to be performed to demonstrate compliance with 3.5.2.

3.5.5 Section properties are to be calculated using an effective breadth of plating to be determined in accordance with Ch 3,1.11.

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Table 6.3.1 Primary member stress criteria

Stress type	Component stresses	Allowable stress level (N/mm^2)
Total direct stress, σ_P	$\sigma_P = \sigma_{MB} + \sigma_{MT} + \sigma_d$	$f_{\sigma gV}\,\sigma_a$
Total shear stress, τ_P	$\tau_P = \tau_T + \tau_{MBT} + \tau_{MT}$	$f_{\tau gV}\,\tau_a$
Equivalent stress, σ_{eq}	$\sigma_{eq} = \sqrt{\sigma^2 + 3\tau^2}$	$1{,}2\,f_{\sigma eg}\,\sigma_a$
Symbols and definitions		
σ_{MB}, σ_{MT}, τ_T, τ_{MBT} and τ_{MT} are component stresses, in N/mm^2, to be taken from Table 6.3.2. $f_{\sigma gV}$, $f_{\tau gV}$ and $f_{\sigma eg}$ are limiting stress coefficients for cross-deck structures to be taken from Table 7.3.2 in Chapter 7. σ_a and τ_a are defined in 1.2.		

Table 6.3.2 Cross-deck component stresses for designs complying with 3.5.3

Component stress type	Nominal stress (N/mm^2)
Hull girder bending stress at strength deck amidships, *see* Table 6.2.1	$\sigma_d = f_{MR}\,\dfrac{M_R}{1000 Z_d}$
Stress induced by the transverse bending moment M_B, as defined in Pt 5, Ch 5,5	$\sigma_{MB} = f_{MB}\,\dfrac{M_B}{nZ}\,10^3$
Stress induced by the torsional moment M_T, as defined in Pt 5, Ch 5,5	$\sigma_{MT} = f_{MT}\,\dfrac{3x_H\,M_T}{n\,(n+1)\,s_p\,Z}\,10^3$
Shear stress induced by the vertical shear force Q_T, as defined in Pt 5, Ch 5,5	$\tau_T = f_{MB}\,\dfrac{5Q_T}{n\,A_w}$
Bending shear stress induced by the torsional moment M_T, as defined in Pt 5, Ch 5,5	$\tau_{MBT} = f_{MT}\,\dfrac{60M_T}{n\,(n+1)\,s_p\,A_w}$
Shear stress induced by the torsional moment M_T, as defined in Pt 5, Ch 5,5	$\tau_{MT} = f_{MT}\,\dfrac{46\kappa\,x_H^2\,M_T}{n\,(n^2+1)\,s_p^2\,I_y}\,10^3$
Symbols and definitions	

Q_T = vertical shear force, in kN, as determined from, Pt 5, Ch 5,5
M_B = transverse bending moment in kNm, as determined from Pt 5, Ch 5,5
M_T = torsional moment in kNm, as determined from Pt 5, Ch 5,5
n = total number of transverse primary stiffeners or bulkheads
A_w = stiffener web area, cm^2
Z = primary stiffeners section modulus, in cm^3
s_p = stiffener spacing, in metres
I_y = moment of inertia of stiffener, cm^4
x_H = transverse distance between the centre of the two hulls, in metres
κ = t_f, for symmetrical I-section, in mm
= $b_b\,h/(b_b + h)$, for constant thickness box sections, in mm
σ_{MB} = stress induced by the transverse bending moment M_B, as defined in Pt 5, Ch 5,5, in N/mm^2
σ_{MT} = stress induced by the torsional moment M_T, as defined in Pt 5, Ch 5,5, in N/mm^2
τ_T = shear stress induced by the vertical shear force Q_T, as defined in Pt 5, Ch 5,5, in N/mm^2
τ_{MBT} = bending shear stress induced by the torsional moment M_T, as defined in Pt 5, Ch 5,5, in N/mm^2
τ_{MT} = shear stress induced by the torsional moment M_T, as defined in Pt 5, Ch 5,5, in N/mm^2
t_f = face plate thickness, in mm
b_b = breadth of box section, in mm
h_b = height of box section, in mm

f_{MR}, f_{MB} and f_{MT} are load combination factors reflecting the portions of each component global design load, M_R, Q_T, M_B and M_T, corresponding to the most severe load combinations, The most severe load combinations are the combinations of loads resulting in the maximum bending, shear and effective stress, respectively. The assessment of these load combinations need to take due consideration for the component load magnitude variation with wave heading and also the phasing in time between them. Generally, f_{MR}, f_{MB}, and f_{MT} are to be taken as indicated in Table 6.3.3.

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Table 6.3.3 Load combination factors

Heading	Factors		
	f_{MB}	f_{MR}	f_{MT}
Head sea	0,1	1,0	0,1
Beam sea	1,0	0,1	0,2
Quartering sea	0,1	0,4	1,0

3.5.6 Where primary stiffening members support areas of plating of the extruded plank type, or the floating frame system is used, the effect of the plating attached to the secondary stiffening members is to be ignored when determining the global section modulus requirements.

3.6 Grillage structures

3.6.1 For complex girder systems, a complete structural analysis using numerical methods may be required to be performed to demonstrate that the stress levels are acceptable when subjected to the most severe and realistic combination of loading conditions intended.

3.6.2 In general, the transverse and vertical girders, bottom and side structures, bridge structure, deck structures and any other parts of the craft which LR considers critical to the craft's structural integrity are to be included in the numerical modelling of the craft.

3.7 Analysis techniques

3.7.1 General or special purpose computer programs or any other analytical techniques may be used provided that the effects of bending, shear, axial and torsion are properly accounted for and the theory and idealisation used can be justified.

3.7.2 In general, grillages consisting of slender girders may be idealised as frames based on beam theory provided proper account of the variations of geometric properties is taken. For cases where such an assumption is not applicable, finite element analysis or equivalent methods may have to be used.

3.7.3 Analysis of the cross deck structures with regard to impact loads due to slamming may have to be carried out using advanced structural analysis techniques.

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Section

1 **General**

2 **Deflection control**

3 **Stress control**

4 **Buckling control**

5 **Vibration control**

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull and multi-hull craft of aluminium construction as defined in Pt 1, Ch 1,1.

1.2 General

1.2.1 The failure modes criteria contained within this Chapter are to be used in the formulae from the preceding Chapters to determine the scantling requirements. In addition, they are to be used when direct calculation methods are proposed as an alternative.

1.3 Symbols and definitions

1.3.1 The symbols and definitions applicable to this Chapter are defined in the appropriate Sections.

1.4 Direct calculations

1.4.1 Where direct calculations are proposed, the requirements of Pt 3, Ch 1,2 are to be complied with.

1.4.2 In addition, with the agreement of Lloyd's Register (hereinafter referred to as 'LR'), tests may be conducted to demonstrate the actual response of the structure and the results verified against the failure mode criteria in this Chapter.

■ *Section 2* Deflection control

2.1 General

2.1.1 The limiting deflection requirements for plate panels and stiffening members are given in terms of limiting deflection coefficient, f_δ, *see* Table 7.2.1. The coefficient equates to a span/deflection ratio in consistent units.

Table 7.2.1 Limiting deflection ratio

Item	Deflection ratio, f_δ
Bottom structure:	
• secondary stiffening	475
• primary girders and web frames	625
Side structure:	
• secondary stiffening	475
• primary girders and web frames	625
Main/strength deck structures:	
• secondary stiffening	625
• primary girders and web frames	775
• hatch covers	775
Superstructures/deckhouses stiffeners:	
(a) Generally: • secondary	400
• primary	475
(b) Coachroof: • secondary	475
• primary	625
(c) House top: • secondary	400
• primary	400
Lower/inner decks and house top, subject to personnel loading:	
• secondary members	475
• primary members	625
Deep tank stiffeners:	
• secondary members	625
• primary members	775
Watertight bulkhead stiffeners:	
• secondary members	400
• primary members	475
Multi-hull cross-deck stiffeners:	
• secondary members	475
• primary members	625
Vehicle deck stiffeners:	
• secondary members	625
• primary members	775
Helicopter/flight deck stiffeners:	
• secondary members	625
• primary members	775
NOTE Where significant curvature exists over the span of the stiffener or breadth of the panel, the allowable deflections will be specially considered.	

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■ *Section 3* Stress control

3.1 General

3.1.1 The nominal limiting stress requirements for plating and primary and secondary stiffening members subject to local loading conditions are given in terms of limiting stress coefficients, *see* Table 7.3.1. The coefficients are expressed as a proportion of the 0,2 per cent proof stress of the material.

3.1.2 The limiting stress coefficients for structural elements subject to global loading conditions are given in Table 7.3.2.

3.1.3 In the determination of the magnitude of the equivalent stress, σ_{eq}, it is assumed that the stresses are combined using the following formula:

$$\sigma_{eq} = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x \sigma_y + 3\tau^2}$$

where

σ_x = direct stress in the x direction

σ_y = direct stress in the y direction

τ = shear stress in the xy plane.

Table 7.3.1 Limiting stress coefficients for local loading *(see continuation)*

Item	Limiting stress coefficient		
	Bending f_σ	Shear f_τ	Equivalent f_e
Shell envelope:			
(a) Bottom shell plating: • slamming zone	0,85	—	—
• elsewhere	0,75	—	—
(b) Side shell plating: • slamming zone	0,85	—	—
• elsewhere	0,75	—	—
(c) Keel	0,75	—	—
Bottom structure:			
(a) Secondary stiffening: • slamming zone	0,75	0,75	—
• elsewhere	0,65	0,65	—
(b) Primary girders and web frames	0,65	0,65	0,75
(c) Engine girders	0,55	0,55	0,75
Side structure:			
(a) Secondary stiffening: • slamming zone	0,75	0,75	—
• elsewhere	0,65	0,65	—
(b) Primary girders and web frames	0,65	0,65	0,75
Bow doors:			
(a) Plating	0,65	—	—
(b) Secondary stiffening	0,51	0,433	—
(c) Primary stiffening	0,51	0,34	0,64
Main/strength deck plating and stiffeners:			
(a) Plating	0,75	—	—
(b) Secondary stiffening	0,65	0,65	—
(c) Primary girders and web frame	0,65	0,65	0,75
(d) Hatch covers	0,55	0,55	0,64

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Table 7.3.1 Limiting stress coefficients for local loading (*conclusion*)

Item		Limiting stress coefficient		
		Bending f_σ	Shear f_τ	Equivalent f_e
Superstructures/deckhouses:				
(a) Deckhouse front, 1st tier:	• plating	0,65	—	—
	• stiffening	0,60	0,60	—
(b) Deckhouse front, upper tiers:	• plating	0,75	—	—
	• stiffening	0,65	0,65	—
(c) Deckhouse aft and sides:	• plating	0,75	—	—
	• stiffening	0,75	0,75	—
(d) Coachroof:	• plating	0,65	—	—
	• stiffening	0,65	0,65	—
(e) House top:	• plating	0,75	—	—
	• stiffening	0,75	0,75	—
(f) Lower/inner decks and house top, subject to personnel loading:				
	• plating	0,75	—	—
	• stiffening	0,60	0,60	—
Bulkheads:				
(a) Watertight bulkhead:	• plating	1,0	—	—
	• secondary stiffening	0,95	0,95	—
	• primary stiffening	0,90	0,90	1,0
(b) Watertight bulkhead doors		0,825	0,825	0,825
(c) Structure supporting watertight doors		0,80	0,80	—
(d) Minor bulkheads:	• plating	0,65	—	—
	• secondary stiffening	0,65	0,65	—
	• primary stiffening	0,65	0,65	0,75
(e) Deep tank bulkheads:	• plating	0,65	—	—
	• secondary stiffening	0,65	0,65	—
	• primary stiffening	0,75	0,75	—
Multi-hull cross-deck structure:				
(a) Plating:	• slamming zone	0,85	—	—
	• elsewhere	0,75	—	—
(b) Secondary stiffening:	• slamming zone	0,75	0,75	—
	• elsewhere	0,65	0,65	—
(c) Primary stiffening		0,65	0,65	0,75
Vehicle deck:				
(a) Plating		0,60	—	—
(b) Secondary stiffening		0,425	0,425	—
(c) Primary stiffening		0,525	0,525	0,75
Helicopter/flight decks:				
(a) Normal usage:	• plating	0,65	—	—
	• secondary stiffening	0,75	0,75	—
	• primary stiffening	0,625	0,625	0,60
(b) Emergency landing:	• plating	0,75	—	—
	• secondary stiffening	1,0	1,0	—
	• primary stiffening	0,825	0,825	0,9
(c) Crane pedestal/foundation structural elements		0,7	0,7	0,75

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Table 7.3.2 Limiting stress coefficients for global loading

Operational mode of craft	Limiting stress coefficient					
	Hull girder			Cross-deck		
	Bending $f_{\sigma gH}$	Shear $f_{\tau gH}$	Equivalent $f_{\sigma eg}$	Bending $f_{\sigma gV}$	Shear $f_{\tau gV}$	Equivalent $f_{\sigma eg}$
$\Gamma \geq 3,0$ $\Delta \leq 0,04\,(L_R B)^{1,5}$	0,80	0,80	0,825	0,80	0,80	0,825
$\Gamma < 3,0$ and $\Delta > 0,4\,(L_R B)^{1,5}$	0,72	0,72	0,75	0,72	0,72	0,75

Symbols

$f_{\sigma gH}$ = limiting hull bending stress coefficient
$f_{\tau gH}$ = limiting hull shear stress coefficient
$f_{\sigma gV}$ = limiting cross-deck bending stress coefficient
$f_{\tau gV}$ = limiting cross-deck shear stress coefficient
$f_{\sigma eg}$ = limiting equivalent stress coefficient
Γ is the Taylor Quotient as defined in Pt 5, Ch 2,2.1.16
Δ is the displacement as defined in Pt 5, Ch 2,2
L_R and B are as defined in Pt 3, Ch 1,6.2

Section 4
Buckling control

4.1 General

4.1.1 This Section contains the requirements for buckling control of plate panels subject to in-plane compressive and/or shear stresses and buckling control of primary and secondary stiffening members subject to axial compressive and shear stresses.

4.1.2 The requirements for buckling control of plate panels are contained in 4.3 to 4.6. The requirements for secondary stiffening members are contained in 4.7 to 4.8. The requirements for primary members are contained in 4.9 and 4.10.

4.1.3 In general all areas of the structure are to meet the buckling strength requirements for the design stresses. The design stresses are to be taken as follows:

(a) Global hull girder bending and shear stresses given in Chapter 6, but not including stresses σ_l and σ_t as defined in Table 6.2.1 in Chapter 6.
(b) Stresses from local compressive loads.

4.1.4 The buckling requirements are to be met using the net scantlings, hence any additional thickness for corrosion margin or Owner's extra is not included in scantlings used to assess the buckling performance.

4.2 Symbols

4.2.1 The symbols used in this Section are defined below and in the appropriate sub-Section:

a = panel length, i.e. parallel to direction of com-pressive stress being considered, in mm
b = panel breadth, i.e. perpendicular to direction of compressive stress being considered, in mm
b_{eb} = lesser of $1,9t_p\sqrt{\frac{E}{\sigma_a}}$ or $0,8b$ mm
l = length of longer edge of plate panel, in metres
s = length of shorter edge of plate panel, in mm (typically the spacing of secondary stiffeners)
t_p = thickness of plating, in mm
A_R = panel aspect ratio
$= \frac{a}{b}$
A_{te} = cross-sectional area of secondary stiffener, in cm^2, including an effective breadth of attached plating, b_{eb}
E = modulus of elasticity of material in N/mm^2
S = spacing of primary member, in metres (measured in direction of compression)
S_p = span of primary members, in metres
σ_a = 0,2 per cent proof stress of the material, in N/mm^2
σ_e = elastic compressive buckling stress, in N/mm^2
σ_c = critical compressive buckling stress, including the effects of plasticity where appropriate, in N/mm^2
τ_a = specified minimum yield shear stress of the material, in N/mm^2
$= \frac{\sigma_a}{\sqrt{3}}$ N/mm^2
τ_e = elastic shear buckling stress, in N/mm^2
τ_c = critical shear buckling stress, in N/mm^2.

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4.3 Plate panel buckling requirements

4.3.1 This Section gives methods for evaluating the buckling strength of plate panels subjected to the following load fields:
(a) uni-axial compressive loads;
(b) shear loads;
(c) bi-axial compressive loads;
(d) uni-axial compressive loads and shear loads;
(e) bi-axial compressive loads and shear loads.

4.3.2 The plate panel buckling requirements will be satisfied if the buckling interaction equations given in Table 7.4.2 for the above load fields are complied with.

4.3.3 The critical compressive buckling stresses and critical shear buckling stresses required for Table 7.4.2 are to be derived in accordance with 4.4.

4.3.4 The buckling factors of safety λ_σ and λ_τ required by Table 7.4.2 are given in Table 7.4.4 for the structural member concerned.

4.3.5 For all structural members which contribute to the hull girder strength, the plate panel buckling requirements for uni-axial compressive loads, Table 7.4.2(a), and shear loads, Table 7.4.2(b) are to be complied with.

4.3.6 In addition to 4.3.5, structural members which are subjected to local compressive loads and/or shear loads are to be verified using the plate panel buckling requirements in Table 7.4.2(c) to (e).

4.3.7 However, where some members of the structure have been designed such that elastic buckling of the plate panel between the stiffeners is allowable, then the requirements of 4.5 must be applied to the buckling analysis of the stiffeners supporting the plating. In addition, panels which do not satisfy the panel buckling requirements must be indicated on the appropriate drawing and the effect of these panels not being effective in transmitting compressive loads taken into account for the hull girder strength calculation.

4.3.8 In general the plate panel buckling requirements for more complex load fields, *see* 4.3.1(c), (d), (e), are to be complied with. Where this is not possible, due to elastic buckling of the panel, then the critical buckling stress, σ_c, may be based on the ultimate collapse strength of the plating, σ_u from 4.5.4, instead of the elastic buckling stress, σ_e, derived in 4.3.5. In addition, the requirements of 4.5 are to be met for the supporting secondary stiffeners and primary members.

4.4 Derivation of the buckling stress for plate panels

4.4.1 The critical compressive buckling stress, σ_c, for a plate panel subjected to uni-axial in-plane compressive loads is to be derived in accordance with Table 7.4.1(a).

4.4.2 The critical shear buckling stress, τ_c, for a plate panel subjected to pure in-plane shear load is to be derived in accordance with Table 7.4.1(b).

4.4.3 For welded plate panels the critical compressive buckling stress is to be reduced to account for the presence of residual welding stresses. The critical buckling stress is to be taken as the minimum of:

$\sigma_{cr} = \sigma_e - \sigma_r$

σ_c derived using 4.4.1

where

σ_r = reduction in compressive buckling stress due to residual welding stresses

$$= \frac{2\beta_{RS}\,\sigma_a}{b/t_p}$$

β_{RS} = residual stress coefficient dependent on type of weld (average value of β_{RS} to be taken as 3)

b, t_p and σ_a are defined in 4.2.1.

4.4.4 In general the effect of lateral loading on plate panels (for example hydrostatic pressure on bottom shell plating) may be neglected and the critical buckling stresses calculated considering the in-plane stresses only.

4.4.5 Unless indicated otherwise, the effect of initial deflection on the buckling strength of plate panels may be ignored.

4.5 Additional requirements for plate panels which buckle elastically

4.5.1 Elastic buckling of plate panels between stiffeners occurs when both the following conditions are satisfied:
(a) The design compressive stress, σ_d, is greater than the elastic buckling stress of the plating, σ_e,
$\sigma_d > \sigma_e$
(b) The elastic buckling stress is less than half the yield stress

$$\sigma_e \leq \frac{\sigma_a}{2}$$

4.5.2 Elastic buckling of local plating between stiffeners, including girders or floors, etc., may be allowed if all of the following conditions are satisfied:
(a) The critical buckling stress of the stiffeners in all buckling modes is greater than the axial stress in the stiffeners after redistribution of the load from the elastically buckled plating into the stiffeners, hence

$$\frac{\sigma_{de}}{\sigma_{c\,(i)}} \leq \frac{1}{\lambda_\sigma}$$

(b) Maximum predicted loadings are used in the calculations.
(c) Functional requirements will allow a degree of plating deformation.

where

σ_{de} is the stiffener axial stress given in 4.5.5

$\sigma_{c\,(i)}$ is given by Table 7.4.3

where

i = a, t, w or f depending on the mode of buckling

λ_σ is the buckling factor of safety

= 1,25.

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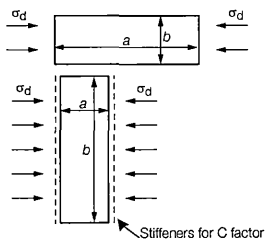
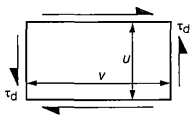
Table 7.4.1 Buckling stress of plate panels

Mode	Elastic buckling stress, N/mm^2, *see* Note	
(a) Uni-axial compression: (i) Long narrow panels, loaded on the narrow edge	$A_R \geq 1$ $\sigma_e = 3{,}62\varphi E \left(\frac{t_p}{b}\right)^2$	
(ii) Short broad panels, loaded on the broad edge	$A_R < 1$ $\sigma_e = 0{,}9C\varphi \left(\frac{b}{a} + \frac{a}{b}\right)^2 E \left(\frac{t_p}{b}\right)^2$	
(b) Pure shear:	$\tau_e = 3{,}62 \left(1{,}335 + \left(\frac{u}{v}\right)^2\right) E \left(\frac{t_p}{u}\right)^2$ NOTE u is to be the minimum dimension	

NOTE
The critical buckling stresses, in N/mm^2, are to be derived from the elastic buckling stresses as follows:

$\sigma_c = \sigma_e$ when $\sigma_e < \frac{\sigma_a}{2}$

$= \sigma_a \left(1 - \frac{\sigma_a}{4\sigma_e}\right)$ when $\sigma_e \geq \frac{\sigma_a}{2}$

σ_c is defined in 4.2.1
σ_a is defined in 4.2.1

$\tau_c = \tau_e$ when $\tau_e < \frac{\tau_a}{2}$

$= \tau_a \left(1 - \frac{\tau_a}{4\tau_e}\right)$ when $\tau_e \geq \frac{\tau_a}{2}$

τ_c is defined in 4.2.1
τ_a is defined in 4.2.1

Symbols

A_R = panel aspect ratio, *see* 4.2.1
σ_e = elastic compressive buckling stress, in N/mm^2
τ_e = elastic shear buckling stress, in N/mm^2
a and b are the panel dimensions in mm, *see* figures above
t_p = thickness of plating, in mm
φ = stress distribution factor for linearly varying compressive stress across plate width
= $0{,}47\mu^2 - 1{,}4\mu + 1{,}93$ for $\mu \geq 0$
= 1 for constant stress

$\mu = \frac{\sigma_{d1}}{\sigma_{d2}}$ where σ_{d1} and σ_{d2} are the smaller and larger average compressive stresses respectively

E = Young's Modulus of elasticity of material, in N/mm^2
C = stiffener influence factor for panels with stiffeners perpendicular to compressive stress
= 1,3 when plating stiffened by floors or deep girders
= 1,21 when stiffeners are built up profiles or rolled angles
= 1,10 when stiffeners are bulb flats
= 1,05 when stiffeners are flat bars
σ_d and τ_d are the design compressive and design shear stresses in the direction illustrated in the figures. With linearly varying stress across the plate panel, σ_d is to be taken as σ_{d2}

4.5.3 The effective breadth of attached plating for stiffeners, girder or beams that is to be used for the determination of the critical buckling stress of the stiffeners attached to plating which buckles elastically is to be taken as follows:

$$b_{eu} = \frac{b\sigma_u}{\sigma_a} \text{ mm}$$

where
σ_u = ultimate buckling strength of plating as given in 4.5.4
b_{eu} = effective panel breadth perpendicular to direction of compressive stress being considered
b is given in 4.2.1.

4.5.4 The ultimate buckling strength of plating, σ_u, which buckles elastically, may be determined as follows:

(a) shortest edge loaded, i.e. $A_R \geq 1$:

$$\sigma_u = \sigma_a \left(\frac{1{,}9}{\Omega} - \frac{0{,}8}{\Omega^2}\right) \text{ N/mm}^2$$

(b) longest edge loaded, i.e. $A_R < 1$:

$$\sigma_u = \frac{1{,}77\sigma_a A_R^{0{,}78}}{\Omega} \text{ N/mm}^2$$

where

$$\Omega = \frac{s}{t_p}\sqrt{\frac{\sigma_a}{E}}$$

A_R and s are defined in 4.2.1.
t_p, E and σ_a are defined in 4.2.1.

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4.5.5 The axial stress in stiffeners attached to plating which is likely to buckle elastically is to be derived as follows:

$$\sigma_{de} = \sigma_d \frac{A_t}{A_{tb}}$$

where

σ_d is the axial stress in the stiffener when the plating can be considered fully effective

$$A_t = A_s + \frac{bt}{100} \text{ cm}^2$$

$$A_{tb} = A_s + \frac{b_{eu}\, t}{100} \text{ cm}^2$$

where

b and b_{eu} are given in 4.5.3

t is the plating thickness, in mm

A_s is the stiffener area in cm^2.

4.6 Shear buckling of stiffened panels

4.6.1 The shear buckling capability of longitudinally stiffened panels between primary members is to satisfy the following condition:

$$\frac{\tau_d}{\tau_c} \leq \frac{1}{\lambda_\tau}$$

where

τ_c is derived from 4.6.3

τ_d is the design shear stress

λ_τ is given in Table 7.4.4.

4.6.2 The elastic shear buckling stress of longitudinally stiffened panels between primary members may be taken as:

$$\tau_e = K_s E \left(\frac{t}{s}\right)^2 \quad \text{for } A_R \geq 1$$

where

$$K_s = 4{,}5\left(\left(\frac{s}{1000l}\right)^2 + \frac{1}{N^2} + \left(\frac{N^2-1}{N^2}\right)\left(\frac{\omega}{1+\omega}\right)\right)^r$$

N = number of subpanels

$$= \frac{1000 S_p}{s}$$

$$\omega = 10 I_{se}$$

I_{se} = moment of inertia of a section, in cm^4, consisting of the longitudinal stiffener and a plate flange of effective width $s/2$

$$r = 1 - 0{,}75\left(\frac{s}{1000l}\right)$$

s, l, E and S_p are as defined in 4.2.1, *see also* Fig. 7.4.1.

4.6.3 The critical shear buckling stress, τ_c, may be determined from τ_e, *see* Note in Table 7.4.1.

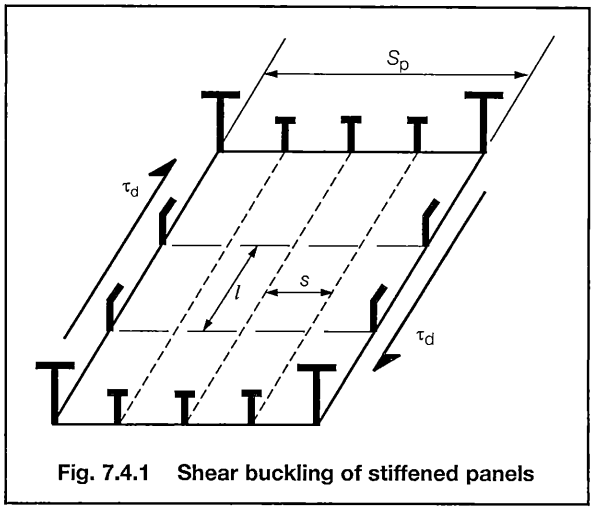

Fig. 7.4.1 Shear buckling of stiffened panels

4.7 Secondary stiffening in direction of compression

4.7.1 The buckling performance of stiffeners will be considered satisfactory if the following conditions are satisfied:

$$\frac{\sigma_d}{\sigma_{c(a)}} \leq \frac{1}{\lambda_\sigma} \qquad \frac{\sigma_d}{\sigma_{c(t)}} \leq \frac{1}{\lambda_\sigma}$$

$$\frac{\sigma_d}{\sigma_{c(w)}} \leq \frac{1}{\lambda_\sigma} \qquad \frac{\sigma_d}{\sigma_{c(f)}} \leq \frac{1}{\lambda_\sigma}$$

where

$\sigma_{c(a)}$, $\sigma_{c(t)}$, $\sigma_{c(w)}$ and $\sigma_{c(f)}$ are the critical buckling stresses of the stiffener for each mode of failure, *see* 4.7.2

σ_d is the design compressive stress, *see also* 4.5 and 4.1.3

λ_σ is the buckling factor of safety given in Table 7.4.4. The value of λ_σ to be chosen depends on the buckling assessment of the attached plating, *see* Note 1 in Table 7.4.4.

4.7.2 The critical buckling stresses for the overall, torsional, web and flange buckling modes of longitudinals and secondary stiffening members under axial compressive loads are to be determined in accordance with Table 7.4.3.

4.7.3 To prevent torsional buckling of secondary stiffeners from occurring before buckling of the plating, the critical torsional buckling stress, $\sigma_{c(t)}$, is to be greater than the critical buckling stress of the attached plating as detailed in 4.4.1.

4.7.4 The critical buckling stresses of the stiffener web, $\sigma_{c(w)}$, and flange, $\sigma_{c(f)}$, are to be greater than the critical torsional buckling stress, hence:

$$\sigma_{c(w)} > \sigma_{c(t)}$$

$$\sigma_{c(f)} > \sigma_{c(t)}$$

4.7.5 To ensure that overall buckling of the stiffened panel cannot occur before local buckling of the secondary stiffener, the critical overall buckling stress $\sigma_{c(a)}$, is to be greater than the critical torsional buckling stress, hence

$$\sigma_{c(a)} > \sigma_{c(t)}$$

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4.8 Secondary stiffening perpendicular to direction of compression

4.8.1 Where a stiffened panel of plating is subjected to a compressive load perpendicular to the direction of the stiffeners, *see* Fig. 7.4.2, e.g. a transversely stiffened panel subject to longitudinal compressive load, the requirements of this Section are to be applied.

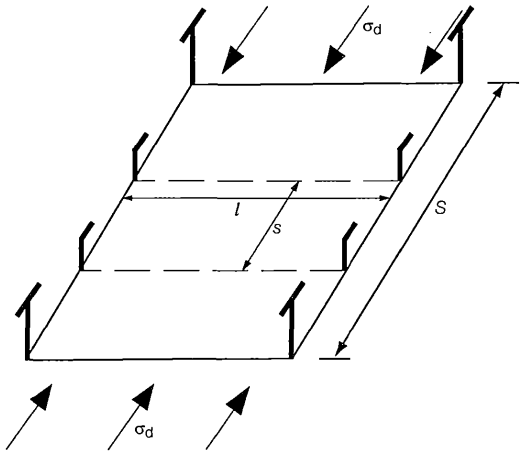

Fig. 7.4.2
Secondary stiffening perpendicular to direction of compression

4.8.2 The minimum area moment of inertia of each stiffener including attached plating of width, *s*, to ensure that overall panel buckling does not precede plate buckling is to be taken as:

$$I_s = \frac{D\,s\,(4N_L^2 - 1)((N_L^2 - 1)^2 - 2\,(N_L^2 + 1)\,\kappa + \kappa^2)}{2\,(5N_L^2 + 1 - \kappa)\,\Pi^4\,E} \text{ mm}^4$$

where

$$D = \frac{E\,t_p^3}{12\,(1 - \upsilon^2)}$$

$\kappa = A_R^2\,\Pi^2$

A_R = plate panel aspect ratio

$$= \frac{s}{1000l}$$

$$\Pi = \frac{S}{l}$$

N_L = number of plate panels

$N_L - 1$ = number of stiffeners

υ = 0,3

s, *l* and *S* are defined in 4.2.1 and shown in Fig.7.4.2

t_p, *E* are defined in 4.2.1.

4.9 Buckling of primary members

4.9.1 Where primary girders are subject to axial compressive loading, the buckling requirements for lateral, torsional, web and flange buckling modes detailed in 4.7 are to be satisfied.

4.9.2 To prevent global buckling from occurring before local panel buckling, transverse primary girders supporting axially loaded longitudinal stiffeners are to have a sectional moment of inertia, including attached plating, of not less than the following:

$$I_g = \frac{0{,}35S_p^4\,I_s}{l^3\,s} \times 10^3 \text{ cm}^4$$

S_p and *s* are as defined in 4.2.1, *see also* Fig.7.4.1

I_g = sectional moment of inertia including attached plating

I_s = moment of inertia of secondary stiffeners, in cm^4, required to satisfy the overall elastic column buckling mode requirement specified in Table 7.4.3

$$= \frac{\sigma_{ep}\,A_{te}\,l_e^2}{0{,}001E}$$

where

$$\sigma_{ep} = 1{,}2\sigma_d \text{ N/mm}^2 \text{ for } \sigma_{e(a)} < \frac{\sigma_a}{2}$$

$$= \frac{\sigma_a^2}{4\,(\sigma_a - 1{,}2\sigma_d)} \text{ for } \sigma_{e(a)} \geq \frac{\sigma_a}{2}$$

σ_d is design stress, in N/mm^2

σ_a and A_{te} are as defined in 4.2.1.

$\sigma_{e(a)}$ is the elastic column buckling stress, *see* 4.7.2

E is defined in 4.2.1

l_e is defined in Table 7.4.3.

4.10 Shear buckling of girder webs

4.10.1 Local panels in girder webs subject to in-plane shear loads are to satisfy the shear buckling requirements in Table 7.4.2, item (b).

4.10.2 The critical shear buckling stress, τ_c, is to be determined using the following formula for τ_e and the Note in Table 7.4.1.

$$\tau_e = 3{,}62\left(1{,}335 + \left(\frac{d_w}{1000l_p}\right)^2\right) E\left(\frac{t_p}{d_w}\right)^2 \text{ N/mm}^2$$

where

d_w = web height, in mm

l_p = unsupported length of web, in metres

t_p and *E* are defined in 4.2.1.

4.11 Pillars and pillar bulkheads

4.11.1 Pillars and pillar bulkheads are to comply with the requirements of Ch 3,10.

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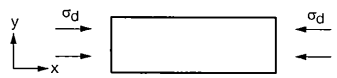
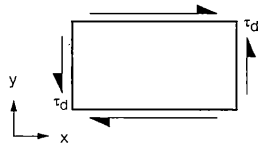
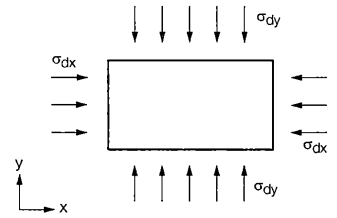
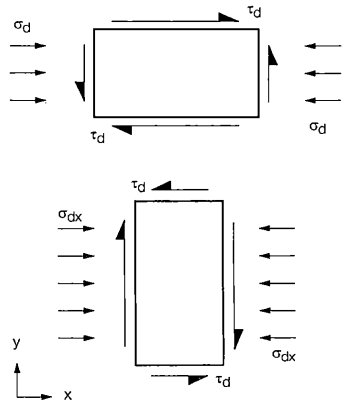
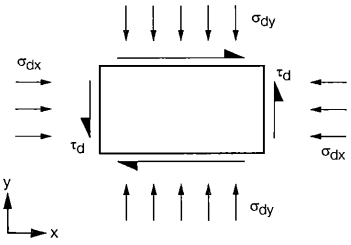
Table 7.4.2 Plate panel buckling requirements

	Stress field	Buckling Interaction formula	
(a)	uni-axial compressive loads	$\frac{\sigma_d}{\sigma_c} \le \frac{1}{\lambda_\sigma}$	
(b)	shear loads	$\frac{\tau_d}{\tau_c} \le \frac{1}{\lambda_\tau}$	
(c)	bi-axial compressive loads	for $A_R = 1{,}0$ $\frac{\sigma_{dx}}{\sigma_{cx}} + \frac{\sigma_{dy}}{\sigma_{cy}} \le 1{,}0$ for other aspect ratios, i.e. $A_R \ne 1{,}0$ $\frac{\sigma_{dx}}{\sigma_{cx}} + \frac{\sigma_{dy}}{\sigma_{cy}} \le G$ when G is taken from Fig. 7.4.3	
(d)	uni-axial compressive loads plus shear load	for $A_R > 1$ $\left(\frac{\sigma_d}{\sigma_c}\right) + \left(\frac{\tau_d}{\tau_c}\right)^2 \le 1$ for $A_R \le 1$ $\left(\frac{1 + 0{,}6A_R}{1{,}6}\right)\left(\frac{\sigma_d}{\sigma_c}\right) + \left(\frac{\tau_d}{\tau_c}\right)^2 \le 1$	
(e)	bi-axial compressive loads plus shear loads	$\frac{0{,}625\left(1 + \frac{0{,}6}{A_R}\right)\left(\frac{\sigma_{dy}}{\sigma_{cy}}\right)}{1 - 0{,}625\left(\frac{\sigma_{dx}}{\sigma_{cx}}\right)} + \frac{\left(\frac{\tau_d}{\tau_c}\right)^2}{1 - \left(\frac{\sigma_{dx}}{\sigma_{cx}}\right)} \le 1$	

Symbols

σ_d = design compressive stress, *see* 4.1.3
σ_c = critical compressive buckling stress, in N/mm^2, for uniaxial compressive load acting independently, *see* 4.3.5
σ_{dx} = design compressive stress in x direction
σ_{dy} = design compressive stress in the y direction
σ_{cx} = critical compressive buckling stress in x direction, *see* 4.3.5
σ_{cy} = critical compressive buckling stress in y direction, *see* 4.3.5
λ_σ = buckling factor of safety for compressive stresses, *see* 4.3.4
λ_τ = buckling factor of safety for shear stresses, *see* 4.3.4
τ_d = design shear stress, in N/mm^2
τ_c = critical shear buckling stress, in N/mm^2, acting independently, *see* 4.3.5
A_R = *see* 4.2.1

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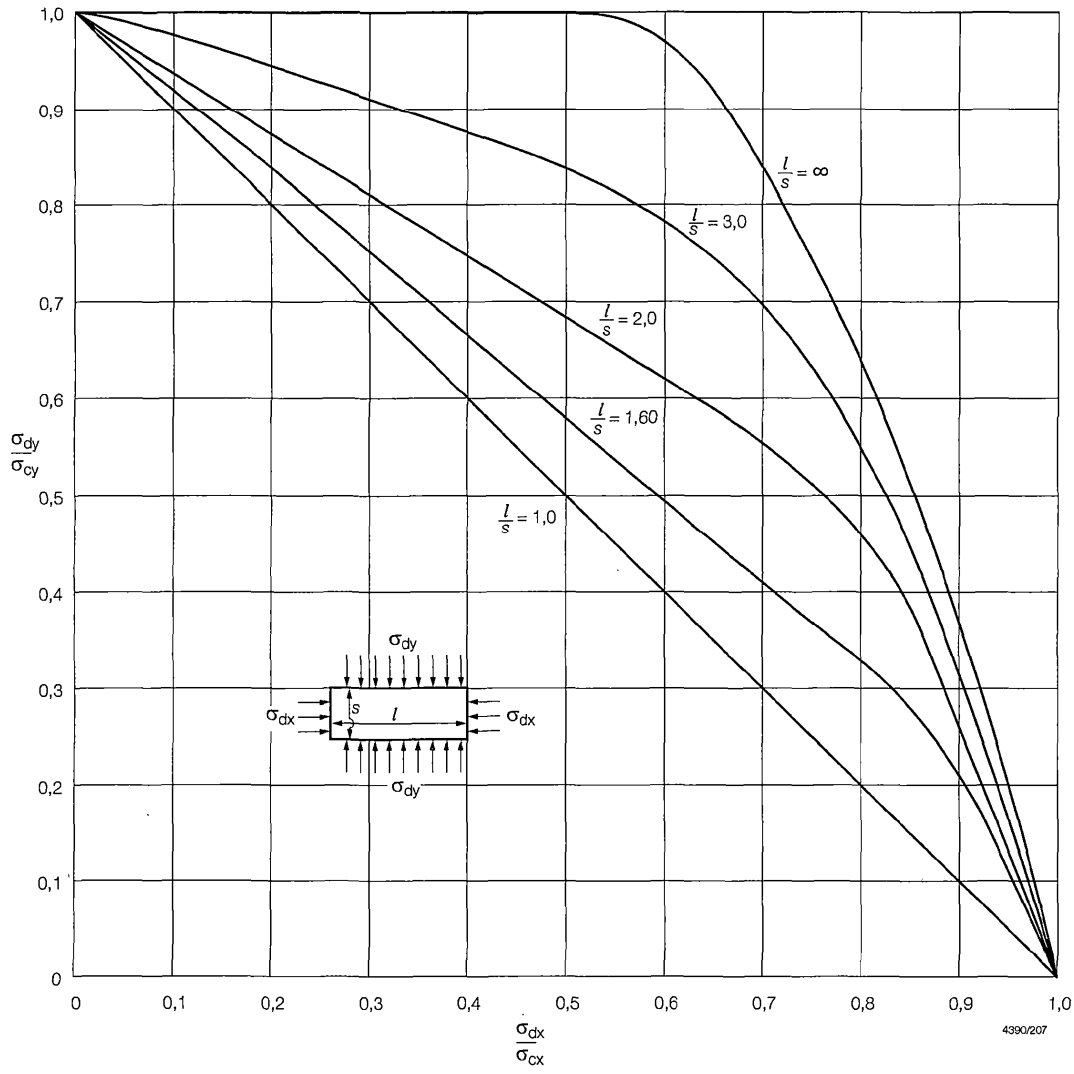

Fig. 7.4.3
Interaction limiting stress curves of G for plate panels subject to bi-axial compression, *see* Table 7.4.2(c)

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Table 7.4.3 Buckling stress of secondary stiffeners (*see continuation*)

Mode	Elastic buckling stress, N/mm^2	Critical buckling stress, N/mm^2 *see* Note
(a) Overall buckling (perpendicular to plane of plating without rotation of cross-section)	$\sigma_{e(a)} = C_f\, 0{,}001\, E \quad I_a$	$\sigma_{c(a)}$
(b) Torsional buckling	$\sigma_{e(t)} = \frac{0{,}001 E\, I_w}{I_p\, l_e^2}\left(m^2 + \frac{K}{m^2}\right) + 0{,}385 E \frac{I_t}{I_p}$	$\sigma_{c(t)}$
(c) Web buckling (excluding flat bar stiffeners)	$\sigma_{e(w)} = 3{,}8\, E \left(\frac{t_w}{d_w}\right)^2$	$\sigma_{c(w)}$
(d) Flange buckling	$\sigma_{e(f)} = 0{,}39\, E \left(\frac{t_f}{b_f}\right)^2$	$\sigma_{c(f)}$

The critical buckling stresses are to be derived from the elastic buckling stresses as follows:

$\sigma_c = \sigma_e$ when $\sigma_e < \frac{\sigma_a}{2}$

$= \sigma_a \left(1 - \frac{\sigma_a}{4\sigma_e}\right)$ when $\sigma_e \geq \frac{\sigma_a}{2}$

Symbols

d_w = web depth, in mm, (excluding flange thickness for rolled sections), *see* Fig. 7.4.4
t_w = web thickness, in mm
b_f = flange width, in mm (including web thickness)
t_f = flange thickness, in mm. For bulb plates, the mean thickness of the bulb may be used, *see* Fig. 7.4.4
l_e = effective span length of stiffener, in metres
C_f = end constraint factor
= 1 where both ends are pinned
= 2 where one end pinned and the other end fixed
= 4 where both ends are fixed
E = Youngs Modulus of elasticity of the material, in N/mm^2
I_a = moment of inertia, in cm^4, of longitudinal, including attached plating of effective width b_{eb}, *see* Note
t_p and σ_a are given in 4.2.1
A_{te} and b_{eb} are given in 4.2.1

NOTE
For stiffeners attached to plating which buckles elastically, *see* 4.5, the effective width of plating is to be taken as b_{eu}.

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Table 7.4.3 Buckling stress of secondary stiffeners (*conclusion*)

I_t = St.Venant's moment of inertia, in cm^4, of longitudinal (without attached plating)

$= \frac{d_w t_w^3}{3} 10^{-4}$ for flat bars

$= \frac{1}{3}\left[d_w t_w^3 + b_f t_f^3 \left(1 - \frac{0{,}63 t_f}{b_f}\right)\right] 10^{-4}$ for built up profiles, rolled angles and bulb plates

I_p = polar moment of inertia, in cm^4, of profile about connection of stiffener to plating

$= \frac{d_w^3 t_w}{3} 10^{-4}$ for flat bars

$= \left(\frac{d_w^3 t_w}{3} + d_w^2 b_f t_f\right) 10^{-4}$ for built up profiles, rolled angles and bulb plates

I_w = sectorial moment of inertia, in cm^6, of profile and connection of stiffener to plating

$= \frac{d_w^3 t_w^3}{36} 10^{-6}$ for flat bars

$= \frac{t_f b_f^3 d_w^2}{12} 10^{-6}$ for 'Tee' profiles

$= \frac{b_f^3 d_w^2}{12 (b_f + d_w)^2} (t_f (b_f^2 + 2 b_f d_w + 4 d_w^2) + 3 t_w b_f d_w) 10^{-6}$ for '*L*' profiles, rolled angles and bulb plates

C = spring stiffness exerted by supporting plate panel

$= \frac{k_p E t_p^3}{3b\left(1 + \frac{1{,}33 k_p d_w t_p^3}{b t_w^3}\right)}$

k_p = $1 - \eta_p$, and is not to be taken as less than zero. For built-up profiles, rolled angles and bulb plates, k_p need not be taken less than 0,1

$\eta_p = \frac{\sigma_d}{\sigma_{ep}}$

σ_{ep} = elastic critical buckling stress, in N/mm^2, of the supporting plate derived from Table 7.4.1

m is determined as follows; e.g. $m = 2$ for $K = 25$

K	0 to 4	4 to 36	36 to 144	144 to 400	400 to 900	900 to 1764	$(m-1)^2 m^2$ to $m^2 (m+1)^2$
m	1	2	3	4	5	6	*m*

$K = \frac{1{,}03 C S^4}{E I_w} 10^4$

σ_d is the design stress, in N/mm^2

all other symbols are as defined in 4.2.1

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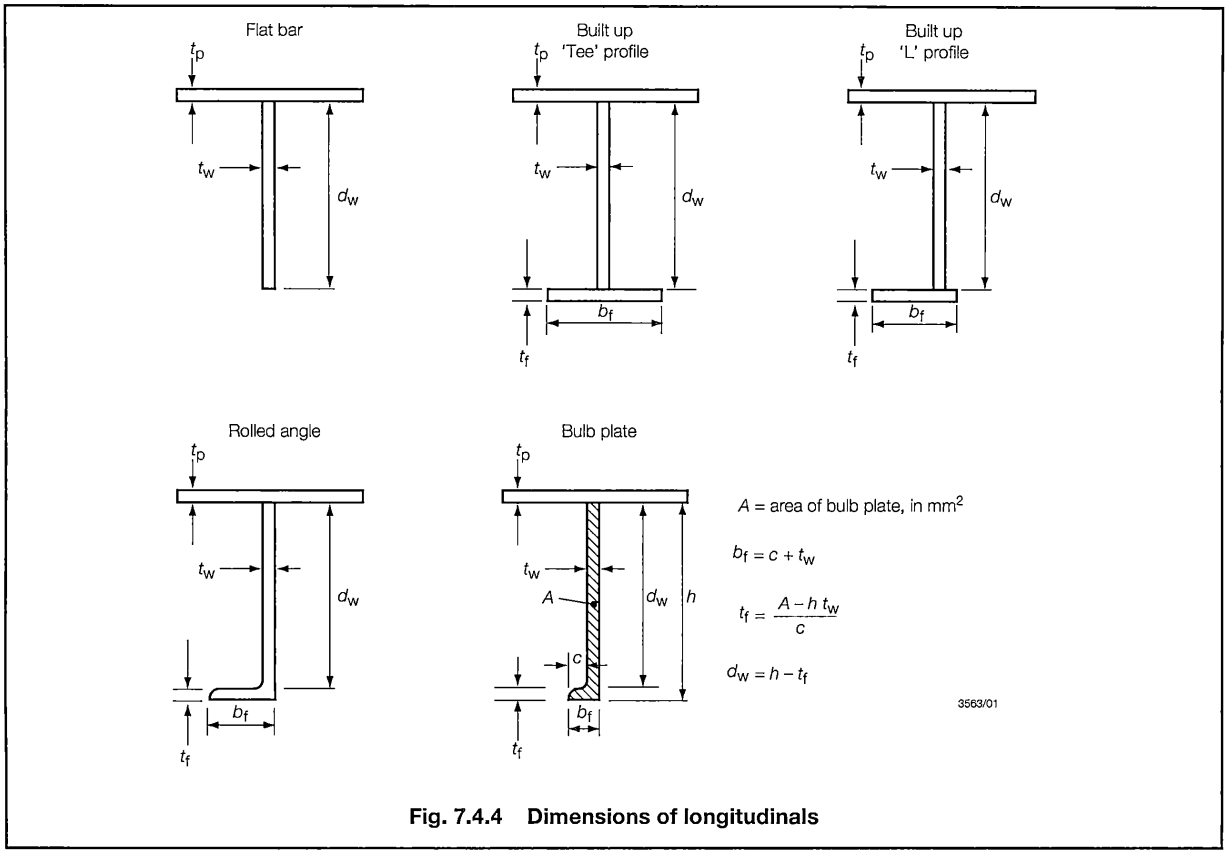

Fig. 7.4.4 Dimensions of longitudinals

Table 7.4.4 Buckling factor of safety

Structural item	Buckling factor of safety (2) Compressive stresses, λ_σ	Buckling factor of safety (3) Shear stresses, λ_τ
Bottom shell plating	1,0	—
Inner bottom plating	1,0	—
Deck plating	1,0	—
Side shell plating	1,0	1,1
Longitudinal bulkhead plating	1,0	1,1
Double bottom girders	1,0	1,1
Longitudinal girders	1,0	1,1
Superstructures/deckhouses (partially longitudinally effective)	1,0	—
Longitudinal secondary stiffeners	1,1(1)	—
Girder and floor web plating subject to local loads	1,1	1,2

NOTES
1. The buckling factor of safety for stiffeners attached to plating which is allowed to buckle in the elastic mode due to the applied loads is to be taken as 1,25, *see also* 4.5.
2. Buckling factor of safety to be applied to the compressive stress due to global longitudinal stresses.
3. Buckling factor of safety to be applied to the shear stress.

■ *Section 5* Vibration control

5.1 General

5.1.1 Natural frequencies are to be investigated for local unstiffened and stiffened panels expected to be exposed to excessive structural vibrations being induced from machinery, propulsion unit or other potential excitation sources.

5.1.2 Where the structural configurations are such that basic structural elements may be modelled individually the natural frequencies may be derived in accordance with 5.3, 5.4 and 5.5, as appropriate. Under other circumstances finite element analysis is to be employed to evaluate the vibration characteristics of the structure considered.

5.2 Frequency band

5.2.1 The natural frequency of panels is generally not to lie within a band of ±20 per cent of a significant excitation frequency.

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5.3 Natural frequency of plate

5.3.1 The natural frequency of a clamped plate in air is given by the following:

$$f_{air} = 5{,}544 \frac{t_p}{ab} \sqrt{\left(\frac{a}{b}\right)^2 + \left(\frac{b}{a}\right)^2 + 0{,}6045} \quad \text{Hz}$$

where

a = panel length, in metres
b = panel breadth, in metres
t_p = panel thickness, in mm.

5.4 Natural frequency of plate stiffener

5.4.1 The natural frequency of a plate stiffener in air is given by the following:

$$f_{air,i} = \frac{K_i}{2\pi L_b^2} \sqrt{\frac{EI}{m\left(1 + \frac{\pi^2 EI}{L_b^2 GA}\right)}} \quad \text{Hz}$$

where

EI = flexural rigidity of plate stiffener combination, in Nm^2
GA = shear rigidity of plate stiffener combination, in N
L_b = beam length, in metres
m = mass per unit length of the stiffener and associated plating, in kg/m
K_i = constant where i refers to the mode of vibration as given in Table 7.5.1.

Table 7.5.1 Vibration mode constant K_i

Mode	1	2	3	4	5
K_i	22,40	61,70	121,0	200,0	299,0

5.5 Effect of submergence

5.5.1 To obtain the frequency, f_{water}, of a plate with one side exposed to air and the other side exposed to a liquid, the frequency calculated in air, f_{air}, may be modified by the following formula:

$$f_{water} = \psi f_{air}$$

where

$$\psi = \sqrt{\frac{\kappa_p}{\kappa_p + \frac{\rho_l}{\rho_p}}}$$

ρ_l = density of the liquid, in kg/m^3
ρ_p = density of the plate, in kg/m^3

$$\kappa_p = \frac{\pi t_p}{1000 a b} \sqrt{a^2 + b^2}$$

where

a, b and t_p are as defined in 5.3.1.

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Rules and Regulations for the Classification of Special Service Craft

Volume 6
Part 8
Hull Construction in Composite
July 2011

Lloyd's Register
LIFE MATTERS

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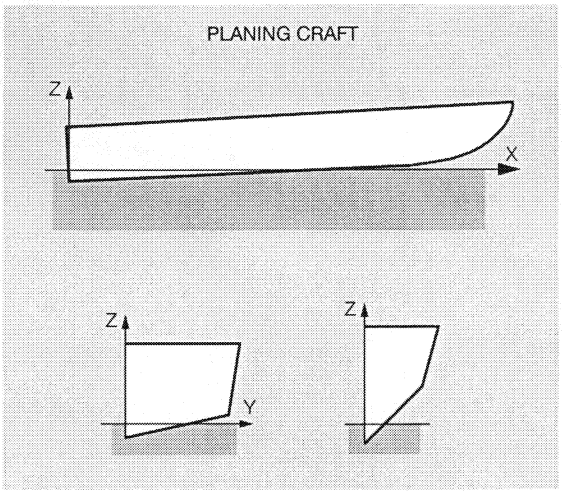
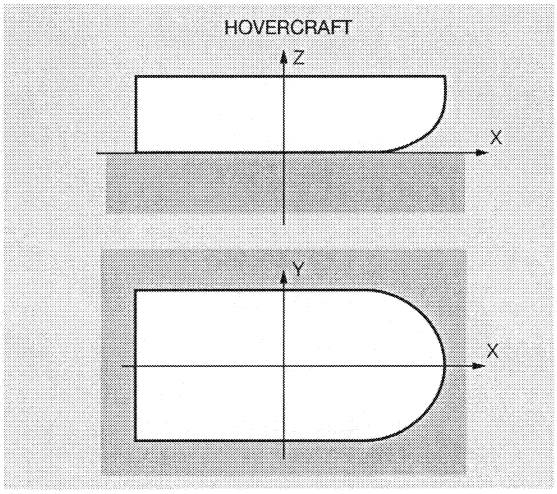
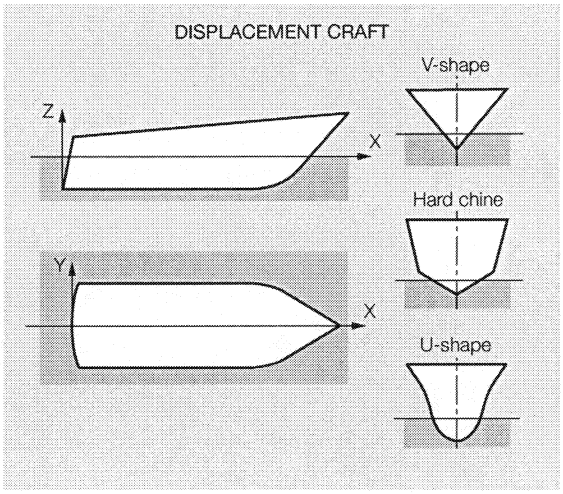
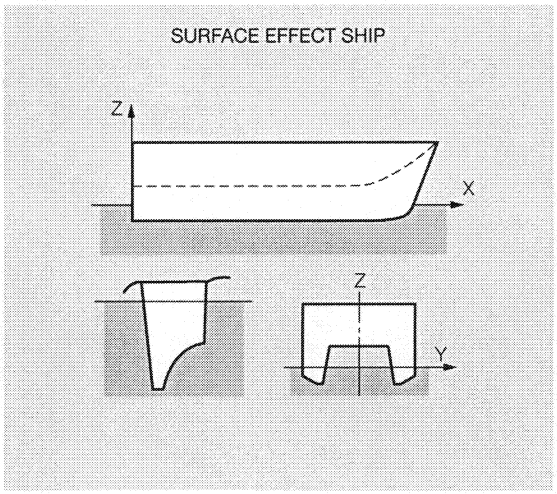
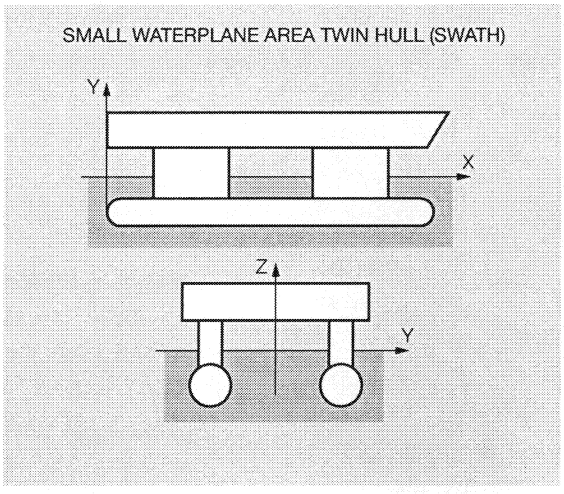
DIFFERENT TYPES OF HULL FORMS COVERED BY THE SPECIAL SERVICE CRAFT RULES

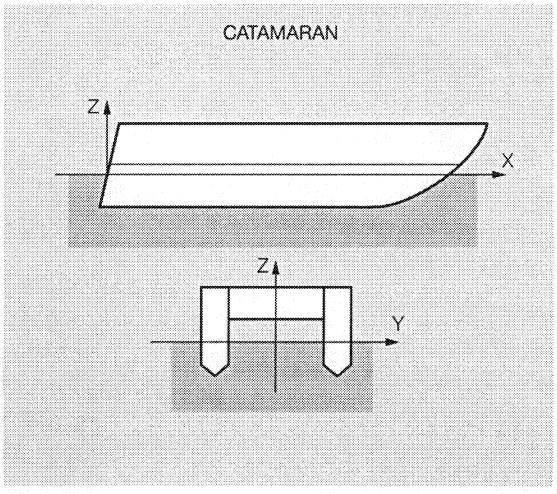












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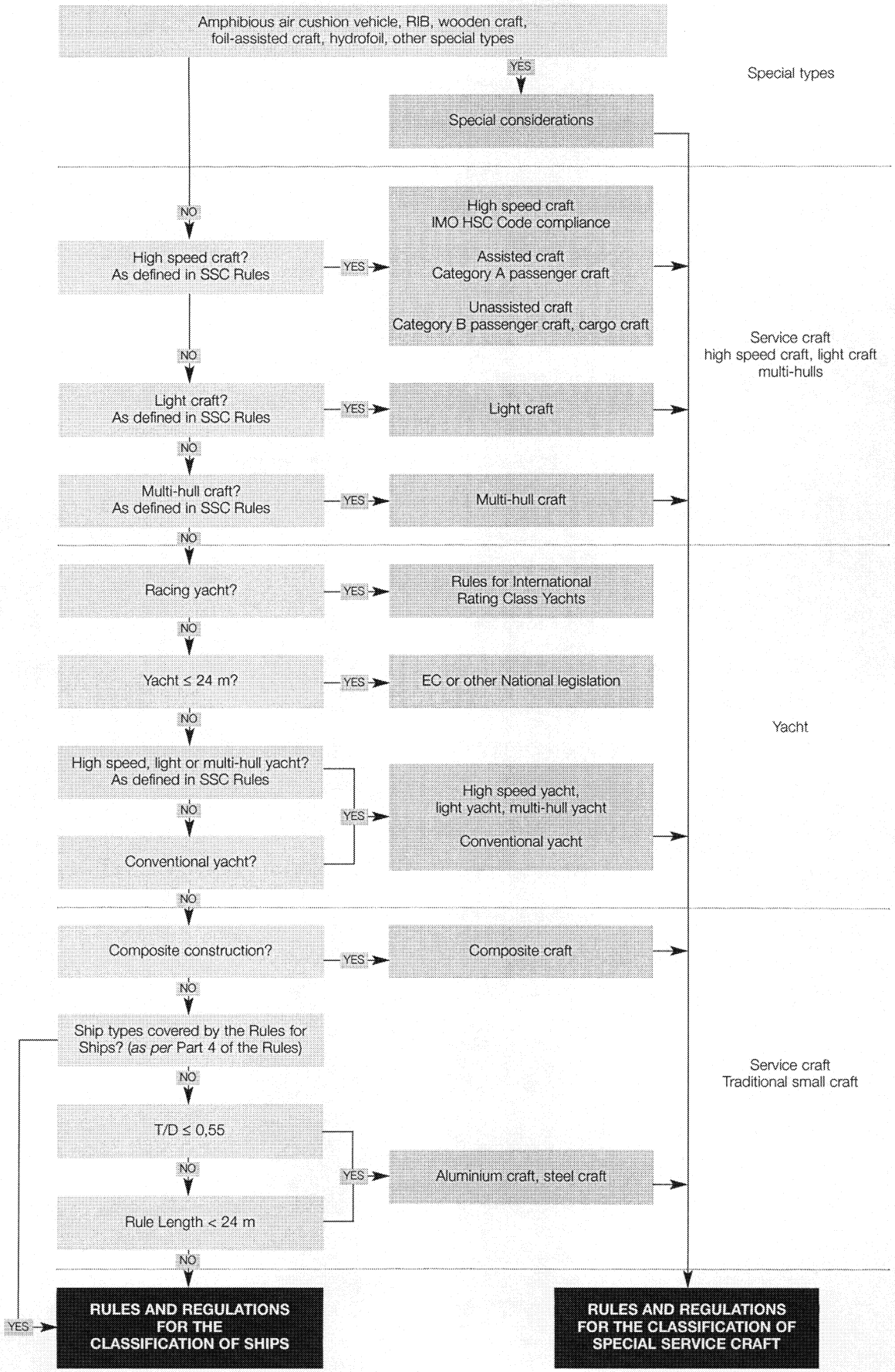

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Section

1 **Application**

2 **General requirements**

■ *Section 1* Application

1.1 General

1.1.1 The Rules are applicable to mono and multi-hull craft of normal form, proportions and speed. Although the Rules are, in general, for fibre reinforced composite craft of laminated construction, other materials for use in hull construction will be specially considered on the basis of the Rules.

1.1.2 The Rules provide for craft of both single and sandwich skin construction.

1.2 Interpretation

1.2.1 The interpretation of the Rules is the sole responsibility and at the sole discretion of Lloyd's Register (hereinafter referred to as 'LR'). Where there is any doubt regarding the interpretation of the Rules it is the Builder's and/or designer's responsibility to obtain clarification from LR prior to submission of plans and data for appraisal.

1.2.2 Where applicable, the Rules take into account unified requirements and interpretations established by the International Association of Classification Societies (IACS).

1.2.3 Attention is drawn to the fact that Codes of Practice issued by IMO or other applicable National Authorities may contain requirements which are outside classification as defined in the Rules.

1.3 Equivalents

1.3.1 Alternative scantlings and arrangements may be accepted as equivalent to the Rule requirements. Details of such proposals are to be submitted for consideration in accordance with Pt 3, Ch 1,3.

1.4 Symbols and definitions

1.4.1 The symbols and definitions for use throughout this Part are as defined within the appropriate Chapters and Sections.

■ *Section 2* General requirements

2.1 General

2.1.1 Specific limitations regarding the application of the Rules are indicated in the various Chapters for differing types of craft.

2.2 Aesthetics

2.2.1 LR is not concerned with the general arrangement, layout and appearance of the craft; the responsibility for such matters remains with the Builders and/or designers to ensure that the agreed specification is complied with. LR is however concerned with the quality of workmanship, and in this respect the acceptance criteria as required by the Rules are to be complied with.

2.3 Constructional configuration

2.3.1 The Rules provide for the basic structural configurations for both single and multi-deck mono and multi-hull craft with single or double bottom arrangements. The structural configuration may also include a single or multiple arrangement of cargo hatch openings and side tanks.

2.3.2 The Rules provide for longitudinal and transverse framing systems.

2.3.3 Novel or other types of framing systems will be considered on the basis of the Rules.

2.4 Plans to be submitted

2.4.1 *Plans covering the following items are to be submitted:*

- Midship sections showing longitudinal and transverse material.
- Profile and decks.
- Deck hatches.
- Bridging structure.
- Shell expansion.
- Laminate schedule.
- Oiltight and watertight bulkheads.
- Propeller brackets.
- Integral tanks.
- Double bottom construction.
- Pillars and girders.
- Aft end construction.
- Engine room construction.
- Engine and thrust seatings.
- Fore end construction.
- Doors, hatches, windows and portlights.
- Deckhouses and superstructures.
- Sternframe.
- Rudder, stock and tiller.
- Anchoring and mooring equipment.
- Loading manuals, preliminary and final (where applicable).
- Ice strengthening.
- Welding (where applicable).
- Hull penetration plans.

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- Support structure for masts, derrick posts or cranes.
- Bilge keels showing connections and detail design.
- Chain-plates.

2.4.2 The following supporting documents are to be submitted:

- General arrangement.
- Capacity plan.
- Lines plan or equivalent.
- Dry-docking plan.
- Towing and mooring arrangements.
- Sail/rigging plan, indicating loadings (as applicable to sailing craft).

2.4.3 The following supporting calculations are to be submitted, *see also* 2.7:

- Equipment Number.
- Hull girder still water and dynamic wave bending moment and shear force as applicable.
- Midship section stiffness.
- Structural items in the aft end, midship and fore end regions of the craft.
- Preliminary freeboard calculation.

2.5 Materials data sheet

2.5.1 Details of all the approved and accepted plastics materials, as required by the Rules, are to be submitted on LR's Reinforced Plastic Structures Materials Data Sheet (Form 2075) with the initial submission of plans. Reference is to be made to Ch 2,2. The types and quantities of curing systems identified on the Materials Data Sheet are to be those recommended by the resin manufacturer for the approved resin systems.

2.5.2 When specifying materials, the exact manufacturer's type designation, identification and reference numbers are to be quoted.

2.5.3 All sandwich core materials are to be of a type acceptable to LR and are to be clearly identified together with any core bonding adhesive to be used.

2.5.4 Fibre contents by weight for each type of reinforcement are to be reported.

2.5.5 All relevant post curing data is to be documented on the Materials Data Sheet.

2.6 Novel features

2.6.1 Where the proposed construction of any part of the hull or machinery is of novel design, or involves the use of unusual material, or where experience, in the opinion of LR, has not sufficiently justified the principle or mode of application involved, special tests or examinations before and during service may be required. In such cases a suitable notation may be entered in the appropriate *Register Book*.

2.7 Direct calculations

2.7.1 Direct calculations may be specifically required by the Rules and may be required for craft having novel design features or in support of alternative arrangements and scantlings. LR may, when requested, undertake calculations on behalf of the designers and make recommendations in regard to suitability of any required model tests.

2.7.2 Where direct calculations are proposed then the requirements of Pt 3, Ch 1,2 are, in general, to be complied with.

2.8 Exceptions

2.8.1 Craft of unusual form, proportions or speed, intended for the carriage of special cargoes, not covered specifically by the Rules, will receive individual consideration based on the general requirements of the Rules.

2.9 Advisory services

2.9.1 The Rules do not cover certain technical characteristics, such as stability, except as mentioned in Pt 1, Ch 2,1.1.11, 1.1.13 and 1.1.14, trim, vibration, docking arrangements, etc. The Committee cannot assume responsibility for these matters but is willing to advise upon them on request.

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Section

1 **General requirements**

2 **Materials**

3 **General construction process**

4 **Additional procedures for sandwich construction**

5 **Details and fastenings**

■ *Section 1* General requirements

1.1 General

1.1.1 The Rules are applicable to craft generally constructed of fibre reinforced plastic in accordance with 2.1.1.

1.1.2 All construction is to be carried out using materials and techniques approved or accepted by Lloyd's Register (hereinafter referred to as 'LR'). Where non-approved or non-accepted materials or production techniques are proposed, it is the responsibility of the Builder and manufacturer to obtain the necessary approval or acceptance and demonstrate their equivalence on the basis of the Rules.

1.1.3 It is the Builder's responsibility to ensure that all materials are used in accordance with the manufacturer's instructions.

1.2 Definitions

1.2.1 Definitions for use throughout this Chapter are as indicated in the appropriate Sections.

1.3 Symbols

1.3.1 Symbols for use throughout this Chapter are as indicated in the appropriate Sections.

1.4 Builder's facilities

1.4.1 The buildings used for production and storage are to be of suitable construction and equipped to provide the required environment, and are to comply with any local or National Authority requirements.

1.4.2 Workshops and equipment are to be in accordance with good manufacturing practice and are to be to the satisfaction of the Surveyor.

1.4.3 The Surveyor is to be allowed unrestricted access during working hours to such parts of the Builder's establishment as may be necessary to ensure that the requirements of the Rules are being complied with.

1.5 Works inspection

1.5.1 Prior to the commencement of production the facilities are to be inspected to the satisfaction of the attending Surveyor. This is to include evidence that the mandatory minimum quality control requirements as outlined in 1.6 and Ch 14,5 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials), are fulfilled.

1.5.2 The Surveyor is to be satisfied that the Builder has the organisation and capability to mould craft to the standards required by the Rules.

1.5.3 The Builder is to rectify any deficiencies to the Surveyor's satisfaction prior to the commencement of production.

1.5.4 The validity of the acceptance of the Builder's works for moulding craft under LR survey is subject to an annual QC audit and monitoring by the attending Surveyor. Where there is a break in the continuity of moulding under LR survey, the facilities will in general, be subject to an additional inspection prior to any recommencement of any moulding carried out under LR survey.

1.5.5 For acceptance the survey is to include procedures covering the Builder's management, organisation and quality systems.

1.6 Quality control

1.6.1 The Builder's mandatory quality systems for composite construction, will be subject to inspection and audit, and are to be in accordance with the requirements of one of the following:

(a) Quality Assurance System in accordance with an International or National Standard (i.e. ISO 9000 and BS ENISO 9001) with assessment and certification carried out by a nationally accredited body and must reflect the minimum quality control requirements under (c) being complied with.

(b) LR's *Quality Assurance Scheme for the Construction of Special Service Craft*.

(c) LR's locally accepted Quality Control System – The Builder is implementing a documented Quality Control System which controls the activities as indicated below, *see also* Ch 14,5 of the Rules for Materials:

- (i) Receipt storage and issue of materials, equipment, etc.
- (ii) Moulding shop.
- (iii) Care and preparation of mould tools, etc.
- (iv) Lay-up process control.
- (v) Inspection of FRP mouldings on release.
- (vi) Installation of machinery and essential systems.
- (vii) Fitting-out.
- (viii) Tests and trials.
- (ix) Plans and document control.
- (x) Records.

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1.6.2 LR's involvement is only in that part of the system which controls the standards required to meet the classification requirements.

1.6.3 The mandatory 'documented' quality control system, in general, requires the Builder to have written down procedures that describe clearly and unambiguously how each of the above activities is carried out, when it is carried out and by whom. These procedures will form part of the system manual which is also to contain a statement of management policy, organisation chart and statements of responsibilities. The manual is to be controlled covering formal issue and revision.

1.7 Moulding shop

1.7.1 Where the conventional hand lay-up or spray lay-up processes are used, an even shop temperature of not less than 16°C, and, in general, of not more than 25°C, is to be maintained throughout the moulding area during the lay-up and curing periods. Where the temperature exceeds 25°C, special consideration is to be given to the resin system.

1.7.2 Where moulding processes other than those in 1.7.1 are to be used, the moulding shop temperature will be subject to individual consideration in conjunction with the written recommendations of the manufacturers of the materials.

1.7.3 The relative humidity in the moulding shop is to be kept below 70 per cent, taking into account the dew point, thus avoiding moisture condensation on moulds and materials.

1.7.4 Sufficient temperature and humidity monitoring equipment is to be provided and detailed records are to be kept in accordance with the quality control system.

1.7.5 It is the responsibility of the Builder to ensure that the ventilation and working conditions, together with discharges into the atmosphere, are such that levels of substances are within the limits specified in any pertinent National or International legislation.

1.7.6 The working areas are to be adequately illuminated. Precautions are to be taken to avoid any effects on the resin cure due to direct sunlight or artificial lighting.

1.8 Storage areas

1.8.1 The resins are to be stored under dry, well-ventilated conditions, in accordance with the manufacturer's recommendations.

1.8.2 Where resin tanks or drums are stored outdoors it is the Builder's responsibility to ensure that the resin manufacturer's storage conditions are complied with.

1.8.3 Where the temperature for materials storage drops below that of the moulding shop i.e. minimum 16°C, the materials are to be pre-conditioned to the moulding shop temperature prior to use.

1.8.4 Curing agents are to be stored separately under clean, dry and well-ventilated conditions in accordance with the manufacturer's recommendations and any local or National legislation.

1.8.5 Fillers and additives are to be stored in closed containers that are impervious to dust and moisture.

1.8.6 Reinforcements are to be stored under dust-free and dry conditions.

1.9 Mould construction

1.9.1 Moulds are to be constructed of a suitable material and are to be adequately stiffened to maintain their overall shape and fairness of form.

1.9.2 The materials used in the construction of moulds are not to affect the resin cure.

1.9.3 The finish on a mould is to be such that the mouldings produced are suitable for the purpose intended. The resultant aesthetic appearance of the moulding is strictly a matter between the moulder and the Owner.

1.9.4 Where multiple section moulds are used, the sections are to be carefully aligned to the attending Surveyor's satisfaction prior to moulding. Mismatch between mould sections is to be eliminated.

1.9.5 Where metallic moulds are used, welding is to be minimised to avoid distortion of panels.

1.9.6 The release agent is to be of a type recommended by the resin manufacturer and is not to affect the cure of the resin.

1.9.7 Prior to use all moulds are to be conditioned to the workshop temperature.

1.10 Materials handling

1.10.1 The arrangements for the receipt, verification against certificates of conformity and subsequent handling of materials are to be covered by the Builder's quality control procedures such that the materials do not suffer contamination or degradation and bear adequate identification at all times; *see* Ch 14,3 of the Rules for Materials. Storage is to be arranged such that materials are used by batch wherever possible, in order of receipt. Materials are not to be used after the manufacturer's date of expiry, except with the prior agreement of LR and new certificates of conformity being obtained from the material manufacturer. Details of the new certificates of conformity are to be entered into the quality control system.

1.10.2 Where materials are found to be non-conforming they are to be rejected in accordance with the Builder's quality control procedure.

1.10.3 All non-conforming materials are to be segregated in their storage areas and marked accordingly.

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1.10.4 Resin/catalyst pumps and spray equipment are to be operated in accordance with the manufacturers instructions. Maintenance and calibration of the mix ratio is to be carried out according to written procedures.

1.11 Faults

1.11.1 All faults are to be classified according to their severity and recorded, together with the remedial action taken, under the requirements of the quality control systems, the documentation being subject to review at the Periodical Survey.

1.11.2 Production faults are to be brought to the attention of the attending Surveyor and a rectification scheme agreed. Deviations from the approved plans are to be to the satisfaction of the attending Surveyor.

1.12 Inspection

1.12.1 It is the Builder's responsibility to carry out the required inspections in accordance with the accepted quality control system.

1.12.2 The Surveyor will monitor the Builder's quality control records and carry out inspections of work in progress during his periodical visits.

1.12.3 During inspections all deviations are to be dealt with under the Builder's agreed quality procedures, *see* 1.6.3.

1.13 Acceptance criteria

1.13.1 Classification is dependent upon the work being carried out in accordance with the approved plans and the requirements of an accepted quality system.

1.13.2 The workmanship is to be to the satisfaction of the attending Surveyor. This will include the verification of the quality control documentation and the remedial action associated with all defects and deficiencies recorded.

1.13.3 Proposed deviations from the approved plans are subject to LR approval. An amended plan is to be submitted to the plan appraisal office, prior to any such changes being introduced.

1.14 Repair

1.14.1 Minor repairs are to be agreed with the attending Surveyor prior to being carried out. The Builder is to incorporate details of the agreed repair procedures in the quality control system in accordance with 1.6.3.

1.14.2 Written details of proposed structural repairs are to be submitted to the Plan Approval Office for approval prior to introduction.

1.15 Scaffolding

1.15.1 Scaffolding/platform arrangements are to be provided to permit adequate access for production and inspection purposes. Such arrangements are to conform to National Authority requirements and are not, in general, to be connected to the moulding or impinge on the mould surface.

1.16 Access

1.16.1 The attending Surveyor is to be permitted reasonable access to all areas of the Builder's premises during normal working hours. Scaffolding/platform arrangements are to be made available in accordance with 1.15.

1.17 Lifting arrangements

1.17.1 Lifting arrangements are to be designed such that mouldings are subjected to minimal distortion and unnecessary stressing. Mouldings are to be adequately supported to avoid distortion during final cure.

■ *Section 2* Materials

2.1 General

2.1.1 The Rules are applicable to craft generally constructed of fibre reinforced plastic (typically with unsaturated polyester resin), using hand lay-up, mechanical deposition, contact moulding techniques or vacuum assisted techniques. Construction may be either single-skin or sandwich construction, or a combination of both.

2.1.2 Other materials (i.e. non-FRP materials) are to be of good quality, suitable for the purpose intended and, where applicable, are to comply with LR's requirements appropriate to the material. Details of these materials are to be stated on the relevant construction plans. Where these materials are attached to, or encapsulated within, the plastics construction, the material is not to affect adversely the cure of the plastics materials.

2.1.3 Where moulding techniques and methods of construction differing from those given in Section 3 are proposed, details are to be submitted for consideration by LR.

2.2 Resin system

2.2.1 The resins used are to be of a type that has been approved by LR for marine construction purposes. Samples of the resin batches being used in the construction may be taken for limited quality control examination at the discretion of the Surveyor, *see* Ch 14,5 of the Rules for Materials.

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2.2.2 The cure procedure for the resin system is to be that recommended by the resin manufacturer for the particular application, so that the resin will cure in the required time, in accordance with the approved cure schedule.

2.2.3 Wax additives are only to be added by the resin manufacturer in accordance with the agreed procedure and tested accordingly. The base resin is to be of an approved type.

2.2.4 Where a resin contains an ingredient that can settle within the resin system, it is the Builder's responsibility to ensure that the resin manufacturer's recommendations regarding mixing and conditioning are complied with prior to use.

2.3 Compliant resins

2.3.1 Compliant resins for structural applications are to be of types accepted by LR, *see* Ch14,2.15 of the Rules for Materials, and are to be used strictly in accordance with the manufacturer's recommendations.

2.3.2 Details of the compliant resin to be used in the construction are to be included on the Material Data Sheet at the initial stages of plan approval. The plans submitted for approval are to identify which compliant resins are used in different applications. Surface preparations and over-bonding are also to be identified on the submitted plans.

2.3.3 Proposals for the use of structural filleting applications using compliant resin are to be submitted in detail. Such proposals will be subject to individual consideration.

2.3.4 The acceptance of the use of structural fillets of compliant resins in place of boundary bonding angle laminates required by Ch 3,1.18, will be subject to the designer/Builder providing the necessary information and test results to demonstrate equivalence with the Rule requirement for boundary bonding angle laminates.

2.3.5 Air inclusions that may affect the structural efficiency of the joint are to be avoided.

2.4 Resin storage

2.4.1 Bulk storage of resin is to be arranged in accordance with the resin manufacturer's recommendations in suitably adapted and insulated tanks. Tanks and pipes are to be periodically flushed in accordance with the resin manufacturer's recommendations. A ready use store is to be provided where appropriate.

2.5 Gel coats, tie coats and water barriers

2.5.1 Gel coats based on orthophthalic polyester resin systems are not acceptable. All gel coats are to be used strictly in accordance with the manufacturer's recommendations. The curing system is to be in accordance with 2.2.2.

2.5.2 Where pigments are to be added reference is to be made to 2.6. Where pigments are added by the Builder, the gel coat is to be allowed to stand for sufficient time to permit entrapped air to be released. The method of mixing is to be carried out strictly in accordance with the resin and pigment manufacturer's instructions.

2.5.3 Where the temperature of the gel coat resin is below that of the workshop, the gel coat resin is to be conditioned to attain the workshop temperature prior to use.

2.5.4 Where the inspection of the mould is an agreed hold point, required by the quality plan, the mould is to be inspected by the attending Surveyor prior to gel coating. The Surveyor may also require to witness the initial application of the gel coat, *see also* 3.3.

2.5.5 Where a gel coat is not used, details of the proposed water barrier are to be submitted for consideration.

2.5.6 Where a painted finish is to be adopted in place of a gel coat a suitable tie coat may be required in accordance with the paint manufacturer's recommendations.

2.5.7 Where the hull is of sandwich construction built on a male plug mould, the water barrier on the outer surface of the hull will be specially considered.

2.6 Curing systems

2.6.1 Curing systems are to be in accordance with 2.2.2 and are to be fully compatible with the resins and reinforcements to be used.

2.6.2 For polyester and vinylester resins the level of catalyst and accelerator are to be as recommended by the manufacturer to ensure full polymerisation of the resin. In general, the rate of gelation is to be controlled by the amount of accelerator added to the resin. The amount of catalyst is not to be less than one per cent, by weight, of the base resin.

2.7 Gelation time

2.7.1 The gelation time is to be suitable for the proposed application such that full wet-out of the reinforcement can be obtained without unnecessary drainage on vertical surfaces or excessive loss of the monomer.

2.7.2 The gelation time quoted on the Material Data Sheet is to be the typical gelation time for a laminate as laid in the mould, i.e. the working life of the resin.

2.7.3 The gelation time may need to be varied to suit changing ambient workshop temperatures. For polyester and vinylester resins this is, in general, to be adjusted by variation of the accelerator and not by variation of the catalyst.

2.7.4 All resins are to be mixed in accordance with the resin manufacturer's recommendations.

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2.8 Colour pigments

2.8.1 The types of pigment used are to be such that the final cure of the resin is not affected.

2.8.2 The pigment may be added to the resin by either the resin manufacturer or the moulder, and when added by the moulder it is to be as a paste dispersal in the same or compatible resin. Pre-pigmented gel coats are recommended. Where pigments are added by the Builder thorough mixing is essential to avoid striations. *See also* 2.2.4 and 2.3.2.

2.8.3 The amount and type of pigment added is not to exceed that recommended by the resin manufacturer for a satisfactory depth of colour. Proposals to use amounts of pigment solids in excess of five per cent, by weight of the base resin, will be subject to individual approval and testing.

2.8.4 It is recommended that pigments are not to be added to the gel coat or laminating resins used in the underwater portion of the hull laminate or in laminates forming the boundaries of oil fuel and water tanks.

2.8.5 The addition of pigments is not to unduly affect the gelation time of the resin system or the physical properties of the gel coat layer of the laminate produced. The resin and/or pigment manufacturer's written confirmation in this respect is to be obtained and recorded in the Builder's quality control documentation.

2.8.6 The aesthetic appearance of mouldings is strictly a matter between the moulder and the Owner.

2.9 Fillers

2.9.1 All fillers added by a Builder are to be of the dispersed type. The amount of filler that may be added to an approved resin is to be that recommended by the resin manufacturer and is not to alter significantly the viscosity of the resin nor is it to affect the overall strength properties of the laminate. Recommendations by the resin manufacturer to adopt amounts of fillers in excess of 13 per cent by weight of the base resin will be subject to individual approval and testing.

2.9.2 Pigments, thixotropes and fire retardant additives are to be considered as fillers in the calculation of total filler content.

2.9.3 Fillers are to be carefully and thoroughly mixed into the base resin that is then to be allowed to stand to ensure that entrapped air is released. The resin manufacturer's recommendations regarding the method of mixing are to be followed.

2.9.4 Fillers are not to be used in the structural laminates forming the boundaries of oil fuel and water tanks.

2.9.5 Details of all fillers and fire retardant additives are to be included on the Material Data Sheet at the initial stages of plan appraisal.

2.9.6 The amount of fire retardant additives may be in excess of that indicated in 2.9.1 provided that due account is taken of the reduced mechanical properties when determining scantlings in accordance with the Rules.

2.10 Fire retardant additives

2.10.1 The attention of Owners and Builders is drawn to the additional statutory regulations regarding fire safety that may be imposed by the National Authority of the country in which the craft is to be registered or the Governments of the states to be visited.

2.10.2 For requirements regarding fire safety, *see* Part 17.

2.10.3 Where laminates are required to have fire retardant or restricting properties, details of the proposals are to be submitted for approval. Where additives to the resin system are used, the type and quantity are to be as recommended by the resin manufacturer. Test results of independently tested fire retardant and fire restricting materials are to be submitted for design purposes.

2.10.4 All fire retardant resin systems are to be used strictly in accordance with the resin manufacturer's recommendations.

2.10.5 The use of fire retardant and fire restricting materials in craft required to comply with statutory requirements will be subject to the individual approval of the National Authority of the country in which the craft is to be registered, or LR where authorised to undertake this work on behalf of the National Authority.

2.11 Fibre reinforcements

2.11.1 All fibre reinforcements are to be of a type approved by LR.

2.11.2 All reinforcements are to be stored strictly in accordance with the manufacturer's recommendations. Rolls of reinforcement are to remain in their original packaging to minimise contamination. The quality control documentation is to provide traceability of all reinforcements using the manufacturer's batch numbers.

2.11.3 The materials are to be free from imperfections, discolouration, foreign matter and other defects.

2.11.4 Pre-impregnated reinforcements are to be suitably stored in an approved area. Detailed storage records are to be maintained as part of the quality control documentation.

2.12 Surfacing materials

2.12.1 Lightweight surfacing materials for reinforcing resin rich surfaces are to be compatible with the resin being used. Details of the materials and the fibre contents, by weight, are to be included on the Materials Data Sheet (Form 2075).

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2.12.2 Where peel ply materials are to be used, the finish is to be such that, after removal, it does not interfere with any subsequent bonding processes.

2.13 Core materials

2.13.1 Core materials for sandwich construction are to be approved by LR, *see* Ch 14,2 of the Rules for Materials.

2.13.2 All core materials are to be used in accordance with the manufacturer's application procedure, a copy of which is to be submitted for information, with the relevant construction plans of the craft. A second copy is to be incorporated into the quality control documentation.

2.13.3 Rigid expanded foam plastics are to:
(a) be of closed-cell types and impervious to water, fuel and oils;
(b) have good ageing stability;
(c) be compatible with the resin system;
(d) have good strength retention at 60°C;
(e) have characteristics and mechanical properties of not less than those indicated in Table 2.2.1; and
(f) if manufactured into formable sheets of small blocks, the open weave backing material and adhesive are to be compatible and soluble, respectively, with the laminating resin.

2.13.4 Balsa wood is to:
(a) be end grained;
(b) have been chemically treated against fungal and insect attack and kiln dried shortly after felling;
(c) have been sterilised;
(d) have been homogenised;
(e) have an average moisture content of 12 per cent;
(f) have characteristics and mechanical properties of not less than those indicated in Table 2.2.2; and
(g) if manufactured into formable sheets of small blocks, the open weave backing material and adhesive are to be compatible and soluble, respectively, with the laminating resin.

2.13.5 Where necessary, foam core materials are to be conditioned in accordance with the manufacturer's recommendations. Conditioning at an elevated temperature, in excess of that which may be experienced in service, may be necessary to ensure the release of any entrapped residual gaseous blowing agents from the cells of the foam core.

2.13.6 Synthetic 'felt' type core materials are to be approved in accordance with Ch 14,2.10 of the Rules for Materials.

2.13.7 Other types of core materials will be individually considered, on the basis of these Rules in relation to their characteristics and intended application.

2.13.8 Balsa wood is to remain in protective packaging until required in production. Part packages are to be sealed to prevent the ingress of moisture.

2.14 Core bonding materials

2.14.1 Core bonding materials for structural applications are to be of types accepted by LR, and are to be used strictly in accordance with the manufacturer's instructions.

2.14.2 Details of the proposed core bonding paste to be used with the core material are to be indicated on the Materials Data Sheet and the appropriate construction plans.

Table 2.2.1 Minimum characteristics and mechanical properties of rigid expanded foams at 20°C

Material	Apparent density (kg/m^3)	Strength (N/mm^2)			Moduli of elasticity (N/mm^2)	
		Tensile	Compressive	Shear	Compressive	Shear
Polyurethane	96	0,85	0,60	0,50	17,20	8,50
Polyvinylchloride	60					

Table 2.2.2 Minimum characteristics and mechanical properties of end-grain balsa

Apparent density (kg/m^3)	Strength (N/mm^2)					Compressive modulus of elasticity (N/mm^2)		Shear modulus of elasticity (N/mm^2)
	Compressive		Tensile		Shear	Direction of stress		
	Direction of stress							
	Parallel to grain	Perpendicular to grain	Parallel to grain	Perpendicular to grain		Parallel to grain	Perpendicular to grain	
96	5,00	0,35	9,00	0,44	1,10	2300	35,20	105
144	10,60	0,57	14,60	0,70	1,64	3900	67,80	129
176	12,80	0,68	20,50	0,80	2,00	5300	89,60	145

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2.14.3 The Builder is to demonstrate that a uniform thickness of bonding paste is obtained by use of notched trowels or comb gauges. For the use of bonding pastes, *see* 4.2.7.

2.15 Adhesives

2.15.1 Adhesives for structural applications are to be of types accepted by LR, *see* Ch 14,2.15 the Rules for Materials, and are to be used strictly in accordance with the manufacturer's recommendations.

2.15.2 The details of all structural adhesives are to be specified on the Materials Data Sheet and on the relevant construction plans submitted.

2.15.3 Details concerning the handling, mixing and application of adhesives are to form part of the Builder's production plan.

2.15.4 Particular attention is to be given to the surface preparation and cleanliness of the surfaces to be bonded.

2.15.5 Where excessive unevenness of the faying surfaces exists a suitable gap filling adhesive is to be used or local undulations removed by the application of additional reinforcements.

2.15.6 The Builder's quality plan is to identify the level of training required for personnel involved in the application of structural adhesives.

2.16 Materials for integrated structural members

2.16.1 Metallic materials, such as steel or aluminium alloys, used in the construction are to comply with the requirements of 2.1.2. Where structural members or components manufactured from these, or other materials, are to be encapsulated within or structurally bonded to laminates, the material is not to adversely affect the cure of the resin system. The surface area of the component that will be in contact with the resin is to be thoroughly cleaned, degreased and, where practicable, either shot blasted or abraded to provide a key.

2.16.2 Where metallic sections are to be bolted into a structure, the bolting requirements are to be determined by direct calculations that are to be submitted for consideration. Appropriate precautions against corrosion are to be taken.

2.16.3 Where plywood and timber members are to be used in structural applications and are to be laminated onto, or encapsulated within the laminate, the surface of the wood is to be suitably prepared and primed prior to laminating.

2.17 Plywood

2.17.1 Plywood, for structural applications, is to be of a high quality marine grade material approved by LR, *see* Ch 14,2.14 of the Rules for Materials. In general, the plywood is to be manufactured to a high standard of finish in accordance with ISO or other Recognised Standards and is to meet, or be equivalent to, the following general requirements:

(a) Have good quality face and core veneers of a durable hardwood species.
(b) The number of veneers is to be in accordance with Table 2.2.3.
(c) The veneers are to be bonded with a WBP (water and boil proof) type adhesive.
(d) Have a moisture content not exceeding 15 per cent.

Table 2.2.3 Number of veneers

Board thickness, mm	Minimum number of plies
up to 9	3
10 to 19	5
20 and above	7

2.17.2 Butts and seams are to be scarfed or butt strapped where necessary. The length of the scarf is to be not less than eight times the plywood thickness. The scarf is to be glued and, if made *in situ*, fitted with a backing strap of width not less than 10 times the panel thickness. The strap is to be glued and fastened with two rows of fastenings of the size given in Table 2.2.4 and spaced at approximately eight times the panel thickness.

2.17.3 Butt straps are to be of the width given in Table 2.2.4 and the same thickness as the panel. The strap is to be glued and double/treble fastened to the panel. Sizes of fastenings are given in Table 2.2.4.

2.17.4 For further information regarding plywood, *see* Ch 3,1.20.

2.18 Timber

2.18.1 The acceptance of timber in the construction will be subject to individual consideration depending upon the intended use and timber involved.

2.18.2 The timber is to be of good quality and properly seasoned. Timber is to be free from heart, sapwood, decay, insect attack, splits, shakes and other imperfections that would adversely affect the efficiency of the material. It is also to be generally free from knots, although an occasional sound intergrown knot would be acceptable.

2.18.3 The moisture content of timber for bonded or overlaminated applications using polyester or epoxy resins is, in general, to be nominally 15 per cent. Contents slightly greater than this value are recommended when resorcinol glues are used, and contents slightly lower than this value are required when phenolic or urea-formaldehyde resins are used.

2.18.4 For further information regarding timber, *see* Ch 3,1.19.

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Table 2.2.4 Butt strap fastenings

Plywood thickness, mm	Breadth of butt strap, mm		Fastenings		
			Wood screws		Copper boat nails, gauge
			Gauge	Dia.,mm	
6	Double fastened	150	8	4,2	10
8		175	10	4,9	10
10		200	10	4,9	8
13		250	12	5,6	8
16		280	12	5,6	6
19	Treble fastened	330	14	6,3	6
22		355	14	6,3	3
25		380	16	7,0	3

NOTES
1. The gauge of wood screws given in the Table is British Standard Gauge, and that of copper boat nails is Imperial Standard Wire Gauge.
2. The diameter of the wood screw is the nominal diameter of the unthreaded shank.

2.19 Release agents

2.19.1 Release agents are to have no inhibiting effect on the gel coat resin and are to be those recommended by the resin manufacturer.

■ *Section 3* General construction process

3.1 General

3.1.1 Provision is made in this Section for the construction of craft built of fibre reinforced plastic using thermosetting materials. Craft built of fibre reinforced thermoplastic materials will be subject to individual consideration.

3.1.2 This Section contains the general Rule requirements to be complied with in the construction of fibre reinforced craft being built under survey. Where detailed requirements are not defined good boat building practices are to be applied.

3.1.3 Craft built of unusual materials or built using unusual techniques will be subject to individual consideration.

3.2 Resin preparation

3.2.1 Curing agents, fillers and pigments are to be added strictly in accordance with the resin manufacturer's recommendations.

3.2.2 Before decanting, all resins are to be thoroughly mixed, deaerated and conditioned to at shop temperature in accordance with the resin manufacturer's instructions.

3.2.3 All measuring equipment is to be certified and suitable for the quantity of material being measured. Valid certificates of calibration are to form part of the quality control documentation.

3.2.4 Where pumping/metering equipment is used it is to be maintained in accordance with the manufacturer's instructions, and a valid certificate of calibration accuracy is to be retained in the quality control documentation.

3.2.5 Quality control records are to be maintained to provide traceability and identification of the resin and all additives used in the resin system. Batch numbers are to be identified.

3.2.6 Any additive used as a production aid must be that recommended by the resin manufacturer and is not to alter the mechanical properties or the characteristics of the cured laminate.

3.3 Laminating

3.3.1 Production is to follow all necessary approved construction plans in accordance with the LR accepted quality plan.

3.3.2 Laminating is to be carried out by skilled operators, who are to be trained and qualified to the level required by the Builder's quality plan and are to be acceptable to LR.

3.3.3 Moulds are to be thoroughly cleaned, dried and allowed to attain the shop temperature before being treated with a suitable release system, *see also* 1.9.7.

3.3.4 The gel coat resin is to be applied by brush, roller or spraying equipment to give a uniform, nominal film thickness of 0,5 mm.

3.3.5 The period of exposure of the gel coat between gelation and the application of the first layer of reinforcement is, in general, to be as short as practicable. In no case is this to be longer than that recommended by the resin manufacturer for that particular resin system. Written confirmation of this is to be obtained and recorded in the Builder's quality control documentation.

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3.3.6 Where a polyester or vinylester gel coat is used it is to be reinforced by a lightweight, powder bound reinforcement, generally not exceeding 300 g/m^2 in weight, applied at a high resin content to give a glass content, by weight, of not greater than 0,286. This reinforcement is to be consolidated by gentle rolling. Care is to be taken not to damage the gel coat. A surface tissue may be incorporated within the gel coat, the details of which are to be clearly stated in the laminate schedule.

3.3.7 All mouldings are to be manufactured from layers of reinforcement, laid in the approved sequence and orientation, each layer being thoroughly impregnated and consolidated to give the required fibre content, by weight, in accordance with the approved plans.

3.3.8 In composite laminates, containing multiple layers of woven reinforcement, woven reinforcement may be laid on woven reinforcement provided that the inter-laminar shear strength is not less than 13,8 N/mm^2; otherwise, a layer of random fibre reinforcement is to be laid alternately with the woven reinforcements.

3.3.9 Excessive exothermic heat generation caused by thick laminate construction is to be avoided. Where thick laminates are to be laid the Builder is to demonstrate to the Surveyor's satisfaction, that the number of plies can be laid wet on wet and that the resultant temperature during the cure cycle does not have any deleterious effect on the mechanical properties of the cured laminate.

3.3.10 Laminating is to be carried out in a sequence such that the time lapse between the application of the successive layers is within the limits recommended by the resin manufacturer and documented in the quality control procedures for the particular resin system. Similarly, the time lapse between the forming and bonding of structural members is to be kept within these limits and, where this is not practicable, the surface of the laminate is to be prepared, in accordance with the resin manufacturer's instructions, to improve the bond.

3.3.11 When laminating is interrupted, and where other than an epoxy resin system is being used, the first of any subsequent layers of reinforcement to be laid in that area is to be of chopped glass fibre or other type of material to enhance the interlaminar strength properties of the laminate.

3.4 Fibre content

3.4.1 To ensure that the resultant thicknesses of the structure is not less than that required to comply with those indicated on the approved plans, the nominal fibre content, by weight, of the individual plies and overall laminate is to be controlled on the basis of the weight of the constituent materials.

3.4.2 Continuous monitoring of resin/reinforcement usage is required for ongoing fibre content verification and is to be recorded under the quality control system, *see* Ch 14,5 of the Rules for Materials.

3.4.3 A method of validating the completed laminate thickness is to be agreed between the Builder and Surveyor. Where electronic thickness measurement methods are employed, the equipment is to be calibrated against a laminate of identical construction. Alternatively a series of areas are to be identified within the craft where samples can be taken to validate the thickness of the laminate (e.g. in way of overboard discharges/seawater intakes/deck openings, etc.).

3.5 Laminate schedule

3.5.1 The laminate schedule is to clearly define the logical sequence of production and is to identify the specific materials to be used.

3.5.2 The schedule is to define the extent of each reinforcement and state relevant details regarding overlapping, staggering thicknesses and tailoring of reinforcements.

3.5.3 Progressive thickness measurements in accordance with 3.4.3 are to be recorded as part of the quality control documentation and, where required, additional reinforcements are to be laid to attain the required thickness.

3.5.4 Areas of local deficiency requiring additional reinforcement and areas that have been found to be increased thickness are to be recorded in the quality control documentation.

3.6 Spray laminating

3.6.1 The equipment for spray deposition of resin and glass fibres is to be inspected during the Workshop Inspection and a sample panel produced. Documentary evidence of maintenance, calibration, catalyst content, fibre length and overall fibre content by weight are to be entered into the quality control documentation. The spray pattern is to give an even distribution, as recommended by the manufacturer of the equipment and is to be to the satisfaction of the attending Surveyor.

3.6.2 Special consideration is to be given to the production environment, ventilation equipment and quality control arrangements to ensure that the finished product meets the requirements of the approved plans.

3.6.3 Unless the mechanical properties are confirmed by testing, the chopped fibre length for a structural laminate is to be not less than 35 mm. In no case is the fibre length to be less than 25 mm.

3.6.4 Spray equipment is only to be operated by trained and competent personnel. Training certification is to form part of the quality control documentation. The use of spray lay-up is to be limited to the parts of the structure to which sufficient access can be obtained to ensure satisfactory laminating.

3.6.5 The weights of resin and reinforcement used is to be monitored continuously to check the glass/resin ratio. Samples are also be taken on a regular basis to validate the calibration of the equipment.

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3.6.6 Where spray lay-up is used to back up the gel coat the weight of sprayed fibre is not to exceed 300 g/m^2, applied at a high resin content to give a glass content by weight, of not greater than 0,286. This should be consolidated by gentle rolling. This first layer of reinforcement is to be allowed to cure to a trimming state before proceeding with the remainder of the laminate.

3.6.7 Consolidation is to be carried out as soon as is practicable after spray deposition. In general, this is to be carried out when a weight of reinforcement equivalent to a thickness of 2–3 mm has been deposited. The thickness of the resulting laminate is to be periodically checked and recorded.

3.6.8 Particular attention is to be given to localised thinning of the laminate in way of chines, coamings, knuckles and openings. Further deposition may be required in such areas to compensate for any reduction in thickness. Alternatively, layers of other equivalent reinforcements may be laid to achieve the required local thickness.

3.7 Release and curing

3.7.1 After completion of the lay-up, the moulding is to be left in the mould for a period to allow the resin to cure before being removed. This period can vary with ambient temperature, the type of resin and the complexity of the moulding, but is to be not less than 12 hours or that recommended by the resin manufacturer.

3.7.2 Care is to be exercised during removal from the mould to ensure that the hull, deck and other large assemblies are adequately braced and supported to avoid damage to and maintain the form of the moulding.

3.7.3 Where female moulds are adopted, all primary stiffening and transverse bulkheads are to be installed prior to removal from the mould unless agreed otherwise on the approved construction schedule and plans.

3.7.4 Mouldings are not to be stored outside of the workshop environment until they have attained the stage of cure recommended by the resin manufacturer for that particular resin. Provision is to be made for mouldings to be protected against adverse weather conditions.

3.7.5 Mouldings are, in general, to be stabilised in the moulding environment for at least 24 hours, or that recommended by the resin manufacturer before the application of any special cure treatment, details of which are to be submitted for approval.

3.8 Barcol hardness

3.8.1 The degree of cure of mouldings is to be measured using a Barcol impressor model GYZJ 934-1 in accordance with BS 2782: Part 10: Method 1001: 1977 (1989) or other equivalent National or International Standard. Alternative equivalent standards of hardness measurement will be considered.

3.8.2 The hardness meter is to be regularly checked for calibration during use. A calibration certificate is to form part of the quality control documentation.

3.8.3 Removal from the mould is not to be attempted until a minimum Barcol reading recommended by the resin manufacturer or a value of 20 has been attained. Subsequently, the moulding is not to be moved outside of the controlled environment until a minimum Barcol reading recommended by the resin manufacturer of 35 (or equivalent) has been recorded.

3.9 Laminate detail

3.9.1 Changes in laminate thickness are to be made using a gradual taper. The length of such taper is, in general, not to be less than 20 times the difference in thickness. Where the construction changes from sandwich laminate to a solid laminate, the thickness of the core material is, in general, to be reduced by a gradual taper of not less than 2:1.

3.9.2 Framing and stiffening sections are to be built up layer by layer in accordance with an approved procedure, particular attention being given to ensure a satisfactory bond and structural continuity at the ends and intersections.

3.9.3 Discontinuities and hard points in the structure are to be avoided, and where the strength of a stiffening member is impaired by any attachment of fittings, openings, drainage arrangements, etc., compensation is to be provided.

3.9.4 Where items are prefabricated outside the mould, they are to be connected by boundary angles formed by layers of reinforcement, structural fillets or other approved method. Where structural fillets are proposed, the scantlings and arrangements will be specially considered.

3.9.5 Polyester, vinylester or epoxide resin may be used in bonded joints, provided that the joint is so designed that the resin bond is in shear. The contact area is to be as large as practicable and the surfaces are to be suitably prepared in accordance with the resin manufacturer's instructions.

3.9.6 The submitted plans are to clearly define the laminate sequence at corner joints. In general, corner laminates are to be boxed and all cuts are to be alternately staggered to avoid a fault line. At corner joints vertical and horizontal laminates are to be laid alternately and butts are to be staggered accordingly.

3.9.7 The submitted plans are to clearly define the details of scarfed joints. In general, scarfs are not to not be steeper than a 12:1 taper. Scarf joints may be either ground or stepped and may be single or double taper. Where single taper scarf joints are proposed, a sealing laminate is to be provided, details of which are to be submitted. Where stepped joints are proposed care is to be taken to ensure that over-cutting does not occur. All joints are to be arranged so that they can be reinforced internally to maintain structural continuity of the laminate.

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3.9.8 Lap joints may be bolted or adhesively bonded, or both. They may be single or double lapped dependent upon the specific application.

3.9.9 Where tray mouldings form part of the integral structure of the craft, full details are to be indicated on the submitted plans. Information regarding tolerances is to be presented together with details of all adhesives and proposed bonding-in techniques. Particular attention is to be given to the design so as to maintain the structural continuity of the webs of any stiffening members.

3.9.10 The hulls of all craft with a service speed of 25 knots or greater are to be moulded as required by Ch 3,3.15.

3.9.11 Chine details are to be clearly indicated on the submitted plans. Spray rails may form part of the structural laminate or may be installed as a laminated or bolted appendage. Where the chine is a laminated appendage, provision is to be made for a sacrificial ply at which failure may occur without undue damage to the remaining structure of the hull. Sandwich structures are to be returned to single skin laminates at chine rails unless agreed otherwise on the approved construction plans. Chine rails are to be infilled and over laminated on the inner surface of the hull. Additional reinforcement is to be laminated into the chine area in accordance with Ch 3,3.8.

3.9.12 Reinforcements are to be arranged to maintain continuity of strength throughout the laminate. Joints in each layer of reinforcement are, in general, to be overlapped. The length of the overlap is dependent upon the type of reinforcement but is not to be less than 50 mm. The position of the joints in the laminate is to be staggered, in general by 150 mm, to maintain as near uniform laminate thickness as practicable. Tests may be required to demonstrate continuity of strength when bi-directional, multi-axial or cross plied reinforcements are used.

3.9.13 As an alternative to overlapping as required by 3.9.12, individual consideration will be given, on the basis of test results, to partial butting of reinforcements manufactured with a salvedge. For such reinforcements the salvedge tails are to be laid on top of each other to provide continuity. Butts in the same vertical plane are to be separated by not less than five passing plies.

3.9.14 Areas of single skin structure in way of the attachment of fittings or equipment are, in general, to be increased in thickness by not less than 50 per cent, with the additional layers staggered beyond the extremities of the surrounding stiffening.

3.9.15 The design of the structure in way of the attachment of fittings or equipment in sandwich structures is to be such that the induced loads can be transmitted into the surrounding structure by bending as opposed to shear. The areas are to, in general, take the form of suitably reinforced single skin areas, *see* 3.9.14, with the additional layers of reinforcement staggered out onto the surrounding inner and outer skins as indicated in Fig. 3.3.1.

3.9.16 Laminate overlapping and staggering arrangements may require to be tested at the discretion of the Surveyor.

3.9.17 Laminates may be fastened mechanically provided that the fastenings are of a corrosion resistant metal and are spaced and positioned so as not to impair the efficiency of the joint. The fastenings are to be of an acceptable type and, where washer plates are used, they are to be of a compatible material. The edges of the laminates and the fastening holes are to be sealed.

3.9.18 Where plywood and timber members are to be matted onto, or encapsulated within, the laminate, the surface of the wood is to be suitably prepared prior to bonding.

3.9.19 For details of through hull fittings, *see* 5.6.

■ *Section 4* Additional procedures for sandwich construction

4.1 General

4.1.1 The methods used in sandwich construction are, in general, to be either wet or dry core bonding techniques or by laminating directly onto the core (e.g. plug moulding).

4.2 Laminating

4.2.1 The forefoot and stem of all craft of composite construction are to be moulded as required by Ch 3,5.11.1.

4.2.2 Where the core material is to be laid onto a pre-moulded skin, it is to be laid as soon as practicable after the laminate cure has passed the exothermic stage.

4.2.3 Where the core is applied to a laminated surface, particular care is to be taken to ensure that a uniform bond is obtained. Where a core is to be applied to an uneven surface, the Surveyor may request additional building up of the surface or contouring of the core to suit.

4.2.4 Where other than epoxy resins are being used, the reinforcement against either side of the core is to be of the chopped strand mat type. Additional flow coating is not to be applied to the foam core prior to laminating.

4.2.5 The submitted plans are to clearly show the staggering of successive plies in both the transverse and longitudinal directions. In general laminates are to be staggered by 50 mm per layer of reinforcement. Where very thin sandwich skins are adopted the rate of laminate stagger will be individually considered.

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4.2.6 Prior to bonding, the core is to be cleaned and primed (sealed) in accordance with the manufacturer's recommendations. The primer is to be allowed to cure and is not to inhibit the subsequent cure of the materials contained within the manufacturer's recommended bonding process. The primer is to seal the panels, including all the surfaces between the blocks of contoured material, without completely filling the surface cells.

4.2.7 Where panels of rigid core material are to be used then dry vacuum bagging techniques are, in general, to be adopted. The core is to be prepared by providing 'breather' holes to ensure efficient removal of air under the core. Bonding paste is to be visible at such breather holes after vacuum bagging. The number and pitch of such 'breather' holes is to be in accordance with the core manufacturer's application procedure and any specific requirements of the core bonding paste manufacturer, *see also* 4.4.3.

4.2.8 Thermoforming of core materials is to be carried out in accordance with the manufacturer's recommendations. Maximum temperature limits are to be strictly observed.

4.2.9 Where panels of contourable core material are to be used it is necessary to ensure that the core is cut/scored through the entire thickness such that the panels will conform to the desired shape of the moulding. The Builder is to demonstrate that the quantity of bonding material indicated in the core manufacturer's application procedure (*see* 2.11.2) is sufficient to penetrate the full depth of the core between the blocks. It is recommended that grid scored panels using a carrier scrim cloth are adopted.

4.2.10 Where the edges of a panel are to be bevelled to single skin the rate of tapering is to be not greater than 30°. In areas where an insert (e.g. higher density foam or plywood) is to be used the rate of taper is not to be greater than 45°.

4.2.11 In all application procedures cured, excess bonding material is to be removed and the panel cleaned and primed prior to the lamination of the final sandwich skin.

4.3 Inserts

4.3.1 Backing or insert pads where fitted in way of the attachment of fittings are to be arranged so that the load can be satisfactorily transmitted into the surrounding structure. The contact area of these pads is to be suitably prepared and free from contamination, *see also* 3.9.14 and 3.9.15.

4.3.2 Inserts in sandwich laminates are to be of a material capable of resisting crushing. Inserts are to be well bonded to the core material and to the laminate skins in strict accordance with the approved plans.

4.3.3 Where plywood inserts are to be used all edges are to be bevelled at an angle of 45°. A small gap is to be provided around each insert to ensure the passage of bonding paste during the vacuum bagging process.

4.4 Vacuum bagging

4.4.1 Where wet vacuum bagging is proposed (with or without a core), full details are to be submitted for consideration.

4.4.2 The Builder is to demonstrate by visual inspection that efficient core bonding can be obtained using the proposed dry vacuum bagging process.

4.4.3 The number, size and distribution of breather holes in panels of rigid core material is to be that recommended in the core manufacturer's application procedure, *see* 4.2.6. Typically, 3 mm diameter breather holes are to be provided at 50 mm centres.

4.4.4 The level of vacuum applied for initial consolidation and during the cure period is not to be higher than that recommended, by the relevant manufacturer of the materials being used, to avoid the possibility of evaporative boiling and excessive loss of monomer.

4.5 Shear ties

4.5.1 Shear ties between the inner and outer skins are to be provided at intervals not greater than that required by Ch 3,1.13, and are to be detailed on the plans submitted for approval.

4.5.2 Alternative shear tie arrangements will be individually considered.

■ *Section 5*
Details and fastenings

5.1 General

5.1.1 This Section contains the general Rule requirements to be complied with for fibre reinforced plastic craft being built under survey. Where detailed requirements are not defined good boat building practices are to be applied. Where different details are to be applied, the Builder is required to provide evidence of satisfactory service experience or acceptable test data.

5.2 Alignment

5.2.1 Details of alignment and building tolerances are to be laid down in the Builder's production plan.

5.2.2 Where details of alignment and building tolerances are not included on the construction plans, or submitted separately for consideration with the plan submission, they may, subject to individual consideration, be agreed locally with the attending Surveyor.

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5.2.3 Particular attention is to be given to the accurate alignment of the following:

(a) girder abutting single skin bulkhead;
(b) girder webs with tank sides;
(c) frames with beams;
(d) deck/bottom girders with bulkhead stiffeners;
(e) tank baffles with floors;
(f) longitudinals where broken at tank ends; and
(g) transom stiffeners with bottom/deck girders.

5.2.4 For larger craft the hull breakage sight-line is to be progressively monitored during the construction of the craft and is to form part of the quality control documentation. The production plan is to identify maximum breakage limits dependent upon the size of the craft.

5.2.5 The production plan is to identify allowable tolerances for the alignment of the primary structural components.

5.2.6 To ensure efficient load transmission intercostal, single skin bulkheads are to be aligned to within half the thickness of the thinner bulkhead. In the case of sandwich construction the tolerance requirements will be individually considered dependent upon the sandwich panel dimensions and the construction of the continuous member. In general, the webs of the intercostal sandwich panel member are to be aligned to within 5 mm. Where poor alignment is identified, additional boundary bonding reinforcements are to be applied as agreed with the attending Surveyor. Such deviations and details of the remedial action taken are to be recorded in the Builder's quality control documentation.

5.2.7 To ensure efficient transmission of shear loads, the alignment tolerance of intercostal 'top hat' stiffener webs is, in general, to be within half of the web thickness. Where poor alignment is identified, additional reinforcements are, in general, to be incorporated into the stiffener webs as agreed with the attending Surveyor. Such deviations and details of the remedial action taken are to be recorded in the Builder's quality control documentation.

5.3 Continuity

5.3.1 Continuity of all primary structural members is to be maintained, as required by the Rules, and abrupt changes of section are to be avoided. Both primary and secondary stiffening members are to be continuous unless otherwise agreed with LR.

5.3.2 Special consideration will be given to the intersection of longitudinal and transverse members. In general the ratio between the depths of the intersecting members is to be 2:1. The shallower member is to be continuous under the supporting members.

5.3.3 Alternative proposals to the requirements given in 5.3.2 will be subject to special consideration in conjunction with the submission of details for maintaining the continuity of reinforcements at intersections in both directions. Where stiffeners are of similar dimensions the primary member is to be continuous. In general the section modulus of the continuous material is to be maintained.

5.4 Openings

5.4.1 All openings are to have well rounded corners and are to be supported on all sides. Cut edges of openings are to be sealed to prevent the ingress of moisture.

5.4.2 All hatch openings are to be supported by a system of transverse and longitudinal stiffeners, the details of which are to be submitted for approval.

5.4.3 The requirements for closing arrangements and outfit are given in Pt 3, Ch 4.

5.4.4 All deck openings are to have corner radii as specified in Ch 3,8.12.

5.4.5 For details of sealing the edges of openings and sandwich panels, *see* 5.10.

5.5 Through bolting and bolted connections

5.5.1 The details of all through bolted structural connections are to be indicated on the relevant construction plans submitted for approval. The design of the joint is to be suitable for its intended purpose with a sufficient number of bolts to satisfactorily close the joint.

5.5.2 Tank tops may be bolted down provided the bolt spacing does not exceed $8d_b$, where d_b is the bolt diameter. A joint, seal or stop water is to be fitted, as necessary, to meet the required integrity.

5.5.3 In general, large headed bolts or large diameter thick washers are to be used to prevent localised crushing damage during tightening.

5.5.4 Where mechanical fastenings are used, the torque is to be indicated on the plans submitted for approval.

5.5.5 Bolting arrangements are, in general, to be in accordance with Ch 2,5.5, 5.6, 5.7 and 5.8. In FRP sandwich construction, inserts of a material capable of resisting crushing are to be fitted in accordance with 4.3.

5.5.6 The diameter of a fastening is not to be less than the thickness of the thinner component being fastened, with a minimum diameter of 6 mm, excepting window frames where the minimum diameter may be 5 mm.

5.5.7 Bolted connections are, in general, to be bonded along all mating surfaces using an accepted structural adhesive, applied in accordance with the manufacturer's requirements. Where connections rely solely on the shear resistance of the connecting bolts the spacing is not to exceed $3d_b$, where d_b is the diameter of the bolt. In areas where subsequent access will either be limited or not possible, self locking nuts are to be provided.

5.5.8 In general, all structural, bolted connections are to use reeled lines of bolts in accordance with the requirements given in Table 2.5.1.

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Table 2.5.1 Bolt pitch requirements in bonded and bolted connections

Location	Pitch
Watertight connections – below static load waterline	$10d_b$
Connections in hull above static load waterline to deck	$15d_b$
Hull to deck connections – bonded with structural adhesive – bolted with mastic sealant (*see* Note 2)	$20d_b$ $20d_b$
Connections in deckhouses	$20d_b$
Deckhouse to deck connections – bonded with structural adhesive – bolted with mastic sealant (*see* Note 2)	$20d_b$ $20d_b$
Minimum distance between reeled lines of bolts	$3d_b$
Minimum distance from centreline of line of bolts to free edge	$2d_b$

NOTES
1. d_b is the diameter of the bolt.
2. Internal boundary sealing angle to be provided.

5.5.9 All structural, single line, bolted connections without adhesive bondings are to be in accordance with the requirements given in Table 4.1.1 in Pt 3, Ch 4.

5.5.10 Care is to be taken to avoid distortion of the frame when window frames are bolted into the structure of the craft. Where necessary, uneven surfaces are to be locally built up to the satisfaction of the attending Surveyor.

5.5.11 Where a restricted service notation of G1 or G2 is applicable the requirements given in this Section will be specially considered dependent upon the sea states for which the craft is designed.

5.5.12 Bolt holes are to be drilled, without undue pressure at break through, having a diametric tolerance of two per cent of the bolt diameter. Where bolted connections are to be made watertight the hole is to be sealed with resin and allowed to cure before the bolt is inserted.

5.5.13 In areas of high stress or where unusual bolting configurations are proposed, testing on the basis of equivalence with the above Rules may be required.

5.6 Through hull fittings

5.6.1 Where fittings penetrate the hull envelope, care is to be taken to seal the hull laminate with resin or other suitable compound, *see* 5.10.

5.6.2 The areas in way of penetrations for fittings in sandwich construction are, in general, to comply with the requirements of 4.3. Where the requirements cannot be complied with, the core is to be replaced locally with a solid core or very high density foam core with compressive properties commensurate with the loads imposed by the securing arrangements, *see* 5.8.2. The exposed edges of such openings are to be sealed watertight, *see* Ch 3,3.10.

5.6.3 All bolted fittings are to be bedded down using a suitable mastic, details of which are to be indicated on the submitted plans.

5.7 Backing bars and tapping plates

5.7.1 The requirements for backing plates and bars will be individually considered, on the basis of the loading imposed, details of which are to be indicated on the submitted plans.

5.7.2 Metallic plates and bars are to be suitably protected against corrosion.

5.7.3 Tapping plates may be encapsulated within the laminate, laminated to or bolted to the structure, *see also* 2.15.1. Where tapping plate edges or corners are likely to give rise to hard spots or stress concentrations the edges are to be suitably rounded.

5.7.4 Where tapping plates are placed on foam cores the plate is to be mounted on a suitable foundation to prevent the movement of the tapping plate during drilling operations.

5.7.5 Direct calculations regarding the scantlings of tapping plates are to be provided at the plan appraisal stage.

5.8 Fastenings

5.8.1 All fastenings are to be of a suitable marine grade. Sizes and specifications are to be indicated on the submitted plans.

5.8.2 In areas where localised crushing of a sandwich core is likely to occur, large diameter washers, compression tubes or inserts or a combination of these are to be adopted.

5.9 Secondary bonding

5.9.1 Laminating is to proceed as a continuous process, as far as practicable, with the minimum of delay between successive plies. Where a secondary bond is to be made it is to be carried out in accordance with the resin manufacturer's recommendation, details of which are to be incorporated in the Builder's quality control documentation. This will, in general, take the form of the area being lightly abraded and wiped with a suitable solvent, which is to be allowed to dry prior to laminating.

5.9.2 Where other than epoxy resins are being used, the first reinforcement is to be of the chopped strand mat type.

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5.9.3 Consideration should be given, especially in highly stressed areas, to the application of peel ply materials to obviate contamination of the exposed surface, and thereby reducing the abrading required to obtain a good secondary bond.

5.10 Exposed edges

5.10.1 The exposed edges of all openings cut in single skin laminate panels are to be suitably sealed. Where such edges are in wet spaces or under water the edges of such openings are to have rounded edges and are to be sealed by two plies of 450 g/m^2 chopped strand mat (or equivalent) reinforcements, *see also* Ch 3,3.10.

5.10.2 Exposed edges of openings cut in sandwich panels are to be suitably sealed, *see* 5.6.2. The cut edges are, in general, to be sealed with a weight of reinforcement not less than that required for the outer skin of the sandwich. Where other than an epoxy resin system is used the first layer of such reinforcement is to be chopped strand mat with a weight not exceeding 450 g/m^2, *see also* Ch 3,3.10.

5.11 Joints

5.11.1 The details of all joints, the proposed jointing procedure and information regarding tolerancing are to be indicated on the submitted plans.

5.11.2 Joints may be bolted or adhesively bonded, or both. Where joints are bolted, full details of the bolt material, the proposed number and spacing are to be provided. Bolts are to be manufactured from a non-corrosive material or protected against corrosion.

5.12 Local reinforcement

5.12.1 Areas subject to local loads or increased stress are to be suitably reinforced, details of which are to be indicated on the submitted plans, *see also* Ch 3,3.14.

5.12.2 Areas of local reinforcement will be individually considered and direct calculations are to be submitted, *see* 3.9.14.

5.13 Hull to deck connections

5.13.1 Details of the hull to deck connection, the method of bonding and the tolerances are to be indicated on the submitted plans.

5.13.2 Hull to deck connections should, in general, be bolted and over-bonded. A suitable mastic or sealing compound is to be incorporated within the joint.

5.13.3 The bolting details should be reeled lines of bolts pitched as specified in Table 2.5.1. Suitable large diameter thick washers should be used under both the head and the nut.

5.13.4 Where a mastic is not used, sealing plies are to be applied on the inside of the hull.

5.13.5 The weight of the over-bonding reinforcement is, in general, not to be taken as less than equivalent to the lighter of the component members being connected, and in no case less than equivalent to three plies of 600 g/m^2 chopped strand mat.

5.13.6 Substantial beam knees are to be provided to maintain structural continuity between the transverse deck and hull stiffening.

5.13.7 The watertight integrity, continuity and strength of the connection is not to be impaired by the attachment of the hull fender.

5.13.8 For guidance details of scantlings required to resist impact loads at deck edge connections, *see* Ch 3,4.19 for side shell in way of fendering and Ch 3,3.6 for sheerstrakes.

5.14 Exhaust systems

5.14.1 Exhaust systems, manufactured from FRP, are to be of the water injected type with a normal operating temperature of 60° to 70°C and a maximum operating temperature of 120°C.

5.14.2 Exhaust pipes, silencers and water separators should be of a Type Approved design, installed strictly in accordance with the manufacturer's requirements.

5.14.3 Where a Type Approved system is not used, the arrangement will be considered on an individual basis. Resins used in the manufacture of exhaust systems are to be of a type approved by LR and are to have good heat and chemical resistance properties with a high deflection temperature under load. A vinylester resin should be used, but a fire retardant polyester resin, having a high heat distortion temperature, will be considered. Test samples may be required dependent upon the proposed arrangement, temperatures and materials.

5.14.4 It is recommended that pigments and additives are not used unless it can be demonstrated that the mechanical properties of the resin system remain unaffected. Resins used are not to show any embrittlement with age.

5.14.5 Special consideration is to be given to post curing of such systems to obtain optimal characteristics.

5.14.6 Due to the weight of water contained within the system, exhaust pipes and fittings are to be efficiently supported.

5.14.7 Exhaust boxes are to be lined with a minimum of two plies of 600 g/m^2 chopped strand mat (or equivalent) using a suitable fire retardant/high temperature resin.

5.14.8 For engineering aspects of exhaust systems reference is to be made to Pt 10, Ch 1,8.6.

5.14.9 National Authority requirements take precedence over the requirements given in this Section.

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5.15 Ballast

5.15.1 The provision of permanent ballast is not to adversely affect the surrounding structure.

5.15.2 Where a resin compound is to be poured into a void space, care is to be taken to minimise the generation of heat that may affect the mechanical and weathering characteristics of the structural laminate.

5.15.3 Details of all ballast materials and the proposed method of installation are to be indicated on the submitted plans.

5.16 Limber holes

5.16.1 Provision is to be made to drain areas likely to accumulate liquids, details of which are to be indicated on the submitted plans.

5.16.2 The size, shape and position of limber holes are not to affect the structural strength of the stiffening members in which they are fitted. Limber holes are, in general, to be positioned at the quarter span of the stiffener.

5.17 Integral tanks (requirements for coatings)

5.17.1 The surfaces of integral tanks are to be provided with a barrier to reduce the ingress of liquid. The details of the proposed system are to be indicated on the submitted plans.

5.17.2 Fresh water tanks are to be coated with a non-toxic and non-tainting coat of resin that is recommended by the resin manufacturer for potable water tanks.

5.17.3 The design and arrangement of oil fuel tanks is to be such that there is no exposed horizontal section at the bottom that could be exposed to a fire. Other fire protection arrangements for oil fuel tanks will be specially considered. For details of fire protection requirements, *see* Part 17.

5.17.4 Where plywood bulkheads form part of a tank boundary, the surface is to be completely protected against the ingress of moisture with a minimum of 4 mm thickness of laminate to provide an effective fluid barrier, regardless of resin and reinforcement type used.

5.17.5 Where outfit items are to be laminated to the tank surface, the heavy coating of resin is to be applied afterwards and the laminated brackets sealed to prevent the ingress of moisture.

5.17.6 The scantlings of integral oil fuel and water tanks are to be in accordance with Ch 3,7. Details regarding sub-division of integral tanks are given in Ch 3,7.11.1.

5.17.7 Integral tanks are to be tested in accordance with Ch 3,7.17.

5.18 Reserve buoyancy

5.18.1 Details of materials to be used and the method of installation of reserve buoyancy are to be indicated on the submitted plans.

5.18.2 Where necessary, buoyancy materials are to be over-laminated *in situ* to prevent the ingress of moisture.

5.19 Shear ties (stiffeners)

5.19.1 Where the total web depth to thickness ratio requirement in Ch 3,1.16 for buckling of stiffener webs is not complied with, cross linking of the stiffener webs at the Rule depth to thickness ratio is to be provided by the use of shear ties, as indicated in Fig. 2.5.1.

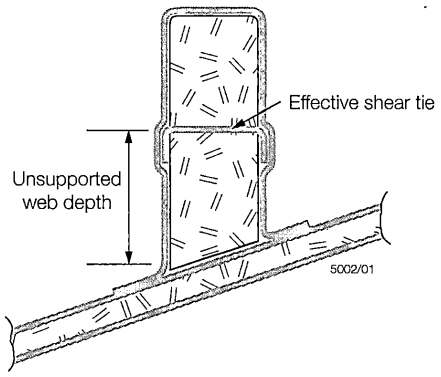

Fig. 2.5.1 Arrangement of shear ties (stiffeners)

5.19.2 Alternative arrangements will be subject to individual consideration in conjunction with submitted direct calculations.

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Scantling Determination for Mono-Hull Craft

Section

1 **General**

2 **Minimum thickness requirements**

3 **Shell envelope laminate**

4 **Shell envelope framing**

5 **Single bottom structure and appendages**

6 **Double bottom structure**

7 **Bulkheads and deep tanks**

8 **Deck structures**

9 **Superstructures, deckhouses and bulwarks**

10 **Pillars and pillar bulkheads**

Section 1 General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull craft of composite construction as defined in Pt 1, Ch 1,1.

1.2 General

1.2.1 The scantlings of motor and sailing, mono-hull craft of conventional form and proportions are to be determined from the formulae contained within this Chapter.

1.2.2 The mechanical properties to be used for scantling calculation purposes are to be 90 per cent of the mean first ply/resin cracking failure values determined from accepted mechanical tests, or the mean values minus twice times the standard deviation for the five samples, whichever is the lesser. All test pieces are to be representative of the product to be manufactured and details submitted for consideration.

1.2.3 In the absence of suitable test data, the mechanical properties of the materials is to be estimated from the appropriate procedures and formulae contained within this Part. The acceptable design values for glass reinforced polyester resin laminates are, in general, not to be taken greater than those determined from Tables 3.1.1 and 3.1.2. Additional information on the application of the various formulae is given in Lloyd's Register's (hereinafter referred to as 'LR') *Guidance Notes for Calculation Procedures for Composite Construction*.

Table 3.1.1 Mechanical properties for chopped strand mat (CSM) reinforcements

Mechanical property	N/mm^2
Ultimate tensile strength	$200G_c + 25$
Tensile modulus	$(15G_c + 2) \times 10^3$
Ultimate compressive strength	$150G_c + 72$
Compressive modulus	$(40G_c - 6) \times 10^3$
Ultimate shear strength	$80G_c + 38$
Shear modulus	$(1{,}7G_c + 2{,}24) \times 10^3$
Ultimate flexural strength	$502G_c^2 + 106{,}8$
Flexural modulus	$(33{,}4G_c^2 + 2{,}2) \times 10^3$
NOTE G_c is as defined in 1.2.6.	

Table 3.1.2 Mechanical properties for woven roving (WR) and cross plied (CP) reinforcements at 0/90° degree orientation

Mechanical property	N/mm^2
Ultimate tensile strength	$400G_c - 10$
Tensile modulus	$(30G_c - 0{,}5) \times 10^3$
Ultimate compressive strength	$150G_c + 72$
Compressive modulus	$(40G_c - 6) \times 10^3$
Ultimate shear strength	$80G_c + 38$
Shear modulus	$(1{,}7G_c + 2{,}24) \times 10^3$
Ultimate flexural strength	$502G_c^2 + 106{,}8$
Flexural modulus	$(33{,}4G_c^2 + 2{,}2) \times 10^3$
NOTE G_c is as defined in 1.2.6.	

1.2.4 The various formulae referred to in 1.2.3 require that sufficient input data be available which relates to each of the proposed materials. The designers and/or Builders are to, in general, agree the values for use in the scantling analysis with LR at the design stage and prior to the submission of plans and data for appraisal.

1.2.5 Typical acceptable values for the various fibre properties of materials commonly in use are given in Table 3.1.3.

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Table 3.1.3 Typical minimum fibre properties

	Specific gravity ζ_F	Tensile modulus N/mm^2	Shear modulus N/mm^2	Poisson's ratio μ_F
E glass	2,56	69000	28000	0,22
S glass	2,49	69000	— *see* Note 3	0,20
R glass	2,58	— *see* Note 3	— *see* Note 3	— *see* Note 3
Aramid	1,45	124000	2800	0,34
LM graphite *see* Note 1	1,80	230000	— *see* Note 3	— *see* Note 3
IM graphite *see* Note 1	1,80	270000	— *see* Note 3	— *see* Note 3
HM graphite *see* Note 1	1,8	300000	— *see* Note 3	— *see* Note 3
IM graphite *see* Note 2	1,9	160000	— *see* Note 3	— *see* Note 3
HM graphite *see* Note 2	2,0	380000	— *see* Note 3	— *see* Note 3
VHM graphite *see* Note 2	2,15	725000	— *see* Note 3	— *see* Note 3

NOTES
1. Polyacryonitrile type.
2. Mesophase pitch precursor type.
3. Actual values to be obtained from the material manufacturer and are to be agreed with LR prior to use.

1.2.6 **Uni-directional reinforcements**, the tensile properties of uni-directional laminates, consisting of E-glass and polyester resin, are to be determined from the procedures contained within this Part. Acceptable design values are, in general, not to be greater than those determined from the following:

Ultimate tensile strength (UDR)

$= 1800G_c^2 - 1400G_c + 510$ N/mm^2

Tensile modulus (UDR)

$= (130G_c^2 - 104G_c + 39) \times 10^3$ N/mm^2

where G_c is the glass content by weight of the reinforcement within the laminate.

1.2.7 Typical acceptable values for the various resin properties of materials commonly in use are given in Table 3.1.4.

1.3 Direct calculations

1.3.1 The scantlings are to be determined by direct calculation where the craft is of unusual design, form or proportions, or where the speed of the craft exceeds 60 knots.

1.3.2 The requirements of this Section may be modified where direct calculation procedures are adopted to analyse the stress distribution in the primary structure.

1.4 Equivalents

1.4.1 LR will consider direct calculations for the derivation of scantlings as an alternative and equivalent to those derived by Rule requirements in accordance with Ch 2,3 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

1.5 Symbols and definitions

1.5.1 The symbols used in this Chapter, unless specified otherwise, are defined as follows:

b = unsupported panel breadth, in mm
b_i = breadth of individual ply, i, in mm
e_f = flexural strain of plate laminate
B = moulded breadth of the craft, in metres
E_{ci} = compressive modulus of individual ply, i, in N/mm^2
E_{cp} = compressive modulus of plate laminate, in N/mm^2
E_i = E_{ti} or E_{ci} for the ply relative to its position above or below the neutral axis
E_F = tensile modulus of the fibres, in N/mm^2
E_R = tensile modulus of the resin, in N/mm^2
E_{ti} = tensile modulus of individual ply, i, in N/mm^2
E_{cps} = compressive modulus of the sandwich skin plate laminate as determined from 1.13.5, in N/mm^2
E_{tps} = tensile modulus of the sandwich skin plate laminate as determined from 1.13.4, in N/mm^2
E_{fp} = flexural modulus of plate laminate, in N/mm^2

Table 3.1.4 Typical minimum resin properties

	Type	Specific gravity ζ_R	Tensile modulus N/mm^2	Shear modulus N/mm^2	Poisson's ratio ν_R
Polyester	Thermosetting	1,20	3400	1300	0,36
Vinylester	Thermosetting	1,44	3500	— *see* Note	— *see* Note
Epoxy	Thermosetting	1,38	3500	— *see* Note	0,39
Phenolic	Thermosetting	1,30	1500~2500 *see* Note	— *see* Note	— *see* Note

NOTE
Actual value to be obtained from the material manufacturer and is to be agreed with LR prior to use.

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E_{tp} = tensile modulus of the plate laminate, in N/mm^2
f_{ci} = fibre content, by weight, of individual ply, *i*
G = shear modulus of sandwich core material, in N/mm^2
I_i = second moment of area for a 1 cm length of the cross section of individual ply, *i*, in cm^4
I_P = second moment of area for a 1 cm length of the cross section of plate laminate, in cm^4
k_A = $85/\sigma_u$
k_s = sandwich laminate aspect ratio correction factor, as defined in 1.13.9
L_R = Rule length of craft, in metres
M = bending moment, as appropriate, in Nm
l_e = effective span length of stiffener, in metres
σ_u = ultimate tensile strength of the plate laminate, in N/mm^2
p = design pressure in kN/m^2, as calculated in Part 5 for the appropriate item
s = stiffener spacing, in mm
t_c = core thickness, in mm
t_i = thickness of individual ply, *i*, in mm
t_p = thickness of plate laminate, in mm
t_s = mean skin thickness, in mm
ν_F = Poisson's ratio for the fibre
ν_R = Poisson's ratio for the resin
V_{Fi} = volume fraction of fibres of individual ply, *i*
W_{Fi} = weight fraction of the fibres of individual ply, *i*
m_{Fi} = mass of reinforcement in individual ply, *i*, in g/m^2
x_i = distance to the centre of individual ply, *i*, from the plate or sandwich laminate surface, in mm
x_L = distance of the neutral axis from the surface of the plate or sandwich laminate, in mm
x_S = the distance of the neutral axis, from the outer surface of the plate or sandwich laminate
y_i = distance from the neutral axis to the outer extremity of an individual ply, *i*, in mm
σ_{ci} = maximum compressive stress within ply, *i*, in N/mm^2
σ_{ti} = maximum tensile stress within ply, *i*, in N/mm^2
ζ_{Fi} = specific gravity of reinforcement in individual ply, *i*
ζ_{Ri} = specific gravity of resin in individual ply, *i*.

1.5.2 The side shell is defined as the portion of the hull between the bottom shell and the deck at side.

1.6 Material properties

1.6.1 The nominal thickness of an individual ply, t_i, may be determined from:

$$t_i = \frac{m_{Fi}\left[\frac{\zeta_{Fi}}{f_{ci}} - (\zeta_{Fi} - \zeta_{Ri})\right]}{1000\zeta_{Fi}\zeta_{Ri}} \text{ mm}$$

where

f_{ci}, t_i, m_{Fi}, ζ_{Fi} and ζ_{Ri} are as defined in 1.5.1.

1.7 Effective width of attached plating

1.7.1 The geometric properties of stiffening sections are to be calculated in accordance with 1.15 using an effective width, $2b_1$, of attached load bearing plating determined as follows:

(a) Single skin construction:

$b_1 = 0{,}5b_w + 10t_{ap}$

(b) Sandwich skin construction:

Generally:

$b_1 = 0{,}5b_w + 10(t_{outer} + t_{inner})$

Where a plywood core is used:

$b_1 = 0{,}5b_w + 10(t_{outer} + t_{inner} + 0{,}5t_{ply})$

where

b_1 = effective width of attached load bearing plating, in mm, and is not to be taken as greater than one half the spacing between the centres of adjacent stiffeners
b_w = base width of the stiffener section, in mm
t_{ap} = thickness, or mean thickness of attached plate laminate, in mm
t_{inner} = thickness, or mean thickness of inner skin laminate, in mm
t_{outer} = thickness, or mean thickness of outer skin laminate, in mm
t_{ply} = thickness of plywood core, in mm.

1.7.2 The geometric properties of primary support members (i.e. girders, stringers, web frames, etc.) are to be calculated in accordance with 1.15 using an effective area of attached load bearing plate laminate of nominal thickness, *t* mm, and of width equal to one-half the sum of spacings between parallel adjacent members or equivalent support.

1.8 Glass fibre and advanced fibre composites

1.8.1 Strength calculations for all advanced fibre composites are to be based on the results of testing of truly representative sections of the proposed design. In general the sections are to be manufactured under typical production conditions using the same materials, fibre contents, methods of lay-up and time delays.

1.8.2 Mechanical testing is, in general, to be based upon the requirements of Ch 14,3 of the Rules for Materials.

1.8.3 Where test data is not available for standard glass fibre laminates, the following theoretical approach is to be used to estimate the tensile modulus and the shear modulus of a laminate:

The tensile modulus of a uni-directional reinforcement at angle θ to the axis of the fibres is to be determined from:

$$E_{\theta i} = \frac{E_{0i}}{\cos^4\theta_i + \frac{E_{0i}}{E_{90i}}\sin^4\theta_i + \frac{1}{4}\left(\frac{E_{0i}}{G_{0/90i}} - 2\nu_{0/90i}\right)\sin^2 2\theta_i} \text{ N/mm}^2$$

where

θ_i = angle of orientation of the fibre relative to the warp direction, and is not to be taken as less than seven degrees to allow for misalignment

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E_{0i}, the longitudinal tensile modulus of individual ply, *i*, for an unfilled resin system is determined from:

$$E_{0i} = E_F V_F + E_R (1 - V_F) \text{ N/mm}^2$$

E_F, V_F and E_R are as defined in 1.5.1

V_F, the volume fraction of the fibres of individual ply, *i*, is determined from:

$$V_F = \frac{W_F \zeta_R}{W_F \zeta_R - W_F \zeta_F + \zeta_F}$$

W_F, ζ_F and ζ_R are as indicated in 1.5.1

E_{90i}, the transverse tensile modulus of individual ply, *i*, is determined from:

$$E_{90i} = \frac{E_F E_R}{E_R V_F + E_F - E_F V_F} \text{ N/mm}^2$$

E_F, E_R and V_F are as indicated in 1.5.1.

$G_{0/90i}$, the shear modulus of individual ply, *i*,is determined from:

$$G_{0/90i} = G_R \left\{ \frac{\frac{G_F}{G_R}(1 + V_F) + (1 - V_F)}{\frac{G_F}{G_R}(1 - V_F) + (1 + V_F)} \right\} \text{ N/mm}^2$$

Where the shear modulus of the resin, G_R is determined from:

$$G_R = \frac{E_R}{2(1 + \nu_R)} \text{ N/mm}^2$$

Where the shear modulus of the fibre, G_F is determined from:

$$G_F = \frac{E_F}{2(1 + \nu_F)} \text{ N/mm}^2$$

E_F, E_R, ν_R and ν_F are as indicated in 1.5.1.

The longitudinal Poisson's ratio, $\nu_{0/90}$, of individual ply, *i*, is determined as follows:

$$\nu_{0/90} = V_F (\nu_F - \nu_R) + \nu_R$$

V_F, ν_F and ν_R are as indicated in 1.5.1.

1.8.4 Where specific test data is not available for glass fibre reinforced polyester laminates, the mechanical properties for design are to be the values determined from the formulae given in Tables 3.1.1 and 3.1.2.

1.9 Plate and sandwich laminates

1.9.1 Unless otherwise specified in this Part, the bending moments, M_b and M_c, to be applied to a 1 cm length of panel, for both plate and sandwich laminates, subjected to lateral pressure are to be determined from:

(a) Bending moment at panel boundary and under base of stiffener, M_b:

$$M_b = \frac{k p b^2}{12} \times 10^{-5} \text{ Nm}$$

(b) Bending moment at centre of panel, M_c:

$$M_c = \frac{(1{,}5 - k) p b^2}{12} \times 10^{-5} \text{ Nm}$$

where

$$k = \frac{\gamma^3 + 1}{\gamma + 1}$$

$$\gamma = \frac{b_w}{b}$$

$b_w < b$ and is as defined below, *see* Fig. 3.1.1:

b = unsupported panel breadth, in mm

b_w = base width of stiffener, in mm

γ = ratio of base width of stiffener to panel breadth

k = bending moment influence coefficient

l_p = panel length, in mm

p = design pressure head as required by Part 5, for the element of plate laminate under consideration, in kN/m^2.

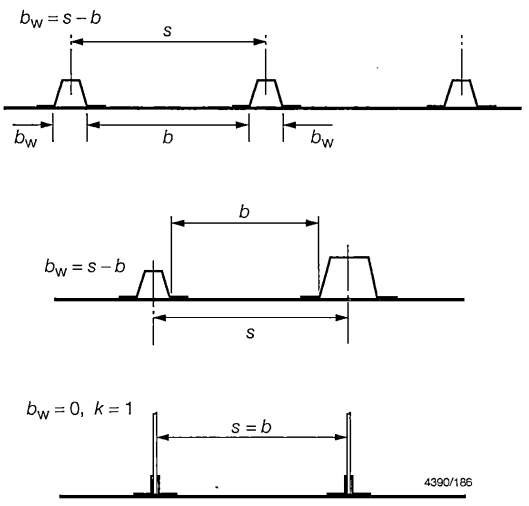

Fig. 3.1.1 Panel dimensions

1.10 Aspect ratio correction

1.10.1 The Rule bending moments, M_b and M_c, to be applied to plate laminates as determined by 1.9.1, may be reduced when the panel aspect ratio is taken into consideration. For panels with aspect ratio less than two the following factor, K_{AR}, may be applied:

$$K_{AR} = 0{,}56 + 0{,}63 \ln (A_R) \geq 0{,}56$$

where

A_R = panel aspect ratio
= panel length/panel breadth

1.11 Convex curvature

1.11.1 The Rule bending moments, M_b and M_c, as determined by 1.9.1, may be reduced where significant curvature exists between the support members. For such panels the following factor, K_c, may be applied:

$$K_c = 1 - 1{,}76 \frac{h}{s} \geq 0{,}56$$

where

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h = the distance, in mm, measured perpendicularly from the chord length s (i.e. spacing) to the highest point of the curved plating arc between the two supports, *see* Fig. 3.1.2.

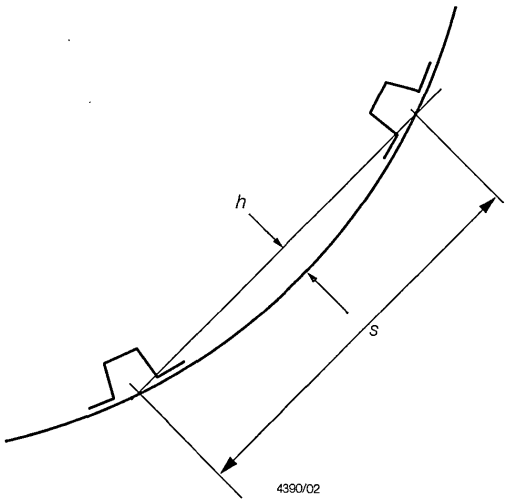

Fig. 3.1.2 Convex curvature

1.12 Determination of properties and stresses for single skin plate laminates

1.12.1 An estimate of the thickness of single skin plating required to carry the bending moment given in 1.9.1, is to be determined from:

$$t = 0{,}146b\sqrt[3]{\frac{p}{E_{tp}}} \text{ mm}$$

where

b, p and E_{tp} are as defined in 1.5.1.

1.12.2 The distance of the neutral axis, x_L, from the surface of the plate laminate is to be determined from the following:

$$x_L = \frac{\Sigma (E_i t_i x_i)}{\Sigma (E_i t_i)} \text{ mm}$$

where

E_i, t_i and x_i are as defined in 1.5.1.

1.12.3 The resultant tensile stress, σ_{ti}, at the extreme outer fibre of an individual ply, i, is to be determined from:

$$\sigma_{ti} = \frac{0{,}1E_{ti}\, y_i\, M}{\Sigma (E_i I_i)} \text{ N/mm}^2$$

where

σ_{ti}, E_{ti}, y_i, M, E_i and I_i are as defined in 1.5.1.

1.12.4 The resultant compressive stress, σ_{ci}, at the extreme outer fibre of an individual ply, i, is to be determined from:

$$\sigma_{ci} = \frac{0{,}1E_{ci}\, y_i\, M}{\Sigma (E_i I_i)} \text{ N/mm}^2$$

where

σ_{ci}, E_{ci}, y_i, M, E_i and I_i are as defined in 1.5.1.

1.12.5 The effective flexural modulus of elasticity in bending, E_{fp}, for the plate laminate is to be determined from:

$$E_{fp} = \frac{\Sigma (E_i I_i)}{I_p} \text{ N/mm}^2$$

where

E_{ti}, I_i and I_P are as defined in 1.5.1.

1.12.6 The apparent flexural strength, sf, of a plate laminate is to be determined from:

$$\sigma_f = E_{fp}\, e_f \text{ N/mm}^2$$

where

E_{fp} and e_f are as defined in 1.5.1.

1.13 Mechanical properties sandwich laminates

1.13.1 For the application of the various formulae relating to the use of sandwich construction, the following assumptions have been made:

(a) the sandwich skins carry the majority of the bending load,

(b) the core carries the majority of the shear load,

(c) the initial estimate of the skin thickness from 1.13.2 is based upon the limiting condition for thin skin theory:

$$\frac{\text{Core thickness}}{\text{Mean facing thickness}} \geq 5{,}77$$

(d) the sandwich skins are of approximately equal thickness (i.e. the panel is of balanced or approximately balanced construction), with the thickness of the outer sandwich facing not greater than:

t_{OUTER} = 1,33 t_{INNER} (excluding gel coat and non-structural materials).

1.13.2 An estimate of the thicknesses of the sandwich skins and core required to carry the Rule bending moment may be determined from the following formula. The subsequent design is then to be tested against the other criteria required by the Rules.

$$t_s = \phi_1 k_S b\sqrt[3]{\frac{p}{E_{tps}}} \text{ mm}$$

where

ϕ_1 = 0,0214 for inner skins
= 0,0286 for outer skins
= 0,1440 for core thickness

k_S, E_{tps}, b and p are as defined in 1.5.1.

1.13.3 Where it is proposed to use a thicker core than assumed in 1.13.2, the required skin thickness, t_s, is to be calculated from:

$$t_s = \frac{\phi^2\, p\, b^3}{E_{tps}\, t_c^2} \times 10^{-3} \text{ mm}$$

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where

ϕ_2 = 0,446 for inner skins
= 0,594 for outer skins

k_S, E_{tps}, b and p are as defined in 1.5.1.

1.13.4 The tensile modulus, E_{tp}, of a plate laminate which forms a skin of a sandwich laminate subject to tensile loading is to be determined from:

$$E_{tps} = \frac{\Sigma (E_{ti}\, t_i)}{\Sigma\, t_i} \text{ N/mm}^2$$

where

E_{tps}, E_{ti} and t_i are as defined in 1.5.1.

1.13.5 The compressive modulus, E_{cp}, of a plate laminate which forms a skin of a sandwich laminate subject to compressive loading is to be determined from:

$$E_{cps} = \frac{\Sigma (E_{ci}\, t_i)}{\Sigma\, t_i} \text{ N/mm}^2$$

where

E_{cps}, E_{ci} and t_i are as defined in 1.5.1.

1.13.6 The distance of the neutral axis, x_S, from the outer surface of the sandwich laminate is to be determined from:

$$x_S = \frac{\Sigma (E_i\, t_i\, x_i)}{\Sigma (E_{ti}\, t_i)} \text{ mm}$$

where

E_i, t_i and x_i are as defined in 1.5.1.

1.13.7 The resultant tensile stress, σ_{ti}, at the extreme outer fibre of an individual ply, i, is to be determined from:

$$\sigma_{ti} = \frac{0{,}1 E_{ti}\, y_i\, M}{\Sigma (E_i\, I_i)} \text{ N/mm}^2$$

where

σ_{ti}, E_{ti}, y_i, M, E_i and I_i are as defined in 1.5.1.

The allowable tensile stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

1.13.8 The resultant compressive stress, σ_{ci}, at the extreme outer fibre of an individual ply, i, is to be determined from:

$$\sigma_{ci} = \frac{0{,}1 E_{ci}\, y_i\, M}{\Sigma (E_i\, I_i)} \text{ N/mm}^2$$

where

σ_{ci}, E_{ci}, y_i, M, E_i and I_i are as defined in 1.5.1.

The allowable compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

1.13.9 The direct core shear stress, τ_c, at the edges of a sandwich panel subjected to lateral pressure is to be determined from:

$$\tau_c = \frac{p\, b\, k_S}{2(t_c + t_s)} \times 10^{-3} \text{ N/mm}^2$$

where

k_S = aspect ratio correction factor
= 0,32 A_R + 0,36 for $A_R \leq 2$
= 1,0 for $A_R > 2$

A_R = panel length/panel breadth

t_c and t_s are as defined in 1.5.1.

The allowable shear stress limits against core shear failure indicated in Ch 7,3.5.1. are to be complied with. For the purposes of this comparison it is assumed that the stated shear properties of the proposed core material have been determined by use of the four point sandwich beam bending test ASTM C393 or equivalent.

1.13.10 Where the core shear stress, τ_c, determined from 1.13.9 is in excess of the limiting stress for a particular core material, the effective shear strength of the core material in the direction of the panel breadth, may be increased by the addition of shear ties. The effective shear strength, τ_{eff}, of the core material is to be determined from:

$$\tau_{eff} = \tau_c + \left(\frac{t_t}{s_t} \times \tau_t\right) \text{ N/mm}^2$$

where

τ_{eff} = effective shear strength of the core material, in N/mm^2

τ_c = shear strength of basic core material, in N/mm^2

t_t = thickness of shear tie material, in mm

τ_t = ultimate shear strength of the shear tie material, in N/mm^2

s_t = spacing or mean spacing of the shear ties, in mm, *see also* 1.13.11.

1.13.11 Where shear ties are to be fitted, the maximum spacing between the shear ties is to be not greater than the maximum panel breadth that can be achieved with the basic core material. Shear ties are also, in general, to be fitted in the sandwich structure beneath primary longitudinal members.

1.13.12 Shear ties fitted between the sandwich skins are to be angled at 45°. The width of shear tie bonding to the sandwich skins is to be 2,5t_c or 50 mm whichever is the greater, *see* Fig. 3.1.3.

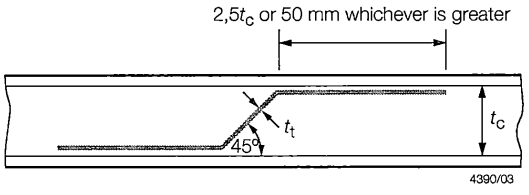

Fig. 3.1.3 Arrangement of shear ties

1.13.13 Shear ties may also be fitted between the webs of deep floors, transverses, girders and other primary stiffening members of top-hat type section. Such shear ties are to be spaced in accordance with the requirements of 1.16.2 and are to have a thickness of $t_w/3$ or 2 mm whichever is the greater, *see also* Ch 2,5.19.1 and LR's *Guidance Notes for Structural Detail*.

1.13.14 Where the Poisson's ratio, ν_f, for a particular facing laminate is known, the deflection, δ, of a flat sandwich panel with all edges assumed to be fully fixed, and subjected to a uniform lateral pressure is to be determined from:

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$$\delta = \frac{p\,b^2}{8t_c}\left(\frac{b^2(1-\nu_f^2)}{24E_{ms}\,t_s\,t_c} + \frac{1}{G}\right) \times 10^{-3} \text{ mm}$$

where the mean skin modulus, E_{ms}, is given by:

$$E_{ms} = \frac{\Sigma\,(E_p\,t_s)}{\Sigma\,t_s} \text{ N/mm}^2$$

E_p is E_{tp} or E_{cp} whichever is the lesser.

where

ν_f, p, b, t_c, t_s, E_{tp}, E_{cp} and G are as defined in 1.5.1 and E_{ms} is the mean modulus of the total skin thicknesses.

1.13.15 Where the Poisson's Ratio, ν_f, for a particular facing laminate is not known, the deflection, δ, of a flat sandwich panel with all edges assumed to be fully fixed, and subjected to a uniform lateral pressure is to be estimated from:

$$\delta = \frac{p\,b^2}{8t_c}\left(\frac{b^2}{24E_{ms}\,t_s\,t_c} + \frac{1}{G}\right) \times 10^{-3} \text{ mm}$$

where

δ, p, b, t_c, t_s, and G, are as defined in 1.5.1

E_{ms} is as defined in 1.13.14.

1.13.16 The deflection determined from 1.13.14 or 1.13.15, as appropriate, is not to exceed the limiting deflection for the structural element under consideration, as indicated in Table 7.2.1 in Chapter 7.

1.14 Stiffeners general

1.14.1 Unless otherwise specified elsewhere in this Part, the Rule bending moment, M_s, to be applied to all stiffening members subjected to uniform lateral pressure is to be determined from:

$$M_s = \phi_M\,s\,l_e^2\,p \text{ Nm}$$

where

ϕ_M = bending moment coefficient as given in Table 3.1.5.

1.14.2 Unless otherwise specified elsewhere in this Part, the Rule shear force, F_s, to be applied to all stiffening members subjected to uniform lateral pressure is to be determined from:

$$F_s = \phi_s\,p\,s\,l_e \text{ N}$$

where

ϕ_S = shear force coefficient as given in Table 3.1.5.

1.14.3 The shear stress, τ_S, in the webs of stiffening members of 'top-hat' type section is to be determined from:

$$\tau_S = \frac{F_S}{2t_w\,d_W} \text{ N/mm}^2$$

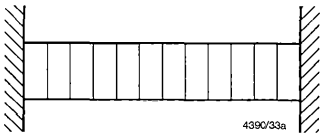
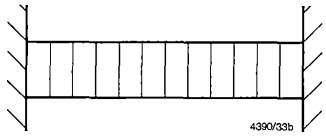
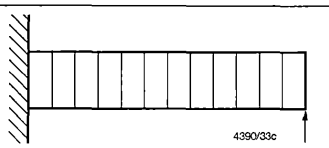
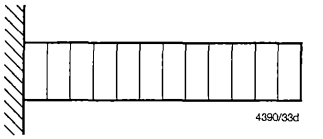
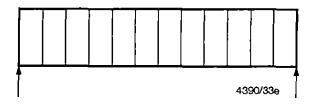
where

F_S = shear force applied to the stiffening member, in *N*, as detailed in 1.14.2

t_W = stiffening member web thickness, in mm

d_W = stiffening member web depth, in mm. (Account is to be taken of the increased effective depth of web where the webs are inclined)

Table 3.1.5 Shear force, bending moment and deflection coefficients

Load model	Position 1	Position 2	Position 3	Position	Shear force, ϕ_S	Bending moment, ϕ_M	Deflection, ϕ_δ	Application
(a)	 4390/33a			1 2 3	1/2 — 1/2	1/12 1/24 1/12	— 1/384 —	Primary and other members where the end fixity is considered encastre
(b)	 4390/33b			1 2 3	1/2 — 1/2	1/10 1/10 1/10	— 1/288 —	Local, secondary and other members where the end fixity is considered to be partial
(c)	 4390/33c			1 2 3	5/8 — 3/8	1/8 9/128 —	— 1/185 —	Various
(d)	 4390/33d			1 2 3	1 — —	1/2 — —	— — 1/8	Various
(e)	 4390/33e			1 2 3	1/2 — 1/2	— 1/8 —	— 5/384 —	Hatch covers, glazing and other members where the ends are simply supported

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The maximum allowable shear stress is not to exceed that determined from Table 7.3.1 in Chapter 7, for the stiffener member under consideration.

1.14.4 The shear stress, τ_S, in the webs of stiffening members of inverted angle or 'T bar' type section is to be determined from:

$$\tau_S = \frac{F_S}{t_W d_W} \text{ N/mm}^2$$

where

F_S, t_W and d_W are as defined in 1.14.3.

The maximum allowable shear stress is not to exceed that determined from Table 7.3.1 in Chapter 7, for the stiffener member under consideration.

1.14.5 Unless otherwise specified elsewhere in this Part, the deflection, δ_s, of stiffening members, subjected to uniform lateral pressure is to be determined from:

$$\delta_s = \frac{\phi_\delta p s l_e^4}{(E I)_s} \times 10^5 \text{ mm}$$

where

$(EI)_s$ = total EI for the stiffener section including an effective width of attached plating as indicated in 1.7.1, in Ncm^4/mm^2

ϕ_δ = deflection coefficient as defined in Table 3.1.5

s, l_e, E, I and p are as defined in 1.5.1.

1.14.6 The maximum allowable deflection is not, in general, to exceed that determined from Table 7.2.1 in Chapter 7 for the stiffener member under consideration.

1.15 Geometric properties stiffener sections

1.15.1 The effective geometric properties of the stiffener sections are to be calculated directly from the dimensions of the section and associated effective width of attached plating in accordance with 1.7. Where the mean line of the stiffener webs is not normal to the attached laminate, and the angle exceeds 20°, the properties of the section are to be determined about an axis parallel to the attached plate laminate. Where plywood, solid timber, aluminium alloy, steel or other materials are integrated into a stiffening member, the effectiveness of the material is to be determined in accordance with 1.20.3. The stress in the individual material is to be limited to the allowable strain associated with the constituent material.

1.15.2 The distance of the neutral axis, x_S, from the outer surface of the plate laminate is to be determined from:

$$x_S = \frac{\Sigma (E_i t_i b_i x_i)}{\Sigma (E_i t_i b_i)} \text{ mm}$$

where

E_i, t_i, b_i and x_i are as defined in 1.5.1.

1.15.3 The resultant extreme fibre tensile stress for an individual ply, σ_{ti}, is to be determined from:

$$\sigma_{ti} = \frac{0{,}1 E_{ti} y_i M}{\Sigma (EI)_s} \text{ N/mm}^2$$

where

σ_{ti}, E_{ti}, y_i, M, E_i and I_i are as defined in 1.5.1.

The term $(EI)_s$ refers to the whole stiffener section, i.e. including the attached plating in accordance with 1.7. *See also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*.

1.15.4 The resultant extreme fibre compressive stress for an individual ply, σ_{ci}, is to be determined from:

$$\sigma_{ci} = \frac{0{,}1 E_{ci} y_i M}{\Sigma (EI)_s}$$

where

σ_{ci}, E_{ci}, y_i, M, E_i and I_i are as defined in 1.5.1.

The term $(EI)_s$ refers to the whole stiffener section, i.e. including the attached plating in accordance with 1.7. *See also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*.

1.16 Stiffener proportions

1.16.1 From structural stability and local buckling considerations, the proportions of stiffening members are, in general, to be in accordance with the requirements of this Section.

1.16.2 The thickness of the web for 'top-hat' type stiffeners, t_w, is to be not less than that required to satisfy the web shear from 1.14.3 and 1.14.4, and in no case is to be taken as less than that determined from the following formula:

$$t_w = \frac{0{,}025 d_w + 1{,}1}{1{,}3 f_w + 0{,}61} \text{ mm}$$

where

d_w = unsupported web depth, in mm

f_w = fibre content, by weight, of the web laminate.

1.16.3 The thickness of the web of an inverted angle or 'T' bar stiffener section is to be twice the web thickness determined from 1.16.2.

1.17 Determination of span points

1.17.1 The effective span, l_e, of a stiffening member is generally less than the overall length, l, by an amount which depends on the design of the end connections. The span points, between which the value of l_e is measured, are to be determined from:

(a) For secondary stiffening members of top-hat type section as shown in Fig. 3.1.4(a) the span point is to be taken at the point where the depth of the end bracket, measured from the face of the secondary stiffening member is equal to the depth of the member. Where there is no end bracket, the span point is to be measured between primary member webs.

(b) For primary stiffening members of top-hat type section as shown in Fig. 3.1.4(b) the span point is to be taken at the point where the depth of the end bracket, measured from the face of the primary stiffening member is equal to the half depth of the member. Where there is no end bracket, the span point is to be measured between primary member webs.

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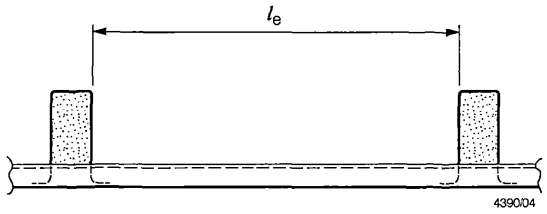

Fig. 3.1.4(a) Span points

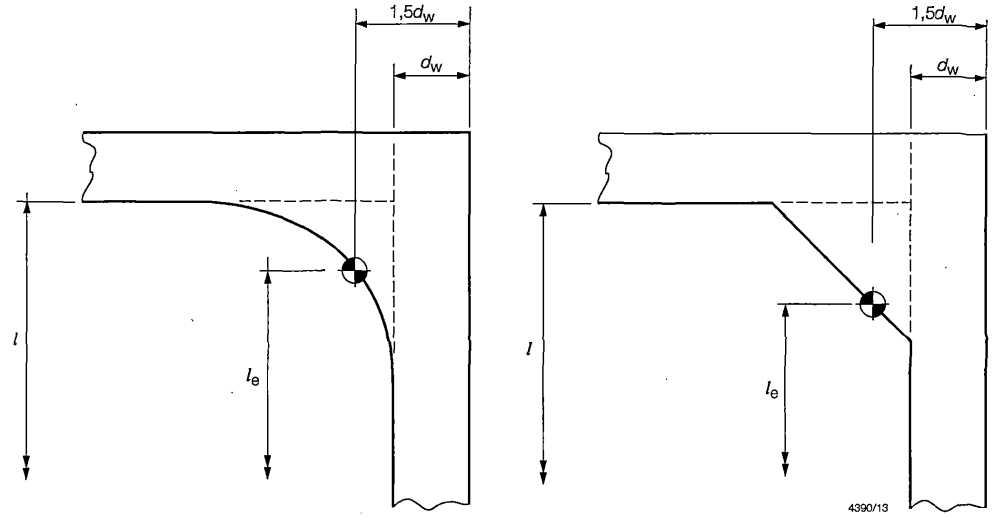

Fig. 3.1.4(b) Span points

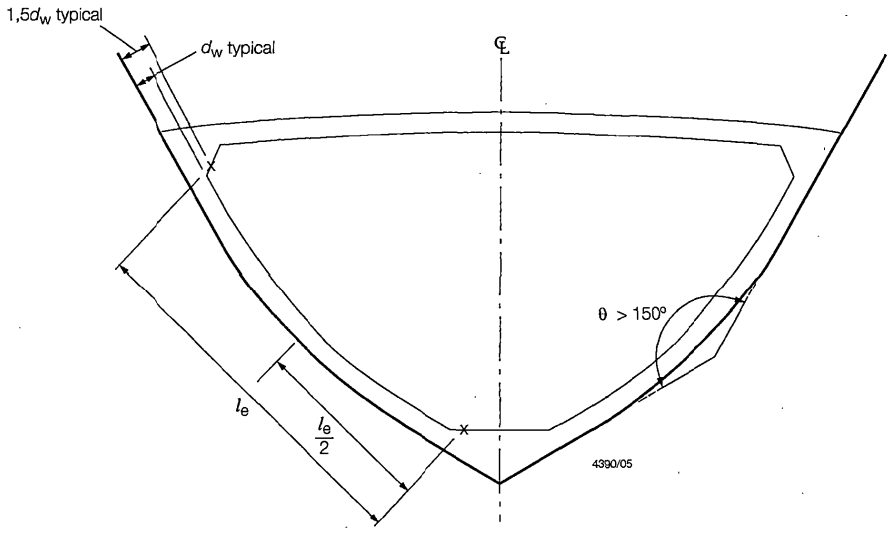

Fig. 3.1.4(c) Span points

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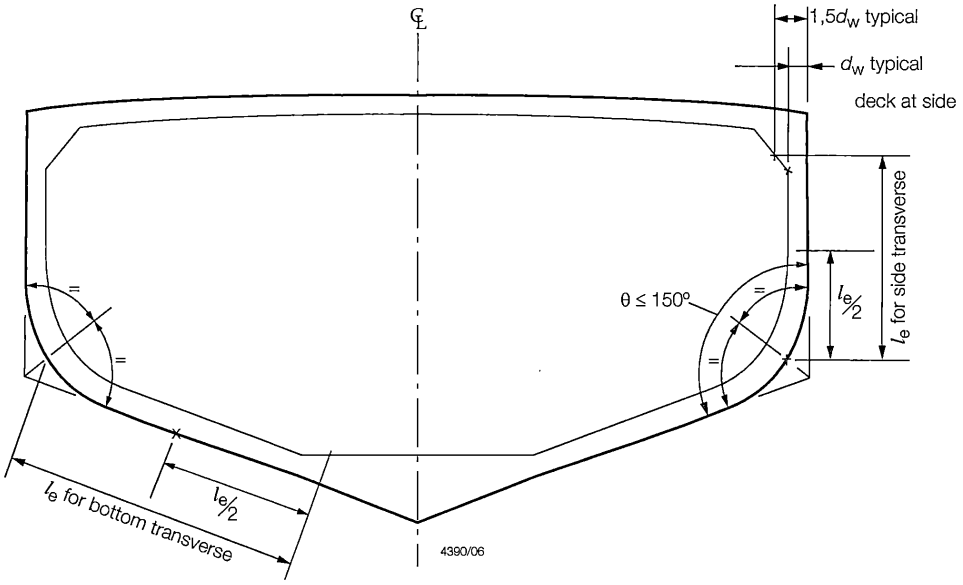

Fig. 3.1.4(d) Span points

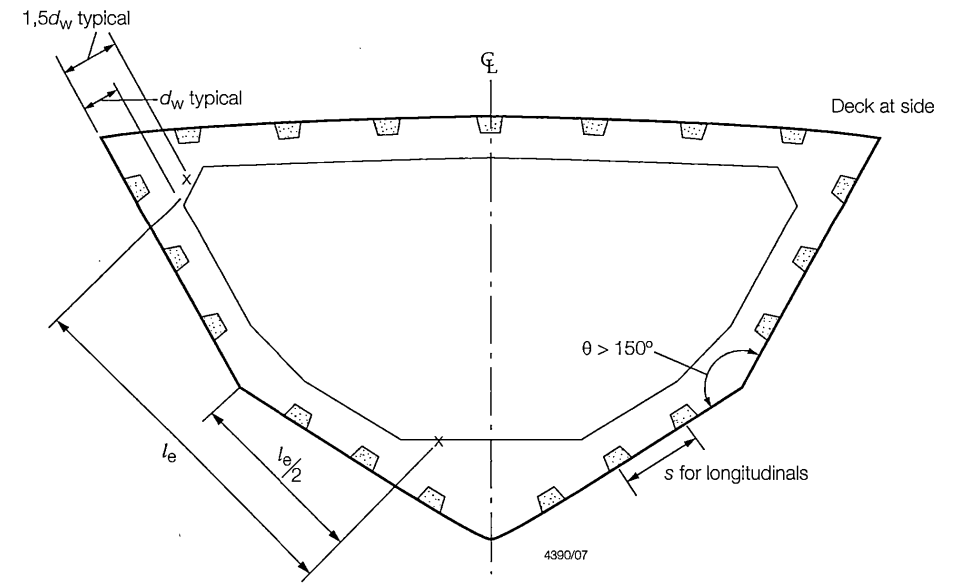

Fig. 3.1.4(e) Span points

1.17.2 Where the stiffener member is inclined to a vertical or horizontal axis and the inclination exceeds 10°, the span is to be measured along the member.

1.17.3 Where the stiffening member is curved then the span is to be taken as the effective chord length.

1.17.4 Where there is a pronounced turn of bilge, chine or the structure is significantly pitched, the span is to be measured as in Fig. 3.1.4(c) to (f).

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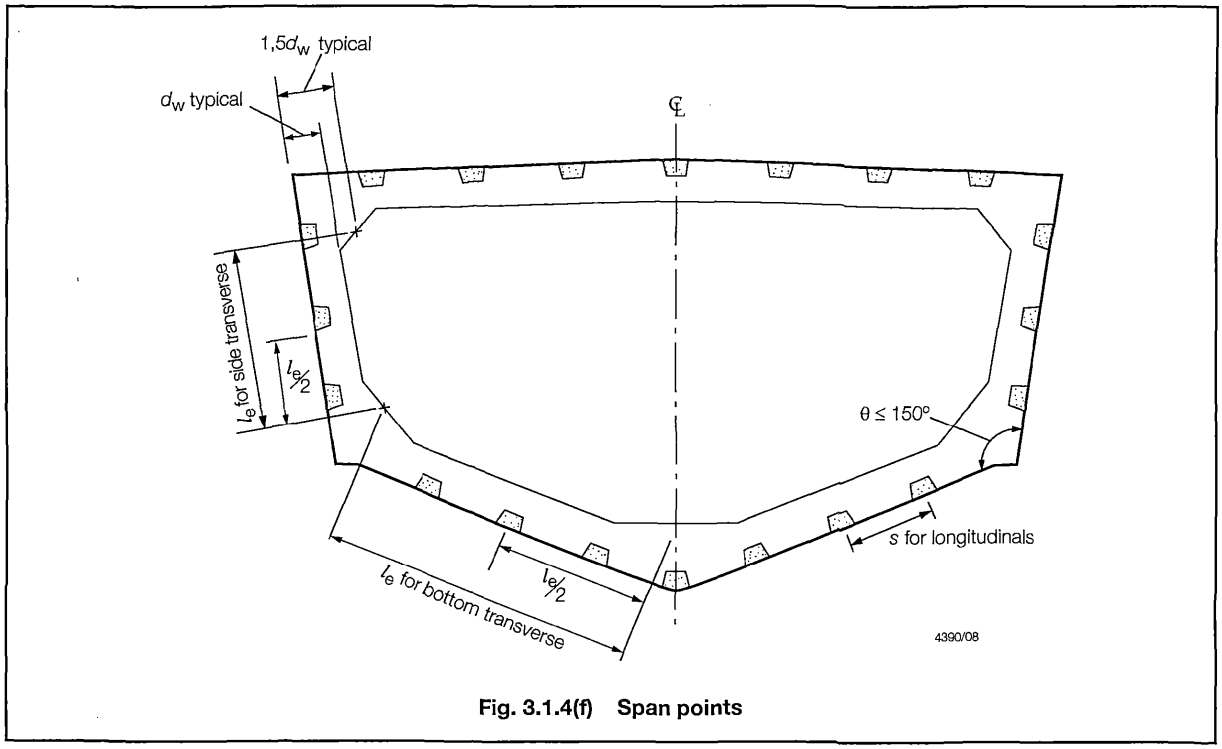

Fig. 3.1.4(f) Span points

1.17.5 The determined effective span assumes that the ends of stiffening members are substantially fixed against rotation and displacement. If the arrangement of supporting structure is such that this condition is not achieved, the span is to be determined excluding any effect from the end brackets.

1.18 Boundary bonding

1.18.1 The connection of the various laminates into assemblies and the connection of units to the main structure is generally to be made by means of single or double angles of the type shown in Fig. 3.1.5.

1.18.2 These matting-in angles are to be formed by layers of reinforcements, laid-up *in situ*, and normally secondary bonded to the structure before the laminates are advanced in cure. Where the laminating schedule is such that this cannot be achieved then suitable peel plies and secondary bonding techniques, as recommended by the resin manufacturer, *see* Ch 2,5.9, are to be arranged in way of the surfaces to be connected.

1.18.3 All surfaces to be bonded are to be clean and suitably prepared prior to the application of the bonding angles. Suitable fillets of compliant resin are to be arranged as shown in Figs. 3.1.6 and 3.1.7.

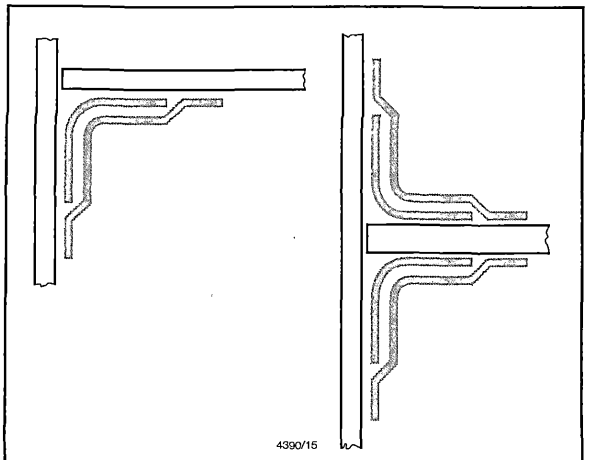

Fig. 3.1.5 Bonding angles

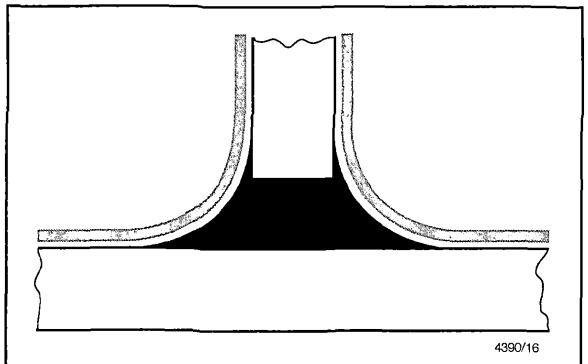

Fig. 3.1.6 Resin fillets

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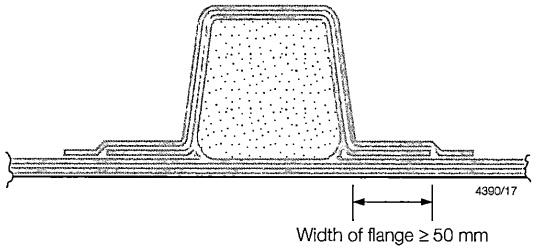

Fig. 3.1.7 Width of bonding angle

1.18.4 Where floors, bulkheads, tank boundaries, etc., are manufactured from plate laminate the weight of the laminate forming each angle is to be not less than 50 per cent of the weight of the lighter member being connected, or 900g/m^2 chopped fibre reinforcement or equivalent, whichever is the greater.

1.18.5 Double angles are normally to be used, but when this is not possible, such as where satisfactory access cannot be achieved on the reverse side, a single angle can be used provided it is suitably increased in width and weight. The weight of a single bonding angle is to be determined by direct calculation, and in no case to be taken as less than two thirds the weight of the lighter laminate being connected or 900 g/m^2 chopped fibre reinforcement or equivalent, whichever is the greater.

1.18.6 Where frames and stiffeners are of the 'top-hat' type, the width of the flange connection to the plate laminate is to be as shown in Fig. 3.1.7. The width of bonding angle is to be 25 mm for the first layer + 15 mm per each additional layer, but not less than 50 mm.

1.18.7 Where sandwich panels are to be connected the weight of bonding is to be not less than the weight of the appropriate skin. The inner and outer skins of primary sandwich structures such as bulkheads are to be effectively 'tied' by a suitable weight of reinforcement or by use of fillets and wedges of suitable compliant resin, as shown in Fig. 3.1.8.

1.18.8 Where the floors, bulkheads, etc., are manufactured from plywood the weight of the laminate forming each angle is to be not less than 50 per cent of the weight of the equivalent thickness of bulkhead in the material used for the bonding angle or the lighter member being connected.

1.18.9 In no case is the thickness of the double bonding angle to be less than 2 mm at a glass content, by weight, of 0,5. Where a glass content is less than 0,5, the thickness is to be not less than that required to resist the same shear force using the formulae in Tables 3.1.1 and 3.1.2.

1.18.10 Alternative bonding arrangements incorporating epoxy fillets, bonded wedges, bolting, etc., may be specially considered. It is however the responsibility of the Builder to demonstrate their suitability and equivalence to the Rule requirements.

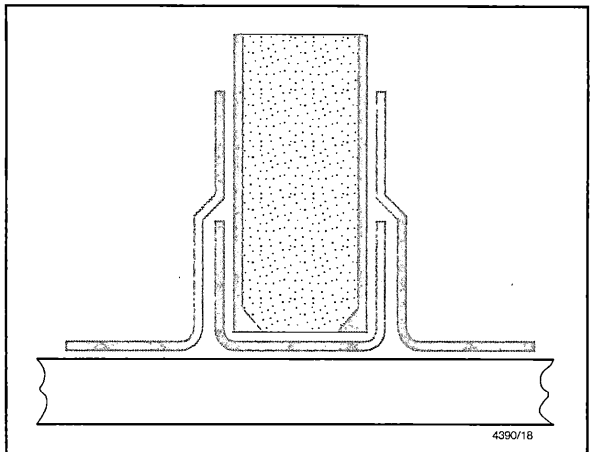

Fig. 3.1.8 Bonding ties

1.19 Timber

1.19.1 It is presumed that, in the selection of the species of timber for a particular application, the designers will relate the known characteristics, strength, density, bending and working capabilities of the particular species to the constructional design. The mechanical properties of timbers and assumptions used for design purposes are to be clearly indicated on the submitted construction plans, *see also* Ch 2,2.17 and 1.15.1.

1.19.2 All timbers are to be identified by their botanical name.

1.19.3 The moisture content of timber which is to be glued, bonded or overlaminated is to be about 15 per cent, *see also* Ch 2,2.17.

1.20 Plywood

1.20.1 Structural plywoods are to comply with Ch 2,2.17, *see also* Ch 2,2.16.3.

1.20.2 The mechanical properties of the plywood proposed for use in structural applications is to be obtained from the plywood manufacturer and submitted for consideration. In the absence of such data LR will estimate the mechanical properties based upon the recognised minimum expected strengths for the particular materials.

1.20.3 Where stiffeners incorporate encapsulated plywood structurally bonded to the plate laminate in accordance with 1.18.8, its effective $E_i I_i$ is to be incorporated into the $\Sigma (E_i I_i)$ as indicated in 1.15, with the basic thickness and tensile/compressive moduli of the plywood being taken as those corresponding to the least effective over the span of the stiffener. Directional considerations for structural plywood incorporated in stiffening members are to be indicated on construction plans submitted for appraisal.

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1.21 Aluminium alloy

1.21.1 The use of aluminium alloy is permitted for craft in accordance with Part 7. Where this material is to be integrated structurally, with the fibre composite structure, *see* Ch 2,2.15 and 1.15.1.

1.22 Steel

1.22.1 The use of steel is permitted for craft in accordance with Part 6. Where this material is to be integrated structurally, with the fibre composite structure, *see* Ch 2,2.15 and 1.15.1.

1.23 Other materials

1.23.1 Special consideration will be given to the use of other types of materials. Details of the type of material, the specification to which it was manufactured and its mechanical properties are to be submitted for appraisal, *see also* 1.15.1.

1.24 Secondary member end connections

1.24.1 Secondary members, i.e. longitudinals, beams, frames and bulkhead stiffeners forming part of the hull structure are, in general, to be connected at their ends in accordance with the requirements of this Section. Where it is desired to adopt bracketless connections, the proposed arrangements will be individually considered on the basis of 1.17.5.

1.24.2 Where end connections are fitted in accordance with these requirements, they may be taken into account in determining the effective span of the member.

1.24.3 Where a longitudinal strength member is cut at a primary support and the continuity of strength is provided by brackets, the scantlings of the brackets are to be such that their section properties and effective cross-sectional area are not less than those of the member. Care is to be taken to ensure correct alignment of the brackets on each side of the primary member.

1.24.4 The thickness of the bracket webs is to be not less than that required for the webs of the stiffening member. *See* 1.14.

1.24.5 The arrangement of the connection between the stiffener and the bracket is to be such that at no point in the connection are the properties reduced to less than that of the stiffener with associated plating.

1.24.6 The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint.

1.24.7 Hard spots are to be avoided in way of end connections.

1.25 Scantlings of end brackets

1.25.1 Secondary members, i.e. longitudinals, beams, frames and bulkhead stiffeners forming part of the hull structure, are generally to be connected at their ends in accordance with the requirements of this Section. Where it is desired to adopt bracketless connections, the proposed arrangements will be individually considered.

1.25.2 Where end connections are fitted in accordance with these requirements, they may be taken into account in determining the effective span of the member.

1.25.3 The symbols used in this sub-Section are defined as follows:

t_w = the thickness of the bracket web, in mm

EI = section stiffness of the secondary member, in Ncm^4/mm^2

1.25.4 Typical arrangements of stiffener end brackets are shown diagrammatically in Fig. 3.1.9.

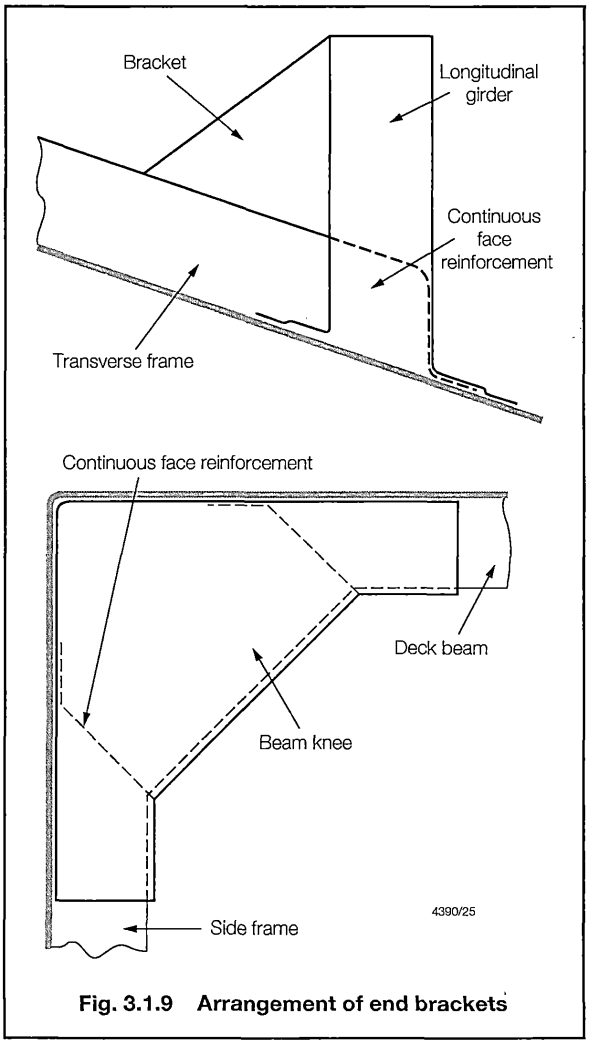

Fig. 3.1.9 Arrangement of end brackets

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1.25.5 The section stiffness, (*EI*), in way of the bracket at the point to which the effective span of the stiffener, l_e, is measured is to be not less than two times the section stiffness of the basic stiffener.

1.25.6 The web thickness, t_w, and face width of end brackets are to be not less than that of the connecting stiffeners. Additionally the requirements of 1.16 are to be complied with.

1.25.7 Where brackets are of the inverted angle or 'T' bar stiffener section, their free edge is to be suitably stiffened by a flange or other equivalent means. The dimensions of the flange are to be such that the requirements of 1.16 are complied with.

1.25.8 Where the free edge of the bracket is hollowed out to form a 'soft-toe', the dimensions of the bracket arms and throat depth are to be increased such that the stiffness requirements of 1.16 are complied with.

1.26 Primary member end connections

1.26.1 Primary members are to be so arranged as to ensure effective continuity of strength, and abrupt changes of depth or section are to be avoided. Where members abut on both sides of a bulkhead, or on other members, arrangements are to be made to ensure that they are in alignment. Primary members in tanks are to form a continuous line of support and wherever possible, a complete ring system.

1.26.2 The members are to have adequate lateral stability and web stiffening and the structure is to be so arranged as to minimise hard spots and other sources of stress concentration.

1.26.3 Primary members are to be provided with adequate end fixity by end brackets or equivalent structure. The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint and effective distribution of the load from the member.

1.26.4 Where the primary member is supported by structure which provides only a low degree of restraint against rotation, the member is generally to be extended for at least two frame spaces, or equivalent, beyond the point of support before being tapered.

1.26.5 Where primary members are subject to concentrated loads, particularly if these are out of line with the member web, additional strengthening will, in general, be required.

1.26.6 The thicknesses of the bracket webs are, in general, to be not less than those of the primary member webs. Where brackets are of the plate type, the free edge of the bracket is to be adequately stiffened and the plate positioned to limit any hard spot.

1.26.7 Where a deck girder or transverse is connected to a vertical member on the shell or bulkhead, the scantlings of the latter may be required to be increased to provide adequate stiffness to resist rotation of the joint.

1.26.8 Where a member is continued over a point of support, such as a pillar or pillar bulkhead stiffener, the design of the end connection is to be such as to ensure the effective distribution of the load into the support. Proposals to fit brackets of reduced scantlings, or alternative arrangements, will be considered.

1.26.9 Connections between primary members forming a ring system are to minimise stress concentrations at the junctions. Integral brackets are generally to be radiused or well rounded at their toes. The arm length of the bracket, measured from the face of the member, is to be not less than the depth of the smaller member forming the connection.

1.27 Arrangements and details

1.27.1 The arrangement of the connection between the stiffener and the bracket is to be such that at no point in the connection is the section stiffness (*EI*), reduced to less than that of the stiffener with associated plating.

1.27.2 The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint.

1.28 Web stability

1.28.1 Primary members of 'top-hat' or single plate laminate construction type section are to be supported by tripping brackets at, in general, four for top hat and alternate frame spacings for plate, of secondary stiffening members respectively.

1.29 Openings in the webs of stiffening members

1.29.1 Where openings are cut in the webs of stiffening members, the depth of the opening is not to exceed 50 per cent of the web depth, and the opening is to be so located that the edges are not less than 25 per cent of the web depth from the face laminate. The length of opening is not to exceed the web depth or 60 per cent of the secondary member spacing, whichever is the greater, and the ends of the openings are to be equidistant from the corners of cut-outs for secondary members. Where larger openings are proposed, the arrangements and compensation required will be specially considered.

1.29.2 Openings are to have smooth edges and well rounded corners. Exposed edges in way of cut-outs in single skin/plate laminate are to be suitably sealed with resin and/or be over laminated. Exposed edges in way of cut-outs in sandwich panels and top hat type stiffening members are to be overlaminated with a weight of laminate not less than the lower of the two skins which form the panel (or stiffener) or 2 mm in thickness whichever is the greater.

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1.29.3 Cut-outs for the passage of secondary members are to be arranged so as to minimise the creation of stress concentrations. To avoid excessive use of filler material the breadth of cut-out is to be kept as small as necessary and the fit as accurate as practicable. Suitable fillets are to be arranged to ensure efficient bonding.

1.29.4 Consideration is to be given to the provision of adequate drainage and unimpeded flow of air and water when designing the cut-outs and connection details.

1.30 Continuity and alignment

1.30.1 The arrangement of material is to be such as will ensure structural continuity. Abrupt changes of shape or section, sharp corners and points of stress concentration are to be avoided.

1.30.2 Where members abut on both sides of a bulkhead or similar structure, care is to be taken to ensure good alignment.

1.30.3 Pillars and pillar bulkheads are to be fitted in the same vertical line wherever possible, and elsewhere arrangements are to be made to transmit the out of line forces satisfactorily. The load at head and heel of pillars is to be effectively distributed and arrangements are to be made to ensure the adequacy and lateral stability of the supporting members.

1.30.4 Continuity is to be maintained where primary members intersect and where the members are of the same depth, *see also* LR's *Guidance Notes for Structural Details*.

1.30.5 End connections of structural members are to provide adequate end fixity and effective distribution of the load into the supporting structure.

1.30.6 The toes of brackets, etc., are not to land on unstiffened panels of plating. Special care is to be taken to avoid notch effects at the toes of brackets, by making the toe concave or otherwise tapering it off in accordance with Fig. 3.4.1 in Chapter 3.

1.31 Arrangements at intersection of continuous secondary and primary members

1.31.1 Cut-outs for the passage of secondary members through the webs of primary members, and the related bonding arrangements, are to be so designed as to minimise stress concentrations around the perimeter of the opening and in the attached hull envelope or bulkhead plating. The critical shear buckling stress of the panel in which the cut-out is made is to be examined. Longitudinals will be required to have double bonding angles which may require to be locally increased in weight in areas of high stress, such as under bulkheads, machinery seating, mast steps, etc. The increased shear stresses in these areas are to be examined.

1.31.2 It is recommended that the web plate connection to the hull envelope, or bulkhead end in a smooth tapered 'soft toe'. Recommended shapes of cut-out are shown in Fig. 3.4.1, but consideration will be given to other shapes on the basis of maintaining equivalent strength and minimising stress concentration.

1.31.3 Alternative arrangements will be considered on the basis of their ability to transmit load with equivalent effectiveness. Details of the calculations made and testing procedures are to be submitted.

■ *Section 2* Minimum thickness requirements

2.1 General

2.1.1 Structural laminates, used for both single skin and sandwich construction are, in general, to incorporate not less than 40 per cent, by weight, of woven or cross-ply reinforcement.

2.2 Single skin laminate

2.2.1 The minimum thicknesses of single skin laminates are as indicated in the appropriate Sections.

2.3 Sandwich skin laminate

2.3.1 The minimum thicknesses of single skin laminates which form the inner and outer skins of sandwich panels are as indicated in the appropriate Sections. Where the structural requirements for thickness of either the bottom shell outer skin, or inner skin in way of an integral tank, is less than 4,5 mm, the acceptance of thicknesses down to a minimum of 3,5 mm will be subject to a vacuum test to demonstrate the watertight integrity and also an impact test for impact resistance of the laminate, *see* 2.8.2.

2.4 Laminate thickness of single and sandwich skin laminates

2.4.1 The Rule minimum skin thicknesses as determined from the appropriate Sections of the Rules are to be corrected for craft type irrespective of the reinforcement being used; the corrected minimum skin thickness of side, bottom, transom, wet-deck, vehicle deck and weather decks is to be determined from:

Single skin laminates:

$$t_T = \omega\, t_{min}$$

Sandwich skin laminates:

$$t_{min} = 2\omega$$

where

ω = Service Type Correction Factor given in Table 3.2.1

t_T = Rule minimum thickness corrected for craft type, in mm.

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Table 3.2.1 Service type correction factor (ω)

Service type notation	ω
Cargo	1,1
Passenger	1,00
Patrol	1,00
Pilot	1,1
Yacht	1,00
Workboat – Motor fishing vessel	1,2

2.4.2 All minimum thicknesses of laminate for both stiffener and laminate components are based on an assumed fibre content, f_c, of 0,5. Where the fibre content by weight, f_c, is less than 0,5, the required minimum thicknesses are to be determined from:

$$t_{fc} = t_{0,5}\,(1,65 - 1,3f_c) \text{ mm}$$

where

t_{fc} = minimum thickness at actual laminate fibre content, in mm

$t_{0,5}$ = Rule basic minimum laminate thickness at fibre content, by weight, of 0,5.

2.4.3 The equation in 2.4.2 relates to polyester 'E' glass laminates. Other laminates will be considered on an equivalence basis.

2.5 Integral tank structure

2.5.1 The minimum thickness of laminate for all stiffening members passing through, or forming the boundary of integral oil fuel and water tanks is to be not less than 4,5 mm irrespective of fibre content.

2.5.2 Where the boundaries of integral oil fuel and water tanks are of sandwich skin construction the minimum thickness of the laminate providing the fluid barrier, without satisfactory material testing, is to be not less than 4,5 mm, *see* 2.3.1.

2.5.3 Where the boundaries of integral oil fuel and water tanks are of single skin construction, in no case is the tank laminate thickness, determined in accordance with 7.4, to be less than 5,0 mm irrespective of fibre content.

2.6 Local reinforcement

2.6.1 The hull and deck are to be locally increased in thickness in way of fittings for rudder tubes, propeller brackets, passenger routes, vehicle lanes, etc. The increase in thickness is to be not less than 50 per cent of the thickness of the adjacent plate laminate. Details of such reinforcement are to be submitted for consideration, *see also* Ch 2,3.9.

2.6.2 Local reinforcement is in general to extend under the adjacent supporting structure and then be tapered gradually to the base laminate thickness over a distance not less than 20 times the difference in thickness, *see* Fig. 3.2.1.

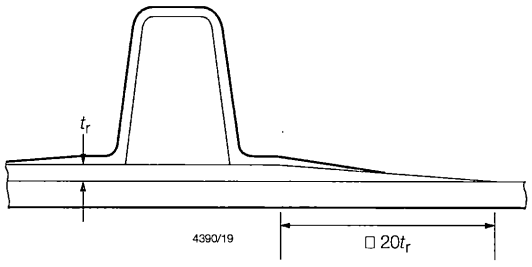

Fig. 3.2.1 Arrangement of local reinforcement

2.6.3 The amount of material laid 'wet on wet' is to be limited to avoid excessive heat generation.

2.6.4 Where a superstructure is fitted, the side shell plating, in way of the end of the superstructure, may be required to be increased in thickness.

2.7 Novel features

2.7.1 Where the Rules do not specifically define the requirements for novel features, the scantlings and arrangements are to be determined by direct calculations. Such calculations are to be carried out on the basis of the Rules, Recognised Standards and good practice, and are to be submitted with the relevant construction plans for appraisal, *see also* Ch 1,2.6.

2.8 Impact considerations

2.8.1 Due consideration is to be given to the scantlings of all structures which may be subject to local impact loadings. Impact tests may be required to be carried out at the discretion of LR to demonstrate the suitability of the proposed scantlings for a particular application.

2.8.2 The minimum skin thickness requirements may, subject to the agreement of LR, be reduced provided that suitable impact tests are carried out to demonstrate that the proposed laminates have not less than the equivalent impact resistance to that of a laminate which satisfies the Rule minimum thickness. In addition it is assumed that this reduced laminate satisfies the structural strength and deflection requirements of the Rules.

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2.9 Sheathing

2.9.1 Areas of shell and deck which are subject to additional wear by abrasion e.g. passenger routes, working areas of fishing craft, forefoot region, etc, are to be suitably protected by local reinforcement or sheathing. This sheathing may be of timber, rubber, steel, additional layers of reinforcement, etc., as appropriate. Details of such sheathing and the method of attachment are to be indicated on the relevant construction plans submitted for appraisal.

2.9.2 The attachment of sheathing by mechanical means such as bolting or other methods is not to impair the structural integrity of the laminate or the watertight integrity of the craft. Through bolting of the hull is to be kept to a minimum and avoided where practicable. The design arrangements in way of any through bolting is to be such that damage to the sheathing will not impair the watertight integrity of the attachment to the hull.

■ *Section 3*
Shell envelope laminate

3.1 General

3.1.1 The requirements in respect of the general plating elements of the shell envelope, excluding the deck, are contained within this Section.

3.2 Keel plate

3.2.1 The width, b_K, and thickness, t_K, of plate keels are not to be taken as less than:

$b_K = 7{,}0L_R + 340$ mm

$t_K = \sqrt{k_t}\ (5{,}0L_R^{0{,}45})$ mm

where

$k_t = \dfrac{152}{\sigma_f}$

L_R = Rule length, in metres, as defined in 1.5.1

σ_f = ultimate flexural strength of the keel plate material, in N/mm^2, *see* 1.12.6.

3.2.2 In no case is the thickness of the keel to be less than that of the adjacent bottom shell plating.

3.2.3 The width and thickness of plate keels are to be maintained throughout the length of the craft from the transom to a point not less than 25 per cent of the freeboard measured at the forward perpendicular (FP), above the deepest load waterline on the stem. Thereafter the keel thickness may be reduced to that required by 3.3 for the stem. Laminate tapers are to be in accordance with Ch 2,3.9.

3.2.4 Where the bottom shell is of sandwich construction the keel is, in general, to be formed by locally returning to single skin construction for a width as required by 3.2.1. The Rule thickness of keel is to comprise both the inner and outer skins of the adjacent bottom shell sandwich plus additional reinforcement as required. The distribution of reinforcement in way of the plate keel and sandwich bottom structure is to be in accordance with Fig. 3.3.1.

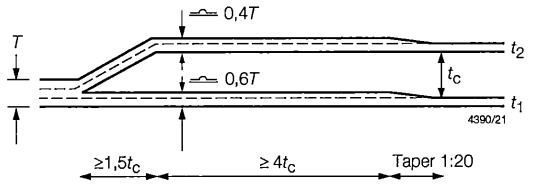

Fig. 3.3.1
Single skin/sandwich skin intersection detail

3.2.5 For large or novel craft, or yachts with externally attached ballast keels, or where it is proposed to incorporate keels of the 'bar' type the scantlings of the keel will be specially considered.

3.3 Stem plate

3.3.1 The thickness of the plate stem, t_s, is not to be taken as less than that given by the following expression:

$t_s = \sqrt{k_t}\ (0{,}29L_R + 9)$ mm

where

k_t = as defined in 3.2.1

L_R = Rule length, in metres, as defined in 1.5.1

σ_f = ultimate flexural strength of the stem plate material, in N/mm^2, *see* 1.12.6.

3.3.2 In no case is the thickness of the plate stem to be taken as less than the thickness of the adjacent side shell plating.

3.3.3 The width of the plate stem is to be not less than the width of keel as required by 3.2.1.

3.3.4 Plate stems are to be supported by horizontal diaphragms and, where the stem radius is large, a centreline stiffener or web may be required.

3.3.5 Where the side shell is of sandwich construction the stem is to be formed by locally returning to single skin construction for a width as required by 3.2.1. The Rule thickness of stem is to comprise both the inner and outer skins of the adjacent side shell sandwich plus additional reinforcement as required. The distribution of reinforcement in way of the plate stem and sandwich bottom structure is to be in accordance with Fig. 3.3.1.

3.3.6 For large or novel craft, the scantlings of the stem will be specially considered, *see also* 5.11.

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3.4 Bottom

3.4.1 The bending moment assumed to be carried by the bottom shell plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for high speed or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 3.4.2 and 3.4.4 respectively.

3.4.2 An estimate of the thickness of **bottom single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

3.4.3 In no case is the minimum thickness of single skin plating to be taken as less than 5,5 mm.

3.4.4 An estimate of the stiffness *EI*, thickness of single skin plating for outer and inner skins of the **bottom sandwich panel** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

3.4.5 In no case are the minimum thicknesses of laminate which form the skins of a sandwich laminate to be taken as less than 4,5 mm and 3,5 mm for the outer and inner skins respectively, *see also* 2.3.1.

3.4.6 For all craft types, the minimum bottom shell thickness as required by 3.4.3 and 3.4.5 is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

3.4.7 Additionally, for high speed craft, the minimum thickness requirements for the bottom shell between the bilge tangential points or chines and the chine line or 150 mm above the static load waterline, whichever is the greater, is not to be less than determined for the side shell using the side shell impact pressure or the bottom shell hydrostatic or pitching pressures associated with a displacement or semi-displacement type craft whichever is the greater, *see* Fig. 3.3.2.

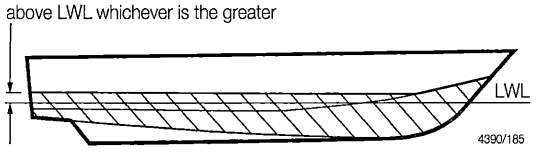

Fig. 3.3.2 Extent of bottom shell

3.4.8 Special consideration may be given to laminate thicknesses lesser than those required by 3.4.2 and 3.4.4, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided, *see* 2.3.1, and the equivalent impact resistance is demonstrated as required by 2.8.2.

3.5 Side

3.5.1 The bending moment assumed to be carried by the side shell plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 3.5.2 and 3.5.4 respectively.

3.5.2 An estimate of the thickness of **side single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

3.5.3 In no case is the minimum thickness of single skin plating to be taken as less than 5 mm.

3.5.4 An estimate of the stiffness *EI*, thickness of single skin plating for outer and inner skins of the **side sandwich panel** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

3.5.5 In no case are the minimum thicknesses of laminate which form the skins of a sandwich laminate to be taken as less than 4 mm and 3 mm for the outer and inner skins respectively.

3.5.6 Special consideration may be given to laminate thicknesses lesser than that required by 3.5.3 and 3.5.5, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided, *see* 2.3.1, and the equivalent impact resistance is demonstrated as required by 2.8.2.

3.6 Sheerstrake

3.6.1 The sheerstrake, is in general, to be taken as the side shell, locally reinforced in way of deck/hull connection and fender attachment. The amount of local reinforcement will be dependent upon the arrangement of structure and the proposed service, but is not to be less than that required by 2.6.

3.6.2 The fendering arrangements for all craft types are the responsibility of the designers/Builders and are outside the scope of classification.

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3.6.3 Where the pressure or impact loadings that a particular type of craft will experience in service are considered by the Builder, or subsequent Owner, to be not covered by, or be greater than, those indicated in Part 5 of the Rules, details of the loadings together with the calculations of how these will be satisfactorily distributed into the craft's structure, are to be submitted for consideration with the relevant construction plans.

3.6.4 The arrangements indicated in 3.6.5, 3.6.6, 4.19.5 and 4.19.6 for pilot and fishing craft are for the guidance of the Builder and subsequent Owners/operators of the craft. Where the intended service for either of these types of craft, or other types of craft which may be subject to loadings resulting from contact with other craft, jetties or similar loading or boarding facilities, is such that the loadings are greater than those that can be satisfactorily distributed into the craft's structure by the arrangements indicated, the strengthening arrangements are to be increased accordingly.

3.6.5 For **pilot craft** and other general workboats which may be subject to repeated impact loadings from contact with other craft, etc., the sheerstrake laminate and stiffening arrangements in way are to be increased locally. An increase in laminate weight of not less than 50 per cent of the side shell laminate weight is to be fitted, extending in general from the bow aft over a distance of $0{,}33L_R$ or 500 mm aft of the point at which the craft reaches its greatest breadth, whichever is the greater, and around the quarters. The additional weight is to extend forward of the quarter and over the transom for a distance of $0{,}075L_R$ or 1,0 m, whichever is the greater. This reinforcement is in general to extend from the deck edge to below the first longitudinal stiffener, or a vertical distance equivalent to 1/3 the freeboard height, whichever is the greater. The additional laminate weight is then to be tapered out to the side shell laminate weight in accordance with the Rules, *see* 3.14.2. For increase in stiffening arrangements, *see* 4.19. Where the side shell is of sandwich construction then in way of the sheerstrake the two skins of the sandwich are to combine and form a single skin. The weight of this single skin is to be the Rule single skin reinforced in accordance with the above or 1,5 times the total sandwich skin laminate weight whichever is the greater. The arrangement and distribution of this additional laminate between the skins in way of the taper is to be in accordance with 3.2.4. Where fendering can be considered to act as a chine/spray rail the extent of bottom shell laminate is, in general, to be to above the lower fender.

3.6.6 **Fishing craft** are, in general, to have their shell laminate as required to satisfy the Rule loadings, increased by 20 per cent. Additionally the side shell is not to be taken as less than the bottom shell weight, and where there are gallows, gantries, nets, or lines, etc., the laminate in way is to be further increased locally and/or suitably protected by sheathing in timber, steel or other means. Where the hull is of sandwich construction in way of the sheerstrake the laminate is to combine to form a single skin as indicated in 3.6.2.

3.6.7 Individual consideration will be given to lesser scantlings than those required by 3.6.3. for fishing craft used for pleasure, light duties, etc. Details of the service are to be submitted for appraisal.

3.7 Transom boundary reinforcement

3.7.1 Additional reinforcement is to be moulded into the transom boundary.

3.7.2 For single skin construction, the total weight of reinforcement is to be not less than twice the weight of the adjacent side shell plate laminate, but need not be greater than Rule keel weight as required by 3.2.

3.8 Chine reinforcement

3.8.1 Additional reinforcement is to be moulded into the chine line knuckle boundary, chines and other areas where there is a change of section.

3.8.2 The chine line knuckle is to be reinforced as required by 3.7 for the transom boundary.

3.8.3 Chine details are to be such that the continuity of structural strength across the panel is maintained. Details of all chines are to submitted for consideration, *see also* LR's *Guidance Notes for Structural Details*.

3.9 Skeg

3.9.1 The thickness of the skeg plating is, in general, to be not less than the thickness of the keel at bottom or 1,5 times the thickness of the bottom shell on the sides, whichever is the greater, *see also* 5.10.

3.10 Shell openings

3.10.1 Openings are to have smooth edges and well rounded corners. Exposed edges in way of cut-outs in single skin/plate laminate are, in general, to be suitably sealed over laminating with not less than 2 x 450 g/m^2 CSM (or equivalent) reinforcements. Alternative arrangements demonstrating the equivalent protection to the ingress of moisture into the laminate will be individually considered in association provided on the relevant plans.

3.10.2 The exposed edges of all openings cut in sandwich panels are to be suitably sealed. In general a high density foam core (or equivalent material) is to be used around the perimeter of such openings. Exposed edges in way of cut-outs in sandwich panels are to be overlaminated with a weight of laminate not less than that required for the outer skin of the sandwich panel.

3.10.3 Where other than an epoxy resin system is used the first layer of reinforcement, as required by 3.10.1 and 3.10.2, is, in general, to be CSM with a weight not exceeding 300 g/m^2.

3.10.4 Sea inlet boxes are to have well rounded corners and, so far as possible are to be kept clear of the bilge radius. Arrangements are to be made to maintain the continuity of structural strength in way of the openings.

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3.11 Appendages

3.11.1 The scantlings of appendages will be subject to special consideration on the basis of the Rules and the design loadings anticipated, but are in no case to be taken as less than that of the surrounding structure.

3.12 Fin and tuck

3.12.1 Additional reinforcement is to be moulded into the fin and tuck areas of yachts which have either internal fixed ballast or external attached ballast keels, *see also* Part 16.

3.12.2 For single skin construction the total weight of reinforcement is not to be less than 1,50 times the weight of the adjacent bottom shell plate laminate, but need not be greater than the Rule keel weight as required by 3.2.

3.13 Transom

3.13.1 The thickness of the stern or transom is to be not less than that required by 3.4 and 3.5 as appropriate. Where water jet or sterndrive units are fitted, the scantlings of the plating in way of the nozzles and connections will be specially considered.

3.14 Local reinforcement

3.14.1 The hull is to be locally increased in thickness in way of fittings for rudder tubes, propeller brackets, etc. The amount of increase is to be not less than 50 per cent of the adjacent plate laminate. Details of such reinforcement are to be submitted.

3.14.2 Local reinforcement is in general to extend under the adjacent supporting structure and then be tapered gradually to the base laminate thickness over a distance of not less than 20 times the difference in thickness, *see* 2.6.

3.15 Hull laminate arrangement

3.15.1 The hulls of all craft with a service speed of 25 knots or greater are to be moulded, such that following local impact, damage progressive stripping of surface reinforcements will not occur. This may be achieved by arranging all hull reinforcements as shown in Fig. 3.3.3.

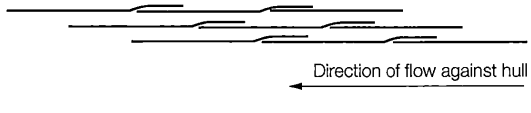

Fig. 3.3.3 Arrangement of hull reinforcement

3.15.2 Details of the laminate sequence and direction of orientation are to be indicated in the laminate schedule as required by Ch 2,3.3.7.

3.15.3 It is recommended that woven reinforcements be laid transversely to minimise the susceptibility to progressive stripping of hull laminates following local impact.

3.15.4 Special consideration is to be given to hull laminates where high glass content is proposed and where orthophthalic resins are used.

3.16 Novel features

3.16.1 Where the Rules do not specifically define the requirements for novel features then the scantlings and arrangements are to be determined by direct calculations. Such calculations are to be carried out on the basis of the Rules, recognised standards and good practice, and are to be submitted for appraisal.

■ *Section 4* Shell envelope framing

4.1 Application

4.1.1 The requirements in this Section apply to longitudinally and transversely framed shell envelopes.

4.2 General

4.2.1 To determine the required scantlings, the formulae indicated in 1.14 are, in general, to be used in conjunction with the design loadings specified in Part 5.

4.3 Symbols and definitions

4.3.1 Symbols and definitions for use throughout this Chapter are as given in 1.5.1 or specified in the appropriate Section.

4.4 Bottom longitudinal stiffeners

4.4.1 The bottom longitudinals are to be supported by bottom transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.4.2 Bottom longitudinals are to be continuous through the supporting structures.

4.4.3 Where it is impracticable to comply with the requirements of 4.4.2, or where it is desired to terminate the bottom longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets.

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4.4.4 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (b).

4.4.5 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.5 Bottom longitudinal primary stiffeners

4.5.1 Bottom longitudinal primary stiffeners are to be supported by bottom deep transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 6 m apart.

4.5.2 Bottom longitudinal primary stiffeners are to maintain their continuity through the supporting structures.

4.5.3 Where it is impracticable to comply with the requirements of 4.5.2, or where it is desired to terminate the bottom longitudinal primary stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.5.4 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (a).

4.5.5 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.6 Bottom transverse stiffeners

4.6.1 Bottom transverse stiffeners are defined as local stiffening members which support the bottom shell, and which may be continuous or intercostal.

4.6.2 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (b).

4.6.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.7 Bottom transverse frames

4.7.1 Bottom transverse frames are defined as stiffening members which support the bottom shell, they are to be effectively continuous and be bracketed at their end connections to side frames and bottom floors as appropriate.

4.7.2 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (a).

4.7.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.8 Bottom transverse web frames

4.8.1 Bottom transverse web frames are defined as primary stiffening members which support bottom shell longitudinals, they are to be continuous and be substantially bracketed at their end connections to side web frames and bottom floors.

4.8.2 Where it is impracticable to comply with the requirements of 4.8.1, or where it is desired to terminate the bottom transverse web frames in way of bulkheads or integral tank boundaries, etc., they are to be bracketed in way of their end connections, to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed', *see* Fig. 3.4.1 and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.8.3 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (a).

4.8.4 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.9 Side longitudinal stiffeners

4.9.1 The side longitudinals are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

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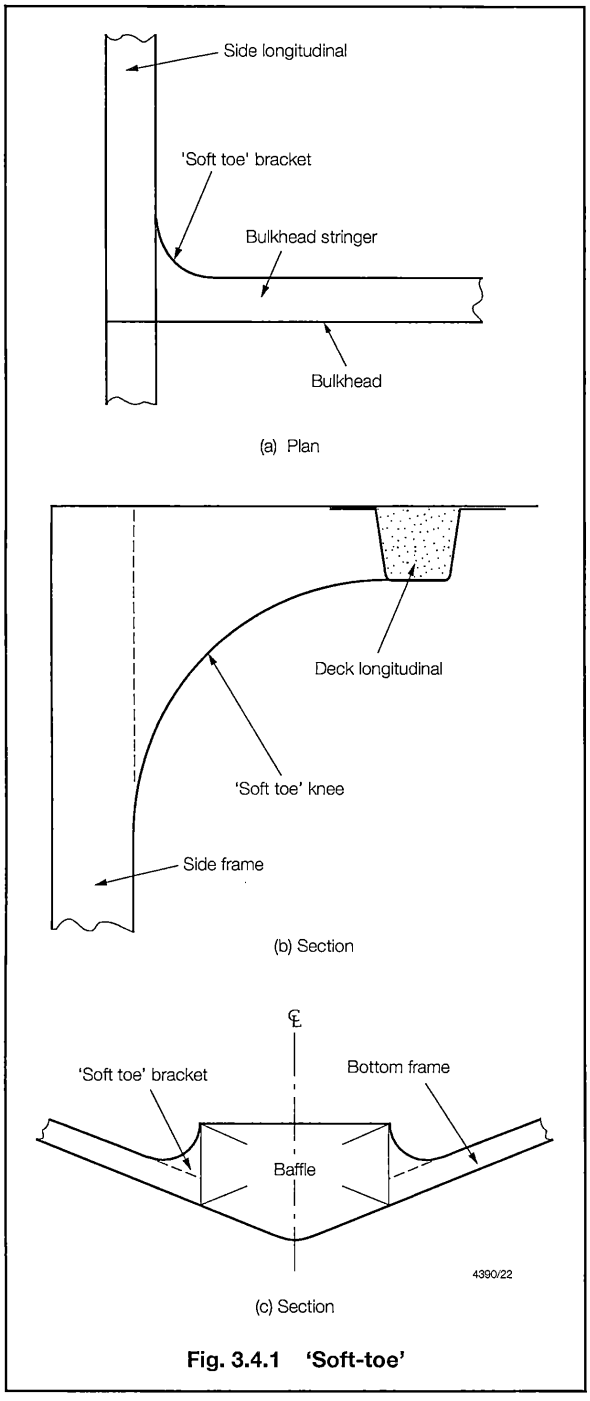

Fig. 3.4.1 'Soft-toe'

4.9.2 Side longitudinals are to be continuous through the supporting structures.

4.9.3 Where it is impracticable to comply with the requirements of 4.9.2, or where it is desired to terminate the side longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets.

4.9.4 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (b).

4.9.5 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.10 Side longitudinal primary stiffeners

4.10.1 Side longitudinal primary stiffeners are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 6 m apart.

4.10.2 Side longitudinal primary stiffeners are to maintain their continuity through the transverse bulkheads and other supporting structures.

4.10.3 Where it is impracticable to comply with the requirements of 4.10.2, or where it is desired to terminate the side longitudinal primary stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.10.4 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (a).

4.10.5 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.11 Side transverse stiffeners

4.11.1 Side transverse stiffeners are defined as local stiffening members which support the side shell, and which may be continuous or intercostal.

4.11.2 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (b).

4.11.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

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4.12 Side transverse frames

4.12.1 Side transverse frames are defined as stiffening members supporting the side shell and spanning continuously between bottom floors/frames and decks. They are to be effectively constrained against rotation at their end connections.

4.12.2 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (a).

4.12.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.13 Side transverse web frames

4.13.1 Side transverse web frames are defined as primary stiffening members which support side shell longitudinals, they are to be continuous and be substantially bracketed at their head and heel connections to deck beams and bottom web frames respectively.

4.13.2 Where it is impracticable to comply with the requirements of 4.13.1, or where it is desired to terminate the side transverse web frames in way of side longitudinal primary stiffeners, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections,to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.13.3 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (a).

4.13.4 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.14 Grouped frames

4.14.1 For the purposes of satisfying Rule requirements, frames may, subject to agreement by LR, be grouped. The number of frames in any group shall not in general exceed five. The summation of section stiffness, EI, for the group of frames is not to be less than the summation of the Rule requirements for the individual framing members. In addition, in no case is the proposed scantlings of an individual framing member within the group to be less than ninety per cent of the Rule value for that member.

4.15 Grillage structures

4.15.1 For complex girder systems, a complete structural analysis using numerical methods may have to be performed to demonstrate that the stress levels are acceptable when subjected to the most severe and realistic combination of loading conditions intended, *see also* 1.3.

4.15.2 General or special purpose computer programs or any other analytical techniques may be used provided that the effects of bending, shear, axial and torsion are properly accounted for and the theory and idealisation used can be justified.

4.15.3 In general, grillages consisting of slender girders may be idealised as frames based on beam theory provided proper account of the variations of geometric properties is taken. For cases where such an assumption is not applicable, finite element analysis or equivalent methods may have to be used.

4.16 Combined framing systems

4.16.1 Where longitudinal and transverse primary stiffeners form grillage structures the scantlings may be derived in accordance with 4.15.

4.17 Floating framing systems

4.17.1 Where the floating frame system is used, the effect of the plating attached to the stiffening members is to be ignored when calculating the required section stiffness, EI, of the primary stiffening members, i.e. the full section stiffness, EI, is to be provided by the primary stiffening member only.

4.18 Frame struts

4.18.1 Where struts are fitted to side shell transverse web frames or longitudinal primary stiffeners to carry axial loads the strut cross-sectional area is to be derived as for pillars in Section 10. If fitted at the stiffener half span point the stiffener section modulus may be taken as half the modulus derived from the general equations for the stiffening member being considered.

4.18.2 Design of end connections is to be such that the strut loads can be efficiently transmitted into the supporting structure.

4.19 Fenders and reinforcement in way

4.19.1 The design of and responsibility for the fendering on any craft rests with the designer and prospective Owner and are outside the scope of classification scantling approval requirements. The arrangement for fendering fitted should not be detrimental to the general working of the structure and therefore the requirements indicated in 4.19.2 to 4.19.6 are provided as recommendations of the areas requiring special consideration by the designer and Builder.

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4.19.2 Wood belting and fenders, which may be subject to considerable impact load, are to be bedded down on a flexible sealing compound or a neoprene type gasket to ensure watertightness. The bolts are to be both adequate in number and size and, where practicable, reeled to prevent perforation of the laminate. Substantial plate washers or, where practicable, a continuous backing plate are to be provided. The arrangement for the attachment of the fender should, in general, be arranged so that where sections of the fender are damaged or torn, the watertight integrity of the hull is not impaired.

4.19.3 The laminate in way of such fittings is to be substantially increased in thickness to prevent overloading, and depending on the position, a back-up block of wood, plastic or metal may be required.

4.19.4 For craft such as pilot craft, fishing craft, etc., which may be subject to repeated impact loadings from contact with other craft whilst in service, due consideration is to be given to increasing the scantlings of stiffening members in way of the fenders. Details of these increased scantlings, anticipated loadings and calculations, are to be indicated on the submitted plans, *see also* 3.6.3 and 3.6.4.

4.19.5 **Pilot craft** are, in general, to be fitted with large knees in way of the sheerstrake in areas as indicated in 3.6.5. The knees are to be aligned between the transverse frames and the deck beams. In the case of longitudinally framed craft, intermediate web frames with knees are to be fitted at a spacing of generally not greater than 500 mm. A side longitudinal with a section modulus of in general, twice that of the Rule longitudinal for the web frame spacing is to be positioned just below the lower fendering to carry the load associated with the dynamic loading from pitching and rolling. Consideration is also to be given to the termination of such brackets by use of a 'soft-toe' in way of the deck. The thickness of the webs for these knees is to be twice that required by 1.16 or 6 mm at a fibre content by weight, of 0,5. Where the fibre content is less than 0,5 the minimum thickness is to be increased by the factor k_c as follows:

$$t_{min} = 6k_c$$

where

$k_c = 1{,}65 - 1{,}3f_c$

f_c is as defined in 1.5.1.

4.19.6 **Fishing craft** engaged in pair trawling and other modes of fishing, and which may be subject to repeated impact loading from contact with the other craft, are to have additional stiffening fitted in way of the impact areas. This may be in the form of large knees, intermediate knees or substantial fendering/rubbing strakes. Additionally, the shell and deck in way of all working areas are to be suitably sheathed.

Section 5
Single bottom structure and appendages

5.1 General

5.1.1 The requirements of this Section provide for single bottom construction of mono-hull craft in association with either transverse or longitudinal framing.

5.1.2 All girders are to extend as far forward and aft as practicable and care is to be taken to avoid any abrupt discontinuity particularly in way of skegs. Where girders are cut at bulkheads, their longitudinal strength is to be maintained.

5.1.3 Particular attention is to be taken to ensure that the continuity of structural strength in way of the intersection of transverse floors and longitudinal girders is maintained. The face reinforcement of such stiffening members is to be effectively continuous.

5.1.4 The single bottom structure in way of the keel, skeg and girders is to be sufficient to withstand the forces imposed by dry-docking the craft.

5.1.5 The breadth and thickness of plate keels are to comply with the requirements detailed in 3.2. *See also* 3.9.1.

5.2 Centreline girder

5.2.1 In craft with single bottoms, a centreline girder is, in general, to be fitted in association with transverse frames, transverses supporting longitudinals or where the breadth of floors at the upper edge is greater than 1,5 m.

5.2.2 Centreline girders may be in the form of intercostal or continuous top hat or plate webs. Where the girder is intercostal, additional bracketing and local reinforcement is to be provided to maintain the continuity of structural strength. The face reinforcement in all cases is to be continuous.

5.2.3 The web depth of the centre girder in general is to be equal to the depth of the floors at the centreline as specified in 5.4.

5.2.4 The web thickness, t_w, for a centre girder of 'top-hat' type section is to be not less than that required by 1.16. or as determined as follows, whichever is the greater:

$$t_w = 1{,}28\sqrt{k_A}\ \left(\sqrt{L_R} + 1\right)\ \text{mm}$$

in no case is t_w to be taken less than 5,0 mm

where

k_A and L_R are as defined in 1.5.1.

5.2.5 The web thickness for a centre girder of single plate laminate construction is to be two times the thickness as required by 5.2.4.

5.2.6 The face area of the centre girder, A_f, is to be not less than:

$$A_f = 1{,}18L_R\,k_A\ \text{cm}^2$$

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where

k_A and L_R are as defined in 1.5.1.

5.2.7 The face area of the centre girder outside 0,5*L* about midships may be reduced to 80 per cent of the value given in 5.2.6.

5.2.8 The face thickness, t_f, is to be not less than the web thickness of the centre girder.

5.2.9 Additionally, the requirements of 4.5 for bottom longitudinal primary stiffeners are to be complied with.

5.3 Side girders

5.3.1 Where the floor breadth at the upper edge exceeds 6,0 m, side girders are to be fitted at each side of the centre girder such that the spacing between the side and centre girders or between the side girders themselves is not greater than 3 m. Side girders, where fitted, are to extend as far forward and aft as practicable and are, in general, to terminate in way of bulkheads, deep floors or other primary transverse structure.

5.3.2 In the engine room, additional side girders are generally to be fitted in way of the main machinery.

5.3.3 The face area of side girders, A_f, is not to be taken as less than:

$$A_f = 0{,}82 L_R k_A \text{ cm}^2$$

where

k_A and L_R are as defined in 1.5.1.

5.3.4 The face thickness, t_f, is not, in general, to be less than the web thickness of the side girder.

5.3.5 The web thickness, t_w, for side girders of 'top-hat' type section is to be not less than as required by 1.16 or as determined as follows, whichever is the greater:

$$t_w = 1{,}28 \sqrt{k_A L_R} \text{ mm}$$

where

k_A and L_R are as defined in 1.5.1

in no case is t_w to be taken less than 5,0 mm.

5.3.6 The web thickness for side girders of single plate laminate construction is to be two times the thickness as required by 5.3.5.

5.3.7 In addition, the requirements of 4.5 for bottom longitudinal primary stiffeners are to be complied with.

5.3.8 Watertight side girders, or side girders forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deep tanks as detailed in 7.3. and 7.4 respectively.

5.4 Floors, general

5.4.1 In transversely framed craft, floors are generally to be fitted at every frame and underneath each bulkhead.

5.4.2 In longitudinally framed craft, floors are to be fitted at every transverse web frame and bulkhead and generally at a spacing not exceeding 2 m. Additional transverse floors or webs are, in general, to be fitted at half web-frame spacing in way of engine seatings and thrust bearings, pillars, skegs, ballast/bilge keels and the bottom of the craft in the forefoot region.

5.4.3 The overall depth of transverse floors at the centre-line, d_f, is not to be taken as less than:

when $B < 10$ m $\quad d_f = 40\,(B + 0{,}85D)$ mm

when $B \geq 10$ m $\quad d_f = 40\,(1{,}5B + 0{,}85D) - 200$ mm

where

B is as defined in 1.5.1.

5.4.4 The web thickness, t_w, for transverse floors of 'top-hat' type section is to be not less than that required by 1.16 or as determined as follows, whichever is the greater:

$$t_w = \sqrt{k_A}\left(\frac{4{,}33 d_f}{1000} + 2{,}75\right)\left(\frac{s}{1000} + 0{,}5\right) \text{ mm}$$

where

d_f is as defined in 5.4.3.

k_A and s are defined in 1.5.1

In no case is t_w to be taken less than 5,0 mm.

5.4.5 The web thickness for transverse floors of single plate laminate construction is to be two times the thickness as required by 5.4.4.

5.4.6 If side frames are attached to the floors by brackets, the depth of floor may be reduced by 15 per cent and the floor thickness determined using the reduced depth. The brackets are to have the same thickness as the floors, and their arm lengths clear of the frame are to be the same as the reduced floor depth given above.

5.4.7 The face area of floors, A_f, is not to be taken as less than:

$$A_f = 0{,}82 L_R k_A \text{ cm}^2$$

where

k_A and L_R are as defined in 1.5.1.

5.4.8 The thickness of the face reinforcement, t_f, is to be not less than the web thickness.

5.4.9 In addition, the requirements of 4.8 for bottom transverse web frames are to be complied with.

5.4.10 Floors are generally to be continuous from side to side.

5.4.11 The tops of floors, in general, may be level from side to side. However, in craft having considerable rise of floor the depth of the floor plate may require to be increased to maintain the required mechanical properties of the section.

5.4.12 The floors in the aft peak are to extend over and provide efficient support to the stern tube where applicable.

5.4.13 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deep tanks as detailed in 7.3 or 7.4 respectively.

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5.5 Floors in machinery spaces

5.5.1 Floors within machinery spaces are to comply with the requirements of 5.4.

5.5.2 The depth and mechanical properties of floors between engine or gearbox girders is to be not less than that required to maintain continuity of structural integrity or 50 per cent of the depth given in 5.4.3. The web thickness and face reinforcement weight of such reduced height floors are to be increased appropriately in order to maintain the continuity of structural strength.

5.6 Machinery seating

5.6.1 The general requirements for machinery seating are given in Pt 3, Ch 2,6.9.

5.6.2 Main and auxiliary engines are to be effectively secured to the hull structure by seatings of adequate scantlings to resist the gravitational thrust, torque and vibration forces which may be imposed upon them.

5.6.3 The longitudinal girders forming the engine seating are to extend as far forward and aft as is practicable and are to be adequately supported by transverse floors or brackets.

5.6.4 Where stiffening is of plate construction, engine holding-down bolts are to be arranged as near as practicable to floors and longitudinal girders. When this cannot be achieved, bracket floors are to be fitted.

5.6.5 Machinery seatings are to be attached by means of primary bonding angles in accordance with 1.18.

5.7 Drainage arrangements

5.7.1 Suitable arrangements are to be made to provide free passage of air from all parts of the tanks to the air pipes, *see also* Pt 9, Ch 1,5.

5.7.2 Sufficient limber holes are to be positioned in the internal bottom structure to allow for the drainage of water from all parts of the bilge to the pump suctions.

5.7.3 Particular attention is to be given to the positioning of limbers to ensure adequate drainage and to avoid stress concentrations. *See* LR's *Guidance Notes for Calculation Procedures for Composite Construction.*

5.7.4 Openings in the webs of stiffening sections, baffle plates, etc., are, in general, to be formed by moulded-in preforms under top hat type stiffening. Edges of openings in plate laminates are to be suitably sealed in accordance with 1.29.

5.8 Rudder horns

5.8.1 The scantlings of the rudder horn will be specially considered and in the case of high aspect ratio or novel designs direct calculations will be required to be submitted in accordance with Pt 3, Ch 1,2.

5.9 Sternframes

5.9.1 Where it is proposed to mould a composite sternframe, the scantlings and arrangements will be specially considered on the basis of direct calculations and loadings submitted by the Builders and designers.

5.10 Skeg construction

5.10.1 Skegs are to be effectively integrated into the adjacent structure and their design is to be such as to facilitate this, *see also* 3.9.

5.10.2 The scantlings of skegs and the internal diaphragms at bulkheads and web frames are to be sufficient to withstand any docking forces to which they may be subjected.

5.11 Forefoot and stem

5.11.1 For craft of composite sandwich construction the forefoot region is to be so designed that in the event of local impact (*see also* 2.8) with floating debris, the resultant damage will be limited. This may be achieved by:

(a) Arranging the individual plies of the laminate such that any delamination will be directed to the outer surface of the laminate, *see* Fig. 3.5.1.
(b) The addition of a 'sacrificial nose', *see* Fig. 3.5.2.
(c) By the addition of suitable sheathing, in accordance with 2.9.
(d) For vessels where the operating high speed waterline results in the exposure of the forefoot region, the laminate sequence in the keel area will be specially considered.

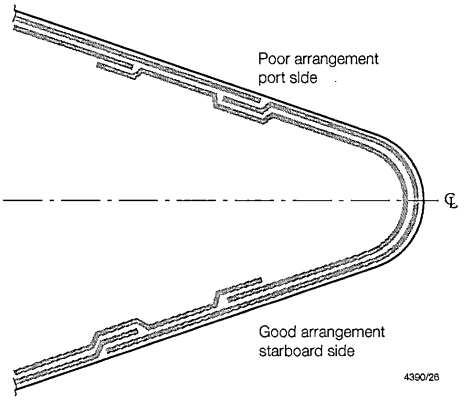

Fig. 3.5.1
Arrangement of laminate in way of forefoot and stem

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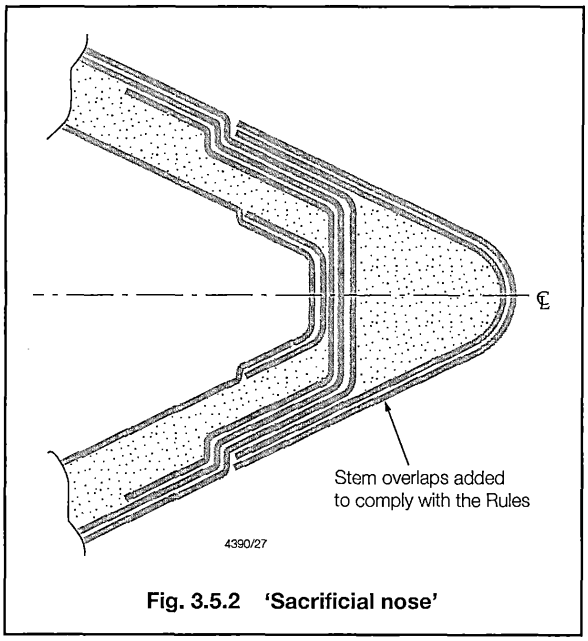

Fig. 3.5.2 'Sacrificial nose'

5.12 Transom knee

5.12.1 Centre and side girders are to be bracketed to the transom framing members by means of substantial knees. The face flat area of the girders may be gradually reduced to that of the transom stiffening member in accordance with Fig. 3.5.3.

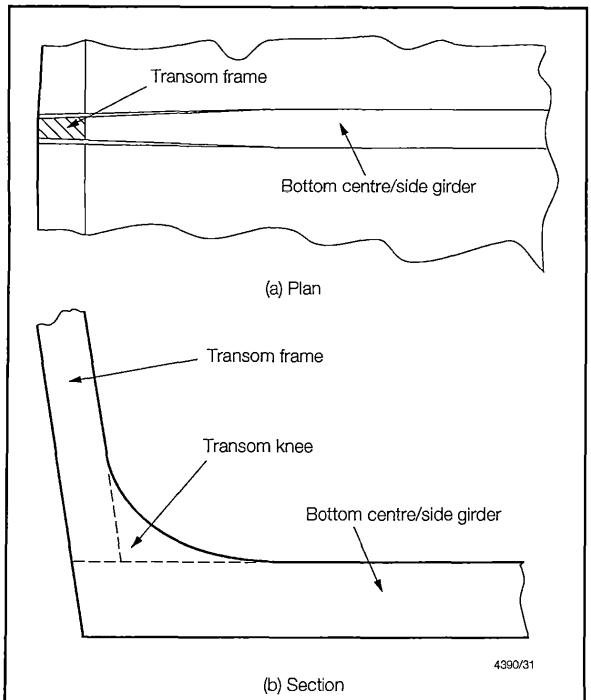

Fig. 3.5.3 Transom knee

5.12.2 Hard spots are to be avoided in way of the end connection, and care taken to ensure that the stiffening member to which the transom knee is bracketed can satisfactorily carry the transmitted bending moment.

■ *Section 6*
Double bottom structure

6.1 General

6.1.1 The requirements given in this Section provide for double bottom construction of mono-hull craft in association with either transverse or longitudinal framing.

6.1.2 Where required in accordance with Pt 3, Ch 2,6, double bottoms are generally to extend from the collision bulkhead to the after peak bulkhead, as far as this is practicable taking into account the design and proper working of the craft. In addition, the inner bottom is to be continued to the craft's side in such a manner as to protect the bottom to the turn of bilge or chine.

6.1.3 The double bottom structure in way of girders and duct keels is to be sufficient to withstand the forces imposed by dry-docking the craft.

6.1.4 The centreline girder and side girders are to extend as far forward and aft as practicable and care is to be taken to avoid any abrupt discontinuity. Where girders are cut at bulkheads, their longitudinal strength is to be maintained.

6.2 Keel

6.2.1 The breadth and thickness of plate keels are to comply with the requirements of 3.2.

6.3 Centreline girder

6.3.1 A centreline girder is to be fitted throughout the length of the craft. The web thickness, t_w, of a centreline girder of 'top-hat' type section is to be not less than as required by 1.16 or as determined as follows, whichever is the greater and in no case is t_w to be taken less than 5 mm:

$$t_w = \sqrt{k_A}\left(\frac{L_R}{8} + 3{,}64\right) \geq 5 \text{ mm}$$

where

k_A and L_R are as defined in 1.5.1.

6.3.2 The web thickness of a centreline girder of single plate laminate construction is to be two times the thickness as required by 6.3.1.

6.3.3 The overall depth of the centre girder, d_{DB}, is not to be taken as less than 630 mm and is to be sufficient to give adequate access to all parts of the double bottom.

6.3.4 Additionally, the requirements of 4.5 for bottom longitudinal primary stiffeners are to be complied with.

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6.4 Side girders

6.4.1 Where the breadth of the floor at the upper edge does not exceed 6,0 m, side girders are not required.

6.4.2 Where the breadth of the floor at the upper edge exceeds 6,0 m, side girders are to be fitted at each side of the centre girder such that the spacing between the side and centre girders or between the side girders themselves is not greater than 3 m. Side girders, where fitted, are to extend as far forward and aft as practicable and are, in general, to terminate in way of bulkheads, deep floors or other primary transverse structure.

6.4.3 Under the main engine, girders extending from the bottom to the top plate of the engine seating are to be fitted. The height of the girders is not to be less than the height of the floor. Engine holding-down bolts are to be arranged as near as practicable to the girders and floors. Where this cannot be achieved, bracket floors are to be fitted.

6.4.4 Side girders are to have a minimum web thickness, t_w, as required by 1.16 but not less than as determined as follows whichever is the greater and in no case is t_w to be taken less than 5,0 mm:

$$t_w = \sqrt{k_A}\ (0{,}064L_R + 4{,}32)\ \text{mm}$$

where

k_A and L_R are as defined in 1.5.1.

6.4.5 The face area and face thickness of side girders are to comply with the requirements for plate floors as defined in 5.4.7 and 5.4.8 respectively.

6.4.6 Additionally, the requirements of 4.5 for bottom longitudinal primary stiffeners are to be complied with.

6.5 Bracket floors

6.5.1 Between plate floors, the shell inner bottom plating is to be supported by bracket floors. The brackets are to have the same thickness as plate floors and, where they are of single skin laminate construction, are to be stiffened on the unsupported edge.

6.5.2 In longitudinally framed craft, the brackets are to extend from the centre or side girder and margin plate to the adjacent longitudinal, but in no case is the breadth of the bracket to be taken less than 3/4 of the depth of centre girder. Brackets are to be fitted at every web frame at the margin plate, and those at the centre girder are to be spaced not more than 1,0 m apart.

6.5.3 In transversely framed craft, the breadth of the brackets attaching the bottom and inner bottom frames to the centre girder and margin plate is to be not less than 3/4 of the depth of the centre girder.

6.6 Plate floors

6.6.1 Plate floors may be of single skin, sandwich skin or 'top-hat' type construction.

6.6.2 The web thickness, t_w, for non-watertight plate floors of 'top-hat' type section is to be not less than as required by 1.16 or as determined as follows, whichever is the greater and in no case is t_w to be taken less than 5,0 mm.

$$t_w = \sqrt{k_A}\ (0{,}064L_R + 4{,}32)\ \text{mm}$$

where

k_A and L_R are as defined in 1.5.1.

6.6.3 The web thickness for transverse floors of single plate laminate construction is to be two times the thickness as required by 6.6.2.

6.6.4 The thickness of the plate laminates which form the skins for plate floors of sandwich skin construction are not to be taken as less than 2 mm.

6.6.5 Additionally, the requirements of 4.8 for bottom transverse web frames are to be complied with.

6.6.6 Plate floors are generally to be continuous between the centre girder and the margin plate.

6.7 Watertight floors

6.7.1 The scantlings of watertight floors are to comply with the requirements for plate floors as detailed in 6.6.

6.7.2 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deep tanks as detailed in 7.3 or 7.4 respectively.

6.8 Tankside brackets

6.8.1 The scantlings of tankside brackets are to comply with the requirements for plate floors as detailed in 6.6.

6.9 Inner bottom laminate

6.9.1 Inner bottom laminates forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deep tanks as detailed in 7.3 or 7.4 respectively and, where forming vehicle, passenger or other decks the requirements of Section 8 are to be complied with.

6.9.2 The bending moment assumed to be carried by the inner bottom plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 6.9.3 and 6.9.5 respectively.

6.9.3 An estimate of the thickness of the **inner bottom single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

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6.9.4 In no case is the minimum thickness of single skin plating to be taken as less than 5 mm.

6.9.5 An estimate of the stiffness EI, the thickness of single skin plating for **outer and inner skins of the bottom sandwich panel** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

6.9.6 In no case are the minimum thicknesses of laminate which form the skins of a sandwich laminate to be taken as less than 4,5 mm and 3,5 mm for the outer and inner skins respectively.

6.9.7 Special consideration may be given to laminate thicknesses lesser than that required by 6.9.4 and 6.9.6, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided, *see* 2.3.1, and the equivalent impact resistance is to be demonstrated as required by 2.8.2.

6.10 Inner bottom longitudinals

6.10.1 The inner bottom longitudinals are to be supported by inner bottom transverse web frames, floors, bulkheads, or other primary structures, generally spaced not more than 2 m apart.

6.10.2 Inner bottom longitudinals are to be continuous through the supporting structures.

6.10.3 Where it is impracticable to comply with the requirements of 6.10.2, or where it is desired to terminate the inner bottom longitudinals in way of bulkheads or integral tank boundaries, the longitudinals are to be bracketed in way of their end connections, to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets.

6.10.4 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (b).

6.10.5 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

6.11 Inner bottom transverse web framing

6.11.1 Inner bottom transverse web frames are defined as primary stiffening members which support inner bottom longitudinals. They are to be continuous and substantially bracketed at their end connections to bottom web frames, bottom floors and tankside brackets.

6.11.2 Where it is impracticable to comply with the requirements of 6.11.1, or where it is desired to terminate the inner bottom transverse web frames in way of centre or side girders, bulkheads or integral tank boundaries, etc., all web frames are to be bracketed in way of their end connections, to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

6.11.3 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (a).

6.11.4 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

6.12 Margin plates

6.12.1 A margin plate, if fitted, is to have a thickness as required for the inner bottom plating.

6.13 Wells

6.13.1 Small wells constructed in the double bottom are not to extend in depth more than necessary. A well extending to the outer bottom may, however, be permitted at the after end of the shaft tunnel of the craft. Other well arrangements (e.g. for lubricating oil under main engines) may be considered provided they give protection equivalent to that afforded by the double bottom.

6.14 Transmission of pillar loads

6.14.1 In double bottoms under widely spaced pillars, the connections of the floors to the girders, and of the floors and girders to the inner bottom, are to be suitably increased. Where pillars are not directly above the intersection of plate floors and girders, partial floors and intercostals are to be fitted as necessary to support the pillars. Manholes are not to be cut in the floors and girders below the heels of pillars. Where longitudinal framing is adopted in the double bottom, equivalent stiffening under the heels of pillars is to be provided, and where the heels of pillars are carried on a tunnel, suitable arrangements are to be made to support the load.

6.15 Drainage arrangements

6.15.1 Suitable arrangements are to be made to provide free passage of air and water from all parts of the tanks to the air pipes and pump suctions.

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6.15.2 Particular attention is to be given to the positioning of limbers to ensure adequate drainage and to avoid stress concentrations, *see also* 5.7.

6.15.3 Openings in the webs of stiffening sections, baffle plates, etc., are to be suitably sealed in accordance with 4.16.

6.16 Manholes

6.16.1 Sufficient manholes are to be cut in the inner bottom, floors and side girders to provide adequate access to and ventilation of all parts of the double bottom. The size of the manhole openings in plate laminates is not, in general, to exceed 50 per cent of the double bottom depth unless edge reinforcement is provided. Holes are, in general, not to be cut in the centre girder, except in tanks at the forward and after ends of the craft, and elsewhere where tank widths are reduced unless additional stiffening and/or compensation is fitted to maintain the structural integrity.

6.17 Pressure testing

6.17.1 Double bottoms are to be tested upon completion with a head of water representing the maximum internal pressure which could be experienced in service, but not less than a head of water equivalent to the level of the upper deck.

■ *Section 7*
Bulkheads and deep tanks

7.1 General

7.1.1 The requirements of this Section apply to craft with bulkheads of either sandwich or single skin composite construction.

7.1.2 Watertight and collision bulkheads are to be fitted in accordance with the requirements of Pt 3, Ch 2,4.

7.1.3 FRP composite bulkheads and plywood bulkheads are, where practicable, to be suitably attached to receiving frames, *see also* LR's *Guidance Notes for Structural Details*. The bulkheads are to be attached using double angles or equivalent, *see* 1.18. Proposals to fit bulkheads and tank boundaries on receiving strips in lieu of frames, will be individually considered.

7.1.4 Where bulkheads are of steel or aluminium construction, their scantlings and arrangements are to be in accordance with Pt 6, Ch 3 or Pt 7, Ch 3 respectively. The method of attachment to the framing will be specially considered.

7.1.5 For bulkheads in way of partially filled holds or tanks, sloshing forces may be required to be taken into account. Where such forces are likely to be significant, the scantlings will be required to be verified by additional calculations which are to be submitted with the plans.

7.1.6 In deep tanks which extend from side to side a centreline bulkhead is generally to be fitted. The bulkhead may be intact or perforated as desired. If intact the scantlings are to comply with the requirements of 7.4 and 7.11 for tank boundary bulkheads. If perforated, they are to comply with the requirements of 7.11 for washplates.

7.1.7 The scantlings of non-watertight or partial bulkheads are, in general, to be as required by 7.3 for watertight bulkheads. Non-watertight or partial bulkheads supporting hull framing are to have scantlings equivalent to frames or web frames, in the same position, as appropriate.

7.2 Symbols and definitions

7.2.1 The symbols and definitions for use within this Section are as given in 1.5.1.

7.3 Watertight bulkheads

7.3.1 Composite watertight bulkheads may be of sandwich construction, with or without stiffeners, or of single skin construction with closely spaced vertical or horizontal stiffeners. Where steel or aluminium alloy bulkheads are fitted, their scantlings and arrangements are to be in accordance with Pt 6, Ch 3 or Pt 7, Ch 3 respectively. Sandwich timber bulkheads, plywood bulkheads or other forms of bulkhead construction will be considered on the basis of equivalent strength and stiffness. Where bulkheads are of novel design they will be specially considered.

7.3.2 The bending moment assumed to be carried by the watertight bulkhead plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 for both non-displacement or displacement type craft. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 7.3.3 and 7.3.5 respectively.

7.3.3 An estimate of the thickness of watertight **bulkhead single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

7.3.4 In no case is the minimum thickness of single skin plating to be taken as less than 2,5 mm.

7.3.5 An estimate of the stiffness *EI*, thickness of single skin plating for outer and inner skins of the **bulkhead sandwich panel** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

7.3.6 In no case is the minimum thickness of laminate which forms the skin of a sandwich laminate to be taken as less than 2 mm.

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7.3.7 Special consideration may be given to laminate thicknesses lesser than that required by 7.3.4 and 7.3.6, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided, *see* 2.3.1, and the equivalent impact resistance is demonstrated as required by 2.8.2.

7.3.8 The Rule requirements for bending moment, shear force, shear stress and deflection for the bulkhead stiffeners are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 for both non displacement or displacement type craft, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the appropriate load model.

7.3.9 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

7.3.10 The geometric properties of stiffener sections are to be calculated in accordance with 1.15 using an effective width of attached plating as indicated in 1.7.

7.3.11 Bulkheads are to be suitably strengthened, if necessary, at the ends of deck girders and where subjected to concentrated loads.

7.3.12 Bulkheads in engine rooms that may be exposed to fuel oils are to be suitably protected against damage by fuel oil and by fire, *see* 7.15.

7.4 Deep tanks

7.4.1 Composite integral/deep tank bulkheads may be of sandwich construction with or without stiffeners, or of single skin with closely spaced vertical or horizontal stiffeners. Where steel or aluminium alloy integral/deep tank bulkheads are fitted, their scantlings and arrangements are to be in accordance with Pt 6, Ch 3 or Pt 7, Ch 3 respectively. Other forms of bulkhead construction will be considered on the basis of equivalent strength and stiffness. Where bulkheads are of novel design they will be specially considered.

7.4.2 The bending moment, M_b or M_c, as appropriate, assumed to be carried by the integral/deep tank bulkhead plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 for both non-displacement or displacement type craft. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 7.4.3 and 7.4.5 respectively.

7.4.3 An estimate of the thickness of **integral/deep tank bulkhead single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

7.4.4 In no case is the minimum thickness of single skin plating to be taken as less than 4,5 mm.

7.4.5 An estimate of the stiffness EI, thickness of single skin plating for outer and inner skins of **integral/deep tank bulkhead sandwich panels** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

7.4.6 In no case is the minimum thickness of laminate which forms the skins of a sandwich laminate to be taken as less than 4 mm and 3 mm for the fluid barrier and exterior skins respectively, *see also* 2.5.2.

7.4.7 Special consideration may be given to laminate thicknesses less than that required by 7.4.4 and 7.4.6, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided, *see* 2.3.1, and the equivalent impact resistance is demonstrated as required by 2.8.2.

7.4.8 The Rule requirements for bending moment, shear force, shear stress and deflection for the integral/deep tank stiffeners are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 for both non-displacement or displacement type craft, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (a).

7.4.9 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

7.4.10 The geometric properties of stiffener sections are to be calculated in accordance with 1.15 using an effective width of attached plating as indicated in 1.7.

7.4.11 Integral/deep tank bulkheads are to be suitably strengthened, if necessary, at the ends of deck girders and where subjected to concentrated loads.

7.4.12 Integral/deep tank bulkheads in engine rooms that may be subjected to fuel oils are to be suitably protected against damage by fuel oil and by fire, *see* 7.15.

7.5 Double bottom tanks

7.5.1 The scantlings of double bottom tanks are to meet the structural requirements for deep tanks in accordance with 7.4.

7.5.2 Where the crown of a double bottom tank forms a vehicle, passenger or other deck, the requirements of Section 8 are also to be complied with.

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7.6 Collision bulkheads

7.6.1 The scantlings of composite collision bulkheads are to meet the requirements of 7.3 but with allowable tensile, compressive and shear stress limits for collision bulkheads as indicated in Table 7.3.1 in Chapter 7.

7.6.2 If the collision bulkhead forms the boundary of a deep tank or cofferdam the requirements of 7.4 are to be complied with.

7.7 Gastight bulkheads

7.7.1 Where gastight bulkheads are fitted, in accordance with Pt 3, Ch 2,4, their scantlings are to be as required for watertight bulkheads.

7.7.2 Gastight bulkheads are to be fitted to protect accommodation spaces from gases and vapour fumes from machinery, exhaust and fuel systems.

7.8 Plywood bulkheads

7.8.1 Plywood used for bulkheads is to be high quality marine plywood, and is to be in accordance with the requirements of Ch 2,2.17.

7.8.2 The structural requirements of plywood watertight bulkheads are to be as required by 7.1.

7.9 Non-watertight or partial bulkheads

7.9.1 Where a bulkhead is structural but non-watertight, the scantlings are, in general, to be as required for watertight bulkheads or equivalent in strength to web frames in the same position. Partial bulkheads that are non-structural are outside the scope of LR classification.

7.10 Stiffeners passing through bulkheads

7.10.1 Primary longitudinal stiffening members are to be continuous through transverse bulkheads.

7.10.2 Where a stiffener passes through a watertight bulkhead the bonding of the stiffener and compensation in way is to be not less than the laminate weight of the bulkhead.

7.10.3 Where structural members pass through the boundaries of watertight bulkheads or integral/deep tanks, and leakage into the adjacent space could be hazardous or undesirable, suitable cofferdams are to be built into the cores of top-hat stiffeners on each side of the boundary. The minimum thickness of such cofferdams is 4,5 mm.

7.10.4 Pipe or cable runs through watertight bulkheads are to be fitted with suitable watertight glands.

7.11 Wash plates

7.11.1 Tanks are to be subdivided as necessary by internal baffles or wash plates and the minimum thickness of the laminate for any internal structure is not, in general, to be less than 4,5 mm at a fibre content of 0,5 or equivalent thickness. Baffles or wash plates which support hull framing are to have scantlings equivalent to web frames in the same position.

7.11.2 Wash plates and wash bulkheads are, in general, to have an area of perforation not less than 10 per cent of the total area of the bulkhead. The perforations are to be so arranged that the efficiency of the bulkhead as a support is not impaired.

7.11.3 The plate thickness is to be not less than the structural element from which the wash bulkhead is formed.

7.12 Cofferdams

7.12.1 A cofferdam is to be fitted between fresh water and oil fuel or sanitary tanks. The scantlings of cofferdams are to comply with the requirements for deep tank bulkheads given in 7.4.

7.13 Coatings

7.13.1 Fuel tanks are to incorporate a resin rich surface or be coated with an oil retardant resin on the internal exposed surfaces. Potable fresh water tanks are similarly to be coated with a suitable non-tainting resin.

7.14 Air pipes

7.14.1 Air pipes sufficient in number and area are to be fitted to each tank in accordance with Pt 15, Ch 2,11.

7.15 Fire protection

7.15.1 Fire protection requirements as given in Part 17 are to be complied with.

7.16 Access

7.16.1 All compartments within the craft are to be accessible in order to facilitate proper maintenance and future structural surveys. Linings on craft-sides, deck-heads and bulkheads etc., must be capable of being removed. Similarly, sufficient space must be available below lower decks/soles to provide proper access to the bottom structure; an adequate number of manholes, removable panels, etc., are to be provided for this purpose.

7.16.2 Doors fitted through watertight bulkheads are to be of equivalent construction to the bulkhead in which they are fitted, permanently attached, capable of being closed watertight from both sides of the bulkhead and are to be tested watertight.

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7.16.3 Doors or hatches are not to be fitted in collision bulkheads, except in craft of less than 21 m Rule length, L_R, or where it would be impracticable to arrange access to the forepeak other than through the collision bulkhead. Where fitted, such doors or hatches are to be watertight, as small as practicable and are to open into the forepeak compartment. Consideration will be given to operation from one side only. Doors or hatches in collision bulkheads are to be kept closed at all times while the craft is at sea.

7.16.4 Particular attention is to be given to the design and workmanship of adequate access manholes in tanks.

7.16.5 Where a manhole is fitted in a tank, the exposed edges of all openings cut in sandwich panels are to be suitably sealed. In general a high density foam core (or equivalent material) is to be used around the perimeter of such openings. Exposed edges in way of cut-outs in sandwich panels are to be overlaminated with a weight of laminate not less than that required for the skin of the sandwich panel exposed to the fluid or 4,5 mm in thickness whichever is the greater, *see* 2.3.1.

7.16.6 Manhole covers are to be attached using bolts/studs spaced at not greater than six diameters. The cover is to be fitted on a suitable seal. Where studs or bolts used to attach the cover plate to the manhole pass through the laminate, they are to be suitably secured, sealed and over-laminated.

7.17 Testing

7.17.1 Integral/deep tanks are to be tested by air pressure or by a head of water. If tested by water, the head is to be either to 1,8 m above the crown of the tank or to the top of the air or overflow pipe, whichever is the greater. When tested by air, the pressure is not to exceed 0,014 N/mm^2. The head to which the tank will be subjected in service is to be indicated on the plans submitted.

■ *Section 8* Deck structures

8.1 General

8.1.1 The deck structure may be of either single skin or sandwich construction and is to be supported by transverse beams with fore and aft girders or by longitudinals with deep transverse beams.

8.1.2 Beams are to be fitted at each frame position and be bracketed to the side frames. Strong beams and deep transverse beams are to align with and be effectively connected to the side web frames. They are also to be fitted at the ends of large openings in the deck.

8.1.3 The ends of beams, longitudinals, girders and transverses are to be effectively built into the adjacent structure, or equivalent arrangements provided.

8.1.4 Primary stiffening members are to be continuous and substantially bracketed at their end connections to maintain continuity of structural strength.

8.1.5 Secondary stiffening members are to be effectively continuous and bracketed at their end connections as appropriate.

8.1.6 Deck structures subject to concentrated loads, such as pillars out of line, are to be suitably reinforced. Where concentrations of loading on one side of a stiffener may occur, the stiffener is to be adequately stiffened against torsion. Additional reinforcements may be required in way of localised areas of high stress.

8.1.7 Deck structures are to comply with the minimum thickness requirements of Section 2.

8.1.8 Tripping brackets are to be fitted on deep webs.

8.2 Symbols and definitions

8.2.1 The symbols defined in 1.5.1 apply, unless otherwise specified.

8.3 Strength/weather deck laminate

8.3.1 The bending moment assumed to be carried by the strength/weather deck plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 8.3.2 and 8.3.4 respectively.

8.3.2 An estimate of the thickness of **strength/weather deck single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

8.3.3 In no case is the minimum thickness of single skin plating to be taken as less than 4 mm.

8.3.4 An estimate of the stiffness EI, thickness of single skin plating for outer and inner skins of the **strength/weather deck sandwich panels** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

8.3.5 In no case are the minimum thicknesses of reinforcements which form the skins of a sandwich laminate to be taken as less than 3 mm and 2 mm for the outer and inner skins respectively.

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8.3.6 Special consideration may be given to laminate thicknesses lesser than that required by 8.3.3 and 8.3.5, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided, *see* 2.3.1, and the equivalent impact resistance is demonstrated as required by 2.8.2.

8.3.7 The scantlings of watertight cockpits are to be of equivalent strength to those for the strength/weather deck, *see also* Part 4.

8.3.8 It is recommended that working areas of the weather deck have an anti-slip surface.

8.3.9 Where decks are sheathed with wood or other materials, details of the method of attachment are to be submitted, *see also* 2.9.

8.4 Lower deck/inside deckhouse deck laminate

8.4.1 The bending moment assumed to be carried by the lower deck/inside deckhouse deck plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 8.4.2 and 8.4.4 respectively.

8.4.2 An estimate of the thickness of the **lower deck/ inside deckhouse deck single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

8.4.3 In no case is the minimum thickness of single skin plating to be taken as less than 3 mm.

8.4.4 An estimate of the stiffness EI, thickness of single skin plating for outer and inner skins of the **lower deck/inside deckhouse deck sandwich panels** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

8.4.5 In no case is the minimum thickness of laminate which forms the skins of a sandwich laminate to be taken as less than 2 mm.

8.4.6 Special consideration may be given to laminate thicknesses lesser than that required by 8.4.3 and 8.4.5, provided that all of the structural strength requirements of the Rules are complied with.

8.5 Accommodation deck laminate

8.5.1 Accommodation decks are, in general, to be treated as lower deck/inside deckhouse decks, with their scantling requirements determined in accordance with 8.4.

8.5.2 Sandwich timber, plywood or other forms of deck construction will be considered on the basis of equivalent strength and stiffness.

8.6 Cargo deck laminate

8.6.1 The bending moment assumed to be carried by the cargo deck plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 8.6.2 and 8.6.4 respectively.

8.6.2 An estimate of the thickness of the **cargo deck single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

8.6.3 In no case is the minimum thickness of single skin plating to be taken as less than 4 mm.

8.6.4 An estimate of the stiffness EI, thickness of single skin plating for outer and inner skins of the **cargo deck sandwich panels** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

8.6.5 In no case is the minimum thickness of laminate which forms the skins of a sandwich laminate to be taken as less than 3 mm and 2 mm for the outer and inner skins respectively.

8.6.6 Special consideration may be given to laminate thicknesses lesser than that required by 8.6.3 and 8.6.5, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided, *see* 2.3.1, and the equivalent impact resistance is demonstrated as required by 2.8.2.

8.7 Decks forming crown of tanks

8.7.1 Decks forming the crowns of tanks are to comply with the requirements for the appropriate deck and, are to be additionally examined for compliance with the requirements for deep tanks given in 7.4.

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8.8 Strength/weather deck stiffening

8.8.1 The Rule requirements for bending moment, shear force, shear stress and deflection for the **strength/weather deck primary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (a).

8.8.2 The Rule requirements for bending moment, shear force, shear stress and deflection for the **strength/weather deck secondary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.8.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

8.8.4 The geometric properties of stiffener sections are to be calculated in accordance with 1.15 using an effective width of attached plating as given in 1.7.

8.9 Lower deck/inside deckhouse stiffening

8.9.1 The Rule requirements for bending moment, shear force, shear stress and deflection for the lower deck/inside deckhouse stiffeners are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the appropriate load model. Primary members are assumed to be load model (a), secondary members are, in general, assumed to load model (b), however special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.9.2 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

8.9.3 The geometric properties of stiffener sections are to be calculated in accordance with 1.15 using an effective width of attached plating as given in 1.7.

8.10 Accommodation deck stiffening

8.10.1 Accommodation decks are, in general, to be treated as lower deck/inside deckhouse decks, with their scantling requirements determined in accordance with 8.9.

8.11 Cargo decks

8.11.1 The Rule requirements for bending moment, shear force, shear stress and deflection for cargo deck stiffeners are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the appropriate load model. Primary members are assumed to be load model (a), secondary members are, in general, assumed to be load model (b), however special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided. Additionally where the cargo comprises wheeled vehicles the requirements of Ch 5,3 are to be complied with.

8.11.2 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

8.11.3 The geometric properties of stiffeners sections are to be calculated in accordance with 1.15 using an effective width of attached plating as given in 1.7.

8.12 Deck openings

8.12.1 All openings are to be supported by an adequate framing system, pillars or cantilevers. When cantilevers are used, stiffening requirements may be derived from direct calculations.

8.12.2 Where stiffening members are stopped in way of an opening, they are to be attached to carlings, girders, transverses or coamings.

8.12.3 The corners of large hatchways in the strength/weather deck within 0,5*L* amidships are to be elliptical, parabolic or rounded, with a radius generally not less than 1/24 of the breadth of the opening.

8.12.4 Where elliptical corners are arranged, the major axis is to be fore and aft, the ratio of the major to minor axis is to be not less than two to one, nor greater than 2,5 to 1, and the minimum half-length of the major axis is to be defined by l_1 in Fig. 3.8.1. Where parabolic corners are arranged, the dimensions are also to be as shown in Fig. 3.8.1.

8.12.5 Where the corners are parabolic or elliptical, increased thickness of laminate will, in general, not be required.

8.12.6 For other shapes of corner, local reinforcement of the size and extent shown in Fig. 3.8.2 will, in general, be required. The required weight of reinforcement is to be not less than 25 per cent greater than the adjacent deck laminate.

8.12.7 For lower decks the corners of large openings are to be rounded, with a radius generally not less than 1/24 of the breadth of the opening.

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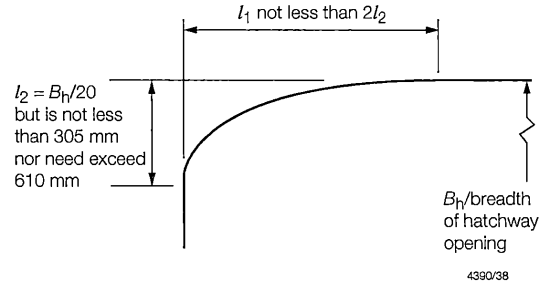

Fig. 3.8.1 Hatch opening geometry

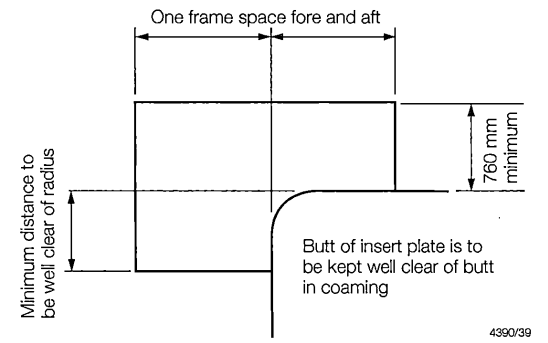

Fig. 3.8.2
Local reinforcement in way of hatch opening

8.12.8 Local reinforcement will be required at lower decks in way of rapid change in hull form to compensate for loss of deck cross-sectional area. Otherwise, local reinforcement will not normally be required.

8.12.9 Adequate transverse strength is to be provided in the deck area between large hatch openings subjected to transverse and buckling loads.

8.12.10 The requirements for closing arrangements and outfit are given in Pt 3, Ch 4.

8.13 Sheathing

8.13.1 The requirements for deck sheathing are given in 2.9.

8.14 Novel features

8.14.1 Novel features will be specially considered in accordance with 2.7.

8.14.2 Where large or novel hatch openings are proposed, detailed calculations are to be submitted to demonstrate that the scantlings and arrangements in way of the openings are adequate to maintain continuity of structural strength.

■ *Section 9* Superstructures, deckhouses and bulwarks

9.1 General

9.1.1 Superstructures, deckhouses and bulwarks may be of single skin or sandwich construction or a combination of both.

9.1.2 Where practicable, superstructures and deckhouses are to be designed with well cambered decks and well radiused corners to build rigidity into the structure.

9.1.3 The laminate and supporting structure are to be suitably reinforced in way of stressed corners of openings, cranes, masts, derrick posts, machinery, fittings and other heavy or vibrating loads.

9.1.4 Primary stiffening members are to be continuous and substantially bracketed at their end connections to maintain continuity of structural strength.

9.1.5 Secondary stiffening members are, in general, to be continuous through supporting structures.

9.1.6 Structures subject to concentrated loads, such as pillars out of line, are to be suitably reinforced. Where concentrations of loading on one side of a stiffener may occur, the stiffener is to be adequately stiffened against torsion. Additional reinforcements may be required in way of localised areas of high stress.

9.1.7 Structures are to comply with the minimum thickness requirements of Section 2.

9.2 Symbols and definitions

9.2.1 The term 'house' is used in this Section to include both superstructures and deckhouses.

9.2.2 The symbols for use within this Section are as defined in 1.5.1 unless otherwise specified.

9.3 House side laminates

9.3.1 The bending moment assumed to be carried by the house side plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 9.3.2 and 9.3.4 respectively.

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9.3.2 An estimate of the thickness of **house side single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.3.3 In no case is the minimum thickness of single skin plating to be taken as less than 2,5 mm.

9.3.4 An estimate of the stiffness EI, thickness of single skin plating for outer and inner skins of the **house side sandwich panels** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.3.5 In no case is the minimum thickness of laminate which forms the skin of a sandwich laminate to be taken as less than 2 mm.

9.4 House front laminates

9.4.1 The bending moment assumed to be carried by the house front plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 9.4.2 and 9.4.4 respectively.

9.4.2 An estimate of the thickness of **house front single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.4.3 In no case is the minimum thickness of single skin plating to be taken as less than 3,0 mm.

9.4.4 An estimate of the stiffness EI, the thickness of single skin plating for outer and inner skins of the **house front sandwich panels** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.4.5 In no case is the minimum thickness of laminate which forms the skin of a sandwich laminate to be taken as less than 2,5 mm.

9.5 House aft end laminates

9.5.1 The bending moment assumed to be carried by the house aft end plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 9.5.2 and 9.5.4 respectively.

9.5.2 An estimate of the thickness of **house aft end single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.5.3 In no case is the minimum thickness of single skin plating to be taken as less than 2,5 mm.

9.5.4 An estimate of the stiffness EI, the thickness of single skin plating for outer and inner skins of the **house aft end sandwich panels** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.5.5 In no case is the minimum thickness of laminate which forms the skin of a sandwich laminate to be taken as less than 2 mm.

9.6 House top laminates

9.6.1 The bending moment assumed to be carried by the house top plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 9.6.3 and 9.6.5 respectively.

9.6.2 An estimate of the thickness of **house top single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.6.3 In no case is the minimum thickness of single skin plating to be taken as less than 2,5 mm.

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9.6.4 An estimate of the stiffness *EI*, the thickness of single skin plating for outer and inner skins of the **house top sandwich panels** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.6.5 In no case is the minimum thickness of laminate which forms the skin of a sandwich laminate to be taken as less than 2 mm.

9.7 Coachroof laminates

9.7.1 The bending moment assumed to be carried by the coachroof plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 9.7.2 and 9.7.4 respectively.

9.7.2 An estimate of the thickness of **coachroof single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.7.3 In no case is the minimum thickness of single skin plating to be taken as less than 2,5 mm.

9.7.4 An estimate of the stiffness *EI*, thickness of single skin plating for outer and inner skins of the **coachroof sandwich panels** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.7.5 In no case is the minimum thickness of laminate which forms the skin of a sandwich laminate to be taken as less than 2 mm.

9.8 Machinery casing laminates

9.8.1 The bending moment assumed to be carried by the machinery casing plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 9.8.2 and 9.8.4 respectively.

9.8.2 An estimate of the thickness of the **machinery casing single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits are indicated in Table 7.3.1 in Chapter 7 for house side plating.

9.8.3 In no case is the minimum thickness of single skin plating to be taken as less than 3,0 mm.

9.8.4 An estimate of the stiffness *EI*, the thickness of single skin plating for outer and inner skins of the **machinery casing sandwich panels** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.8.5 In no case is the minimum thickness of laminate which forms the skin of a sandwich laminate to be taken as less than 2,5 mm.

9.9 Forecastle requirements

9.9.1 The side laminate may be a continuation of the hull laminate, an integral part of the deck moulding or connected as a separate assembly. The laminate is to be the same weight as the side hull laminate at the deck edge position, and is to be increased along the connection, if fitted, to the top edge of the hull. Suitable scarfing arrangements are to be made to ensure the continuity of the effect of the sheerstrake at the break and at the upper edge of the forecastle side. The laminate is to be stiffened by sideframes carried up or they may be stopped short of the deck provided the ends are effectively built-in. Deep webs are to be fitted to ensure overall rigidity of the side laminate.

9.10 House side stiffeners

9.10.1 The Rule requirements for bending moment, shear force, shear stress and deflection for the **house side primary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (a).

9.10.2 The Rule requirements for bending moment, shear force, shear stress and deflection for the **house side secondary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

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9.10.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

9.10.4 The geometric properties of stiffener sections are to be calculated in accordance with 1.15 using an effective width of attached plating as given in 1.7.

9.11 House front stiffeners

9.11.1 The Rule requirements for bending moment, shear force, shear stress and deflection for the **house front primary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (a).

9.11.2 The Rule requirements for bending moment, shear force, shear stress and deflection for the **house front secondary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.11.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

9.11.4 The geometric properties of stiffeners sections are to be calculated in accordance with 1.15 using an effective width of attached plating as given in 1.7.

9.12 House aft end stiffeners

9.12.1 The Rule requirements for bending moment, shear force, shear stress and deflection for the **house aft end primary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (a).

9.12.2 The Rule requirements for bending moment, shear force, shear stress and deflection for the **house aft end secondary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.12.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

9.12.4 The geometric properties of stiffener sections are to be calculated in accordance with 1.15 using an effective width of attached plating as given in 1.7.

9.13 House top stiffeners

9.13.1 The house top is to be efficiently supported by a system of transverse or longitudinal beams and girders. The span of the beams is generally not to exceed 2,4 m and the beams are to be effectively built into the house upper coamings and girders.

9.13.2 The Rule requirements for bending moment, shear force, shear stress and deflection for the **house top primary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (a).

9.13.3 The Rule requirements for bending moment, shear force, shear stress and deflection for the **house top secondary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.13.4 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

9.13.5 The geometric properties of stiffeners sections are to be calculated in accordance with 1.15 using an effective width of attached plating as given in 1.7.

9.14 Coachroof stiffeners

9.14.1 The Rule requirements for bending moment, shear force, shear stress and deflection for the **coachroof primary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (a).

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9.14.2 The Rule requirements for the bending moment, shear force, shear stress and deflection for the **coachroof secondary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.14.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

9.14.4 The geometric properties of stiffener sections are to be calculated in accordance with 1.15 using an effective width of attached plating as given in 1.7.

9.15 Machinery casing stiffeners

9.15.1 The Rule requirements for bending moment, shear force, shear stress and deflection for the **machinery casing primary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (a).

9.15.2 The Rule requirements for bending moment, shear force, shear stress and deflection for the **machinery casing secondary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.15.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

9.15.4 Where casing sides act as girders supporting decks over, care is to be taken that access openings do not seriously weaken the structure. Openings are to be effectively framed and reinforced if found necessary. Particular attention is to be paid to stiffening where the casing supports the funnel or exhaust uptakes.

9.15.5 Where casing stiffeners carry loads from deck transverses, girders, etc., or where they are in line with pillars below, they are to be suitably reinforced.

9.15.6 The geometric properties of stiffener sections are to be calculated in accordance with 1.15 using an effective width of attached plating as given in 1.7.

9.16 Forecastle stiffeners

9.16.1 The Rule requirements for bending moment, shear force, shear stress and deflection for the **forecastle primary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (a).

9.16.2 The Rule requirements for bending moment, shear force, shear stress and deflection for the **forecastle secondary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.16.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

9.16.4 The geometric properties of stiffener sections are to be calculated in accordance with 1.15 using an effective width of attached plating as given in 1.7.

9.17 Superstructures formed by extending side structure

9.17.1 Superstructure first tier sides formed by extending the hull side structure are to be in accordance with the requirements for house fronts indicated in 9.4 and 9.11 for laminates and stiffeners respectively, but need not be taken as greater than the side structure requirements at the deck edge at the same longitudinal position.

9.18 Fire aspects

9.18.1 Fire detection, protection and extinction requirements are given in Part 17.

9.19 Openings

9.19.1 All openings are to be substantially framed and have well rounded corners. Arrangements are to be made to minimise the effect of discontinuities. Continuous coamings or girders are to be fitted below and above doors and similar openings.

9.19.2 Particular attention is to be paid to the effectiveness of end bulkheads when large openings for doors and windows are fitted, and also to the upper deck stiffening in way.

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9.19.3 Special care is to be taken to minimise the size and number of openings in the side bulkheads in the region of the ends of houses within $0,5L_R$ amidships. Account is to be taken of the high vertical shear loading which may occur in these areas.

9.19.4 The requirements for closing arrangements and outfit are given in Pt 3, Ch 4.

9.20 Mullions

9.20.1 Window openings are to be suitably framed and mullions will in general be required.

9.20.2 The scantlings of mullions are to be not less than as required for a stiffener in the same position.

9.20.3 The geometric properties of stiffener sections are to be calculated in accordance with 1.15 using an effective width of attached plating as indicated in 1.7, in no case is the width of effective plating to be taken greater than the distance between adjacent window openings.

9.20.4 Where significant shear forces are to be transmitted by window frames, adequate shear rigidity requires to be verified.

9.21 Global strength

9.21.1 Transverse rigidity is to be maintained throughout the length of the house by means of web frames, bulkheads or partial bulkheads. Particular attention is to be paid when a superimposed tier is wider than its supporting tier and when significant loads are carried on the house top.

9.21.2 Where practicable, web frames are to be arranged in line with bulkheads below.

9.21.3 Internal bulkheads are to be fitted in line with bulkheads or deep primary stiffeners below.

9.22 House/deck connection

9.22.1 Adequate support under the ends of houses is to be provided in the form of webs, pillars, diaphragms or bulkheads in conjunction with reinforced deck beams.

9.22.2 Special attention is to be given to the connection of the house to the deck in order to provide an adequate load distribution and avoid stress concentrations.

9.22.3 Typical design details of house/deck connections are given in LR's *Guidance Notes for Structural Details*.

9.23 Sheathing

9.23.1 Sheathing arrangements are to comply with 2.9.

9.24 Novel features

9.24.1 Laminate and stiffener requirements may need to be determined by direct calculation where the house is of unusual design, form or proportions, *see also* 2.7.

9.25 Bulwarks

9.25.1 General requirements for bulwarks are given in Pt 3, Ch 4.8.

9.25.2 The bending moment assumed to be carried by the bulwark plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 9.25.3 and 9.25.5 respectively.

9.25.3 An estimate of the thickness of the **bulwark single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.25.4 In no case is the minimum thickness of single skin plating to be taken as less than 2,5 mm.

9.25.5 An estimate of the stiffness EI, thickness of single skin plating for outer and inner skins of the **bulwark sandwich panels** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.25.6 In no case is the minimum thickness of laminate which forms the skin of a sandwich laminate to be taken as less than 2 mm.

9.25.7 The Rule requirements for bending moment, shear force, shear stress and deflection for the **bulwark stays** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (d).

9.25.8 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

9.25.9 The geometric properties of stiffener sections are to be calculated in accordance with 1.15 using an effective width of attached plating as given in 1.7.

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9.25.10 Bulwarks should not be cut for gangway or other openings near the breaks of houses.

9.25.11 Attention is to be paid to avoid discontinuity of strength of the bulwark, particularly in way of local increases in stress and changes in height.

9.25.12 **Fishing craft** are to have bulwarks fitted. The bulwark may be formed as a continuation of the hull laminate, an integral part of the deck moulding or connected as a separate assembly. Where the bulwark is considered to be stressed and contributing to the global strength of the craft, the laminate weight of the bulwark is not to be less than the sheer laminate weight. In no case is the bulwark laminate weight to be taken as less than 80 per cent of the shell weight. The bulwark is to be supported by suitable stiffening which may be formed by a continuation of the side frames, or by top hat, or plate laminate stays of the same weight as the bulwark. These frames are not generally to be spaced more than two side frame spacings apart.

9.25.13 In way of gantries, trawl gallows, mooring pipes etc. the laminate in way is to be increased by 50 per cent.

9.25.14 **Pilot craft** are to be fitted with sufficient hand rails adjacent to the exposed areas of the working decks and platforms and in addition these areas should have non skid surfaces.

9.26 Freeing arrangements

9.26.1 The requirements for freeing arrangements are given in Pt 3, Ch 4,9.

9.27 Free flow area

9.27.1 The requirements for free flow area are given in Pt 3, Ch 4,9.3.

9.28 Guard rails

9.28.1 The requirements for guard rails are given in Pt 3, Ch 4,8.4.

■ *Section 10* Pillars and pillar bulkheads

10.1 General

10.1.1 Pillars are to be arranged to transmit loads from decks and superstructures into the bottom structure. Pillars are to be constructed out of materials of adequate compressive strength and modulus, usually steel or aluminium and these are generally to be of solid, tubular or *I* beam form. A pillar may be a fabricated trunk or partial bulkhead.

10.2 Symbols and definitions

10.2.1 The symbols for use within this Section are as defined in 1.5.1, unless otherwise specified in the appropriate sub-Section.

10.3 Determination of spans

10.3.1 The effective span length of pillar, l_{ep}, is in general the distance between the head and heel of pillar. Where substantial brackets are fitted, the effective length of pillar, l_{ep}, may be reduced by 2/3 of the depth of the brackets at each end.

10.4 Head and heel connection

10.4.1 The structure in way of head and heel connections is to be suitably reinforced. The webs and face reinforcement of such supporting structure are to be locally increased as necessary with due account being taken of both the compression and bending moment in way.

10.4.2 Pillars are to be attached at their heads and heels to plates supported by efficient brackets. Where the attachment is through bolted, suitable inserts or compression tubes are to be incorporated within the deck and hull framing to prevent over-compression and damage to the laminate in way. Alternatively, tapping plates may be incorporated within the face reinforcement of the stiffener. Details of the proposed arrangement are to be indicated on the submitted plans.

10.5 Alignment and arrangement

10.5.1 Pillars are to be fitted on main structural members. They should be fitted below deckhouses, windlasses,winches, capstans and elsewhere where considered necessary.

10.5.2 Wherever possible, deck pillars are to be fitted in the same vertical line as pillars above and below, and effective arrangements are to be made to distribute the load at the heads and heels of all pillars.

10.5.3 Where pillars support eccentric loads, or are subjected to lateral pressures, they are to be suitably strengthened for the additional bending moment imposed upon them.

10.6 Minimum thickness

10.6.1 The minimum wall thickness of steel or aluminium pillars are to be as required by Pt 6, Ch 3 or Pt 7, Ch 3 respectively.

10.6.2 The minimum wall thickness of FRP pillars will be specially considered.

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10.7 Pillar scantlings

10.7.1 The scantlings of steel or aluminium pillars, and pillar bulkheads, are to be as required by Pt 6, Ch 3 and Pt 7, Ch 3 respectively.

10.7.2 The scantlings of FRP pillars/pillar bulkheads are to be in accordance with 10.10.

10.7.3 Where a pillar is of unusual material, the scantlings will be specially considered.

10.8 Pillars in tanks

10.8.1 Pillars are in no circumstances to pass through tanks. Where loads are to be transmitted through the tank, pillars within the tanks are to be carefully aligned with the external pillars.

10.8.2 Pillars within tanks are, in general, to be of solid cross section. Proposals to use hollow section or tubular pillars will be subject to special consideration and the scantlings as determined from the Rules may be required to be increased dependent upon the material to be used, the fluid contained and the arrangement of the pillars. Hollow pillars are to be adequately drained and vented.

10.8.3 Pillars within tanks which may be subjected to tensile stresses due to hydrostatic pressure, are to be designed to provide sufficient connection to withstand the tension load imposed.

10.9 Pillar bulkheads

10.9.1 Where the pillar bulkhead is of steel or aluminium construction the method of attachment to the surrounding structure/framing will be specially considered.

10.9.2 Where a pillar bulkhead supports a concentrated load the structure in way is to be suitably reinforced to distribute the load into the adjacent stiffening.

10.10 Composite pillars and pillar bulkhead scantlings

10.10.1 The load P_p, assumed to be carried by a pillar is to be determined from:

$$P_p = S_{gt}\, b_{gt}\, P_c + P_a \quad \text{kN}$$

where

P_p = design load supported by the pillar, which is to be taken as not less than 5 kN

P_c = basic deck girder design pressure as appropriate, plus any other loadings above the pillar, in kN/m^2

P_a = load, in kN, from pillar or pillars above, assumed zero if there are no pillars over

S_{gt} = spacing, or mean spacing, of girders or transverses, in metres

b_{gt} = distance between centres of two adjacent spans of girders or transverses supported by the pillars, in metres.

10.10.2 The load P_b, assumed to be carried by a pillar bulkhead is to be determined from:

$$P_{pb} = S_{bs}\, b_{pb}\, P_c + P_a \quad \text{kN}$$

where

P_{pb} = design load supported by the stiffener plate combination of the pillar bulkhead, in kN

P_c = basic deck girder design pressure, as appropriate, plus any other loadings directly above the pillar, in kN/m^2

S_{bs} = spacing, or mean spacing of bulkheads or effective transverses/longitudinal stiffeners, in metres

b_{pb} = distance between centres of two adjacent spans of girders or transverses supported by the pillar bulkhead, in metres, and can be taken as the distance between pillar bulkhead stiffeners where the stiffener at the top of the bulkhead effectively distributes the load evenly into the stiffeners.

10.10.3 The slenderness ratio (l_{ep}/r) of a pillar or plate stiffener combination is to be determined from:

$$r = \sqrt{\frac{\Sigma\,(E_i\, I_i)}{\Sigma\,(E_i\, A_i)}} \quad \text{cm}$$

where

r = least radius of gyration of pillar cross section, in cm

l_{ep} = effective length of pillar, in cm

E_i, I_i and A_i are as defined in 1.5.1.

10.10.4 The compressive loads P_p or P_{pb}, from 10.10.1 and 10.10.2 for pillars and pillar bulkheads respectively are not to exceed a function of the critical load P_{cr}, determined from 10.10.5:

$$P_p \text{ (or } P_{pb}) < f_p\, P_{cr} \quad \text{kN}$$

where

f_p is a factor dependent upon location and is as indicated in Table 3.10.1.

Table 3.10.1 Pillar location factors

Location	f_p
Supporting weatherdeck	0,50
Supporting vehicle deck	0,25
Supporting passenger deck	0,50
Supporting lower/inner deck	0,75
Supporting coachroof	0,75
Supporting deckhouse top	1,00

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10.10.5 The critical compressive load, P_{cr}, for pillars and plate/stiffener combinations with a slenderness ratio (l_e/r) between 75 and 110 may be determined from:

$$P_{cr} = \frac{k\,\pi^2\,\Sigma\,(E_{ci}\,I_i)}{l_{ep}^2} \times 10^5 \quad \text{kN}$$

where

l_{ep} = effective span length of pillar or stiffener plate combination, in metres

E_{ci} = compressive modulus of plate laminate, in N/mm^2

k = end fixity factor

= 1,5 for full fixed/bracketed

= 0,75 for partially fixed

= 0,5 for free ended

Where the proposed slenderness ratio is below 75 the pillar will be specially considered. Slenderness ratios in excess of 110 are not to be contemplated.

10.10.6 The stiffener/plate combination used to determine the scantlings for pillar bulkheads is to be that of a stiffener with an effective width of attached plating carrying a load as determined from 1.7.

10.10.7 The scantlings of wooden pillar bulkheads will be specially considered on the basis of the Rules. Such pillar bulkheads are to be of equivalent strength, stiffness and load carrying capability.

10.11 Detail in way of sandwich structure

10.11.1 The attachment of pillars to sandwich structures should, in general, be through an area of single skin laminate, *see* Ch 2,4.3. Where this is not practicable and the attachment of the pillar has to be by bolting through a sandwich structure then a wood, or other suitable solid insert is to be fitted in the core in way.

10.12 Fire aspects

10.12.1 Pillars are to be suitably protected against fire, where necessary, be self extinguishing or be capable of resisting fire damage. All pillars are to comply with Part 17.

10.13 Novel features

10.13.1 Where pillars are of unusual design or constructed from novel material they will be specially considered in accordance with 2.7.

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Scantling Determination for Multi-Hull Craft

Section

1 **General**

2 **Minimum thickness requirements**

3 **Shell envelope laminate**

4 **Shell envelope framing**

5 **Single bottom structure and appendages**

6 **Double bottom structure**

7 **Bulkheads and deep tanks**

8 **Deck structures**

9 **Superstructures, deckhouses, bulwarks and pillars**

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to multi-hull craft of composite construction as defined in Pt 1, Ch 1,1.

1.2 General

1.2.1 Except as otherwise specified within this Chapter, the scantlings and arrangements of multi-hull craft are to be determined in accordance with the procedures described in, or as required by Chapter 3 for mono-hull craft, using the pressures from Part 5 appropriate to multi-hull craft.

1.3 Direct calculations

1.3.1 Where the craft is of unusual design, form or proportions, or where the speed of the craft exceeds 60 knots the scantlings are to be determined by direct calculation.

1.3.2 The requirements of this Chapter may be modified where direct calculation procedures are adopted to analyse the stress distribution in the primary structure.

1.4 Equivalents

1.4.1 Lloyd's Register (hereinafter referred to as 'LR') will consider direct calculations for the derivation of scantlings as an alternative and equivalent to those derived by Rule requirements in accordance with Pt 3, Ch 1,2.

1.5 Symbols and definitions

1.5.1 Unless otherwise specified the symbols and definitions for use within this Chapter are as defined in Ch 3,1.5.

1.5.2 **Bottom outboard.** For high speed craft, where the scantlings of the bottom shell are governed by impact pressure considerations, the bottom outboard shell is defined as the area of the hull between the outboard edge of the keel and the outer bilge tangential point. For displacement and semi displacement type craft where the scantlings of the bottom shell are governed by either hydrostatic or pitching pressures, the bottom outboard shell is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

1.5.3 **Bottom inboard.** For high speed craft, where the scantlings of the bottom shell are governed by impact pressure considerations, the bottom inboard shell is defined as the area of the hull between the inboard edge of the keel and the inner bilge tangential point. For displacement and semi displacement type craft where the scantlings of the bottom shell are governed by either hydrostatic or pitching pressures the bottom inboard shell is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

1.5.4 **Cross-deck.** The cross-deck is defined as the structure which forms the bridge connection between any two adjacent hulls.

1.5.5 **Haunch.** The haunch is defined as the transition area between the cross-deck and the side inboard shell laminate.

1.5.6 **Side inboard.** The side inboard is defined as the area between the bottom inboard shell and the wet-deck (or lower edge of the haunches, where fitted).

1.5.7 **Side outboard.** The side outboard is defined as the area between bottom outboard shell and the deck at side.

1.5.8 **Wet-deck.** The wet-deck is defined as the area between the upper edges of the side inboard laminate (or upper edges of the haunches, where fitted).

■ *Section 2* Minimum thickness requirements

2.1 General

2.1.1 The minimum thickness requirements are to be in accordance with Ch 3,2.

2.1.2 In addition, where laminates contribute to the global strength of the craft, the thickness is to be not less than that required to satisfy global strength requirements.

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■ *Section 3*
Shell envelope laminate

3.1 General

3.1.1 Except as otherwise specified within this Section, the scantlings and arrangements for the shell envelope laminate are to be determined in accordance with the procedures described in, or as required by Ch 3,3 for mono-hull craft, using the pressures from Part 5 appropriate to multi-hull craft.

3.2 Keel plates

3.2.1 The breadth, b_K, and thickness, t_K, of plate keels are not to be taken as less than:

$b_K = 5{,}0L_R + 250$ mm

$t_K = \sqrt{k_t}\ (5{,}0L_R^{0{,}45})$ mm

where

L_R = Rule length, in metres, as defined in Pt 3, Ch 2,6.1

k_t is as defined in Ch 3,2.1.

3.2.2 In no case is the thickness of the keel to be less than that of the adjacent bottom shell laminate.

3.2.3 The width and thickness of plate keels are to be maintained throughout the length of the craft from the transom to a point not less than 25 per cent of the freeboard measured at the forward perpendicular (FP) above the deepest load waterline on the stem. Thereafter the keel thickness may be reduced to that required by Ch 3,3.3.1 for the stem. Laminate tapers are to comply with Ch 3,2.6.2.

3.2.4 Where the bottom shell is of sandwich construction the keel is to be formed by locally returning to single skin construction for a width as required by 3.2.1. The Rule thickness of keel is to comprise both the inner and outer skins of the adjacent bottom shell sandwich plus additional reinforcement as required. The distribution of reinforcement in way of the plate keel and sandwich bottom structure is to be in accordance with Fig. 4.3.1. *See also* Ch 3,3.2.4.

3.2.5 For large, novel, asymmetric hull form craft, or yachts with externally attached ballast keels, or where it is proposed to incorporate keels of the 'bar' type the scantlings of the keel will be specially considered.

3.3 Bottom outboard

3.3.1 For all craft types, the minimum bottom outboard shell laminate thickness as required by the Rules is to be extended over the region as defined in 1.5.2 for displacement and semi-displacement craft.

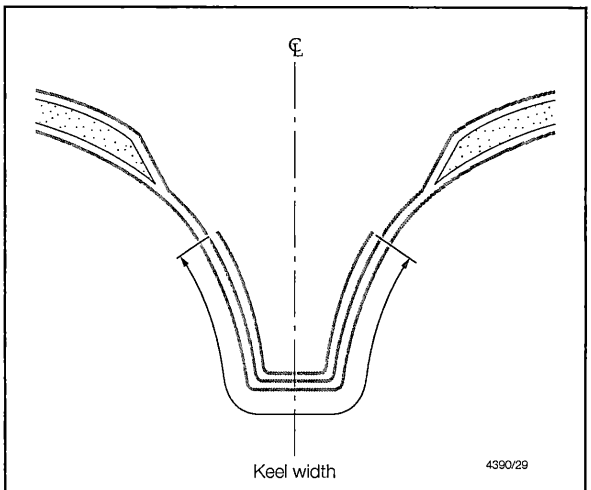

Fig. 4.3.1
Single skin/Sandwich skin intersection detail

3.3.2 The bending moment assumed to be carried by the bottom outboard shell laminate is to be not less than that determined by Ch 3,1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 3.3.3 and 3.3.5 respectively.

3.3.3 An estimate of the thickness of **bottom outboard single skin laminate** is to be determined from Ch 3,1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using Ch 3,1.12.3 and Ch 3,1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

3.3.4 In no case is the minimum thickness of single skin laminate to be taken as less than 5,5 mm.

3.3.5 An estimate of the stiffness *EI*, the thickness of single skin laminate for outer and inner skins of the **bottom outboard sandwich panel** and the thickness of core material is to be determined from Ch 3,1.13.2 and Ch 3,1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using Ch 3,1.13.7 and Ch 3,1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

3.3.6 In no case are the minimum thicknesses of laminate which form the skins of a sandwich laminate to be taken as less than 4,5 mm and 3,5 mm for the outer and inner skins respectively.

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3.3.7 Special consideration may be given to laminate thicknesses lesser than those required by 3.3.4 and 3.3.6, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided, *see* Ch 3,2.3.1, and the equivalent impact resistance is demonstrated as required by Ch 3,2.8.2.

3.4 Bottom inboard

3.4.1 The scantlings and arrangements for bottom inboard shell laminate are to be determined in accordance with the procedures described in 3.3 using the bottom inboard shell design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.5 Side outboard

3.5.1 The side outboard shell is as defined in 1.5.7.

3.5.2 For all craft types, the minimum side outboard shell laminate thickness as required by the Rules is to be extended over the region as defined in 3.5.1 for displacement and semi-displacement craft.

3.5.3 The bending moment assumed to be carried by the side outboard shell laminate is to be not less than that determined by Ch 3,1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 3.5.4 and 3.5.6 respectively.

3.5.4 An estimate of the thickness of **side outboard single skin laminate** is to be determined from Ch 3,1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using Ch 3,1.12.3 and Ch 3,1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

3.5.5 In no case is the minimum thickness of single skin laminate to be taken as less than 5 mm.

3.5.6 An estimate of the stiffness *EI*, the thickness of single skin laminate for outer and inner skins of the **side outboard sandwich panel** and the thickness of core material is to be determined from Ch 3,1.13.2 and Ch 3,1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using Ch 3,1.13.7 and Ch 3,1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

3.5.7 In no case are the minimum thicknesses of laminate which form the skins of a sandwich laminate to be taken as less than 4 mm and 3 mm for the outer and inner skins respectively.

3.5.8 Special consideration may be given to laminate thicknesses lesser than those required by 3.5.5 and 3.5.7, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided, *see* Ch 3,2.3.1, and the equivalent impact resistance is demonstrated as required by Ch 3,2.8.2.

3.6 Side inboard

3.6.1 The scantlings and arrangements for side inboard shell laminate are to be determined in accordance with the procedures described in 3.3 using the side inboard shell design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate.

3.7 Wet-deck

3.7.1 The wet-deck is as defined in 1.5.8.

3.7.2 The bending moment assumed to be carried by the wet-deck laminate is to be not less than that determined by Ch 3,1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 3.7.3 and 3.7.5 respectively.

3.7.3 An estimate of the thickness of wet-deck single skin laminate is to be determined from Ch 3,1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using Ch 3,1.12.3 and Ch 3,1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

3.7.4 In no case is the minimum thickness of single skin laminate to be taken as less than 5 mm.

3.7.5 An estimate of the *EI*, the thickness of single skin laminate for outer and inner skins of the wet-deck sandwich panel and the thickness of core material is to be determined from Ch 3,1.13.2 and Ch 3,1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using Ch 3,1.13.7 and Ch 3,1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

3.7.6 In no case are the minimum thicknesses of laminate which form the skins of a sandwich laminate to be taken as less than 4 mm and 3 mm for the outer and inner skins respectively.

3.7.7 Special consideration may be given to laminate thicknesses lesser than those required by 3.7.4 and 3.7.6, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided, *see* Ch 3,2.3.1, and the equivalent impact resistance is demonstrated as required by Ch 3,2.8.2.

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3.7.8 The wet-deck laminate on the underside of the cross-deck structure may require to be additionally protected, particularly where the air gap is small and there is a high risk of localised impact due to collision with floating debris, ice, etc., in the service area. In such cases the requirements for sheathing, given in Ch 3,2.9, are to be complied with.

3.8 Transom

3.8.1 The scantlings and arrangements of transoms are to be not less than as required for the adjacent bottom inboard or side outboard structure as appropriate.

3.8.2 Where water jet or sterndrive units are fitted, the scantlings of the plating in way of the nozzles and connections will be specially considered.

3.9 Haunch reinforcement (SWATH)

3.9.1 For craft above 30 m in length, L_R, the stresses in the haunch area are to be derived using a two dimensional fine mesh finite element analysis. The model is to extend horizontally into the box structure and vertically into the strut structure. All discontinuities and cut-outs are to be modelled in order to determine shear stresses at critical locations and stresses for the determination of fatigue strength.

3.9.2 Due consideration is to be given to shear lag when calculating the effective breadth of the attached laminate.

3.10 Lower hull (SWATH)

3.10.1 Where the lower hull structure incorporates ring frames and attached shell laminate fitted between bulkheads or diaphragms, the thickness of the lower hull shell laminate may be derived from an established method for shell analysis or recognised standard for pressure vessels. Modes of failure to be considered are buckling, frame collapse, inter frame shell collapse and overall frame shell collapse between bulkheads. Copies of direct calculations are to be submitted for consideration.

3.10.2 In general the design load to be used is the pressure load given in Pt 5, Ch 4,3.1. If other loads are considered to be of significance for the scantling determination these are to be taken into account.

3.11 Novel features

3.11.1 Where the Rules do not specifically define the requirements for laminate elements with novel features then the scantlings and arrangements are to be determined by direct calculations. Such calculations are to be carried out on the basis of the Rules, recognised standards and good practice, and are to be submitted for consideration.

Section 4
Shell envelope framing

4.1 General

4.1.1 Except as otherwise specified within this Section, the scantlings and arrangements for shell envelope framing are to be determined in accordance with the procedures described in, or as required by Ch 3,4 for mono-hull craft, using the pressures from Part 5 appropriate to multi-hull craft.

4.1.2 The requirements in this Section apply to longitudinally and transversely framed shell envelopes.

4.2 Bottom outboard longitudinal stiffeners

4.2.1 The bottom outboard longitudinal stiffeners are to be supported by bottom transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.2.2 Bottom outboard longitudinal stiffeners are to be continuous through the supporting structures.

4.2.3 Where it is impracticable to comply with the requirements of 4.2.2, or where it is desired to terminate the bottom outboard longitudinal stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.2.4 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1, or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 in Chapter 3 for the load model (b).

4.2.5 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7 and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.3 Bottom outboard longitudinal primary stiffeners

4.3.1 The bottom outboard longitudinal primary stiffeners are to be supported by bottom transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 6 m apart.

4.3.2 Bottom outboard longitudinal primary stiffeners are to be continuous through the supporting structures.

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4.3.3 Where it is impracticable to comply with the requirements of 4.3.2, or where it is desired to terminate the bottom outboard longitudinal primary stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.3.4 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 in Chapter 3 for the load model (a).

4.3.5 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.4 Bottom outboard transverse stiffeners

4.4.1 Bottom outboard transverse stiffeners are defined as local stiffening members which support the bottom shell, and which may be continuous or intercostal.

4.4.2 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 in Chapter 3 for the load model (b).

4.4.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.5 Bottom outboard transverse frames

4.5.1 Bottom outboard transverse frames are defined as stiffening members which support the bottom shell, they are to be effectively continuous and be bracketed at their end connections to side frames and bottom floors as appropriate.

4.5.2 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 in Chapter 3 for the load model (a).

4.5.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.6 Bottom outboard transverse web frames

4.6.1 Bottom outboard transverse web frames are defined as primary stiffening members which support bottom shell longitudinals, they are to be continuous and be substantially bracketed at their end connections to side web frames and bottom floors.

4.6.2 Where it is impracticable to comply with the requirements of 4.6.1, or where it is desired to terminate the bottom inboard transverse web frames in way of bulkheads or integral tank boundaries, etc., all web frames are to be bracketed in way of their end connections, to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' (*see* Fig. 3.4.1 in Chapter 3) and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.6.3 The Rule requirements for the bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 in Chapter 3 for the load model (a).

4.6.4 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.7 Bottom inboard longitudinal stiffeners

4.7.1 The scantlings and arrangements for bottom inboard longitudinal stiffeners are to be determined in accordance with the procedures described in 4.2 using the bottom inboard longitudinal stiffeners design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.8 Bottom inboard longitudinal primary stiffeners

4.8.1 The scantlings and arrangements for bottom inboard longitudinal primary stiffeners are to be determined in accordance with the procedures described in 4.3 using the bottom inboard longitudinal primary stiffeners design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.9 Bottom inboard transverse stiffeners

4.9.1 The scantlings and arrangements for bottom inboard transverse stiffeners are to be determined in accordance with the procedures described in 4.4 using the bottom inboard transverse stiffeners design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

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4.10 Bottom inboard transverse frames

4.10.1 The scantlings and arrangements for bottom inboard transverse frames are to be determined in accordance with the procedures described in 4.5 using the bottom inboard transverse frames design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.11 Bottom inboard transverse web frames

4.11.1 The scantlings and arrangements for bottom inboard transverse web frames are to be determined in accordance with the procedures described in 4.6 using the bottom inboard transverse web frames design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.12 Side outboard longitudinal stiffeners

4.12.1 The side outboard longitudinal stiffeners are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.12.2 Side outboard longitudinal stiffeners are to be continuous through the supporting structures.

4.12.3 Where it is impracticable to comply with the requirements of 4.12.2, or where it is desired to terminate the side outboard longitudinal stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.12.4 The Rule requirements for the bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 in Chapter 3 for the load model (b).

4.12.5 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.13 Side outboard longitudinal primary stiffeners

4.13.1 The side outboard longitudinal primary stiffeners are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 6 m apart.

4.13.2 Side outboard longitudinal primary stiffeners are to be continuous through the supporting structures.

4.13.3 Where it is impracticable to comply with the requirements of 4.13.2, or where it is desired to terminate the side outboard longitudinal primary stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.13.4 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 in Chapter 3 for the load model (a).

4.13.5 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.14 Side outboard transverse stiffeners

4.14.1 Side outboard transverse stiffeners are defined as local stiffening members which support the side shell, and which may be continuous or intercostal.

4.14.2 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 in Chapter 3 for the load model (b).

4.14.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.15 Side outboard transverse frames

4.15.1 Side outboard transverse frames are defined as stiffening members supporting the side shell and spanning continuously between bottom floors/frames and decks. They are to be effectively constrained against rotation at their end connections.

4.15.2 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 in Chapter 3 for the load model (a).

4.15.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

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4.16 Side outboard transverse web frames

4.16.1 Side outboard transverse web frames are defined as primary stiffening members which support side shell longitudinals, they are to be continuous and be substantially bracketed at their end connections to side web frames and side floors.

4.16.2 Where it is impracticable to comply with the requirements of 4.16.1, or where it is desired to terminate the side outboard transverse web frames in way of bulkheads or integral tank boundaries, etc., all web frames are to be bracketed in way of their end connections, to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed', *see* Fig. 3.4.1 in Chapter 3, and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.16.3 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 in Chapter 3 for the load model (a).

4.16.4 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.17 Side inboard longitudinal stiffeners

4.17.1 The scantlings and arrangements for side inboard longitudinal stiffeners are to be determined in accordance with the procedures described in 4.12 using the side inboard longitudinal stiffeners design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.18 Side inboard longitudinal primary stiffeners

4.18.1 The scantlings and arrangements for side inboard longitudinal primary stiffeners are to be determined in accordance with the procedures described in 4.8 using the side inboard longitudinal primary stiffeners design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.19 Side inboard transverse stiffeners

4.19.1 The scantlings and arrangements for side inboard transverse stiffeners are to be determined in accordance with the procedures described in 4.14 using the side inboard transverse stiffeners design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.20 Side inboard transverse frames

4.20.1 The scantlings and arrangements for side inboard transverse frames are to be determined in accordance with the procedures described in 4.15 using the side inboard transverse frames design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.21 Side inboard transverse web frames

4.21.1 The scantlings and arrangements for side inboard transverse web frames are to be determined in accordance with the procedures described in 4.16 using the side inboard transverse web frames design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.22 Wet-deck longitudinal stiffeners

4.22.1 The wet-deck longitudinal stiffeners are to be supported by transverse web frames, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.22.2 Wet-deck longitudinal stiffeners are to be continuous through the supporting structures.

4.22.3 Where it is impracticable to comply with the requirements of 4.22.2, or where it is desired to terminate the wet-deck longitudinal stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.22.4 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 in Chapter 3 for the load model (b).

4.22.5 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.22.6 In no case are the scantlings and arrangements for the wet-deck longitudinal stiffeners to be taken less than as required for the side inboard longitudinal stiffeners indicated in 4.17.

4.23 Wet-deck longitudinal primary stiffeners

4.23.1 The wet-deck longitudinal primary stiffeners are to be supported by transverse web frames, bulkheads, or other primary structure, generally spaced not more than 6 m apart.

4.23.2 Wet-deck longitudinal primary stiffeners are to be continuous through the supporting structures.

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4.23.3 Where it is impracticable to comply with the requirements of 4.23.2, or where it is desired to terminate the wet-deck longitudinal primary stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.23.4 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 in Chapter 3 for the load model (a).

4.23.5 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.23.6 In no case are the scantlings and arrangements for the wet-deck longitudinal primary stiffeners to be taken less than as required for the side inboard longitudinal primary stiffeners indicated in 4.18.

4.23.7 Additionally the requirements of Chapter 6, in respect of global strength are to be complied with.

4.24 Wet-deck transverse stiffeners

4.24.1 Wet-deck transverse stiffeners are defined as local stiffening members which support the wet-deck shell, and which may be continuous or intercostal.

4.24.2 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 in Chapter 3 for the load model (b).

4.24.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.24.4 In no case are the scantlings and arrangements for the wet-deck transverse stiffeners to be taken less than as required for the side inboard transverse stiffeners indicated in 4.19.

4.25 Wet-deck transverse frames

4.25.1 Wet-deck transverse frames are defined as stiffening members which support the wet-deck shell, they are to be effectively continuous and be bracketed at their end connections to side frames and side floors as appropriate.

4.25.2 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 in Chapter 3 for the load model (a).

4.25.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.25.4 In no case are the scantlings and arrangements for the wet-deck transverse frames to be taken less than as required for the side inboard transverse frames indicated in 4.20.

4.26 Wet-deck transverse web frames

4.26.1 Wet-deck transverse web frames are defined as primary stiffening members which support wet-deck longitudinals, they are to be continuous and be substantially bracketed at their end connections to side web frames and side floors.

4.26.2 Where it is impracticable to comply with the requirements of 4.26.1, or where it is desired to terminate the wet-deck transverse web frames in way of bulkheads or integral tank boundaries, etc., all web frames are to be bracketed in way of their end connections, to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed', *see* Fig. 3.4.1 in Chapter 3, and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.26.3 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 in Chapter 3 for the load model (a).

4.26.4 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.26.5 In no case are the scantlings and arrangements for the wet-deck transverse web frames to be taken less than as required for the side inboard transverse web frames indicated in 4.21.

4.26.6 Primary transverse web frame members which link the strength deck to the wet-deck structure and which carry the transverse global loading, are additionally to comply with Ch 6,3.4.

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4.26.7 Particular care is to be taken to ensure that the continuity of transverse structural strength is maintained. All primary transverse members are to be continuous through the side inboard structure and be integrated into transverse bulkheads or other primary structure within each hull, *see* Fig. 4.4.1. In the case of trimaran type craft the primary transverse members are to be continuous through the centre hull. Additionally the side inboard shell laminate in way of the intersection is to be locally increased in thickness by not less than 50 per cent. Copies of direct calculations are to be submitted for consideration.

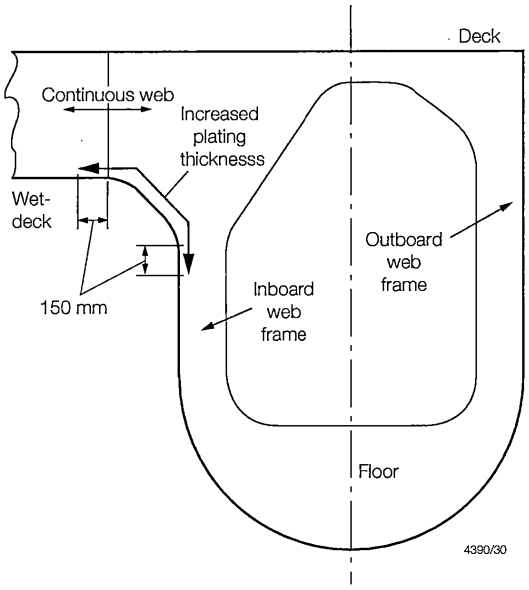

Fig. 4.4.1
End connection detail, wet-deck structure

4.27 Novel features

4.27.1 Where the Rules do not specifically define the requirements for novel features then the scantlings and arrangements are to be determined by direct calculations. Such calculations are to be carried out on the basis of the Rules, recognised standards and good practice, and are to be submitted for consideration.

■ *Section 5*
Single bottom structure and appendages

5.1 General

5.1.1 Except as otherwise specified within this Section, the scantlings and arrangements for single bottom structure and appendages are to be determined in accordance with the procedures described in, or as required by Ch 3,5 for mono-hull craft, using the pressures from Part 5 appropriate to multi-hull craft.

5.1.2 The minimum thickness requirements detailed in 2.1 are to be complied with as appropriate.

5.2 Keel

5.2.1 The scantlings and arrangements of plate keels are to be in accordance with 3.2. Where it is proposed to incorporate keels of the bar type such arrangements would require to be specially considered.

5.3 Centre girder

5.3.1 Centreline girders are to be fitted throughout the length of each hull and are generally to be fitted in association with transverse frames, transverses supporting longitudinals or where the breadth of floors at the upper edge is greater than 1,5 m.

5.3.2 Centreline girders may be formed with intercostal or continuous top hat or plate webs. Where girder webs are intercostal, additional bracketing and local reinforcement are to be provided to maintain the continuity of structural strength. The face reinforcement in all cases is to be continuous.

5.3.3 The web depth of the centre girder in general is to be equal to the depth of the floors at the centreline as specified in 5.5.

5.3.4 The web thickness, t_w, for a centre girder of 'top-hat' type section is to be not less than that required by Ch 3,1.16. or as determined as follows whichever is the greater and in no case is t_w to be taken less than 5,0 mm:

$$t_w = \sqrt{k_A}\ (\sqrt{L_R} + 1{,}37)\ \text{mm}$$

where

k_A and L_R are as defined in Ch 3,1.5.1.

5.3.5 The web thickness for a centre girder of single plate laminate construction is to be two times the thickness as required by 5.3.4.

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5.3.6 The face area of the centre girder, A_f, is to be not less than:

$$A_f = 1{,}18 L_R k_A \text{ cm}^2$$

where

$$k_A = \frac{85}{\sigma_u}$$

σ_u = ultimate tensile strength of the face area laminate, in N/mm^2

L_R = as defined in Ch 3,1.5.1.

5.3.7 The face area of the centre girder outside $0{,}5L_R$ about midships may be reduced to 80 per cent of the value given in 5.3.6.

5.3.8 The face thickness, t_f, is to be not less than the web thickness of the centre girder.

5.3.9 Additionally, the requirements of 4.8 for bottom longitudinal primary stiffeners are to be complied with.

5.4 Side girder

5.4.1 Where the floor breadth at the upper edge exceeds 4,0 m side girders are to be fitted at each side of the centre girder such that the spacing between the side and centre girders or between the side girders themselves is not greater than 3 m. Side girders where fitted are to extend as far forward and aft as practicable and are in general to terminate in way of bulkheads, deep floors or other primary transverse structure.

5.4.2 In the engine room, additional side girders are generally to be fitted in way of the main machinery.

5.4.3 The face area of side girders, A_f, is not to be taken as less than:

$$A_f = 0{,}82 L_R k_A \text{ cm}^2$$

where

k_A and L_R are as defined in Ch 3,1.5.1.

5.4.4 The web thickness, t_w, for side girders of 'top-hat' type section is to be not less than as required by Ch 3,1.16. or as determined as follows whichever is the greater and in no case is t_w to be taken less than 5,0 mm:

$$t_w = \sqrt{0{,}66 k_A L_R} \text{ mm}$$

where

k_A and L_R are as defined in Ch 3,1.5.1.

5.4.5 The web thickness for side girders of single plate laminate construction is to be two times the thickness as required by 5.4.4.

5.4.6 Additionally, the requirements of 4.8 for bottom longitudinal primary stiffeners are to be complied with.

5.4.7 Watertight side girders, or side girders forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deeptanks as detailed in Ch 3,7.3. and Ch 3,7.4 respectively.

5.5 Floors

5.5.1 In transversely framed craft, floors are generally to be fitted at every frame and underneath each bulkhead.

5.5.2 In longitudinally framed craft, floors are to be fitted at every transverse web frame and bulkhead and generally at a spacing not exceeding 2 m. Additional transverse floors or webs are to be fitted at half web-frame spacing in way of engine seatings and thrust bearings, pillars, skegs, ballast/bilge keels and the bottom of the craft in the forefoot region.

5.5.3 The overall depth of transverse floors at the centre-line, d_W, is not to be taken as less than:

$$d_W = 6{,}2 L_R + 50 \text{ mm}$$

5.5.4 The web thickness, t_w, for transverse floors of 'top-hat' type section is to be not less than as required by Ch 3,1.16. or as determined as follows whichever is the greater and in no case is t_w to be taken less than 5,0 mm:

$$t_w = \sqrt{k_A}\left(\frac{4{,}33 d_W}{1000} + 2{,}75\right)\left(\frac{s}{1000} + 0{,}5\right) \text{ mm}$$

where

d_W = as defined in 5.5.3

k_A and s are as defined in 5.3.6.

5.5.5 The web thickness for transverse floors of single plate laminate construction is to be two times the thickness as required by 5.5.4.

5.5.6 If the side frames of the craft are attached to the floors by brackets, the depth of floor may be reduced by 15 per cent and the floor thickness determined using the reduced depth. The brackets are to have the same thickness as the floors, and their arm lengths clear of the frame are to be the same as the reduced floor depth given above.

5.5.7 The face area of floors, A_f, is not to be taken as less than:

$$A_f = 0{,}82 L_R k_A \text{ cm}^2$$

where

k_A and L_R are as defined in Ch 3,1.5.1.

5.5.8 The thickness of the face laminate, t_f, is to be not less than the web thickness.

5.5.9 In addition, the requirements of 4.11 for bottom inboard transverse web frames are to be complied with.

5.5.10 Floors are generally to be continuous from side to side.

5.5.11 The tops of floors, in general, may be level from side to side. However, in craft having considerable rise of floor the depth of the floor plate may require to be increased to maintain the required mechanical properties of the section.

5.5.12 The floors in the aft peak are to extend over and provide efficient support to the stern tube(s) where applicable.

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5.5.13 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deeptanks as detailed in Ch 3,7.3 or Ch 3,7.4 respectively.

5.6 Floors in machinery space

5.6.1 The depth and mechanical properties of floors between engine or gearbox girders is to be not less than that required to maintain continuity of structural integrity or 50 per cent of the depth given in 5.5.3. The web thickness and face reinforcement weight of such reduced height floors are to be increased appropriately in order to maintain the continuity of structural strength.

5.7 Lower hull (SWATH)

5.7.1 Where the lower hull structure incorporates ring frames and attached shell laminate fitted between bulkheads or diaphragms, the scantlings of the lower hull shell stiffening may be derived from an established method for stiffening analysis or recognised standard for pressure vessels. Modes of failure to be considered are buckling, frame collapse, inter frame shell collapse and overall frame shell collapse between bulkheads. Copies of detailed calculations are to be submitted for consideration.

5.7.2 In general, the design load used is to be the design pressure from Pt 5,Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate. If other loads are considered to be of significance for the scantling determination these are to be taken into account.

5.8 Forefoot and stem

5.8.1 The scantlings and arrangements for the forefoot and stem construction are to be in accordance with Ch 3,5.11.

5.9 Transom knee

5.9.1 Transom knees are to be fitted in each hull as necessary in accordance with Ch 3,5.12.

■ *Section 6*
Double bottom structure

6.1 General

6.1.1 Except as otherwise specified within this Section, the scantlings and arrangements for double bottom structure are to be determined in accordance with the procedures described in, or as required by Ch 3,6 for mono-hull craft, using the pressures from Part 5 appropriate to multi-hull craft.

6.1.2 The minimum thickness requirements detailed in Ch 3,2.1 are to be complied with as appropriate.

6.2 Keel

6.2.1 The breadth and thickness of plate keels are to comply with the requirements of 3.2.

6.3 Centreline girder

6.3.1 A centreline girder is to be fitted throughout the length of each hull. The web thickness, t_w, of centre girders of 'top-hat' type section is to be not less than as required by Ch 3,1.16. or as determined as follows whichever is the greater and in no case is t_w to be taken less than 5,0 mm:

$t_w = \sqrt{k_A}\ (0{,}073L_R + 3{,}64)$ mm within $0{,}4L_R$ amidships

$= \sqrt{k_A}\ (0{,}073L_R + 2{,}73)$ mm at ends

where

k_A and L_R are as defined in Ch 3,1.5.1.

6.3.2 The web thickness for a centreline girder of single plate laminate construction is to be two times the thickness as required by 6.3.1.

6.3.3 The overall depth of the centreline girder, d_{DB}, is not to be taken as less than 630 mm and is to be sufficient to give adequate access to all parts of the double bottom.

6.3.4 Additionally, the requirements of 4.8 for bottom inboard longitudinal primary stiffeners are to be complied with.

6.4 Side girders

6.4.1 Where the breadth of the floor at the upper edge, within a single hull, does not exceed 4,0 m, side girders are not required. Vertical stiffeners are to be fitted to the floors on each side of the centreline girder, the number and positions of these stiffeners being dependent on the arrangement of the double bottom structure.

6.4.2 Where the breadth of the floor at the upper edge, within a single hull, exceeds 4,0 m, side girders are to be fitted at each side of the centre girder such that the spacing between the side and centre girders or between the side girders themselves is not greater than 3 m. Side girders, where fitted, are to extend as far forward and aft as practicable and are in general to terminate in way of bulkheads, deep floors or other primary transverse structure.

6.4.3 Under the main engine, girders extending from the bottom to the top plate of the engine seating are to be fitted. The height of the girders is not to be less than the height of the floor. Engine holding-down bolts are to be arranged as near as practicable to the girders and floors. Where this cannot be achieved, bracket floors are to be fitted.

6.4.4 Side girders are to have a minimum web thickness, t_w, as required by Ch 3,1.16 but not less than as determined as follows whichever is the greater and in no case is t_w to be taken less than 5,0 mm:

$t_w = \sqrt{k_A}\ (0{,}064L_R + 4{,}32)$ mm

where

k_A and L_R are as defined in Ch 3,1.5.1.

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6.4.5 Additionally, the requirements of 4.8 for bottom inboard longitudinal primary stiffeners are to be complied with.

6.5 Plate floors

6.5.1 Plate floors may be of single skin, sandwich skin or 'top-hat' type construction, and are to comply with the requirements of 5.5 where applicable.

6.5.2 The web thickness, t_w, of non-watertight plate floors of 'top-hat' type section is to be not less than as required by Ch 3,1.16 or as determined as follows whichever is the greater and in no case is t_w to be taken less than 5,0 mm:

$$t_w = \sqrt{k_A}\ (0{,}036L_R + 4)\ \text{mm}$$

where

k_A and L_R are as defined in Ch 3,1.5.1.

6.5.3 The web thickness for transverse floors of single plate laminate construction is to be two times the thickness as required by 6.5.2.

6.5.4 The thickness of plate laminates which form the skins for plate floors of sandwich skin construction are in no case to be taken as less than 2 mm.

6.5.5 Additionally, the requirements of 4.11 for bottom inboard transverse web frames are to be complied with.

6.5.6 Plate floors are generally to be continuous between the centre girder and the margin plate.

■ *Section 7* Bulkheads and deep tanks

7.1 General

7.1.1 Except as otherwise specified within this Section, the scantlings and arrangements for bulkheads and deep tanks are to be determined in accordance with the procedures described in, or as required by Ch 3,7 for mono-hull craft, using the pressures from Part 5 appropriate to multi-hull craft.

7.1.2 The scantlings of non-watertight or partial bulkheads are in general to be as required for watertight bulkheads. Non-watertight or partial bulkheads supporting hull framing are to have scantlings equivalent to frames or web frames as appropriate, in the same position.

7.1.3 Sandwich wood bulkheads, plywood bulkheads or other forms of bulkhead construction will be considered on the basis of equivalent strength.

7.2 Longitudinal bulkheads within cross-deck structure

7.2.1 Longitudinal bulkheads are to be fitted within the cross-deck structure to prevent cross flooding and the spread of flame and smoke. The minimum number of such bulkheads is to be two for catamarans and four for trimarans. Quadrimarans and other craft of novel configuration will be specially considered.

7.2.2 The scantlings and arrangements of cross-deck longitudinal bulkheads are to be determined in accordance with the procedures described in Ch 3,7.3 and Ch 3,7.4 for bulkheads in mono-hull craft.

7.2.3 In addition the requirements of 7.4 in respect of global strength are to be complied with.

7.3 Transverse bulkheads within the cross-deck structure

7.3.1 The scantlings and arrangements of cross-deck transverse bulkheads are to be determined in accordance with the procedures described in Ch 3,7.3 and Ch 3,7.4 for bulkheads in mono-hull craft.

7.3.2 In addition the requirements of 7.4 in respect of global strength are to be complied with.

7.4 Additional strength required for global loadings

7.4.1 Where transverse bulkheads or deep tank bulkheads within the cross-deck structure are to assist in resisting torsional or bending loads between the hulls, then the watertight/deep tank bulkheads may be required to be additionally stiffened and the laminate or skin thicknesses may require to be increased. For hull girder strength requirements, *see* Ch 6,3.

7.4.2 Longitudinal bulkheads within the cross-deck structure that are to assist in maintaining the longitudinal strength of the vessel are to satisfy both bulkhead/deep tank and longitudinal strength requirements. This may require additional stiffening and increase in plate thickness requirements. For hull girder strength requirements, *see* Ch 6,3.

7.4.3 Where longitudinal or transverse cross-deck bulkheads/deep tanks are to carry global loads, detailed calculations are to be submitted.

7.4.4 For longitudinal or transverse cross-deck members carrying global loads, consideration is to be given to stiffener arrangement, alignment, and continuity in order to maximise the rigidity and stiffness of the structure, in resisting the torsional/bending loads. Due consideration is to be given to the wrinkling and buckling of the skins of sandwich plate laminates. Discontinuity of structural bulkheads is to be avoided.

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7.5 Access

7.5.1 Access through the cross-deck structure may be permitted, provided that the global strength requirements are satisfied. Cut-outs through the bulkhead are not to exceed 50 per cent of its depth. The edges of cut-out in sandwich panels are to be suitably reinforced while those of single skin construction are to be sealed.

7.5.2 Where the cross-deck structure acts as a watertight bulkhead pipe or cable runs through, the watertight bulkheads are to be fitted with suitable watertight glands.

7.6 Local strength

7.6.1 Bulkheads that form the cross-deck structure are to be suitably strengthened, if necessary, at the ends of deck girders and where subjected to concentrated loads.

7.7 Integral/deep tanks within cross-deck structure

7.7.1 Where the cross-deck structure forms the boundaries of deep tanks, the scantlings of these boundaries are to satisfy both deep tank and global strength requirements. For general and structural requirements for deep tanks, *see* Ch 3,7.4. For global considerations of strength, *see* Ch 6,3.

■ *Section 8*
Deck structures

8.1 General

8.1.1 Except as otherwise specified within this Section, the scantlings and arrangements for deck structures are to be determined in accordance with the procedures described in, or as required by Ch 3,8 for mono-hull craft, using the pressures from Part 5 appropriate to multi-hull craft.

8.1.2 Deck structures are to comply with the minimum thickness requirements of Section 2.

8.1.3 Special attention is to be given to the connections of primary transverse beams to hull side web frames in order to provide adequate load distribution and avoid stress concentrations.

8.1.4 Primary stiffening members are to be continuous and substantially bracketed at their end connections to maintain continuity of structural strength.

8.1.5 Secondary stiffening members are to be effectively continuous and bracketed at their end connections as appropriate.

8.1.6 Design loads to be applied for cross-deck scantling calculations are transverse vertical bending moment and shear force, twin hull torsional connecting moment, external pressure load and appropriate internal loads as defined in Part 5.

8.2 Arrangements

8.2.1 Deck structures are to comply with the longitudinal and transverse global strength requirements given in Chapter 6.

8.3 Symbols and definitions

8.3.1 The term 'cross-deck' is used in this Section for the bridging deck, connecting two or more hulls, carrying global transverse loads. *See also* 1.5.4.

8.4 Cross-deck laminate

8.4.1 The bending moment assumed to be carried by the cross-deck laminate is to be not less than that determined by Ch 3,1.9.1, using the design pressure from Pt 5, Ch 3,3.1, or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 8.4.2 and 8.4.4 respectively.

8.4.2 An estimate of the thickness of **strength/weather deck single skin laminate** is to be determined from Ch 3,1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using Ch 3,1.12.3 and Ch 3,1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

8.4.3 In no case is the minimum thickness of single skin laminate to be taken as less than 4 mm.

8.4.4 An estimate of the stiffness, *EI*, thickness of single skin laminate for outer and inner skins of the **strength/ weather deck sandwich panels** and the thickness of core material is to be determined from Ch 3,1.13.2 and Ch 3,1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using Ch 3,1.13.7 and Ch 3,1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

8.4.5 In no case are the minimum thicknesses of laminate which form the skins of a sandwich laminate to be taken as less than 3 mm and 2 mm for the outer and inner skins respectively.

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8.4.6 Special consideration may be given to laminate thicknesses lesser than those required by 8.4.3 and 8.4.5, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided and the equivalent impact resistance is demonstrated as required by Ch 3,2.8.2.

8.4.7 The scantlings of watertight cockpits are to be of equivalent strength to those for the strength/weather deck, *see also* Part 4.

8.4.8 It is recommended that working areas of the weather deck have an anti-slip surface.

8.4.9 Where decks are sheathed with wood or other materials, details of the method of attachment are to be submitted, *see also* Ch 3,2.9.

8.5 Cross-deck stiffening

8.5.1 The Rule requirements for bending moment, shear force, shear stress and deflection for the cross-deck primary stiffeners are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1, or Pt 5, Ch 4.3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 in Chapter 3 for the load model (a).

8.5.2 The Rule requirements for bending moment, shear force, shear stress and deflection for the cross-deck secondary stiffeners are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1, or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 in Chapter 3 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.5.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

8.5.4 The geometric properties of stiffener sections are to be calculated in accordance with Ch 3,1.15 using an effective width of attached laminate as given in Ch 3,1.7.

8.5.5 For cases where there may be excessive rotations or deflections at supports or where the lateral pressure distribution is non-uniform, the above scantlings may have to be increased appropriately.

8.5.6 Where stiffeners are subject to concentrated loads such as pillars, the concentrated loads are to be superimposed on the lateral pressure and strength calculations carried out to demonstrate compliance with the deflection and stress criteria given in Table 7.2.1 in Chapter 7 and Table 7.3.1 in Chapter 7.

8.5.7 Where the floating frame system is used, the effect of the plating attached to the stiffening members is to be ignored when calculating the required section stiffness, *EI*, of the primary stiffening members, i.e. the full stiffness, *EI*, is to be provided by the primary stiffening members only.

8.5.8 Openings in the cross-deck for hatches etc., are to comply with the requirements of Ch 3,8.12.

8.6 Novel features

8.6.1 Where the cross-deck structure is of unusual design, form or proportions, the scantlings are to be determined by direct calculation, *see* Ch 3,2.7.

■ *Section 9*
Superstructures, deckhouses, bulwarks and pillars

9.1 General

9.1.1 The scantlings and arrangements for superstructures, deckhouses and bulwarks are to be determined in accordance with the procedures described in, or as required for mono-hull craft indicated in Ch 3,9.

9.1.2 The scantlings and arrangements for pillars are to be determined in accordance with the procedures described in, or as required for mono-hull craft indicated in Ch 3,10.

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Section

1 **General**

2 **Special features**

3 **Vehicle decks**

4 **Movable decks**

5 **Helicopter landing areas**

6 **Strengthening requirements for navigation in ice conditions**

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to both mono-hull and multi-hull craft of composite construction.

1.2 Symbols and definitions

1.2.1 The symbols in this Section are as defined in Ch 3,1.5.1 and in the appropriate sub-Section.

■ *Section 2* Special features

2.1 Water jet propulsion systems – Construction

2.1.1 The requirements for the construction and installation of water jet units apply irrespective of rated power.

2.1.2 Water jet ducts may be fabricated as an integral part of the hull structure, or as a bolted-in unit. In either case, detailed plans indicating dimensions, scantlings and materials of construction of the following are to be submitted in triplicate:

(a) Arrangement of the system including intended method of attachment to the hull and building-in, geometry of tunnel, shell opening, method of stiffening, reinforcement, etc.
(b) Shaft sealing arrangements.
(c) Details of any shafting support or guide vanes used in the water jet system.
(d) Details and arrangements of inspection ports, their closing appliances and sealing arrangement, etc.
(e) Details and arrangements of protection gratings and their attachments.

2.1.3 When submitting the plans requested in 2.1.2, details of the designers' loadings and their positions of application in the hull are to be submitted and are to include maximum applied thrust, moments and tunnel pressures for which approval of the propulsion system is sought.

2.1.4 All materials used in construction are to be manufactured and tested in accordance with the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

2.1.5 Aluminium alloys, where used, are to be of suitable marine grades in accordance with the requirements of Part 7.

2.1.6 Irrespective of the material used, the strength and supporting structure of all tunnels are to be examined by direct calculation procedures which are to be submitted. In no case are the scantlings to be taken as less than the Rule requirements for the surrounding structure. The strength of the hull structure in way of tunnels is to be maintained. The structure is to be adequately reinforced and compensated as necessary. All openings are to be suitably reinforced and have radiused corners.

2.1.7 Consideration is to be given to providing the inlet to the tunnel with a suitable guard to prevent the ingress of large objects into the rotodynamic machinery. The dimensions of the guard are to strike a balance between undue efficiency loss due to flow restriction and viscous losses, the size of object allowed to pass and susceptibility to clog with weed and other flow restricting matter.

2.1.8 The inlet profile of the tunnel is to be so designed as to provide a smooth uptake of water over the range of craft operating trims and avoid significant separation of the flow into the rotating machinery.

2.1.9 The leading edges of FRP tunnels are to be additionally reinforced by suitable means. Proposals are to be submitted as required by 2.1.2.

2.1.10 Single or multiple water jet unit installations having a total rated power in excess of 500 kW are to be contained within their own watertight compartment. Other arrangements for maintaining watertight integrity may be specially considered depending on the size and installation layout.

2.1.11 For details of machinery requirements, *see* Pt 10, Ch 2, Machinery Requirements.

2.2 Water jet propulsion systems – Installation

2.2.1 Standard units built for 'off the shelf' supply and which include the duct are to be installed strictly in accordance with the manufacturer's instructions, *see also* 2.1.4.

2.2.2 Integral water jet ducts are to be constructed in accordance with the manufacturer's requirements and the relevant plans submitted as required by 2.1.2.

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2.2.3 Where load is transmitted into the transom and/or bottom shell, the thickness of the laminate adjacent to the jet unit is to be increased. The increase in thickness is to be not less than 50 per cent of the calculated transom and bottom laminate thicknesses respectively or 12 mm, whichever is the greater. Such reinforcement is to extend beyond the surrounding stiffening structure.

2.2.4 For 'bolted in' units, hull receiving rings are to be of a material compatible with the hull. Scantlings of the receiving rings are to be as required by the jet unit manufacturer and suitably edge prepared prior to bonding in place. The receiving ring is to be installed using an approved laminating procedure. Where a manufacturer's specification is not provided, full details are to be submitted.

2.2.5 Bolt sizes and spacings are to be specified by the manufacturer, and are to be of suitable marine grade, insulated as appropriate and locked by suitable means.

2.2.6 Where studs are proposed for the receiving ring(s), the remaining thickness below the depth of blind tap is to be not less than 0,2 times the thickness of the receiving ring or 5 mm whichever is the greater. Bottoms of all blind taps are to be free of sharp corners.

2.2.7 The use of approved alignment resins may be considered where accurate seating and faying surfaces are required. Details are to be submitted for consideration and approval.

2.2.8 Where a water jet unit forms an integral part of the hull structure, such units are to be installed using an approved laminating procedure and in accordance with the manufacturer's instructions. Materials to be laminated are to be of compatible specifications.

2.2.9 Water jet units transmitting thrust into the transom structure are to be supported by a system of radial, athwartship and vertical stiffening. Drawings are to be accompanied by a set of detailed structural calculations. Where complex installations are proposed, a finite element model may be submitted in lieu of direct calculations.

2.2.10 Water jet units transmitting thrust to a bottom shell connection or intermediate tunnel connection are to be supported by additional stiffening, the details and calculations for which are to be submitted.

2.2.11 In general, sandwich skin laminates in way of water jet installations are to be brought together to form single skins complying with 2.2.3. Proposals to use sandwich construction in way of installations will be specially considered, subject to the use of appropriate structural core materials and direct calculations being submitted in support.

2.2.12 Exposed edges of laminates subject to water flow are to be over laminated and protected by suitable means; proposals are to be submitted for consideration.

2.2.13 Where the jet-unit is an FRP premoulding of an approved type, the surface of the unit is to be suitably abraded and degreased prior to installation in the mould tool and subsequent over laminating of the main hull structure. Particular care is to be given to material compatibility of the resin system used for the premould and main hull laminate.

2.3 Foil support arrangements

2.3.1 The materials and construction of the lifting surface will be considered on a case by case basis.

2.3.2 The design and performance of the lifting surface is outside the scope of classification. However, when submitting structural plans for the hull connection installation, the designer/Builder is to define:

(a) Operating mode, i.e. fully submerged or surface piercing.
(b) Maximum operational speed for which approval is sought.
(c) Maximum, direct, bending, shear and torque loads generated by the foil at the point of attachment(s).
(d) The type of profile or section used, e.g. N.A.C.A.
(e) Supply of lift/drag profile.
(f) If the foil is fixed, movable or retractable.
(g) If the foil is fitted with control surfaces.
(h) If the vertical leg(s) act as a rudder(s).
(j) If shaft liners are carried to the foils at which support arrangements are provided.
(k) If water intakes/scoops are fitted.
(l) If propulsion units are fitted.

2.3.3 The scantlings and arrangements of foils and their supporting structure will be required to be specially considered in the following cases where:

(a) Propulsion units are incorporated within the foil.
(b) Foils carry shaft support arrangements.
(c) The foils are of novel design.

2.3.4 Where fully submerged foils are 'built-in' to the hull, the attachment area is to be contained within a watertight compartment. The structural arrangements of 2.4 are to be complied with as appropriate.

2.3.5 Where foils are to be bolted to the structural foundation and not 'built in', calculations are to be submitted. These are to demonstrate that the effect of loading arising from high speed impact, grounding, fouling, etc., is limited to failure of the bolted connection. In all cases the structural and watertight integrity of the craft is to be maintained.

2.3.6 Attachment points of foils are in all cases to be contained within a watertight compartment.

2.3.7 Foils attached by rivetted means are, in addition, to comply with Pt 7, Ch 2,4.25.

2.3.8 Bow fairing doors fitted on forward retracting bow foils are to be weathertight and are to comply with the requirements of Pt 3, Ch 4.

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2.3.9 Aft bulkheads of bow foil compartments are to comply with the requirements for collision bulkheads as detailed in Ch 3,7.6.

2.3.10 Hydraulically operated retracting systems are to be equipped with low pressure alarms, together with a manual system of operation in the event of system failure.

2.3.11 A mechanical locking system is to be provided on retracting systems when the system is in both the operational and 'stowed' conditions.

2.4 Surface drive mountings

2.4.1 Transoms through which surface drive systems pass and which are required to carry thrust, significant weight, torque, moment, etc., are to be adequately reinforced.

2.4.2 The thickness of transom laminate is to be not less than 50 per cent greater than the adjacent plating or as advised by the drive manufacturer, whichever is the greater.

2.4.3 Steering rams are to be mounted on suitably reinforced areas of laminate supported by additional internal stiffening; details are to be submitted for consideration.

2.5 Sea inlet scoops

2.5.1 Sea inlet scoops may be integral with or an appendage to the hull.

2.5.2 Scoops are to be suitably positioned to minimise ventilation.

2.5.3 Suitable protective arrangements are to be provided to minimise the ingress of debris. The net area through the proposed arrangement is to be not less than twice that of the valves connected to the scoop. Provision is to be made for clearing the scoops by the use of suitable means; proposals are to be submitted.

2.5.4 Scoops are to be contained within a watertight compartment.

2.5.5 The laminate thickness in way of integral scoops is to be not less than 50 per cent greater than that of the adjacent shell laminate, with additional reinforcement at the leading edge.

2.5.6 For all composite construction, scoops are to be fitted as bolted appendages.

2.5.7 For craft navigating in ice, the arrangements will be specially considered on an individual basis.

2.6 Crane support arrangements

2.6.1 Crane pedestals are to be efficiently supported and, in general, are to be carried through the deck and satisfactorily scarfed into the surrounding structure. Alternatively, crane pedestals may comprise of a foundation, in which case the foundation and its supporting structure are to be of substantial construction. Proposals for other support arrangements will be specially considered.

2.6.2 The pedestal or proposed arrangement is to be designed with respect to the worst possible combinations of loads resulting from the crane self weight, live load, wind and crane accelerations together with those resulting from the craft's heel and trim. The designer's calculations for loadings are to be indicated on the plans to be submitted.

2.6.3 Stowage arrangements are to be taken into account when calculating the loads applied to the pedestal.

2.6.4 When submitting plans for the proposed foundation, the designer is to include his design calculations covering the parameters indicated in 2.6.2.

2.6.5 The deck laminate is to be additionally reinforced in way of crane foundations. The thickness of reinforcement is to be that required by the designer's calculations but in no case less than 50 per cent the thickness of the adjacent plating.

2.6.6 Laminate tapers are to be in accordance with Ch 2,3.9.

2.7 Skirt attachment

2.7.1 The design and scantlings of the skirt are, in general, outside the scope of classification, however the designers/builders are to submit their proposals in respect of the attachment detail. The following supporting information is to be submitted:

(a) Cushion pressure,

(b) Calculations demonstrating that the effect of damage to the flexible membrane and/or the retaining section arising from high speed impact, grounding, fouling, etc., will not compromise the structural and watertight integrity of the craft.

2.7.2 The skirt is to be securely attached around its periphery. The supporting structure is to be suitably reinforced by the use of tapping plates incorporated into the laminate.

2.7.3 Where the skirt is retained by bolting the retaining bars are to be as long as practicable, with the fasteners being spaced not more than 50 mm apart.

2.7.4 Where the design of the skirt is such that the flexible edge is retained by the use of a pre-formed channel, only the bolted connection of the preform to the hull structure is to be considered.

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2.8 Trim tab arrangements

2.8.1 The shape, design and scantlings of the trim tab are outside the scope of classification, however Lloyd's Register (hereinafter referred to as 'LR') is concerned with their attachment to the hull structure.

2.8.2 The designer/Builder is to submit the following:

(a) Detailed calculations indicating the maximum lift force generated by the tab for which acceptance is sought together with the corresponding speed and displacement.

(b) Details of the hull attachment and loadings in way for the trim tab and actuation system.

(c) Details and calculations of the local internal reinforcement to resist the loading in way of the attachment.

2.8.3 Bearing materials used are to be of an approved type.

2.8.4 Fully submerged retractable trim tabs will be specially considered on a case by case basis.

2.9 Spray rails

2.9.1 Spray rails are, in general, to be integrated into the hull structure but may be added in the form of an appendage on completion of the hull shell.

2.9.2 Where spray rails are integrated, they are to have a laminate thickness not less than the adjacent bottom shell and additionally have section properties equivalent to that required for a longitudinal stiffener in the same position.

2.9.3 Where spray rails are added as an appendage, they are to be attached in accordance with an approved bonding/laminating procedure and are additionally to comply with the strength requirements of 2.9.2. Composite preforms bonded to the outer hull are to be manufactured and bonded using approved materials, compatible with the hull laminate.

2.9.4 Spray rails are to be supported by the internal stiffening arrangements and by additional local reinforcement as necessary.

2.9.5 In no case are the toes of spray rails to terminate on unsupported shell laminate.

2.9.6 In sandwich construction the outer skin is to be a smooth continuous surface, with spray rails attached as required by 2.9.3.

2.10 Other lifting surfaces

2.10.1 Other lifting surfaces not specifically covered by the Rules will be individually considered on the basis of submitted direct calculations.

2.10.2 Structure or hull shapes above the running waterline designed to generate aerodynamic lift may be individually considered on a case by case basis.

2.10.3 Aerodynamic, hydrodynamic and aero-hydrodynamic stability are outside the scope of classification and are subject to the approval of the National Administration concerned.

2.11 Propeller ducting

2.11.1 Where propellers are fitted within ducts/tunnels the laminate weight in way of the blades is to be increased by 50 per cent.

2.11.2 The tunnel wall in way of the propeller blades is to be additionally stiffened.

2.12 Ride control ducting and installation for Surface Effect Ships (SES)

2.12.1 Ducts penetrating the side inboard shell plating are to comply with the scantling requirements for side inboard structures, over their entire length, in the appropriate material.

2.12.2 Ducts penetrating the wet-deck are to comply with the scantling requirements for wet-deck structures over their entire length, in the appropriate material.

2.12.3 Open ends of ducts are to be fitted with a suitable protective grille.

2.12.4 The vent assembly, its design, construction and operation is outside the scope of classification and is the responsibility of the ride control system designer.

2.12.5 Details of the installation and securing arrangements of the vent valve assembly into the duct are to be submitted for approval.

■ *Section 3* Vehicle decks

3.1 General

3.1.1 Where it is proposed to construct vehicle decks in FRP composite materials, each case will be subject to individual consideration. The scantlings are to be determined by direct calculation or on the basis of the requirements of Chapter 3, in conjunction with the procedures, loadings and general requirements for vehicle decks of aluminium alloy construction, as indicated in Pt 7, Ch 5.

3.1.2 It is recommended that single skin laminate construction incorporating longitudinal or transverse stiffening be adopted. Where it is proposed to use sandwich skin construction, particular care is to be given to the selection of the core material. Such proposals will require to be specially considered, and testing may be required to demonstrate the suitability of the panels.

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3.1.3 The deck and supporting structure are to be designed on the basis of the maximum loading to which they may be subjected in service. Where applicable, the hatch covers are to be similarly designed. In no case, however, are the scantlings to be less than would be required for a weather or cargo deck or hatch cover, as applicable.

3.1.4 Details of the deck loading resulting from the proposed stowage or operation of vehicles are to be supplied by the Builder. These details are to include axle and wheel spacing, the wheel load, type of tyre and tyre print dimensions for the vehicles. The vehicle types and wheel loads for which the vehicle decks, including hatch covers where applicable, have been approved are to be included in the craft's documentation and contained in a notice displayed on each deck. For design purposes, the wheel loading is to be taken as not less than 3,0 kN.

3.1.5 The scantling requirements are based on structural strength and limitations on stress and deflection, with no allowance made for wear and tear. Local reinforcement is to be fitted as necessary, particularly in way of vehicle lanes and passenger routes.

3.1.6 Deck fittings in way of vehicle lanes are to be recessed.

3.2 Securing arrangements

3.2.1 Details of the loads and connections to the hull of vehicle securing arrangements are to be indicated on the plans submitted with the Designer's calculations.

3.3 Access

3.3.1 Where access to the vehicle deck is provided by bow, side and stern doors, these openings are to comply with the requirements of Pt 3, Ch 4,4.

3.3.2 Doors providing pedestrian access between vehicle decks and accommodation spaces are to be gastight, and have scantlings and fire restricting characteristics equivalent to the surrounding structure, *see also* Part 17.

3.4 Hatch covers

3.4.1 The scantlings and arrangements of hatch covers located within vehicle decks are to be not less than those required by the Rules for the supporting structure in which such hatches are fitted. In general, the end fixity of primary stiffening members is to be taken as simply supported. Local and secondary stiffening members may be either partially or fully fixed at their end connections dependent upon the proposed arrangement.

3.4.2 In no case, however, are the scantlings of plate or sandwich laminates and stiffeners to be less than would be required for a weather or cargo deck, or hatch cover, as applicable.

3.4.3 Where unusual arrangements of hatch cover stiffening are proposed, the scantlings of plating and stiffeners may be determined by direct calculations using a two-dimensional grillage determination.

3.5 Heavy and special loads

3.5.1 Where heavy or special loads are proposed to be carried, the scantlings and arrangements of the deck structure will be individually considered on the basis of submitted calculations.

3.5.2 Due account is to be taken of the acceleration levels due to craft motion applicable to particular items of heavy mass such as vehicles, containers, pallets, etc.

3.6 Direct calculations

3.6.1 LR will consider direct calculations for the derivation of vehicle deck scantlings as an alternative and equivalent to those derived by Rule requirements. The assumptions made and the calculation procedures used are to be submitted for appraisal in accordance with Pt 3, Ch 1,2.

■ *Section 4* Movable decks

4.1 Classification

4.1.1 Movable decks other than those described in 4.1.2 are not a classification item, although consideration is to be given to the associated supporting structure. Where movable decks are fitted, it is recommended that they are to be based on the requirements of this Section.

4.1.2 At the Owner's or Builder's request, however, movable decks will be included as a classification item, and the class notation **Removable decks** will be entered in the *Register Book*. In such cases, all movable decks on board the craft are to comply with the requirements of this Section.

4.2 Arrangements and designs

4.2.1 Movable decks are generally to be constructed as pontoons comprising a web structure with top decking. Other forms of construction will be individually considered.

4.2.2 Positive means of control are to be provided to secure decks in the lowered position.

4.2.3 The decks are to be efficiently supported, and hinges, pillars, chains or other means (or a combination of these) are to be designed on the basis of the imposed loads. Where supporting chains and fittings are required, they are to have a factor of safety of at least two on the proof load.

4.2.4 Plans showing the proposed scantlings and arrangements of the system are to be submitted.

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4.2.5 Where it is proposed to stow the pontoons on deck, when not in use, details of the proposals for racks, fittings, etc., are to be submitted for consideration.

4.3 Loading

4.3.1 The loading requirements for movable decks are to be in accordance with 3.1.

4.3.2 Where it is proposed also to use the decks for general cargo, the design loadings are to be submitted for consideration.

4.4 Scantling determination

4.4.1 The scantlings and arrangements of movable decks are to be not less than required by the Rules for the supporting structure in which they are fitted. In general the end fixity of primary stiffening members is to be taken as simply supported. Local and secondary stiffening members may be either partially or fully fixed at their end connections dependent upon the proposed arrangement.

4.5 Deflection

4.5.1 Where wheeled vehicles are to be used, the supporting arrangements are to be such that the movement at the edge of one pontoon relative to the next does not exceed 50 mm during loading or unloading operations.

4.6 Direct calculations

4.6.1 As an alternative to the requirements of 4.3 to 4.5, the structure may be designed on the basis of a direct calculation using a grillage idealisation. The method adopted and the stress levels proposed for the material of construction are to be submitted for consideration, *see also* Pt 3, Ch 1,2.

■ *Section 5* Helicopter landing areas

5.1 General

5.1.1 Where it is proposed to construct helicopter landing areas in FRP composite materials, each case will be subject to individual consideration.

5.1.2 Helicopter landing areas are to be designed to suit the largest helicopter type which it is intended to use. In general, the diameter of the landing area is to be not less than 1,25 times the rotor diameter.

5.1.3 Attention is drawn to the requirements of National and other Authorities concerning the construction of helicopter landing platforms and the operation of helicopters as they affect the craft.

5.1.4 Plans are to be submitted showing the proposed scantlings and arrangements of the structure. The type, size and weight of helicopters to be used are also to be indicated. Details of the helicopter types to be used are to be included in the craft's documentation, and be contained in a notice displayed on the helicopter landing deck.

5.1.5 Where the landing area forms part of a weather or erection deck, the scantlings are to be not less than those required for decks in the same position.

5.1.6 The requirements for fire protection, detection and extinction are to comply with Part 17. Special consideration is to be given to the insulation standard if the space below the helicopter deck is a high fire-risk space.

5.1.7 It is recommended that single skin laminate construction incorporating longitudinal or transverse stiffening is to be adopted. Where it is proposed to use sandwich skin construction, particular care is to be given to the selection of the core material; such proposals will require to be specially considered, and testing may be required to demonstrate the suitability of the panels.

5.2 Symbols

5.2.1 The symbols in this Section are as defined in Ch 3,1.5.1 and in the appropriate sub-Section.

5.3 Arrangements

5.3.1 The landing area is to be sufficiently large to allow for the landing and manoeuvring of the helicopter, and is to be approached by a clear landing and take-off sector complying in extent with the applicable regulations.

5.3.2 The landing area is to be free of any projections above the level of the deck. Projections in the zone surrounding the landing area are to be kept below the heights permitted by the regulations.

5.3.3 Suitable arrangements are to be made to minimise the risk of personnel or machinery sliding off the landing area. A non-slip surface and anchoring devices are to be provided.

5.3.4 Arrangements are to be made for drainage of the platform, including drainage of spilt fuel.

5.3.5 Details of the connections to the hull of helicopter securing arrangements are to be submitted for approval.

5.3.6 Engine uptake arrangements are to be sited such that exhaust gases cannot be drawn into helicopter engine intakes during helicopter take off or landing operations.

5.4 Loadings

5.4.1 The load cases to be investigated are to be not less than those required by Pt 7, Ch 5,6 for helicopter landing areas of aluminium alloy construction.

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5.4.2 The proposed loadings are to be agreed with LR prior to scantling analysis and submission of structural plans for appraisal.

5.4.3 Details of the deck loading resulting from the proposed stowage arrangements of helicopters are to be supplied by the Builder. These details are to include the axle and wheel spacing, the wheel load, type of tyre and tyre print dimensions for the helicopter. For design purposes the wheel loading is to be taken as not less than 3,0 kN (0,3 tonne-f).

5.4.4 Where it is proposed also to use the decks for general cargo or other alternative use, the design loadings are to be submitted for consideration.

5.5 Scantlings

5.5.1 The scantlings and arrangements of helicopter landing areas are to be not less than those required by the Rules for the supporting structure in which the helicopter landing areas are fitted. In general the end fixity of primary stiffening members is to be taken as simply supported. Local and secondary stiffening members may be either partially or fully fixed at their end connections dependent upon the proposed arrangement.

■ *Section 6*
Strengthening requirements for navigation in ice conditions

6.1 General

6.1.1 The strengthening requirements detailed in this Section are applicable to craft, other than those assigned the notation **HSC** and/or **LDC** (*see* Pt 1, Ch 2), intended for operation in light first year ice conditions in areas other than the northern Baltic corresponding to unbroken level ice of thickness not greater than 0,4 m.

6.1.2 Craft complying with the requirements of this Section, in addition to the requirements for sea-going service where applicable, will be eligible for the special features notation **Ice Class 1D**. Alternatively, a Special Duties Notation may be assigned indicating that the craft has been additionally strengthened for duties in ice, *see* Pt 1, Ch 2,3.8.3.

6.1.3 Craft designed to operate in ice conditions other than those detailed in 6.1.1 are to comply with Part 8 of the Rules for Ships.

6.1.4 The requirements of this Section are applicable to both longitudinally and transversely framed craft and concern the shell laminate and framing in the forward region, the stem, sternframe, rudder and the steering gear.

6.1.5 The vertical extent of the ice strengthening is related to the ice light and ice load waterlines, which are defined in 6.2. The maximum and minimum Ice Class draughts at both the fore and aft ends will be stated on the Class Certificate.

6.1.6 The requirements of this Section assume that when approaching ice infested waters the craft's speed will be reduced appropriately. The vertical extent of ice strengthening for craft intended to operate in ice conditions at speeds exceeding 15 knots will be specially considered.

6.1.7 The ballast capacity of propeller-driven craft is to be sufficient to give adequate propeller immersion in all ice navigating conditions without trimming the craft in such a manner that the actual waterline at the bow is below the ice light waterline. Ballast tanks situated above the ice light waterline and adjacent to the shell, which are intended to be used in ice navigating conditions, are to be provided with heating pipes.

6.1.8 Side scuttles are not to be situated in the ice belt.

6.2 Definitions

6.2.1 The Ice Load Waterline is that corresponding to the Fresh Water Summer Loadline.

6.2.2 The Ice Light Waterline is that corresponding to the lightest condition in which the craft is expected to navigate in ice.

6.2.3 The Ice Load Waterline and the Ice Light Waterline are to be indicated on the plans. For navigation in certain geographical areas, the relevant National Authority may require the maximum Ice Class draught to be marked on the craft in a specified manner.

6.2.4 The Main Ice Belt Zone extends vertically from 500 mm below the Ice Light Waterline to 400 mm above the Ice Load waterline and horizontally from the stem to $0{,}02L_R$ m aft of the point at which the deepest load waterline reaches its greatest breadth. L_R is as defined in Pt 3, Ch 1,6.2.1.

6.3 *Powering of ice strengthened craft*

6.3.1 Ice strengthened craft are assumed to be capable of developing sufficient thrust to permit continuous mode icebreaking at a speed of at least five knots in ice having a thickness of 0,4 m and a snow cover of at least 0,3 m.

6.4 Shell laminate

6.4.1 It is assumed that single skin laminate construction incorporating longitudinal or transverse stiffening will be adopted. Where it is proposed to use sandwich skin construction, particular care is to be given to the selection of the core material; such proposals will require to be specially considered, and testing may be required to demonstrate the suitability of the panels.

6.4.2 In way of the main ice belt zone, the thickness of the shell laminate is to be determined by direct calculation. A copy of these calculations is to be submitted for consideration.

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6.4.3 Changes in laminate thicknesses are to take place gradually, and in no case is the length of taper to be less than 20 times the difference in thickness. Additionally individual plys of the laminate are to be arranged such that any delamination will be directed to the outer surface of the laminate.

6.4.4 If the weather deck in any part of the craft is situated below the upper limit of the ice belt, the bulwark is to be reinforced to the same degree as the shell plating in the main ice belt.

6.5 Shell framing

6.5.1 Ice framing is to extend to a minimum distance of 1000 mm above the Ice Load Waterline and 1600 mm below the Ice Light Waterline between the stem and $0{,}02L_R$ m aft of the point at which the deepest load waterline reaches its greatest breadth. L_R is as defined in Pt 3, Ch 1,6.2.1.

6.5.2 The web thickness for ice framing members of top-hat or plate section is to be determined by direct calculation. A copy of these calculations is to be submitted for consideration.

6.5.3 Ice frames are to be attached to the shell plating by double primary bonding angles in accordance with Ch 3,1.18. The web area of ice frames is to be maintained; air and drain holes are to be kept to a minimum.

6.5.4 Main and intermediate frames within the minimum extent of ice framing are to be efficiently supported to prevent tripping. The distance between anti-tripping supports is not to exceed 1000 mm.

6.5.5 The bending moment assumed to be carried by the ice framing stiffening member is not to be taken as less than 50 per cent greater than that required by the appropriate Section of the Rules for the stiffening member subjected to hydrostatic or pitching pressure whichever is the greater.

6.6 Stem construction

6.6.1 The stem is to be additionally protected/reinforced by a metallic shoe or other equivalent arrangement. The shoe/reinforcement is to extend from the keel plate to 750 mm above the ice load waterline and is to be internally strengthened by closely spaced floors, brackets or webs. Details of such protection and the method of attachment are to be submitted for consideration.

6.6.2 Attachment by mechanical means such as bolting or other methods is not to impair the watertight integrity of the craft. Through bolting of the hull is to be kept to a minimum and avoided where practicable.

6.7 Stern construction

6.7.1 A transom stern is not normally to extend below the ice load waterline. Where this cannot be avoided, the transom is to be kept as narrow as possible and the scantlings of plating and stiffeners are to be as required for the midship region.

6.8 Bossings and shaft struts

6.8.1 For craft with two or more propellers, shafting and sterntubes are generally to be enclosed within plated bossings. If detached supporting struts are necessary, their design, strengthening and attachment to the hull will be specially considered, *see also* Pt 3, Ch 3,3.4.

6.9 Rudder and steering arrangements

6.9.1 Rudder posts, rudder horns, sole pieces, rudder stocks and pintles are to be dimensioned in accordance with Chapter 3 of the Rules for Materials. The speed used in the calculations is to be the service speed or 14 knots, whichever is the greater.

6.9.2 The thickness of rudder plate laminate and webs is to be increased by 50 per cent over the requirements of Pt 3, Ch 3,2.

6.9.3 Due regard is to be paid to the method of securing the rudder in the centreline position when backing into ice. Where possible, rudder stoppers working on the blade or rudder head are to be fitted.

6.9.4 Where steering nozzles are fitted, the thickness of the shroud plating is, in general, to include an abrasion allowance of 20 per cent.

6.9.5 The scantlings of the stock, pintles, gudgeon and sole pieces associated with the nozzle are to be increased on the basis given in 6.9.1. However, the diameter of the nozzle stock is to be not less than that calculated in the astern condition taking the astern speed as 7 knots or the actual astern speed, whichever is the greater.

6.9.6 Nozzles with articulated flaps will be subject to special consideration.

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Section

1 **General**

2 **Hull girder strength for mono-hull craft**

3 **Hull girder strength for multi-hull craft**

Section 1 General

1.1 Application

1.1.1 The requirements for longitudinal and transverse global strength for both mono-hull and multi-hull craft of composite construction, are contained within this Chapter. Due consideration is taken of the dynamic effects, where appropriate, in both the crest and trough wave landing conditions.

1.2 Symbols and definitions

1.2.1 Unless specified otherwise the symbols used in this Chapter are defined as follows:

a_i = cross sectional area of the individual ply, *i*, in m^2

E_{ci} = compressive modulus of individual ply, *i*, in N/mm^2

E_i = E_{ti}, or E_{ci} of the individual ply *i*, relative to its position above or below the neutral axis, in N/mm^2

E_{ti} = tensile modulus of individual ply, *i*, in N/mm^2

I_i = inertia of the of individual ply, *i*, about the neutral axis, in mm^4

M_R = the appropriate Rule bending moment, as defined in Pt 5, Ch 5,5

Q_R = the appropriate Rule shear force, as defined in Pt 5, Ch 5,5

x_i = the distance to the centre of area of the individual ply, *i*, from the outer surface of the keel plate laminate, in metres

y_i = vertical distance from the hull transverse neutral axis to the centre of the individual ply, in metres

y_{NA} = the distance of the neutral axis, from the outer surface of the keel plate laminate, in metres.

$\Sigma(E_i I_i)_H$ = total $(EI)_H$ (stiffness) for the hull midship section, in Nm^4/mm^2

σ_{ci} = compressive stress within an individual element, *i*, in N/mm^2

σ_{ti} = tensile stress within an individual element, *i*, in N/mm^2

τ_H = shear stress at any position along the length of the craft, in N/mm^2

L_R and B are as defined in Pt 3, Ch 1,6.2.

1.2.2 The strength deck is to be taken as follows:

(a) Where there is a complete upper deck the strength deck is the upper deck.

(b) Where the upper deck is stepped, as in the case of raised quarterdeck craft, the strength deck is stepped as shown in Fig. 6.1.1.

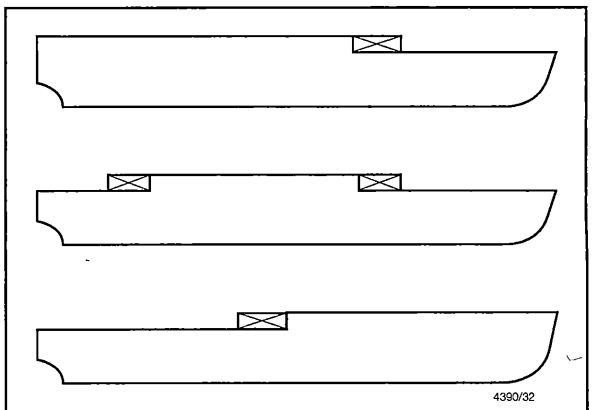

Fig. 6.1.1 Strength deck

1.3 General

1.3.1 The additional pressures arising from the influence of the global loading are considered in the determination of the longitudinal strength requirements for local and secondary stiffening and bottom shell laminate.

1.3.2 All continuous longitudinal structural material is to be included in the calculation of the stiffness, $(EI)_H$, of the hull midship section, and the lever, y_i, is to be measured vertically from the neutral axis to the centre of the individual ply, *i*. The inertia of an individual horizontal ply, *i*, about its own axes is to be ignored.

1.3.3 Structural members which contribute to the overall hull girder strength are to be carefully aligned so as to avoid discontinuities resulting in abrupt variations of stresses and are to be kept clear of any form of openings which may affect their structural performance.

1.3.4 In general, superstructures or deckhouses will not be accepted as contributing to the global longitudinal or transverse strength of the craft. However, where it is proposed to include substantial, continuous stiffening members, special consideration will be given to their inclusion on submission of the designer's/builder's calculations. Such calculations are to make due allowance for superstructure efficiency. *See also* Pt 7, Ch 6,2.5.

1.3.5 Where continuous deck longitudinals or deck girders are arranged above the strength deck, special consideration may be given to the inclusion of their sectional area in the calculation of the hull stiffness $(EI)_H$. The lever is to be taken to a position corresponding to the depth of the longitudinal member above the moulded deckline at side amidships. Each such case will be individually considered.

1.3.6 Adequate transition brackets are to be fitted at the ends of effective continuous longitudinal strength members in the deck and bottom structures.

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1.3.7 Scantlings of all continuous longitudinal members of the hull girder based on the minimum section stiffness requirements given in 2.2 are to be maintained within $0{,}4L_R$ amidships. However, in special cases, based on consideration of type of ship, hull form and loading conditions, the scantlings may be gradually reduced towards the ends of the $0{,}4L_R$ part, bearing in mind the desire not to inhibit the vessel's loading and operational flexibility. L_R is as defined in 1.2.1.

1.4 Openings

1.4.1 Deck openings having a length in the fore and aft directions exceeding $0{,}1B$ m or a breadth exceeding $0{,}05B$ m, are always to be deducted from the sectional areas used in the section stiffness calculation. B is as defined in 1.2.1.

1.4.2 Deck openings smaller than stated in 1.4.1 including manholes, need not be deducted provided they are isolated and the sum of their breadths or shadow area breadths (*see* 1.4.3), in one transverse section does not exceed $0{,}06\,(B_1 - \Sigma b_1)$. where

B_1 = breadth of craft at section considered

$\Sigma\, b_1$ = sum of breadths of deductible openings.

Where a large number of deck openings are proposed in any transverse space, special consideration will be required.

1.4.3 Where calculating deduction-free openings, the openings are assumed to have longitudinal extensions as shown by the shaded areas in Fig. 6.1.2. The shadow area is obtained by drawing two tangent lines to an opening angle of 30°. The sections to be considered are to be perpendicular to the centreline of the ship and are to result in the maximum deduction in each transverse space.

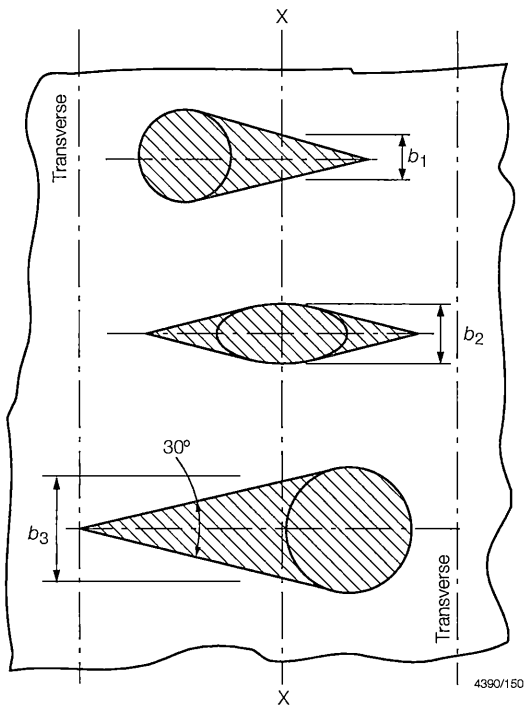
1.4.4 Isolated openings in longitudinals or longitudinal girders need not be deducted if their depth does not exceed 25 per cent of the web depth or 75 mm whichever is the lesser.

1.4.5 Openings are considered isolated if they are spaced not less than 1 m apart.

1.4.6 A reduction for drainage holes and scallops in beams and girders, etc., is not necessary so long as the original section stiffness at deck or keel is reduced by no more than three per cent.

1.5 Direct calculation procedure

1.5.1 In direct calculation procedures capable of deriving the wave induced loads on the ship, and hence the required modulus, account is to be taken of the ship's actual form and weight distribution.



Total equivalent breadth of small openings at XX = $b_1 + b_2 + b_3$

Fig. 6.1.2 Isolated openings

1.5.2 Lloyd's Register's (hereinafter referred to as 'LR') direct calculation method involves derivation of response to regular waves by strip theory, short-term response to irregular waves using the sea spectrum concept, and long-term response predictions using statistical distributions of sea states. Other direct calculation methods submitted for approval are normally to contain these three elements and produce similar and consistent results when compared with LR's methods.

1.6 Approved calculation systems

1.6.1 Where the assumptions, method and procedures of a longitudinal strength calculation system have received general approval from LR, calculations using the system for a particular ship may be submitted.

1.7 Information required

1.7.1 In order that an assessment of the longitudinal strength requirements can be made, the following information is to be submitted, in LR's standard format where appropriate:

(a) General arrangement and capacity plan or list, showing details of the volume and position of centre of gravity of all tanks and compartments.

(b) Bonjean data, in the form of tables or curves, for at least 21 equally spaced stations along the hull. A lines plan and/or Tables of offsets may also be required.

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(c) Details of the calculated lightweight and its distribution.
(d) Details of the weights and centres of gravity of all deadweight items for each of the main loading conditions. It is recommended that this information be submitted in the form of a preliminary Loading Manual, and that it includes the calculated still water and dynamic bending moments and shear forces.

1.8 Loading guidance information

1.8.1 Sufficient information is to be supplied to the Master of every craft to enable him to arrange loading in such a way as to avoid the creation of unacceptable stresses in the craft's structure.

■ *Section 2* Hull girder strength for mono-hull craft

2.1 General

2.1.1 Longitudinal strength calculations are to be submitted for all craft with a Rule length, L_R, exceeding 40 m, covering the range of load and ballast conditions proposed, in order to determine the required hull girder strength. Still water, static wave and dynamic bending moments and shear forces are to be calculated for both departure and arrival conditions.

2.1.2 For craft of ordinary hull form with a Rule length, L_R, less than 40 m, the minimum hull girder strength requirements are generally satisfied by scantlings obtained from local strength requirements. However longitudinal strength calculations may be required at LR's discretion dependent upon the hull form, constructional arrangement and proposed loading.

2.1.3 Where the Rule length, L_R, of the craft exceeds 65 m, or for new designs of large, structurally complicated craft, the design loads and scantling determination formulae in this Chapter are to be supplemented by direct calculation and structural analysis by 3-D finite element methods. These supplementary calculations are to include the results of model tests and full scale measurement where available or required by LR. Full details of such methods and all assumptions and calculations, which are to be based on generally accepted theories, are to be submitted for appraisal.

2.2 Bending strength

2.2.1 The effective geometric properties of the midship section are to be calculated directly from the dimensions of the section using only the effective material elements which contribute to the global longitudinal strength. For the purposes of this analysis an element may be a deck plating, longitudinal girder, inner bottom, etc., or other continuous member.

2.2.2 The distance of the neutral axis, y_{NA}, from the outer surface of the keel plate laminate may be determined from the following:

$$y_{NA} = \frac{\Sigma (E_i a_i x_i)}{\Sigma (E_i a_i)_H} \text{ m}$$

2.2.3 The resultant compressive stress within an individual ply, *i*, may be determined from the following:

$$\sigma_{ci} = \frac{E_{ci} y_i M_R}{\Sigma (E_i I_i)_H} \times 10^{-3} \text{ N/mm}^2$$

2.2.4 The resultant tensile stress within an individual ply, *i*, may be determined from the following:

$$\sigma_{ti} = \frac{E_{ti} y_i M_R}{\Sigma (E_i I_i)_H} \times 10^{-3} \text{ N/mm}^2$$

2.2.5 The ultimate tensile and compressive strengths of the laminate or face reinforcement which form an element, may be determined from suitable tests or alternatively may be predicted using classical stress/strain relationships with due account being taken of the amounts of different materials and their associated strain rates to failure. In this respect materials which are incompatible in terms of their strain rates to failure are not to be mixed. Where materials are mixed the requirements of 2.2.6 for reserve factors are to be complied with when a first ply failure analysis is carried out.

2.2.6 The allowable tensile and compressive stress limits indicated in Table 7.3.2 in Chapter 7 are to be complied with.

2.3 Shear strength

2.3.1 The shear strength of the craft at any position along the length is to be examined. The shear stress, τ_H, is determined from the following:

$$\tau_H = \frac{Q_R}{A_\tau} \times 10^{-3} \text{ N/mm}^2$$

where

A_τ = effective shear area of transverse section, in m^2, to be taken as the net sectional area of the side shell plating and the longitudinal bulkheads after deductions for openings, in m^2

Q_R is as defined in 1.2.1.

2.3.2 The allowable shear stress limits indicated in Table 7.3.2 in Chapter 7 are to be complied with.

2.4 Torsional strength

2.4.1 Torsional stresses are typically small for ordinary mono-hulls less than 65 m in Rule length, L_R, and can generally be ignored.

2.4.2 The calculation of torsional stresses and/or deflections may be required when considering craft with unusual form or proportions, or with large deck openings. In general, calculations may be required to be carried out using a direct calculation procedure. Such calculations are to be submitted in accordance with 1.5.

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Section 3
Hull girder strength for multi-hull craft

3.1 Application

3.1.1 Except as otherwise specified within this Section, the global strength requirements for multi-hull craft are to comply with Section 2.

3.1.2 Longitudinal strength calculations are to be submitted for all craft with a Rule length, L_R, exceeding 35 m, covering the range of load conditions proposed, in order to determine the required hull girder strength. Still water, static wave and dynamic bending moments and shear forces are to be calculated for both departure and arrival conditions and for any special mid-voyage conditions caused by changes in ballast distribution.

3.1.3 For craft of ordinary hull form with Rule length, L_R, less than 35 m, the minimum hull girder strength requirements are generally satisfied by scantlings obtained from local strength requirements. However longitudinal strength calculations may be required at LR's discretion dependent upon the hull form, constructional arrangement and proposed loading.

3.1.4 Where the Rule length, L_R, of the craft exceeds 50 m, or for new designs of large, structurally complicated craft, the design loads and scantling determination formulae in this Chapter are to be supplemented by direct calculation and structural analysis by 3-D finite element methods. These supplementary calculations are to include the results of model tests and full scale measurement where available or required by LR. Full details of such methods and all assumptions and calculations, which are to be based on generally accepted theories, are to be submitted for appraisal.

3.1.5 The strength deck plating in way of the cross-deck structure, the wet-deck plating, longitudinal bulkheads and girders, and other continuous members may be included in the determination of the midship section stiffness.

3.1.6 Special consideration will be given to the global strength requirements for craft with more than two hulls linked by cross-deck structure.

3.2 Hull longitudinal bending strength

3.2.1 The requirements of 2.2 are to be complied with, using the appropriate design bending moment applicable to multi-hull craft, as determined from Pt 5, Ch 5,5.

3.2.2 The allowable tensile and compressive stress limits indicated in Table 7.3.2 in Chapter 7 are to be complied with.

3.3 Hull shear strength

3.3.1 The requirements of 2.3 are to be complied with in so far as they are applicable.

3.3.2 The allowable shear stress limits indicated in Table 7.3.2 in Chapter 7 are to be complied with.

3.4 Torsional strength

3.4.1 At the discretion of LR or where a craft is of unusual form or novel construction, the torsional stress is to be determined by direct calculation methods using the twin hull torsional connecting moment as defined in Pt 5, Ch 5. Such calculations are to be submitted in accordance with 1.5.

3.5 Strength of cross-deck structures

3.5.1 Cross-deck structures are to have adequate transverse strength in relation to the design loads and moments. Generally the net areas with effective flange, after deductions of openings, are to be used for the calculations of the total stiffness of the longitudinal section of the cross-deck structures. The effective shear area of transverse strength members is the net web area after deduction of openings.

3.5.2 The twin hull transverse bending strength of the craft at any position along the length is to be examined.

3.5.3 The twin hull transverse bending stresses for both the compressive and tensile cases are to be determined by direct calculation methods, or on the basis of 2.2.3 and 2.2.4 respectively. The stresses are to be determined in conjunction with the twin hull transverse bending moment, M_R, as defined in Pt 5, Ch 5,5.

3.5.4 Due consideration is to be given to the increased bending moments which may arise due to local point loadings from pillars, fuel bunkers, heavy items of machinery, stores, etc.

3.5.5 The shear strength of the cross-deck structure is to be examined by applying the appropriate vertical shear force at the centreline of the cross-deck structure between the twin hulls. The shear stress, τ_V, is to be determined from:

$$\tau_V = \frac{Q_R}{A_\tau} \times 10^{-3} \quad N/mm^2$$

where

A_τ = the net cross sectional area of the primary transverse cross-deck structure, in m^2

Q_R is as defined in 1.2.1.

3.5.6 The allowable shear stress limits indicated in Table 7.3.2 in Chapter 7 are to be complied with.

3.6 Grillage structures

3.6.1 For complex girder systems, a complete structural analysis using numerical methods may be required to be performed to demonstrate that the stress levels are acceptable when subjected to the most severe and realistic combination of loading conditions intended, *see also* Ch 3,4.15.

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3.6.2 In general, the transverse and vertical girders, bottom and side structures, bridge structure, deck structures and any other parts of the craft which LR considers critical to the craft's structural integrity are to be included in the numerical modelling of the craft.

3.7 Analysis techniques

3.7.1 General or special purpose computer programs or any other analytical techniques may be used provided that the effects of bending, shear, axial and torsion are properly accounted for and the theory and idealisation used can be justified.

3.7.2 In general, grillages consisting of slender girders may be idealised as frames based on beam theory provided proper account of the variations of geometric properties is taken. For cases where such an assumption is not applicable, finite element analysis or equivalent methods may have to be used.

3.7.3 Analysis of the cross deck structures with regard to impact loads due to slamming may have to be carried out using advanced structural analysis techniques.

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Section

1 **General**

2 **Deflection control**

3 **Stress control**

4 **Buckling control**

5 **Impact control**

6 **Temperature control of cored sandwich structures**

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull and multi-hull craft of composite construction as defined in Ch 1,1.1.

1.2 General

1.2.1 The failure modes criteria contained within this Chapter are to be used in formulae from the preceding Chapters to determine the scantling requirements. In addition, they are to be used when direct calculations are proposed as an alternative.

1.3 Symbols and definitions

1.3.1 The symbols and definitions applicable to this Chapter are defined below or in the appropriate Section:

f_δ = span/deflection ratio.

1.4 Direct calculations

1.4.1 The requirements of this Section may be modified where direct calculation procedures are adopted to analyse the various failure modes.

1.5 Equivalents

1.5.1 Where direct calculations are proposed, the requirements of Pt 3, Ch 1,2 are to be complied with.

1.5.2 In addition, with the agreement of Lloyd's Register (hereinafter referred to as 'LR'), tests may be conducted to demonstrate the actual response of the structure and the results verified against the failure mode criteria in this Chapter.

■ *Section 2* Deflection control

2.1 General

2.1.1 The requirements in respect of limiting deflection for both panels and stiffening members are given in this Section. These limits are generally based on a span/deflection ratio, f_δ, as given in Table 7.2.1, in consistent units.

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Table 7.2.1 Limiting span/deflection ratio

Item	f_δ
Shell envelope:	
• sandwich construction	100
Bottom structure:	
• secondary stiffening	150
• primary girders and web frames	200
Side structure:	
• secondary stiffening	150
• primary girders and web frames	200
Main/strength deck structures:	
• sandwich construction	150
• secondary stiffening	200
• primary girders and web frames	250
• hatch covers	250
Superstructure/deckhouse laminates:	
(a) Generally: • sandwich construction	100
(b) Coachroof: • sandwich construction	150
(c) House top: • sandwich construction	100
(d) Lower/inner decks and house top subject to personnel loading:	
• sandwich construction	150
Superstructure/deckhouse stiffeners:	
(a) Generally: • secondary	100
• primary	150
(b) Coachroof: • secondary	150
• primary	200
(c) House top: • secondary	100
• primary	100
(d) Lower/inner decks and house top subject to personnel loading:	
• secondary members	150
• primary members	200
Deep tank structures:	
(a) Laminates: • sandwich construction	150
(b) Stiffeners: • secondary members	175
• primary members	200
Watertight bulkhead structures:	
(a) Laminates: • sandwich construction	100
(b) Stiffeners: • secondary members	125
• primary members	150
Multihull cross-deck structures:	
(a) Laminates: • sandwich construction	100
(b) Stiffeners: • secondary members	125
• primary members	150
Vehicle deck structures:	
(a) Laminates: • sandwich construction	150
(b) Stiffeners: • secondary members	200
• primary members	250
Helicopter/flight decks:	
(a) Laminates: • sandwich construction	150
(b) Stiffeners: • secondary members	200
• primary members	250

NOTE
Where significant curvature exists over the span of the stiffener or breadth of the panel, the allowable deflections will be specially considered.

Section 3
Stress control

3.1 General

3.1.1 The nominal limiting stress for panels and primary and secondary stiffening members, subject to local and global loading conditions, are given in this Section.

3.2 Tensile and compressive stress

3.2.1 The limiting tensile and compressive stress criteria values for local and global loading conditions are given in Tables 7.3.1 and 7.3.2 respectively. These values are expressed as a fraction of the ultimate tensile and compressive strength of the laminate at first ply failure.

3.2.2 The ultimate compressive strength of the sandwich skin laminate shall not be taken greater than the critical skin buckling stress given by

$$\sigma_{cr} = 0{,}5\,(E_{cps}E_cG)^{1/3}$$

where

σ_{cr} = critical skin buckling stress, in N/mm^2

E_c = compressive modulus of the core material, in N/mm^2

E_{cps} and G are as defined in Ch 3,1.5.1

3.3 Shear stress

3.3.1 The limiting shear stress criteria values for local and global loadings are given in Tables 7.3.1 and 7.3.2 respectively. These values are expressed as a fraction of the ultimate shear strength of the laminate.

3.4 Interlaminar shear stress

3.4.1 The interlaminar shear strength of the proposed laminate is to be demonstrated to be not less than 13,8 N/mm^2.

3.5 Core shear stress

3.5.1 The limiting core shear stress criteria values are given in Table 7.3.3. These values are expressed as a fraction of the ultimate core shear strength of the core material, *see also* Ch 3,1.13.9.

3.5.2 The ultimate core shear strength of the core material is to be taken as 90 per cent of the mean ultimate shear strength determined from accepted mechanical tests, or the mean minus two standard deviations based on a minimum of five samples, whichever is less. All test pieces are to be representative of the product to be manufactured and details are to be submitted for consideration.

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Table 7.3.1 Limiting stress criteria for local loading (*see continuation*)

Item	Limiting stress fraction		
	Tensile	Compressive	Shear
Shell envelope:			
(a) Bottom shell laminate:			
• slamming zone	0,28	0,28	—
• elsewhere	0,25	0,25	—
(b) Side shell laminate:			
• slamming zone	0,33	0,33	—
• elsewhere	0,30	0,30	—
(c) Keel	0,25	0,25	—
Bottom structure:			
(a) Secondary stiffening:			
• slamming zone	0,33	0,33	0,33
• elsewhere	0,30	0,30	0,30
(b) Primary girders and web frames	0,33	0,33	0,33
(c) Engine girders	0,33	0,33	0,33
Side structure:			
(a) Secondary stiffening:			
• slamming zone	0,33	0,33	0,33
• elsewhere	0,30	0,30	0,30
(b) Primary girders and web frames	0,33	0,33	0,33
Main/strength deck laminate and stiffeners:			
(a) Laminate	0,30	0,30	—
(b) Secondary stiffening	0,30	0,30	0,30
(c) Primary girders and web frames	0,33	0,33	0,33
(d) Hatch covers	0,25	0,25	0,25
Superstructures/deckhouses:			
(a) Deckhouse front, 1st tier:			
• laminate	0,30	0,30	—
• stiffening	0,33	0,33	0,33
(b) Deckhouse front, upper tiers:			
• laminate	0,30	0,30	—
• stiffening	0,33	0,33	0,33
(c) Deckhouse, aft and sides:			
• laminate	0,30	0,30	—
• stiffening	0,33	0,33	0,33
(d) Coachroof:			
• laminate	0,30	0,30	—
• stiffening	0,33	0,33	0,33
(e) House top, not subject to personnel loading:			
• laminate	0,40	0,40	—
• stiffening	0,40	0,40	0,40
(f) Lower/inner decks and house top, subject to personnel loading:			
• laminate	0,33	0,33	—
• stiffening	0,30	0,30	0,30

Table 7.3.1 Limiting stress criteria for local loading (*see continuation*)

Item	Limiting stress fraction		
	Tensile	Compressive	Shear
Bulkheads:			
(a) Collision bulkhead:			
• laminate	0,26	0,26	—
• secondary stiffening	0,32	0,32	0,32
• primary stiffening	0,32	0,32	0,32
(b) Watertight bulkhead:			
• laminate	0,33	0,33	—
• secondary stiffening	0,40	0,40	0,40
• primary stiffening	0,40	0,40	0,40
(c) Watertight bulkhead doors:			
• in collision bulkhead	0,25	0,25	—
• in other bulkheads	0,33	0,33	—
(d) Structure supporting watertight doors:			
• in collision bulkhead	0,25	0,25	0,25
• in other bulkheads	0,33	0,33	0,33
(e) Minor bulkheads:			
• laminate	0,50	0,50	—
• secondary stiffening	0,50	0,50	0,50
• primary stiffening	0,50	0,50	0,50
(f) Deep tank bulkheads:			
• laminate	0,25	0,25	—
• secondary stiffening	0,33	0,33	0,33
• primary stiffening	0,33	0,33	0,33
Multihull cross-deck structure:			
(a) Laminate:			
• slamming zone	0,33	0,33	—
• elsewhere	0,30	0,30	—
(b) Secondary stiffening:			
• slamming zone	0,33	0,33	0,33
• elsewhere	0,30	0,30	0,30
(c) Primary stiffening	0,33	0,33	0,33
Vehicle deck:			
(a) Laminate	0,25	0,25	—
(b) Secondary stiffening	0,33	0,33	0,33
(c) Primary stiffening	0,33	0,33	0,33
Helicopter/flight decks:			
(a) Normal usage:			
• laminate	0,25	0,25	—
• secondary stiffening	0,33	0,33	0,33
• primary stiffening	0,33	0,33	0,33
(b) Emergency landing:			
• laminate	0,33	0,33	—
• secondary stiffening	0,43	0,43	0,43
• primary stiffening	0,43	0,43	0,43

3.5.3 In the absence of suitable test data, LR will consider basing the ultimate core shear strength on manufacturer recommended minimum design values based on mechanical tests performed by the core material manufacturer using accepted test methods.

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Table 7.3.2 Limiting stress criteria for global loading

Operational mode of craft	Limiting stress fraction			
	Tensile	Compressive	Shear *see* Note 1	Shear *see* Note 2
$\Gamma \geq 3,0$ or $\Delta \leq 0,04(L_R B)^{1,5}$	0,33	0,33	0,33	0,33
$\Gamma < 3,0$ and $\Delta > 0,04(L_R B)^{1,5}$	0,25	0,25	0,25	0,25

NOTES
1. Limiting stress fraction for the hull shear stress at any point along the craft length.
2. Limiting stress fraction for the vertical shear stress for the cross-deck structure.

Δ is the displacement as defined in Pt 5, Ch 2,2.
Γ is the Taylor Quotient as defined in Pt 5, Ch 2,2.1.16.
L_R and B are as defined in Pt 3, Ch 1,6.2.

Table 7.3.3 Limiting core shear stress criteria

Core Material	Limiting shear stress fraction
PVC	0,45
All other cores	0,35

■ *Section 4*

Buckling control

4.1 General

4.1.1 The requirements in respect of the control of buckling of single skin and sandwich panels, including global buckling of structures, pillars and pillar bulkheads are given in this Section.

4.2 Single skin laminate

4.2.1 Where single skin laminate panels are subject to compressive loading likely to cause axial buckling, design calculations are to be submitted indicating the margin against failure.

4.3 Sandwich skin laminate

4.3.1 Where sandwich panel skin laminates are subject to compressive loading likely to cause axial buckling, design calculations are to be submitted indicating the margin against failure.

4.3.2 Where sandwich panels subject to compressive loading have skin thicknesses which are less than the minimum required by Ch 3,2.3, design calculations are to be submitted indicating the margin against failure due to wrinkling of the sandwich skin laminates.

4.3.3 Where production methods or the craft design gives rise to local distortion or irregularity of the sandwich, the designer is to make due allowance for the reduction in critical wrinkling stress.

4.4 Pillars and pillar bulkheads

4.4.1 In general, the requirements in respect of the control of buckling of pillars and pillar bulkheads are given in Ch 3,10.

■ *Section 5*
Impact control

5.1 General

5.1.1 Skin thicknesses may be accepted which are below the stated Rule minima indicated throughout the Rules provided that acceptable stress levels are predicted for the in service condition and that equivalent impact strength can be demonstrated to the satisfaction of LR. In such cases due consideration is to be given to providing a satisfactory water barrier and ensuring suitability to resist abrasion, local point loadings, etc., *see* Ch 3,2.

5.2 Testing

5.2.1 All impact tests are to be comparative tests using the Rule basic laminate as the comparative standard. Original and tested samples of both the proposed laminate and the Rule comparison laminate are to be submitted for LR's consideration together with a detailed test report. Testing is to be carried out by the Builder and witnessed by the LR Surveyor or at an independent testing establishment, acceptable to LR. Comparison will be by visual inspection only and interpretation of the results will be at the sole discretion of LR.

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Section 6
Temperature control of cored sandwich structures

6.1 General

6.1.1 Where foam core materials are used in sandwich construction the properties at elevated temperature are to be considered. Where appropriate the mechanical properties are to be those at the maximum ambient temperature expected under normal operating conditions.

6.1.2 Alternatively other methods of controlling the temperature of the core may be considered, e.g. inserts, insulation.

6.2 Information required

6.2.1 The source of the mechanical properties data is to be shown on the Materials Data Sheet (Form 2075) when the plans are initially submitted for approval.

6.2.2 Test data is to be submitted for each grade of foam core in respect of:

- Core shear strength.
- Core shear modulus.
- Tensile strength
  (only for high density cores, i.e. > 100 kg/m^3).
- Tensile modulus
  (only for high density cores, i.e. > 100 kg/m^3).

6.3 Testing

6.3.1 Core materials are to be tested in accordance with the *Rules for the Manufacture, Testing and Certification of Materials*.

6.4 National Authority requirements

6.4.1 National Authority requirements are to be complied with as applicable.

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LIFE MATTERS

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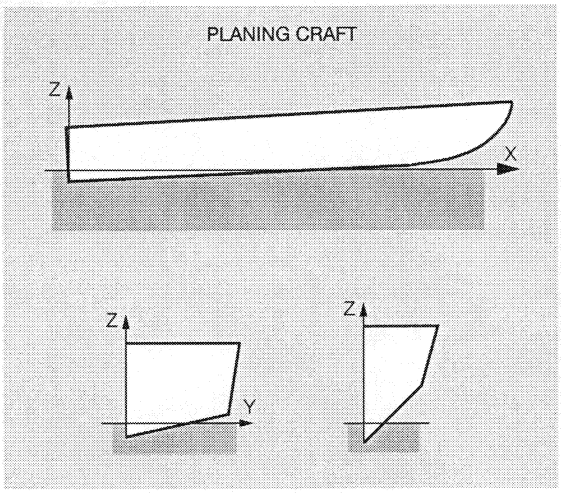
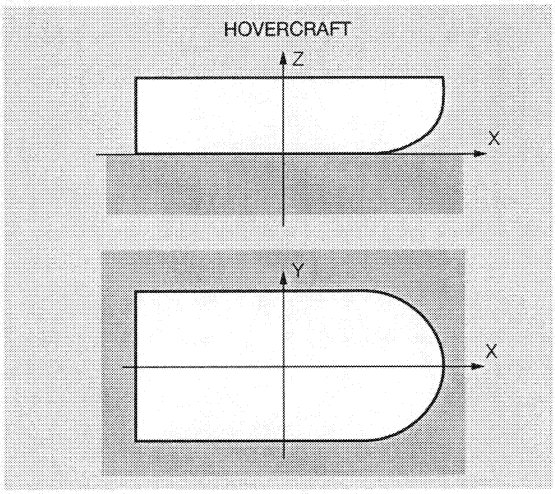
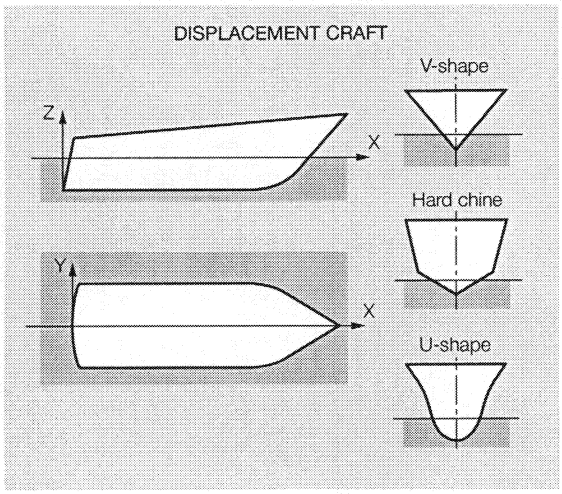
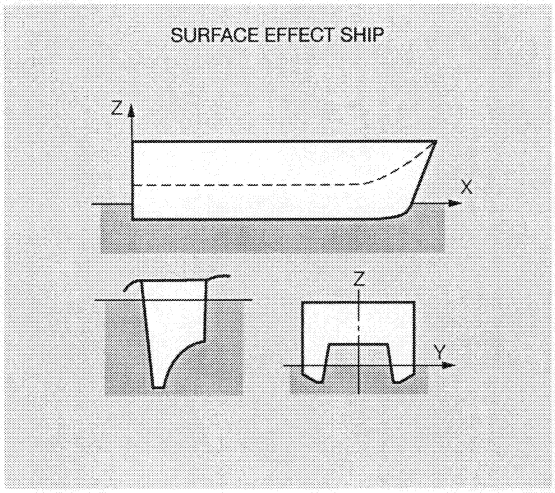
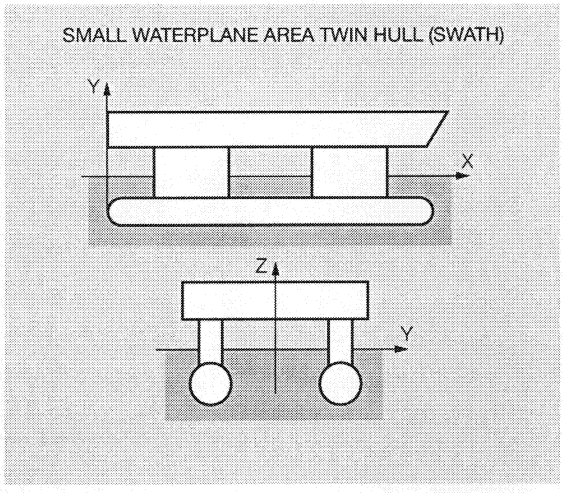
DIFFERENT TYPES OF HULL FORMS COVERED BY THE SPECIAL SERVICE CRAFT RULES

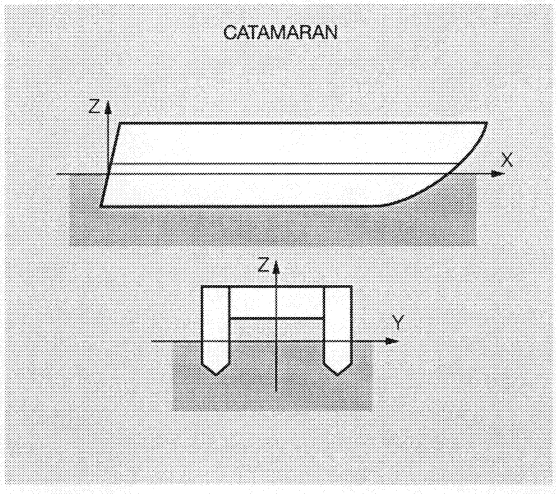












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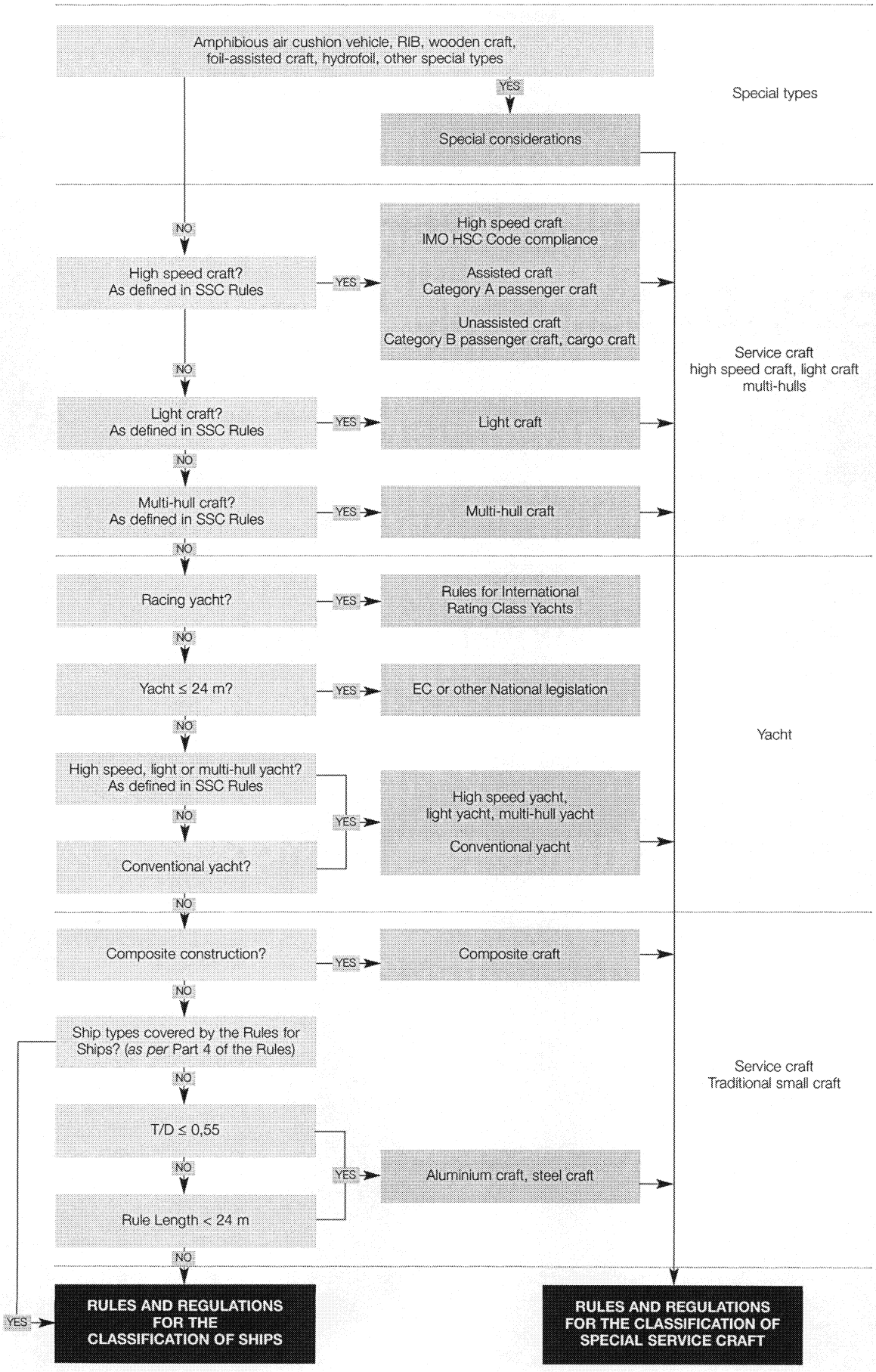
DIFFERENT TYPES OF CRAFT COVERED BY THE SPECIAL SERVICE CRAFT RULES



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Rules and Regulations for the Classification of Special Service Craft

Volume 7
Part 9
General Requirements for Machinery
July 2011

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LIFE MATTERS

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2 **Particulars to be submitted**

3 **Certification of materials**

4 **Operating conditions**

5 **Securing of machinery**

6 **Requirements for craft which are not required to comply with the HSC Code**

■ *Section 1* General requirements

1.1 Application

1.1.1 Parts 9 to 16 apply to the design, construction, installation and testing of:

- Main propulsion machinery systems
- Essential auxiliary machinery systems except where stated otherwise
- Steering and manoeuvring systems

together with their associated equipment, pressure plant, piping systems, control engineering and electrical engineering systems for the craft types stated in Pt 1, Ch 2,1.

1.1.2 The Rules incorporate those requirements of the *International Convention for the Safety of Life at Sea, 1974* as amended (SOLAS 74) Chapter X – Safety Measures for High Speed Craft (*International Code of Safety for High Speed Craft*) hereinafter referred to as the HSC code, as applicable to the classification of such craft.

1.1.3 Requirements for craft which are not required to comply with the IMO Code for High Speed Craft are given at the end of each Chapter. Requirements for service craft, yachts of 24 m or greater and other craft types have been included in these requirements. For the purposes of Parts 9 to 16, small craft are service craft of less than 24 m in length.

1.1.4 Special requirements are included for main and auxiliary machinery, pumping and piping, electrical and control engineering and fire extinction for yachts that are 500 gt or more.

1.1.5 These Rules are applicable to machinery systems burning distillate fuels which do not require to be heated.

1.2 General

1.2.1 The units and formulae used in the Rules are in SI Units.

1.2.2 It is the responsibility of the Shipbuilder as main contractor to ensure that the information required is prepared and submitted.

1.2.3 Where the craft is defined as a Passenger (B) Craft (*see* Pt 1, Ch 2,3), sufficient redundancy is to be provided such that in the event of damage to any part of a main propulsion drive system, the craft is able to maintain sufficient seaway.

1.2.4 Sufficient astern power is to be provided to maintain control of the craft in all normal circumstances.

1.2.5 The main propulsion machinery will be approved for the maximum continuous power, and associated shaft speed, required to achieve the maximum craft velocity at the certified maximum operational weight in smooth water.

1.2.6 Main propulsion machinery will be considered for operation at a higher power rating than the classification rating for short time intervals (referred to as short term high power operation) in conjunction with the intended operation service profile.

1.2.7 Provision shall be made to facilitate cleaning, inspection and mantenance of main propulsion and auxiliary machinery including boilers and pressure vessels.

1.3 Fuel flash point

1.3.1 The flash point (closed cup test) of oil fuel is in general to be not less than 60°C. For emergency generator engines a flash point of not less than 43°C is permissible.

1.3.2 Oil fuel with a flash point lower than 60°C may be used where it can be shown that the temperature of the oil fuel will always be not less than 10°C below its flash point.

1.3.3 The use of fuel with a flash point below 43°C is not recommended. However, fuel with a lower flash point , but not lower than 35°C, may be used in gas turbines only, subject to compliance with the provisions in Section 4.

1.4 Exhaust

1.4.1 Where the surface temperature of the exhaust pipes and silencer may exceed 220°C, they are to be water cooled or efficiently lagged to minimise the risk of fire and to prevent damage by heat. Where lagging covering the exhaust piping system including flanges is oil-absorbing or may permit penetration of oil, the lagging is to be encased in sheet metal or equivalent. In locations where the Surveyor is satisfied that oil impingement could not occur, the lagging need not be encased.

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1.5 Bearings

1.5.1 Roller element bearings are to have an L10 design life of at least 30 000 hours, based upon the design operating conditions, including short term high power operation. An L10 design life of less than 30 000 hours would be accepted, provided it is proposed in conjunction with the manufacturer's design/maintenance manual.

1.6 Vibration of shaft systems

1.6.1 The Shipbuilders are to ensure that the systems are free from excessive vibrations, excessive bearing reactions and excessive bending moments under all design operating conditions.

1.6.2 Where changes are subsequently made to a dynamic system which has been approved by Lloyd's Register (hereinafter referred to as 'LR'), e.g. machining a shaft, fitting a propeller of a different design to the working propeller or fitting a different flexible coupling, full details of the changes are to be advised. Revised calculations may be required to be submitted.

1.6.3 Where there is experience of previous similar systems which have been approved, full details of these installations may be submitted for consideration in lieu of calculations.

1.7 Alternative system of survey

1.7.1 Where items of machinery are manufactured as individual or series produced units, LR will give consideration to the adoption of a survey procedure based upon an approved quality assurance system to ISO 9001 (or equivalent) utilising regular and systematic audits of the approved manufacturing and quality control processes and procedures as an alternative to the direct survey of individual components.

■ *Section 2*
Particulars to be submitted

2.1 Submission of information

2.1.1 At least three copies of plans, information and specifications as listed are to be submitted before commencement of manufacture.

2.2 Plans

2.2.1 Plans are to indicate clearly the scantlings and materials of construction. Any design alteration to the plan is to be resubmitted for approval, indicating clearly the alteration.

2.2.2 Individual Chapters also list plans to be submitted for specific machinery systems or components.

2.2.3 Where machinery system components have been approved under LR's Type Approval System or Machinery General Design Appraisal for the proposed design conditions or service, plans of the components will not be required to be submitted for individual newbuildings. Full details of the components are to be advised.

2.2.4 Plans showing the arrangement of resiliently mounted machinery are to indicate the number, position, type, and design of mounts.

2.2.5 The plans of arrangement of resin chocks for machinery requiring accurate alignment are to be submitted.

2.3 Calculations and specifications

2.3.1 Relevant data covering the following topics is to be submitted.

2.3.2 **Service Profile.** The machinery power/speed operational envelope indicating all the intended operational points applicable to the class notation, and any short term high power operation.

2.3.3 **Classification rating**:

(a) The following operational parameters are to be taken, using the design conditions for the intended Class Notation:
- Total barometric pressure, in bar.
- Temperature of engine room, or suction air, in °C.
- The relative humidity, in per cent.
- Temperature of sea water, or charge air coolant inlet, in °C.

(b) For unrestricted service, the following operational parameters ambient reference conditions are to be taken:
- Total barometric pressure, at 1000 mb.
- Temperature of engine room or suction air, at 45°C.
- Relative humidity, at 60 per cent.
- Temperature of sea water or charge air coolant inlet, at 32°C.

2.3.4 **Short term high power operation.** Where the propulsion machinery is being considered for short term high power operation, full details of the power, speed and time intervals together with fatigue endurance calculations, and documentary evidence indicating the suitability of the component design under these conditions and for the intended class notation are required. The following are to be considered; prime mover, gearbox, flexible coupling, vibration dampers, shafting and propeller:

(a) The accrued number of load cycles and the percentage component overload are to be those recommended by the designers.

(b) Excessive overload may require the interval between surveys to be reduced.

(c) Machinery is to be maintained in accordance with the manufacturers' requirements.

2.3.5 **Damper and Flexible Coupling characteristics.** Documentary evidence that the characteristics have been verified.

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2.3.6 **Machinery Fastening.**

(a) Documentary evidence and calculations indicating that machinery is securely mounted for the accelerations to be expected during service.

(b) Calculations that mountings of large masses such as main engines, auxiliary engines, lift fans and electrical equipment can withstand the design collision acceleration according to 5.2.1 without fracturing.

(c) Natural frequency calculation of resilient mounted machinery.

(d) For non-metallic machinery chocks:
  (i) Resin type.
  (ii) The effective area and minimum thickness of the chocks.
  (iii) The total deadweight loading of machinery.
  (iv) The thrust load, where applicable, that will be applied to the chocked item.
  (v) The loading to be applied to the holding-down bolts.
  (vi) The material of the holding-down bolts.
  (vii) The number, thread size, and waisted shank diameter (where applicable) of the holding-down bolts.

2.3.7 **Manuals.** The operation and maintenance manuals.

2.3.8 **Failure Mode and Effect Analysis.** Where required for high speed craft, an FMEA is to be carried out covering the following systems:

(a) Main and auxiliary machinery systems, and their controls.

(b) Steering systems.

(c) Electrical systems.

2.3.9 **Fatigue Strength Analysis.** Where undertaken as an alternative to the requirements of the individual Chapters, fatigue strength analysis of components indicating a factor of safety of 1,5 at the design loads based on a suitable fatigue failure criteria. The effects of stress concentrations, material properties and operating environment are to be taken into account.

■ *Section 3* Certification of materials

3.1 Materials of construction

3.1.1 Materials used in the construction are to be in accordance with, or shown to be equivalent to *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials). Details of all materials included and not included in the Rules for Materials are to be forwarded as soon as possible (preferably at the design concept stage) and before commencement of manufacture.

3.1.2 Materials used in the construction of machinery and its installation are not to contain asbestos.

■ *Section 4* Operating conditions

4.1 Machinery control

4.1.1 The design and arrangement is to be such that the machinery can be started and controlled on board, without external aid, so that the operating conditions for which the craft is classed, can be maintained.

4.2 Inclinations of the craft

4.2.1 The main and auxiliary machinery is to be designed and installed such that it operates satisfactorily under the conditions as shown in Table 1.4.1.

Table 1.4.1 Inclinations

Installations, components	Angle of inclination, degrees, *see* Note 1			
	Athwartship		Fore-and-aft	
	Static	Dynamic	Static	Dynamic
Main and auxiliary machinery essential to the propulsion and safety of the craft	15	22,5	5 *see* Note 2	7,5
Emergency machinery and equipment fitted in accordance with Statutory Requirements	22,5	22,5	10	10

NOTES
1. Athwartships and fore-and-aft inclination may occur simultaneously.
2. Where the length of the craft exceeds 100 m, the fore-and-aft static angle of inclination may be taken as:

$$\frac{500}{L_{WL}} \text{ degrees}$$

where
L_{WL} = craft waterline length, in metres

4.2.2 The arrangements for lubricating bearings and for draining crankcase and other oil sumps of main and auxiliary engines, gearcases, electric generators, motors, and other running machinery are to be so designed that lubrication will remain efficient with the craft inclined under the conditions as shown in Table 1.4.1.

4.2.3 Deviations from these conditions may be accepted taking into consideration type and size of the craft and the class notation. The Shipbuilder is to ensure that the main and auxiliary machinery is capable of operating at the proposed angles of inclination.

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4.3 Power ratings

4.3.1 In the Chapters where the dimensions of any particular component are determined from shaft power, P, in kW (H, in shp), and revolutions per minute, R, the values to be used are to be derived from the following:

- For main propelling machinery, the maximum shaft power and corresponding revolutions per minute giving the maximum torque for which the machinery is to be classed.
- For auxiliary machinery, the maximum continuous shaft power and corresponding revolutions per minute which will be used in service.

4.4 Ambient operating conditions

4.4.1 Main and essential auxiliary machinery and equipment is to be capable of operating satisfactorily under the conditions shown in Table 1.4.2.

Table 1.4.2 Ambient operating conditions

Air		
Installations, Components	Location, arrangement	Temperature range (°C)
Machinery and electrical installations	In enclosed spaces	0 to +45, *see* Note 1
	On machinery components, boilers. In spaces subject to higher and lower temperatures	According to specific local conditions, *see* Note 2
	On the open deck	–25 to +45, *see* Note 1
Water		
Coolant		Temperature (°C)
Sea-water or charge air coolant inlet to charge air cooler		-2 to +32, *see* Notes 1 and 3

NOTES
1. For ships intended to be classed for restricted service, a deviation from the temperatures stated may be considered.
2. Details of local environmental conditions are stated in Annex B of IEC 60092: *Electrical installations in ships – Part 101: Definitions and general requirements.*
3. Charge air cooling arrangements utilising re-circulated cooling to maintain temperatures in a different range are accepted where the machinery and equipment operation is not degraded with a primary supply of cooling in the temperature range stated in this Table.

4.4.2 Where it is intended to allow for operation in ambient temperatures outside those shown in Table 1.4.2, the permissible temperatures and associated periods of time are to be specified and details are to be submitted for consideration. Propelling and essential auxiliary machinery, *see* Pt 1, Ch 2, 3.10.1, is to retain a continuous level of functional capability under these conditions and any level of degraded performance is to be defined. Operation under these circumstances is not to be the cause of damage to equipment in the system and is additionally to be acceptable to the National Authority of the country in which the craft is to be registered

■ *Section 5* Securing of machinery

5.1 Fastenings

5.1.1 Bedplates, thrust seatings and other fastenings are to be of robust construction. The machinery is to be securely fixed to the craft's structure, such that the arrangement is sufficient to restrain the dynamic forces arising from vertical and horizontal acceleration appropriate to the intended service.

5.2 Collision load

5.2.1 Unless an accurate analysis of the collision load is submitted and found acceptable by LR, the collision load is to be determined from:

$$g(\text{collision}) = 1{,}2\,\frac{P_{coll}}{\Delta g}$$

where the load P_{coll} is taken as the lesser of:

$$P_{coll} = 460\,(M\,C_L)^{2/3}\;\;(E\,C_H)^{1/3}\ \text{kN}$$

$$P_{coll} = 9000\,M\,C_L\;[C_H\,(T+2)]^{1/2}\ \text{kN}$$

where

C_H = a factor given in Table 1.5.1

$$C_L = \frac{(165 + L_{WL})}{245}\left(\frac{L_{WL}}{80}\right)^{0,4}$$

D = craft depth, in metres, from the underside of keel amidships to the top of effective hull girder

E = $0{,}5\Delta\,V^2$ kNm

H_T = minimum height, in metres, from tunnel or wet-deck bottom to the top of effective hull girder for catamarans and surface effect ships
= D for air cushion vehicles

L_{WL} = craft waterline length, in metres

M = 1,3 for high tensile steel
= 1,0 for aluminium alloy
= 0,95 for mild steel
= 0,8 for fibre reinforced plastics

T = buoyancy tank clearance to skirt tip, in metres, (negative) for ACVs
= lifted clearance from keel to water surface, in metres, (negative) for hydrofoils
= craft draught to the underside of keel amidships, in metres, for all other craft

V = operational speed of craft, in m/s

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g = gravitational acceleration = 9,806 m/s^2
Δ = craft displacement, to be taken as the mean of the lightweight and maximum operational weight, in tonnes.

Table 1.5.1 Factor C_H

Factor, C_H	Catamarans, SES	Mono-hulls, H Foils	ACVs
C_H	$\frac{T + 2 + f\,(D/2)}{2D}$	$\frac{T + 2 + f\,(D/2)}{2D}$	$\frac{f}{4}$
where $f = 0$ for $f = 1$ for $f = 2$ for	 $T + 2 < D - H_T$ $D > T + 2 \geq D - H_T$ $T + 2 \geq DM$	 $T + 2 < D$ $T + 2 \geq D$ —	 — $H_T > 2$ $H_T \leq 2$

5.3 Resilient mounts

5.3.1 Creep of rubber mounts and the effects on the alignment are also to be considered.

5.3.2 Shafting, piping connections and electrical cable connections are to be provided with sufficient flexibility to accommodate such movements. Particular attention should be paid to exhaust bellows and the effectiveness of flexible couplings.

5.3.3 Limit stops are to be fitted as necessary to ensure that manufacturers' limits are not exceeded. Suitable means are to be provided to accommodate propeller thrust.

5.3.4 Mounts are to be shielded from the possible detrimental effects of oil.

5.4 Machinery mounted on resin chocks

5.4.1 These Rules relate to the application of synthetic resin compounds as materials for chocks under machinery components where accurate alignments are important, e.g. main engine, gearbox and auxiliary installations where the engine and generator do not share a common baseplate.

5.4.2 Resin compounds used in these applications are to be of a type accepted by LR.

5.4.3 The use of resin for chocking gas turbine casings or similar high temperature applications will not be considered.

Section 6
Requirements for craft which are not required to comply with the HSC Code

6.1 Plans and particulars

6.1.1 At least three copies of the following plans are to be submitted for approval at the earliest opportunity:

- Crankshaft including details of the material specification.
- Gearing including details of the material specification.
- Arrangement and details of the propulsion shafting, couplings and bearing disposition, etc.
- Propeller where the diameter exceeds 1 m.
- Diagrammatic arrangements of the exhaust systems indicating the materials, methods of cooling, and if water spray is injected, the method of draining.
- Starting air system and receivers.
- Diagrammatic arrangements of pumping and piping systems including the air and sounding pipes for the tanks.
- Diagrammatic arrangements of bilge and fire water pumps and piping for craft having a Rules length of 12 m and over and which are subdivided into watertight compartments.
- Diagrammatic arrangement of oil fuel piping.
- Construction arrangements of separate oil fuel tanks having a capacity exceeding 250 litres.
- Electrical equipment as detailed in Pt 16, Ch 2.
- Steering gear machinery and hydraulic circuit diagram if applicable.
- Fire extinction equipment as detailed in Part 17.
- Safety plan showing the position of all fire prevention controls, fixed and loose equipment and portable extinguishers, *see* Pt 17, Ch 1 to 4.
- Control circuits and alarm points as detailed in Pt 16, Ch 1.

6.1.2 The following particulars are to be submitted with the plans of crankshaft, gearbox or shafting as applicable:

- Name of manufacturer.
- Type designation.
- Particulars of engine cycle.
- Number of cylinders and vee angle where applicable.
- Maximum combustion pressure and mean indicated pressure.
- Span of bearings adjacent to a crank measured from centreline of the bearing to the centreline of the adjacent bearing.
- Proposed shaft power (kW) and revolutions per minute of the engine at each operating condition.
- Gear box reduction ratio.
- For engines over 500 kW, *see* Pt 10, Ch 1,3.

6.1.3 Where machinery system components or equipment have been approved under LR's Type Approval System or Machinery General Design Appraisal for the proposed design conditions or intended service, full details of the components should be advised to enable the validity of the approval to be checked. In cases where valid approvals are confirmed, plans are not required to be submitted for approval for individual craft.

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6.2 Calculations

6.2.1 Design calculations are to be submitted for the following systems and conditions:

(a) Direct calculation for design strength of machinery supports, such as engine mountings, on craft subjected to high accelerations, *see* Section 5.

(b) Calculations of torsional vibrations for main engines where the power exceeds 500 kW and for auxiliary engines for essential services where the power exceeds 110 kW.

6.3 Certification of materials

6.3.1 The requirements of 3.1 apply to all types of craft.

6.3.2 Where no provision is made in these Rules, materials may be accepted provided that they comply with an approved specification and such tests as may be considered necessary by the Surveyor.

6.3.3 The requirements for materials for machinery components are indicated in the relevant Part or Chapter of the Rules.

6.4 Operating conditions

6.4.1 The requirements of 4.2 do not apply to yachts or service craft less than 24 m.

6.4.2 For patrol craft and high speed craft of 24 m or greater, the main and auxiliary machinery is to be designed to operate under the conditions defined in Sections 4 and 5.

6.4.3 If operation under the required accelerations cannot be demonstrated on trials, alternative documentary evidence is to be presented to confirm that the machinery is capable of operating under such conditions.

6.4.4 Additional trials or conditions may be imposed to prove the machinery as considered necessary.

6.5 Securing of machinery

6.5.1 The requirements of 5.1, 5.3 and 5.4 apply.

6.5.2 Engines are to be installed so as to permit easy access to fittings, such as lubricating oil connections, bilge suctions and sea cocks.

6.5.3 Where the hull is constructed of FRP, wood or composites, and the hull surfaces are not adequately protected against oil contamination, drip trays are to be fitted under those parts of the engine and gearbox where leakage of oil fuel or lubricating oil might occur. Means are to be provided for removing any leakage easily.

6.5.4 Where resilient mounts are fitted, the name of the manufacturer and details of the type of mounting are to be indicated on the plan of the shafting.

6.5.5 Where inclinations beyond those defined in 4.2 might be experienced, such as yacht roll over, means are to be provided to prevent machinery becoming dislodged.

6.5.6 Satisfactory arrangements are to be made to transmit the propulsion thrust into the craft structure.

6.6 Ventilation of machinery spaces

6.6.1 For yachts and service craft of less than 24 m the ventilation of the machinery space is to be adequate for all conditions of the operation of the machinery and in no case is to be less than that required by the engine manufacturer.

6.6.2 The engine compartment is to be provided with inlet and outlet ventilating ducts. One or more inlet ducts are to extend down to a suitable low level.

6.6.3 Outlet ducts are to be connected near or at the top of the compartment and are to be arranged for natural or mechanical extraction as necessary.

6.6.4 Consideration will be given to equivalent alternative arrangements provided full details are submitted before construction is commenced.

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Surveys During Construction, Installation and Sea Trials

Section

1 **General requirements**

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■ *Section 1* General requirements

1.1 Surveys during construction

1.1.1 Machinery is to be surveyed at the manufacturer's works from the commencement of work until the final test under working conditions. The Surveyors are to be satisfied that the materials, workmanship and arrangements are satisfactory and in accordance with the Rules.

1.1.2 Lloyd's Register's (hereinafter referred to as LR) requirements for the conditions of manufacture, survey and certification of materials used for the production of forged steel and castings used in the production of components are given in *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

1.2 Miscellaneous surveys

1.2.1 Resilient mounts are to be installed under survey and the machinery tested under full working conditions.

1.2.2 Alignment of machinery is to be checked after the first six months of operation.

■ *Section 2* Diesel engines

2.1 Construction and welding

2.1.1 Welding of engine structures is to be in accordance with the requirements specified in Chapter 13 of the Rules for Materials.

2.1.2 On completion of welding and stress relief heat treatment, welds are to be examined. Welds in transverse girder assemblies are to be crack detected by an approved method. Other joints are to be similarly tested if required by the Surveyors.

2.1.3 Forgings and castings are to be examined at the manufacturer's works.

2.2 Hydraulic testing

2.2.1 Items are to be tested by hydraulic pressure as indicated in Table 2.2.1.

2.3 Non-destructive testing

2.3.1 Non-destructive examination of welded construction is to be conducted in accordance with the requirements specified in Chapter 13 of the Rules for Materials.

2.4 Engine type testing

2.4.1 New engine types or developments of existing types are to be subjected to an agreed programme of type testing to complement the design appraisal and review of documentation. The programme will need to include short term high power operation where applicable.

2.4.2 Guidelines for type testing of engines will be supplied on application.

2.4.3 Wherever practical, type tests are to be conducted with the engine control systems operational in the approved configuration, *see* Pt 10, Ch 1,2.1.5 and 2.1.6. Configuration management documents are to be reviewed at testing for validity and referenced in the type test report.

2.4.4 An engine type is defined in terms of:

- Basic engine data, e.g. bore, stroke.
- Working cycle; 2 stroke, 4 stroke.
- Cylinder arrangement; in-line, vee.
- Cylinder rating.
- Fuel supply, e.g. direct or indirect injection.
- Gas exchange; natural aspiration, pressure charging arrangement.

2.4.5 Where an engine type has subsequently proved satisfactory in service with a number of applications a maximum uprating of 10 per cent may be considered without a further complete type test.

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Table 2.2.1 Test pressures

Item	Test pressure
Fuel injection system { Pump body, pressure side; Valve; Pipe }	The lesser of 1,5*p* or *p* + 295 bar
Cylinder cover, cooling space Cylinder liner, over the whole length of cooling space Piston crown, cooling space (where piston rod seals cooling space, test after assembly)	7,0 bar
Cylinder jacket, cooling space Exhaust valve, cooling space Turbo-charger, cooling space Exhaust pipe, cooling space Coolers, each side Engine driven pumps (oil, water, fuel, bilge)	The greater of 4,0 bar or 1,5*p*
Air compressor, including cylinders, covers, intercoolers and aftercoolers	Air side: 1,5*p* Water side: The greater of 4,0 bar or 1,5*p*
Scavenge pump cylinder	4,0 bar

NOTES
1. *p* is the maximum working pressure, in bar, in the item concerned.
2. Fuel pumps of the jerk or timed pump system are not included.
3. Turbo-charger air coolers need only be tested on the water side.
4. For forged steel cylinder covers alternative testing methods will be specially considered.

2.4.6 A type test will be considered to cover engines of a given design for a range of cylinder numbers in a given cylinder arrangement.

■ *Section 3* Turbo-chargers

3.1 Type testing

3.1.1 A type test is to consist of a hot gas running test of at least one hour duration at the maximum permissible speed and maximum permissible temperature. Following the test the turbo-charger is to be completely dismantled for examination of all parts.

3.1.2 Alternative arrangements will be considered.

3.2 Dynamic balancing

3.2.1 All rotors are to be dynamically balanced on final assembly to the Surveyor's satisfaction.

3.3 Overspeed tests

3.3.1 All fully bladed rotor sections and impeller/inducer wheels are to be overspeed tested for three minutes at either 20 per cent above the maximum permissible speed at room temperature or 10 per cent above the maximum permissible speed at the normal working temperature.

3.4 Mechanical running tests

3.4.1 Turbo-chargers are to be given a mechanical running test of 20 minutes duration at the maximum permissible speed.

3.4.2 Upon application, with details of an historical audit covering previous testing of turbo-chargers manufactured under an approved quality assurance scheme, consideration will be given to confining the test to a representative sample of turbo-chargers.

■ *Section 4* Gas turbines

4.1 Dynamic balancing

4.1.1 All rotors as finished-bladed and complete with half-coupling are to be dynamically balanced in accordance with the manufacturer's specification in a machine of sensitivity appropriate to the size of rotor.

4.2 Hydraulic testing

4.2.1 All casings are to be tested to a hydraulic pressure equal to 1,5 times the highest pressure in the casing during normal operation, or 1,5 times the pressure during starting, whichever is the higher. For test purposes, if necessary, the casings may be subdivided with temporary diaphragms for distribution of test pressure.

4.2.2 Where hydraulic tests cannot be carried out on the casing, alternative proposals will be considered.

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4.2.3 Intercoolers and heat exchangers are to be tested to 1,5 times the maximum working pressure on each side separately.

4.3 Overspeed tests

4.3.1 Before installation, the gas turbine is to be tested for five minutes at five per cent above the nominal setting of the overspeed protective device, or 15 per cent above the maximum design speed, whichever is the higher.

4.3.2 Where it is impracticable to overspeed the complete installation, each rotor, completely bladed and with all relevant parts such as half-couplings, is to be overspeed-tested individually at the appropriate speed.

■ *Section 5* Gearing

5.1 Construction and welding

5.1.1 Where castings are used for wheel centres, any radial slots in the periphery are to be fitted with permanent chocks before shrinking-on the rim.

5.1.2 Where welded construction is used for the manufacture of wheels and gearcases, welding is to be in accordance with the requirements specified in Chapter 13 of the Rules for Materials.

5.1.3 Welded constructions are to be stress relief heat treated on completion of welding.

5.1.4 Bolted attachments within the gear case are to be secured by locking wire or equivalent means.

5.2 Accuracy of gear cutting

5.2.1 The machining accuracy (Q grade) of pinions and wheels is to be demonstrated. For this purpose records of measurements are to be available for review.

5.3 Non-destructive testing

5.3.1 Magnetic particle or liquid penetrant testing is to be carried out on the teeth of all surface hardened forgings. This examination may also be requested on the finished machined teeth of through hardened gear forgings.

5.3.2 The manufacturer is to carry out an ultrasonic examination of all forgings where the finished diameter of the surfaces, where teeth will be cut, is in excess of 200 mm, and is to provide LR with a signed statement that such inspection has not revealed any significant internal defects.

5.3.3 On gear forgings where the teeth have been surface hardened, additional test pieces may be required to be processed with the forgings and subsequently sectioned to determine the depth of the hardened zone. These tests are to be carried out at the discretion of the Surveyor, and for induction or carburised gearing the depth of the hardened zone is to be in accordance with the approved specification. For nitrided gearing, the full depth of the hardened zone, i.e. depth to core hardness, is to be not less than 0,5 mm and the hardness at a depth of 0,25 mm is to be not less than 500 Hv.

5.4 Dynamic balancing

5.4.1 All rotating elements such as pinion and wheel shaft assemblies and coupling parts, are to be appropriately balanced.

5.4.2 The permissible residual unbalance, U, is defined as follows:

$$U = \frac{60m}{R} \times 10^3 \text{ g mm} \quad \text{for } R \leq 3000$$

$$U = \frac{24m}{R} \times 10^3 \text{ g mm} \quad \text{for } R > 3000$$

where

m = mass of rotating element, in kg

R = maximum service rev/min of the rotating element.

5.4.3 Where the size or geometry of a rotating element precludes measurement of the residual unbalance a full speed running test of the assembled gear unit at the manufacturer's works will normally be required to demonstrate satisfactory operation.

5.5 Meshing tests

5.5.1 Initially, meshing gears are to be carefully matched on the basis of the accuracy measurements taken. The alignment is to be demonstrated in the workshop by meshing in the gearbox without oil clearance in the bearings. Meshing is to be carried out with the gears locating in their light load positions and a load sufficient to overcome pinion weight and axial movement is to be imposed.

5.5.2 The gears are to be suitably coated to demonstrate the contact marking. The thickness of the coating to determine the contact marking is not to exceed 0,005 mm. The marking is to reflect the accuracy grade specified and end relief, crowning or helix correction, where these have been applied.

5.5.3 For gears without crowning or helix correction the marking is to be not less than shown in Table 2.5.1.

5.5.4 Where allowance has been given for end relief, crowning or helix correction, the normal shop meshing tests are to be supplemented by tooth alignment traces or other approved means to demonstrate the effectiveness of such modifications.

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Table 2.5.1 No load tooth contact marking

ISO accuracy grade	Contact marking area
$Q \leq 5$ $Q \geq 6$	50% b x 40% h_w + 40% b x 20% h_w 35% b x 40% h_w + 35% b x 20% h_w
NOTES 1. Where b is the face width and h_w is the working tooth depth. 2. For spur gears, the values of h_w should be increased by a further 10%.	

5.5.5 For gears with crowning or helix correction, the marking is to correspond to the designed no load contact pattern.

5.5.6 A permanent record is to be made of the meshing contact for the purpose of checking the alignment when installed on board the craft.

5.5.7 The full load tooth contact marking is to be not less than shown in Table 2.5.2.

Table 2.5.2 Full load tooth contact marking

ISO accuracy grade	Contact marking area
$Q \leq 5$ $Q \geq 6$	60% b x 70% h_w + 30% b x 50% h_w 45% b x 60% h_w + 35% b x 40% h_w
NOTES 1. Where b is the face width and h_w is the working tooth depth. 2. For spur gears, the values of h_w should be increased by a further 10%.	

5.5.8 Where, due to the compactness of the gear unit, meshing tests of individual units cannot be verified visually, consideration may be given to the gear manufacturer providing suitable evidence that the design meshing condition has been attained on units of the same design.

5.5.9 The normal backlash between any pair of gears should not be less than:

$$\frac{a\,\alpha_n}{90000} + 0{,}1 \text{ mm}$$

where

α_n = normal pressure angle, in degrees

a = centre distance, in mm.

■ *Section 6* Shafting systems

6.1 Construction and installation

6.1.1 Boring of the sternframe, fitting of the sterntube and bearings and aligning the shafting are to be carried out to a formal traceable procedure.

6.1.2 Before boring the sternframe the structure should be generally complete to the upper deck and to the engine-room forward bulkhead.

■ *Section 7* Propellers

7.1 Construction and welding

7.1.1 Castings are to be examined at the manufacturer's works.

7.1.2 All finished propellers are to be examined for material defects and finish, and measured for dimensional accuracy of diameter and pitch. Propeller repairs by welding, where proposed, are to be in accordance with the requirements of Ch 9,1 of the Rules for Materials.

7.2 Shop tests of keyless propellers

7.2.1 The bedding of the propeller with the shaft is to be demonstrated. Sufficient time is to be allowed for the temperature of the components to equalise before bedding. Alternative means for demonstrating the bedding of the propeller will be considered.

7.2.2 Means are to be provided to indicate the relative axial position of the propeller boss on the shaft taper.

7.3 Shop tests of controllable pitch propellers

7.3.1 The components of controllable pitch propellers are also subject to material tests, as in the case of solid propellers.

7.3.2 Examination of all the major components including dimensional checks, hydraulic pressure testing of the hub and cone assembly and the oil distribution box, where fitted, together with a full shop trial of the completed controllable pitch propeller assembly, is to be carried out.

7.4 Final fitting of keyless propellers

7.4.1 After verifying that the propeller and shaft are at the same temperature and the mating surfaces are clean and free from oil or grease, the propeller is to be fitted on the shaft under survey. The propeller nut is to be securely locked to the shaft.

7.4.2 Permanent reference marks are to be made on the propeller boss nut and shaft to indicate angular and axial positioning of the propeller. Care is to be taken in marking the inboard end of the shaft taper to minimise stress raising effects.

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7.4.3 The outside of the propeller boss is to be hard stamped with the following details:

- For oil injection method of fitting, the start point load, in Newtons, and the axial pull-up at 0°C and 35°C, in mm.
- For the dry fitting method, the push-up load at 0°C and 35°C, in Newtons.

7.4.4 A copy of the fitting curve relative to temperature and means for determining any subsequent movement of the propeller are to be placed on board.

7.5 Final fitting of keyed propellers

7.5.1 The fit of the screwshaft cone to both the working and any spare propeller is to be carried out under survey. Generally, a satisfactory fit for keyed type propellers should show a light, overall marking of the cone surface with a tendency towards heavier marking in way of the larger diameter of the cone face. The final fit to cone should be made with the key in place.

■ *Section 8* Water jet units

8.1 Construction and welding

8.1.1 The following components are to be inspected at the manufacturer's works:

- Steering nozzle.
- Reverse bucket.
- Stator impeller.
- Integral bearing.

8.1.2 Welded construction is to be in accordance with the requirements specified in Chapter 13 of the Rules for Materials.

8.1.3 Welded components are to comply with the requirements of Pt 15, Ch 4 and be subject to stress relief heat treatment upon completion. Where an impeller has welded blades, non-destructive testing is to be carried out to an approved procedure.

8.2 Testing

8.2.1 Testing of the first installation of a new type of water jet unit is required and is to demonstrate the adequacy of the steering and reversing mechanisms during the most arduous manoeuvres.

8.2.2 Upon completion, the impeller assembly is to be suitably balanced in accordance with ISO 940 Grade G6,3 or an equivalent Standard.

■ *Section 9* Thrusters

9.1 Azimuth thrusters

9.1.1 The performance specified for the craft is to be demonstrated.

9.1.2 The actual values of steering torque are to be verified during sea trials to confirm that the design maximum dynamic duty torque has not been exceeded.

9.2 Tunnel thrusters

9.2.1 It is to be demonstrated that the thruster unit meets the specified performance.

■ *Section 10* Steering systems

10.1 Construction

10.1.1 The requirements of the Rules relating to the testing of Class I pressure vessels, piping and related fittings including hydraulic testing apply.

10.2 Type testing

10.2.1 Each type of power unit pump is to be subjected to a type test. The type test is to be for a duration of not less than 100 hours, the test arrangements are to be such that the pump may run in idling conditions, and at maximum delivery capacity at maximum working pressure. During the test, idling periods are to be alternated with periods at maximum delivery capacity at maximum working pressure. The passage from one condition to another should occur at least as quickly as on board. During the whole test no abnormal heating, excessive vibration or other irregularities are permitted. After the test, the pump is to be opened out and inspected. Type tests may be waived for a power unit which has been proven to be reliable in marine service.

10.3 Testing

10.3.1 After installation on board the craft the steering unit is to be subjected to the applicable hydrostatic and running tests.

10.3.2 The steering system is to be demonstrated to show that the requirements of the Rules have been met. The trial is to include the operation of the following:

(a) The steering system, including demonstration of the functional performances.
(b) The steering power units, including transfer between steering power units.
(c) The isolation of one power actuating system, checking the time for regaining steering capability.

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(d) The hydraulic fluid recharging system (may be effected at the dockside).
(e) The emergency power supply.
(f) The steering controls, including transfer of control and local control.
(g) The means of communication between the steering compartment and the wheelhouse, also the engine room, if applicable (may be effected at the dockside).
(h) The alarms and indicators (may be effected at the dockside).
(j) Where the steering system is designed to avoid hydraulic locking this feature is to be demonstrated (may be effected at the dockside).

Section 11
Sea trials

11.1 Sea trials requirements

11.1.1 Sea trials are to be of sufficient duration and carried out under normal operating conditions applicable to the intended class notation. Individual Chapters give specific requirements.

11.2 Programme

11.2.1 Sea trials are to include the demonstration of:
(a) The adequacy of the starting arrangements of the main engines, auxiliary systems and emergency generators.
(b) The effectiveness of the steering gear control systems.
(c) Manoeuvring, to include:
- starting;
- normal and emergency stopping;
- reversing;
- governor testing;
- safety devices, and associated indicators and alarms.

(d) The redundancy arrangements for Category B craft.
(e) Tooth contact markings in geared installations using a recognised technique. The marking is to be as detailed in 5.5.
(f) For controllable pitch propellers, the pitch setting under failure conditions.

11.3 Performance testing

11.3.1 It is to be verified that the propeller performs satisfactorily under ahead and astern conditions. Where controllable pitch propellers are fitted, the free route astern trial is to be carried out with the propeller blades set in the full pitch astern condition.

11.3.2 It is to be verified that large movements of resiliently mounted machinery do not occur during start up and stop, or during normal operating conditions.

11.3.3 The installation should be tested to ensure that gas turbines cannot be continuously operated within any speed range where excessive vibration, stalling or surging may be encountered.

11.3.4 Overloading of machinery is not to occur under continuous astern power.

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■ *Section 1* General requirements

1.1 Application

1.1.1 This Chapter is to be read in conjunction with the General Requirements for Machinery in Part 9.

1.1.2 The requirements of Section 4 do not apply to diesel engines intended for essential services where power does not exceed 110 kW.

1.2 Power ratings

1.2.1 In this Chapter where the dimensions of any particular component are determined from shaft power, *P*, in kW, and revolutions per minute, *R*, the values to be used are those defined in Part 9.

1.3 Power conditions for generator sets

1.3.1 Auxiliary engines coupled to electrical generators are to be capable under service conditions of developing continuously the power to drive the generators at full rated output (kW) and of developing for a short period (15 minutes) an overload power of not less than 10 per cent, *see* Pt 16, Ch 2.

1.4 Inclination of craft

1.4.1 Main and essential auxiliary diesel engines are to operate satisfactorily under the conditions as shown in Table 1.4.1 in Pt 9, Ch 1.

1.5 Engine type testing

1.5.1 Engines are to be subjected to type testing in accordance with Pt 9, Ch 2,2.4.

■ *Section 2* Particulars to be submitted

2.1 Plans and information

2.1.1 At least three copies of the following plans are to be submitted for consideration:

- Crankshaft assembly plan (for each crank-throw).
- Crankshaft details plan (for each crank-throw).
- Thrust shaft or intermediate shaft (if integral with engine).
- Output shaft coupling bolts.
- Main engine securing arrangements where non-metallic chocks are used.
- Type and arrangement of crankcase explosion relief valves.
- Arrangement and welding specifications with details of the procedures for fabricated bedplate, thrust bearing bedplate, crankcases, frames and entablatures. Details of materials, welding consumables, fit-up conditions, fabrication sequence and heat treatments are to be included.
- Details of the securing and collision arrangements, *see also* Part 9.
- Schematic oil fuel system, including controls and safety devices.
- Lubricating oil system.
- Starting air system.
- Cooling water system.
- Control engineering aspects in accordance with Part 16.
- Shielding of high pressure fuel pipes.
- Crankshaft design data as outlined in Section 4.
- Combustion pressure-displacement relationship.
- High pressure parts for fuel oil injection system with specification of pressures, pipe dimensions and materials.
- For new engine types that have not been approved by LR, the proposed type test programme.
- The type test report on completion of type testing for a new engine type. For mass produced engines a separate report is to be submitted for each engine requiring approval, *see* 10.5.

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- Additionally, for mass produced engines:

(a) For consideration of an engine type to be approved:
  (i) Engine specification, *see* 11.1.4.
  (ii) Manufacturing processes and quality control information, *see* 11.2.3.
  (iii) List of sub-contractors for main parts.
  (iv) Procedures for configuring during commissioning.

(b) For engines of an approved type to be installed on a craft, a compliance and inspection certificate, *see* 11.4.

- For engine control, alarm monitoring and safety systems, the plans and information required by Pt 16, Ch 1,1.2.
- For electronically controlled engines, the plans and information required by 13.2.
- Schematic layouts showing details and arrangements of oil mist detection/monitoring and alarm systems.

2.1.2 The following information and calculations are to be submitted for information:

- Power/speed operational envelope.
- Calculations and information for short term high power operation where applicable.
- Longitudinal and transverse cross-section.
- Cast bedplate, thrust bearing bedplate, crankcase and frames.
- Cylinder head assembly.
- Cylinder liner.
- Piston assembly.
- Tie rod.
- Connecting rod, piston rod, and crosshead assemblies.
- Camshaft drive and camshaft general arrangement.
- Shielding and insulation of exhaust pipes.
- Operation and maintenance manuals.
- Vibration dampers/detuners and moment compensators.
- Details of turbochargers.
- Cross-sectional plans of the assembled turbo-charger with main dimensions.
- Fully dimensioned plans of the rotor.
- Material particulars with details of welding and surface treatments.
- Turbo-charger operating and test data.
- Manufacturer's burst test assessment.
- Material specifications covering the listed components together with details of any surface treatments, non-destructive testing and hydraulic tests.
- Arrangement of interior lighting, where provided.
- Engine Type test programme, where required including proposals for short term high power operation.
- Alternative proposals for hydraulic tests where design features are such that modifications to the test requirements are necessary.
- Thrust bearing assembly (if integral with engine and not integrated in the bedplate).
- Counterweights, where attached to crank-throw, including fastening.
- Main engine holding down arrangement (metal chocks).

2.1.3 Where it is proposed to use alloy castings, micro alloyed or alloy steel forgings or iron castings, details of the chemical composition, heat treatment and mechanical properties are to be submitted.

2.1.4 A Failure Mode and Effects Analysis (FMEA) as required by Part 9 is to be submitted. The FMEA is to include the following associated sub-systems:

- Starting and stopping.
- Oil fuel.
- Lubricating oil.
- Cooling water (fresh and sea).
- Air induction.
- Exhaust.
- Engine mounting.
- Control and monitoring.
- Electrical power supplies.
- Hydraulic oil (for valve lift).

2.1.5 Plans and details for dead craft condition starting arrangements are to be submitted for appraisal, *see* 7.1.

2.1.6 For engine types built under licence it is intended that the above documentation be submitted by the Licensor. Each Licensee is then to submit the following:

- A list, based on the above, of all documents required with the relevant drawing numbers and revision status from both Licensor and Licensee.
- The associated documents where the Licensee proposes design modifications to components. In such cases a statement is to be made confirming the Licensor's acceptance of the proposed changes.

In all cases a complete set of endorsed documents will be required by the Surveyor attending the Licensee's works.

2.1.7 Where considered necessary additional documentation may be required.

■ *Section 3* Materials

3.1 Materials test and inspections

3.1.1 Components for engines are to be tested as indicated in Table 1.3.1 and in accordance with the relevant requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

3.2 Crankshaft materials

3.2.1 The specified minimum tensile strength of castings and forgings for crankshafts is to be selected within the following general limits:

(a) Carbon-manganese steel castings – 400 to 550 N/mm^2.

(b) Carbon-manganese steel forgings (normalised and tempered) – 400 to 600 N/mm^2.

(c) Carbon-manganese steel forgings (quenched and tempered) – not exceeding 700 N/mm^2.

(d) Alloy steel castings – not exceeding 700 N/mm^2.

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Table 1.3.1 Material testing requirements

Component	Material tests	Non-destructive tests	
		Magnetic particle or Liquid penetrant	Ultrasonic
Crankshaft	all	all	all
Crankshaft coupling flange (non-integral) for main propulsion engines	above 400 mm bore	—	—
Crankshaft coupling bolts	above 400 mm bore	—	—
Steel piston crowns	above 400 mm bore	above 400 mm bore	all
Piston rods	above 400 mm bore	above 400 mm bore	above 400 mm bore
Connecting rods, including bearing caps	all	all	above 400 mm bore
Crosshead	above 400 mm bore	—	—
Cylinder liner	above 300 mm bore	—	—
Cylinder cover	above 300 mm bore	above 400 mm bore	all
Steel castings for welded bedplates	all	all	all
Steel forgings for welded bedplates	all	—	—
Plates for welded bedplates, frames and entablatures	all	—	—
Crankcases, welded or cast	all	—	—
Tie rods	all	above 400 mm bore	—
Turbo-charger, shaft and rotor	above 300 mm bore	—	—
Bolts and studs for cylinder covers, crossheads, main bearings, connecting rod bearings	above 300 mm bore	above 400 mm bore	—
Steel gear wheels for camshaft drives	above 400 mm bore	above 400 mm bore	—

NOTES
1. For closed-die forged crankshafts the ultrasonic examination may be confined to the initial production and to subsequent occasional checks.
2. Magnetic particle or liquid penetrant testing of tie rods may be confined to the threaded portions and the adjacent material over a length equal to that of the thread.
3. Cylinder covers and liners manufactured from spheroidal or nodular graphite iron castings may not be suitable for ultrasonic NDE, depending upon the grain size and geometry. An alternative NDE procedure is to be agreed with LR.
4. Bore dimensions refer to engine cylinder bores.
5. All required material tests are to be witnessed by the Surveyor unless alternative arrangements have been specifically agreed by LR.
6. For mass produced engines, *see* Section 10.

(e) Alloy steel forgings – not exceeding 1000 N/mm^2.
(f) Spheroidal or nodular graphite iron castings – 370 to 800 N/mm^2.

■ *Section 4* Crankshaft design

4.1 Application

4.1.1 The formulae given in this Section are applicable to solid or semi-built crankshafts, having a main support bearing adjacent to each crankpin, and are intended to be applied to a single crankthrow analysed by the static determinate method.

4.1.2 Alternative methods, including a fully documented stress analysis, will be considered.

4.1.3 Calculations are to be carried out for the maximum continuous power rating for all designed operating conditions. Calculations are to include short term high power operation where applicable.

4.1.4 Designs of crankshafts not included in this scope will be subject to special consideration.

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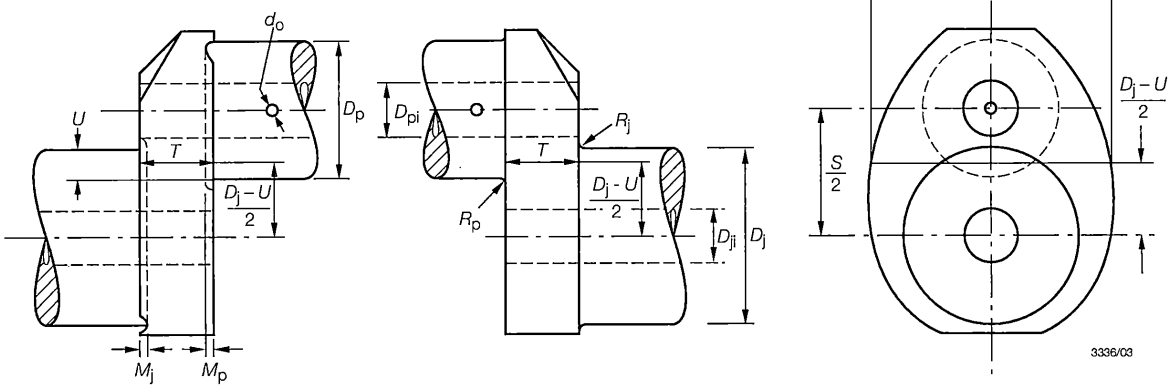
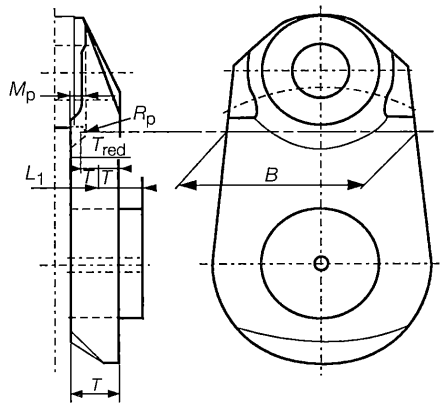


Fig. 1.4.1(a) Crank dimensions necessary for the calculation of stress concentration factors

4.2 Symbols

4.2.1 For the purposes of this Chapter the following symbols apply, *see also* Fig. 1.4.1:

h = radial thickness of web, in mm
k_e = bending stress factor
B = transverse breadth of web, in mm
D_p, D_j = outside diameter of pin or main journal, in mm
D_{pi}, D_{ji} = internal diameter of pin or main journal, in mm
D_s = shrink diameter of main journal in web, in mm
d_o = diameter of radial oil bore in crankpin, in mm
F = alternating force at the web centreline, in N
K_1 = fatigue enhancement factor due to manufacturing process
K_2 = fatigue enhancement factor due to surface treatment
M_b = alternating bending moment at web centreline, in N-mm (NOTE: alternating is taken to be 1/2 range value)
M_{BON} = alternating bending moment calculated at the outlet of crankpin oil bore
M_p, M_j = undercut of fillet radius into web measured from web face, in mm
R_p, R_j = fillet radius at junction of web and pin or journal, in mm
S = stroke, in mm
T = axial thickness of web, in mm
T_a = alternating torsional moment at crankpin or crank journal, in N-mm (NOTE: alternating is taken to be 1/2 range value)
U = pin overlap
α_B = bending stress concentration factor for crankpin
α_T = torsional stress concentration factor for crankpin
β_B = bending stress concentration factor for main journal
β_Q = direct shear stress concentration factor for main journal
β_T = torsional stress concentration factor for main journal
γ_B = bending stress concentration factor for radially drilled oil hole in the crankpin
γ_T = torsional stress concentration factor for radially drilled oil hole in the crankpin
σ_{ax} = alternating axial stress, in N/mm^2
σ_b = alternating bending stress, in N/mm^2
σ_{BON} = alternating bending stress in the outlet of the oil bore, in N/mm^2
σ_p,σ_j = maximum bending stress in pin and main journal taking into account stress raisers, in N/mm^2



Crankshaft without overlap

Fig 1.4.1(b)
Crank dimensions for crankshaft without overlap

σ_u = specified minimum UTS of material, in N/mm^2
σ_y = specified minimum yield stress of material, in N/mm^2
σ_{BO} = maximum bending stress in the outlet of the oil bore, in N/mm^2
σ_Q = alternating direct stress, in N/mm^2
τ_a = alternating torsional stress, in N/mm^2
τ_p, τ_j = maximum torsional stress in pin and main journals taking into account stress raisers, in N/mm^2
τ_{tob} = maximum torsional stress in outlet of crankpin oil bore taking into account stress raisers, in N/mm^2.

4.3 Stress concentration factors

4.3.1 Geometric factors. Crankshaft variables to be used in calculating the geometric stress concentrations together with their limits of applicability are shown in Table 1.4.1.

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Table 1.4.1 Crankshaft variables

Variable	Range	
	Lower	Upper
$b = B/D_p$	1,10	2,20
$d_j = D_{ji}/D_p$	0,00	0,80
$d_p = D_{pi}/D_p$	0,00	0,80
$m_j = M_j/D_p$	0,00	r_{jb}
$m_p = M_p/D_p$	0,00	r_p
$r_{jB} = R_j/D_p$	0,03	0,13
$r_{jT} = R_j/D_j$	0,03	0,13
$r_p = R_p/D_p$	0,03	0,13
$t = T/D_p$	0,20	0,80
$t = T_{red}/D_p$ *see* Note 3	0,20	0,80
$d = d_o/D_p$	0,00	0,20
$u = U/D_p$		0,50

NOTES
1. Where variables fall outside the range, alternative methods are to be used and full details submitted for consideration.
2. A lower limit of u can be extended down to large negative values provided that:
   (i) If calculated f(rec) < 1 then the factor f(rec) is not to be considered (f(rec) = 1)
   (ii) If $u < -0,5$ then f(ut) and f(ru) are to be evaluated replacing the actual value of u by –0,5.
3. For crankshafts without overlap *see also* 4.3.6.

4.3.2 Crankpin stress concentration factors:

Bending

$$\alpha_B = 2,70\, f(ut)\, f(t)\, f(b)\, f(r)\, f(dp)\, f(dj)\, f(rec)$$

where

$$f(ut) = 1,52 - 4,1t + 11,2t^2 - 13,6t^3 + 6,07t^4 - u\,(1,86 - 8,26t + 18,2t^2 - 18,5t^3 + 6,93t^4) - u^2\,(3,84 - 25,0t + 70,6t^2 - 87,0t^3 + 39,2t^4)$$

$$f(t) = 2,18t^{0,717}$$

$$f(b) = 0,684 - 0,0077b + 0,147b^2$$

$$f(r) = 0,208r_p^{(-0,523)}$$

$$f(dp) = 1 + 0,315(d_p) - 1,52(d_p)^2 + 2,41(d_p)^3$$

$$f(dj) = 1 + 0,27d_j - 1,02(d_j)^2 + 0,531(d_j)^3$$

$$f(rec) = 1 + (m_p + m_j)\,(1,8 + 3,2u)$$

valid only between $u = -0,5$ and 0,5

Torsion

$$\alpha_T = 0,8\, f(ru)\, f(b)\, f(t)$$

where

$$f(ru) = r_p^{-(0,22 + 0,1u)}$$

$$f(b) = 7,9 - 10,65b + 5,35b^2 - 0,857b^3$$

$$f(t) = t^{(-0,145)}$$

4.3.3 Crank journal stress concentration factors (not applicable to semi-built crankshafts)

Bending

$$\beta_B = 2,71 f_B(ut)\, f_B(t)\, f_B(b)\, f_B(r)\, f_B(dj)\, f_B(dp)\, f(rec)$$

where

$$f_B(ut) = 1,2 - 0,5t + 0,32t^2 - u\,(0,80 - 1,15t + 0,55t^2) - u^2\,(2,16 - 2,33t + 1,26t^2)$$

$$f_B(t) = 2,24t^{0,755}$$

$$f_B(b) = 0,562 + 0,12b + 0,118b^2$$

$$f_B(r) = 0,191r_{jB}^{(-0,557)}$$

$$f_B(dj) = 1 - 0,644d_j + 1,23(d_j)^2$$

$$f_B(dp) = 1 - 0,19d_p + 0,0073(d_p)^2$$

$$f(rec) = 1 + (m_p + m_j)\,(1,8 + 3,2u)$$

valid only between $u = -0,5$ and 0,5

Direct shear

$$\beta_Q = 3,01 f_Q(u)\, f_Q(t)\, f_Q(b)\, f_Q(r)\, f_Q(dp)\, f(rec)$$

where

$$f_Q(u) = 1,08 + 0,88u - 1,52(u)^2$$

$$f_Q(t) = \frac{t}{0,0637 + 0,937t}$$

$$f_Q(b) = b - 0,5$$

$$f_Q(r) = 0,533r_{jB}^{(-0,204)}$$

$$f_Q(dp) = 1 - 1,19d_p + 1,74(d_p)^2$$

$$f(rec) = 1 + (m_p + m_j)\,(1,8 + 3,2u)$$

valid only between $u = -0,5$ and 0,5

Torsion

$$\beta_T = 0,8 f(ru)\, f(b)\, f(t)$$

where

$$f(ru) = r_{jT}^{-(0,22 + 0,1u)}$$

$$f(b) = 7,9 - 10,65b + 5,35b^2 - 0,857b^3$$

$$f(t) = t^{(-0,145)}$$

4.3.4 Crankpin oil bore stress concentration factors for radially drilled oil holes:

- Bending

$$\gamma_B = 3 - 5,88 \bullet d_o + 34,6 \bullet d_o^2$$

- Torsion

$$\gamma_T = 4 - 6 \bullet d_o + 30 \bullet d_o^2$$

4.3.5 Where experimental measurements of the stress concentrations are available these may be used. The full documented analysis of the experimental measurements is to be submitted for consideration.

4.3.6 In the case of semi-built crankshafts when $M_p > R_p$ the web thickness is to be taken as:

$T_{red} = T - (M_p - R_p)$ and the web width B is to be taken in way of the crankpin fillet radius centre *see* Fig. 1.4.1(b).

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4.4 Nominal stresses

4.4.1 The nominal alternating bending stress, σ_b, is to be calculated from the maximum and minimum bending moment at the web centreline taking into account all forces being applied to the crank throw in one working cycle with the crank throw simply supported at the mid length of the main journals.

4.4.2 Nominal bending stresses are referred to the web bending modulus.

4.4.3 Nominal alternating bending stress:

$$\sigma_b = \pm \frac{M_b}{Z_{web}} k_e \text{ N/mm}^2$$

where

$$Z_{web} = \frac{BT^2}{6} \text{ mm}^3$$

k_e = 0,8 for crosshead engines
= 1,0 for trunk piston engines.

4.4.4 Nominal alternating bending stress in the outlet of the crankpin oil bore:

$$\sigma_{BON} = \pm \frac{M_{BON}}{Z_{crankpin}}$$

where

M_{BON} is taken as the ½ range value

$M_{BON} = \pm \frac{1}{2} (M_{BOmax} - M_{BOmin})$

and

$M_{BO} = (M_{BTO} \cos\psi + M_{BRO} \sin\psi)$, *see* Fig. 1.4.2

The two relevant bending moments are taken in the crankpin cross-section through the oil bore.

M_{BRO} = bending moment of the radial component of the connecting-rod force

M_{BTO} = bending moment of the tangential component of the connecting-rod force

$Z_{crankpin} = \frac{\pi}{32} \frac{D^4 - d^4}{D}$ $Z_{crankpin}$ related to the cross-section of axially bored crankpin.

4.4.5 The nominal direct shear stress in the web for the purpose of assessing the main journal is to be added algebraically to the bending stress, using the alternating forces which have been used in deriving M_b in 4.4.3.

4.4.6 Nominal stress is referred to the web cross-section area or the pin cross-section area as applicable.

4.4.7 Nominal alternating direct shear stress:

$$\sigma_Q = \pm \frac{F}{A_{web}} k_e \text{ N/mm}^2$$

where

$A_{web} = BT \text{ mm}^2$

4.4.8 The nominal alternating torsional stress, τ_a, is to be taken into consideration. The value is to be derived from forced-damped vibration calculations of the complete dynamic system. Alternative methods will be given consideration. The engine designer is to advise the maximum level of alternating vibratory stress that is permitted.

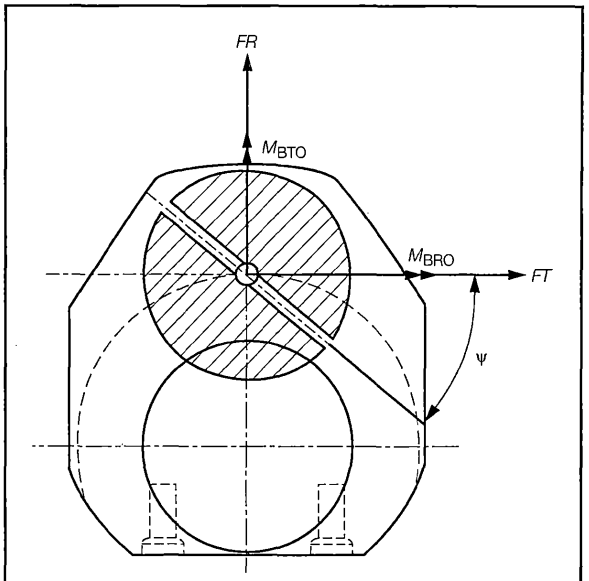

Fig. 1.4.2 Crankpin section through the oil bore

4.4.9 The results of torsional vibration calculations for the full dynamic system, carried out in accordance with Part 13 are to be submitted.

4.4.10 Nominal alternating torsional stress:

$$\tau_a = \pm \frac{T_a}{Z_T} \text{ N/mm}^2$$

where

Z_T = torsional modulus of crankpin and main journal

$$= \frac{\pi}{16} \left[\frac{(D^4 - d^4)}{D} \right] \text{ mm}^3$$

D = outside diameter of crankpin or main journal, in mm

d = inside diameter of crankpin or main journal, in mm

τ_a is to be ascertained from assessment of the torsional vibration calculations where the maximum and minimum torques are determined for every mass point of the complete dynamic system and for the entire speed range by means of a harmonic synthesis of the forced vibrations from the 1st order up to and including the 15th order for 2-stroke cycle engines and from the 0,5th order up to and including the 12th order for 4-stroke cycle engines. Whilst doing so, allowance must be made for the damping that exists in the system and for unfavourable conditions (misfiring [*] in one of the cylinders). The speed step calculation shall be selected in such a way that any resonance found in the operational speed range of the engine shall be detected.

If T_a is not known, a value can be calculated by the following formula as an approximation in the first instance:

$$T_a = \left((18{,}6 - 0{,}0132 D_e) \times \left(\frac{\sigma_u + 160}{560} \right) \right) \times Z_e \text{ N/mm}$$

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where

$$D_e = D_j \sqrt[3]{1 + \left(\frac{D_{ji}}{D_j}\right)^4}$$

or

$$D_p \sqrt[3]{1 - \left(\frac{D_{pi}}{D_p}\right)^4}$$

whichever is the smaller

Z_e = corresponding torsional modulus

$$= \pi \frac{(D_e^4 - d^4)}{16 D_e} \text{ mm}^3.$$

4.4.11 For the purpose of the crankshaft assessment, the nominal alternating torsional stress considered in calculations is to be the highest calculated value, according to the method described in 4.4.10, occurring at the most torsionally loaded mass point of the crankshaft system.

4.4.12 The approval of the crankshaft will be based on the installation having the largest nominal alternating torsional stress (but not exceeding the maximum figure specified by the engine manufacturer). For each installation it is to be ensured by calculation that the maximum approved nominal alternating tersional stress is not exceeded.

4.4.13 Reference should be made to Pt 13, Ch 1 on the calculations of torsional vibration characteristics.

4.4.14 In addition to the bending stress, σ_b, the axial vibratory stress, σ_{ax}, is to be taken into consideration, for crosshead type engines. For trunk piston engines, $\sigma_{ax} = 0$. The value is to be derived from forced-damped vibration calculations of the complete dynamic system. Alternative methods will be given consideration. The engine designer is to advise the maximum level of alternating vibratory stress that is permitted. The corresponding crankshaft free-end deflection is also to be stated.

4.5 Maximum stress levels

4.5.1 Crankpin fillet:

- Maximum alternating bending stress:

$\sigma_p = \alpha_B (\sigma_b + \sigma_{ax})$ N/mm^2

where

α_B = bending stress concentration, *see* 4.3.2.

- Maximum alternating torsional stress:

$\tau_p = \alpha_T \tau_{ax}$ N/mm^2

where

α_T = torsional stress concentration, *see* 4.3.2

τ_a = nominal alternating torsional stress in crankpin N/mm^2.

4.5.2 Outlet of crankpin oil bore

- Maximum alternating bending stress:

$\sigma_{BO} = \gamma_B (\sigma_{BON} + \sigma_{ax})$ N/mm^2

where

γ_B = bending stress concentration factor, *see* 4.3.4

- Maximum alternating torsional stress:

$\tau_{tob} = \gamma_T \tau_a$ N/mm^2

where

γ_T = torsional stress concentration factor, *see* 4.3.4

τ_a = nominal alternating torsional stress in crankpin N/mm^2.

4.5.3 Crank journal fillet (not applicable to semi-built crankshafts):

Maximum alternating bending stress:

$\sigma_j = \beta_B (\sigma_b + \sigma_{ax}) + \beta_Q \sigma_Q$ N/mm^2

where

β_B = bending stress concentration, *see* 4.3.3

β_Q = direct stress concentration, *see* 4.3.3.

Maximum alternating torsional stress:

$\tau_j = \beta_T \tau_a$ N/mm^2

where

β_T = torsional stress concentration, *see* 4.3.3

τ_a = nominal alternating torsional stress in main journal N/mm^2.

4.6 Equivalent alternating stress

4.6.1 Equivalent alternating stress of the crankpin, σ_{ep}, or crank journal σ_{ej}, is defined as:

$$\sigma_{ep},\sigma_{ej} = \sqrt{(\sigma + 10)^2 + 3\tau^2} \text{ N/mm}^2$$

where

$\sigma = \sigma_p$ or σ_j N/mm^2

$\tau = \tau_p$ or τ_j N/mm^2

4.6.2 Equivalent alternating stress for the outlet of the crankpin oil bore σ_{eob}, is defined as:

$$\sigma_{eob} = \pm \frac{1}{3} \sigma_{bo} \left[1 + 2\sqrt{1 + \frac{9}{4}\left(\frac{\tau_{to}}{\sigma_{bo}}\right)^2}\right] \text{ N/mm}^2.$$

4.7 Fatigue strength

4.7.1 The fatigue strength of a crankshaft is based upon the crankpin and crank journal as follows:

$$\sigma_{fp} = K_1 K_2 (0{,}42\sigma_u + 39{,}3)\left(0{,}264 + 1{,}073 D_p^{-0,2} + \frac{785 - \sigma_u}{4900} + \frac{196}{\sigma_u}\sqrt{\frac{1}{R_p}}\right) \text{ N/mm}^2$$

To calculate the fatigue strength in the oil bore area, replace R_p with $\frac{1}{2}d_o$ and σ_{fp} with σ_{fob}.

$$\sigma_{fj} = K_1 K_2 (0{,}42\sigma_u + 39{,}3)\left(0{,}264 + 1{,}073 D_j^{-0,2} + \frac{785 - \sigma_u}{4900} + \frac{196}{\sigma_u}\sqrt{\frac{1}{R_j}}\right) \text{ N/mm}^2$$

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where

σ_u = UTS of crankpin or crank journal as appropriate, in N/mm^2

K_1 = fatigue endurance factor appropriate to the manufacturing process
= 1,05 for continuous grain-flow (CGF) or die-forged
= 1,0 for freedom forged (without CGF)
= 0,93 for cast steel manufactured using a LR approved cold rolling process

K_2 = fatigue enhancement factor for surface treatment. These treatments are to be applied to the fillet radii.

4.7.2 A value for K_2 will be assigned upon application by the engine designers. Full details of the process, together with the results of full scale fatigue tests will be required to be submitted for consideration. Alternatively, the following values may be taken (surface hardened zone to include fillet radii):

K_2 = 1,15 for induction hardened
= 1,25 for nitrided

Where a value of K_1 or K_2 greater than unity is to be applied then details of the manufacturing process are to be submitted.

4.8 Acceptability criteria

4.8.1 The acceptability factor, Q, is to be greater than 1,15:

$$Q = \frac{\sigma_f}{\sigma_e}$$ for crankpin, journal and the outlet of crankpin oil bore

where

$\sigma_f = \sigma_{fp}$, σ_{fj} or σ_{fob}

$\sigma_e = \sigma_{ep}$, σ_{ej} or σ_{eob}.

4.9 Crankshaft oil hole

4.9.1 The junction of the oil hole with the crankpin or main journal surface is to be formed with an adequate radius and smooth surface finish down to a minimum depth equal to 1,5 times the oil bore diameter.

4.9.2 Fatigue strength calculations or, alternatively, fatigue test results may be required to demonstrate acceptability.

4.9.3 When journal diameter is equal or larger than the crankpin diameter, the outlets of main journal oil bores are to be formed in a similar way to the crankpin oil bores, otherwise separate fatigue strength calculations or, alternatively, fatigue test results may be required.

4.10 Shrink fit of semi-built crankshafts

4.10.1 The maximum permissible internal diameter in the journal pin is to be calculated in accordance with the following formula:

$$D_{ji} = D_s \sqrt{1 - \frac{4000 FoS\, M_{max}}{\mu \pi D_s^2 L_s \sigma_{yj}}}$$

where the symbols are as defined in 4.10.7.

4.10.2 When 4.10.1 cannot be complied with, then 4.10.7 is not applicable. In such cases δ_{min} and δ_{max} are to be established from FEM calculations.

4.10.3 The following formulae are applicable to crankshafts assembled by shrinking main journals into the crankwebs.

4.10.4 In general, the radius of transition, R_j, between the main journal diameter, D_j, and the shrink diameter, D_s, is to be not less than $0{,}015D_j$ or $0{,}5(D_s - D_j)$.

4.10.5 The distance, y, between the underside of the pin and the shrink diameter should be greater than $0{,}05D_s$.

4.10.6 Deviations from these parameters will be specially considered.

4.10.7 The proposed diametral interference is to be within the following limits, *see also* Fig. 1.4.3:

The minimum required diametral interference is to be taken as the greater of:

$$\delta_{min} = \frac{12{,}156 \times 10^6 (FoS)}{T\, Ds\, \mu\, E} \frac{P}{R} (1 + C) \frac{k^2 - l^2}{(k^2 - 1)(1 - l^2)} \text{ mm}$$

or

$$\delta_{min} = \frac{\sigma_y D_s}{E} \text{ mm}$$

where

h = minimum radial thickness of the web around the diameter D_s, mm

$k = \frac{D_o}{D_s}$

$l = \frac{D_{ji}}{D_s}$

C = ratio of torsional vibratory torque to the mean transmitted torque at the P/R rating being considered

$D_o = D_s + 2h$, mm

D_s = shrink diameter, mm

E = Young's modulus of elasticity of crankshaft material, N/mm^2

FoS = Factor of Safety against rotational slippage to be taken as 2,0. A value less than 2,0 may be used where documented by experiments to demonstrate acceptability

P = output power, in kW

R = speed at associated power, in rpm

T = crankweb thickness, in mm

μ = coefficient of static friction to be taken as 0,2 for degreased surfaces. A value greater than 0,2 may be used where documented by experiments to demonstrate acceptability

σ_{yj} = minimum yield strength of material for journal pin

M_{max} = absolute maximum value of the torque taking Ch 8,2 into consideration

L_s = length of shrink fit, in mm

Maximum diametral interference, δ_{max}, is not to be greater than:

$$\delta_{max} = \frac{\sigma_y D_s}{E} + \frac{0{,}8D_s}{1000} \text{ mm}$$

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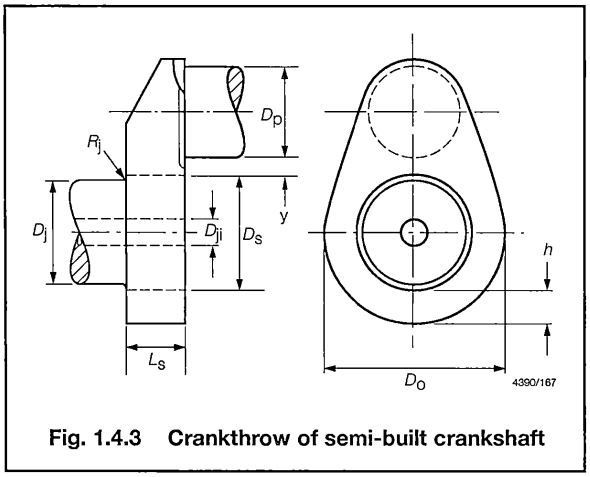

Fig. 1.4.3 Crankthrow of semi-built crankshaft

4.10.8 Reference marks are to be provided on the outer junction of the crankwebs with the journals.

■ *Section 5* Construction and welded structures

5.1 Crankcases

5.1.1 Crankcases and their doors are to be of robust construction to withstand anticipated crankcase pressures that may arise during a crankcase explosion, taking into account the installation of explosion relief valves required by Section 6, and the doors are to be securely fastened so that they will not be readily displaced by a crankcase explosion.

5.2 Welded joints

5.2.1 Bedplates and major components of engine structures are to be made with a minimum number of welded joints.

5.2.2 Double welded butt joints are to be adopted wherever possible in view of their superior fatigue strength.

5.2.3 Girder and frame assemblies should, so far as possible, be made from one plate or slab, shaped as necessary, rather than by welding together a number of small pieces.

5.2.4 Steel castings are to be used for parts which would otherwise require complicated weldments.

5.2.5 Care is to be taken to avoid stress concentrations such as sharp corners and abrupt changes in section.

5.2.6 Joints in parts of the engine structure which are stressed by the main gas or inertia loads are to be designed as continuous full strength welds and for complete fusion of the joint. They are to be so arranged that, in general, welds do not intersect, and that welding can be effected without difficulty and adequate inspection can be carried out. Abrupt changes in plate section are to be avoided and where plates of substantially unequal thickness are to be butt welded, the thickness of the heavier plate is to be gradually tapered to that of the thinner plate. Tee joints are to be made with full bevel or equivalent weld preparation to ensure full penetration.

5.2.7 In single plate transverse girders the castings for main bearing housings are to be formed with web extensions which can be butt welded to the flange and vertical web plates of the girder. Stiffeners in the transverse girder are to be attached to the flanges by full penetration welds.

5.3 Materials and construction

5.3.1 All welded construction is to be in accordance with the requirements specified in Chapter 13 of the Rules for Materials.

5.3.2 Plates, sections, forgings and castings are to be of welding quality in accordance with the requirements of the Rules for Materials, and with a carbon content generally not exceeding 0,23 per cent. Steels with higher carbon contents may be approved subject to satisfactory results from welding procedure tests.

■ *Section 6* Safety arrangements on engines

6.1 Cylinder relief valves

6.1.1 Scavenge spaces in open connection with cylinders are to be provided with explosion relief valves.

6.2 Crankcase relief valves

6.2.1 Crankcases are to be provided with lightweight spring-loaded valves or other quick-acting and self-closing devices to relieve the crankcases of pressure in the event of an internal explosion and to prevent any inrush of air thereafter. The valves are to be designed and constructed to open quickly and be fully open at a pressure not greater than 0,2 bar.

6.2.2 The valve lids are to be made of ductile material capable of withstanding the shock of contact with stoppers at the full open position.

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6.2.3 Each valve is to be fitted with a flame arrester that permits flow for crankcase pressure relief and prevents the passage of flame following a crankcase explosion. The valves are to be type tested in a configuration that represents the installation arrangements that will be used on an engine and in accordance with Section 15. The valves are to be positioned on engines to minimise the possibility of danger and damage arising from emission of the crankcase atmosphere. Where shielding from the emissions is fitted to a valve, the valve is to be type tested to demonstrate that the shielding does not adversely affect the operational effectiveness of the valve.

6.2.4 In engines having cylinders not exceeding 200 mm bore or having a crankcase gross volume not exceeding 0,6 m^3, relief valves may be omitted.

6.2.5 In engines having cylinders exceeding 200 mm but not exceeding 250 mm bore, at least two relief valves are to be fitted; each valve is to be located at or near the ends of the crankcase. Where the engine has more than eight crank throws an additional valve is to be fitted near the centre of the engine.

6.2.6 In engines having cylinders exceeding 250 mm but not exceeding 300 mm bore, at least one relief valve is to be fitted in way of each alternate crank throw with a minimum of two valves. For engines having 3, 5, 7, 9, etc., crank throws, the number of relief valves is not to be less than 2, 3, 4, 5, etc., respectively.

6.2.7 In engines having cylinders exceeding 300 mm bore at least one valve is to be fitted in way of each main crank throw.

6.2.8 Additional relief valves are to be fitted for separate spaces on the crankcase, such as gear or chaincases for camshaft or similar drives, when the gross volume of such spaces exceeds 0,6 m^3.

6.2.9 The combined free area of the crankcase relief valves fitted on an engine is to be not less than 115 cm^2/m^3 based on the volume of the crankcase.

6.2.10 The free area of each relief valve is to be not less than 45 cm^2.

6.2.11 The free area of the relief valve is the minimum flow area at any section through the valve when the valve is fully open.

6.2.12 In determining the volume of the crankcase for the purpose of calculating the combined free area of the crankcase relief valves, the volume of the stationary parts within the crankcase may be deducted from the total internal volume of the crankcase. No deduction shall be made for the volumes of the rotating and reciprocating components.

6.2.13 The valves are to be provided with a copy of the manufacturer's installation and maintenance manual for the size and type of valve being supplied for installation on a particular engine. The manual is to contain the following information:

- Description of valve with details of function and design limits.
- Copy of type test certification.
- Installation instructions.
- Maintenance and in-service instructions to include testing and renewal of any sealing arrangements.
- Actions required after a crankcase explosion.

6.2.14 A copy of the installation and maintenance manual required by 6.2.13 is to be provided on board the ship.

6.2.15 Plans showing details and arrangements of the relief valves are to be submitted for approval, *see* 2.1.

6.2.16 The valves are to be provided with suitable markings that include the following information:

- Name and address of manufacturer.
- Designation and size.
- Month/Year of manufacture.
- Approved installation orientation.

6.3 Vent pipes

6.3.1 Through ventilation, and any arrangement which could produce a flow of external air within the crankcase, is in principle not permitted except for trunk piston type dual fuel engines where crankcase ventilation is to be provided. Where crankcase vent or breather pipes are fitted, they are to be made as small as practicable and/or as long as possible to minimise the inrush of air after an explosion. Vent or breather pipes from crankcases of main engines are to be led to a safe position on deck or other approved position.

6.3.2 If provision is made for the extraction of gases from within the crankcase, e.g. for oil mist detection purposes, the vacuum within the crankcase is not to exceed 25 mm of water.

6.3.3 Lubricating oil drain pipes from engine sump to drain tank are to be submerged at their outlet ends. Where two or more engines are installed, vent pipes, if fitted, and lubrication oil drain pipes are to be independent to avoid intercommunication between crankcases.

6.4 Warning notice

6.4.1 A warning notice is to be fitted in a prominent position, preferably on a crankcase door on each side of the engine, or alternatively at the engine room control station. This warning notice is to specify that whenever overheating is suspected in the crankcase, the crankcase doors or sight holes are not to be opened until a reasonable time has elapsed after stopping the engine, sufficient to permit adequate cooling within the crankcase.

6.5 Crankcase access and lighting

6.5.1 Where access to crankcase spaces is necessary for inspection purposes, suitably positioned rungs or equivalent arrangements are to be provided as considered appropriate.

6.5.2 Interior lighting, where fitted, is to be flameproof.

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6.6 Oil mist detection

6.6.1 Where crankcase oil mist detection arrangements are fitted, they are to be of a type approved by LR, tested in accordance with Section 16 and comply with 6.6.2 to 6.6.15.

6.6.2 The oil mist detection system and arrangements are to be installed in accordance with the engine designer's and oil mist detection equipment manufacturer's instructions/ recommendations. The following particulars are to be included in the instructions:

(a) A schematic layout of the engine oil mist detection and alarm system showing locations of engine crankcase sample points and cabling/piping arrangements together with pipe dimensions to the detector.
(b) Evidence of study to justify the selected locations of sample points and sample extraction rate (if applicable) in consideration of the crankcase arrangements and geometry, and the predicted crankcase atmosphere where oil mist can accumulate.
(c) The manufacturer's maintenance and test manual.
(d) Information relating to type or in-service testing of the engine with engine protection system test arrangements having approved types of oil mist detection equipment.

6.6.3 A copy of the oil mist detection equipment maintenance and test manual required by 6.6.2 is to be provided on board the craft.

6.6.4 Oil mist detection and alarm information is to be capable of being read from a safe location away from the engine.

6.6.5 In the case of multi engine installations, each engine is to be provided with individual, dedicated oil mist detection arrangements and alarm(s).

6.6.6 Oil mist detection and alarm systems are to be capable of being tested on the test bed and on board when the engine is at a standstill and when the engine is running at normal operating conditions in accordance with test procedures that are acceptable to LR.

6.6.7 Alarms and safeguards for the oil mist detection system are to be in accordance with Pt 16, Ch 1 as applicable.

6.6.8 The oil mist detection arrangements are to provide an alarm indication in the event of a foreseeable functional failure in the equipment and installation arrangements.

6.6.9 The oil mist detection system is to provide an indication that any lenses fitted in the equipment and used in determination of the oil mist level have been partially obscured to a degree that will affect the reliability of the information and alarm indication.

6.6.10 Where oil mist detection equipment includes the use of programmable electronic systems, the arrangements are to be in accordance with Pt 16, Ch 1, as applicable.

6.6.11 Schematic layouts showing details and arrangements of oil mist detection and alarm systems are to be submitted. *See* 2.1.

6.6.12 The equipment together with detectors is to be tested when installed on the test bed and on board the craft to demonstrate that the detection and alarm system functions correctly. The testing arrangements are to be to the satisfaction of the Surveyor.

6.6.13 Where sequential oil mist detection arrangements are provided, the sampling frequency and time is to be as short as reasonably practicable.

6.6.14 Where alternative methods are provided for the prevention of the build-up of oil mist that may lead to a potentially explosive condition within the crankcase, detailed information is to be submitted for consideration. The information is to include:

(a) Engine particulars – type, power, speed, stroke, bore and crankcase volume.
(b) Details of arrangements designed to prevent the build up of potentially explosive conditions within the crankcase, e.g., bearing temperature monitoring, oil splash temperature monitoring, crankcase pressure monitoring, and recirculation arrangements.
(c) Evidence to demonstrate that the arrangements are effective in preventing the build up of potentially explosive conditions together with details of in-service experience.
(d) Operating instructions and the maintenance and test instructions.

6.6.15 Where it is proposed to use the introduction of inert gas into the crankcase to minimise a potential crankcase explosion, details of the arrangements are to be submitted for consideration.

■ *Section 7* Starting arrangements

7.1 Dead craft condition starting arrangements

7.1.1 Means are to be provided to ensure that machinery can be brought into operation from the dead craft condition without external aid.

7.1.2 Dead craft condition for the purpose of 7.1.1 is to be understood to mean a condition under which the main propulsion plant and auxiliaries are not in operation. In restoring propulsion, no stored energy for starting and operating the propulsion plant is assumed to be available. Additionally, neither the main source of electrical power nor other essential auxiliaries is assumed to be available for starting and operating the propulsion plant.

7.1.3 Where the emergency source of power is an emergency generator which fully complies with the requirements of Pt 16, Ch 2, this generator may be used for restoring operation of the main propulsion plant, boilers and auxiliaries where any power supplies necessary for engine operation are also protected to a similar level as the starting arrangements.

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7.1.4 Where there is no emergency generator installed or an emergency generator does not comply with Pt 16, Ch 2, the arrangements for bringing main and auxiliary machinery into operation are to be such that the initial charge of starting air or initial electrical power and any power supplies for engine operation can be developed on board the craft without external aid. If, for this purpose, an emergency air compressor or an electric generator is required, these units are to be powered by a hand-starting oil engine or a hand-operated compressor. The arrangements for bringing main and auxiliary machinery into operation are to have capacity such that the starting energy and any power supplies for engine operation are available within 30 minutes of a dead craft condition.

7.2 Starting arrangements – Air compressors

7.2.1 Two or more air compressors are to be fitted having a total capacity, together with a topping-up compressor where fitted, capable of charging the air receivers within one hour from atmospheric pressure, to the pressure sufficient for the number of starts required by 7.3. At least one of the air compressors is to be independent of the main propulsion unit and the capacity of the main air compressors is to be approximately equally divided between them. The capacity of an emergency compressor which may be installed to satisfy the requirements of 7.1 is to be ignored.

7.2.2 The compressors are to be so designed that the temperature of the air discharged to the starting air receivers will not substantially exceed 93°C in service. A small fusible plug or an alarm device operating at 121°C is to be provided on each compressor to give warning of excessive air temperature. The emergency air compressor is excepted from these requirements.

7.2.3 Each compressor is to be fitted with a safety valve so proportioned and adjusted that the accumulation with the outlet valve closed will not exceed 10 per cent of the maximum working pressure. The casings of the cooling water spaces are to be fitted with a safety valve or bursting disc so that ample relief will be provided in the event of the bursting of an air cooler tube.

7.2.4 Each compressor is to be fitted with an alarm for failure of the lubricating oil supply which will initiate an automatic shutdown.

7.3 Air receivers

7.3.1 Where the main engine is arranged for air starting the total air receiver capacity is to be sufficient to provide without replenishment, not less than 12 consecutive starts of the main engine, alternating between ahead and astern if of the reversible type and not less than six consecutive starts if of the non-reversible type. At least two air receivers of approximately equal capacity are to be provided. For scantlings and fittings of air receivers, *see* Pt 15, Ch 4.

7.3.2 For multi-engine installations, where more than one engine is driving each propulsion shaft line, the following requirements apply:

(a) Twin engine installations driving fixed pitch propeller, where one of the engines can be reversed, six consecutive starts per engine are required.

(b) For all other types of multi-engine installations three consecutive starts per engine are required.

7.3.3 Each air receiver is to be fitted with a drain arrangement at its lowest part, permitting oil and water to be blown out.

7.3.4 Each receiver which can be isolated from a relief valve is to be provided with a suitable fusible plug to discharge the contents in case of fire. The melting point of the fusible plug is to be approximately 150°C, *see also* Pt 15, Ch 4,9.2.

7.3.5 Receivers used for the storage of air for the control of remotely operated valves are to be fitted with relief valves and not fusible plugs.

7.4 Starting air pipe systems and safety fittings

7.4.1 Air start piping systems are in general to comply with the requirements of Part 15, due regard being paid to the particular type of installation.

7.4.2 In designing the compressed air installation, care is to be taken that the compressor air inlets will be located in an atmosphere reasonably free from oil vapour or, alternatively, an air duct from outside the machinery space is to be led to the compressors.

7.4.3 The air discharge pipe from the compressors is to be led direct to the starting air receivers. Provision is to be made for intercepting and draining oil and water in the air discharge for which purpose a separator or filter is to be fitted in the discharge pipe between compressors and receivers.

7.4.4 The starting air pipe system from receivers to main and auxiliary engines is to be entirely separate from the compressor discharge pipe system. Stop valves on the receivers are to permit slow opening to avoid sudden pressure rises in the piping system. Valve chests and fittings in the piping system are to be of ductile material.

7.4.5 Drain valves for removing accumulations of oil and water are to be fitted on compressors, separators, filters and receivers. In the case of any low-level pipelines, drain valves are to be fitted to suitably located drain pots or separators.

7.4.6 The starting air piping system is to be protected against the effects of explosions by providing an isolating non-return valve or equivalent at the starting air supply to each engine.

7.4.7 In direct reversing engines bursting discs or flame arresters are to be fitted at the starting valves on each cylinder; in non-reversing and auxiliary engines at least one such device is to be fitted at the supply inlet to the starting air manifold on each engine. The fitting of bursting discs or flame arresters may be waived in engines where the cylinder bore does not exceed 230 mm.

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7.4.8 Alternative safety arrangements may be submitted for consideration.

7.5 Electrical starting arrangements

7.5.1 Where main engines are fitted with electric starters, two batteries are to be fitted. Each battery is to be capable of starting the engines when cold and the combined capacity is to be sufficient without recharging to provide the number of starts of the main engines as required by 7.3.

7.5.2 Electric starting arrangements for auxiliary engines are to have two separate batteries or be supplied by separate circuits from the main engine batteries when such are provided. Where one of the auxiliary engines only is fitted with an electric starter one battery will be acceptable.

7.5.3 The combined capacity of the batteries for starting the auxiliary engines is to be sufficient for at least three starts for each engine.

7.5.4 Engine starting batteries are to be used only for the purposes of starting the engines and for the engines' own control, alarm, monitoring and safety arrangements. Means are to be provided to ensure that the stored energy in the batteries is maintained at a level required to start the engines as defined in 7.5.1 and 7.5.3.

7.5.5 Where engines are fitted with electric starting batteries, an alarm is to be provided for low battery level.

7.5.6 The requirements for battery installations are given in Pt 16, Ch 2.

7.6 Starting of the emergency source of power

7.6.1 Emergency generators are to be capable of being readily started in their cold conditions down to a temperature of 10°C. If this is impracticable, or if lower temperatures are likely to be encountered, consideration is to be given to the provision and maintenance of heating arrangements, so that ready starting will be assured.

7.6.2 Each emergency generator that is arranged to be automatically started is to be equipped with an approved starting system having two independent sources of stored energy, each of which is sufficient for at least three consecutive starts. When hand (manual) starting is demonstrated to be effective, only one source of stored energy need be provided. However, this source of stored energy is to be protected against depletion below the level required for starting.

7.6.3 Provision is to be made to maintain continuously the stored energy at all times, and for this purpose:

(a) Electrical and hydraulic starting systems are to be maintained from the emergency switchboard.

(b) Compressed air starting systems may be maintained by the main or auxiliary compressed air receivers, through a suitable non-return valve, or by an emergency air compressor energised by the emergency switchboard.

(c) All these starting, charging and energy storing devices are to be located in the emergency generator room. These devices are not to be used for any purpose other than the operation of the emergency generator.

7.6.4 When automatic starting is not required by the Rules and where it can be demonstrated as being effective, hand (manual) starting is permissible, such as manual cranking, inertial starters, manual hydraulic accumulators, powder charge cartridges.

7.6.5 When hand (manual) starting is not practicable, the provisions of 7.6.2 and 7.6.3 are to be complied with except that starting may be manually initiated.

7.6.6 Electric starting arrangements are to also satisfy 7.5.2 to 7.5.5.

7.7 Engine control, alarm monitoring and safety system power supplies

7.7.1 Power supplies are to be arranged so that power for electrically powered control, alarm monitoring and safety systems required for engine starting and operation will remain available in the event of a failure. Power is to remain available to permit starting attempts for the number of starts specified by this Section for each source of stored energy.

7.7.2 Where adequate battery and charging capacity exists, an engine starting battery may be used as one source of electrical power required by 8.6.1.

7.7.3 An alarm is to be activated in the event of failure of a power supply and, where applicable, low battery charge level. Manual power supply changeover facilities are permitted.

■ *Section 8* Piping systems

8.1 General

8.1.1 Diesel engine piping systems are, in general, to comply with the requirements of Pt 15, Ch 1 and Ch 3, due regard being paid to the particular type of installation.

8.1.2 Short lengths of synthetic rubber hoses that comply with the requirements of Pt 15, Ch 1,13 may be used in diesel engine piping systems to accommodate relative movement between machinery and fixed piping systems.

8.2 Oil fuel systems

8.2.1 Oil fuel arrangements are to comply with the requirements of Pt 15, Ch 3,3 and 3,4, as applicable.

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8.2.2 All external high pressure fuel delivery lines between the high pressure fuel pumps and fuel injectors are to be protected with a jacketed piping system capable of containing fuel from a high pressure line failure. If flexible hoses are used for shielding purposes, these arrangements are to be approved.

8.2.3 The protection is to prevent oil fuel or oil fuel mist from reaching a source of ignition on the engine or its surroundings. Suitable drainage arrangements are to be made for draining any oil fuel leakage and for preventing contamination of the lubricating oil by oil fuel.

8.3 Oil fuel filters and fittings

8.3.1 Two or more filters are to be fitted in the oil fuel supply lines to the main and auxiliary engines, and the arrangements are to be such that any filter can be cleaned without interrupting the supply of filtered oil fuel to the engines.

8.3.2 Drip trays are to be fitted under oil fuel filters and other fittings which are required to be opened up frequently for cleaning or adjustment or where there is the possibility of leakage. Alternative arrangements may be acceptable and full details should be submitted for consideration.

8.4 Lubricating oil systems

8.4.1 Lubricating oil arrangements are to comply with the requirements of Part 15 as applicable.

8.5 Engine cooling water systems

8.5.1 Cooling water arrangements are to comply with the requirements of Part 15, as applicable.

8.6 Inlet and exhaust systems

8.6.1 Engine inlets are to be arranged to provide sufficient air to the engines whilst minimising the ingestion of harmful particles.

8.6.2 Where the exhaust is led overboard near the waterline, means are to be provided to prevent water from being siphoned back to the engine. Where the exhaust is cooled by water spray, the exhaust pipes are to be self-draining overboard. Erosion/corrosion resistant shut-off flaps or other devices are to be fitted on the hull side shell or pipe end and acceptable arrangements made to prevent water flooding the space or entering the engine exhaust manifold.

8.6.3 Where the exhausts of two or more engines are led to a common silencer or exhaust gas-heated boiler or economiser, an isolating device is to be provided in each exhaust pipe.

8.6.4 The arrangement of the exhaust system is to be such as to prevent exhaust gases being drawn into the manned spaces, air conditioning systems and air intakes. They should not discharge into air cushion intakes.

8.7 High pressure oil systems

8.7.1 Where flammable oils are used in high pressure systems, the oil pipe lines between the high pressure oil pump and actuating oil pistons are to be protected with a jacketed piping system capable of preventing oil spray from a high pressure line failure.

■ *Section 9* Control and monitoring

9.1 General

9.1.1 The Control and Monitoring systems are to comply with the requirements of Part 16.

9.1.2 While it is recommended that oil mist detection, engine bearing temperature monitors or alternative methods for crankcase protection be fitted, they are in any case to be provided:

(a) When arrangements are fitted to override the automatic stop for excessive reduction of the lubricating oil supply pressure.

(b) For engines of 2,250 kW and above or having cylinders of more than 300 mm bore.

NOTES:

1. For medium and high speed engines automatic shutdown of the engine is to occur, *see also* 9.7.2.
2. Where arrangements are made to override the automatic shutdown due to high oil mist or bearing temperature, the override is to be independent of other overrides.
3. Where engine bearing temperature monitors or alternative methods are provided for the prevention of the build-up of oil mist that may lead to a potentially explosive condition within the crankcase, details are to be submitted for consideration. The submission is to demonstrate that the arrangements are equivalent to those provided by oil mist detection, *see* 6.6.14.

9.1.3 All main and auxiliary engines intended for essential services are to be provided with means of indicating the lubricating oil pressure supply to them. Where such engines are of more than 220 kW, audible and visual alarms are to be fitted to give warning of an appreciable reduction in pressure of the lubricating oil supply. Further, these alarms are to be actuated from the outlet side of any restrictions, such as filters, coolers, etc.

9.2 Main engine governors

9.2.1 An efficient governor is to be fitted to each main engine so adjusted that the speed does not exceed that for which the engine is to be classed by more than 15 per cent.

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9.3 Auxiliary engine governors

9.3.1 Auxiliary engines intended for driving electric generators are to be fitted with governors which, with fixed setting, are to control the speed within 10 per cent momentary variation and 5 per cent permanent variation under the following conditions:

(a) Full load is suddenly taken off.

(b) Full load is suddenly applied following a minimum of 15 minutes no load. If the BMEP is greater than 8 bar the load may be applied as follows:

$$\frac{800}{BMEP}\ \%\ \left(\text{but not less than } \frac{1}{3} \text{ full load}\right)$$, then full load being attained in not more than two equal stages as rapidly as possible.

9.3.2 Emergency engines are to comply with 9.3.1 except that the initial load required by 9.3.1(b) is to be not less than the total connected emergency statutory load.

9.3.3 For alternating current installations, the permanent speed variation of the machines intended for parallel operation are to be equal within a tolerance of ±0,5 per cent. Momentary speed variations with load changes in accordance with 9.5.1 are to return to and remain within one per cent of the final steady state speed in not more than eight seconds.

9.4 Overspeed protective devices

9.4.1 Each main engine developing 220 kW or over which can be declutched or which drives a controllable (reversible) pitch propeller, also each auxiliary engine developing 220 kW and over for driving an electric generator, is to be fitted with an approved overspeed protective device.

9.4.2 The overspeed protective device, including its driving mechanism, is to be independent of the governor required by 9.4 or 9.5 and is to be so adjusted that the speed does not exceed that for which the engine and its driven machinery are to be classed by more than 20 per cent for main engines and 15 per cent for auxiliary engines.

9.5 Engine stopping

9.5.1 At least two independent means of stopping the engines quickly from the control station under any conditions are to be available.

9.6 Unattended machinery

9.6.1 Where machinery is fitted with automatic or remote controls so that under normal operating conditions it does not require any manual intervention by the operators, it is to be provided with the alarms and safety arrangements required by 9.1 to 9.8 as appropriate. Alternative arrangements which provide equivalent safeguards will be considered.

9.6.2 Where a first stage alarm together with a second stage alarm and automatic shutdown of machinery are required by Tables 1.9.1 and 1.9.2, the sensors and circuits utilised for the second stage alarm and automatic shutdown are to be independent of those required for the first stage alarm.

9.6.3 Means are to be provided to prevent leaks from high pressure oil fuel injection piping for main and auxiliary engines dripping or spraying onto hot surfaces or into machinery air inlets. Such leakage is to be collected and, where practicable, led to a collector tank(s) fitted in a safe position. An alarm is to be provided to indicate that leakage is taking place. These requirements may also be applicable to high pressure hydraulic oil piping depending upon the location.

9.6.4 Where machinery specified in this Section is required to be provided with a standby pump, the standby pump is to start automatically if the discharge pressure from the working pumps falls below a predetermined value.

9.7 Diesel engines for propulsion purposes

9.7.1 Alarms and safeguards are indicated in 9.7.2 to 9.7.8 and Table 1.9.1, *see also* 9.1.2 and 9.6.3.

9.7.2 Alarms are to operate, and indication is to be given at the relevant control stations that the speed or power of the main propulsion engine(s) is to be reduced for the following fault conditions:

(a) Oil mist in crankcase or high bearing temperature (if detection is fitted, *see* 9.1.2).
(b) Low piston coolant pressure or flow.
(c) High piston coolant outlet temperature.
(d) Low cylinder coolant pressure or flow.
(e) High cylinder coolant temperature.
(f) High exhaust gas temperature per cylinder or deviation from average temperature (high).
(g) High thrust bearing temperature.
(h) Low cylinder lubricator flow.

NOTES:

1. For medium and high speed engines automatic slowdown is required for items (d), (e), (f) and (h). However, an automatic shutdown is required for (a).
2. Common sensors are acceptable for alarms and slowdown functions.

9.7.3 Reduction of speed or power may be effected by either manual or automatic control.

9.7.4 The following engine services are to be fitted with automatic temperature controls so as to maintain steady state conditions throughout the normal operating range of the propulsion engine(s):

(a) Lubricating oil supply.
(b) Piston coolant supply, where applicable.
(c) Cylinder coolant supply, where applicable.
(d) Fuel valve coolant supply, where applicable.

9.7.5 Indication of the starting air pressure is to be provided at each control station from which it is possible to start the main propulsion engine(s).

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Table 1.9.1 Oil engines for propulsion purposes alarms and safeguards (*see continuation*)

Item	Alarm	Note
Lubricating oil sump level	Low	Engines (and gearing if fitted)
Lubricating oil inlet pressure*++	1st stage Low++	Engines (and gearing if fitted)
	2nd stage Low	Automatic shutdown engines (and gearing if fitted), *see* 9.6.2
Lubricating oil inlet temperature*	High	Engines (and gearing if fitted)
Lubricating oil filters differential pressure	High	—
Cylinder lubricator flow	Low unit	One sensor per lubricator
Piston coolant inlet pressure	Low	If a separate system
Piston coolant outlet temperature*	High	Per cylinder (if a separate system)
Piston coolant outlet flow*	Low	Per cylinder (if a separate system)
Cylinder coolant inlet pressure or flow*++	Low	—
Cylinder coolant outlet temperature*++	1st stage High++	Per cylinder (if a separate system) or manifold++
	2nd stage High	Automatic shutdown medium and high speed engines, *see* 9.6.2
Sea-water cooling pressure	Low	—
Thrust bearing temperature*	High	—
Common rail servo oil pressure	Low	—
Fuel valve coolant pressure	Low	If a separate system
Fuel valve coolant temperature	High	If a separate system
Oil fuel pressure from booster pump	Low	—
Oil fuel temperature or viscosity*	High and Low	Heavy oil only
Common rail fuel oil pressure	Low	—
Charge air cooler outlet temperature	High and Low	4 stroke medium and high speed engines
Scavenge air temperature	High	Per cylinder, (fire detection, 2 stroke engines)
Exhaust gas temperature*	High	Per cylinder (or deviation from average temperature)

Table 1.9.1 Oil engines for propulsion purposes alarms and safeguards (*conclusion*)

Item	Alarm	Note
Turbo-charger exhaust gas outlet temperature*	High	—
Turbo-charger lubricating oil inlet pressure	Low	If system not integral with turbo-charger
Turbo-charger lubricating oil outlet temperature	High	Each bearing, if system not integral with turbo-charger. *See* Note 4
Starting air pressure*	Low	Before engine manoeuvring valve
Overspeed*	High	Automatic shutdown of engine, *see also* 9.4. Details of alternative proposals in accordance with the manufacturer's instructions may be submitted for consideration
Automatic start of engine	Failure	*See* 9.7.6
Electrical starting battery charge level	Low	—

NOTES
1. Where 'per cylinder' appears in this Table, suitable alarms may be situated on manifold outlets for medium and high speed engines.
2. For engines and gearing of 1500 kW or less, only the items marked* are required.
3. For service craft with engines of 500 kW or less, only the items marked ++ are required.
4. Where the outlet temperature for each bearing cannot be measured due to the design, details of alternative proposals in accordance with the turbocharger manufacturer's instructions may be submitted for consideration.

9.7.6 The number of automatic consecutive attempts which fail to produce a start is to be limited to three attempts. For reversible engines which are started and stopped for manoeuvring purposes, means are to be provided to maintain sufficient starting air in the air receivers. For electric starting, *see* 7.5.

9.7.7 Prolonged running in a restricted speed range is to be prevented automatically or, alternatively, an indication of restricted speed ranges is to be provided at each control station.

9.8 Auxiliary and other engines

9.8.1 Alarms and safeguards are indicated in Table 1.9.2, *see also* 9.1.2 and 9.6.3.

9.8.2 For engines operating on heavy oil fuel, automatic temperature of viscosity controls is to be provided.

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Table 1.9.2 Auxiliary engine alarms and safeguards

Item	Alarm	Note
Lubricating oil inlet temperature	High	—
Lubricating oil inlet pressure	1st stage Low	—
	2nd stage Low	Automatic shutdown of engine, *see* 9.6.2
Coolant outlet temperature	1st stage High	For engines over 220 kW
	2nd stage High	For engines over 220 kW Automatic shutdown of engine, *see* 9.6.2
Coolant pressure or flow	Low	—
Overspeed	High	Automatic shutdown of engine, *see also* 9.4. Details of alternative proposals in accordance with the manufacturer's instructions may be submitted for consideration
Starting air pressure	Low	—
Electrical starting battery charge level	Low	—
Oil fuel inlet temperature or viscosity	High and low	Heavy oil only
Common rail servo oil pressure	Low	—
Common rail fuel oil pressure	Low	—

9.9 Alarms and safeguards for emergency diesel engines

9.9.1 These requirements apply to emergency diesel engines required to be immediately available in an emergency and capable of being controlled remotely or automatically.

9.9.2 Alarms and safeguards are indicated in Table 1.9.3. *See also* 9.1.2 and 9.6.3.

9.9.3 The safety and alarm systems are to be designed to 'fail safe'. The characteristics of the 'fail safe' operation are to be evaluated on the basis not only of the system and its associated machinery, but also the complete installation, as well as the craft.

9.9.4 Regardless of the engine output, if shutdowns additional to those specified in Table 1.9.3 are provided except for the overspeed shutdown, they are to be automatically overridden when the engine is in automatic or remote control mode during navigation.

Table 1.9.3 Alarms and safeguards for emergency diesel engines

Item	Alarm	Alarm	Note
Emergency diesel engine	≥ 220 kW	<220 kW	
Fuel oil leakage from pressure pipes	Leakage	Leakage	*See* 9.6.3
Lubricating oil temperature	High	—	—
Lubricating oil pressure	Low	Low	—
Oil mist concentration in crankcase	High	—	*See* Note
Coolant pressure or flow	Low	—	—
Coolant temperature (can be air)	High	High	—
Overspeed	High	—	Automatic shutdown

NOTE
For engines having a power of more than 2250 kW or a cylinder bore of more than 300 mm.

9.9.5 Grouped alarms of at least those items listed in Table 1.9.3 are to be arranged on the bridge.

9.9.6 In addition to the fuel oil control from outside the space, a local means of engine shutdown is to be provided.

9.9.7 Local indications of at least those items listed in Table 1.9.3 are to be provided within the same space as the diesel engines and are to remain operational in the event of failure of the alarm and safety systems.

■ *Section 10* Requirements for craft which are not required to comply with the HSC Code

10.1 General

10.1.1 The requirements of Sections 1 to 9 apply to craft which are not required to comply with the HSC code, unless specifically exempted by the contents of this Section.

10.1.2 The requirements of 1.4.1 do not apply to yachts or service craft less than 24 m.

10.1.3 The requirements of 1.5.1 do not apply to service craft less than 24 m.

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10.2 Details to be submitted

10.2.1 The requirements of 2.1.1 do not apply to yachts or service craft less than 24 m, *see* Pt 9, Ch 1,6.1.

10.2.2 The requirements of 2.1.4 (FMEA as detailed in Part 9) do not apply to yachts or to service craft less than 24 m unless used for passenger carrying duties.

10.3 Materials

10.3.1 Materials for which no provision is made in this Part of the Rules may be accepted provided that they comply with an approved specification and such tests as may be considered necessary.

10.4 Crankshaft design

10.4.1 The requirements of Section 4 do not apply to the following types of craft having main or auxiliary diesel engines with a power output not exceeding 110 kW:
(a) service craft of less than 24 m,
(b) yachts,
(c) ACVs.

■ *Section 11*
Mass produced engines

11.1 Definition

11.1.1 Mass produced engines, for main and auxiliary purposes, are defined as those which are produced under the following criteria:
(a) In quantity under strict quality control of material and parts, according to a quality assurance scheme acceptable to LR.
(b) By the use of jigs and automatic machine tools designed to machine parts to specified tolerances for interchangeability, and which are verified on a regular inspection basis.
(c) By assembly with parts taken from stock and requiring little or no fitting.
(d) With bench tests carried out on individual assembled engines according to a specified programme.
(e) With appraisal by final examination of engines selected at random after workshop testing.

11.1.2 Castings, forgings and other parts for use in mass produced engines are also to be produced by methods similar to those given in 11.1.1(a), (b) and (c), with appropriate inspection.

11.1.3 Pressure testing of components is to comply with Pt 9, Ch 2,2.2.

11.1.4 The specification of a mass produced engine is to define the limits of manufacture of all component parts. The total production output is to be certified by the manufacturer and verified as may be required, by LR in accordance with the agreed manufacturer's quality assurance scheme, *see* 11.1.1(a).

11.2 Procedure for approval of mass produced engines

11.2.1 The procedure outlined in 11.2.2 to 11.2.5 applies to the inspection and certification of mass produced oil engines having a bore not exceeding 300 mm.

11.2.2 For the approval of a mass produced engine type, the manufacturer is to submit:
(a) The plans and particulars required by 2.1 for assessment;
(b) As necessary, information to assess compliance with Section 4;
(c) A list of subcontractors for main parts; and
(d) Control, alarm monitoring and safety system configuration procedures, *see* 11.4.2.

11.2.3 The manufacturer is to supply full information regarding the manufacturing processes and quality control procedures applied in the workshops. The information is to address the following:
(a) Organisation of quality control systems.
(b) Recording of quality control operations.
(c) Qualification and independence of personnel in charge of quality control.

11.2.4 A running type test of at least 100 hours duration is to be carried out on an engine chosen from the production line. The type testing is to comply with 11.5.

11.2.5 LR reserves the right to limit the duration of validity of approval of a mass produced engine. LR is to be informed, without delay, of any change in the design of the engine, including changes to the software and control, alarm monitoring or safety systems, in the manufacturing or quality, control processes, in the selection of materials or in the list of subcontractors for main parts.

11.3 Continuous review of production

11.3.1 LR Surveyors are to be provided free access to the manufacturer's workshops and to the quality control files.

11.3.2 The control of production, which is subject to survey, is to include the following:
(a) Inspection and testing records are to be maintained to the satisfaction of the Surveyor.
(b) The system for identification of parts is to be in accordance with recognised practice, and acceptable to LR.

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(c) The manufacturer is to provide full information about the quality control of the parts supplied by subcontractors for which certification may be required. LR reserves the right to apply direct and individual inspection procedures for parts supplied by subcontractors when deemed necessary.
(d) At the request of an attending LR surveyor, a workshop test may be required for an individual engine.

11.4 Compliance and inspection certificate

11.4.1 Each engine which is to be installed on a ship classed by LR is to be supplied with a statement certifying that the engine is identical to the one which underwent the tests specified in 11.2.4, and state the test and inspection results. The statement is to be made on a form agreed with LR. Each statement is to include the identification number which appears on the engine. A copy of this statement is to be submitted to LR.

11.4.2 The certificate is to include reference to the manufacturer's procedures to be followed during commissioning for configuring control, alarm monitoring and safety systems for multi-purpose engines or other engine types that require parameters and settings to be adjusted for the intended application.

11.5 Type test conditions

11.5.1 The requirements in this Section are applicable to the type testing of mass produced internal combustion engines where the manufacturer has requested approval. Omission or simplification of the type test requirements will be considered by LR for engines of an established type on application by the manufacturer.

11.5.2 The engine to be tested is to be selected from the production line and agreed by LR.

11.5.3 The type tests are to be conducted with the engine control systems operational in the approved configuration, *see* 2.1.5 and 2.1.6. Configuration management documents are to be reviewed at testing for validity and referenced in the type test report.

11.5.4 The duration and programme of type tests is to include the following:
(a) 80 h at rated output.
(b) 8 h at 110 per cent overload.
(c) 10 h at varying partial loads (25 per cent, 50 per cent, 75 per cent and 90 per cent of rated output).
(d) 2 h at maximum intermittent loads.
(e) Starting tests.
(f) Reverse running of direct reversing engines.
(g) Testing of speed governor.
(h) Testing of over-speed device.
(j) Testing of lubricating oil system failure alarm device.
(k) Testing of the engine with turbocharger out of action when applicable.
(l) Testing of minimum speed for main propulsion engines and the idling speed for auxiliary engines.

11.5.5 The type tests in 11.5.4 at the required outputs are to be combined together in working cycles for the whole duration within the limits indicated. *See also* 11.5.11 and 11.5.12.

11.5.6 The overload testing required by 11.5.4 is to be carried out with the following conditons:
(a) 110 per cent of rated power at 103 per cent revolutions per minute for engines directly driving propellers.
(b) 110 per cent of rated power at 100 per cent revolutions per minute for engines driving electrical generators or for other auxiliary purposes.

11.5.7 For prototype engines, the duration and programme of tests are to be specially agreed between the manufacturer and LR.

11.5.8 As far as practicable during type testing, the following particulars are to be continuously recorded:
(a) Ambient air temperature.
(b) Ambient air pressure.
(c) Atmospheric humidity.
(d) External cooling water temperature.
(e) Fuel and lubrication oil characteristics.

11.5.9 In addition to the particulars stated in 11.5.8 and as far as practicable, the following are also to be continuosly measured and recorded:
(a) Engine revolutions per minute.
(b) Brake power.
(c) Torque.
(d) Maximum combustion pressure.
(e) Indicator pressure diagrams where practicable.
(f) Exhaust smoke (with an approved smoke meter).
(g) Lubricating oil pressure and temperature.
(h) Exhaust gas temperature in exhaust manifold, and, where facilities are available, from each cylinder.
(j) For turbocharged engines:
- Turbocharger revolutions per minute.
- Air temperature and pressures before and after turbo-blower and charge cooler.
- Exhaust gas temperature and pressures before and after the turbine.
- The cooling water inlet temperature to the charge air cooler.

11.5.10 After the type test, the main parts and especially those subject to wear are to be dismantled for examination by LR Surveyors.

11.5.11 For engines that are required to be approved for different purposes (multi-purpose engines), and that have different performance profiles and control, alarm, monitoring and safety systems configurations for each purpose, the programme and duration of test is to be modified to cover the whole range of the engine performance, taking into account the most severe conditions and intended purpose(s).

11.5.12 The rated output for which the engine is to be tested is the output corresponding to that declared by the manufacturer and agreed by LR, i.e. actual maximum power which the engine is capable of delivering continuously between the normal maintenance intervals stated by the manufacturer at the rated speed and under the stated ambient conditions.

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■ *Section 12*
Mass produced turbo-chargers

12.1 Application

12.1.1 The following procedure applies to the inspection of exhaust driven turbo chargers which are manufactured on the basis of mass production methods similar to 11.1 as applicable and for which the maker has requested the approval.

12.2 Procedure for approval of mass produced turbo-chargers

12.2.1 The procedure outlined in 12.2.2 to 12.2.5 applies to the inspection and certification of mass produced turbo-chargers when a simplified method of inspection has been requested by the manufacturers.

12.2.2 For the approval of a mass produced turbo-charger, the manufacturer is to submit, in addition to the plans and particulars required by Chapter 1, as applicable, a list of main current suppliers and subcontractors for rotating parts and an operation and maintenance manual.

12.2.3 The manufacturer will supply full information regarding the material and quality control system used in the organisation as well as the inspection methods, the way of recording and proposed frequency, and the method of material testing of important parts.

12.2.4 A Type test, *see* Pt 9, Ch 2,3.1, is to be carried out on a standard unit taken from the assembly line and is to be witnessed by the Surveyor. The performance data which may have to be verified are to be made available at the time of the type test. For manufacturers who have facilities for testing the turbo-charger unit on an engine for which the turbo-charger is intended, substitution of the hot running test by a test run of one hour's duration at overload (110 per cent of the rated output) may be considered.

12.2.5 LR reserves the right to limit the duration of validity of approval of a mass produced turbo-charger. LR is to be informed, without delay, of any change in the design of the turbo-charger, in the manufacturing or control processes, in the selection of materials or in the list of subcontractors for main parts.

12.3 Continuous inspection of individual units

12.3.1 LR Surveyors are to be provided with free access to the manufacturer's workshop to inspect at random the quality control measures and to witness the tests required by 12.3.3 to 12.3.7 as deemed necessary, and to have free access to all control records and subcontractor's certificates.

12.3.2 Each individual unit is to be tested in accordance with 12.3.4 to 12.3.7 by the maker who is to issue a final certificate.

12.3.3 Rotating parts of the turbo-charger blower are to be marked for easy identification with the appropriate certificate.

12.3.4 Material tests of the rotating parts are to be carried out by the maker or his subcontractor in accordance with the requirements of the Rules for Materials as applicable. The relevant certificate is to be produced and filed to the satisfaction of the Surveyor.

12.3.5 Pressure tests are to be carried out in accordance with Table 2.2.1. Special consideration will be given where design or testing features may require modification of the test requirements.

12.3.6 Dynamic balancing and overspeed tests are to be carried out, *see* Pt 9, Ch 2,3.2 and 3.3, in accordance with the approved procedure for quality control. If each forged wheel is individually controlled by an approved non-destructive examination method, then no overspeed test may be required except for wheels of the test unit.

12.3.7 A mechanical running test, *see* Pt 9, Ch 2,3.4, is to be carried out. The duration of the running test may be reduced to 10 minutes provided that the manufacturer is able to verify the distribution of defects established during the running tests on the basis of a sufficient number of tested turbo-chargers. For manufacturers who have facilities in their works for testing the turbo-chargers on an engine for which the turbo-chargers are intended, the bench test may be replaced by a test run of 20 minutes at overload (110 per cent of the rated output) on this engine.

12.4 Compliance and certificate

12.4.1 For every turbo-charger unit liable to be installed on an engine intended for a ship classed by LR, the manufacturer is to supply a statement certifying that the turbo-charger is identical with one that underwent the tests specified in 12.2.4 and that prescribed tests were carried out. Results of these tests are also to be stated. This statement is to be made on a form agreed with LR and a copy is to be sent to LR. Each statement must have a number which is to appear on the turbo-charger.

■ *Section 13*
Electronically controlled engines

13.1 Scope

13.1.1 The requirements of this Section are applicable to engines for propulsion, auxiliary or emergency power purposes with programmable electronic systems implemented and used to control fuel injection timing and duration, and which may also control combustion air or exhaust systems. The requirements of this Section also apply to programmable electronic systems used to control other functions (e.g. starting and control air, cylinder lubrication, etc.) where essential for the operation of the engine.

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13.1.2 These engines may be of the slow, medium or high-speed type. They generally have no direct camshaft driven fuel systems, but have common rail fuel/hydraulic arrangements and may have hydraulic actuating systems for the functioning of the exhaust systems.

13.1.3 The operation of these engines relies on the effective monitoring of a number of parameters such as crank angle, engine speed, temperatures and pressures using programmable electronic systems to provide the services essential for the operation of the engine such as fuel injection, air inlet, exhaust and speed control.

13.1.4 Details of proposals to deviate from the requirements of this Section are to be submitted and will be considered on the basis of a technical justification produced by the Enginebuilder.

13.1.5 Each engine is to be configured for the specified performance and is to satisfy the relevant requirements for propulsion, auxiliary or emergency engines.

13.1.6 During the life of the engine details of any proposed changes to control, alarm, monitoring or safety systems which may affect safety and the reliable operation of the engine are to be submitted to LR for approval.

13.2 Plans and particulars

13.2.1 In addition to the plans and particulars required by Section 2 the following information is to be submitted:

(a) A general overview of the operating principles, supported by schematics explaining the functionality of individual systems and sub-systems. The information is to relate to the engine capability and functionality under defined operating and emergency conditions such as recovery from a failure or malfunction, with particular reference to the functioning of programmable electronic systems and any sub-systems. The information is also to indicate if the engine has different modes of operation, such as to limit exhaust gas emissions and/or to run under an economic fuel consumption mode or any other mode that is electronically controlled.

(b) Operating manuals which describe the particulars of each system and, together with maintenance instructions, include reference to the functioning of sub-systems.

(c) A risk-based analysis of the mechanical, pressure containing, electrical, electronic and programmable electronic systems and arrangements that support the operation of the engine. The analysis is to demonstrate that suitable risk mitigation has been achieved in accordance with 13.3.

(d) Details of hydraulic systems for actuation of subsystems (fuel injection or exhaust), to include details of the design/construction of pipes, pumps, valves, accumulators and the control of valves/pumps. Details of pump drive arrangements are also to be included.

(e) Quality plan for sourcing, design, installation and testing of all components used in the oil fuel and hydraulic oil systems installed with the engine for engine operation.

(f) Fatigue analysis for all high pressure oil fuel and hydraulic oil piping arrangements required for engine operation where failure of the pipe or its connection or a component would be the cause of engine unavailability. The analysis is to concentrate on high pressure components and sub-systems and recognise the pressures and fluctuating stresses that the pipe system may be subject to in normal service.

(g) Evidence of type testing of the engine with the programmable electronic system, or a proposed test plan at the Enginebuilders with the programmable electronic system functioning, to verify the functionality and behaviour under all operating and fault conditions of the programmable electronic system.

(h) Schedule of testing at Enginebuilders, pre-sea trial commissioning and sea trials. The test schedules are to identify all modes of engine operation and the sea trials are to include typical port manoeuvres under the intended engine operating modes. The schedule is to include:
(i) testing and trials to demonstrate that the engine is capable of operating as described in (a);
(ii) tests to verify that the response of the complete mechanical, hydraulic, electrical and electronic system is as predicted for the intended operational modes; and
(iii) testing required to verify the conclusions of the risk-based analysis.

The scope of these tests is to be agreed with LR.

13.2.2 In addition to the applicable plans and particulars required by Pt 16, Ch 1,1.2.3 to 1.2.6 the following information for control, alarm, monitoring and safety systems relating to the operation of an electronically controlled engine is to be submitted:

(a) Engine configuration details, *see* 13.5.2;
(b) Software quality plans, including configuration management documents;
(c) Software safety evidence; and
(d) Software assessment inspection report.

13.3 Risk-based analysis

13.3.1 An analysis is to be carried out in accordance with relevant standards acceptable to LR to demonstrate compliance with the applicable requirements of this sub-Section appropriate to the engine application. The analysis is to be a risk-based consideration of engine operation and craft and personnel safety, and is to demonstrate adequate risk mitigation through fault tolerance and/or reliability in accordance with the specified criteria in 13.3.2 to 13.3.4 relevant to the engine application.

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13.3.2 For craft with a single main propulsion engine, a Failure Mode and Effects Analysis (FMEA), or alternative recognised analysis of system reliability, is to be carried out and is to demonstrate that an electronic control system failure:

(a) will not result in the loss of the ability to provide the services essential for the operation of the engine, *see* Pt 16, Ch 1,2.5.11 and 2.12.2;

(b) will not affect the normal operation of the services essential for the operation of the engine other than those services dependent upon the failed part, *see* Pt 16, Ch 1,2.13.4 and 2.13.5; and

(c) will not leave either the engine, or any equipment or machinery associated with the engine, or the craft in an unsafe condition, *see* Pt 16, Ch 1,2.3.12, 2.4.6, 2.5.5, 2.10.3, 2.10.4 and 2.13.5.

13.3.3 A risk-based analysis is to be carried out for:

(a) main engines on craft with multiple main engines or other means of providing propulsion power; and/or

(b) auxiliary engines intended to drive electric generators forming the craft's main source of electrical power or otherwise providing power for essential services.

The analysis is to demonstrate that adequate hazard mitigation has been incorporated in electronically controlled engine systems or the overall craft installation with respect to personnel safety and providing propulsion power and/or power for essential services for the safety of the craft. Arrangements satisfying the criteria of 13.3.2(a) to (c) will also be acceptable.

13.3.4 For engines for emergency power purposes, a risk-based analysis is to be carried out to demonstrate that the design incorporates adequate hazard mitigation, such that the likelihood of an electronic control system failure, resulting in the loss of the ability to provide emergency power when required, has been reduced to a level considered acceptable by LR, and that means are provided to detect failures and permit personnel to restore engine availability to operate on demand. Failures which would result in engine failure and/or damage or loss of availability are to be identified, and the report is to include documentation of:

(a) component reliability evidence;

(b) failure detection and alarms; and

(c) failure response required to restore engine availability and maintain personnel safety.

13.3.5 The risk-based analysis report is to:

(a) Identify the standards used for analysis and system design;

(b) Identify the engine, its purpose and the associated objectives of the analysis;

(c) Identify any assumptions made in the analysis.;

(d) Identify the equipment, system or sub-system, mode of operation and the equipment;

(e) Identify potential failure modes and their causes.

(f) Evaluate the local effects (e.g. fuel injection failure) and the effects on the system as a whole (e.g. loss of propulsion power) of each failure mode;

(g) Identify measures for reducing the risks associated with each failure mode (e.g. system design, failure detection and alarms, redundancy, quality control procedures for sourcing, manufacture and testing, etc.); and

(h) Identify trials and testing necessary to prove conclusions.

13.3.6 At sub-system level, it is acceptable to consider failure of equipment items and their functions, e.g. failure of a pump to produce flow or pressure head. It is not required that the failure of components within that pump be analysed, and failure need only be dealt with as a cause of failure of the pump.

13.4 Oil fuel and hydraulic oil systems

13.4.1 Oil fuel and hydraulic oil piping system arrangements are to comply with Part 15 as applicable.

13.4.2 Where pumps are essential for engine operation, no fewer than two oil fuel and two hydraulic oil pressure pumps are to be provided for their respective service and arranged such that failure of one pump does not render the other inoperative. Each oil fuel pump and hydraulic oil pump is to be capable of supplying the quantity of oil for engine operation at its maximum continuous rating and arranged ready for immediate use.

13.4.3 The oil fuel pressure piping between the oil fuel high pressure pumps and the fuel injectors is to be protected with a jacketed piping system capable of containing oil fuel leakage from a high pressure pipe failure.

13.4.4 The hydraulic oil pressure piping between the high pressure hydraulic pumps and hydraulic actuators is to be protected with a jacketed piping system capable of containing hydraulic oil leakage from a high pressure pipe failure.

13.4.5 Accumulators and associated high pressure piping are to be designed, manufactured and tested in accordance with a standard applicable to the maximum pressure and temperature rating of the system.

13.4.6 All valves, cocks and screwed connections are to be of a type-tested type applicable to the maximum service conditions anticipated in normal service.

13.4.7 Isolating valves and cocks are to be located as near as practicable to the equipment to be isolated. All valves forming part of the oil fuel and hydraulic oil installation are to be capable of being controlled from readily accessible positions above the working platform.

13.4.8 High pressure oil fuel and high pressure hydraulic oil piping systems are to be provided with high pressure alarms with set points that do not exceed the system design pressures.

13.4.9 High pressure oil fuel and high pressure hydraulic piping systems are to be provided with suitable relief valves on any part of the system that can be isolated and in which pressure can be generated. The settings of the relief valves are not to exceed the design pressures. The valves are to be of adequate size and so arranged as to avoid an undue rise in pressure above the design pressures.

13.4.10 Equipment fitted for monitoring pressures and temperatures in the high pressure oil fuel and high pressure hydraulic oil systems is to comply with a recognised standard suitable to the anticipated vibration and temperature conditions.

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13.4.11 A fatigue analysis is to be carried out in accordance with a standard applicable to the system under consideration and all anticipated pressure, pulsation and vibration loads are to be addressed. The analysis is to demonstrate that the design and arrangements are such that the likelihood of failure is as low as reasonably practicable. The analysis is to identify all assumptions made and standards to be applied during manufacture and testing of the system. Any potential weak points which may develop due to incorrect construction or assembly are also to be identified.

13.4.12 For high pressure oil containing and mechanical power transmission systems, the quality plan for sourcing, design, installation and testing of components is to address the following issues:

(a) Design and manufacturing standard(s) applied.
(b) Materials used for construction of key components and their sources.
(c) Details of the quality control system applied during manufacture and testing.
(d) Details of type approval, type testing or approved type status assigned to the machinery or equipment.
(e) Details of installation and testing recommendations for the machinery or equipment.

13.5 Control engineering systems

13.5.1 Control, alarm, monitoring, safety and programmable electronic systems are to comply with Pt 16, Ch 1 as applicable.

13.5.2 The engine control, alarm monitoring and safety systems are to be configured to comply with the relevant requirements (e.g. operating profile, alarms, shutdowns, etc.) of this Chapter and Pt 16, Ch 1 for an engine for main, auxiliary or emergency power purposes. Details of the engine configuration are to be submitted for consideration, identifying:

(a) Local and remote means to carry out system configuration.
(b) Enginebuilder procedures for undertaking configuring.
(c) Roles and responsibilities for configuration (e.g. Enginebuilder, engine packager, system integrator or other nominated party) with accompanying schedule.
(d) Configurable settings and parameters (including those not to be modified from a default value).
(e) Configuration for propulsion, auxiliary or emergency engine application.

Configuration records are to be maintained and are to be made available to the Surveyor at testing and trials and on request in accordance with Pt 16, Ch 1,1.4 and 6.1.3.

13.6 Software

13.6.1 Software lifecycle activities are to be carried out in accordance with an acceptable quality management system, *see* Pt 16, Ch 1,2.10.21, 2.12.2 and 2.12.7.

13.6.2 Appropriate safety related processes, methods, techniques and tools are to be applied to software development and maintenance by the Enginebuilder. Selection and application of techniques and measures in accordance with Annex A of IEC 61508-3, *Functional safety of electrical/electronic/programmable electronic systems: Software requirements*, or other relevant standards or codes acceptable to LR, will generally be acceptable.

13.6.3 To demonstrate compliance with 13.6.1 and 13.6.2:

(a) software quality plans and safety evidence are to be submitted for consideration, *see* 13.2.2(b) and (c); and
(b) an assessment inspection of the Enginebuilder's completed development is to be carried out by LR. The inspection is to be tailored to verify application of the standards and codes used in software safety assurance accepted by LR.

■ *Section 14* Programme for trials of diesel engines to assess operational capability

14.1 Works trials (acceptance test)

14.1.1 Diesel engines which are to be subjected to trials on the test bed at the manufacturer's works and under attendance by the Surveyor(s) are to be tested in accordance with the scope of works trials specified in 14.1.2 to 14.1.10. The scope of the trials is to be agreed between the LR Surveyor and the manufacturer prior to testing. At the discretion of the Surveyor, the scope of the trials may be extended depending on the engine application.

14.1.2 For electronically controlled engines:

(a) works tests in accordance with 13.2.1(h); and
(b) verification of engine configuration, *see* 13.5.2, and that the approved software quality plans, including the software configuration management process, are being applied.

14.1.3 For all stages of the works trials, the pertaining operation values are to be measured and recorded by the engine manufacturer. All results are to be compiled in an acceptance protocol to be issued by the engine manufacturer.

14.1.4 In each case given in Table 1.14.1, all measurements conducted at the various load points shall be carried out at steady operating conditions. The readings for 100 per cent power (rated power at rated speed) are to be taken twice at an interval of at least 30 minutes.

14.1.5 The data to be measured and recorded, when testing the engine at various load points, are to include all necessary parameters for the engine operation. The crankshaft deflection is to be checked when this check is required by the manufacturer during the operating life of the engine. Crankshaft deflection measurements are to be taken before (cold condition) and after (hot condition) works acceptance trials.

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Table 1.14.1 Scope of works trials for diesel engines

Main engines driving propellers and waterjets		
Trial condition	Duration	Note
100 per cent power (rated power) at rated engine speed, *R*	≥ 60 minutes	After having reached steady conditions
110 per cent power at engine speed corresponding to 1,032**R*	30–45 minutes	After having reached steady conditions (1)
90 per cent (or maximum continuous power), 75 per cent, 50 per cent and 25 per cent	—	Powers in accordance with the nominal propeller curve
Starting and reversing manoeuvres	—	—
Testing of governor and independent overspeed protective device	—	*See* 9.2
Shut-down device	—	*See* 9.4
Engines driving generators		
Trial condition	Duration	Note
100 per cent power (rated power) at rated engine speed, *R*	≥ 50 minutes	After having reached steady conditions (2)
110 per cent power	15 minutes	After having reached steady conditions (2) (3)
75 per cent, 50 per cent and 25 per cent power and idle run	—	(2)
Start-up tests	—	—
Testing of governor and independent overspeed protective device	—	*See* 9.3
Shut-down device	—	*See* 9.4

NOTES
1. After running on the test bed, the fuel delivery system of main engines is normally to be so adjusted that overload power cannot be given in service.
2. The test is to be performed at rated speed with a constant governor setting.
3. After running on the test bed, the fuel delivery system of diesel engines driving generators must be adjusted such that overload (110 per cent) power can be given in service after installation on board, so that the governing characteristics including the activation of generator protective devices can be fulfilled at all times.

14.1.6 Checks of components to be presented for inspection after the works trials are left to the discretion of the Surveyor.

14.1.7 The Surveyor may require that after the trials the fuel delivery system is restricted so as to limit the engines to run at not more than 100 per cent power. The setting of the restriction is to be made as applicable to the intended fuel. Any restriction settings, and other changes to the engine's fuel injection equipment required for operation on special fuels, are to be recorded and included by the engine manufacturer.

14.1.8 For the duration of the acceptance test, no interventions or adjustments will be made to the machinery under test.

14.1.9 The testing of exhaust gas emissions is to comply with MARPOL as applicable.

14.1.10 For all stages that the engine is to be tested and where no duration is specified in Table 1.14.1, the load point is to be maintained for a sufficient period to allow pertaining values to be measured and recorded when the engine has achieved a steady operating condition.

14.2 On board trials

14.2.1 After the conclusion of the running-in programme prescribed by the engine manufacturer, engines are to undergo on board trials as specified in Table 1.14.2. The scope of the trials is to be agreed between the LR Surveyor and the Builder prior to testing.

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Table 1.14.2 Scope of shipboard trials for diesel engines

Main engines driving fixed-pitch propellers (1) (2)		
Trial condition	Duration	Note
At rated engine speed, *R*	≥ 4 hours	—
At engine speed corresponding to normal continuous power	≥ 2 hours	—
At engine speed corresponding to 1,032**R*	30 minutes	Where the engine adjustment permits, *see* 14.1.7
At minimum on-load speed	—	—
Starting and reversing manoeuvres	—	*See* Ch 1,7
In reverse direction of propeller rotation during the dock or sea trials at a minimum engine speed of 0,7**R*	10 minutes	—
Control, monitoring, alarms and safety systems	—	Operation to be demonstrated
Where imposed, test to ensure engine can pass safely through barred speed range	—	—
Single engine driving generator for propulsion only		
Trial condition	Duration	Note
100% power (rated propulsion power), *see* 14.2.3	≥ 4 hours	(3) (4)
At normal continuous propulsion power	≥ 2 hours	(3) (4)
110% power (rated propulsion power)	30 minutes	
In reverse direction of propeller rotation at a minimum speed of 70% of the nominal propeller speed	10 minutes	(3) (4)
Starting manoeuvres	—	—
Control, monitoring, alarm and safety systems	—	Operation to be demonstrated

NOTES
1. For main propulsion engines driving controllable pitch propellers, waterjets or reversing gears, the tests for main engines driving fixed-pitch propellers apply as appropriate.
2. Controllable pitch propellers are to be tested with various propeller pitches.
3. The tests to be performed at rated speed with a constant governor setting.
4. Tests are to be based on the rated electrical powers of the electric propulsion motors.

14.2.2 Engines driving generators or important auxiliaries are to be subjected to an operational test for at least 4 hours. During the test, the set concerned is required to operate at its rated power for an extended period. It is to be demonstrated that the engine is capable of supplying 100 per cent of its rated power, and in the case of on board generating sets, account shall be taken of the times needed to actuate the generator's overload protection system

14.2.3 In addition to 14.2.2, for engines driving generators for electric propulsion motors as well as auxiliaries, an operational test is to be carried out of at least 4 hours duration at a load which corresponds to 100 per cent of the electric propulsion motor(s) rated power. The astern/ahead manoeuvring capability of the propulsion system is to be demonstrated.

14.2.4 Trials are to include demonstration of engine control, monitoring, alarm and safety system operation to confirm that they have been provided, installed and configured as intended and in accordance with the relevant requirements for main, auxiliary or emergency engines.

14.2.5 For electronically controlled engines:
(a) On board tests in accordance with 13.2.1(h); and
(b) verification of engine configuration, *see* 13.5.2, and that the approved software quality plans, including the software configuration management process, are being applied.

14.2.6 The suitability of an engine to burn residual or other special fuels is to be demonstrated, if the machinery installation is arranged to burn such fuels in service. *See also* Pt 16, Ch 1,6.2.1.

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14.2.7 At the discretion of the attending Surveyor, the scope of the trials may be expanded in consideration of special operating conditions, such as towing, trawling, etc.

Section 15
Type testing procedure for crankcase explosion relief valves

15.1 Scope

15.1.1 To specify type tests and identify standard test conditions using methane gas and air mixture to demonstrate that LR requirements are satisfied for crankcase explosion relief valves intended to be fitted to engines and gear cases.

15.1.2 The test procedure is only applicable to explosion relief valves fitted with flame arresters. Where internal oil wetting of a flame arrester is a design feature of an explosion relief valve, alternative testing arrangements that demonstrate compliance with these requirements may be proposed by the manufacturer. The alternative testing arrangements are to be submitted to LR for approval.

15.2 Purpose

15.2.1 The purpose of type testing crankcase explosion relief valves is fourfold:

(a) To verify the effectiveness of the flame arrester.
(b) To verify that the valve closes after an explosion.
(c) To verify that the valve is gas/air tight after an explosion.
(d) To establish the level of over-pressure protection provided by the valve.

15.3 Test facilities

15.3.1 Test houses for carrying out type testing of crankcase explosion relief valves are to meet the following requirements:

(a) The test houses where testing is carried out are to be accredited to a National or International Standard for the testing of explosion protection devices, such as ISO/IEC 17025.
(b) The test facilities are to be acceptable to LR.
(c) The test facilities are to be equipped so that they can perform and record explosion testing in accordance with this procedure.
(d) The test facilities are to have equipment for controlling and measuring a methane gas in air concentration within a test vessel to an accuracy of ±0,1 per cent.
(e) The test facilities are to be capable of effective point-located ignition of a methane gas in air mixture.
(f) The pressure measuring equipment is to be capable of measuring the pressure in the test vessel in at least two positions, one at the valve and the other at the test vessel centre. The measuring arrangements are to be capable of measuring and recording the pressure changes throughout an explosion test at a frequency recognising the speed of events during an explosion. The result of each test is to be documented by video recording and by recording with a heat sensitive camera.
(g) The test vessel for explosion testing is to have documented dimensions. The dimensions are to be such that the vessel is not pipe-like with the distance between dished ends being not more than 2,5 times the diameter. The internal volume of the test vessel is to include any standpipe arrangements.
(h) The test vessel is to be provided with a flange, located centrally at one end at 90° to the vessel longitudinal axis for mounting the explosion relief valve. The test vessel is to be arranged in an orientation consistent with how the valve will be installed in service, i.e., in the vertical plane or the horizontal plane.
(j) A circular flat plate is to be provided for fitting between the pressure vessel flange and valve to be tested with the following dimensions:
    1. Outside diameter of 2 times the outer diameter of the valve top cover.
    2. Internal bore having the same internal diameter as the valve is to be tested.
(k) The test vessel is to have connections for measuring the methane in air mixture at the top and bottom.
(l) The test vessel is to be provided with a means of fitting an ignition source at a position as specified in 15.4.3.
(m) The test vessel volume is to be as far as practicable, related to the size and capability of the relief valve to be tested. In general, the volume is to correspond to the requirement in 6.3.1 for the free area of explosion relief valve to be not less than 115 cm^2/m^3 of crankcase gross volume, e.g., the testing of a valve having 1150 cm^2 of free area, would require a test vessel with a volume of 10 m^3. The following is to apply:
    (i) Where the free area of relief valves is greater than 115 cm^2/m^3 of the crankcase gross volume, the volume of the test vessel is to be consistent with the design ratio.
    (ii) In no case is the volume of the test vessel to vary by more than ±15 per cent from the design cm^2/m^3 volume ratio.

15.4 Explosion test process

15.4.1 All explosion tests to verify the functionality of crankcase explosion relief valves are to be carried out using an air and methane mixture with a volumetric methane concentration of 9,5 per cent ±0,5 per cent. The pressure in the test vessel is to be not less than atmospheric and is not to exceed the opening pressure of the relief valve.

15.4.2 The concentration of methane in the test vessel is to be measured at the top and bottom of the vessel and these concentrations are not to differ by more than 0,5 per cent.

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15.4.3 The ignition of the methane and air mixture is to be made at the centreline of the test vessel at a position approximately one third of the height or length of the test vessel opposite to where the valve is mounted.

15.4.4 The ignition is to be made using a maximum 100 joule explosive charge.

15.5 Valves to be tested

15.5.1 The valves used for type testing (including the testing specified in 15.5.3) are to be selected from the manufacturer's normal production line for such valves by the LR Surveyor witnessing the tests.

15.5.2 For approval of a specific valve size, three valves are to be tested in accordance with 15.5.3 and 15.6. For a series of valves, *see* 15.8.

15.5.3 The valves selected for type testing are to have been previously tested at the manufacturer's works to demonstrate that the opening pressure is in accordance with the specification within a tolerance of ±20 per cent and that the valve is air tight at a pressure below the opening pressure for at least 30 seconds. This test is to verify that the valve is air tight following assembly at the manufacturer's works and that the valve begins to open at the required pressure demonstrating that the correct spring has been fitted.

15.5.4 The type testing of valves is to recognise the orientation in which they are intended to be installed on the engine or gear case. Three valves of each size are to be tested for each intended installation orientation, i.e. in the vertical and/or horizontal positions.

15.6 Method

15.6.1 The following requirements are to be satisfied at explosion testing:

(a) The explosion testing is to be witnessed by a LR surveyor.

(b) Where valves are to be installed on an engine or gear case with shielding arrangements to deflect the emission of explosion combustion products, the valves are to be tested with the shielding arrangements fitted.

(c) Successive explosion testing to establish a valve's functionality is to be carried out as quickly as possible during stable weather conditions.

(d) The pressure rise and decay during all explosion testing is to be recorded.

(e) The external condition of the valves is to be monitored during each test for indication of any flame release by video and heat sensitive camera.

15.6.2 The explosion testing is to be in three stages for each valve that is required to be approved as being type tested.

15.6.3 **Stage 1.** Two explosion tests are to be carried out in the test vessel with the circular plate as specified in 15.3.1(j) fitted and the opening in the plate covered by a 0,05 mm thick polythene film. These tests establish a reference pressure level for determination of the capability of a relief valve in terms of pressure rise in the test vessel, *see* 15.7.1(f).

15.6.4 **Stage 2.**

(a) Two explosion tests are to be carried out on three different valves of the same size. Each valve is to be mounted in the orientation for which approval is sought, i.e., in the vertical or horizontal position with the circular plate described in 15.3.1(j) located between the valve and pressure vessel mounting flange.

(b) The first of the two tests on each valve is to be carried out with a 0,05 mm thick polythene bag, having a minimum diameter of three times the diameter of the circular plate and volume not less than 30 per cent of the test vessel, enclosing the valve and circular plate. Before carrying out the explosion test the polythene bag is to be empty of air. The polythene bag is required to provide a readily visible means of assessing whether there is flame transmission through the relief valve following an explosion. During the test, the explosion pressure will open the valve and some unburned methane/air mixture will be collected in the polythene bag. When the flame reaches the flame arrester and if there is flame transmission through the flame arrester, the methane/air mixture in the bag will be ignited and this will be visible.

(c) Provided that the first explosion test successfully demonstrated that there was no indication of combustion outside the flame arrester and there are no signs of damage to the flame arrester or valve, a second explosion test without the polythene bag arrangement is to be carried out as quickly as possible after the first test. During the second explosion test, the valve is to be visually monitored for any indication of combustion outside the flame arrester and video records are to be kept for subsequent analysis. The second test is required to demonstrate that the valve can still function in the event of a secondary crankcase explosion.

(d) After each explosion, the test vessel is to be maintained in the closed condition for at least 10 seconds to enable the tightness of the valve to be ascertained. The tightness of the valve can be verified during the test from the pressure/time records or by a separate test after completing the second explosion test.

15.6.5 **Stage 3.** Carry out two further explosion tests as described in Stage 1. These further tests are required to provide an average baseline value for assessment of pressure rise, recognising that the test vessel ambient conditions may have changed during the testing of the explosion relief valves in Stage 2.

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15.7 Assessment and records

15.7.1 For the purposes of verifying compliance with the requirements of this Section, the assessment and records of the valves used for explosion testing is to address the following:

(a) The valves to be tested are to have evidence of appraisal/approval by LR, *see also* 15.5.1.

(b) The designation, dimensions and characteristics of the valves to be tested are to be recorded. This is to include the free area of the valve and of the flame arrester, and the amount of valve lift at 0,2 bar.

(c) The test vessel volume is to be determined and recorded.

(d) For acceptance of the functioning of the flame arrester there is not to be any indication of flame or combustion outside the valve during an explosion test.

(e) The pressure rise and decay during an explosion is to be recorded, with indication of the pressure variation showing the maximum overpressure and steady under-pressure in the test vessel during testing. The pressure variation is to be recorded at two points in the pressure vessel.

(f) The effect of an explosion relief valve in terms of pressure rise following an explosion is ascertained from maximum pressures recorded at the centre of the test vessel during the three stages. The pressure rise within the test vessel due to the installation of a relief valve is the difference between average pressure of the four explosions from Stages 1 and 3 and the average of the first tests on the three valves in Stage 2. The pressure rise is not to exceed the limit specified by the manufacturer.

(g) The valve tightness is to be ascertained by verifying from the records at the time of testing that an under-pressure of at least 0,3 bar is held by the test vessel for at least 10 seconds following an explosion. This test is to verify that the valve has effectively closed and is reasonably gas-tight following dynamic operation during an explosion.

(h) After each explosion test in Stage 2, the external condition of the flame arrester is to be examined for signs of serious damage and/or deformation that may affect the operation of the valve.

(j) After completing the explosion tests, the valves are to be dismantled and the condition of all components ascertained and documented. In particular, any indication of valve sticking or uneven opening that may affect the operation of the valve is to be noted. Photographic records of the valve condition are to be taken and included in the report.

15.8 Design series qualification

15.8.1 The qualification of quenching devices to prevent the passage of flame can be evaluated for other similar devices of identical type where one device has been tested and found satisfactory.

15.8.2 The quenching ability of a flame arrester depends on the total mass of quenching lamellas/mesh. Provided the materials, thickness of materials, length of lamellas/thickness of mesh layer and the quenching gaps are the same, then the same quenching ability can be qualified for different sizes of flame arresters subject to (a) and (b) being satisfied.

(a) $$\frac{n_1}{n_2} = \sqrt{\frac{S_1}{S_2}}$$

(a) $$\frac{A_1}{A_2} = \frac{S_1}{S_2}$$

where

n_1 = total depth of flame arrester corresponding to the number of lamellas of size 1 quenching device for a valve with a relief area equal to S_1

n_2 = total depth of flame arrester corresponding to the number of lamellas of size 2 quenching device for a valve with a relief area equal to S_2

A_1 = free area of quenching device for a valve with a relief area equal to S_1

A_2 = free area of quenching device for a valve with a relief area equal to S_2.

15.8.3 The qualification of explosion relief valves of larger sizes than that which has been previously satisfactorily tested in accordance with 15.6 and 15.7 can be evaluated where valves are of identical type and have identical features of construction subject to the following:

(a) The free area of a larger valve does not exceed three times + 5 per cent that of the valve that has been satisfactorily tested.

(b) One valve of the largest size, subject to (a), requiring qualification is subject to satisfactory testing required by 15.5.3 and 15.6.4 except that a single valve will be accepted in 15.6.4(a) and the volume of the test vessel is not to be less than one third of the volume required by 15.3.1(m).

(c) The assessment and records are to be in accordance with 15.7, noting that 15.7.1(f) will only be applicable to Stage 2 for a single valve.

15.8.4 The qualification of explosion relief valves of smaller sizes than that which has been previously satisfactorily tested in accordance with 15.6 and 15.7 can be evaluated where valves are of identical type and have identical features of construction subject to the following:

(a) The free area of a smaller valve is not less than one third of that of the valve that has been satisfactorily tested.

(b) One valve of the smallest size, subject to (a), requiring qualification is subject to satisfactory testing required by 15.5.3 and 15.6.4 except that a single valve will be accepted in 15.6.4(a) and the volume of the test vessel is not to be more than the volume required by 15.3.1(m).

(c) The assessment and records are to be in accordance with 15.7, noting that 15.7.1(f) will only be applicable to Stage 2 for a single valve.

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15.9 The report

15.9.1 The test house is to deliver a full report that includes the following information and documents:

(a) Test specification.
(b) Details of test pressure vessel and valves tested.
(c) The orientation in which the valve was tested (vertical or horizontal position).
(d) Methane in air concentration for each test.
(e) Ignition source.
(f) Pressure curves for each test.
(g) Video recordings of each valve test.
(h) The assessment and records stated in 15.7.

15.10 Approval

15.10.1 The approval of an explosion relief valve is at the discretion of LR, based on the appraisal of plans and particulars and the test facility's report of the results of type testing.

■ *Section 16*
Type testing procedure for crankcase oil mist detection and alarm equipment

16.1 Scope

16.1.1 To specify the tests required to demonstrate that crankcase oil mist detection and alarm equipment intended to be fitted to diesel engines satisfy LR requirements.

16.1.2 This test procedure is also applicable to oil mist detection and alarm arrangements intended for gear cases.

16.2 Purpose

16.2.1 The purpose of type testing crankcase oil mist detection and alarm equipment is sevenfold:

(a) To verify the functionality of the system.
(b) To verify the effectiveness of the oil mist detectors.
(c) To verify the accuracy of the oil mist detectors.
(d) To verify the alarm set points.
(e) To verify time delays between oil mist leaving the source and alarm activation.
(f) To verify functional failure detection.
(g) To verify the influence of optical obscuration on detection.

16.3 Test facilities

16.3.1 Test houses carrying out type testing of crankcase oil mist detection and alarm equipment are to satisfy the following criteria:

(a) A full range of facilities for carrying out the environmental and functionality tests required by this procedure shall be available and be acceptable to LR.
(b) The test house that verifies the functionality of the equipment is to be equipped so that it can control, measure and record oil mist concentration levels in terms of mg/l to an accuracy of ±10 per cent in accordance with this procedure.

16.4 Equipment testing

16.4.1 The range of tests is to include the following for the alarm/monitoring panel:

(a) Functional tests described in 16.5.
(b) Electrical power supply failure test.
(c) Power supply variation test.
(d) Dry heat test.
(e) Damp heat test.
(f) Vibration test.
(g) EMC test.
(h) Insulation resistance test.
(j) High voltage test.
(k) Static and dynamic inclinations, if moving parts are contained.

16.4.2 The range of tests is to include the following for the detectors:

(a) Functional tests described in 16.5.
(b) Electrical power supply failure test.
(c) Power supply variation test.
(d) Dry heat test.
(e) Damp heat test.
(f) Vibration test.
(g) EMC test.
(h) Insulation resistance test.
(j) High voltage test.
(k) Static and dynamic inclinations.

16.5 Functional tests

16.5.1 All tests to verify the functionality of crankcase oil mist detection and alarm equipment are to be carried out in accordance with 16.5.2 to 16.5.6 with an oil mist concentration in air, known in terms of mg/l to an accuracy of ±10 per cent.

16.5.2 The concentration of oil mist in the test chamber is to be measured in the top and bottom of the chamber and these concentrations are not to differ by more than 10 per cent. *See* 16.7.2(a).

16.5.3 The oil mist monitoring arrangements are to be capable of detecting oil mist in air concentrations of between 0 and 10 per cent of the lower explosive limit (LEL), which corresponds to an oil mist concentration of approximately 50 mg/l (15 per cent oil-air mixture) or between 0 and a percentage corresponding to a level not less than twice the maximum oil mist concentration alarm set point.

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16.5.4 The alarm set point for oil mist concentration in air is to provide an alarm at a maximum setting corresponding to not more than 5 per cent of the LEL or approximately 2,5mg/l.

16.5.5 Where alarm set points can be altered, the means of adjustment and indication of set points are to be verified against the equipment manufacturer's instructions.

16.5.6 Where oil mist is drawn into a detector via piping arrangements, the time delay between the sample leaving the crankcase and operation of the alarm is to be determined for the longest and shortest lengths of pipes recommended by the manufacturer. The pipe arrangements are to be in accordance with the manufacturer's instructions/recommendations.

16.5.7 Detector equipment that is in contact with the crankcase atmosphere and may be exposed to oil splash and spray from engine lubricating oil is to be tested to demonstrate that openings do not occlude or become blocked under continuous oil splash or spray conditions. Testing is to be in accordance with arrangements proposed by the manufacturer and agreed by LR.

16.5.8 Detector equipment may be exposed to water vapour from the crankcase atmosphere which may affect the sensitivity of the equipment. It is to be demonstrated that exposure to such conditions will not affect the functional operation of the detector equipment. Where exposure to water vapour and/or water condensation has been identified as a possible source of equipment malfunctioning, testing is to demonstrate that any mitigating arrangements such as heating are effective. Testing is to be in accordance with arrangements proposed by the manufacturer and agreed by LR. This testing is in addition to that required by 16.4.2(e) and is concerned with the effects of condensation caused by the detection equipment being at a lower temperature than the crankcase atmosphere.

16.6 Detectors and alarm equipment to be tested

16.6.1 The detectors and alarm equipment selected for the type testing are to be selected from the manufacturer's normal production line by the LR Surveyor witnessing the tests.

16.6.2 Two detectors are to be tested. One is to be tested in the clean condition and the other in a condition representing the maximum level of lens obscuration specified by the manufacturer.

16.7 Method

16.7.1 The requirements of 16.7 are to be satisfied at type testing.

16.7.2 Oil mist generation is to satisfy the following:

(a) Oil mist is to be generated with suitable equipment using an SAE 80 monograde mineral oil or equivalent and supplied to a test chamber having a volume of not less than 1 m^3. The oil mist produced is to have a maximum droplet size of 5 µm. The oil droplet size is to be checked using the sedimentation method.

(b) The oil mist concentrations used are to be ascertained by the gravimetric deterministic method or equivalent. For this test, the gravimetric deterministic method is a process where the difference in weight of a 0,8 µm pore size membrane filter is ascertained from weighing the filter before and after drawing 1 litre of oil mist through the filter from the oil mist test chamber. The oil mist chamber is to be fitted with a recirculating fan.

(c) Samples of oil mist are to be taken at regular intervals and the results plotted against the oil mist detector output. The oil mist detector is to be located adjacent to where the oil mist samples are drawn off.

(d) The results of a gravimetric analysis are considered invalid and are to be rejected if the resultant calibration curve has an increasing gradient with respect to the oil mist detection reading. This situation occurs when insufficient time has been allowed for the oil mist to become homogeneous. Single results that are more than 10 per cent below the calibration curve are to be rejected. This situation occurs when the integrity of the filter unit has been compromised and not all of the oil is collected on the filter paper.

(e) The filters require to be weighed to a precision of 0,1 mg and the volume of air/oil mist sampled to 10 ml.

16.7.3 The testing is to be witnessed by an LR Surveyor where type testing approval is required by LR.

16.7.4 Oil mist detection equipment is to be tested in the orientation (vertical, horizontal or inclined) in which it is intended to be installed on an engine or gear case as specified by the equipment manufacturer.

16.7.5 Type testing is to be carried out for each type of oil mist detection and alarm equipment for which a manufacturer seeks LR approval. Where sensitivity levels can be adjusted, testing is to be carried out at the extreme and mid-point level settings.

16.8 Assessment

16.8.1 Assessment of oil mist detection equipment after testing is to address the following:

(a) The equipment to be tested is to have evidence of design appraisal/approval by LR, *see also* 16.6.1.

(b) Details of the detection equipment to be tested are to be recorded such as name of manufacturer, type designation, oil mist concentration assessment capability and alarm settings.

(c) After completing the tests, the detection equipment is to be examined and the condition of all components ascertained and documented. Photographic records of the monitoring equipment condition are to be taken and included in the report.

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16.9 Design series qualification

16.9.1 The approval of one type of detection equipment may be used to qualify other devices having identical construction details. Proposals are to be submitted for consideration.

16.10 The report

16.10.1 The test house is to provide a full report which includes the following information and documents:

(a) Test specification.
(b) Details of equipment tested.
(c) Results of tests.

16.11 Acceptance

16.11.1 Acceptance of crankcase oil mist detection equipment is at the discretion of LR, based on the appraisal of plans and particulars and the test house report of the results of type testing.

16.11.2 The following information is to be submitted to LR for acceptance of oil mist detection equipment and alarm arrangements:

(a) Description of oil mist detection equipment and system including alarms.
(b) Copy of the test house report identified in 16.10.
(c) Schematic layout of engine oil mist detection arrangements showing location of detectors/sensors and piping arrangements and dimensions.
(d) Maintenance and test manual which is to include the following information:
    - Intended use of equipment and its operation.
    - Functionality tests to demonstrate that the equipment is operational and that any faults can be identified and corrective actions notified.
    - Maintenance routines and spare parts recommendations.
    - Limit setting and instructions for safe limit levels.
    - Where necessary, details of configurations in which the equipment is and is not to be used.

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Section

1 **General requirements**

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3 **Materials**

4 **Design**

5 **Construction**

6 **Starting arrangements**

7 **Piping systems**

8 **Control and monitoring**

9 **Requirements for craft which are not required to comply with the HSC Code**

■ *Section 1* General requirements

1.1 Application

1.1.1 This Chapter is to be read in conjunction with the General Requirements for Machinery in Part 9.

1.1.2 The requirements of this Chapter are applicable to gas turbines for main propulsion and essential auxiliary services.

1.2 Power ratings

1.2.1 In this Chapter, where the dimensions of any particular component are determined from shaft power, *P*, in kW, and revolutions per minute, *R*, the values to be used are those defined in Part 9.

1.3 Power conditions for generator sets

1.3.1 Auxiliary gas turbines coupled to electrical generators are to be capable under service conditions of developing continuously the power to drive the generators at full rated output and of developing for a short period (15 minutes) an overload power of not less than 10 per cent, *see* Pt 16, Ch 2.

1.4 Inclination of craft

1.4.1 Main and essential auxiliary gas turbines are to operate satisfactorily under the conditions as shown in Table 1.4.1 in Pt 9, Ch 1.

■ *Section 2* Particulars to be submitted

2.1 Plans and information

2.1.1 At least three copies of the following plans are to be submitted:

- Sectional assembly.
- Casings.
- Combustion chambers and heat exchangers.
- Rotors, bearings and couplings.
- Blades and blade attachments.
- Inlet and exhaust ducting.
- Securing arrangement (including details of resilient mounts where applicable).
- Control engineering aspects in accordance with Pt 16, Ch 1.
- Fuel oil system schematic, including controls and safety devices.
- Lubricating oil system schematic.
- Starting system schematic.
- Cooling water system schematic, where applicable.

2.1.2 The following information and calculations are to be submitted:

(a) Details of the acoustic enclosure fire detection and extinguishing system, where applicable.

(b) Power/speed operational envelope.
Calculations and information for short term high power operation, where applicable.
Operation and Maintenance Manuals.

(c) Calculations of the critical speeds of blade and rotor vibration, giving full details of the basic assumptions.
An analysis of the effect of a rotor blade failure and any details of service experience, *see* 4.3.

(d) High temperature characteristics of the materials, where applicable, including (at the working temperatures) the associated creep rate and rupture strength for the designed service life, fatigue strength, corrosion resistance and scaling properties.
Particulars of heat treatment, including stress relief, where applicable.
Material specifications covering the listed components together with details of any surface treatments, non-destructive testing and hydraulic tests.

2.1.3 The most onerous pressures and temperatures to which each component may be subjected are to be indicated on plans or provided as part of the design specification.

2.1.4 Calculations of the steady state stresses, including the effect of stress raisers, etc., in the turbine and compressor rotors and blading at the maximum speed and temperature in service are to be submitted. Such calculations should indicate the designed service life and be accompanied, where possible, by test results substantiating the limiting criteria.

2.1.5 Details of calculations and tests to establish the service life of other stressed parts, including gearing (where applicable), bearings, seals, etc., are also to be submitted. All calculations and tests should take account of all relevant environmental factors including particular type of service and fuel intended to be used.

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2.1.6 Components fabricated by means of welding will be considered for acceptance if constructed by firms whose works are properly equipped to undertake welding of the standards appropriate to the components. Details are to be submitted for consideration.

2.1.7 Before work is commenced, manufacturers are to submit for consideration details of proposed welding procedures and their proposals for routine examination of joints by non-destructive means.

2.1.8 The manufacturer's proposals for testing the gas turbine are to be submitted for consideration.

2.1.9 A Failure Mode and Effects Analysis (FMEA) is to be submitted as detailed in Part 9.

■ *Section 3* Materials

3.1 Materials for forgings

3.1.1 Rotors and discs are to be of forged steel. For carbon and carbon-manganese steel forgings, the specified minimum tensile strength is to be selected within the limits of 400 and 600 N/mm^2. For alloy steel rotor forgings, the specified minimum tensile strength is to be selected within the limits of 500 and 800 N/mm^2. For discs and other alloy steel forgings, the specified minimum tensile strength is to be selected within the limits of 500 and 1000 N/mm^2. *See also Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

3.1.2 For alloy steels, specifications giving the proposed chemical composition and heat treatment are to be submitted for approval.

3.1.3 When it is proposed to use a material of higher tensile strength, full details are to be submitted for approval.

3.1.4 Components of non-ferrous construction should be submitted for consideration, together with full details of materials to be used and method of fabrication.

3.2 Material tests and inspection

3.2.1 Components are to be tested in accordance with the relevant requirements of the Rules for Materials.

3.2.2 For components of novel design special consideration will be given to the material test and non-destructive testing requirements.

■ *Section 4* Design

4.1 General

4.1.1 All parts of turbines, compressors, etc., are to have clearances and fits consistent with adequate provision for the relative thermal expansion of the various components. Special attention is to be given to minimising casing and rotor distortion under all operating conditions.

4.1.2 Turbine bearings are to be so disposed and supported that lubrication is not adversely affected by heat flow from adjacent hot parts. Effective means are to be provided for intercepting oil leakage and preventing oil from reaching high temperature glands and casings.

4.2 Vibration

4.2.1 Care is to be taken in the design and manufacture of turbine and compressor rotors, rotor discs and rotor blades to ensure freedom from undue vibration within the operating speed range. Where critical speeds are found by calculation to occur within the operating speed range, vibration measurements may be requested in order to verify the calculations, *see* Part 13.

4.3 Containment

4.3.1 Gas turbines are to be designed and installed so as to contain debris in the event of an internal failure.

4.3.2 The gas turbine is to be located such that any flying debris resulting from a failure will not endanger the craft, other machinery, occupants of the craft or any other persons.

4.3.3 Where an acoustic enclosure is fitted which completely surrounds the gas generator and the high pressure oil pipes, a fire detection and extinguishing system is to be provided for the acoustic enclosure.

4.4 External influences

4.4.1 Pipes and ducting connected to casings are to be so designed that no excessive thrust loads or moments are applied by them to the compressors and turbines.

4.4.2 Platform gratings and fittings in way of the supports are to be so arranged that casing expansion is not restricted.

4.4.3 Where main turbine seatings incorporating a tank structure are proposed, consideration is to be given to the temperature variation of the tank in service to ensure that turbine alignment will not be adversely affected.

4.4.4 For securing arrangements, including resilient mounting, *see* Pt 9, Ch 1.

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■ *Section 5* Construction

5.1 Welded components

5.1.1 All welded construction is to be in accordance with the requirements specified in Chapter 13 of the Rules for Materials.

5.1.2 Major joints are to be designed as full-strength welds and for complete fusion of the joint.

5.1.3 Stress relief heat treatment is to be applied to all cylinders, rotors and associated components on completion of the welding of all joints and attached structures, *see* Part 15.

■ *Section 6* Starting arrangements

6.1 Initial starting arrangements

6.1.1 Equipment for starting main and auxiliary turbines is to be provided and arranged such that the necessary initial charge of starting air or initial electric power can be developed on board the craft without external aid. If for this purpose an emergency air compressor or electric generator is required, these units are to be power driven by manually started oil engines except in the case of small installations where a hand operated compressor of approved capacity may be accepted. Alternatively, other devices of approved type may be accepted as a means of providing the initial start, *see also* Pt 16, Ch 2,2.4.2.

6.2 Purging before ignition

6.2.1 Means are to be provided, preferably automatic or interlocked, to clear all parts of the gas turbine of the accumulation of oil fuel or for purging gaseous fuel before ignition commences on starting, or recommences after failure to start. The purge is to be of sufficient duration to displace at least three times the volume of the exhaust system.

6.3 Air starting

6.3.1 Where the gas turbine is arranged for air starting the total air receiver capacity is to be sufficient to provide, without replenishment, not less than six consecutive starts. At least two air receivers of approximately equal capacity are to be provided. For scantlings and fittings of air receivers, *see* Part 15.

6.3.2 For multi-engine installations three consecutive starts per engine are required.

6.4 Electric starting

6.4.1 Where main turbines are fitted with electric starters, two batteries are to be fitted. Each battery is to be capable of starting the turbines when cold and the combined capacity is to be sufficient without recharging to provide the number of starts of the main turbines as required by 6.3.

6.4.2 Electric starting arrangements for auxiliary turbines are to have two separate batteries or be supplied by separate circuits from the main turbine batteries when such are provided. Where one of the auxiliary turbines only is fitted with an electric starter one battery will be acceptable.

6.4.3 The combined capacity of the batteries for starting the auxiliary turbines is to be sufficient for at least three starts for each turbine.

6.4.4 The requirements for battery installations are given in Pt 16, Ch 2.

■ *Section 7* Piping systems

7.1 General

7.1.1 Gas turbine piping systems are, in general, to comply with the requirements given in Pt 15, Ch 1 and Ch 3, due regard being paid to the particular type of installation.

7.1.2 Synthetic rubber hoses, with single or double closely woven integral wire braid reinforcement, or convoluted metal pipes with wire braid protection, may be used in compressed air, fresh water, sea-water, oil fuel and lubricating oil systems. Where synthetic rubber hoses are used for fuel or supply to burners, the hoses are to have external wire braid protection in addition to the integral wire braid.

7.2 Oil fuel systems

7.2.1 Oil fuel arrangements are to comply with the requirements of Pt 15, Ch 3.

7.2.2 Two or more filters are to be fitted in the oil fuel supply lines to the main and auxiliary turbines, and the arrangements are to be such that any filter can be cleaned without interrupting the supply of filtered oil fuel to the turbines.

7.3 Lubricating oil systems

7.3.1 Lubricating oil arrangements are to comply with the requirements of Pt 15, Ch 3.

7.3.2 Where the lubricating oil for main propelling gas turbines is circulated under pressure, provision is to be made for the efficient filtration of the oil. The filters are to be capable of being cleaned without stopping the turbine or reducing the supply of filtered oil to the turbine.

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7.4 Cooling systems

7.4.1 Cooling water arrangements are to comply with the requirements of Pt 15, Ch 3, as applicable.

7.5 Inlet and exhaust systems

7.5.1 The air-inlet system is to be designed to minimise the ingestion of harmful particles. Icing up of air intakes is to be prevented.

7.5.2 Means for preventing the accumulation of salt deposits in the compressors and turbines, e.g. water washing, are to be provided.

7.5.3 The arrangement of the exhaust system is to be such as to prevent exhaust gases being drawn into manned spaces, air conditioning systems and air intakes. They should not discharge into air cushion intakes.

7.5.4 Where the exhaust is led overboard near the waterline, means are to be provided to prevent water from being siphoned back to the turbine. Where the exhaust is cooled by water spray, the exhaust pipes are to be self draining overboard. Erosion/corrosion resistant shut off flaps or other devices are to be fitted on the hull side shell or pipe end and acceptable arrangements made to prevent water flooding the space.

7.5.5 Where two or more turbines have a common exhaust, an isolating device is to be provided in each exhaust pipe.

7.5.6 The exhaust system is to be arranged so that hot exhaust gases are directed away from areas to which personnel have access, either on board or in the vicinity of where the craft is berthed.

■ *Section 8* Control and monitoring

8.1 General

8.1.1 Control engineering systems are to comply with the requirements of Part 16.

8.2 Overspeed protective devices

8.2.1 An overspeed protective device is to be provided for each shaft of main and auxiliary turbines to automatically shut off the fuel, near the burners, to prevent a dangerous overspeed condition of the shaft, unless it can be established that such a condition cannot arise.

8.2.2 The overspeed device is to be set to operate before the speed of the line exceeds the rated maximum speed by 10 per cent. For auxiliary turbines driving electric generators this setting may be increased to 15 per cent.

8.3 Speed governors

8.3.1 Where a main propulsion installation incorporates a reverse gear, electric transmission or controllable (reversible) pitch propeller, a speed governor, independent of the overspeed protective device, is to be fitted and is to be capable of controlling the speed of the unloaded power turbine without bringing the overspeed protective device into action.

8.3.2 Where an auxiliary turbine is intended for driving an electric generator, a speed governor, independent of the overspeed protective device, is to be fitted which, with fixed setting, is to control the speed within 10 per cent momentary variation and five per cent permanent variation when full load is suddenly taken off or put on. The permanent speed variations of a.c. machines intended for parallel operations are to be equal within a tolerance of ±0,5 per cent.

8.4 Lubricating oil failure

8.4.1 Main turbines are to have an arrangement whereby fuel is automatically shut off, near the burners, in the event of failure of the lubrication system.

8.5 Indication of temperature

8.5.1 Means are to be provided for indicating the temperature of power turbine exhaust gases.

8.6 Automatic and remote controls

8.6.1 Where gas turbines are fitted with automatic or remote controls so that under normal operating conditions they do not require any manual intervention by the operators, they are to be provided with the alarm and safety arrangements required by 8.6.2 and Table 2.8.1 as appropriate. Alternative arrangements which provide equivalent safeguards will be considered.

8.6.2 The following turbine services are to be fitted with automatic temperature controls so as to maintain steady state conditions throughout the normal operating range of the turbine:

(a) Lubricating oil supply.
(b) Oil fuel supply, *see also* 8.6.3.
(c) Exhaust gas.

8.6.3 The oil fuel supply may be fitted with an automatic control for viscosity instead of the temperature control required by 8.6.2.

8.6.4 A means of manually shutting off the fuel in an emergency is to be provided at the manoeuvring station.

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Table 2.8.1 Alarms and safeguards

Item	Alarm	Note
Overspeed	High	Automatic shut down
Lubricating oil pressure for turbine and gearing	1st stage low	
	2nd stage low	Automatic shut down
Lubricating oil temperature	High	
Lubricating oil filter differential pressure	High	
Oil fuel supply pressure	Low	
Oil fuel supply temperature	High	
Bearing temperature	High	
Exhaust gas temperature	1st stage high	
	2nd stage high	Automatic shut down
Turbine vibration	1st stage high	
	2nd stage high	Automatic shut down
Rotor axial displacement	High	Automatic shut down, *see* Note 2
Flame and ignition	Failure	Automatic shut down
Automatic starting	Failure	Automatic shut down
Compressor inlet vacuum	1st stage high	
	2nd stage high	Automatic shut down
Control system	Failure	

NOTES
1. Automatic or interlocked means are to be provided for clearing all parts of the main gas turbine of the accumulation of liquid fuel or for purging gaseous fuel, before ignition commences on starting or recommences after failure to start.
2. Except for gas turbines with rolling element bearings.

■ *Section 9*
Requirements for craft which are not required to comply with the HSC Code

9.1 General

9.1.1 The requirements of Sections 1 to 8 apply to craft which are not required to comply with the HSC Code, unless specifically exempted by the contents of this Section.

9.1.2 The requirements of 1.4.1 do not apply to yachts or service craft less than 24 m.

9.2 Information and calculations

9.2.1 Gas turbines for craft with a power output not exceeding 110 kW do not have to comply with 2.1.2(c) and (d) or 2.1.4 to 2.1.7 inclusive and 2.1.9.

9.3 Starting arrangements

9.3.1 Craft with a Service Group notation of G1 or G2 do not have to comply with 6.1.1.

9.4 Piping systems

9.4.1 Soft solder is not to be used for attaching pipe fittings forming part of oil fuel systems.

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Rules and Regulations for the Classification of Special Service Craft

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2 **Particulars to be submitted**

3 **Materials**

4 **Design of gearing**

5 **Piping systems for gearing**

6 **Control and monitoring**

7 **Requirements for craft which are not required to comply with the HSC Code**

■ *Section 1* General requirements

1.1 Application

1.1.1 This Chapter is to be read in conjunction with the General Requirements for Machinery in Part 9.

1.1.2 The requirements of this Chapter, except where otherwise stated are applicable to electric motor, gas turbine and diesel engine gearing for driving:

(a) Conventional, totally submerged propeller(s)/impeller(s) for main propulsion purposes, for transmitted powers greater than 220 kW.

(b) Auxiliary machinery which is essential for the safety of the craft or for safety of persons on board where the transmitted powers exceed 110 kW.

NOTE

Alternatively calculations using the methods defined in ISO 6336 – *Calculation of load capacity of spur and helical gears* will be considered.

1.1.3 Gear designs for applications other than those specified in 1.1.2 will be specially considered.

1.1.4 In any mesh, the terms pinion and wheel refer to the smaller and larger gear respectively.

1.1.5 Bevel gears will be specially considered on the basis of a conversion to equivalent cylindrical gears.

1.1.6 For vibration and alignment requirements, *see* Part 13.

1.2 Power ratings

1.2.1 In this Chapter where the dimensions of any particular components are determined from shaft power, P, in kW, and revolutions per minute, R, the values to be used are those defined in Part 9.

1.3 Inclination of craft

1.3.1 Main and auxiliary gear units are to operate satisfactorily under the conditions as shown in Table 1.4.1 in Pt 9, Ch 1.

■ *Section 2* Particulars to be submitted

2.1 Submission of information

2.1.1 At least three copies of the following plans and information as detailed in 2.2 to 2.3 are to be submitted.

2.2 Plans

2.2.1 **Gearing:**

(a) Cross sectional views indicating general arrangement.

(b) Detailed plans of elements.

2.2.2 **Shafting and auxiliary systems:**

(a) Mass elastic schematic showing gear unit torsional data.

(b) Arrangements plan indicating bearing positions.

(c) Detailed plans indicating scantlings of shafts, couplings and bolting.

(d) Schematic plans of the lubricating oil system, together with pipe material, relief valve and working pressures.

(e) Schematic of the control and electrical system.

2.3 Information

2.3.1 **Gearing:**

(a) Operational power/speed envelope for each pinion.

(b) Number of teeth in each gear.

(c) Reference diameters.

(d) Helix angles at reference diameters.

(e) Normal pitches of teeth at reference diameters.

(f) Tip diameters.

(g) Root diameters.

(h) Face widths and gaps, where applicable.

(j) Pressure angles of teeth (normal or transverse) at reference diameters.

(k) Accuracy grade Q in accordance with ISO 1328 or an equivalent Standard.

(l) Surface texture of tooth flanks and roots.

(m) Minimum backlash.

(n) Centre distance.

(o) Basic rack tooth form.

(p) Protuberance and final machining allowance.

(q) Details of post hobbing processes, if any.

(r) Details of tooth flank corrections, if adopted.

(s) Case depth for surface-hardened teeth.

(t) Shrinkage allowance for shrunk-on rims and hubs.

(u) Type of coupling proposed for oil engine applications.

(v) Details of surface treatment.

(w) Additional measures, not covered by the Rules, taken during manufacture of the gear elements, to improve the load capacity of the gear teeth.

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(x) Calculations for short term high power operation, where applicable, *see* Part 9.
(y) Failure mode effects analysis as required by Part 9.
(z) Specifications for carbon-manganese and alloy steel forging materials of pinions, pinion sleeves, wheel rims, gear wheels, couplings, bolting and all transmission shafting, giving chemical composition, heat treatment and mechanical properties.

2.3.2 **Shafting and auxiliary systems:**
(a) Details of clutch units, where fitted.
(b) Details of alarms and control systems, where fitted.
(c) Schematic plans of the lubricating oil system, together with pipe material, relief valve and working pressures.

■ *Section 3* Materials

3.1 Requirements and specifications

3.1.1 Components for gearboxes are to be in accordance with the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

3.1.2 Manufacturers' certificates for forgings may be accepted where the transmitted power does not exceed 220 kW, *see* Ch 1,3.1.3(b) of the Rules for Materials.

3.1.3 In the selection of materials for pinions and wheels, consideration is to be given to their compatibility in operation. Except in the case of low reduction ratios, for gears of through-hardened steels, provision is also to be made for a hardness differential between pinion teeth and wheel teeth. For this purpose, the specified minimum tensile strength of the wheel rim material is not to be more than 85 per cent of that of the pinion.

3.1.4 Gear wheel and rim forgings with a specified minimum tensile strength not in excess of 760 N/mm^2 may be made in carbon-manganese steel. Gear wheel or rim forgings where the specified minimum tensile strength is in excess of 760 N/mm^2, and all pinion or pinion sleeve forgings are to be made in a suitable alloy steel.

3.1.5 Forgings for couplings, quill shafts and gear wheel shafts are to comply with the requirements of Chapter 2.

■ *Section 4* Design of gearing

4.1 Symbols

4.1.1 The following symbols apply:

a = centre distance, in mm
b = face width, in mm
NOTE: unless otherwise specified, b is to be taken as the lesser value of b_1 or b_2
In the case of double helical gears $b = 2b_B$ where b_B is the width of one helix
d = reference diameter, in mm
d_a = tip diameter, in mm
d_{an} = virtual tip diameter, in mm
d_b = base diameter, in mm
d_{bn} = virtual base diameter, in mm
d_{en} = virtual diameter to the highest point of single tooth pair contact, in mm
d_f = root diameter, in mm
d_{fn} = virtual root diameter, in mm
d_n = virtual reference diameter, in mm
d_s = shrink diameter, in mm
d_w = pitch circle diameter, in mm
f_{ma} = tooth flank misalignment due to manufacturing errors, in μm
f_{pb} = maximum base pitch deviation of wheel, in μm
f_{Sh} = tooth flank misalignment due to wheel and pinion deflections, in μm
f_{Sho} = intermediary factor for the determination of f_{Sh}
g_α = length of line of action for external gears, in mm:

$$= 0{,}5\sqrt{(d_{a1}^2 - d_{b1}^2)} + 0{,}5\sqrt{(d_{a2}^2 - d_{b2}^2)} - a\sin\alpha_{tw}$$

for internal gears:

$$= 0{,}5\sqrt{(d_{a1}^2 - d_{b1}^2)} - 0{,}5\sqrt{(d_{a2}^2 - d_{b2}^2)} + a\sin\alpha_{tw}$$

h = total depth of tooth, in mm
h_{ao} = basic rack addendum of tool, in mm
h_F = bending moment arm for root stress, in mm
h_W = sum of actual tooth addenda of pinion and wheel, in mm
m_n = normal module, in mm
n = rev/min of pinion
q = machining allowances, in mm
q_s = notch parameter
q' = intermediary factor for the determination of C_γ

$$u = \text{gear ratio} = \frac{\text{Number of teeth in wheel}}{\text{Number of teeth in pinion}} \geq 1$$

v = linear speed at pitch circle, in m/s
x = addendum modification coefficient
y_α = running in allowance, in μm
y_β = running in allowance, in μm
z = number of teeth

$$z_n = \text{virtual number of teeth} = \frac{z}{\cos^2\beta_o \cos\beta}$$

C_γ = tooth mesh stiffness (mean total mesh stiffness per unit face width), in N/mm μm
F_t = nominal tangential tooth load, in N

$$= \frac{P}{nd}\, 19{,}098 \times 10^6$$

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F_β = total tooth alignment deviation (maximum value specified), in μm
$F_{\beta x}$ = actual longitudinal tooth flank deviation before running in, in μm
$F_{\beta y}$ = actual longitudinal tooth flank deviation after running in, in μm
HV = Vickers hardness number
K_A = application factor
$K_{F\alpha}$ = transverse load distribution factor
$K_{F\beta}$ = longitudinal load distribution factor
$K_{H\alpha}$ = transverse load distribution factor
$K_{H\beta}$ = longitudinal load distribution factor
K_v = dynamic factor
$K_{v\alpha}$ = dynamic factor for spur gears
$K_{v\beta}$ = dynamic factor for helical gears
K_γ = load sharing factor
P = transmitted power, in kW
P_r = radial pressure at shrinkage surface, in N/mm^2
P_{ro} = protuberance of tool, in mm
Q = accuracy grade derived from ISO 1328 – *Cylindrical gears – ISO system of accuracy*
R_a = surface roughness – arithmetical mean deviation (C.L.A.) as determined by an instrument having a minimum wavelength cut-off of 0,8 mm and for a sampling length of 2,5 mm, in μm
S_{pr} = residual undercut left by protuberance in mm
$S_{F\,min}$ = minimum factor of safety for bending stress
S_{Fn} = tooth root chord in the critical section, in mm
$S_{H\,min}$ = minimum factor of safety for Hertzian contact stress
Y_D = design factor
Y_F = tooth form factor
$Y_{R\,rel\,T}$ = relative surface finish factor
Y_S = stress concentration factor
Y_{ST} = stress correction factor
Y_x = size factor
Y_β = helix angle factor
$Y_{\delta\,rel\,T}$ = relative notch sensitivity factor
Z_E = material elasticity factor
Z_H = zone factor
Z_R = surface finish factor
Z_V = velocity factor
Z_X = size factor
Z_β = helix angle factor
Z_ε = contact ratio factor
α_{en} = pressure angle at the highest point of single tooth contact, in degrees
α_n = normal pressure angle at reference diameter, in degrees
α_t = transverse pressure angle at reference diameter, in degrees
α_{tw} = transverse pressure angle at pitch circle diameter, in degrees
α_{Fen} = angle for application of load at the highest point of single tooth contact, in degrees
β = helix angle at reference diameter, in degrees
β_b = helix angle at base diameter, in degrees
γ = intermediary factor for the determination of f_{Sh}
ε_α = transverse contact ratio

$$= \frac{g\alpha \cos\beta}{\pi\, m_n \cos\alpha_t}$$

$\varepsilon_{\alpha n}$ = virtual transverse contact ratio
ε_β = overlap ratio

$$= \frac{b \sin\beta}{\pi\, m_n}$$

ε_γ = total contact ratio
ρ_{ao} = tip radius of tool, in mm
ρ_c = relative radius of curvature at pitch point, in mm

$$= \frac{a \sin\alpha_{tw}\, u}{\cos\beta_b\,(1+u)^2}$$

ρ_F = tooth root fillet radius at the contact of the 30° tangent, in mm
σ_y = yield or 0,2 per cent proof stress, in N/mm^2
σ_B = ultimate tensile strength, in N/mm^2
σ_F = bending stress at tooth root, N/mm^2
$\sigma_{F\,lim}$ = endurance limit for bending stress in N/mm^2
σ_{FP} = allowable bending stress at the tooth root, in N/mm^2
σ_H = Hertzian contact stress at the pitch circle, in N/mm^2
$\sigma_{H\,lim}$ = endurance limit for Hertzian contact stress, in N/mm^2
σ_{HP} = allowable Hertzian contact stress, in N/mm^2

Subscript: $_1$ = pinion
$_2$ = wheel
$_0$ = tool

NOTE
a and *z* are considered positive for both external and internal gearing for the purposes of these calculations.

4.2 Tooth form

4.2.1 The tooth profile in the transverse section is to be of involute shape, and the roots of the teeth are to be formed with smooth fillets of radii not less than $0{,}25m_n$.

4.2.2 All sharp edges left on the tips and ends of pinion and wheel teeth after hobbing and finishing are to be removed.

4.3 Tooth loading factors

4.3.1 For values of application factor, K_A, *see* Table 1.4.1.

Table 1.4.1 Values of K_A

Main and auxiliary gears	K_A
Main propulsion – electric motor or gas turbine, reduction gears	1,15
Main propulsion – diesel engine reduction gears:	
Hydraulic coupling or equivalent on input	1,10
High elastic coupling on input	1,30
Other coupling	1,50
Auxiliary Gears:	
Electric, gas turbine and diesel engine drives with hydraulic coupling or equivalent on input	1,00
Diesel engine drives with high elastic coupling on input	1,20
Diesel engine drives with other couplings	1,40

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4.3.2 Load sharing factor, K_γ. When a gear drives two or more mating gears where the total transmitted load is not evenly distributed between the individual meshes, K_γ is to be taken as 1,15, otherwise K_γ is to be taken as 1,0. Alternatively, where measured data exists, a derived value will be considered.

4.3.3 **Dynamic factor, K_v:**

For helical gears with $\varepsilon_\beta \geq 1$:

$$K_v = 1 + Q^2 v z_1 10^{-5} = K_{VB}$$

For helical gears with $\varepsilon_\beta \leq 1$:

$$K_v = K_{va} - \varepsilon_\beta (K_{va} - K_{v\beta})$$

For spur gears:

$$K_v = 1 + 1{,}8\, Q^2 v z_1 10^{-5} = K_{va}$$

where $\dfrac{v z_1}{100} > 14$ for helical gears, and

where $\dfrac{v z_1}{100} > 10$ for spur gears, the value of K_v will be specially considered

NOTE

Q is to be taken as the larger value of Q_1 or Q_2.

4.3.4 **Longitudinal load distribution factors, $K_{H\beta}$ and $K_{F\beta}$:**

$$K_{H\beta} = 1 + \frac{b\, F_{\beta y}\, C\gamma}{2F_t\, K_A\, K_\gamma\, K_v}$$

Calculated values of $K_{H\beta} > 2$ are to be reduced by improved accuracy and helix correction as necessary:

where

$F_{\beta y} = F_{\beta x} - y_\beta$ and

$F_{\beta x} = 1{,}33 f_{Sh} + f_{ma}$

$f_{ma} = \dfrac{2}{3} F_\beta$ at the design stage, or

$f_{ma} = \dfrac{2}{3} F_\beta$ where helix correction has been applied

$f_{Sh} = f_{Sho} \dfrac{F_t\, K_A\, K_\gamma\, K_v}{b}$ where

$f_{Sho} = 23\gamma\ 10^{-3}$ µm mm/N for gears without helix correction or crowning and without end relief, or

$= 12\gamma\ 10^{-3}$ µm mm/N for gears without helix correction but with crowning, *see* Note 1

$= 16\gamma\ 10^{-3}$ µm mm/N for gears without helix correction or crowning but with end relief, where

$\gamma = \left(\dfrac{b}{d_1}\right)$ for single helical and spur gears

$= 3\left(\dfrac{b}{2d_1}\right)^2$ for double helical gears

The following minimum values are applicable, these also being the values where helix correction has been applied:

$f_{Sho} = 10 \times 10^{-3}$ µm mm/N for helical gears, or

$= 5 \times 10^{-3}$ µm mm/N for spur gears

For through-hardened steels and surface hardened steels running on through-hardened steels:

$y_\beta = \dfrac{320}{\sigma_{H\,lim}} F_{\beta x}$ up to an upper limit value of

$y_\beta = \dfrac{12800}{\sigma_{H\,lim}}$ m, and

For surface hardened steels, when

$y_\beta = 0{,}15 F_{\beta x}$ up to an upper limit value of

$y_\beta = 6$ m

$F_{F\beta} = K_{H\beta}\, n$

where

$$n = \frac{\left(\dfrac{b}{h}\right)^2}{1 + \dfrac{b}{h} + \left(\dfrac{b}{h}\right)^2}$$

NOTES

1. $\dfrac{b}{h}$ is to be taken as the smaller of $\dfrac{b_1}{h_1}$ or $\dfrac{b_2}{h_2}$

2. For double helical gears $\dfrac{b}{2}$ is to be substituted for b in the equation for n.

4.3.5 **Transverse load distribution factors, $K_{H\alpha}$ and $K_{F\alpha}$**

$K_{H\alpha} = K_{F\alpha} \geq 1{,}000$

where

$\varepsilon\gamma \leq 2$

$$K_{H\alpha} = \frac{\varepsilon\gamma}{2}\left(0{,}9 + \frac{0{,}4C\gamma\,(f_{pb} - Y_\alpha)\, b}{F_t\, K_A\, K_\gamma\, K_v\, K_{H\beta}}\right)$$

where

$\varepsilon\gamma \leq 2$

$$K_{H\alpha} = 0{,}9 + 0{,}4\sqrt{\frac{2\,(\varepsilon_\gamma - 1)}{\varepsilon_\gamma}}\left(\frac{C_\gamma\,(f_{pb} - y_\alpha)\, b}{F_t\, K_A\, K_\gamma\, K_v\, K_{H\beta}}\right), \text{ but}$$

$K_{H\alpha} \leq \dfrac{\varepsilon_\gamma}{\varepsilon_a Z_\varepsilon^2}$ and

$K_{F\alpha} \leq \dfrac{\varepsilon_\gamma}{0{,}25\varepsilon_\gamma + 0{,}75}$

When tip relief is applied, f_{pb} is to be half of the maximum specified value:

$y_\alpha = \dfrac{160}{\sigma_{H\,lim}} f_{pb}$ for through-hardened steels, when

$y_\alpha \leq \dfrac{6400}{\sigma_{H\,lim}}$ µm and

$y_\alpha = 0{,}075 f_{pb}$ for surface hardened steels, when

$y_\alpha \leq 3$ µm

When pinion and wheel are manufactured from different materials:

$y_\alpha = \dfrac{y_{\alpha 1} + y_{\alpha 2}}{2}$

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NOTE
Tip relief is to take the form of either tip and root relief on the pinion, or tip relief on pinion and wheel.

4.3.6 **Tooth mesh stiffness, C_γ:**

$$C_\gamma = \frac{0,8}{q^1} \cos\beta\,(0,75\varepsilon_\alpha + 0,25) \quad \text{N/mm}\,\mu\text{m}$$

where

$$q^1 = 0,04723 + \frac{0,1551}{z_{n1}} + \frac{0,25791}{z_{n2}} - 0,00635x_1 - \frac{0,11654x_1}{z_{n1}} - 0,00193x_2 - \frac{0,24188x_2}{z_{n2}} + 0,00529x_1^2 + 0,00182x_2^2$$

For internals gears $z_{n2} = \infty$
Other calculation methods for C_γ will be specially considered.

4.4 Tooth loading for surface stress

4.4.1 The Hertzian contact stress, σ_H, at the pitch circle is not to exceed the allowable Hertzian contact stress, σ_{HP}:

$$\sigma_H = Z_H Z_E Z_\varepsilon Z_\beta \sqrt{\frac{F_t\,(u+1)}{d_1\,bu} K_A K_\gamma K_v K_{H\beta} K_{Ha}}$$

and

$$\sigma_{HP} = \frac{\sigma_{H\,lim} Z_R Z_v Z_X}{S_{H\,min}} \text{ for the pinion/wheel combination}$$

where

$$Z_H = \sqrt{\frac{2\cos\beta_b \cos\alpha_{tw}}{\cos^2\alpha_t \sin\alpha_{tw}}}$$

Z_E = 189,8 for steel

$$Z_\varepsilon = \sqrt{\frac{4-\varepsilon_\alpha}{3}(1-\varepsilon_\beta) + \frac{\varepsilon_\beta}{\varepsilon_\alpha}} \text{ for } \varepsilon_\beta < 1 \text{ and}$$

$$Z_\varepsilon = \sqrt{\frac{1}{\varepsilon_\alpha}} \text{ for } \varepsilon_\beta \geq 1$$

$$Z_\beta = \sqrt{\cos\beta}$$

$$Z_R = \left(\frac{1}{R_a}\right)^{0,11} \text{ but } Z_R \leq 1,14$$

Where R_a is the surface roughness value of the tooth flanks. When pinion and wheel tooth flanks differ then the larger value of R_a is to be taken:

$$Z_v = 0,88 + 0,23\left(0,8 + \frac{32}{v}\right)^{-0,5}$$

For values of Z_x, *see* Table 1.4.2
$\sigma_{H\,lim}$, *see* Table 1.4.3
$S_{H\,min}$, *see* Table 1.4.4.

Table 1.4.2 Values of Z_x

Pinion heat treatment		Z_x
Carburised and induction-hardened	$m_n \leq 10$ $10 < m_n < 30$ $30 \leq m_n$	1,00 1,05 – 0,005 m_n 0,9
Nitrided	$m_n < 7,5$ $7,5 < m_n < 30$ $30 \leq m_n$	1,00 1,08 – 0,005 m_n 0,75
Through-hardened	All modules	1,00

Table 1.4.3 Values of endurance limit for Hertzian contact stress, $\sigma_{H\,lim}$

Heat treatment		
Pinion	Wheel	
Through-hardened	Through-hardened	$0,46\sigma_{B2} + 255$
Surface-hardened	Through-hardened	$0,42\sigma_{B2} + 415$
Carburised, nitrided or induction-hardened	Soft bath nitrided (tufftrided)	1000
Carburised, nitrided or induction-hardened	Induction-hardened	$0,88HV_2 + 675$
Carburised or nitrided	Nitrided	1300
Carburised	Carburised	1500

Table 1.4.4 Factors of safety

	$S_{H\,min}$	$S_{F\,min}$
Main propulsion gears	1,40	1,80
Auxiliary gears	1,15	1,40

4.5 Tooth loading for bending stress

4.5.1 The bending stress at the tooth root, σ_F is not to exceed the allowable tooth root bending stress σ_{FP}:

$$\sigma_F = \frac{F_t}{b\,m_n} Y_F Y_S Y_\beta K_A K_\gamma K_v K_{F\beta} K_{F\alpha} \quad \text{N/mm}^2$$

$$\sigma_{FP} = \frac{\sigma_{F\,lim} Y_{ST} Y_{d\,rel\,T} Y_{R\,rel\,T} Y_x}{S_{F\,min} Y_D} \quad \text{N/mm}^2$$

NOTE
If b_1 and b_2 are not equal the load bearing width of the wider face taken is not to exceed that of the smaller plus $2m_n$.

For values of $S_{F\,min}$, *see* Table 1.4.4
$\sigma_{F\,lim}$, *see* Table 1.4.5
Stress correction factor Y_{ST} = 2.

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Table 1.4.5 Values of endurance limit for bending stress, $\sigma_{F\,lim}$

Heat treatment	$\sigma_{F\,lim}$ N/mm^2
Through-hardened carbon steel	$0{,}09\sigma_B + 150$
Through-hardened alloy steel	$0{,}1\sigma_B + 185$
Soft bath nitrided (Tufftrided)	330
Induction hardened	$0{,}35\,HV + 125$
Gas nitrided	390
Carburised A	450
Carburised B	410

NOTES
1. A is applicable for Cr Ni Mo carburising steels.
2. B is applicable for other carburising steels.

4.5.2 **Tooth form factor, Y_F:**

$$Y_F = \frac{6\,\frac{h_F}{m_n}\cos\alpha_{Fen}}{\left(\frac{S_{Fn}}{m_n}\right)^2\cos\alpha_n}$$

where

h_F, α_{Fen} and S_{Fn} are shown in Fig. 1.4.1.

$$\frac{S_{Fn}}{m_n} = z_n\sin\left(\frac{\pi}{3} - \nu\right) + \sqrt{3}\left(\frac{G}{\cos\nu} - \frac{\rho_{ao}}{m_n}\right)$$

where

$$\nu = \frac{2G}{z_n}\tan\nu - H$$

$$G = \frac{\rho_{ao}}{m_n} - \frac{h_{ao}}{m_n} + x$$

$$H = \frac{2}{z_n}\left(\frac{\pi}{2} - \frac{E}{m_n}\right) - \frac{\pi}{3}$$

$$E = \frac{\pi}{4}m_n - h_{ao}\tan\alpha_n + \frac{S_{pr}}{\cos\alpha_n} - (1 - \sin\alpha_n)\frac{\rho_{ao}}{\cos\alpha_n}$$

E, h_{ao}, α_n, S_{pr} and ρ_{ao} are shown in Fig. 1.4.2.

$$\frac{\rho_F}{m_n} = \frac{\rho_{ao}}{m_n} + \frac{2G^2}{\cos\nu\,(z_n\cos^2\nu - 2G)}$$

$$d_{en} = \frac{2z}{|z|}\left\{\left[\sqrt{\left(\frac{d_n}{2}\right)^2 - \left(\frac{d_{bn}}{2}\right)^2} - \frac{\pi d\cos\beta\cos\alpha_n}{|z|}(\varepsilon_{\alpha n} - 1)\right]^2 + \left(\frac{d_{bn}}{2}\right)^2\right\}^{1/2}$$

where

$$d_{an} = d_n + d_a - d$$

$$d_n = \frac{d}{\cos^2\beta_b}$$

$$d_{bn} = d_n\cos\alpha_n$$

$$\varepsilon_{\alpha n} = \frac{d}{\cos^2\beta_b}$$

$$\gamma_e = \frac{\frac{\zeta\pi}{2} + 2x\tan\alpha_n}{z_n} + \text{inv.}\,\alpha_n - \text{inv.}\,\alpha_{en}$$

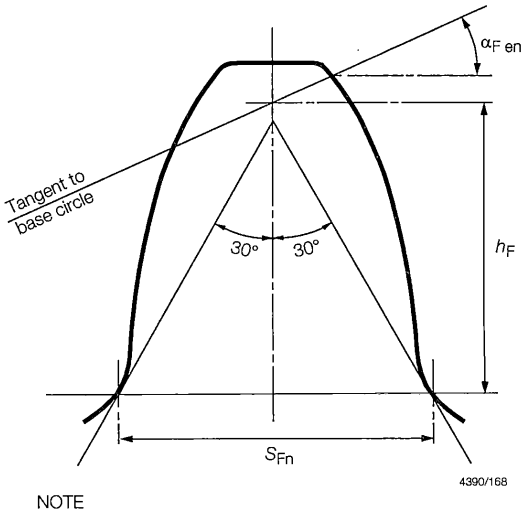
where

$$\alpha_{en} = \arccos\frac{d_{bn}}{d_{en}}$$

$$\frac{h_F}{m_n} = \frac{1}{2}\left[(\cos\gamma_e - \sin\gamma_e\tan\alpha_{F\,en})\frac{d_{en}}{m_n} - z_n\cos\left(\frac{\pi}{3} - \nu\right) - \frac{G}{\cos\nu} + \frac{\rho_{ao}}{m_n}\right]$$

where

$$\alpha_{F\,en} = \alpha_{en} - \gamma_e.$$



NOTE
For helical gears the normal section is taken with the virtual number of teeth

Fig. 1.4.1 Normal tooth section

4.5.3 For internal tooth forms the form factor is calculated, as an approximation, for a substitute gear rack with the form of the basic rack in the normal section, but having the same tooth depth as the internal gear:

$$\frac{S_{Fn2}}{m_n} = 2\left[\frac{\pi}{4} + \tan\alpha\left(\frac{h_{ao2} - \rho_{ao2}}{m_n}\right) + \left(\frac{\rho_{ao2} - S_{pr}}{m_n}\right) - \frac{\rho_{ao2}}{m_n}\cos\frac{\pi}{6}\right], \text{ and}$$

$$\frac{h_{F2}}{m_n} = \frac{d_{en2} - d_{fn2}}{2m_n} - \left[\frac{\pi}{4} + \left(\frac{h_{ao2}}{m_n} - \frac{d_{en2} - d_{fn2}}{2m_n}\right)\tan\alpha_n\right]\tan\alpha_n - \frac{\rho_{ao2}}{m_n}\left(1 - \sin\frac{\pi}{6}\right)$$

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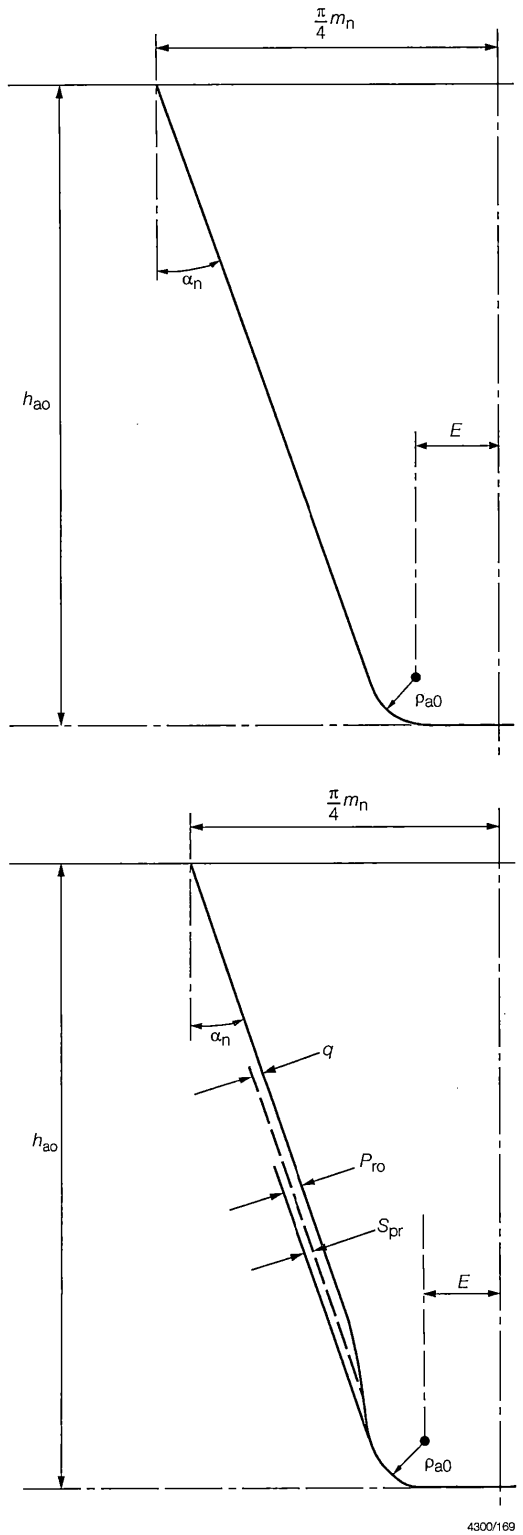

NOTES
1. Dimensions shown in rack profile of tooth
2. $S_{pr} = P_{ro} - q$

Fig. 1.4.2 External tooth forms

where

$\alpha_{F\,en}$ is taken as being equal to α_n

$$\rho_{F2} = \frac{\rho_{ao2}}{2}$$

d_{en2} is calculated as d_{en} for external gears, and

$$d_{fn} = d - d_f - d_n$$

4.5.4 Stress concentration factor, Y_s

$$Y_s = (1{,}2 + 0{,}13L)\, q_s^{\left(\frac{1}{1{,}21 + 2.3/L}\right)}$$

where

$$L = \frac{S_{Fn}}{h_F}$$

$$q_S = \frac{S_{Fn}}{2\rho_F}$$

when

$q_s < 1$ the value of Y_s is to be specially considered.

The formula for Y_s is applicable to external gears with $\alpha_n = 20°$ but may be used as an approximation for other pressure angles and internal gears.

4.5.5 Helix angle factor Y_β

$$Y_\beta = 1 - \left(\varepsilon_\beta \frac{\beta}{120}\right), \text{ if } \varepsilon_\beta > 1 \text{ let } \varepsilon_\beta = 1$$

but

$$Y_b \geq 1 - 0{,}25\varepsilon_\beta \geq 0{,}75$$

4.5.6 Relative notch sensitivity factor, $Y_{\delta\,rel\,T}$

$Y_{\delta\,rel\,T} = 1 + 0{,}036\,(q_s - 2{,}5)\left(1 - \frac{\sigma_y}{1200}\right)$ for through-hardened steels

$= 1 + 0{,}008\,(q_s - 2{,}5)$ for carburised and induction-hardened steels, and

$= 1 + 0{,}04\,(q_s - 2{,}5)$ for nitrided steels.

4.5.7 Relative surface finish factor, $Y_{R\,rel\,T}$

$Y_{R\,rel\,T} = 1{,}674 - 0{,}529\,(6R_a + 1)^{0{,}1}$ for through-hardened, carburised and induction hardened steels, and

$= 4{,}299 - 3{,}259\,(6R_a + 1)^{0{,}005}$ for nitrided steels.

4.5.8 Size factor, Y_x

$Y_x = 1{,}00$, when $m_n \leq 5$

$= 1{,}03 - 0{,}006m_n$ for through-hardened steels

$= 0{,}85$, when $m_n \geq 30$

$= 1{,}05 - 0{,}01\,m_n$ for surface-hardened steels

$= 0{,}80$, when $m_n \geq 25$.

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4.5.9 **Design factor, Y_D**

Y_D = 0,83 for gears treated with a controlled shot peening process

= 1,5 for idler gears

= 1,25 for shrunk on gears, or

$$= 1 + \frac{0{,}2 d_s^2\, d\, P_r\, b}{F_t\, \sigma_{F\,lim}\, (d_f^2 - d_s^2)}$$, otherwise

= 1,00, or any combination of the above – e.g. Y_D = (0,83 x 1,5) for an idler gear treated with a controlled shot peening process.

4.6 Factors of safety

4.6.1 Factors of safety are shown in Table 1.4.4.

4.7 Design of enclosed gear shafting

4.7.1 The following symbols apply:

P in kW and *R* in rpm, *see* 1.2.1.

L = span between shaft bearing centres, in mm

α_n = normal pressure angle at the gear reference diameter, in degrees

β = helix angle at the gear reference diameter, in degrees

d_w = pitch circle diameter of the gear teeth, in mm

σ_u = specified minimum tensile strength of the shaft material, in N/mm^2

NOTE

Numerical value used for σ_u is not to exceed 800 N/mm^2 for gear and thrust shafts and 1100 N/mm^2 for quill shafts.

4.7.2 This sub-Section is applicable to the main and ancillary transmission shafting, enclosed within the gearcase.

4.7.3 The diameter of the enclosed gear shafting adjacent to the pinion or wheel is to be not less than the greater of d_b or d_t, where:

$$d_b = 365 \left(\frac{P\,L}{R\, d_w\, S_b} \right)^{1/3} \left(1 + \left(\frac{\tan \alpha_n}{\cos\beta} + \frac{\tan\beta\, d_w}{L} \right)^2 \right)^{1/6}$$

$$d_t = 365 \left(\frac{P}{R\, S_s} \right)^{1/3}$$

where

$S_b = 45 + 0{,}24\,(\sigma_u - 400)$ and

$S_s = 42 + 0{,}09\,(\sigma_u - 400)$.

4.7.4 For the purposes of the above it is assumed that the pinion or wheel is mounted symmetrically spaced between bearings.

4.7.5 Outside a length equal to the required diameter at the pinion or wheel, the diameter may be reduced, if applicable, to that required for d_t.

4.7.6 For bevel gear shafts, where a bearing is located adjacent to the gear section, the diameter of the shaft is to be not less than d_t. Where a bearing is not located adjacent to the gear the diameter of the shaft will be specially considered.

4.7.7 The diameter of quill shaft (not axially constrained and subject only to external torsional loading) is to be not less than given by the following formula:

$$\text{Diameter of quill shaft} = 101 \sqrt[3]{\frac{P400}{R\,\sigma_u}} \text{ mm.}$$

4.7.8 Where a shaft, located within the gearcase, is subject to the main propulsion thrust, the diameter at the collars of the shaft transmitting torque, or in way of the axial bearing where a roller bearing is used as a thrust bearing, is to be not less than $1{,}1 d_t$. For thrust bearings located outside the gearcase, *see* Chapter 2.

4.8 Gear wheels

4.8.1 In general, arrangements are to be made so that the interior structure of the wheel may be examined. Alternative proposals will be specially considered.

4.9 External shafting and components

4.9.1 For shafting external to the gearbox and other components ancillaries, *see* Pt 11, Ch 2.

4.10 Clutch actuation

4.10.1 Where a clutch is fitted in the transmission, normal engagement shall not cause excessive stresses in the transmission or the driven machinery. Inadvertent operation of any clutch is not to produce dangerously high stresses in the transmission or driven machinery.

4.11 Gearcases

4.11.1 Gearcases and their supports are to be designed sufficiently stiff such that misalignment at the mesh due to movements of the external foundations and the thermal effects under all conditions of service do not disturb the overall tooth contact.

4.11.2 Inspection openings are to be provided at the peripheries of gearcases to enable the teeth of pinions and wheels to be readily examined. Where the construction of gearcases is such that sections of the structure cannot be readily be moved for inspection purposes, access openings of adequate size are also to be provided at the ends of the gearcases to permit examination of the structure of the wheels. Their attachment to the shafts is to be capable of being examined by removal of bearing caps or by equivalent means.

4.11.3 For gearcases fabricated by fusion welding the carbon content of the steels should generally not exceed 0,23 per cent. Steels with higher carbon content may be approved subject to satisfactory results from weld procedure tests.

4.11.4 Gearcases are to be stress relieved upon completion of all welding.

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4.11.5 Gearcases manufactured from material other than steel will be considered upon full details being submitted.

4.12 Backlash

4.12.1 The normal backlash between any pair of gears should not be less than:

$$\frac{a\alpha_n}{90\,000} + 0{,}1 \text{ mm}$$

4.12.2 The normal backlash is not to exceed three times the value calculated in 4.12.1.

4.13 Alignment

4.13.1 Reduction gears with sleeve bearings, for main and auxiliary purposes are to be provided with means for checking the internal alignment of the various elements in the gearcases.

4.13.2 In the case of separately mounted reduction gearing for main propulsion, means are to be provided by the gear manufacturer to enable the Surveyors to verify that no distortion of the gearcase has taken place, when chocked and secured to its seating on board the craft.

■ *Section 5* Piping systems for gearing

5.1 General

5.1.1 Piping systems for gearing are to comply with the general design requirements given in Part 15.

5.1.2 The specific requirements for lubricating/hydraulic oil systems and standby arrangements are given in Part 15.

5.1.3 Lubricating oil lines are to be screened, or otherwise suitably protected, to avoid oil spray or oil leakages onto hot surfaces, into machinery air intakes or other sources of ignition. The number of joints in such piping systems should be kept to a minimum. Flexible pipes are to be of an approved type.

5.2 Pumps

5.2.1 Where lubricating oil for the reduction gearing is circulated under pressure, pump standby arrangements are to be provided in accordance with Part 15.

5.3 Filters

5.3.1 Where the lubricating oil for the reduction gearing is circulated under pressure, provision is to be made for the efficient filtration of the oil. The filters are to be capable of being cleaned without stopping the gear set or reducing the supply of filtered oil to the gearing.

■ *Section 6* Control and monitoring

6.1 General

6.1.1 Control engineering systems are to be in accordance with Part 16.

6.1.2 All main and auxiliary gear units, intended for essential services, are to be provided with means of indicating the lubricating oil supply pressure. Audible and visual alarms are to be fitted to give warning of an appreciable reduction in pressure of the lubricating oil supply. These alarms are to be actuated from the outlet side of any restrictions, such as filters, coolers, etc.

6.2 Unattended machinery

6.2.1 Where the machinery is fitted with automatic or remote controls so that under normal operating conditions it does not require any manual intervention by the operators, gear units are to be provided with the alarms and safety arrangements required by 6.2.2 and Table 1.6.1. The sensors and circuits utilised for the second stage alarm and automatic shut down in Table 1.6.1 are to be independent of those required for the first stage alarm.

Table 1.6.1 Alarms and safeguards

Item	Alarm	Note
Lubricating oil sump level	Low	
Lubricating oil inlet pressure*	1st Stage Low	
	2nd Stage Low	Automatic shutdown of engine
Lubricating oil inlet temperature*	High	
Thrust bearing temperature*	High	
NOTE For transmitted powers of 1500 kW or less, only the items marked * are required.		

6.2.2 Where the gear unit is required to be provided with a standby pump, the standby pump is to start automatically if the discharge pressure from the working pump falls below a predetermined value.

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Section 7
Requirements for craft which are not required to comply with the HSC Code

7.1 Details to be submitted

7.1.1 Failure mode effect analysis is not required for craft which do not require to comply with the HSC Code.

7.1.2 Mass elastic schematic showing gear unit torsional data is only required for gears with an input power greater than 500 kW, *see* 2.2.2 and Part 13.

7.2 Design of gearing

7.2.1 Where they are not intended for passenger carrying duties, the gearing factors of safety for yachts, service craft less than 24 m and ACVs are to satisfy Table 1.7.1.

Table 1.7.1 Factors of safety

	$S_{H\,min}$	$S_{F\,min}$
Main propulsion gears for yachts, etc., single screw	1,25	1,50
Main propulsion gears for yachts, etc., multiple screw	1,20	1,45

7.3 Piping systems

7.3.1 For service craft less than 24 m and for yachts the requirements of 5.2.1 and 5.3.1 do not apply. These craft are to have gearing provided with an efficient lubricating oil pump, a cooler where necessary, and a filter arrangement which can be cleaned.

7.4 Control and monitoring

7.4.1 For service craft less than 24 m the alarms required by 6.2.1 are not required.

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Section

1 **General requirements**

2 **Particulars to be submitted**

3 **Materials**

4 **Design and construction**

5 **Control and monitoring**

6 **Requirements for craft which are not required to comply with the HSC Code**

■ *Section 1* General requirements

1.1 Application

1.1.1 This Chapter is to be read in conjunction with the General Requirements for Machinery in Part 9.

1.1.2 This Chapter gives the requirements for the dimensions of transmission shafts, couplings, coupling bolts, keys, keyways, sternbushes and other associated components of main propulsion shafting.

1.1.3 The diameters may require to be modified as a result of alignment considerations and vibration characteristics (*see* Part 13), or the inclusion of stress raisers, other than those contained in this Chapter.

1.1.4 For shafting enclosed within an gearbox, *see* Ch 1,4.7.

1.1.5 For diesel engine crankshaft and turbine rotor shafting, *see* Part 10.

1.2 Power ratings

1.2.1 In this Chapter, the dimensions of main propulsion component are determined from shaft power, *P*, in kW, and revolutions per minute, *R*, and general requirements defined in Pt 9, Ch 1,1.

1.2.2 For auxiliary machinery, the maximum continuous shaft power and corresponding revolutions per minute which will be used in service are to be stated.

1.3 Clutches

1.3.1 Clutches for single engine propulsion plants are to be provided with a suitable means for emergency operation in the event of loss of operating fluid systems. Their suitability for short term high power operation is to be demonstrated.

1.4 Safety

1.4.1 Means are to be provided such that in the event of a failure to a shaft or coupling the occupants of the craft are not endangered, either directly or by damaging the craft or its systems. Where necessary, guards may be fitted to achieve compliance with these requirements.

■ *Section 2* Particulars to be submitted

2.1 Plans

2.1.1 At least three copies of the following plans are to be submitted:

- Shafting arrangement.
- Thrust shaft.
- Intermediate shafting.
- Tube shaft, where applicable.
- Screwshaft.
- Screwshaft oil gland.
- Screwshaft protection.
- Sternbush and arrangement in housing.
- Couplings.
- Coupling bolts.
- Flexible coupling.
- Cardan shafts.

2.1.2 The shafting arrangement plan is to indicate the relative position of the main engine(s), flywheel, flexible coupling(s), gearing, thrust block, line shafting and bearing(s), sterntube, 'A' bracket and propulsion device, as applicable.

2.2 Calculations and specifications

2.2.1 The following calculations and specifications are to be submitted:

- Calculations, or relevant documentation indicating the suitability of all components for short term high power operation, where applicable.
- Where undertaken as an alternative to the requirements of this Chapter, fatigue endurance calculations of all components according to Part 9.
- Vibration analysis and alignment analysis as required by Part 13.
- The material specifications, including the minimum specified tensile strength of each shaft and coupling component are to be stated. Where corrosion resistant material not included in Table 2.4.1 is used for unprotected screwshafts the corrosion fatigue strength in sea-water is to be stated together with the chemical composition and mechanical properties.
- Where it is proposed to use composite (non-metallic) shafts, details of materials, resin, lay-up procedure and documentary evidence of fatigue endurance strength.

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■ *Section 3* Materials

3.1 Materials for shafts

3.1.1 Components are to be manufactured and tested in accordance with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

3.1.2 Where it is proposed to use alloy steel forgings, particulars of the chemical composition, mechanical properties and heat treatment are to be submitted for approval. For main propulsion shafting, not exposed to sea water, in alloy steels, the specified minimum tensile strength is not to exceed 800 N/mm^2 and for other forgings is not to exceed 1100 N/mm^2.

3.1.3 Unprotected screwshafts and tubeshafts exposed to sea-water are in general to be manufactured, from corrosion resistant ferrous or non-ferrous material, such as those indicated in Table 2.4.1.

3.1.4 In the selection of materials for shafts, keys, locking nuts etc., consideration is to be given to their compatibility with the proposed propeller material.

3.1.5 Where shafts are manufactured from composite material the process is to be approved.

■ *Section 4* Design and construction

4.1 Fatigue strength analysis

4.1.1 As an alternative to the following requirements, a fatigue strength analysis of components can be submitted indicating a factor of safety of 1,5 at the design loads, based on a suitable fatigue failure criteria. The effects of stress concentrations, material properties and operating environment are to be taken into account.

4.2 Intermediate shafts

4.2.1 The diameter, d, of the intermediate shaft is to be not less than:

$$d = Fk \sqrt[3]{\frac{P}{R}\left(\frac{560}{\sigma_u + 160}\right)} \text{ mm}$$

where

k = 1,0 for shafts with integral coupling flanges complying with 4.8 or shrink fit couplings

= 1,10 for shafts with keyways, where the fillet radii in the transverse section of the bottom of the keyway are not less than 0,0125d

= 1,10 for shafts with transverse or radial holes where the diameter of the hole does not exceed 0,3d

= 1,20 for shafts with longitudinal slots having a length of not more than 1,4d and a width of not more than 0,2d where d, is determined with k = 1,0

F = 95 for turbine installations, electric propulsion installations and diesel engine installations with slip type couplings

= 100 for other diesel engine installations

P and R are as defined in Part 9

σ_u = specified minimum tensile strength of the shaft material, in N/mm^2.

4.2.2 Beyond a length of 0,2d from the end of a keyway, transverse hole or radial hole and 0,3d from the end of a longitudinal slot, the diameter of the shaft may be gradually reduced to that determined with k = 1,0.

4.2.3 For shafts with design features other than stated as above, the value of k will be specially considered.

4.2.4 The Rule diameter of the intermediate shaft for diesel engines, turbines and electric propelling motors may be reduced by 3,5 per cent for craft classed G1 (Service Group 1), *see* Pt 1, Ch 2,3.5.

4.3 Thrust shafts

4.3.1 The diameter at the collars of the thrust shaft transmitting torque or in way of the axial bearing where a roller bearing is used as a thrust bearing is to be not less than that required for the intermediate shaft in accordance with 4.2 with a k value of 1,10. Beyond a length equal to the thrust shaft diameter from the collars, the diameter may be tapered down to that required for the intermediate shaft with a k value of 1,0. For the purpose of the foregoing calculations, σ_u is to be taken as the minimum tensile strength of the thrust shaft material, in N/mm^2.

4.4 Screwshafts and tube shafts

4.4.1 Screwshafts and tube shafts, (i.e the shaft which passes through the sterntube, but does not carry the propeller), made from carbon manganese steel are to be protected by a continuous bronze liner, where exposed to sea water. Alternatively, the liner may be omitted provided the shaft is arranged to run in an oil lubricated bush with an approved oil sealing gland at the after end. Lengths of shafting between sterntubes and brackets, which are readily visible when the craft is slipped, may be protected by coatings of an approved type.

4.4.2 Means for the protection of screwshafts and tube-shafts are not required when the shafts are made of corrosion resistant material.

4.4.3 The diameter, d_p of the protected forged steel screwshaft immediately forward of the forward face of the propeller boss or, if applicable, the forward face of the screw-shaft flange, is to be not less than:

$$d_p = 100k \sqrt[3]{\frac{P}{R}\left(\frac{560}{\sigma_u + 160}\right)} \text{ mm}$$

where

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k = 1,22 for a shaft carrying a keyless propeller, or where the propeller is attached to an integral flange, and where the shaft is fitted with a continuous liner, a coating of an approved type, or is oil lubricated and provided with an approved type of oil sealing gland

= 1,26 for a shaft carrying a keyed propeller and where the shaft is fitted with a continuous liner, a coating of an approved type, or is oil lubricated and provided with an approved type of oil sealing gland

P and R are as defined in Part 9

σ_u = specified minimum tensile strength of the shaft material, in N/mm^2 but is not to be taken as greater than 600 N/mm^2.

4.4.4 The diameter, d_p of the screwshaft determined in accordance with 4.4.3 is to extend over a length not less than that to the forward edge of the bearing immediately forward of the propeller or $2{,}5d_p$ whichever is the greater.

4.4.5 The diameter of the portion of the screwshaft and tube shaft forward of the length required by 4.4.4 to the forward end of the stern tube seal is to be determined in accordance with 4.4.3 with a k value of 1,15. The change of diameter from that determined with k = 1,22 or 1,26 to that determined with k = 1,15 should be gradual.

4.4.6 Screwshafts which run in sterntubes and tube shafts may have the diameter forward of the forward stern tube seal gradually reduced to the diameter of the intermediate shaft. Abrupt changes in shaft section at the screwshaft/tube shaft to intermediate shaft couplings are to be avoided.

4.4.7 The diameter of unprotected screwshafts and tube shafts of materials having properties as shown in Table 2.4.1 is to be not less than:

$$d_{up} = 128A\sqrt[3]{\frac{P}{R}}$$

where

'A' is taken from Table 2.4.1 and

P and R are as defined in Part 9.

Table 2.4.1 Provisional 'A' Value for use in unprotected screwshaft formula

Material	'A' Value
Stainless steel type 316 (austenitic)	0,71
Stainless steel type 431 (martensitic)	0,69
Manganese bronze	0,8
Aluminium bronze	0,65
Nickel copper alloy – monel 400	0,65
Nickel copper alloy – monel K 500	0,55
Duplex steels	0,49

4.4.8 The diameter of unprotected screwshafts of materials having properties as shown in Table 2.4.1 forward of the forward stern tube seal is to be determined in accordance with 4.4.7 or 4.4.3, whichever is less.

4.5 Hollow shafts

4.5.1 Where the thrust, intermediate, tube shafts and screwshafts have central holes having a diameter greater than 0,4 times the outside diameter, the equivalent diameter, d_e, of a solid shaft is not to be less than the Rule size, d, (of a solid shaft), where d_e is given by:

$$d_e = d_o\sqrt[3]{1-\left(\frac{d_i}{d_o}\right)^4}$$

where

d_o = proposed outside diameter, in mm

d_i = diameter of central hole; in mm.

4.5.2 Where the diameter of the central hole does not exceed 0,4 times the outside diameter, the diameter is to be calculated in accordance with the appropriate requirements for a solid shaft.

4.6 Cardan shafts

4.6.1 Cardan shafts, used in installations having more than one propulsion shaftline, are to be of an approved design, suitable for the designed operating conditions including short term high power operation. Consideration will be given to accepting the use of approved cardan shafts in single propulsion unit applications if a complete spare interchangeable end joint is provided on board.

4.6.2 Cardan shaft ends are to be contained within substantial tubular guards that also permit ready access for inspection and maintenance.

4.7 Coupling bolts

4.7.1 Close tolerance fitted bolts transmitting shear are to have a diameter, d_b, at the flange joining faces of the couplings not less than:

$$d_b = \sqrt{\frac{240}{nD}\,\frac{10^6}{\sigma_u}\,\frac{P}{R}}\ \text{mm}$$

where

n = number of bolts in the coupling

D = pitch circle diameter of bolts, in mm

σ_u = specified minimum tensile strength of bolts, in N/mm^2

P and R are as defined in Part 9.

4.7.2 At the joining faces of couplings, other than within the crankshaft and at the thrust shaft/crankshaft coupling, the Rule diameter of the coupling bolts may be reduced by 5,2 per cent for craft classed exclusively for smooth water service.

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4.7.3 Where dowels or expansion bolts are fitted to transmit torque in shear they are to comply with the requirements of 4.7.1. The expansion bolts are to be installed, and the bolt holes in the flanges are to be correctly aligned in accordance with manufacturer's instructions.

4.7.4 The minimum diameter of tap bolts or of bolts in clearance holes at the joining faces of coupling flanges, pretensioned to 70 per cent of the bolt material yield strength value, is not to be less than:

$$d_R = 1{,}348 \sqrt{\left(\frac{120\,10^6 F P (1 + C)}{R D} + Q\right) \frac{1}{n \sigma_y}}$$

where d_R is taken as the lesser of:

(a) Mean of effective (pitch) and minor diameters of the threads.

(b) Bolt shank diameter away from threads. (Not for waisted bolts which will be specially considered.)

P and R are defined in Part 9.

F = 2,5 where the flange connection is not accessible from within the craft
= 2,0 where the flange connection is accessible from within the craft

C = ratio of vibratory/mean torque values at the rotational speed being considered

D = pitch circle diameter of bolt holes, in mm

Q = external load on bolt in N (+ve tensile load tending to separate flange, –ve)

n = number of tap or clearance bolts

σ_y = bolt material yield stress in N/mm^2.

4.7.5 Consideration will be given to those arrangements where the bolts are pretensioned to loads other than 70 per cent of the material yield strength.

4.7.6 Where clamp bolts are fitted they are to comply with the requirements of 4.7.4 and are to be installed, and the bolt holes in the flanges correctly aligned, in accordance with manufacturer's instructions.

4.8 Flange connections of couplings

4.8.1 The minimum thicknesses of the coupling flanges are to be equal to the diameters of the coupling bolts at the face of the couplings as required by 4.7.1, and for this purpose the minimum tensile strength of the bolts is to be taken as equivalent to that of the shafts. For intermediate, thrust shafts, and the inboard end of of the screwshaft, the thickness of the coupling flange is in no case to be less than 0,20 of the diameter of the intermediate shaft as required by 4.2.1.

4.8.2 The fillet radius at the base of the coupling flange, integral with the shaft, is to be not less than 0,08 of the diameter of the shaft at the coupling. The fillets are to have a smooth finish and are not to be recessed in way of nut and bolt heads.

4.8.3 Where the propeller is attached by means of a flange, the thickness of the flange is to be not less than 0,25 of the actual diameter of the adjacent part of the screwshaft. The fillet radius at the base of the coupling flange is to be not less than 0,125 of the diameter of the shaft at the coupling.

4.8.4 All couplings which transmit torque are to be of approved dimensions.

4.8.5 Where couplings are separate from the shafts, provision is to be made to resist the astern pull.

4.8.6 Where a coupling is shrunk on to the parallel portion of a shaft or is mounted on a slight taper, e.g. by means of the oil pressure injection method, the assembly is to meet the requirements of 4.11.

4.9 Tooth couplings

4.9.1 The contact stress, S_c, at the flanks of mating teeth of a gear coupling is not to exceed that given in Table 2.4.2, where

$$S_c = \frac{24{,}10^6 P}{R d_p b h z} \text{ N/mm}^2$$

where

P and R are defined in Part 9.

d_p = pitch circle diameter of coupling teeth, in mm

b = tooth facewidth, in mm

h = tooth height, in mm

z = number of teeth (per coupling half).

Table 2.4.2 Allowable S_c values

Tooth material surface treatment	Allowable S_c Value N/mm^2
Surface hardened teeth	19
Through hardened teeth	11

4.9.2 Where experience has shown that under similar operating and alignment conditions, a higher tooth loading can be accommodated full details are to be submitted for consideration.

4.10 Flexible couplings

4.10.1 Details of flexible couplings are to be submitted together with the manufacturer's rating capacity, for the designed operating conditions including short term high power operation. Verification of coupling characteristics will be required.

4.10.2 In determining the allowable mean, maximum and vibratory torque ratings consideration of the mechanical properties of the selected elastic element type in compression, shear and fatigue loading together with heat absorption/ generation is to be given.

4.10.3 In determining the allowable torque ratings of the steel spring couplings, consideration of the material mechanical properties to withstand fatigue loading and overheating is to be given.

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4.11 Interference fit assemblies

4.11.1 The interference fit assembly is to have a capacity to transmit a torque of $S.T_{max}$ without slippage.

NOTE

For guidance purposes only $T_{max} = T_{mean}\ (1 + C)$

where

C is to be taken from Table 2.4.3

S = 2,0 for assemblies accessible from within the vessel

= 2,5 for assemblies not accessible from within the vessel.

Table 2.4.3 'C' values for guidance purposes

Coupling location	C
High Speed Shafting — I.C engine driven	0,3
High Speed Shafting — Electric Motor or Turbine driven	0,1
Low Speed Shafting — main or PTO stage gearing	0,1

4.11.2 The effect of any axial load acting on the assembly is to be considered.

4.11.3 The resulting equivalent von Mises stress in the assembly is not to be greater than the yield strength of the component material.

4.11.4 Reference marks are to be provided on the adjacent surfaces of parts secured by shrinkage alone.

4.12 Keys and keyways for propeller connections

4.12.1 Round ended or sled-runner ended keys are to be used, and the keyways in the propeller boss and cone of the screwshaft are to be provided with a smooth fillet at the bottom of the keyways. The radius of the fillet is to be at least 0,0125 of the diameter of the screwshaft at the top of the cone. The sharp edges at the top of the keyways are to be removed.

4.12.2 Two screwed pins are to be provided for securing the key in the keyway, and the forward pin is to be placed at least one-third of the length of the key from the end. The depth of the tapped holes for the screwed pins is not to exceed the pin diameter, and the edges of the holes are to be slightly bevelled. The omission of pins for keys for small diameter shafts will be specially considered.

4.12.3 The distance between the top of the cone and the forward end of the keyway is to be not less than 0,2 of the diameter of the screwshaft at the top of the cone.

4.12.4 The effective sectional area of the key in shear, is to be not less than:

$$\frac{155d^3}{\sigma_u d_1}\ \text{mm}^2$$

where

d = diameter, in mm, required for the intermediate shaft determined in accordance with 4.2, based on material having a specified minimum tensile strength of 400 N/mm^2 and $k = 1$

d_1 = diameter of shaft at mid-length of the key, in mm

σ_u = specified minimum tensile strength (UTS) of the key material, N/mm^2.

4.12.5 The effective area in crushing of key, shaft or boss is to be not less than:

$$\frac{24d^3}{\sigma_y d_1}\ \text{mm}^2$$

where

σ_y = yield strength of key, shaft or boss material as appropriate, N/mm^2.

4.13 Keys and keyways for inboard shaft connections

4.13.1 Round ended keys are to be used and the keyways are to be provided with a smooth fillet at the bottom of the keyways. The radius of the fillet is to be at least 0,0125 of the diameter of the shaft at the coupling. The sharp edges at the top of the keyways are to be removed.

4.13.2 The effective area of the key in shear, A, is to be not less than:

$$A = \frac{126d^3}{\sigma_u d_1}\ \text{mm}^2$$

where

d = diameter, in mm, required for the intermediate shaft determined in accordance with 4.2, based on material having a specified minimum tensile strength of 400 N/mm^2 and $k = 1$

d_1 = diameter of shaft at mid-length of the key, in mm

σ_u = specified minimum tensile strength (UTS) of the key material, N/mm^2

Alternatively, consideration will be given to keys conforming to the design requirements of a recognised National Standard.

4.14 Corrosion resistant liners on shafts

4.14.1 Liners may be bronze, gunmetal, stainless steel or other approved alloy.

4.14.2 The thickness, t, of liners fitted on screwshafts or on tube shafts, in way of the bushes, is to be not less, when new, than given by the following formula:

$$t = \frac{D + 230}{32}\ \text{mm}$$

where

t = thickness of the liner, in mm

D = diameter of the screwshaft or tube shaft under the liner, in mm.

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4.14.3 The thickness of a continuous liner between the bushes is to be not less than $0,75t$.

4.14.4 Continuous liners are to be fabricated or cast in one piece.

4.14.5 Where liners consist of two or more lengths, these are to be butt welded together. In general, the lead content of the gunmetal of each length forming a butt welded liner is not to exceed 0,5 per cent. The composition of the electrodes or filler rods is to be substantially lead-free.

4.14.6 The circumferential butt welds are to be of multi-run, full penetration type. Provision is to be made for contraction of the weld by arranging for a suitable length of the liner containing the weld, if possible about three times the shaft diameter, to be free of the shaft. To prevent damage to the surface of the shaft during welding, a strip of heat resisting material covered by a copper strip should be inserted between the shaft and the liner in way of the joint. Other methods for welding this joint may be accepted if approved. The welding is to be carried out by an approved method and to the Surveyor's satisfaction.

4.14.7 Each continuous liner or length of liner is to be tested by hydraulic pressure to 2,0 bar after rough machining.

4.14.8 Liners are to be carefully shrunk onto the shafts by hydraulic pressure. Pins are not to be used to secure the liners.

4.14.9 Effective means are to be provided for preventing water from reaching the shaft at the part between the after end of the liner and the propeller boss.

4.15 Intermediate bearings

4.15.1 Long unsupported lengths of shafting are to be avoided by the fitting of steady bearings at suitable positions, *see* Part 13.

4.16 Sternbushes and sterntube arrangement

4.16.1 Where the sterntube or sternbushes are to be installed using a resin, of an approved type, the following requirements are to be met:

(a) Pouring and venting holes are to be provided at opposite ends with the vent hole at the highest point.

(b) The minimum radial gap occupied by the resin is to be not less than 6 mm at any one point with a nominal resin thickness of 12 mm.

(c) In the case of oil lubricated sterntube bearings, the arrangement of the oil grooves is to be such as to promote a positive circulation of oil in the bearing.

(d) Provision is to be made for the remote measurement of the temperature at the aft end of the aft bearing, with indication and alarms at the control stations.

4.16.2 The length of the bearing in the sternbush next to and supporting the propeller is to be as follows:

(a) For water lubricated bearings which are lined with rubber composition or staves of approved plastics material, the length is to be not less than four times the diameter required for the screwshaft under the liner.

(b) For water lubricated bearings lined with two or more circumferentially spaced sectors, of an approved plastics material, without axial grooves in the lower half, the length of the bearing is to be such that the nominal bearing pressure will not exceed 0,55 N/mm^2. The length of the bearing is to be not less than twice its diameter.

(c) For bearings which are white-metal lined, oil lubricated and provided with an approved type of oil sealing gland, the length of the bearing is to be approximately twice the diameter required for the screwshaft and is to be such that the nominal bearing pressure will not exceed 0,8 N/mm^2. The length of the bearing is to be not less than 1,5 times its diameter.

(d) For bearings of cast iron and bronze which are oil lubricated and fitted with an approved oil sealing gland, the length of the bearing is, in general, to be not less than four times the diameter required for the screwshaft.

(e) Oil lubricated non-metallic bearings are to be manufactured from an approved material. The length of the bearing is to be such that the maximum approved bearing pressure is not exceeded for any limiting length to diameter ratio.

4.16.3 Sternbushes are to be adequately secured in housings.

4.16.4 Forced water lubrication is to be provided for all bearings lined with rubber or plastics. The supply of water may come from a circulating pump or other pressure source. Flow indicators are to be provided for the water service to plastics and rubber bearings. The water grooves in the bearings are to be of ample section and of a shape which will be little affected by weardown, particularly for bearings of the plastics type.

4.16.5 The shut-off valve or cock controlling the supply of water is to be fitted directly to the after peak bulkhead, or to the sterntube where the water supply enters the sterntube forward of the bulkhead.

4.16.6 Oil sealing glands must be capable of accommodating the effects of differential expansion between hull and line of shafting for all sea temperatures in the proposed area of operation. This requirement applies particularly to those glands which span the gap and maintain oiltightness between the sterntube and the propeller boss.

4.16.7 Where a tank supplying lubricating oil to the sternbush is fitted, it is to be located above the load waterline and is to be provided with a low level alarm device in the machinery space, *see also* 5.1.1.

4.16.8 Where sternbush bearings are oil lubricated, provision is to be made for cooling the oil by maintaining water in the after peak tank above the level of the sterntube or by other approved means. Means for ascertaining the temperature of the oil in the sterntube are also to be provided.

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4.16.9 Where an ***IWS** (In-water Survey) notation is to be assigned, means are to be provided for ascertaining the clearance in the sternbush with the vessel afloat.

4.17 Vibration and alignment

4.17.1 For the requirements for torsional, axial and lateral vibration, and for alignment of the shafting, *see* Part 13.

■ *Section 5* Control and monitoring

5.1 Unattended machinery

5.1.1 Where sterntube lubrication oil systems are fitted with automatic or remote controls so that under normal operating conditions they do not require any manual intervention by the operators, they are to be provided with the alarms indicated in Table 2.5.1.

Table 2.5.1 Alarms

Item	Alarm
Sterntube lubricating oil tank level	Low
Sterntube bearing temperature (oil lubricated)	High

■ *Section 6* Requirements for craft which are not required to comply with the HSC Code

6.1 General

6.1.1 Service craft of less than 24 m do not have to comply with 1.3.1 in respect of emergency operation of clutches on single screw installations.

6.2 Details to be submitted

6.2.1 The corrosion fatigue strength of corrosion resistant shaft material need not be submitted if the material is as shown in Table 2.4.1, *see also* 2.2.

6.3 Materials

6.3.1 The proposals to use extruded non-ferrous or composite materials will receive special consideration.

6.3.2 For the survey and testing of shaft material, *see* the Rules for Materials.

6.4 Sternbushes and sterntube arrangement

6.4.1 For service craft less than 24 m, the requirements of 4.16.1 do not apply. Sterntube bearings of approved plastics materials are to be installed so as to ensure a supply of water for lubrication in accordance with the bearing manufacturer's recommendations.

6.4.2 The aftermost propeller shaft bearing in the sterntube is to be secured to prevent rotational and axial movement.

6.4.3 For service craft less than 24 m, the requirements of 4.16.8 do not apply.

6.4.4 The lubrication of propulsion shafting bearings on SES craft less than 24 m will be considered.

6.5 Alarms

6.5.1 The requirements of 5.1.1 do not apply to service craft less than 24 m.

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1 **General requirements**

2 **Plans and particulars**

3 **Materials**

4 **Propeller design**

5 **Piping systems**

6 **Control and monitoring**

7 **Requirements for craft which are not required to comply with the HSC Code**

Section 1
General requirements

1.1 Application

1.1.1 This Chapter is to be read in conjunction with the General Requirements for Machinery in Part 9.

1.2 Power ratings

1.2.1 In this Chapter where the dimensions of main propulsion components are determined from shaft power, P, in kW, and revolutions per minute, R, the values to be used are those defined in Part 9.

1.3 Highly skewed propellers

1.3.1 The maximum skew angle of a propeller blade is defined as the angle, in projected view of the blade, between a line drawn through the blade tip and the shaft centreline and a second line through the shaft centreline which acts as a tangent to the locus of the mid-points of the helical blade sections, *see* Fig. 1.1.1.

1.4 Supercavitating propellers

1.4.1 A supercavitating propeller is defined as one in which the sheet cavity is designed to cover the entire blade width over at least the outer 50 per cent of the blade span.

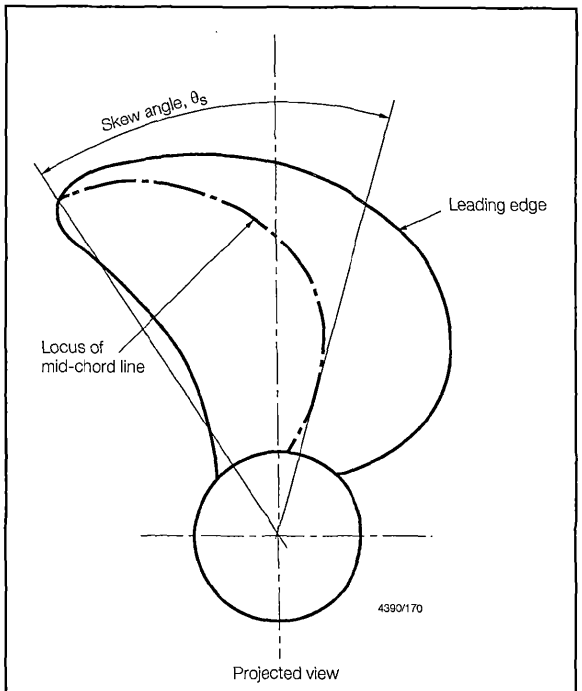

Fig. 1.1.1 Definition of skew angle

Section 2
Plans and particulars

2.1 Particulars to be submitted

2.1.1 At least three copies of the following plans and information are to be submitted.

2.2 Plans

2.2.1 A plan of the propeller, together with the following particulars is to be submitted:

(a) Maximum blade thickness of the expanded cylindrical section considered, in mm, excluding any allowance for fillet, T, in mm.
(b) Maximum shaft power, P, in kW, *see* Part 9.
(c) Estimated craft speed at design loaded draught in the free running condition at maximum shaft power and corresponding revolutions per minute (see (b) and (d)).
(d) Revolutions per minute of the propeller at maximum power, R.
(e) Propeller diameter, D, in metres.
(f) Pitch at 25 per cent radius (for solid propellers only), $P_{0,25}$, in metres.
(g) Pitch at 35 per cent radius (for controllable pitch propellers only), $P_{0,35}$, in metres.
(h) Pitch at 60 per cent radius, $P_{0,6}$, in metres.
(j) Pitch at 70 per cent radius, $P_{0,7}$, in metres.

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(k) Length of blade section of the expanded cylindrical section at 25 per cent radius (for solid propellers only), $L_{0,25}$, in mm.
(l) Length of blade section of the expanded cylindrical section at 35 per cent radius (for controllable pitch propellers only), $L_{0,35}$, in mm.
(m) Length of blade section of the expanding cylindrical section at 60 per cent radius, $L_{0,6}$, in mm.
(n) Rake at blade tip measured at shaft axis (backward rake positive, forward rake negative), *A*, in mm.
(o) Number of blades, *N*.
(p) Developed area ratio, *B*.
(q) Material: type and specified minimum tensile strength.
(r) Skew angle, θ_s, in degrees, *see* Fig. 1.1.1.
(s) Connection of propeller to shaft- details of fit, push up and securing.
(t) Keyed connection details.
(u) Details of control/hydraulic system and pressures for CP Propellers actuating mechanisms.
(v) Inertia of propeller assembly, kgm^2.
(w) Total mass of propeller assembly, kg.

2.2.2 For propellers having a skew angle equal or greater than 50° in addition to the particulars detailed in 2.2.1 details are to be submitted of:
(a) Full blade section details at each radial station defined for manufacture.
(b) A detailed blade stress computation supported by the following hydrodynamic data for the ahead mean wake condition and when absorbing full power:
  (i) Radial distribution of lift and drag coefficients, section inflow velocities and hydrodynamic pitch angles.
  (ii) Section pressure distributions calculated by either an advised viscid or viscous procedure.

2.3 Calculations and information

2.3.1 In cases where the craft has been the subject of model wake field tests a copy of the results is to be submitted.

2.3.2 The following information is to be submitted as applicable:
- For controllable pitch propellers plans (in diagrammatic form) of the hydraulic systems together with pipe material and working pressures.
- Details of control engineering aspects in accordance with Part 16.
- Calculations, or relevant documentation indicating the suitability of all components for short term high power operation.
- Where undertaken, fatigue strength analysis of components indicating a factor of safety of 1,5 at the design loads.
- For cases where the propeller material is not specified in Table 1.3.1, details of the chemical composition, mechanical properties and density are to be provided, together with results of fatigue tests in sea water in order to assign a value for *U*.

■ *Section 3* Materials

3.1 Castings for propellers

3.1.1 Castings for propellers and propeller blades are to comply with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials). The chemical composition and mechanical properties of steel castings are given in Ch 4,5 of the Rules for Materials and those of the copper alloys are given in Ch 9,1 of the Rules for Materials.

3.1.2 The specified minimum tensile strength of the castings is to be not less than stated in Table 1.3.1.

Table 1.3.1 Materials for propellers

Material	Specified minimum tensile strength N/mm^2	*G* Density g/cm^3	*U* Allowable stress N/mm^2
Carbon steels	400	7,9	20,6
Low alloy steels	440	7,9	20,6
13% chromium stainless steels	540	7,7	41
Chromium – nickel austenitic stainless steel	450	7,9	41
Duplex stainless steels	590	7,8	41
Grade Cu 1 Manganese bronze (high tensile brass)	440	8,3	39
Grade Cu 2 Ni-Manganese bronze (high tensile brass)	440	8,3	39
Grade Cu 3 Ni-Aluminium bronze	590	7,6	56
Grade Cu 4 Mn-Aluminium bronze	630	7,5	46

3.1.3 Where propellers of carbon and low alloy steels shown in Table 1.3.1 are provided with an approved method of cathodic protection, special consideration will be given to the value of *U*.

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Section 4
Propeller design

4.1 Minimum blade thickness

4.1.1 For propellers having a skew angle of less than 25° as defined in 1.3.1, the minimum blade thickness, T, of the propeller blades at 25 per cent radius for solid propellers, 35 per cent radius for controllable pitch propellers, neglecting any increase due to fillets, and at 60 per cent radius, is to be not less than:

$$T = \frac{KCA}{EFULN} + 100\sqrt{\frac{3150MP}{EFRULN}} \text{ mm}$$

where

L = $L_{0,25}$, $L_{0,35}$, or $L_{0,6}$, as appropriate

$$K = \frac{GBD^3R^2}{675}$$

G = density, in g/cm^3, *see* Table 1.3.1

U = allowable stress, in N/mm^2, *see* 4.1.2, 4.1.3, 4.1.4 and Table 1.3.1.

$$E = \frac{\text{actual face modulus}}{0{,}09T^2L}$$

For aerofoil sections with and without trailing edge washback, E may be taken as 1,0 and 1,25 respectively.

For solid propellers at 25 per cent radius

C = 1,0

$$F = \frac{P_{0,25}}{D} + 0{,}8$$

$$M = 1{,}0 + \frac{3{,}75D}{P_{0,7}} + 2{,}8\frac{P_{0,25}}{D}$$

For controllable pitch propellers at 35 per cent radius

C = 1,4

$$F = \frac{P_{0,35}}{D} + 1{,}6$$

$$M = 1{,}35 + \frac{5D}{P_{0,7}} + 2{,}6\frac{P_{0,35}}{D}$$

For all propellers at 60 per cent radius

C = 1,6

$$F = \frac{P_{0,6}}{D} + 4{,}5$$

$$M = 1{,}35 + \frac{5D}{P_{0,7}} + 1{,}35\frac{P_{0,6}}{D}$$

4.1.2 The fillet radius between the root of a blade and the boss of a propeller is to be not less than the Rule thickness of the blade or equivalent at this location. Composite radiused fillets or elliptical fillets which provide a greater effective radius to the blade are acceptable and are to be preferred. Where fillet radii of the required size cannot be provided, the value of U is to be multiplied by

$$\left(\frac{r}{T}\right)^{0,2}$$

where

r = proposed fillet radius at the root, in mm

T = Rule thickness of the blade at the root, in mm.

Where a propeller has bolted-on blades, consideration is also to be given to the distribution of stress in the palms of the blades. In particular, the fillets of recessed bolt holes and the lands between bolt holes are not to induce stresses which exceed those permitted at the outer end of the fillet radius between the blade and the palm. Counterbored bolt holes in blade flanges are to be provided with adequate fillet radii at the bottom of the counter bore.

4.1.3 The value U may be increased by 10 per cent for twin screw and outboard propellers of triple screw craft.

4.1.4 For propellers having skew angles of 25° or greater, but less than 50°, the mid chord thickness, $T_{sk0,6}$, at the 60 per cent radius is to be not less than:

$$T_{sk0,6} = 0{,}54T_{0,6}\sqrt{(1 + 0{,}1\theta_s)} \text{ mm}$$

The mid chord thickness, $T_{sk\,root}$, at 25 or 35 per cent radius, neglecting any increase due to fillets, is to be not less than:

$$T_{sk\,root} = 0{,}75T_{root}\sqrt[4]{(1 + 0{,}1\theta_s)} \text{ mm}$$

where

θ_s = proposed skew angle as defined in 1.3.1

$T_{0,6}$ = thickness at 60 per cent radius, calculated by 4.1.1

$T_{sk\,root}$ = thickness at 25 per cent radius or 35 per cent radius, calculated by 4.1.1

The thickness at the remaining radii are to be joined by a fair curve and the sections are to be of suitable aerofoil section.

4.1.5 Results of detailed calculations where carried out, are to be submitted.

4.1.6 Where the design of a propeller has been based on analysis of reliable wake survey data in conjunction with a detailed fatigue analysis and is deemed to permit scantlings less than required by 5.1.1, a detailed stress analysis for the blades is to be submitted for consideration.

4.2 Interference fit of keyless propellers

4.2.1 The symbols used in 4.2.2 are defined as follows:

d_1 = diameter of the screwshaft cone at the mid-length of the boss or sleeve, in mm

d_3 = outside diameter of the boss at its mid-length, in mm

d_i = bore diameter of screwshaft, in mm

$$k_3 = \frac{d_3}{d_1}$$

$$l = \frac{d_i}{d_1}$$

$$p_1 = \frac{2M}{A_1\,\theta_1\,V_1}\left(-1 + \sqrt{1 + V_1\left(\frac{F_1{}^2}{M^2} + 1\right)}\right)$$

A_1 = contact area fitting at screwshaft, in mm^2

$$B_3 = \frac{1}{E_3}\left(\frac{k_3{}^2 + 1}{k_3{}^2 - 1} + \nu_3\right) + \frac{1}{E_1}\left(\frac{1 + l^2}{1 - l^2} - \nu 1\right)$$

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C = 0 for turbine installations or electric propulsion

$= \frac{\text{vibratory torque at the service speed}}{\text{mean torque at the service speed}}$ for oil engine installations

E_1 = modulus of elasticity of screwshaft material, in N/mm^2

E_3 = modulus of elasticity of propeller material, in N/mm^2

$F_1 = \frac{2000Q}{d_1}(1 + C)$

M = propeller thrust, in N

Q = mean torque corresponding to P and R as defined in Part 9, in Nm

T_1 = temperature at time of fitting propeller on shaft, in °C

$V_1 = 0{,}51\left(\frac{\mu_1}{\theta_1}\right)^2 - 1$

α_1 = coefficient of linear expansion of screwshaft material, in mm/mm/°C

α_3 = coefficient of linear expansion of propeller material, in mm/mm/°C

θ_1 = taper of the screwshaft cone, but is not to exceed $\frac{1}{15}$ on the diameter, i.e. $\theta_1 \leq \frac{1}{15}$

μ_1 = coefficient of friction for fitting of boss assembly on shaft
= 0,13 for oil injection method of fitting

ν_1 = Poisson's ratio for screwshaft material

ν_3 = Poisson's ratio for propeller material.

4.2.2 Where it is proposed to fit a keyless propeller by the oil shrink method, the pull-up, δ on the screwshaft is to be not less than:

$$\delta = \frac{d_1}{\theta_1}\left(p_1 B_3 + (\alpha_3 - \alpha_1)(35 - T_1)\right) \text{ mm}$$

The yield stress or 0,2 per cent proof stress, σ_0, of the propeller material is to be not less than:

$$\sigma_0 = \frac{1{,}4}{B_3}\left(\frac{\theta_1 \delta_p}{d_1} + T_1(\alpha_3 - \alpha_1)\right)\frac{\sqrt{3k_3^4 + 1}}{k_3^2 - 1} \text{ N/mm}^2$$

where

δ_p = proposed pull-up at the fitting temperature. The start point load, W, to determine the actual pull-up is to be not less than:

$$W = A_1\left(0{,}002 + \frac{\theta_1}{20}\right)\left(p_1 + \frac{18}{B_3}(\alpha_3 - \alpha_1)\right) \text{ N.}$$

4.3 Keyed propellers pushed up by an hydraulic nut

4.3.1 Calculations are to be undertaken to show that the proof stress of the boss material is not exceeded in way of the keyway root fillet radius. In order to reduce the likelihood of frettage a grip stress of not less than 20 N/mm^2 between boss and shaft is to be achieved.

4.4 Propeller boss

4.4.1 The forward edge of the bore of the propeller boss is to be rounded to a 6 mm radius. In the case of keyed propellers, the length of the forward fitting surface is to be about one diameter.

4.4.2 Drilling holes through propeller bosses is to be avoided, except where it is essential to the design.

4.5 Fixed and steering nozzles

4.5.1 The requirements for scantlings for fixed and steering nozzles are given in Pt 3, Ch 3,4.

■ *Section 5* Piping systems

5.1 General

5.1.1 The piping system for a controllable pitch propeller is to comply with the general design requirements given in Part 15.

5.1.2 The specific requirements for lubricating hydraulic oil systems and standby arrangements are given in Part 15.

5.1.3 The hydraulic power operating systems are to be provided with arrangements to maintain the cleanliness of the hydraulic fluid, taking into consideration the type and design of the hydraulic system.

■ *Section 6* Control and monitoring

6.1 General

6.1.1 Control and monitoring is to comply with the requirements of Pt 16, Ch 1.

6.2 Automatic and remote controls

6.2.1 Where controllable pitch propellers are fitted with automatic or remote controls so that under normal operating conditions they do not require any manual intervention by the operators, they are to be provided with the alarms and safety arrangements required by 6.2.2, 6.2.3 and Table 1.6.1.

6.2.2 For controllable pitch propellers for main propulsion, a standby or alternative power source of actuating medium for controlling the pitch of the propeller blades is to be provided. Automatic start of the standby pump supplying hydraulic power for pitch control is to be provided.

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Table 1.6.1 Alarms

Item	Alarm	Note
Hydraulic system pressure	Low	—
Hydraulic oil supply tank level	Low	—
Hydraulic oil temperature	High	Where an oil cooler is fitted
Power supply to the control system between the remote control station and hydraulic actuator	Failure	Failure of any power supply to a control system is to operate an audible and visual alarm
Propulsion motor	Overload	*See* Part 16

6.2.3 For controllable pitch propellers, a shaft speed indicator and a pitch indicator which shows the degree of pitch as a measure of the propeller blade or actuator movement are to be provided at each station from which it is possible to control shaft speed or propeller pitch.

■ *Section 7*
Requirements for craft which are not required to comply with the HSC Code

7.1 Propellers not exceeding one metre in diameter

7.1.1 The materials and the scantlings need not comply with Sections 1 to 3 inclusive or 4.1 to 4.3 inclusive.

7.1.2 Propellers for service craft less than 24 m and main engine power output not exceeding 500 kW are to be manufactured from materials in accordance with the Rules for Materials at a works recognised for the quality of its casting and machining, and be free from defects.

7.1.3 Certificates of construction are not required.

7.1.4 Specific requirements for the piping systems are given in Part 15.

7.1.5 The alarm and monitoring arrangements, and for controllable pitch propellers, the safety arrangements and standby power sources, will be specially considered, *see also* Part 16.

7.2 Alternative materials and design

7.2.1 Propellers made from materials not listed in the Rules for Materials or of unusual form or design will be specially considered.

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Waterjet Systems

Section

1 **Scope**

2 **General requirements**

3 **Design requirements**

4 **Piping systems**

5 **Control and monitoring**

6 **Electrical systems**

7 **Inspection testing and fitting of waterjets**

8 **Installation, maintenance and replacement**

■ *Section 1* Scope

1.1 General

1.1.1 For the purposes of these Rules, a waterjet propulsion unit is described as a machine which takes in water, by means of a suitable inlet and conduit, and accelerates the mass of water using an impeller and nozzle to form a jet propulsion system. The waterjet system comprises the unit and its associated actuation and control devices. The detail of the prime mover is excluded but not its effect on the waterjet system.

1.1.2 This Chapter defines the requirements for the design and service life of marine waterjet propulsion systems and is to be read in conjunction with the General Requirements for the Design and Construction of Machinery in Chapter 1.

1.1.3 The requirements for a fixed or steerable waterjet propulsion system rated at 500 kW and above, which is integral with the ship's hull structure and forms a means of main propulsion, are detailed in this Chapter. This includes support arrangements, controls and the systems necessary to maintain operation and functionality of the waterjet unit.

1.1.4 These requirements relate to waterjets driven by axial or mixed flow pumps. Where units driven by radial flow pumps or inducers are proposed, details are to be submitted for consideration.

■ *Section 2* General requirements

2.1 Waterjet arrangement

2.1.1 In general, for a ship to be assigned an unrestricted service notation, a minimum of two waterjet systems is to be provided where these form the sole means of propulsion. For ships where a single waterjet system is the sole means of propulsion, a detailed engineering and safety justification is to be evaluated by LR, *see* 2.3.22. This evaluation process will include a risk analysis, using a recognised technique to verify that sufficient levels of redundancy and monitoring are incorporated in the waterjet unit's essential support systems and operating equipment.

2.1.2 Waterjet propulsion units are to be capable of continuous operation between their maximum and minimum output power rating at specified operating conditions, *see* Ch 1,3 and within the operational service profiles defined by 2.3.11 and 2.3.12.

2.1.3 It is the Shipbuilder's responsibility to ensure that all of the installed equipment is suitable for operation in the location and under the environmental conditions defined in Chapter 1. Where anticipated environmental conditions are outside these limits or where additional conditions are to be considered, such as vibration and impulsive accelerations, requirements and details of compliance are to be submitted to LR.

2.2 Plans to be submitted

2.2.1 Plans, in triplicate, and information as detailed below and in 2.3 and 2.4 are to be submitted for consideration.

2.2.2 General arrangement plans showing details of the following:

(a) Shafting assembly indicating bearing positions.
(b) Steering assembly.
(c) Reversing assembly.
(d) Shaft sealing arrangement assembly.
(e) Longitudinal section of the complete waterjet unit.

2.2.3 Detailed and dimensioned plans indicating scantlings, materials of construction and, where applicable, surface finish of the following:

(a) Arrangement of the system, including the intended method of attachment to the hull and building-in, tunnel geometry, shell openings, method of stiffening, reinforcement, etc.
(b) All torque transmitting components, including the shafting system, impeller and stator if fitted.
(c) Steering components, together with a description and line diagram of the control circuit. This is to include steerable exit waterjet nozzles where fitted.
(d) Components of the retractable buckets where these are used for providing astern thrust.
(e) The bearing or bearings absorbing the thrust and supporting the impeller, together with the method of lubrication.

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(f) Details of any shafting support or guide vanes used in the waterjet system.

2.2.4 Schematic plans of the lubrication and hydraulics required for steering/reversing systems, together with pipe material, relief valves and the working pressures required.

2.3 Calculations and information

2.3.1 Strength calculations based on fatigue considerations incorporating the maximum continuous torque rating and the most 'onerous' operating condition, *see* 2.3.12, including any short-term high power operation, and including the effects of mean and fluctuating loads, transitory loadings, residual stress allowances, and stress raisers, for the following components:

(a) Impeller, stator and any bolting arrangements supporting propulsion or steering loads.
(b) Shaft supports and coupling arrangements.
(c) Inlet guide vanes, if fitted.
(d) Steering components, including the lugs of steerable nozzles where fitted.
(e) Retractable buckets and associated mechanisms which are used to provide astern thrust. A calculation of the hydrodynamic transient loads is to be made for each design and is to include the full ahead to full astern condition. The calculation procedure used is to be supported, where possible, with full scale or model test data, or satisfactory service experience, to validate the design method.

2.3.2 Calculations supporting the connection method of the impeller to the shaft including details of the fit, push-up, securing, bolting arrangements, etc. In addition, where lengths of shafts are joined using couplings of the shrunk element type, full particulars of the method of achieving the grip force.

2.3.3 Calculations relating to the design of the shaftline as evidence of compliance with Pt 11, Ch 2.

2.3.4 Torsional vibration calculations of the complete dynamic system in accordance with the relevant requirements included in Pt 13, Ch 1.

2.3.5 Shaft lateral vibration calculations where required by Pt 13, Ch 3.

2.3.6 Calculations of the tunnel strength and supporting structure.

2.3.7 A calculation to determine the stresses within the impeller blade.

2.3.8 A calculation of the blade natural frequency for the impeller blades.

2.3.9 A calculation of the relative blade passing frequency between the rotor and stator blades.

2.3.10 The value of the fluctuating stresses during one revolution of the impeller and from transient loadings.

2.3.11 Details of the power/speed range of operation, indicating the maximum continuous torque rating, together with the associated thrusts; this information may be presented in the form of a characteristic curve for the waterjet.

2.3.12 The waterjet thrust for the assessment of the strength condition being considered is to be as follows:

(a) For ships which are intended to operate predominantly in a free-running condition and at steady service conditions, the waterjet thrust is to correspond to the absorption of the maximum continuous shaft power and corresponding revolutions per minute, giving the maximum torque for which the shaft system is approved.
(b) For ships which are designed for several operating conditions, the maximum thrust associated with these conditions and the absorption of the corresponding power, in addition to the maximum continuous powering condition, are to be used in the calculation.
(c) The justification for the thrust selected is to be submitted for consideration in the approval process and this is to include the ship type and the ship speed at the conditions considered.

2.3.13 A justification that the waterjet system will meet the self-priming criteria, *see* 3.1.6.

2.3.14 Specifications of materials and NDE procedures for components essential for propulsion and steering operation and, in the case of the impeller and stator, the yield strength and the fatigue characteristics of the material intended for their manufacture.

2.3.15 A detailed weld specification where an impeller has welded blades.

2.3.16 Full details of the means of corrosion protection in the case of carbon or carbon manganese steel shafts. Alternatively, where it is proposed to use composite shafts, details of the connections at flanges, materials, resin, lay-up procedures, quality control procedures and documentary evidence of fatigue endurance strength is to be provided.

2.3.17 Dry impeller mass and polar moment of inertia.

2.3.18 The prime mover type and designation.

2.3.19 Details of the control engineering aspects of the system design in accordance with Pt 16, Ch 1.

2.3.20 The tolerance specification, agreed between the manufacturer and the Shipbuilder or Owner, to which the components of the unit are to be manufactured is to be defined together with a justification.

2.3.21 Details of the waterjet's loading reactions together with the positions of application within the hull and is to include the maximum applied thrust, tunnel pressures, moments and forces imposed on the ship.

2.3.22 The waterjet unit's rated flow and head.

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2.3.23 Where an engineering and safety justification report is required, the following supporting information is to be submitted:

- A Failure Mode and Effects Analysis report (FMEA), *see* 2.4.
- Design standards and assumptions.
- Limiting operating parameters.
- A statement and evidence in respect of the anticipated reliability of any non-duplicated components.

2.3.24 Recommended installation, inspection, maintenance and component replacement procedures. This is to include any in-water engineering procedures where recommended by the waterjet manufacturer.

2.3.25 All transient loads which the steering unit is likely to experience from manoeuvring, accelerating, decelerating and the sea conditions.

2.4 Failure Mode and Effects Analysis (FMEA)

2.4.1 An FMEA is to be carried out where a single waterjet system is the ship's sole means of propulsion, *see* 2.2.3. The FMEA is to identify components where a single failure could cause the loss of all propulsion and/or steering capability and the proposed arrangements for preventing and mitigating the effects of such a failure.

2.4.2 The FMEA is to be carried out using the format presented in Table 22.2.1 in Chapter 22 of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships) or an equivalent format that addresses the same reliability issues. Analyses in accordance with IEC 60812 *Analysis for System Reliability – Procedure for Failure Mode and Effects Analysis*, or the IMO Code of Safety for High Speed Craft, 2000, Annex 4 – *Procedures for Failure Mode and Effects Analysis*, would be acceptable.

2.4.3 The FMEA is to be organised in terms of equipment and function. The effects of item failures at a stated level and at higher levels are to be analysed to determine these effects on the system as a whole. Actions for mitigation of the effects of failure are to be determined, *see* 2.4.1.

2.4.4 The FMEA is to:

(a) identify the equipment or sub-system and mode of operation;
(b) identify potential failure modes and their causes;
(c) evaluate the effects on the system of each failure mode;
(d) identify measures for reducing the risks associated with each failure mode;
(e) identify measures for preventing failure; and
(f) identify trials and testing necessary to prove conclusions.

2.4.5 At sub-system level it is acceptable, for the purposes of these Rules, to consider failure of equipment items and their functions. It is not required that the failure of components within that equipment item be analysed, *see* Ch 22,2.1.5 of the Rules for Ships.

2.4.6 Where a FMEA is used for consideration of systems that depend on software-based functions for control or co-ordination, the analysis is to investigate failure of the functions rather than a specific analysis of the software code itself.

■ *Section 3* Design requirements

3.1 General

3.1.1 The arrangement of waterjet units is to be such that the ship can be satisfactorily manoeuvred to a declared performance capability. The operating conditions covered are to include the following:

(a) Maximum continuous shaft power/speed to the impeller in the ahead condition at the declared steering angles and conditions.
(b) Manoeuvring speeds of the impeller shaft and/or reversing mechanism in the ahead and astern direction at the declared steering angles and sea conditions.
(c) The stopping manoeuvre described in Pt 9, Ch 2,8.2.
(d) Astern running conditions for the craft.

3.1.2 The mean loadings are those loadings induced by the waterjet absorbing the mean torque supplied by the prime mover.

3.1.3 Fluctuating loads are defined as those loads which occur during one revolution of the impeller due to cyclic variations. For example, the spatial flow variations and torsional vibration at nominally steady state operating conditions.

3.1.4 Transient loads are defined as those loadings resulting from acceleration and deceleration of the ship, manoeuvring, seaway conditions and other similar forms of loading. This also includes any significant back-pressure effects developed from the operation of the reversing bucket, if fitted.

3.1.5 To ensure self-priming of the waterjet unit, the shaft centreline of the unit is to be lower than the light draught static waterline of the ship. In cases where this is either impracticable or undesirable, the distance of the impeller shaft centreline above the ship's light draught waterline is to be less than or equal to 10 per cent of the pump inlet diameter.

3.1.6 Provision is to be made to allow for the in-service visual inspection of the complete blade surfaces of both the impeller and stator blades using either a direct visual or borescope inspection technique.

3.2 Shaftline

3.2.1 The diameter of the shaftline components are to comply with Pt 11, Ch 2. For calculation purposes the shaft carrying the impeller is to be taken as equivalent to a screw-shaft.

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3.2.2 Where it is proposed to use carbon or carbon manganese steel shafts which may be in contact with sea-water, these are to be protected.

3.2.3 The diameter of unprotected screwshafts of corrosion-resistant material is not to be less than that given in Pt 11, Ch 2,4.4.7.

3.2.4 The use of composite shafts is permitted, *see* 2.3.16.

3.2.5 Where lengths of shafts are joined using couplings of the shrunk element type, a factor of safety, based upon the mean plus the vibratory and transient torques, against slippage of 2,0 is to be achieved for couplings which are located inboard and 2,5 for couplings which are located outboard.

3.2.6 Where shaftline components are bolted together, the design of the bolted connection should demonstrate a factor of safety of 1,5 when considered in the context of the mean, fluctuating and transitory loadings.

3.2.7 If a keyed fitting of the impeller to the shaft is contemplated, then the requirements of Pt 11, Ch 2,4.12 are to be satisfied.

3.2.8 Where it is proposed to fit a keyless impeller, the fitting is to comply with the requirements of Ch 1,4.2, as applicable, excluding the requirements for Ice Class. Use of the words 'propeller' and 'screwshaft' are to be taken as meaning 'impeller' and 'impellershaft' respectively.

3.3 Shaft support system and guide vanes

3.3.1 In cases where the shaft requires support from the tunnel walls ahead of the impeller or, alternatively, where guide vanes are required to assist the flow around a bend in the ducting system, the supports or guide vanes are to be suitably aligned to the flow and have suitably rounded leading and trailing edges or be of an aerofoil section.

3.3.2 In general, the fillet radius should be greater than or equal to the maximum thickness of the vane or support at that location. Smaller radii may be considered, for which the results of an approved measurement programme or calculation procedure are to be submitted. In all cases, a factor of safety of at least 1,5 is to be demonstrated for the maximum designed operating conditions.

3.3.3 A facility for the inspection of the supports or guide vanes is to be provided, which will allow either direct visual or borescope inspection of these components and their transition to other members.

3.4 Impeller

3.4.1 A calculation to determine the stresses within the impeller blades is to be carried out which takes into account the mean blade loading, fluctuating loadings, transient loads and centrifugal force. The computations may be accomplished by either classical methods or numerical analysis. Designs of waterjet systems which have been based on a combination of computational fluid dynamics and finite element methods will be considered. However, it will be necessary to demonstrate to the satisfaction of LR that the formulation of the methods used has been correlated with previous full scale measurement or other calculation experience.

3.4.2 For the purposes of the calculation required by this sub-Section, the fluctuating stresses during one revolution of the impeller is to be taken as 20 per cent of the maximum mean stress, and the stresses from transient loadings are to be taken as 15 per cent of the hydrodynamic mean stress, unless otherwise specified by the designer.

3.4.3 The fatigue assessment of the impeller blades is to be based on the stress in the root sections, excluding the influence of the blade root fillets. This assessment is to include the following components:

- the maximum stresses derived from the mean loading, including both the hydrodynamic and centrifugal components;
- the amplitude of the fluctuating stresses during one revolution of the impeller;
- the stresses derived from transient loading and an allowance for any residual stresses in the material.

It is permissible to combine the variable components of stress in a linear fatigue damage accumulation assessment procedure. A factor of safety of at least 1,5 against fatigue failure is to be demonstrated for the maximum continuous rating condition or any other more onerous condition, *see* 3.1.1.

3.4.4 In general, the fillet radius is to be greater than the maximum thickness of the impeller blade at that location. Composite radiused fillets or elliptical fillets which provide an improved stress concentration factor are preferred.

3.4.5 Where an impeller has bolted-on blades, consideration is to be given to the distribution of stress in the palms of the blade and in the hub and bolting arrangements.

3.4.6 Where an impeller has welded blades, the welds are to be of the full penetration type or of equivalent strength. Where laser welding is to be used, details are to be submitted for consideration.

3.4.7 The blades are to be provided with hydrodynamically faired leading and trailing edges which may be either of simple radius or of a more complex aerofoil edge form. The tip clearance, whilst being kept to a minimum for hydrodynamic purposes, is to be sufficient to allow for any transient vibrational behaviour, axial shaft movement or differential thermal expansion.

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3.4.8 A calculation of the blade natural frequency for the impeller blades is to be undertaken. The fundamental natural frequency in water of the blade is to be shown to lie outside any expected excitation frequencies within a speed range of the waterjet unit and up to 10 per cent above the maximum impeller speed.

3.5 Stator

3.5.1 The stator blades, where fitted, are to be designed to be capable of withstanding the combined hydrodynamic mean, fluctuating, transient and mechanical loads, including any loads transmitted via shaft bearings, developed by the unit and reacted through the blades when the impeller is absorbing full power. Consideration is to be given to situations when the vessel is either free running or in a condition specified by 3.1.1 or undergoing stopping, accelerating or decelerating manoeuvres. A factor of safety against mechanical failure by yielding of the blades of 1,5 is to be demonstrated.

3.5.2 In general, the fillet radius is to be greater than the maximum thickness of the blade at that location. Composite radiused fillets or elliptical fillets which provide improved stress concentration factors are preferred.

3.5.3 If the stator ring comprises a segmented assembly, then consideration is also to be given to the distribution of stress in the various adjacent members of the overall assembly.

3.5.4 A calculation of the relative blade passing frequency between the rotor and stator blades is to demonstrate that this does not coincide with the natural frequency of the stator blades over the speed range of the waterjet unit and up to 10 per cent above maximum impeller speed.

3.5.5 The stator blades are to be provided with hydrodynamically faired leading edges which may have either a simple radius or a more complex aerofoil edge form.

3.5.6 Where the stator blading assembly forms part of the nozzle, the requirements of 3.7 are to be considered in association with those for the stator assembly.

3.6 Tunnel and securing arrangements

3.6.1 The tunnel is to be adequately supported, framed and fully integrated into the hull structure. The critical locations and integrity of the supports and framing are to be as specified in the FMEA and agreed by the Shipbuilder and LR.

3.6.2 The tunnel and supporting structure scantlings are to be not less than the Rule requirements for the surrounding structure. The strength of the hull structure in way of tunnel(s) is to be maintained. The structure is to be adequately reinforced and compensated as necessary. All openings are to be suitably reinforced and have radiused corners.

3.6.3 Consideration is to be given to providing the inlet to the tunnel with a suitable guard to prevent the ingress of large objects into the rotodynamic machinery. The dimensions of this guard, if fitted, are to strike a balance between undue efficiency loss due to flow restriction and viscous losses, the size of object allowed to pass and the susceptibility to clog with weed and other flow-restricting matter.

3.6.4 The inlet profile of the tunnel is to be designed so as to provide a smooth uptake of the water over the range of vessel operating trims and avoid significant separation and/or cavitation of the flow which may then pass downstream into the rotating machinery.

3.6.5 Design consideration is to take account of pressures which could develop as a result of a duct blockage as well as in relation to the axial location of rotating parts.

3.6.6 The strength of the tunnel and supporting structure are to be examined by direct calculation procedures.

3.7 Nozzle/steering arrangements

3.7.1 In general, the steering systems and components are to comply with the requirements of Pt 14, Ch 1.

3.7.2 Nozzles can be either of a fixed or steerable form. The design of the nozzle is to take into account fully the change in pressure distribution along its inner surface together with the other mechanical loads (e.g. stator assembly loads) and transient loads caused by the flow directing attachments which may be reacted through the body of the nozzle. In this analysis, the changes to the pressure distribution caused by transient manoeuvres are to be considered.

3.7.3 In addition to the requirements of Pt 14, Ch 1, the steering mechanism and bucket are to be capable of maintaining the manoeuvrability of the ship in terms of turning circle, zig-zag and stopping requirements within the limits defined by IMO Resolution MSC.137(76), Standards for Ship Manoeuvrability.

3.7.4 Consideration is to be given to all transient loads which the steering unit is likely to experience from manoeuvring, accelerating, decelerating and the sea conditions.

3.7.5 The nozzle/bucket is to be given mechanical protection by the Shipbuilder from other impact damage such as collision.

3.8 Bolts

3.8.1 Detailed consideration and analysis is to be given to essential bolting arrangements in critical locations as specified in the FMEA and where indicated by the Manufacturer or Shipbuilder and agreed by LR. These are to include bolts used in the securing of blades or guide vanes, assembly of the unit in the ship and any conduit components.

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■ *Section 4* Piping systems

4.1 General

4.1.1 The piping systems for a waterjet unit are to comply with the general requirements of Pt 15, Ch 3.

4.1.2 Lubricating and hydraulic oil systems and standby arrangements are to comply with the requirements of Pt 15, Ch 3; in addition, steering hydraulic systems are to comply with the applicable requirements of Pt 14, Ch 1.

■ *Section 5* Control and monitoring

5.1 General

5.1.1 In addition to this Section, the control engineering systems are to comply with Pt 16, Ch 1.

5.1.2 Steering control for the waterjet is to be provided at the ship's normal conning stations.

5.1.3 For waterjets used as the only means of propulsion and steering, a standby or alternative power source for the actuating device, that controls the angular position and/or the reversing angle, is to be provided. Automatic start of the standby pump supplying hydraulic power for steering and reversing is to be provided.

5.1.4 Means are to be provided at each control station to stop each waterjet.

5.2 Monitoring and Alarms

5.2.1 In addition to the requirements of Pt 14, Ch 1, alarms and monitoring requirements are indicated in 5.2.2 to 5.2.4 and Table 12.5.1.

5.2.2 An indication of the angular position of the nozzle is to be provided at each station from which it is possible to control the direction of thrust from the units.

5.2.3 An indication of both the required and actual reversing bucket position is to be provided at each station from which it is possible to control the reversal of thrust.

5.2.4 All alarms associated with waterjet unit faults are to be indicated individually at the control stations and in accordance with the alarm system specified by Pt 16, Ch 1.

■ *Section 6* Electrical systems

6.1 Installation and distribution arrangements

6.1.1 The electrical installation is to comply with the relevant sections of Pt 16, Ch 2.

6.1.2 Waterjet auxiliaries and controls are to be served by individual circuits. Services that are duplicated are to be separated throughout their length as widely as practicable and without the use of common feeders, transformers, converters, protective devices or control circuits.

■ *Section 7* Inspection, testing and fitting of waterjets

7.1 General

7.1.1 The finished impeller is to be statically balanced on completion of the manufacturing process and meet the requirements of ISO 1940 or an alternative standard acceptable to LR. In the case where the blade tip speed is greater than 60 m/s, dynamic balancing is required unless otherwise agreed by the Manufacturer and LR.

Table 12.5.1 Alarms

Item	Alarm	Note
Hydraulic system pressure	Low	–
Hydraulic oil supply tank level	Low	–
Hydraulic oil temperature	High	Where an oil cooler is fitted
Lubricating oil temperature	High	
Lubricating oil pressure	Low	In forced lubrication systems
Lubricating oil tank level	Low	Where a tank is provided
Ratio of jet rpm/vessel speed	High	Only if installed power per jet > 4 MW
Control system failure	Fault	Includes follow-up failure of steering or reversng system
Control system power supply	Failure	

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7.1.2 The following tests, markings and inspections are to be carried out in the presence of the Surveyor:

(a) The balancing of the impeller or the blades.

(b) Non-destructive examination of the impeller blades and the principal component parts of the propulsion system: for austenitic stainless steels, *see* Ch 4,8, and for aluminium alloys, *see* Ch 8,3, of the Rules for Materials.

(c) The quality of the fit of the impeller boss on the shaft taper.

(d) The fitting of the impeller to the shaft and its subsequent functional testing.

(e) The finished surfaces of the impeller boss, hub, conical bores, fillets, cones and blade surfaces are to be shown to conform to the tolerances specified on the impeller drawing.

7.1.3 Bolts and nuts in critical locations, as specified in the FMEA and where indicated by the Manufacturer or Shipbuilder and agreed by LR, are to be equipped with adequate securing arrangements to the satisfaction of the LR Surveyor.

7.2 Shop tests and installation of waterjet systems

7.2.1 The completed waterjet unit is to undergo a tightness test in which an internal hydrostatic pressure of 1,5 bar above the maximum working pressure of the unit is to be applied.

7.2.2 In cases where the impeller is fitted to the shaft using an interference fit, the bedding of the impeller with the shaft is to be demonstrated in the shop to the satisfaction of the LR Surveyor. Sufficient time is to be allowed for the temperature of the components to equalise before bedding. A contact marking between the bore of the impeller boss and the shaft surface of better than 80 per cent is to be demonstrated when the contact marking ink is spread thinly on the surface of the shaft. Alternative means for demonstrating the bedding of the impeller will be considered.

7.2.3 Means are to be provided to indicate the relative axial position of the impeller boss on the shaft. Permanent reference marks are to be made on the impeller boss, shaft and any nut to indicate angular and axial positioning of the impeller. Care is to be taken in marking the inboard end of the shaft taper to minimise stress-raising effects.

7.2.4 A copy of the fitting curve relative to temperature and means for determining any subsequent movement are to be placed on board.

7.2.5 The impeller running clearances are to be checked following the installation of the unit in the ship.

7.2.6 The thrust bearing clearances in the waterjet system are to be verified against the required design values. This is to be done following the installation of the unit in the ship.

7.2.7 The piping systems are to be adequately flushed in accordance with the Manufacturer's recommendations and the final levels of contamination recorded. Similarly, pressure testing of the piping systems is to comply with Pt 15, Ch 1.

7.3 Sea trial requirements

7.3.1 The following requirements are to be complied with:

- Pt 9, Ch 2,8.2 for sea trials.
- Pt 14, Ch 1,4.4 for steering trials.

In addition, the general design capability specified in 3.1.1 is to be demonstrated to the Surveyor's satisfaction.

7.3.2 The control systems relating to the correct functioning of the waterjet is to be the subject of harbour and then sea trials. Demonstration of the requirements of Pt 16, Ch 1 is required and the design combinations of control functions are to be undertaken during the trials programme.

7.3.3 On sea trials and under free running conditions, the relationship between ship speed and impeller rotational speed is to be verified against the waterjet's design basis.

7.3.4 Any trials and testing identified from the FMEA report, *see* 2.4, are to be carried out.

■ *Section 8* Installation, maintenance and replacement

8.1 General

8.1.1 All waterjet system propulsion units are to be provided with a copy of the Manufacturer's installation and maintenance manual that is pertinent to the actual equipment. *See* 2.3.24.

8.1.2 The manual required by 8.1.1 is to be placed on board and is to contain the following information:

(a) Description of the waterjet propulsion system with details of function and design operating limits. This is also to include details of support systems such as lubrication, cooling and condition monitoring arrangements.

(b) Identification of all components together with details of any that have a defined maximum operating life.

(c) Instructions for installation of the system on board ship with details of any required specialised equipment.

(d) Instructions for commissioning at initial installation and following maintenance.

(e) Maintenance and service instructions to include inspection/renewal of bearings and sealing arrangements. This is also to include component fitting procedures, clearance measurements and lubricating oil treatment where applicable.

(f) Actions required in the event of fault/failure conditions being detected.

(g) Precautions to be taken by personnel working during installation and maintenance.

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Section

1 **General requirements**

2 **Particulars to be submitted**

3 **Materials**

4 **Design and construction**

5 **Piping systems**

6 **Control and monitoring**

7 **Electrical systems**

8 **Requirements for craft which are not required to comply with the HSC Code**

Section 1 General requirements

1.1 Application

1.1.1 This Chapter is to be read in conjunction with the General Requirements for Machinery in Part 9.

1.1.2 This Chapter gives requirements for fixed or steerable thruster units (azimuth thrusters) which are used for propulsion and steering, and also applies to transverse propulsion (tunnel) thrusters which are an aid to manoeuvring.

1.1.3 In this Chapter where the dimensions of any particular component are determined from shaft power, P, in kW, and revolutions per minute, R, the values to be used are those defined in Part 9.

1.2 Redundancy

1.2.1 A minimum of two azimuth thruster units are to be provided where these form the sole means of propulsion. Where a single azimuth thruster installation is proposed, it will be subject to consideration, taking into account the proposed restricted area notation.

1.2.2 The failure of one azimuth thruster unit or its control system is not to render any other thruster inoperative.

1.3 Inclination of craft

1.3.1 Thruster units are to operate satisfactorily under the conditions as shown in Part 9.

Section 2 Particulars to be submitted

2.1 Submission of information

2.1.1 At least three copies of the following plans are to be submitted.

2.1.2 **Fixed/Azimuth propulsion thrusters**

(a) A general arrangement sectional assembly plan showing all the connections of the torque transmitting components from the prime mover to the propeller, together with the azimuthing mechanism and, if a nozzle is provided, the nozzle ring structure and nozzle support struts.

(b) Detailed and dimensional plans of the individual torque transmitting components.

(c) Schematic plans of lubricating and hydraulic systems, together with pipe material, relief valves and working pressures.

2.1.3 **Tunnel thrusters.**

Structural assembly plan including connections to tunnel.

2.2 Calculations and specifications

2.2.1 At least three copies of the following information are to be submitted.

2.2.2 **Fixed/Azimuth propulsion thrusters**

(a) Thruster prime mover type and operational power/speed envelope.

(b) Rating and type of motor for the azimuthing mechanism (e.g. type – hydraulic or electric).

(c) Gearing calculations for the azimuthing mechanism which is to be designed to a recognised National Standard.

(d) Bearing specifications.

(e) Details of control engineering aspects in accordance with Pt 16, Ch 1.

(f) Calculations indicating suitability of components for short term high power operation, where applicable. *See* Part 9.

(g) Where carried out in accordance with Part 9, a fatigue strength analysis of components indicating a factor of safety of 1,5 at the design loads, based on a suitable fatigue failure criteria.

2.2.3 **Tunnel thrusters.** Specification for materials of gears, shafts, couplings and propeller, stock and struts.

Section 3 Materials

3.1 Azimuth thrusters

3.1.1 The materials used in the construction are to be manufactured and tested in accordance with the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

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■ *Section 4* Design and construction

4.1 General

4.1.1 The arrangement of all types of thrusters is to be such that the craft can be manoeuvred in accordance with the design specifications.

4.1.2 The requirements associated with the structural and watertight integrity and the installation arrangement are to be in accordance with Pt 3, Ch 3.

4.1.3 In addition to the requirements of this Section reference is to be made to:

(a) Main transmission gearing (Pt 11, Ch 1).
(b) Main transmission shafting (Pt 11, Ch 2).
(c) Propeller (Chapter 1).
(d) Torsional vibration (Pt 13, Ch 1).
(e) Lateral vibration for shafting systems which include cardan shafts (Pt 13, Ch 3).

4.2 Azimuth thrusters

4.2.1 The following requirements are to be complied with:

(a) The azimuthing mechanism is to be capable of a maximum rotational speed of not less than 1,5 rev/min.
(b) Gearing for the azimuthing mechanism is to be designed to a recognised National Standard.
The design is to consider both static ($<10^3$ cycles) and dynamic loading conditions.
(c) Under dynamic operating conditions, the gear is to be considered for
  (i) design maximum dynamic duty steering torque,
  (ii) variable loading, where applicable. A spectrum (duty) factor may be used. The load spectrum value is to be derived using load measurements of similar units, where possible.
(d) Under a static duty ($<10^3$ load cycles) steering torque, which should be not less than M_T, as defined in 4.3.1.
(e) The following minimum factor of safety values are to be achieved:
Surface Stress $S_{Hmin} = 1,0$.
Bending Stress $S_{Fmin} = 1,5$.
(f) For hydraulic pressure retaining parts and load bearing components, *see also* Part 14.

4.3 Azimuth thrusters with a nozzle

4.3.1 Where the propeller is contained within a nozzle, the equivalent rudder stock diameter in way of tiller, used in Table 1.4.1 in Pt 14, Ch 1 is to be determined as follows:

$$d_{SU} = 26,03 \sqrt[3]{(V+3)^2 A_N X_{PF}} \quad \text{mm}$$

where

V = maximum service speed, in knots, which the craft is designed to maintain under thruster operation
A_N = projected nozzle area, in m^2, and is equal to the length of the nozzle multiplied by the mean external vertical height of the nozzle
X_{PF} = horizontal distance from the centreline of the steering tube to the centre of pressure, in metres. The position of the centre of pressure is determined from Table 3.2.6 in Pt 3, Ch 3.

The corresponding maximum turning moment, M_T, is to be determined as follows:

$$M_T = 11,1 \times d_{SU}^3 \quad \text{Nmm}$$

4.3.2 In addition to the requirements of Part 3 the scantlings of the nozzle stock or steering tube are to be such that the section modulus Z against transverse bending at any section x–x is not less than:

$$Z = 1,73 \sqrt{(V+3)^4 A_N^2 X_{PF}^2 + \frac{a^2}{4} T_M^2 10^4} \quad \text{cm}^3$$

where

a = dimension, in metres, as shown in Fig. 3.4.1
T_M = maximum thrust of the thruster unit, in tonnes.

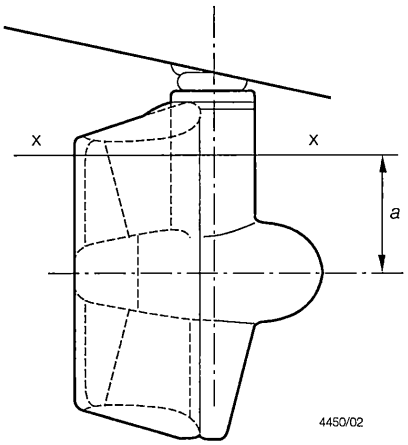

Fig. 3.4.1 Azimuth thruster

4.3.3 The scantlings of nozzle connections or struts will be specially considered. In the case of certain high powered craft, direct calculation may be required.

4.3.4 Where the propeller is not contained in a nozzle, the scantlings in way of the tiller will be subject to special consideration.

■ *Section 5* Piping systems

5.1 General

5.1.1 The piping system for azimuth thrusters is to comply with the general design requirements given in Pt 15, Ch 1.

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5.1.2 The specific requirements for lubricating/hydraulic oil systems and standby arrangements are given in Pt 15, Ch 3.

5.2 Azimuth thruster

5.2.1 The hydraulic power operating systems for each azimuth thruster are to be provided with the following:

(a) arrangements to maintain the cleanliness of the hydraulic fluid, taking into consideration the type and design of the hydraulic system,

(b) a fixed storage tank having sufficient capacity to recharge at least one azimuth power actuating system including the reservoir. The piping from the storage tank is to be permanent and arranged in such a manner as to allow recharging from within the thruster space.

5.2.2 Where the lubricating oil for the azimuth thrusters is circulated under pressure, provision is to be made for the efficient filtration of the oil. The filters are to be capable of being cleaned without stopping the thruster or reducing the supply of filtered oil.

■ *Section 6* Control and monitoring

6.1 General

6.1.1 Except where indicated in this Section the control engineering systems are to be in accordance with Pt 16, Ch 1.

6.1.2 Azimuthing control for azimuth thruster(s) and propeller pitch control for azimuth and/or tunnel thruster(s) are to be provided from the navigating bridge, the main machinery control station and locally.

6.1.3 Means are to be provided at the remote control station(s) to stop each azimuth or tunnel thruster unit.

6.2 Monitoring and alarms

6.2.1 Alarms and monitoring requirements are indicated in 6.2.2, 6.2.3 and Table 3.6.1.

6.2.2 An indication of the angular position of the azimuth thruster(s) and the propeller pitch position for azimuth and/or tunnel thruster(s) are to be provided at each station from which it is possible to control the direction of thrust or the pitch.

6.2.3 All alarms associated with thruster unit faults are to be indicated individually on the navigating bridge and in accordance with the alarm system specified by Part 16.

Table 3.6.1 Alarms

Item	Alarm	Note
Thruster, azimuth or tunnel	—	Indicators, *see* 6.2.2
Azimuthing motor	Power failure, single phase	Also running indication on bridge and at machinery control station
Propeller pitch motor	Power failure	Also running indication on bridge and at machinery control station
Propulsion motor	Overload, power failure	Also running indication on bridge and at machinery control station
Control system	Failure	
Hydraulic oil supply tank level	Low	
Hydraulic oil system pressure	Low	
Hydraulic oil system temperature	High	Where oil cooler is fitted
Hydraulic oil filters differential pressure	High	Where oil filters are fitted
Lubricating oil supply pressure	Low	If separate forced lubrication

■ *Section 7* Electrical systems

7.1 General

7.1.1 The electrical installation is to be designed, constructed and installed in accordance with the requirements of Part 16.

7.2 Emergency power for steering systems and drives

7.2.1 For high speed craft, in the event of total power failure, either:

(a) emergency power for steering systems/drives is to be restored automatically within five seconds. To achieve this an interim fast acting system may be required to come into operation until such time as the auxiliary/emergency power source comes on line. (Note: starting arrangements are to comply with the requirements relating to starting arrangements of emergency generators), or

(b) means are to be provided to bring the craft to a safe condition.

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7.3 Circuits

7.3.1 Azimuth thruster auxiliaries and controls are to be served by individual circuits. Services that are duplicated are to be separated throughout their length as widely as is practicable and without the use of common feeders, transformers, converters, protective devices or control circuits.

■ *Section 8*
Requirements for craft which are not required to comply with the HSC Code

8.1 Design and installation

8.1.1 Tunnel thrusters on service craft less than 24 m and yachts which are not essential for steering and manoeuvring do not have to comply with the design requirements of this Chapter.

8.1.2 The installation of such thrusters is to be such as to maintain the structural and watertight integrity of the craft.

8.2 Control and monitoring

8.2.1 Alarms and monitoring requirements of Table 3.6.1 are not required for service craft of less than 24 m.

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Rules and Regulations for the Classification of Special Service Craft

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Section

1 **General requirements**

2 **Details to be submitted**

3 **Design**

4 **Measurements**

5 **Requirements for craft which are not required to comply with the HSC Code**

■ *Section 1* General requirements

1.1 Application

1.1.1 This Section is to be read in conjunction with the requirements of Parts 9, 10, 11 and 12.

1.1.2 Unless otherwise advised, it is the responsibility of the Builder as main contractor to ensure, in co-operation with the Enginebuilders, that the information required by this Chapter is prepared and submitted.

1.1.3 The requirements of this Chapter are applicable to the following systems:

(a) Main propulsion systems formed by oil engines, turbines or electric motors, directly driven or geared to the shafting.

(b) Machinery driven at constant speed by oil engines, developing 110 kW and over, for essential auxiliary services including generator sets which are the source of power for main electric propulsion motors.

1.2 Power ratings

1.2.1 In this Chapter where shaft power, *P*, in kW, and revolutions per minute, *R*, are referred to, the values to be used are those defined in Part 9.

1.3 Basic requirements

1.3.1 System designs are to take account of the potential effects of engine and component malfunction and variability in characteristic values.

1.3.2 Where torques, stresses or amplitudes are found to exceed the limits for continuous operation, restrictions in speed and/or power will be imposed.

■ *Section 2* Details to be submitted

2.1 Particulars to be submitted

2.1.1 Torsional vibration calculations, including an analysis of the vibratory torques and stresses for the full dynamic system.

2.1.2 Particulars of the division of power and utilisation, throughout the speed range, for turbines, multi-engine or other combined power installations, and those with power take-off systems. For multi-engined installations, special considerations associated with the possible variations in the mode of operation and phasing of engines.

2.1.3 Details of operating conditions encountered in service for prolonged periods, e.g. idling speed, combinator characteristics for installations equipped with controllable pitch propellers.

2.1.4 Details, obtained from the manufacturers, of the principal characteristics of machinery components such as dampers and couplings, confirming their capability to withstand the effects of vibratory loading including, where appropriate, heat dissipation. Evidence that the data which is used to represent the characteristics of components, which has been quoted from other sources, is supported by a programme of physical measurement and control.

2.1.5 Where installations include electric motors, generators or non-integral pumps, drawings showing the principal dimensions of the shaft, together with the manufacturer's estimates of mass moment of inertia for the rotating parts.

2.1.6 Details of vibration or performance monitoring proposals where required.

2.2 Scope of calculations

2.2.1 Calculations are to be carried out, by recognised techniques, for the full dynamic system formed by the oil engines, turbines, motors, generators, flexible couplings, gearing, shafting and propeller, where applicable, including all branches.

2.2.2 Calculations are to give due consideration to the potential deviation in values used to represent component characteristics due to manufacturing/service variability.

2.2.3 The calculations carried out on oil engine systems are to be based on the Enginebuilders' harmonic torque data. (On request, Lloyd's Register (hereinafter referred to as 'LR') can provide a table of generalised harmonic torque components for use where appropriate.) The calculations are to take account of the effects of engine malfunction commonly experienced in service, such as a cylinder not firing. Calculations are also to take account of a degree of imbalance between cylinders, characteristic of the normal operation of an engine under service conditions.

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2.2.4 Whilst limits for torsional vibration stress in crankshafts are no longer stated explicitly, calculations are to include estimates of crankshaft stress at all designated operating/service speeds, as well as at any major critical speed.

2.2.5 Calculations are to take into account the possible effects of excitation from propeller rotation. Where the system shows some sensitivity to this phenomenon, propeller makers' data should be used as a basis for calculation, and submitted.

2.2.6 Where the torsional stiffness of flexible couplings varies with torque, frequency or speed, calculations should be representative of the appropriate range of effective dynamic stiffness.

■ *Section 3* Design

3.1 Symbols and definitions

3.1.1 The symbols used in this Section are defined as follows:

d = minimum diameter of shaft considered, in mm
r = ratio N/N_s or N_c/N_s whichever is applicable
N = engine speed, in rev/min
N_c = critical speed, in rev/min
N_s = maximum continuous engine speed, in rev/min, or, in the case of constant speed generating sets, the full load speed, in rev/min
Q_s = rated full load mean torque
τ_c = maximum value of the vibration stress for continuous running at or below the maximum speed, in N/mm^2
τ_t = permissible stress due to torsional vibrations for transient operation, in N/mm^2
σ_u = specified minimum tensile strength of the shaft material, in N/mm^2
C_k = a factor for different shaft design features, *see* Table 1.3.1
C_d = a size factor defined as $0,35 + 0,93d^{-0,2}$
k = the factor used in determining minimum shaft diameter, defined in Pt 11, Ch 2,4.2.1 and 4.4.3.

Table 1.3.1 C_k factors

For intermediate shafts with			For thrust shafts external to engines		For propeller shafts
Integral coupling flanges	Shrink fit couplings	Keyways	On both sides of thrust collar	In way of axial bearing where a roller bearing is used as a thrust bearing	For which $k = 1,22$ and $= 1,26$
1,0	1,0	0,60	0,85	0,85	0,55

NOTE
The determination of C_k – factors for shafts other than shown in this Table is at the discretion of LR.

3.1.2 Alternating torsional vibration stresses are to be based on half-range amplitudes of stress resulting from the alternating torque (which is superimposed on the mean torque) representing the synthesis of all harmonic orders present.

3.1.3 All vibration stress limits relate to the synthesis or measurement of total nominal torsional stress and are to be based on the plain section of the shafting neglecting stress raisers.

3.2 Limiting stress in propulsion shafting

3.2.1 The following stress limits apply to intermediate shafts, thrust shafts and to screwshafts fully protected from seawater. For screwshafts, the limits apply to the minimum section between the forward end of the propeller boss and the forward stern gland.

3.2.2 In the case of unprotected screwshafts, special consideration will be given.

3.2.3 In no part of the propulsion shafting system may the alternating torsional vibration stresses exceed the values of τ_c for continuous operation, and τ_t for transient running, given by the following formulae:

$$\tau_c = \frac{\sigma_u + 160}{18} C_k C_d (3 - 2r^2) \text{ for } r < 0,9 \quad \text{N/mm}^2$$

$$\tau_c = \frac{\sigma_u + 160}{18} C_k C_d \, 1,38 \text{ for } 0,9 \le r \le 1,05 \quad \text{N/mm}^2$$

$$\tau_t = \pm 1,7\tau_c \frac{1}{\sqrt{C_k}} \text{ for } r \le 0,8$$

3.2.4 In general, the tensile strength of the steel used is to comply with the requirements of Pt 11, Ch 2. For the calculation of the permissible limits of stresses due to torsional vibration, σ_u is not to be taken as more than 800 N/mm^2 in the case of intermediate shafts and 600 N/mm^2 in the case of thrust and propeller shafts.

3.2.5 Where the scantlings of coupling bolts and straight shafting differ from the minimum required by the Rules, special consideration will be given.

3.3 Generator sets

3.3.1 Natural frequencies of the complete set are to be sufficiently removed from the firing impulse frequency at the full load speed, particularly where flexible couplings are interposed between the engine and generator.

3.3.2 Within the speed limits of $0,95N_s$ and $1,05N_s$ the vibration stresses in the transmission shafting are not to exceed the values given by the following formula:

$$\tau_c = \pm (21 - 0,014d) \text{ N/mm}^2.$$

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3.3.3 Vibration stresses in the transmission shafting due to critical speeds which have to be passed through in starting and stopping, are not to exceed the values given by the following formula:

$\tau_t = 5{,}5\tau_c$.

3.3.4 The amplitudes of total vibratory inertia torques imposed on the generator rotors are to be limited to $\pm 2{,}0Q_s$ in general, or to $\pm 2{,}5Q_s$ for close-coupled revolving field alternating current generators, over the speed range from $0{,}95N_s$ to $1{,}05N_s$. Below $0{,}95N_s$ the amplitudes are to be limited to $\pm 6{,}0Q_s$. Where two or more generators are driven from one engine, each generator is to be considered separately in relation to its own rated torque.

3.3.5 The rotor shaft and structure are to be designed to withstand these magnitudes of vibratory torque. Where it can be shown that they are capable of withstanding a higher vibratory torque, special consideration will be given.

3.3.6 In addition to withstanding the vibratory conditions over the speed range from $0{,}95N_s$ to $1{,}05N_s$ flexible couplings, if fitted, are to be capable of withstanding the vibratory torques and twists arising from transient criticals and short-circuit currents.

3.3.7 In the case of alternating current generators, resultant vibratory amplitudes at the rotor are not to exceed ±3,5 electrical degrees under both full load working conditions and the malfunction condition mentioned in 2.2.3.

3.4 Other auxiliary machinery systems

3.4.1 The relevant requirements of 3.3.1, 3.3.2 and 3.3.3 are also applicable to other machinery installations such as pumps or compressors.

3.5 Other machinery components

3.5.1 **Torsional vibration dampers**. The use of dampers or detuners to limit vibratory stress due to resonances which occur within the range between $0{,}85N_s$ and $1{,}05N_s$ are to be considered. If fitted, these should be of a type which makes adequate provision for dissipation of heat. Where necessary, performance monitoring may be required.

3.5.2 **Flexible couplings**:

(a) Flexible couplings included in an installation are to be capable of transmitting the mean and vibratory loads without exceeding the makers' recommended limits for angular amplitude or heat dissipation.

(b) Where calculations indicate that the limits recommended by the manufacturer may be exceeded under misfiring conditions, a suitable means is to be provided for detecting and indicating misfiring. Under these circumstances power and/or speed restriction may be required. Where machinery is non-essential, disconnection of the branch containing the coupling would be an acceptable action in the event of misfiring.

3.5.3 **Gearing**:

(a) The torsional vibration characteristics are to comply with the requirements of 2.2. The vibratory torque should not exceed one-third of the full transmission torque throughout the speed range. In cases where the proposed transmission torque loading on the gear teeth is less than the maximum allowable, special consideration will be given the acceptance of additional vibratory loading on the gears.

(b) Where calculations indicate the possibility of torque reversal, the operating speed range is to be determined on the basis of observations during sea trials.

3.6 Restricted speed and/or power ranges

3.6.1 Restricted speed and/or power ranges will be imposed where the stresses exceed the limiting values, τ_c, for continuous running. Similar restrictions will be imposed, or other protective measures required to be taken, where vibratory torques or amplitudes are considered to be excessive for particular machinery items.

3.6.2 Critical responses which give rise to speed restrictions are to be arranged sufficiently removed from the maximum revolutions per minute to ensure that, in general, at $r = 0{,}8$ the stress due to the upper flank does not exceed τ_c.

3.6.3 Where shafting stresses due to a torsional critical response exceed the limiting values, τ_c, for continuous running, the speed restriction will be from:

$$= \frac{16}{18-r} N_c \text{ to } \frac{18-r}{16} N_c \text{ inclusive.}$$

3.6.4 Where calculated vibration stresses due to criticals below $0{,}8N_s$ marginally exceed τ_c or where the critical speeds are sharply tuned, the range of revolutions restricted for continuous operation may be reduced.

3.6.5 In cases where the resonance curve of a critical speed has been derived from measurements, the range of revolutions to be avoided for continuous running may be taken as that over which the measured stresses are in excess of τ_c, having regard to tachometer accuracy.

3.6.6 Where restricted speed ranges under normal operating conditions are imposed, notice boards are to be fitted at the control stations stating that the engine is not to be run continuously between the speed limits obtained as above, and the engine tachometers are to be marked accordingly.

3.6.7 Where vibration stresses approach the limiting value, τ_t, the range of revolutions restricted for continuous operation may be extended. The notice boards are to indicate that this range must be passed through rapidly.

3.6.8 For excessive vibratory torque, stress or amplitude in other components, based on 3.6.1 to 3.6.3, the limits of any speed/power restriction are to be such as to maintain acceptable levels during continuous operation.

3.6.9 Where the restrictions are imposed for the contingency of an engine malfunction or component failure, the limits are to be entered in the machinery operating manual.

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3.6.10 There are to be no restricted speed ranges imposed above a speed ratio of $r \geq 0,8$ under normal operating conditions.

3.7 Tachometer accuracy

3.7.1 Where restricted speed ranges are imposed as a condition of approval, the tachometer accuracy is to be checked against the counter readings, or by equivalent means, in the presence of the Surveyors to verify that it reads correctly within ±2 per cent in way of the restricted range of revolutions.

3.8 Governor control

3.8.1 Where there is significant critical response above and close to the service speed, consideration will be given to the effect of temporary overspeed.

■ *Section 4* Measurements

4.1 General requirements

4.1.1 Where calculations indicate that the limits for torsional vibration within the range of working speeds are exceeded, measurements, using an appropriate technique, may be taken from the machinery installation for the purpose of approval of torsional vibration characteristics, or determining the need for restricted speed ranges and the confirmation of their limits.

4.1.2 Where differences between calculated and measured levels of stress, torque or angular amplitude arise, the stress limits are to be applied to the stresses measured on the completed installation.

4.1.3 The method of measurement is to be appropriate to the machinery components and the parameters which are of concern. Where shaft stresses have been estimated from angular amplitude measurements, and are found to be close to limits, strain gauge techniques may be required. When measurements are required, detailed proposals are to be submitted.

4.2 Vibration monitoring

4.2.1 Where calculations and/or measurements have indicated the possibility of excessive vibratory stresses, torques or angular amplitudes in the event of a malfunction, vibration or performance monitoring, directly or indirectly, may be required.

■ *Section 5* Requirements for craft which are not required to comply with the HSC Code

5.1 General requirements

5.1.1 The requirements of this Chapter do not apply to the following types of vessel having main engines not exceeding 500 kW power output or auxiliary engines not exceeding 110 kW output for essential services:

(a) Service craft of less than 24 m.
(b) Yachts.
(c) ACVs.

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Section

1 **General requirements**

2 **Details to be submitted**

3 **Design**

4 **Measurements**

5 **Requirements for craft which are not required to comply with the HSC Code**

■ *Section 1* General requirements

1.1 Application

1.1.1 This Section is to be read in conjunction with the requirements of Parts 9, 10, 11 and 12.

1.1.2 Unless otherwise advised, it is the responsibility of the Builder as main contractor to ensure, in co-operation with the Enginebuilders, that the information required by this Chapter is prepared and submitted.

1.1.3 The requirements of this Chapter are applicable to the following systems:

- Main propulsion systems formed by oil engines, turbines or electric motors, directly driven or geared to the shafting.

1.2 Power ratings

1.2.1 In this Chapter where shaft power, P, in kW, and revolutions per minute, R, are referred to, the values to be used are those defined in Part 9.

1.3 Basic requirements

1.3.1 For all main propulsion systems, the Builders are to ensure that axial vibration amplitudes are satisfactory throughout the speed range. Where natural frequency calculations indicate significant axial vibration responses, sufficiently wide restricted speed ranges will be imposed. Alternatively, measurements may be used to determine the speed ranges at which amplitudes are excessive for continuous running.

■ *Section 2* Details to be submitted

2.1 Particulars to be submitted

2.1.1 The results of calculations, together with recommendations for any speed restrictions found necessary.

2.1.2 The Enginebuilder's recommendation for axial vibration amplitude limits.

2.1.3 Estimate of flexibility of the thrust bearing and its supporting structure.

2.2 Scope of calculations

2.2.1 Calculations of axial vibration natural frequency are to be carried out using appropriate techniques, taking into account the effects of flexibility of the thrust bearing, for shaft systems where the propeller is:

(a) Driven directly by a reciprocating internal combustion engine.

(b) Driven via gears, or directly by an electric motor, and where the total length of shaft between propeller and thrust bearing is in excess of 60 times the intermediate shaft diameter.

2.2.2 Where an axial vibration damper is fitted, the calculations are to consider the effect of a malfunction of the damper.

■ *Section 3* Design

3.1 Symbols

3.1.1 The symbols used in this Section are as follows:

D = outside diameter of shaft, taken as an average over length l, in mm

d = internal diameter of shaft, in mm

l = length of shaft line between propeller and thrust bearing, in mm

m = mass of shaft line considered, in kg
$= 0{,}785\,(D^2 - d^2)\,G\,l$

M = dry mass of propeller, in kg

$A = \dfrac{m}{M}$

$M_e = M\,(A + 2)$

n = number of propeller blades

k = estimated stiffness at thrust block bearing, in N/m

E = modulus of elasticity of shaft material, in N/mm^2

G = density of shaft material, in kg/mm^3

N_c = critical speed, in rev/min.

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3.2 Critical frequency of axial vibration

3.2.1 For those systems as defined in 2.2.1(b) the propeller speed at which the critical frequency occurs may be estimated using the following formula:

$$N_c = \frac{0,98}{n}\left(\frac{ab}{a+b}\right)^{1/2} \text{ rev/min}$$

where

$$a = \frac{E}{G\,I^2}(66,2 + 97,5A - 8,88A^2)^2 \text{ c/min}^2$$

$$b = 91,2\,\frac{k}{M_e} \text{ c/min}^2.$$

3.2.2 Where the results of this method indicate the possibility of an axial vibration resonance in the vicinity of the service speed, calculations using a more accurate method will be required.

3.3 Restricted speed ranges

3.3.1 The limits of any speed restriction are to be such as to maintain axial amplitudes within recommended levels during continuous operation.

3.3.2 Limits of a speed restriction, where required, may be determined from calculation or on the basis of measurement.

3.3.3 Where a speed restriction is imposed for the contingency of a damper malfunction, the speed limits are to be entered in the operating manual and regular monitoring of the axial vibration amplitude is required. Details of proposals for monitoring are to be submitted.

■ *Section 4* Measurements

4.1 General requirements

4.1.1 Where calculations indicate the possibility of excessive axial vibration amplitudes within the range of working speeds under normal or malfunction conditions, measurements are required to be taken from the shafting system for the purpose of determining the need for restricted speed ranges.

4.2 Vibration monitoring

4.2.1 Where a vibration monitoring system is to be specified, details of proposals are to be submitted.

■ *Section 5* Requirements for craft which are not required to comply with the HSC Code

5.1 General requirements

5.1.1 The requirements of this Chapter do not apply to the following types of vessel having main engines not exceeding 500 kW power output or auxiliary engines not exceeding 110 kW output for essential services:

(a) Service craft of less than 24 m.
(b) Yachts.
(c) ACVs.

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Lateral Vibration

Section

1 **General requirements**

2 **Details to be submitted**

3 **Measurements**

4 **Requirements for craft which are not required to comply with the HSC Code**

■ *Section 1* General requirements

1.1 Application

1.1.1 This Section is to be read in conjunction with the requirements of Parts 9, 10, 11 and 12.

1.1.2 Unless otherwise advised, it is the responsibility of the Builder as main contractor to ensure, in co-operation with the Enginebuilders, that the information required by this Chapter is prepared and submitted.

1.1.3 The requirements of this Chapter are applicable to the following systems:

- Main propulsion systems formed by oil engines, turbines or electric motors, directly driven or geared to the shafting.

1.2 Power ratings

1.2.1 In this Chapter where shaft power, P, in kW, and revolutions per minute, R, are referred to, the values to be used are those defined in Part 9.

1.3 Basic requirements

1.3.1 For all main propulsion shafting systems, the Builders are to ensure that lateral vibration characteristics are satisfactory throughout the speed range.

■ *Section 2* Details to be submitted

2.1 Particulars to be submitted

2.1.1 Calculations of the lateral vibration characteristics of shafting systems having supports outboard of the hull or incorporating cardan shafts are to be submitted.

2.2 Calculations

2.2.1 The calculations in 2.1.1, taking account of bearing, oil-film (where applicable) and structural dynamic stiffnesses, are to investigate the excitation frequencies which may result in significant amplitudes within the speed range, and are to indicate relative deflections and bending moments throughout the shafting system.

■ *Section 3* Measurements

3.1 General requirements

3.1.1 Where calculations indicate the possibility of significant lateral vibration responses within the range of working speeds, measurements using an appropriate recognised technique may be required to be taken from the shafting system for the purpose of determining that hazardous whirling or excessive vibration does not occur.

3.1.2 The method of measurement is to be appropriate to the machinery arrangement and the modes of vibration which are of concern. When measurements are required, detailed proposals are to be submitted in advance.

■ *Section 4* Requirements for craft which are not required to comply with the HSC Code

4.1 General requirements

4.1.1 The requirements of this Chapter do not apply to the following types of vessel having main engines not exceeding 500 kW power output unless the spacing of bearings on the propulsion shafting exceeds 30 diameters or cardan shafts are used in the propulsion shafting system:

(a) Service craft of less than 24 m.
(b) Yachts.
(c) ACVs.

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Section

1 **Shaft alignment**

2 **Requirements for craft which are not required to comply with the HSC Code**

■ *Section 1* Shaft alignment

1.1 General

1.1.1 The Builder is to carry out shaft alignment calculations for all installations and to prepare alignment procedures detailing the proposed alignment method and the alignment checks.

1.2 Particulars to be submitted for approval – Shaft alignment calculations

1.2.1 Shaft alignment calculations are to be submitted to Lloyd's Register (hereinafter referred to as 'LR') for approval for the following shafting systems where the screwshaft has a diameter of 250 mm or greater in way of the aftermost sterntube bearing:

(a) All geared installations.
(b) Installations with one shaftline bearing, or less, inboard of the forward sterntube bearing.
(c) Where prime movers or shaftline bearings are installed on resilient mountings.

1.2.2 The shaft alignment calculations are to take into account the:

(a) thermal displacements of the bearings between cold static and hot dynamic machinery conditions;
(b) buoyancy effect of the propeller immersion due to the craft's operating draughts;
(c) effect of predicted hull deformations over the range of the craft's operating draughts, where known;
(d) gear forces, where appropriate;
(e) for multi-engined installations, possible contributions in the mode of operation;
(f) propeller offset thrust effects, where applicable;
(g) bearing loading in the horizontal plane, where appropriate; and
(h) bearing weardown, where applicable, and its effect on the bearing loads.

1.2.3 The shaft alignment calculations are to state the:

(a) expected bearing loads at light and normal ballast, fully loaded and any other draughts deemed to be part of the craft's operating profile, for the machinery in cold and hot, static and dynamic conditions;
(b) bearing influence coefficients and the deflection, slope, bending moment and shear force along the shaftline;
(c) details of propeller offset thrust effects, where employed in calculation;
(d) details of proposed slope-bore of the aftermost sterntube bearing, where applicable;
(e) manufacturer's specified limits for bending moment and shear force at the shaft couplings of the gearbox/prime movers;
(f) estimated bearing weardown rates for water or grease-lubricated sterntube bearings;
(g) origin of findings where the effect of hull deformation has been considered, *viz.* whether finite element calculations or measured results from sister or similar craft have been used;
(h) anticipated thermal rise of prime movers and gearing units between cold static and hot running conditions; and
(j) manufacturer's allowable bearing loads.

1.3 Particulars to be submitted for review – Shaft alignment procedure

1.3.1 A shaft alignment procedure is to be submitted for all main propulsion installations detailing, as a minimum, the:

(a) expected bearing loads at light and normal ballast, fully loaded and any other draughts deemed to be part of the craft's operating profile, for the machinery in cold and hot, static and dynamic conditions;
(b) maximum permissible loads for the proposed bearing designs;
(c) design bearing offsets from the straight line;
(d) design gaps and sags;
(e) location and loads for the temporary shaft supports;
(f) expected relative slope of the shaft and the bearing in the aftermost sterntube bearing;
(g) details of slope-bore of the aftermost sterntube bearing, where applied;
(h) expected shear forces and bending moments at the forward end flange of the shafting system connecting to the gear output shaft or, for direct-drive installations, to the prime mover output flange;
(j) proposed bearing load measurement technique and its estimated accuracy;
(k) jack correction factors for each bearing where the bearing load is measured using a specified jacking technique;
(l) proposed shaft alignment acceptance criteria, including the tolerances; and
(m) flexible coupling alignment criteria.

1.4 Design and installation criteria

1.4.1 For main propulsion installations, the shafting is to be aligned to give, in all conditions of craft loading and machinery operation, bearing load distribution satisfying the requirements of 1.4.2.

1.4.2 Design and installation of the shafting is to satisfy the following criteria:

(a) The Builder is to position the bearings and construct the bearing seatings to minimise the effects of hull deflections under any of the craft's operating conditions.
(b) Relative slope between the propeller shaft and the aftermost sterntube bearing is, in general, not to exceed 3×10^{-4} rad.
(c) Sterntube bearing loads are to satisfy the requirements of Pt 11, Ch 2,4.16.2.

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(d) Intermediate shaft bearings' loads are not to exceed 80 per cent of the bearing manufacturer's allowable maximum load, for plain journal bearings, based on the bearing projected area.
(e) Main gear wheel bearing loads are to be within the gear-box manufacturer's specified limits.
(f) Resulting shear forces and bending moments are to meet the equipment manufacturer's specified coupling conditions throughout the shafting system.
(g) The manufacturer's radial, axial and angular alignment limits for the flexible couplings are to be maintained.

1.5 Measurements

1.5.1 Where calculations indicate that the system is sensitive to changes in alignment under different service conditions, the optimised shaft alignment is to be verified by measurements during sea trials using an approved strain gauge technique.

1.6 Flexible couplings

1.6.1 Where the shafting system incorporates flexible couplings, the effects of such couplings on the various modes of vibration are to be considered, *see* Section 2.

■ *Section 2*
Requirements for craft which are not required to comply with the HSC Code

2.1 General requirements

2.1.1 The requirements of Section 1 do not apply to the following types of vessel where the main engine does not exceed 500 kW power output:
(a) Service craft of less than 24 m.
(b) Yachts.
(c) ACVs.

2.1.2 The engines, shafting, sterntubes and propeller brackets are to be carefully fitted and well secured to the hull of the craft so that satisfactory alignment of the shafting will be maintained in service.

2.1.3 The alignment of the sterntube and propeller brackets is to be demonstrated before launching and the shafting and engine alignment verified when afloat.

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Rules and Regulations for the Classification of Special Service Craft

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Steering Systems
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Section

1 **General requirements**

2 **Particulars to be submitted**

3 **Materials**

4 **Design and performance**

5 **Piping systems**

6 **Control, monitoring and electrical equipment**

7 **Requirements for craft which are not required to comply with the HSC Code**

■ *Section 1* General requirements

1.1 Application

1.1.1 This Chapter is to be read in conjunction with the General Requirements for Machinery in Part 9.

1.1.2 The requirements of this Chapter apply to the design and construction of steering systems.

(a) A steering system includes:
- all steering devices;
- all mechanical, electrical, and hydraulic linkages;
- all power devices, including manual devices;
- all controls and all actuating systems.

(b) Steering may be achieved by means of:
- air or water rudders;
- foils, flaps, steerable propellers or jets;
- yaw control ports or transverse thrusters;
- differential propulsive thrust;
- variable geometry of the craft or its lift system components; or
- by a combination of these devices.

1.2 Provision of steering gear

1.2.1 Craft are to be provided with a means for steering which is to be of adequate strength and suitable design to enable the craft's heading and direction of travel to be effectively controlled at all designed operating conditions.

1.2.2 Craft are to be provided with a main steering system and an independent auxiliary steering unit. The main and the auxiliary steering units are to be so arranged that the failure of one of them will not render the other one inoperative or unable to bring the craft to a safe situation.

1.2.3 An auxiliary steering system is not a requirement provided the craft is fitted with two independent and identical steering systems, one of which is capable of steering the craft when the second system becomes inoperative.

1.3 Definitions

1.3.1 **Main steering system** means the machinery, the actuator(s), the power units, if any, ancillary equipment, and the means of applying the steering torque, if applicable, necessary for the purpose of steering the craft under design conditions.

1.3.2 **Auxiliary steering system** means the equipment other than any part of the main steering unit necessary to steer the craft in the event of failure of the main steering system.

1.3.3 **Steering power system** means:

(a) In the case of electric steering system, an electric motor and its associated electrical parts.

(b) In the case of electrohydraulic steering system, an electric motor and its associated electrical parts and connected pump.

(c) In the case of other hydraulic steering system units, a driving engine and connected pump.

1.3.4 **Steering control system** means the equipment by which orders are transmitted from the control station to the steering power units. Steering control systems comprise transmitters, receivers, hydraulic control pumps and their associated motors, motor controllers, piping and cables.

1.3.5 **Maximum working pressure** means the expected pressure in the system when the steering unit is operated under the most onerous design condition.

■ *Section 2* Particulars to be submitted

2.1 Submission of information

2.1.1 At least three copies of the plans and information as detailed in 2.2 and 2.3 are to be submitted.

2.2 Plans

2.2.1 Detailed plans of all load bearing, and torque transmitting components and hydraulic pressure retaining parts of the steering system together with proposed rated torque, all relief valve settings, and scantlings.

2.2.2 Schematic of the hydraulic systems, together with pipe material, relief valve and working pressures.

2.2.3 Details of control engineering aspects in accordance with Pt 16, Ch 1.

2.3 Calculations and information

2.3.1 The manoeuvring characteristics for which the craft has been designed.

2.3.2 Material specifications.

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Section 3
Materials

3.1 General

3.1.1 All components are to be in accordance with the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

3.1.2 All steering unit components transmitting mechanical forces are to be of steel or other approved ductile material. In general, such material is to have an elongation of not less than 12 per cent nor a tensile strength in excess of 650 N/mm^2. Special consideration will be given to the acceptance of grey cast iron for low pressure valve bodies and mechanical parts with low stress levels.

3.1.3 Consideration will be given to the acceptance of non-ferrous materials as applicable.

Section 4
Design and performance

4.1 General

4.1.1 Power-operated steering units are to be provided with positive arrangements, such as limit switches, for stopping the unit before the mechanical stops are reached. These arrangements are to be synchronised with the unit itself and not with the steering unit control mechanism.

4.1.2 The steering unit is to be secured to the seating by fitted bolts, and suitable chocking arrangements are to be provided. The seating is to be of substantial construction.

4.1.3 All welded joints within the pressure boundary of an actuator or connecting parts transmitting mechanical loads are to be of full penetration type or of equivalent strength.

4.1.4 Steering devices involving variable geometry of the craft or its lift system components are to be so constructed that any failure of the drive linkage or actuating system will not significantly hazard the craft.

4.2 Actuating systems

4.2.1 Actuators are to be designed in accordance with the relevant requirements of Part 15 for Class I pressure vessels (notwithstanding any exemptions for hydraulic cylinders).

4.2.2 Accumulators, if fitted, are to comply with the relevant requirements of Part 15.

4.2.3 The design pressure for calculations to determine the scantlings of piping and other steering components subjected to internal hydraulic pressure shall be at least 1,25 times the maximum working pressure to be expected under the operational conditions specified taking into account any pressure which may exist in the low pressure side of the system. Fatigue criteria may be applied for the design of piping and components, taking into account pulsating pressures due to dynamic loads.

4.2.4 The permissible primary general membrane stress is not to exceed the lower of the following values:

$$\frac{\sigma_B}{A} \text{ or } \frac{\sigma_y}{B}$$

where

σ_B = specified minimum tensile strength of material at ambient temperature

σ_y = specified minimum yield stress or 0,2 per cent proof stress of the material, at ambient temperature.

A and *B* are given by the following Table:

	Wrought steel	Cast steel	Nodular cast iron
A	3,5	4	5
B	1,7	2	3

4.2.5 Oil seals between non-moving parts, forming part of the external pressure boundary, should be of the metal upon metal type or of an equivalent type.

4.2.6 Hydraulic power operated steering units are to be provided with the following:

(a) Arrangements to maintain the cleanliness of the hydraulic fluid taking into consideration the type and design of the hydraulic system;

(b) A fixed storage tank having sufficient capacity to recharge at least one power actuating system including the reservoir. The storage tank is to be provided with a contents gauge and be permanently connected by piping in such a manner that the hydraulic systems can be readily recharged from a position within the steering unit compartment, if applicable.

4.3 Rudder systems

4.3.1 For the requirements of rudder and rudder stock, *see* Pt 3, Ch 3.

4.3.2 Tillers and quadrants are to comply with the requirements of Table 1.4.1.

4.3.3 On double rudder installations, where the two tillers are connected by mechanical means (tie-bar), the strength and stability of the tie-bar is to be assessed using the maximum steering torque applied to the stock.

4.3.4 Where higher tensile steel bolts are used on bolted tillers and quadrants, the yield and ultimate tensile stresses of the bolt material are to be stated on plans submitted for approval, together with full details of the methods to be adopted to obtain the required setting-up stress. Where proprietary nuts or systems are used, the manufacturer's instructions for assembly are to be adhered to.

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Table 1.4.1 Connection of tiller to stock

(1) Dry fit – tiller to stock for M_T (*see* Notes)	(a) For keyed connection, factor of safety against slippage = 1,1 (b) For keyless connection, factor of safety against slippage = 2,2 (c) Coefficient of friction = 0,17 (d) Grip stress not to be less than 20 N/mm^2
(2) Hydraulic fit – tiller to stock for M_T (*see* Notes)	(a) For keyed connection, factor of safety against slippage = 1,1 (b) For keyless connection, factor of safety against slippage = 2,2 (c) Coefficient of friction = 0,12 (d) Grip stress not to be less than 20 N/mm^2
(3) Bolted tiller and quadrant (*see* Symbols and Notes)	Shim to be fitted between two halves before machining to take rudder stock, then removed prior to fitting Minimum thickness of shim: For 4 connecting bolts: $t_s = 0{,}0014 d_{SU}$ mm For 6 connecting bolts: $t_s = 0{,}0012 d_{SU}$ mm Key to be fitted Diameter of bolts, $\delta_T = \dfrac{0{,}60 d_{SU}}{\sqrt{n_T}}$ mm Distance from centre of stock to centre of bolts should generally be equal to $d_{SU}\left(1{,}0 + \dfrac{0{,}30}{\sqrt{n_T}}\right)$ mm Thickness of flange on each half of the bolted tiller $\dfrac{0{,}66 d_{SU}}{\sqrt{n_T}}$ mm
(4) Key (*see* Symbols and Notes)	Effective sectional area in shear $\geq 0{,}25 d_{SU}^2$ mm^2 Key thickness $\geq 0{,}17 d_{SU}$ mm Keyway is to extend over full depth of tiller and is to have a rounded end. Corners are to be provided with suitable radii to avoid high stress at the keyway root.
(5) Section modulus – tiller arm (at any point within its length about vertical axis) (*see* Symbols and Notes)	To be not less than the greater of: (a) $Z_{TA} = \dfrac{0{,}15 d_{SU}^3 (b_T - b_s)}{1000 b_T}$ cm^3 (b) $Z_{TA} = \dfrac{0{,}06 d_{SU}^3 (b_T - 0{,}9 d_{SU})}{1000 b_T}$ cm^3 If more than one arm is fitted, combined modulus is not to be less than the greater of (a) or (b). For solid tillers, the breadth to depth ratio is not to exceed 2.
(6) Boss (*see* Symbols and Notes)	Depth of boss $\geq d_{SU}$ Thickness of boss in way of tiller $\geq 0{,}4 d_{SU}$

Symbols

b_s = distance between the section of the tiller arm under consideration and the centre of the rudder stock, in mm
NOTE: b_T and b_s are to be measured with zero rudder angle

b_T = distance from the point of application of the load on the tiller to the rudder stock, in mm

n_T = number of bolts in coupling, but generally not to be taken greater than six

t_s = thickness of shim for machining bolted tillers and quadrants, in mm

Z_{TA} = section modulus of tiller arm, in cm^3

d_{SU} = *see* Pt 3, Ch 3

δ_T = diameter of bolts securing bolted tillers and quadrants, in mm

σ_o = minimum yield stress or 0,5 per cent proof stress of the tiller bolt material, in N/mm^2

NOTES
1. If $d_{SU} > 400$ mm, higher tensile steel bolts are to be used for bolted tillers. A predetermined setting-up load equivalent to a stress of approximately $0{,}7\sigma_o$ should be applied to each bolt assembly. A lower stress may be accepted provided that two keys, complying with item (4) are fitted.
2. Where M_T, the maximum turning moment applied to the stock, is to be taken as the greater of the following:
   (a) $11{,}1 d_{SU}^3$ Nmm where d_{SU} is to be determined from Table 3.2.7 in Pt 3, Ch 3 with σ_o taken as 235 N/mm^2 and $N = 0$.
   (b) The torque generated by the steering gear at the maximum working pressure, *see* 1.3.5.

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4.3.5 All steering components transmitting mechanical forces to the rudder stock, which are not protected against overload by structural rudder stops or mechanical buffers, are to have a strength at least equivalent to that of the rudder stock in way of the tiller.

4.3.6 In bow rudders having a vertical locking pin operated from the deck above, positive means are to be provided to ensure that the pin can be lowered only when the rudder is exactly central. In addition, an indicator is to be fitted at the deck to show when the rudder is exactly central.

4.4 Performance

4.4.1 The main steering system is to be:
(a) Of adequate strength and capable of steering the craft at all speeds and conditions for which the craft is designed and this shall be demonstrated during trials;
(b) operated by power where necessary to meet the requirements of (a) and in any case when the Rules require a rudder stock over 120 mm diameter in way of the tiller; and
(c) so designed that it will not be damaged at maximum astern speed.

4.4.2 The auxiliary steering system is to be:
(a) Of adequate strength and capable of steering the craft at navigable speed and of being brought speedily into action in an emergency.
(b) Operated by power where necessary to meet the requirements of (a) and in any case when the Rules, require a rudder stock over 230 mm diameter in way of the tiller.
(c) Where manual operated steering units are proposed, these are acceptable when the operation does not require an effort exceeding 160N under normal conditions.

4.4.3 Main and auxiliary steering power units are to be:
(a) Arranged to re-start automatically when power is restored after power failure.
(b) Capable of being brought into operation from a position at the control station. In the event of a power failure to any one of the steering power units, an audible and visual alarm is to be given on the control station.
(c) Arranged so that transfer between units can be readily effected.

4.4.4 For high speed craft, in the event of total power failure, either:
(a) emergency power for steering systems/drives is to be restored automatically within five seconds. To achieve this an interim fast acting system may be required to come into operation until such time as auxiliary/ emergency power source comes on line. (Note: starting arrangements are to comply with the requirements relating to starting arrangements of emergency generators); or
(b) means are to be provided to bring the craft to a safe condition.

4.4.5 Where the steering unit is so interconnected that more than one power system, or control system, can be simultaneously operated, the design is to be such that hydraulic locking caused by a single failure cannot occur.

4.4.6 Steering systems, other than of the hydraulic type, will be accepted provided the standards are considered equivalent to the requirements of this Section.

■ *Section 5* Piping systems

5.1 Components

5.1.1 Piping, joints, valves, flanges and other fittings are to comply within the requirements of Pt 15, Ch 1 for Class 1 piping system components. The design pressure is to be in accordance with 4.2.3.

5.2 Valve and relief valve arrangements

5.2.1 For vessels with non-duplicated actuators, isolating valves are to be fitted at the connection of pipes to the actuator, and are to be directly fitted on the actuator.

5.2.2 Arrangements for bleeding air from the hydraulic system are to be provided, where necessary.

5.2.3 Relief valves are to be fitted to any part of the hydraulic system which can be isolated and in which pressure can be generated from the power source or from external forces. The settings of the relief valves is not to exceed the design pressure. The valves are to be of adequate size and so arranged as to avoid an undue rise in pressure above the design pressure.

5.2.4 Relief valves for protecting any part of the hydraulic system which can be isolated, as required by 5.2.3 are to comply with the following:
(a) The setting pressure is not to be less than 1,25 times the maximum working pressure.
(b) The minimum discharge capacity of the relief valve(s) is not to be less than 110 per cent of the total capacity of the pumps which can deliver through it (them).
Under such conditions the rise in pressure is not to exceed 10 per cent of the setting pressure. In this regard, due consideration is to be given to extreme foreseen ambient conditions in respect of oil viscosity.

5.3 Flexible hoses

5.3.1 Flexible hoses are to be of approved type, *see* Pt 15, Ch 1,13.

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Section 6
Control, monitoring and electrical equipment

6.1 Control

6.1.1 All steering systems are to be be operated from the craft's control station.

6.1.2 If steering systems can also be operated from other positions, then two-way communication is to be arranged between the control station and these other positions.

6.1.3 Steering control is to be provided:

(a) For the main steering unit, both at the control station and in the steering unit compartment, where applicable;

(b) Where the main steering unit is arranged by two independent control systems, both operable from the control station. This does not require duplication of the steering wheel or steering lever. Where the control system consists of a hydraulic telemotor, a second independent system need not be fitted.

(c) For the auxiliary steering unit, in the steering unit compartment and, if power operated, it is also to be operable from the control station and is to be independent of the control system for the main steering system.

6.1.4 Electrical control systems are to be independent and separated as far as is practicable throughout their length.

6.1.5 Any main and auxiliary steering unit control system operable from the control station is to comply with the following:

(a) Means are to be provided in the steering unit compartment, if applicable, for disconnecting any control system operable at the control station from the steering unit it serves;

(b) The system is to be capable of being brought into operation from a position on the control station.

6.1.6 Appropriate operating instructions with a block diagram showing the change-over procedures for steering unit control systems and steering unit actuating systems are to be permanently displayed at the control station and in the steering unit compartment, if applicable.

6.1.7 Where the system failure alarms for hydraulic lock, *see* Table 1.6.1, are provided, appropriate instructions are to be placed on the control station to shut down the system at fault.

6.2 Monitoring

6.2.1 Alarms and monitoring requirements are indicated in 6.2.2, 6.2.3 and Table 1.6.1.

Table 1.6.1 Alarms

Item	Alarm	Note
Angular position of the Steering Mechanism	—	Indication, *see* 6.1.6
	Failure	*See* 6.2.4
Steering power units, power	Failure	—
Steering motors	Overload Single phase	For alarm and running indication locations. *see* 6.3.2 and 6.3.3
Control system	Failure	*See* 6.2.4
Control system power	Failure	—
Steering gear hydraulic oil level	Low	Each reservoir to be be monitored. For Alarm locations, *see* 6.3.4.
Auto pilot	Failure	Running indication
Hydraulic oil temperature	High	Where oil cooler is fitted
Hydraulic lock	Fault	Where more than one system (either power or control) can be operated simultaneously each each system is to be monitored, *see* Note
Hydraulic oil filter differential pressure	High	When oil filters are fitted

NOTE
This alarm is to identify the system at fault and is to be activated when (for example):
- position of the variable displacement pump control system does not correspond with given order; or
- incorrect position of 3-way full flow valve or similar in constant delivery pump system is detected.

6.2.2 The angular position of the steering mechanism is to:

(a) Where the main steering unit is power operated, be indicated at the control station, and other positions as applicable. The angular indication is to be independent of the steering unit control system; and is to indicate any abnormal responses or malfunctions. The logic of such feedback and indications are to be consistent with the other alarms and indications so that in an emergency operators are unlikely to be confused.

(b) Be recognisable in the steering unit compartment, if applicable.

6.2.3 The alarms described in Table 1.6.1 are to be indicated on the navigating bridge and the additional locations described and are to be in accordance with the alarm system specified by Pt 16, Ch 1,2.3.

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6.2.4 Steering control systems are to be monitored and an audible and visual alarm is to be initiated on the navigation bridge in the event of:

- failure of the control system, including command and fee back circuits; or
- unacceptable deviation between the rudder order and actual rudder position and/or unacceptable delay in response to changes in the rudder order.

6.3 Electrical equipment

6.3.1 Short circuit protection, and overload alarm and, in the case of polyphase circuits, an alarm to indicate failure of any one of the phases is to be provided for each main and auxiliary motor circuit. Protective devices are to operate at not less than twice the full load current of the motor or circuit protected and are to allow excess current to pass during the normal accelerating period of the motors.

6.3.2 The alarms required by 6.3.1 are to be provided on the bridge and in the main machinery space or control room from which the main machinery is normally controlled.

6.3.3 Indicators for running indication of each main and auxiliary motor are to be installed on the control station and at a suitable main machinery control position.

6.3.4 A low-level alarm is to be provided for each steering system hydraulic fluid reservoir to give the earliest practicable indication of hydraulic fluid leakage. Alarms are to be given on the navigation bridge and in the machinery space where they can be readily observed.

6.3.5 Two exclusive circuits are to be provided for each electric or electrohydraulic steering unit arrangement consisting of one or more electric motors.

6.3.6 Each of these circuits is to be fed from the main switchboard. One of these circuits may pass through the emergency switchboard.

6.3.7 One of these circuits may be connected to the motor of an associated auxiliary electric or electrohydraulic power unit.

6.3.8 Each of these circuits is to have adequate capacity to supply all the motors which can be connected to it and which can operate simultaneously.

6.3.9 These circuits are to be separated throughout their length as widely as is practicable.

6.3.10 Each main and auxiliary electric control system which is to be operated from the control station is to comply with the following:

(a) It is to be served with electric power by a separate circuit supplied from the associated steering unit power circuit, from a point within the steering unit compartment, or directly from the same section of switchboard busbars, main or emergency, to which the associated steering unit power circuit is connected.

(b) Each separate circuit is to be provided with short circuit protection only.

■ *Section 7*
Requirements for craft which are not required to comply with the HSC Code

7.1 Introduction

7.1.1 The requirements of Sections 1 to 6 of this Chapter apply, except where modified by this Section.

7.2 Design and performance

7.2.1 In craft over 50 m in length, the main steering system is to be power operated.

7.2.2 Service craft of length 50 m or less, or sailing yachts of length 50 m or less, may have manual steering. Where wheel steering is fitted, an alternative means of steering (which may be a hand tiller) is to be readily available, and the performance of both systems is to be in accordance with 7.2.6.

7.2.3 The main steering gear is to be capable of steering the craft at the maximum ahead speed and turning the rudder from hardover to hardover in 30 seconds.

7.2.4 Where wire rope steering leads are fitted, they are to be of suitable construction. Wire rope is to be stainless steel or suitably protected against corrosion and the strength of the rope is to be as follows:

$$\text{Breaking load} = \frac{d_{SU}^3}{100R} \text{ kN}$$

where

d_{SU} is the basic stock diameter at quadrant or tiller given by Table 3.2.7 in Pt 3, Ch 3, in mm.

R = radius of quadrant, or length of tiller arm, in mm.

7.2.5 Steering leads are to be as direct as possible, and sharp bends are to be avoided. Sheaves are to be of adequate diameter and designed to prevent the steering leads from jumping or jamming.

7.2.6 Means are to be provided for adjusting the tension in the steering leads.

7.2.7 Where considered necessary, an efficient locking or brake arrangement is to be fitted to keep the rudder steady when a change from one type of steering to the other is required.

7.2.8 Where manually operated steering is permitted, the effort required to operate the tiller or steering wheel is to be not more than 160 N under normal conditions.

7.3 Control and monitoring

7.3.1 The alarms and safeguards for yachts and service craft less than 24 m are to be adequate for the type of steering system employed, *see* Table 1.7.1.

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Table 1.7.1 Alarms

Item	Alarm	Note
Angular position of the Steering Mechanism	—	Indication
Steering power units, power	Failure	—
Steering motors	Overload, single phase	Also running indication on bridge
Control system power	Failure	—
Steering gear hydraulic oil level	Low	—
Auto pilot	Failure	Running indication
Hydraulic oil temperature	High	Where oil cooler is fitted

7.3.2 The requirements of 6.3.5 do not apply to service craft less than 24 m.

7.4 Electrical equipment

7.4.1 Consideration will be given to the electrical control equipment of simple steering systems on service craft less than 24 m or yachts, *see* Pt 16, Ch 2.

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Rules and Regulations for the Classification of Special Service Craft

Volume 7
Part 15
Piping Systems and Pressure Plant
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■ *Section 1* Application

1.1 General

1.1.1 The requirements of this Chapter apply to the design and construction of piping systems including pipe fittings forming part of such systems.

■ *Section 2* Details to be submitted

2.1 Plans and information

2.1.1 At least three copies of the following plans and information are to be submitted.

2.1.2 Venting, sounding and drainage arrangements for all watertight compartments.

2.1.3 The following diagrammatic plans including details of the material and pipe dimensions/thickness:

- Bilge and ballast system including the capacities of the pumps on bilge service.
- Lubricating oil systems.
- Flammable liquids used for control and heating systems.
- Power transmission systems for services essential for safety or for the operation of the craft at sea.
- Cooling water systems for main and auxiliary services.
- Compressed air systems for main and auxiliary services.
- Steam systems with a design pressure above 7 bar.

2.1.4 Arrangement of oil fuel storage tanks with a capacity of over 0,5 m^3 where these do not form part of the structure of the craft.

2.1.5 Where it is intended to use plastic pipes for Class I, Class II and any Class III systems for which there are requirements in these Rules, details of the following:

(a) Properties of the materials.
(b) Operating conditions.
(c) Intended service and location.
(d) Pipes, fittings and joints.

2.1.6 Design details of the following components:

(a) Flexible hoses.
(b) Sounding devices.
(c) Resiliently seated valves.
(d) Expansion joints.
(e) Components of an unusual or novel nature.

2.1.7 The requirements for plans and information for the fire-fighting systems are given in Pt 17, Ch 1,1.2.3.

■ *Section 3* Class of pipes

3.1 General

3.1.1 Pipework systems are divided into three classes depending on the internal fluid and design temperature and pressure of the system.

3.1.2 Material test requirements for the different classes of pipe are detailed in the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

3.1.3 Acceptable jointing methods for the different classes of pipe are given in the appropriate Section of this Chapter. Material certificate requirements are given in Section 11.

3.1.4 The maximum design pressure and temperature for Class II and III systems is given in Table 1.3.1. To illustrate, *see* Fig. 1.3.1.

3.1.5 Class I pipes are to be used where either the maximum design pressure or design temperature exceeds that applicable to Class II pipes.

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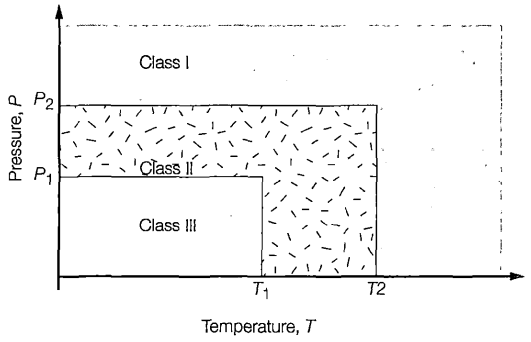
Table 1.3.1 Maximum pressure and temperature conditions for Class II and III piping systems

Piping system	Class II		Class III	
	p	*T*	*p*	*T*
	bar	°C	bar	°C
Steam	16,0	300	7,0	170
Flammable liquids (see Note)	16,0	150	7,0	60
Other media	40,0	300	16,0	200

NOTE
Flammable liquids include: oil fuel, thermal oil and lubricating oil.



NOTE
T_1 and P_1 correspond to the maximum temperatures and pressures for a Class III piping system and T_2 and P_2 to those for a Class II piping system depending on the service.

Fig. 1.3.1 Classes of piping system

3.1.6 Class III pipes may also be used for open ended piping, e.g. overflows, vents, boiler waste steam pipes, open-ended drains, sounding pipes, etc.

■ *Section 4* Design symbols and definitions

4.1 Design symbols

4.1.1 The symbols used in this Chapter are defined as follows:

- a = percentage negative manufacturing tolerance on thickness
- c = corrosion allowance, in mm
- d = inside diameter of pipe, in mm, *see* 4.1.3
- e = weld efficiency factor, *see* 4.1.4
- p = design pressure, in bar, *see* 4.2
- p_t = hydraulic test pressure, in bar
- t = the minimum thickness of a straight pipe, in mm, including corrosion allowance and negative tolerance, where applicable
- t_b = the minimum thickness of a straight pipe to be used for a pipe bend, in mm, including bending allowance, corrosion allowance and negative tolerance, where applicable
- D = outside diameter of pipe, in mm, *see* 4.1.2
- R = radius of curvature of a pipe bend at the centre line of the pipe, in mm
- T = design temperature, in °C, *see* 4.3.1
- σ = maximum permissible design stress, in N/mm^2.

4.1.2 The outside diameter, D, is subject to manufacturing tolerances, but these are not to be used in the evaluation of formulae.

4.1.3 The inside diameter, d, is not to be confused with nominal pipe size, which is an accepted designation associated with outside diameters of standard rolling sizes.

4.1.4 The weld efficiency factor, e, is to be taken as 1,0 for seamless and electric resistance or induction welded steel pipes.

4.2 Design pressure

4.2.1 The design pressure, p, is the maximum permissible working pressure and is to be not less than the highest set pressure of the safety valve or relief valve. In systems which have no safety valve or relief valve, the design pressure is to to be taken as 1,1 times the maximum working pressure.

4.2.2 The design pressure of piping on the discharge from pumps is to be taken as the pump pressure at full rated speed against a shut valve. Where a safety valve or other protective device is fitted to restrict the pressure to a lower value than the shut valve load, the design pressure is to be the highest set pressure of the device.

4.2.3 For design pressure of steering system components and piping, *see* Part 14.

4.3 Design temperature

4.3.1 The design temperature is to be taken as the maximum temperature of the internal fluid, but in no case is it to be less than 50°C.

■ *Section 5* Carbon and low alloy steels

5.1 General

5.1.1 The minimum thickness of steel pipes is to be determined by the formulae given in 5.1.2 and 5.1.3 except that in no case is it to be less than that shown in Table 1.5.1.

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Table 1.5.1 Minimum thickness for steel pipes

External diameter *D* mm	Minimum pipe thickness mm
10,2–12	1,6
13,5–19	1,8
20–44,5	2,0
48,3–63,5	2,3
70–82,5	2,6
88,9–108	2,9
114,3–127	3,2
133–139,7	3,6
152,4–168,3	4,0
177,8 and over	4,5

NOTES
1. The thickness of air, overflow and sounding pipes for structural tanks is to be not less than 4,5 mm.
2. The thickness of bilge, ballast and general sea water pipes is to be not less than 4,0 mm.
3. The thickness of bilge, air, overflow and sounding pipes through ballast and oil fuel tanks, ballast lines through oil fuel tanks and oil fuel lines through ballast tanks is to be not less than 6,3 mm.
4. For air, bilge, ballast, oil fuel, overflow, sounding, and venting pipes as mentioned in Notes 1 to 3, where the pipes are efficiently protected against corrosion the thickness may be reduced by not more than 1 mm.
5. For air and sounding pipes the minimum thickness applies to the part of the pipe outside the tank but not exposed to weather. The section of pipe exposed to weather may be required to be suitably increased in thickness in accordance with statutory and loadline requirements as applicable.

5.1.2 The minimum thickness, t, of straight steel pressure pipes is to be determined by the following formula:

$$t = \left(\frac{pD}{20\sigma e + p} + c\right)\frac{100}{100 - a} \text{ mm}$$

where
symbols are as defined in 4.1.1
c is obtained from Table 1.5.2, *see also* 5.1.4
σ may be obtained directly from Table 1.5.3 or from the formula given in 5.1.6.

Table 1.5.2 Values of corrosion allowance (*c*) for steel pipes

Piping service	*c*, in mm
Saturated steam systems	0,8
Compressed air systems	1,0
Hydraulic oil systems	0,3
Lubricating oil systems	0,3
Fuel oil systems	1,0
Refrigerating plants	0,3
Fresh water systems	0,8
Sea-water systems in general	3,0

5.1.3 The minimum thickness, t_b, of a straight steel pipe to be used for a pipe bend is to be determined by the following formula, except where it can be demonstrated that the use of a thickness less than t_b would not reduce the thickness below t at any point after bending:

$$t_b = \left[\left(\frac{pD}{20\sigma e + p}\right)\left(1 + \frac{D}{2{,}5R}\right) + c\right]\frac{100}{100 - a} \text{ mm}$$

where
symbols are as defined in 4.1.1
c and σ are obtained as in 5.1.2
in general, R is to be not less than $3D$.

5.1.4 For pipes passing through tanks, where the thickness has been calculated in accordance with 5.1.2 or 5.1.3, an additional corrosion allowance is to be added to take account of external corrosion; the addition will depend on the external medium and the value is to be in accordance with Table 1.5.2.

5.1.5 Where the pipes are efficiently protected against corrosion, the corrosion allowance, c, may be reduced by not more than 50 per cent.

Table 1.5.3 Carbon and carbon-manganese steel pipes

Specified minimum tensile strength, N/mm^2	Maximum permissible design stress, N/mm^2												
	Maximum design temperature, °C												
	50	100	150	200	250	300	350	400	410	420	430	440	450
320	107	105	99	92	78	62	57	55	55	54	54	54	49
360	120	117	110	103	91	76	69	68	68	68	64	56	49
410	136	131	124	117	106	93	86	84	79	71	64	56	49
460	151	146	139	132	122	111	101	99	98	85	73	62	53
490	160	156	148	141	131	121	111	109	98	85	73	62	53

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5.1.6 The maximum permissible design stress, σ, is to be taken as the lowest of the following values:

$$\sigma = \frac{E_t}{1,6}$$

$$\sigma = \frac{R_{20}}{2,7}$$

$$\sigma = \frac{S_R}{1,6}$$

where

E_t = specified minimum lower yield or 0,2 per cent proof stress at the design temperature

R_{20} = specified minimum tensile strength at ambient temperature

S_R = average stress to produce rupture in 100 000 hours at the design temperature

Values of E_t, R_{20} and S_R may be obtained from Chapter 6 of the Rules for Materials. Intermediate values may be obtained by interpolation.

5.1.7 Steel stub pipes between the shell plating and the sea valve are to be of short rigid construction, adequately supported and of substantial thickness.

5.2 Steel pipe joints

5.2.1 Joints in steel pipelines may be made by:

- Screwed on or welded on bolted flanges.
- Butt welds between pipes or between pipes and valve chests.
- Socket welded joints (up to 60,3 mm outside diameter).
- Threaded sleeve joints (parallel thread), *see also* 5.5.
- Special types of approved joints that have been shown to be suitable for the design conditions, *see also* 5.4.

5.2.2 All welding of pipes is to be in accordance with the requirements specified in Chapter 13 of the Rules for Materials.

5.2.3 Where pipes are joined by welding a suitable number of flanged joints are to be provided at suitable positions to facilitate installation and removal for maintenance.

5.2.4 Where welded pipes are protected against corrosion then the corrosion protection is to be applied after welding or the corrosion protection is to be made good in way of the weld damaged area.

5.2.5 Where it is not possible to make good the corrosion protection of the weld damaged area, then the pipe is to be considered to have no corrosion protection.

5.2.6 Where backing rings are used for welding pipes, then the effect of the flow obstruction of the backing ring and erosion/crevice corrosion of the backing ring is to be taken into account.

5.3 Welded-on flanges, butt welded joints and fabricated branch pieces

5.3.1 The dimensions and material of flanges and bolting, and the pressure-temperature rating of bolted flanges in pressure pipelines, in accordance with National or other established standards will be accepted.

5.3.2 The types of welded-on flanges are to be suitable for the pressure, temperature and service for which the pipes are intended.

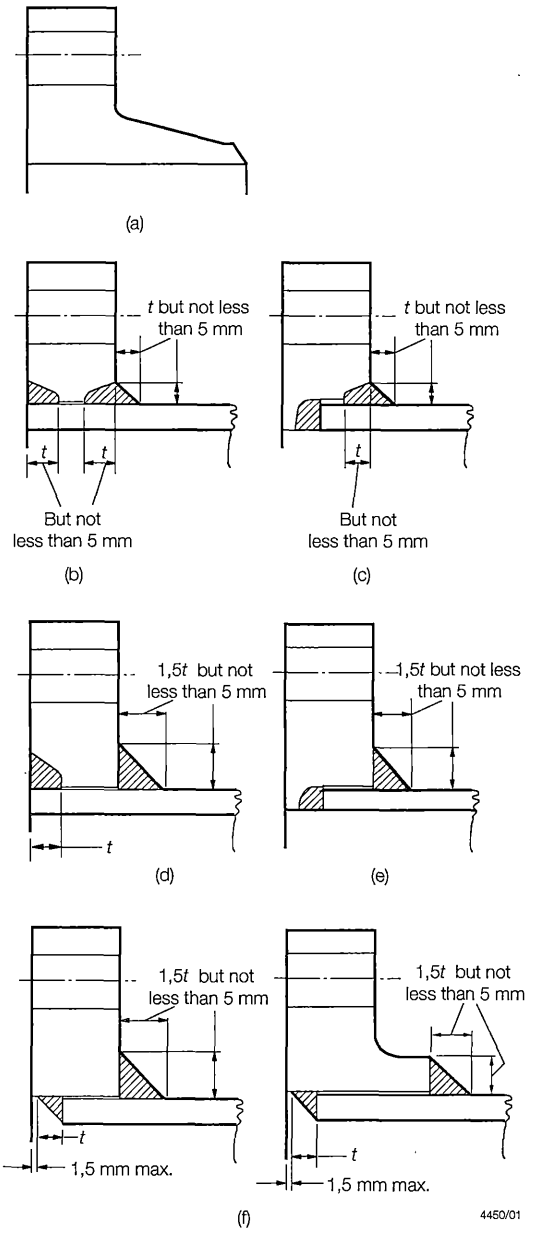

Fig. 1.5.1
Typical examples of welded flange connections

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Table 1.5.4 Limiting design conditions for flange types

Flange type	Maximum pressure	Maximum temperature	Maximum pipe o.d.	Minimum pipe bore
		°C	mm	mm
(a)	Pressure-temperature ratings to be in accordance with a recognised standard	No restriction	No restriction	No restriction
(b)		No restriction	168,3 for alloy steels*	No restriction
(c)		No restriction	168,3 for alloy steels*	75
(d)		425	No restriction	No restriction
(e)		425	No restriction	75
(f)		425	No restriction	No restriction

* No restriction for carbon steels

5.3.3 Typical examples of welded-on flange attachments are shown in Fig. 1.5.1, and limiting design conditions for flange types (a) to (f) are shown in Table 1.5.4.

5.3.4 Welded-on flanges are not to be a tight fit on the pipes. The maximum clearance between the bore of the flange and the outside diameter of the pipe is to be 3 mm at any point, and the sum of the clearances diametrically opposite is not to exceed 5 mm.

5.3.5 Where butt welds are employed in the attachment of flange type (a), in pipe-to-pipe joints or in the construction of branch pieces, the adjacent pieces are to be matched at the bores. This may be effected by drifting, roller expanding or machining, provided that the pipe wall is not reduced below the designed thickness. If the parts to be joined differ in wall thickness, the thicker wall is to be gradually tapered to the thickness of the thinner at the butt joint. The welding necks of valve chests are to be sufficiently long to ensure that the valves are not distorted as the result of welding and subsequent heat treatment of the joints.

5.3.6 Where backing rings are used with flange type (a) they are to fit closely to the bore of the pipe and should be removed after welding. The rings are to be made of the same material as the pipes or of mild steel having a sulphur content not greater than 0,05 per cent.

5.3.7 Branches may be attached to pressure pipes by means of welding provided that the pipe is reinforced at the branch by a compensating plate or collar or other approved means, or alternatively that the thickness of pipe and branch are increased to maintain the strength of the pipe. These requirements also apply to fabricated branch pieces.

5.4 Screwed fittings

5.4.1 Screwed fittings including compression fittings may be used in piping systems not exceeding 41 mm outside diameter. Where the fittings are not in accordance with an acceptable standard then Lloyd's Register (hereinafter referred to as 'LR') may require the fittings to be subjected to special tests to demonstrate their suitability.

5.5 Threaded sleeve joints (parallel thread)

5.5.1 Threaded sleeve joints in accordance with National or other established standards may be used within the limits given in Table 1.5.5. They are not to be used in piping systems conveying flammable liquids.

Table 1.5.5 Limiting design conditions for threaded sleeve joints

Nominal bore	Maximum pressure	Maximum temperature
mm	bar (kgf/cm^2)	°C
≤ 25	12,0 (12,2)	260
> 25 ≤ 40	10,0 (10,2)	260
> 40 ≤ 80	8,5 (8,7)	260
> 80 ≤ 100	7,0 (7,1)	260

5.6 Socket weld joints

5.6.1 Socket weld joints may be used with carbon steel pipes not exceeding 60,3 mm outside diameter. Socket weld fittings are to be of forged steel and the material is to be compatible with the associated piping. Such joints are not to be used where fatigue, severe erosion or crevice corrosion is expected to occur. *See also* Ch 4,7.3.9.

5.6.2 The thickness of the socket weld fittings is to meet the requirements of 5.1.3 but is to be not less than 1,25 times the nominal thickness of the pipe or tube. The diametrical clearance between the outside diameter of the pipe and the bore of the fitting is not to exceed 0,8 mm, and a gap of approximately 1,5 mm is to be provided between the end of the pipe and the bottom of the socket.

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5.6.3 The leg lengths of the fillet weld connecting the pipe to the socket weld fitting are to be such that the throat dimension of the weld is not less than the nominal thickness of the pipe or tube.

5.7 Welded sleeve joints

5.7.1 Welded sleeve joints may be used in Class III systems only, subject to the restrictions and general dimensional requirements given in 5.6 for socket weld joints.

5.7.2 The pipe ends are to be located in the centre of the sleeve with a 1,5 to 2,0 mm gap.

5.8 Other mechanical couplings

5.8.1 Pipe unions, compression couplings, or slip-on joints, as shown in Fig. 1.5.2, may be used if type approved for the service conditions and the intended application. The type approval is to be based on the results of testing of the actual joints. The acceptable use for each service is indicated in Table 1.5.6 and dependence upon the Class of piping, with limiting pipe dimensions, is indicated in Table 1.5.7.

5.8.2 Where the application of mechanical joints results in a reduction in pipe wall thickness due to the use of bite type rings or other structural elements, this is to be taken into account in determining the minimum wall thickness of the pipe to withstand the design pressure.

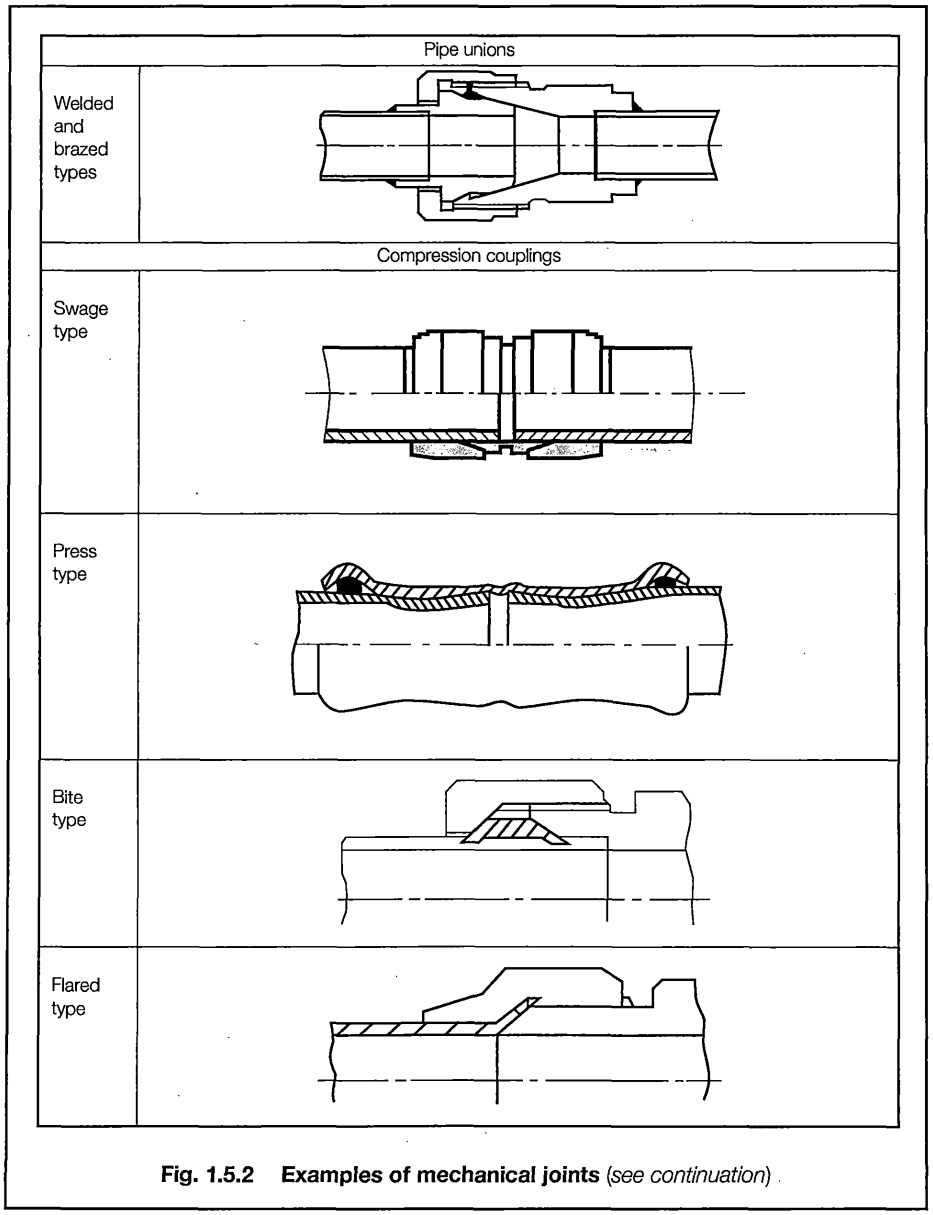

Fig. 1.5.2 Examples of mechanical joints (*see continuation*)

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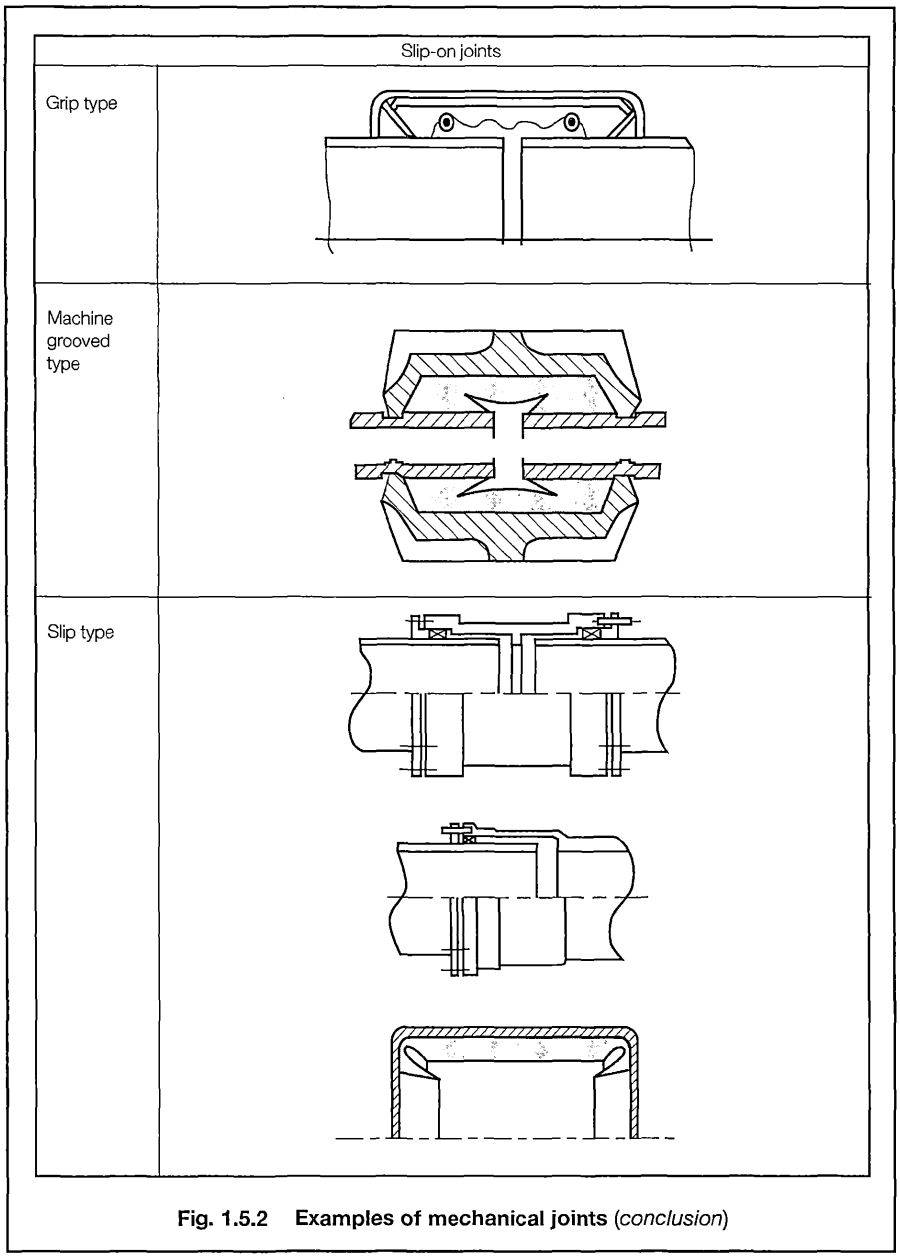

Fig. 1.5.2 Examples of mechanical joints (*conclusion*)

5.8.3 Construction of mechanical joints is to prevent the possibility of tightness failure affected by pressure pulsation, piping vibration, temperature variation and other similar adverse effects occurring during operation on board.

5.8.4 Materials of mechanical joints are to be compatible with the piping material and internal and external media.

5.8.5 Mechanical joints for pressure pipes are to be tested to a burst pressure of 4 times the design pressure. For design pressures above 200 bar the required burst pressure will be specially considered.

5.8.6 In general, mechanical joints are to be of fire-resistant type where required by Table 1.5.6.

5.8.7 Mechanical joints, which in the event of damage could cause fire or flooding, are not to be used in piping sections directly connected to the sea openings or tanks containing flammable fluids.

5.8.8 Mechanical joints are to be designed to withstand internal and external pressure as applicable and where used in suction lines are to be capable of operating under vacuum.

5.8.9 Generally, slip-on joints are not to be used in pipelines in cargo holds, tanks, and other spaces which are not easily accessible. Application of these joints inside tanks may only be accepted where the medium conveyed is the same as that in the tanks.

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Table 1.5.6 Application of mechanical joints

Systems	Kind of connections		
	Pipe unions	Compression couplings (6)	Slip-on joints
Flammable fluids (Flash point <60°)			
Cargo oil lines	+	+	+5
Crude oil washing lines	+	+	+5
Vent lines	+	+	+3
Inert gas			
Water seal effluent lines	+	+	+
Scrubber effluent lines	+	+	+
Main lines	+	+	+2,5
Distribution lines	+	+	+5
Flammable fluids (Flash point > 60°)			
Cargo oil lines	+	+	+5
Fuel oil lines	+	+	+2,3
Lubricating oil lines	+	+	+2,3
Hydraulic oil	+	+	+2,3
Thermal oil	+	+	+2,3
Sea-water			
Bilge lines	+	+	+1
Fire main and water spray	+	+	+3
Foam system	+	+	+3
Sprinkler system	+	+	+3
Ballast system	+	+	+1
Cooling water system	+	+	+1
Tank cleaning services	+	+	+
Non-essential systems	+	+	+
Fresh water			
Cooling water system	+	+	+1
Condensate return	+	+	+1
Non-essential system	+	+	+
Sanitary/Drains/Scuppers			
Deck drains (internal)	+	+	+4
Sanitary drains	+	+	+
Scuppers and discharge (overboard)	+	+	—
Sounding/vent			
Water tanks/Dry spaces	+	+	+
Oil tanks (f.p.> 60°C)	+	+	+2,3
Miscellaneous			
Starting/Control air (1)	+	+	—
Service air (non-essential)	+	+	+
Brine	+	+	+
CO_2 system	+	+	—
Steam	+	+	—

KEY
+ Application is allowed
— Application is not allowed

NOTES
1. Inside machinery spaces of Category A – only approved fire resistant types.
2. Not inside machinery spaces of Category A or accommodation spaces. May be accepted in other machinery spaces provided the joints are located in easily visible and accessible positions.
3. Approved fire resistant types.
4. Above freeboard deck only.
5. In pump rooms and open decks – only approved fire resistant types.
6. If compression couplings include any components which are sensitive to heat, they are to be of approved fire resistant type as required for slip-on joints.

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Table 1.5.7 Application of mechanical joints depending on class of piping

Types of joints	Classes of piping systems		
	Class I	Class II	Class III
Pipe unions			
Welded and brazed type	+(OD ≤ 60,3 mm)	+(OD ≤ 60,3 mm)	+
Compression couplings			
Swage type	–	–	+
Bite type	+(OD ≤ 60,3 mm)	+(OD ≤ 60,3 mm)	+
Flared type	+(OD ≤ 60,3 mm)	+(OD ≤ 60,3 mm)	+
Press type	–	–	+
Slip-on joints			
Machine grooved type	+	+	+
Grip type	–	+	+
Slip type	–	+	+

KEY
+ Application is allowed
– Application is not allowed

5.8.10 Unrestrained slip-on joints are only to be used in cases where compensation of lateral pipe deformation is necessary. Usage of these joints as the main means of pipe connection is not permitted.

■ *Section 6* Copper and copper alloys

6.1 General

6.1.1 Copper and copper alloy pipes are acceptable for a wide range of services, including bilge pipework and where non heat-sensitive material is required.

6.1.2 The maximum permissible service temperature of copper and copper alloy pipes, valves and fittings is not to exceed 200°C for copper and aluminium brass, and 300°C for copper-nickel. Cast bronze valves and fittings complying with the requirements of Chapter 9 of the Rules for Materials may be accepted up to 260°C.

6.1.3 The minimum thickness, t, of straight copper and copper alloy pipes is to be determined by the following formula but is not to be less than that shown in Table 1.6.1:

$$t = \left(\frac{pD}{20\sigma + p} + c\right)\frac{100}{100 - a} \text{ mm}$$

where

symbols are as defined in 4.1.1

c = 0,8 mm for copper, aluminium brass, and copper-nickel alloys where the nickel content is less than 10 per cent
= 0,5 mm for copper-nickel alloys where the nickel content is 10 per cent or greater
= 0 where the media are non-corrosive relative to the pipe material

σ may be obtained from Table 1.6.2.

Intermediate values may be obtained by linear interpolation.

Table 1.6.1 Minimum thickness for copper and copper alloy pipes

Standard pipe sizes (outside diameter)			Minimum overriding nominal thickness	
			Copper	Copper alloy
8	to	10	1,0	0,8
12	to	20	1,2	1,0
25	to	44,5	1,5	1,2
50	to	76,1	2,0	1,5
88,9	to	108	2,5	2,0
133	to	159	3,0	2,5
193,7	to	267	3,5	3,0
273	to	457,2	4,0	3,5
508	and	over	4,5	4,0

6.1.4 The minimum thickness t_b, of a straight seamless copper or copper alloy pipe to be used for a pipe bend is to be determined by the formula below, except where it can be demonstrated that the use of a thickness less than t_b would not reduce the thickness below t at any point after bending:

$$t_b = \left[\left(\frac{pD}{20\sigma + p}\right)\left(1 + \frac{D}{2{,}5R}\right) + c\right]\frac{100}{100 - a} \text{ mm}$$

where

symbols are as defined in 4.1.1

c and σ are obtained as in 6.1.3

in general, R is to be not less than $3D$.

6.1.5 Pipes are to be seamless, and branches are to be provided by cast or stamped fittings, pipe pressing or other approved fabrications.

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Table 1.6.2 Copper and copper alloy pipes

Pipe material	Condition of supply	Specified minimum tensile strength, N/mm^2	Permissible stress, N/mm^2										
			Maximum design temperature, °C										
			50	75	100	125	150	175	200	225	250	275	300
Copper	Annealed	220	41,2	41,2	40,2	40,2	34,3	27,5	18,6	—	—	—	—
Aluminium brass	Annealed	320	78,5	78,5	78,5	78,5	78,5	51,0	24,5	—	—	—	—
90/19 Copper-nickel iron	Annealed	270	68,6	68,6	67,7	65,7	63,7	61,8	58,8	55,9	52,0	48,1	44,1
70/30 Copper-nickel	Annealed	360	81,4	79,4	77,5	75,5	73,5	71,6	69,6	67,7	65,7	63,7	61,8

6.1.6 Brazing and welding materials are to be suitable for the operating temperature and for the medium being carried.

6.1.7 Where silver brazing is used, strength is to be obtained by means of the bond in a capillary space over the whole area of the mating surfaces. A fillet braze at the back of the flange or at the face is undesirable. The alloy used for silver brazing is to contain not less than 49 per cent silver.

6.1.8 The use of copper-zinc brazing alloy is not permitted.

6.2 Heat treatment

6.2.1 Pipes which have been hardened by cold bending are to be suitably heat treated on completion of manufacture and prior to being tested by hydraulic pressure. Copper pipes are to be annealed and copper alloy pipes are to be either annealed or stress relief heat treated.

■ *Section 7* Cast iron

7.1 General

7.1.1 Grey cast iron valves and fittings will, in general, be accepted in Class III piping systems except as stated in 7.1.5. Grey cast iron valves and fittings may be accepted in the Class II steam systems referred to in Table 1.3.1 but the design pressure or temperature is not to exceed 13 bar or 220°C, respectively.

7.1.2 Spheroidal or nodular graphite iron castings for valves and fittings in Class II and Class III piping systems are to be made in a grade having a specified minimum elongation not less than 12 per cent on a gauge length of $5{,}65\sqrt{S_o}$, where S_o is the actual cross-sectional area of the test piece.

7.1.3 Proposals for the use of this material in Class I piping systems will be specially considered, but in no case is the material to be used in systems where the design temperature exceeds 350°C.

7.1.4 Where the elongation is less than the minimum required by 7.1.2, the material is, in general, to be subject to the same limitations as grey cast iron.

7.1.5 Grey cast iron is not to be used for the following:

- Valves and fittings for boiler blow-down systems and other piping systems subject to shock or vibration.
- Shell valves and fittings, *see* Ch 2,3.1.
- Valves fitted on the collision bulkhead.

■ *Section 8* Plastics

8.1 General

8.1.1 Proposals to use plastics pipes will be considered in relation to the properties of the materials, the operating conditions and the intended service and location. Special consideration will be given to any proposed service for plastics pipes not mentioned in these Rules.

8.1.2 Attention is also to be given to *Guidelines for the Application of Plastics Pipes on Ships* contained in IMO Resolution A.753(18).

8.1.3 Plastics pipes and fittings will, in general, be accepted in Class III piping systems.

8.1.4 Plastics pipes are not acceptable for oil fuel, lubricating oil or other flammable liquid systems in machinery spaces, cargo holds and other spaces of high fire risk.

8.1.5 For Class I, Class II and any Class III piping systems for which there are Rule requirements, the pipes are to be of a type which has been approved by LR.

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8.1.6 For domestic and similar services where there are no Rule requirements, the pipes need not be of a type which has been approved by LR. However, the fire safety aspects as referenced in 8.4, are to be taken into account.

8.1.7 The use of plastics pipes may be restricted by statutory requirements of the National Authority of the country in which the craft is to be registered.

8.2 Design and performance criteria

8.2.1 Pipes and fittings are to be of robust construction and are to comply with a national or other established standard, consistent with the intended use. Particulars of pipes, fittings and joints are to be submitted for consideration.

8.2.2 The design and performance criteria of all piping systems, independent of service or location, are to meet the requirements of 8.3.

8.2.3 Depending on the service and location, the fire safety aspects such as fire endurance, and fire protection coatings, are to meet the requirements of 8.4.

8.2.4 Plastics piping is to be electrically conductive when:

(a) Carrying fluids capable of generating electrostatic charges.

(b) Passing through hazardous zones and spaces, regardless of the fluid being conveyed.

Suitable precautions against the build up of electrostatic charges are to be provided in accordance with the requirements of 8.5, *see also* Pt 16, Ch 2,1.12.

8.3 Design strength

8.3.1 The strength of pipes is to be determined by hydrostatic pressure tests to failure on representative sizes of pipe. The strength of fittings is to be not less than the strength of the pipes.

8.3.2 In service, the pipe is not to be subjected to a pressure greater than the nominal internal pressure pN_i.

8.3.3 The nominal internal pressure, pN_i, of the pipe is to be determined by the lesser of the following:

$$pN_i \leq \frac{P_{st}}{4}$$

$$pN_i \leq \frac{P_{lt}}{2,5}$$

where

p_{st} = short term hydrostatic test failure pressure, in bar

p_{lt} = long term hydrostatic test failure pressure (100 000 hours), in bar.

Due to the length of time stipulated for the long term test, testing may be carried out over a reduced period of time and the results extrapolated using a suitable standard such as ASTM D2837 and ASTM D1598.

8.3.4 The nominal external pressure, pN_e of the pipe, defined as the maximum total of internal vacuum and external static pressure head to which the pipe may be subjected, is to be determined by the following:

$$pN_e \leq \frac{P_{col}}{3}$$

where

p_{col} = pipe collapse pressure in bar

The pipe collapse pressure is to be not less than 3 bar.

8.3.5 Piping is to meet the design requirements of 8.3.2 and 8.3.4 over the range of service temperature it will experience.

8.3.6 High temperature limits and pressure reductions relative to nominal pressures are to be in accordance with a recognised standard, but in each case the maximum working temperature is to be at least 20°C lower than the minimum temperature of deflection under load of the resin or plastics material without reinforcement. The minimum temperature of deflection under load is not to be less than 80°C, *see also* Ch 14,4 of the Rules for Materials.

8.3.7 Where it is proposed to use plastics piping in low temperature services, design strength testing is to be made at a temperature 10°C lower than the minimum working temperature.

8.3.8 For guidance, typical temperature and pressure limits are indicated in Tables 1.8.1 and 1.8.2. The Tables are related to water service only.

8.3.9 The selection of plastics materials for piping is to take account of other factors such as impact resistance, ageing, fatigue, erosion resistance, fluid absorption and material compatibility such that the design strength of the piping is not reduced below that required by these Rules.

8.3.10 Design strength values may be verified experimentally or by a combination of testing and calculation methods.

8.4 Fire performance criteria

8.4.1 Where plastics pipes are used in systems essential for the safe operation of the craft, or for containing combustible fluids or sea-water where leakage or failure could result in fire or in the flooding of watertight compartments, the pipes and fittings are to be of a type which have been fire endurance tested, *see also* 8.2.3.

8.4.2 Where a fire protective coating of pipes and fittings is necessary for achieving the fire endurance standards required, the coating is to be resistant to products likely to come into contact with the piping and be suitable for the intended application.

8.5 Electrical conductivity

8.5.1 Where a piping system is required to be electrically conductive for the control of static electricity, the resistance per unit length of the pipe, bends, elbows, fabricated branch pieces, etc., is not to exceed 0,1 MΩ/m, *see also* 8.2.4.

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Table 1.8.1 Typical temperature and pressure limits for thermoplastic pipes

Material	Nominal pressure, bar	Maximum permissible working pressure, bar						
		–20°C to 0°C	30°C	40°C	50°C	60°C	70°C	80°C
PVC	10		7,5	6				
	16		12	9	6			
ABS	10	7,5	7,5	7	6			
	16	12	12	10,5	9	7,5	6	
HDPE	10	7,5	6					
	16	12	9,5	6				

Abbreviations:

PVC Polyvinyl chloride
ABS Acrylonitrile – butadiene – styrene
HDPE High density polyethylene

Table 1.8.2 Typical temperature and pressure limits for glass fibre reinforced epoxy (GRE) and glass fibre reinforced polyester (GRP) pipes

Min. temperature of deflection under load of resin	Nominal pressure, bar	Maximum permissible working pressure, bar							
		–50°C to 30°C	40°C	50°C	60°C	70°C	80°C	90°C	95°C
80°C	10	10	9	7,5	6				
	16	16	14	12	9,5				
	25	16	16	16	15				
100°C	10	10	10	9,5	8,5	7	6		
	16	16	16	15	13,5	11	9,5		
	25	16	16	16	16	16	15		
135°C	10	10	10	10	10	9,5	8,5	7	6
	16	16	16	16	16	15	13,5	11	9,5
	25	16	16	16	16	16	16	16	15

8.6 Installation and construction

8.6.1 All pipes are to be adequately but freely supported. Suitable provision is to be made for expansion and contraction to take place without unduly straining the pipes.

8.6.2 Pipes may be joined by mechanical couplings or by bonding methods such as welding, laminating, adhesive bonding or other approved means.

8.6.3 Sufficient mechanical joints are to be provided to enable the pipes to be readily removed.

8.6.4 The required fire endurance level of the pipe is to be maintained in way of pipe supports, joints and fittings, including those between plastics and metallic pipes.

8.6.5 Where piping systems are arranged to pass through watertight bulkheads or decks, provision is to be made for maintaining the integrity of the bulkhead or deck by means of metallic bulkhead pieces. The bulkhead pieces are to be protected against corrosion and so constructed to be of a strength equivalent to the intact bulkhead; attention is drawn to 8.6.1. Details of the arrangements are to be submitted for approval.

8.6.6 Where a piping system is required to be electrically conductive, for the control of static electricity, continuity is to be maintained across the joints and fittings, and the system is to be earthed, *see also* Pt 16, Ch 2,1.12.

8.7 Testing

8.7.1 The hydraulic testing of pipes and fittings is to be in accordance with 14.1.2. For pipes and fittings not employing hand lay up techniques, the hydrostatic pressure test required by Ch 14,4.9 of the Rules for Materials may be replaced by testing carried out in accordance with the requirements stipulated in a National or International Standard, consistent with the intended use for which the pipe or fittings are manufactured, provided there is an effective quality system in place complying with the requirements of Ch 14,4.4 of the Rules for Materials and the testing is completed to the satisfaction of the LR Surveyor.

8.7.2 Where a piping system is required to be electrically conductive, tests are to be carried out to verify that the resistance to earth from any point in the system does not exceed 1 MΩ.

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Section 9
Austenitic stainless steel

9.1 General

9.1.1 Stainless steels may be used for a wide range of services and are particularly suitable for use at elevated temperatures. For guidance on the use of austenitic steels in sea water systems, *see* 16.3.4.

9.1.2 The minimum thickness of stainless steel pipes is to be determined from the formula given in 5.1.2 or 5.1.3 using a corrosion allowance of 0,8 mm. Values of the 0,2 per cent proof stress and tensile strength of the material for use in the formula in 5.1.6 may be obtained from Table 6.5.2 in Chapter 6 of the Rules for Materials.

9.1.3 Where stainless steel is used in lubricating oil and hydraulic oil systems, the corrosion allowance may be reduced to 0,3 mm.

9.1.4 In no case is the thickness of stainless steel pipes to be less than that shown in Table 1.9.1.

Table 1.9.1 Minimum thickness for austenitic stainless steel pipes

Standard pipe sizes (outside diameter)			Minimum nominal thickness
mm		mm	mm
10,2	to	17,2	1,0
21,3	to	48,3	1,6
60,3	to	88,9	2,0
114,3	to	168,3	2,3
219,1			2,6
273,0			2,9
323,9	to	406,4	3,6
over	406,4		4,0

NOTE
The external diameters and thicknesses have been selected from ISO-Standard 1127:1980. Diameters and thicknesses according to other National or International Standards may be accepted.

9.1.5 Joints in stainless steel pipework may be made by any of the techniques described in 5.2 to 5.7.

9.1.6 Where pipework is butt welded, this should preferably be accomplished without the use of backing rings, in order to eliminate the possibility of crevice corrosion between the backing ring and pipe.

Section 10
Aluminium alloy

10.1 General

10.1.1 The use of aluminium alloy material in Class III piping systems will be considered in relation to the fluid being conveyed and operating conditions of temperature and pressure.

10.1.2 In general, aluminium alloy may be used for air and sounding pipes for water tanks and dry spaces providing it can be shown that pipe failure will not cause a loss of integrity across watertight divisions. In craft of aluminium construction, aluminium alloy may also be used for air and sounding pipes for oil fuel, lubricating oil and other flammable liquid tanks provided the pipes are suitably protected against the effects of fire.

10.1.3 Aluminium alloy pipes are not to be used in machinery spaces or cargo holds for conveying oil fuel, lubricating oil or other flammable liquids, or for bilge suction pipework within machinery spaces.

Table 1.10.1 Minimum thickness of aluminium pipes

Nominal pipe size (mm)	Minimum wall thickness (mm)
10	1,7
15	2,1
20	2,1
25	2,8
40	2,8
50	2,8
80	3,0
100	3,0
150	3,4
200	3,8
250 and over	4,2

10.1.4 Aluminium alloy pipes are not acceptable for fire extinguishing pipes unless they are suitably protected against the effect of heat. The use of aluminium alloy with appropriate insulation will be considered when it has been demonstrated that the arrangements provide equivalent structural and integrity properties compared to steel. In open and exposed locations, where the insulation material is likely to suffer from mechanical damage, suitable protection is to be provided.

10.1.5 The minimum thickness of aluminium alloy pipes is to be not less than that shown in Table 1.10.1.

10.1.6 Design requirements for aluminium pressure pipes for design pressures greater than 7 bar will be specially considered.

10.1.7 Attention is drawn to the susceptibility of aluminium to corrosion in the region of welded connections.

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Section 11
Material certificates

11.1 Metallic materials

11.1.1 Materials for Class I and II piping systems and components as defined in Table 1.3.1, also for shell valves and fittings and fittings on the collision bulkhead are to be manufactured and tested in accordance with the Rules for Materials.

11.1.2 Ferrous castings and forgings for Class I and II piping systems are to be produced at a works approved by LR.

11.1.3 Materials for Class III piping systems are to be manufactured and tested in accordance with the requirements of acceptable National Standards.

11.1.4 The Manufacturer's materials test certificate will be accepted for all classes of piping and components in lieu of an LR materials certificate where the maximum design conditions are less than shown in Table 1.11.1.

Table 1.11.1 Maximum conditions for pipes, valves and fittings for which Manufacturer's materials test certificate is acceptable

Material	Working temperature °C	*DN* = Nominal Diameter, mm P_W = Working Pressure, bar
Carbon and low alloy steel. Stainless steel. Spheroidal or nodular cast iron.	< 300	*DN* < 50 or P_W x *DN* < 2500
Copper alloy	< 200	*DN* < 50 or P_W x *DN* < 1500

11.2 Non-metallic materials

11.2.1 Pipes and fittings intended for applications in Class I, Class II and Class III systems for which there are Rule requirements are to be manufactured in accordance with Chapter 14 of the Rules for Materials.

Section 12
Requirements for valves

12.1 General

12.1.1 The design, construction and operational capability of valves are to be in accordance with an acceptable National or International Standard appropriate for the piping system. Where valves are not in accordance with an acceptable Standard, details are to be submitted for consideration.

12.1.2 Valves are to be made of steel, cast iron, copper alloy, or other approved material suitable for the intended purpose.

12.1.3 Valves having isolation or sealing components sensitive to heat are not to be used in spaces where leakage or failure caused by fire could result in fire spread, flooding or the loss of an essential service.

12.1.4 Where valves are required to be capable of being closed remotely in the event of fire, the valves, including their control gear, are to be of steel construction or of an acceptable fire tested design.

12.1.5 Valves are to be arranged for clockwise closing and are to be provided with indicators showing whether they are open or shut unless this is readily obvious.

12.1.6 Valves are to be so constructed as to prevent the possibility of valve covers or glands being slackened back or loosened when the valves are operated.

12.1.7 Valves and cocks are to be fitted with legible nameplates, and, unless otherwise specifically mentioned in the Rules, the valves and cocks are to be fitted in places where they are at all times readily accessible.

12.1.8 Valves are to be used within their specified pressure and temperature rating for all normal operating conditions, and are to be suitable for the intended purpose.

12.1.9 Valves intended for submerged installation are to be suitable for both internal and external media. Spindle sealing is to prevent ingress of external media at the maximum external pressure head expected in service.

12.1.10 Additional requirements for shell valves are given in Ch 2,3.

12.2 Valves with remote control

12.2.1 All valves which are provided with remote control are to be arranged for local manual operation, independent of the remote operating mechanism.

12.2.2 In the case of valves which are required by the Rules to be provided with remote control, opening and/or closing of the valves by local manual means is not to render the remote control system inoperable.

12.3 Resiliently seated valves

12.3.1 Valves, having isolation or sealing components sensitive to heat, are not to be used in spaces where leakage or failure caused by fire could result in fire spread, flooding or loss of an essential service.

12.3.2 Where the valves are of the diaphragm type, they are not acceptable as shut off valves at the shell plating.

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12.3.3 Resiliently seated valves are not to be used in main or auxiliary machinery spaces as branch or direct bilge suction valves or as pump suction valves from the main bilge line (except where the valve is located in the immediate vicinity of the pump and in series with a metal seated non-return valve. The non-return valve is to be fitted on the bilge main side of the resiliently seated valve). Where they are used in other locations and within auxiliary machinery spaces having little or no fire risk they should be of an approved fire safe type and used in conjunction with a metal seated non-return valve.

12.3.4 Resiliently seated valves are not acceptable for use in fire water mains unless they have been satisfactorily fire tested.

Section 13
Requirements for flexible hoses

13.1 General

13.1.1 A flexible hose assembly is a short length of metallic or non-metallic hose normally with prefabricated end fittings ready for installation.

13.1.2 For the purpose of approval for the applications in 13.2, details of the materials and construction of the hoses, and the method of attaching the end fittings together with evidence of satisfactory prototype testing, are to be submitted for consideration.

13.1.3 The use of hose clamps and similar types of end attachments are not be used for flexible hoses in piping systems for steam, flammable media, starting air systems or for sea water systems where failure may result in flooding. In other piping systems, the use of hose clamps may be accepted where the working pressure is less than 5 bar and provided that there are two clamps at each end connection.

13.1.4 Flexible hoses are to be limited to a length necessary to provide for relative movement between fixed and flexibly mounted items of machinery/equipment or systems.

13.1.5 Flexible hoses are not to be used to compensate for misalignment between sections of piping.

13.1.6 Flexible hose assemblies are not to be installed where they may be subjected to torsional deformation (twisting) under normal operating conditions.

13.1.7 The number of flexible hoses in piping systems mentioned in this Section is to be kept to a minimum and to be limited for the purpose stated in 13.2.1.

13.1.8 Where flexible hoses are intended for conveying flammable fluids in piping systems that are in close proximity to hot surfaces, electrical installation or other sources of ignition, the risk of ignition due to failure of the hose assembly and subsequent release of fluids is to be mitigated as far as practicable by the use of screens or other suitable protection.

13.1.9 Flexible hoses are to be installed in clearly visible and readily accessible locations.

13.1.10 The installation of flexible hose assemblies is to be in accordance with the manufacturer's instructions and use limitations with particular attention to the following:

(a) Orientation.
(b) End connection support (where necessary).
(c) Avoidance of hose contact that could cause rubbing and abrasion.
(d) Minimum bend radii.

13.1.11 Flexible hoses are to be permanently marked by the manufacturer with the following details:

(a) Hose manufacturer's name or trademark.
(b) Date of manufacture (month/year).
(c) Designation type reference.
(d) Nominal diameter.
(e) Pressure rating.
(f) Temperature rating.

Where a flexible hose assembly is made up of items from different manufacturers, the components are to be clearly identified and traceable to evidence of prototype testing.

13.2 Applications for rubber hoses

13.2.1 Short joining lengths of flexible hoses complying with the requirements of this Section may be used, where necessary, to accommodate relative movement between various items of machinery connected to permanent piping systems. The requirements of this Section may also be applied to temporarily-connected flexible hoses or hoses of portable equipment.

13.2.2 Rubber or plastics hoses, with integral cotton or similar braid reinforcement, may be used in fresh and sea-water cooling systems. In the case of sea-water systems, where failure of the hoses could give rise to the danger of flooding, the hoses are to be suitably enclosed.

13.2.3 Rubber hoses, with single, double or more closely woven integral wire braid or other suitable material reinforcement, or convoluted metal pipes with wire braid protection, may be used in bilge, ballast, compressed air, fresh water, sea-water, oil fuel, lubricating oil, Class III steam, hydraulic and thermal oil systems. Flexible hoses of plastics materials for the same purposes, such as Teflon or Nylon, which are unable to be reinforced by incorporating closely woven integral wire braid are to have suitable material reinforcement as far as practicable. Where rubber or plastics hoses are used for oil fuel supply to burners, the hoses are to have external wire braid protection in addition to the integral wire braid. Flexible hoses for use in steam systems are to be of metallic construction.

13.2.4 Flexible hoses are not to be used in high pressure fuel oil injection systems.

13.2.5 The requirements in this Section for flexible hose assemblies are not applicable to hoses intended to be used in fixed fire extinguishing systems.

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13.3 Design requirements

13.3.1 Flexible hose assemblies are to be designed and constructed in accordance with recognised National or International Standards acceptable to LR.

13.3.2 Flexible hoses are to be complete with approved end fittings in accordance with manufacturer's specification. End connections which do not have flanges are to comply with 5.8 as applicable and each type of hose/fitting combination is to be subject to prototype testing to the same standard as that required by the hose with particular reference to pressure and impulse tests.

13.3.3 Flexible hose assemblies intended for installation in piping systems where pressure pulses and/or high levels of vibration are expected to occur in service, are to be designed for the maximum expected impulse peak pressure and forces due to vibration. The tests required by 13.4 are to take into consideration the maximum anticipated in-service pressures, vibration frequencies and forces due to installation.

13.3.4 Flexible hose assemblies constructed of non-metallic materials intended for installation in piping systems for flammable media, and sea-water systems where failure may result in flooding, are to be of fire-resistant type. Fire resistance is to be demonstrated by testing to ISO 15540 and ISO 15541.

13.3.5 Flexible hose assemblies are to be suitable for the intended location and application, taking into consideration ambient conditions, compatibility with fluids under working pressure and temperature conditions consistent with the manufacturer's instructions and any other applicable requirements in the Rules.

13.4 Testing

13.4.1 Acceptance of flexible hose assemblies is subject to satisfactory prototype testing. Prototype test programmes for flexible hose assemblies are to be submitted by the manufacturer and are to be sufficiently detailed to demonstrate performance in accordance with the specified standards.

13.4.2 For a particular hose type complete with end fittings, the tests, as applicable, are to be carried out on different nominal diameters for pressure, burst, impulse and fire resistance in accordance with the requirements of the relevant standard. The following standards are to be used as applicable:

- ISO 6802 – *Rubber and plastics hoses and hose assemblies – Hydraulic pressure impulse test without flexing*.
- ISO 6803 – *Rubber and plastics hoses and hose assemblies – Hydraulic pressure impulse test with flexing*.
- ISO 15540 – *Ships and marine technology – Fire resistance of hose assemblies – Test methods*.
- ISO 15541 – *Ships and marine technology – Fire resistance of hose assemblies – Requirements for test bench*.
- ISO 10380 – *Pipework – Corrugated metal hoses and hose assemblies*.

Other Standards may be accepted where agreed by LR.

13.4.3 All flexible hose assemblies are to be satisfactorily prototype burst tested to an international standard (*see* Note) to demonstrate they are able to withstand a pressure of not less than four times the design pressure without indication of failure or leakage.

NOTE:
The International Standards, e.g. EN or SAE for burst testing of non-metallic hoses, require the pressure to be increased until burst without any holding period at 4 x Maximum Working Pressure.

■ *Section 14* Hydraulic tests on pipes and fittings

14.1 Hydraulic tests before installation on board

14.1.1 All Class I and II pipes and their associated fittings are to be tested by hydraulic pressure. Further, all steam, feed, compressed air and oil fuel pipes, together with their fittings, are to be similarly tested where the design pressure is greater than 7 bar. The test is to be carried out after completion of manufacture and before installation on board and, where applicable, before insulating and coating.

14.1.2 The test pressure is to be 1,5 times the design pressure, as defined in 4.2.

14.1.3 Shell valves and valves on the collision bulkhead are to be tested by hydraulic pressure to 1,5 times the nominal pressure rating of the valve at ambient temperature.

14.2 Testing after assembly on board

14.2.1 Oil fuel piping is to be tested by hydraulic pressure, after installation on board, to 1,5 times the design pressure but in no case to less than 3,5 bar.

14.2.2 Where pipes specified in 14.1.1 are butt welded together during assembly on board, they are to be tested by hydraulic pressure in accordance with the requirements of 14.2.1 after welding. The pipe lengths may be insulated, except in way of the joints made during installation and before the hydraulic test is carried out.

14.2.3 The hydraulic test required by 14.2.2 may be omitted provided non–destructive tests by ultrasonic or radiographic methods are carried out on the entire circumference of all butt welds with satisfactory results.

14.2.4 Where ultrasonic tests have been carried out, the manufacturer is to provide the Surveyor with a signed statement confirming that ultrasonic examination has been carried out by an approved operator and that there were no indications of defects which could be expected to have prejudicial effect on the service performance of the piping.

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■ *Cross-reference*

See also Ch 2,2.4 for testing after installation.

■ *Section 15* Requirements for small craft which are not required to comply with the HSC Code

15.1 General

15.1.1 The requirements of Sections 1 to 13 apply, except where modified by this Section.

15.2 Details to be submitted

15.2.1 Details of oil fuel storage tanks over 0,25 m^3, where these do not form part of the structure of the craft, are to be submitted.

15.2.2 Design details of the components listed in 2.1.6 are not required.

15.3 Materials

15.3.1 Materials for which no provision is made in this Chapter may be accepted provided that they comply with an acceptable National or International Standard and are satisfactorily tested as may be considered necessary. Manufacturer's material test certificates are not required unless the material is of unusual or special specification.

15.3.2 Shell valves and cocks, inlet chests, distance pieces and other sea connections are to be of approved ductile material. Due attention is to be paid to the compatibility of the material with that of the shell. Ordinary grey cast iron is not acceptable.

15.4 Aluminium alloy

15.4.1 Proposals for the use of aluminium alloy pipes in bilge systems in machinery spaces will be considered, provided that a single failure in any section of the pipe does not render the whole system inoperable.

15.4.2 Aluminium alloy pipes may be used for fire-fighting systems outside machinery spaces in locations of low fire risk.

15.5 Plastics pipes

15.5.1 IMO Resolution A.753(18) *Guidelines for the Application of Plastics Pipes on Ships* does not apply.

15.5.2 The requirements of 8.1.5 do not apply but where plastics pipes are used for bilge and cooling water services they are to be of a type which has been approved by LR. However, fire endurance testing is not required.

15.5.3 Where plastics pipes are used in bilge systems in machinery spaces, a single failure in any section of the pipe is not to render the whole system inoperable.

15.6 Copper and copper alloys

15.6.1 Where copper and copper alloy pipes are in accordance with an acceptable National Standard/ Specification which is applicable to the intended service or media, Table 1.6.1 need not be applied.

■ *Section 16* Guidance notes on metal pipes for water services

16.1 General

16.1.1 These guidance notes, except where it is specifically stated, apply to sea-water piping systems.

16.1.2 In addition to the selection of suitable materials, careful attention should be given to the design details of the piping system and the workmanship in fabrication, construction and installation of the pipework in order to obtain maximum life in service.

16.2 Materials

16.2.1 Materials used in sea water piping systems include:

- Galvanised steel.
- Stainless and duplex steel, *see also* 16.3.4.
- Steel pipes lined with rubber, plastics or stoved coatings.
- Copper.
- 90/10 copper-nickel-iron.
- 70/30 copper-nickel.
- Aluminium alloy.
- Aluminium brass.
- Bronze.
- Approved plastics.

16.2.2 Selection of materials should be based on:

- The ability to resist general and localised corrosion, such as pitting, impingement attack and cavitation throughout all the flow velocities likely to be encountered;
- Compatibility with the other materials in the system, such as valve bodies and casings, in order to minimise bimetallic corrosion;
- The ability to resist selective corrosion, e.g. dezincification of brass, dealuminification of aluminium brass and graphitisation of cast iron;
- The ability to resist stress corrosion and corrosion fatigue, and;
- The amenability to fabrication by normal practices.

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16.3 *Steel pipes*

16.3.1 Steel pipes should be protected against corrosion and protective coatings should be applied on completion of all fabrication, i.e. bending, forming and welding of the steel pipes.

16.3.2 Welds should be free from lack of fusion and crevices. The surfaces should be dressed to remove slag and spatter and this should be done before coating. The coating should be continuous around the ends of the pipes and on the faces of flanges.

16.3.3 Galvanising the bores and flanges of steel pipes as protection against corrosion is common practice, and is recommended as the minimum protection for pipes in sea-water systems, including those for bilge and ballast service.

16.3.4 Austenitic stainless steel pipes are not recommended for salt water services in polluted waters or where stagnant conditions exist. Steel of specification 316L or better may give satisfactory service in water circulating systems for clean sea water.

16.3.5 Rubber lined pipes are effective against corrosion and suitable for higher water velocities. The rubber lining should be free from defects, e.g. discontinuities, pinholes, etc., and it is essential that the bonding of the rubber to the bore of the pipe and flange face is sound. Rubber linings should be applied by firms specialising in this form of protection.

16.3.6 The foregoing comments on rubber lined pipes also apply to pipes lined with plastics.

16.3.7 Stove coating of pipes as protection against corrosion should only be used where the pipes will be efficiently protected against mechanical damage.

16.4 Copper and copper alloy pipes

16.4.1 Copper pipes are particularly susceptible to perforation by corrosion/erosion and should only be used for low water velocities and where there is no excessive local turbulence.

16.4.2 Aluminium brass and copper-nickel-iron alloy pipes give good service in reasonably clean sea-water. For service with polluted river or harbour waters, copper-nickel-iron alloy pipes with at least 10 per cent nickel are preferable. Alpha-brasses, i.e. those containing 70 per cent or more copper, must be inhibited effectively against dezincification by suitable additions to the composition. Alpha beta-brasses, i.e. those containing less than 70 per cent copper, should not be used for pipes and fittings.

16.4.3 New copper alloy pipes should not be exposed initially to polluted water. Clean sea-water should be used at first to allow the metals to develop protective films. If this is not available the system should be filled with inhibited town mains water.

16.5 Flanges

16.5.1 Where pipes are exposed to sea-water on both external and internal surfaces, flanges should be made, preferably, of the same material. Where sea-water is confined to the bores of pipes, flanges may be of the same material or of less noble metal than that of the pipe.

16.5.2 Fixed or loose type flanges may be used. The fixed flanges should be attached to the pipes by fillet welds or by capillary silver brazing. Where welding is used, the fillet weld at the back should be a strength weld and that in the face, a seal weld.

16.5.3 Inert gas shielded arc welding is the preferred process but metal arc welding may be used on copper-nickel-iron alloy pipes.

16.5.4 Mild steel flanges may be attached by argon arc welding to copper-nickel-iron pipes and give satisfactory service, provided that no part of the steel is exposed to the sea-water.

16.5.5 Where silver brazing is used, strength should be obtained by means of the bond in a capillary space over the whole area of the mating surfaces. A fillet braze at the back of the flange or at the face is undesirable. The alloy used for silver brazing should contain not less than 49 per cent silver.

16.5.6 The use of a copper-zinc brazing alloy is not permitted.

16.6 Water velocity

16.6.1 Water velocities should be carefully assessed at the design stage and the materials of pipes, valves, etc., selected to suit the conditions.

16.6.2 The water velocity in copper pipes should not exceed 1 m/s.

16.6.3 The water velocity in the pipes of the materials below should normally be not less than about 1 m/s in order to avoid fouling and subsequent pitting, but should not be greater than the following:

Galvanised steel	3,0 m/s
Aluminium brass	3,0 m/s
90/10 copper-nickel-iron	3,5 m/s
70/30 copper-nickel	5,0 m/s.

16.7 Fabrication and installation

16.7.1 Attention should be given to ensuring streamlined flow and reducing entrained air in the system to a minimum. Abrupt changes in the direction of flow, protrusions in the bores of pipes and other restrictions of flow should be avoided. Branches in continuous flow lines should be set at a shallow angle to the main pipe, and the junction should be smooth.

16.7.2 Pipe bores should be smooth and clean.

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16.7.3 Jointing should be flush with the bore surfaces of pipes and misalignment of adjacent flange faces should be reduced to a minimum.

16.7.4 Pipe bends should be of as large a radius as possible, and the bore surfaces should be smooth and free from puckering at these positions. Any carbonaceous films or deposits formed on the bore surfaces during the bending processes should be carefully removed. Organic substances are not recommended for the filling of pipes for bending purposes.

16.7.5 The position of supports should be given special consideration in order to minimise vibration and ensure that excessive bending moments are not imposed on the pipes.

16.7.6 Systems should not be left idle for long periods, especially where the water is polluted.

16.7.7 Strainers should be provided at the inlet to sea-water systems.

16.8 Metal pipes for fresh water services

16.8.1 Mild steel or copper pipes are normally satisfactory for service in fresh water applications. Hot fresh water, however, may promote corrosion in mild steel pipes unless the hardness and pH of the water are controlled.

16.8.2 Water with a slight salt content should not be left stagnant for long periods in mild steel pipes. Low salinity and the limited supply of oxygen in such conditions promote the formation of black iron oxide, and this may give rise to severe pitting. Where stagnant conditions are unavoidable, steel pipes should be galvanised, or pipes of suitable non-ferrous material used.

16.8.3 Copper alloy pipes should be treated to remove any carbonaceous films or deposits before the tubes are put into service.

16.8.4 Brass fittings and flanges in contact with water should be made of an alpha-brass effectively inhibited against dezincification by suitable additions to the composition.

16.8.5 Aluminium brass has been widely used as material for heat exchanger and condenser tubes, but its use in 'once through' systems is not recommended since, under certain conditions, it is prone to pitting and cracking.

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Section

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■ *Section 1* General

1.1 Application

1.1.1 The requirements of Sections 1 to 11 of this Chapter apply to all craft which are required to satisfy the relevant design and construction regulations of the HSC Code.

1.1.2 Special requirements for multi-hull craft are given in Section 12.

1.1.3 Additional requirements for Passenger (B) Craft are given in Section 13.

1.1.4 Requirements for craft of less than 24 m not required to comply with the HSC Code are given in Section 14.

1.1.5 Requirements for craft of 24 m or more not required to comply with the HSC Code are given in Section 15.

1.1.6 Additional requirements for yachts that are 500 gt or more are given in Section 16.

1.1.7 The requirements for air cushion vehicles are given in Section 17.

1.1.8 In addition to the requirements of this Chapter, attention should be given to any relevant statutory requirements of the National Authority of the country in which the craft is to be registered.

1.1.9 Consideration will be given to special cases or to arrangements which are equivalent to those required by these Rules.

1.2 Details to be submitted

1.2.1 The plans and information detailed in Chapter 1 are to be submitted before commencement of work.

1.3 Watertight and non-watertight decks

1.3.1 For the purpose of this Section, a non-watertight deck covered by a weathertight structure may be taken as equivalent to a watertight deck. For definitions of the terms watertight and weathertight, *see* Pt 3, Ch 1.

■ *Section 2* Construction and installation

2.1 Installation

2.1.1 All pipes for essential services are to be secured in position to prevent chafing or lateral movement.

2.1.2 Long or heavy lengths of pipe are to be supported by bearers so that no undue load is carried by pipe connections or pumps and fittings to which they are attached.

2.2 Provision for expansion

2.2.1 Suitable provision for expansion is to be made, where necessary, in each range of pipes.

2.2.2 Where expansion pieces are fitted, arrangements are to be provided to protect against over extension and compression. The adjoining pipes are to be suitably aligned, supported, guided and anchored. Where necessary, expansion pieces of the bellows type are to be protected against mechanical damage.

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2.3 Miscellaneous requirements

2.3.1 All pipes situated in cargo spaces, chain lockers or other positions where they are liable to mechanical damage are to be efficiently protected.

2.3.2 So far as practicable, pipelines, including exhaust pipes from engines, are not to be routed in the vicinity of switchboards or other electrical appliances in positions where the drip or escape of fluids, gas or steam from joints or fittings could cause damage to the electrical installation. Where it is not practicable to comply with these requirements, drip trays or shields are to be provided as found necessary.

2.4 Testing after installation

2.4.1 After installation on board, all steam, hydraulic, compressed air and other piping systems covered by Ch 1,2.1.3 together with associated fittings which are under internal pressure, are to be subjected to a running test at the intended maximum working pressure.

■ *Section 3* Shell valves and fittings (other than those on scuppers and sanitary discharges)

3.1 Construction

3.1.1 All sea inlet and overboard discharge pipes are to be fitted with valves or cocks secured direct to the shell or to fabricated water boxes attached to the shell.

3.1.2 Distance pieces of short rigid construction and made of approved material may be fitted between the valve and shell. The thickness of such pipes is to be equivalent to shell thickness.

3.1.3 The arrangements are to be such that the section of pipe immediately inboard of the shell valve may be removed without affecting the watertight integrity of the hull.

3.1.4 The valves are to be in accordance with the general requirements for valves given in Ch 1,12.

3.1.5 Shell valves are to be manufactured from non-heat sensitive materials and tested in accordance with the appropriate requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials). Special consideration will be given to the use of other materials on craft of aluminium or composite construction. Where the valves are manufactured from spheroidal or nodular graphite cast iron they are to be produced at a works approved by Lloyd's Register (hereinafter referred to as 'LR'). Grey cast iron is not acceptable.

3.1.6 Shell valves are to be fitted in accessible positions and are to be capable of being operated from positions which are readily accessible in case of influx of water to the compartment.

3.1.7 Valve hand wheels and cock handles are to be suitably retained on the spindles. Means are to be provided to indicate whether the valve or cock is open or closed.

3.1.8 The scantlings of valves and valve stools fitted with steam or compressed air clearing connections are to be suitable for the maximum pressure to which the valves and stools may be subjected.

3.1.9 Shell valves are to be hydraulically tested before installation in accordance with Ch 1,14.

■ *Section 4* Bilge pumping and drainage systems

4.1 General

4.1.1 Arrangements are to be made for draining all watertight compartments other than those intended for permanent storage of fluids. Where drainage is not considered necessary, drainage arrangements may be omitted provided the safety of the craft is not impaired.

4.1.2 Pumping arrangements are to be provided having suctions and means of drainage so arranged that any water within any watertight compartment of the craft or any watertight section of any compartment, can be pumped out through at least one suction under all possible conditions of list and trim in the maximum assumed damage condition.

4.1.3 The bilge pumping system is to be designed to prevent water flowing from one watertight compartment to another.

4.1.4 The necessary valves for controlling the bilge suctions are to be capable of being operated from above the watertight deck.

4.1.5 Where a bilge main is not fitted and a compartment is served by a fixed submersible pump in accordance with Section 10, then an additional emergency means of pumping out the compartment is to be provided, *see* Section 6.

4.1.6 Small compartments may be drained by individual hand pump suctions.

4.1.7 The intactness of watertight bulkheads is not to be impaired by the fitting of scuppers discharging to machinery spaces or tunnels from adjacent compartments situated below the highest watertight deck.

4.1.8 Any unattended space for which bilge pumping arrangements are required is to be provided with a bilge level alarm.

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4.1.9 Where it is intended to carry flammable or toxic liquids in enclosed spaces, the bilge system shall be designed to prevent pumping of such liquids through piping and pumps in machinery or other spaces where a source of ignition may exist.

■ *Section 5*
Bilge drainage of machinery spaces with a propulsion prime mover

5.1 General

5.1.1 The bilge drainage arrangements are to comply with Section 4, except that the arrangements are to be such that any water which may enter this compartment can be pumped out through at least two bilge suctions under all possible conditions of list and trim in the maximum assumed damage condition.

5.1.2 Where a bilge main is fitted, one of the suctions referred to in 5.1.1 is to be a branch bilge suction i.e. a suction connected to the bilge main. The second bilge suction is to be a direct bilge suction as detailed in 8.6.

5.1.3 Where a bilge main is not fitted, the branch bilge suction referred to in 5.1.2 may be replaced by a suction from a submersible bilge pump. The second bilge suction is to be either a second submersible bilge pump or a direct bilge suction as detailed in 8.6.

5.1.4 The emergency bilge drainage arrangements detailed in Section 6 are to be provided where either 5.1.2 or 5.1.3 applies.

5.2 Additional bilge suctions

5.2.1 Additional bilge suctions may be required for the drainage of wells or other recesses.

■ *Section 6*
Emergency bilge drainage

6.1 Emergency bilge drainage

6.1.1 In machinery spaces the emergency bilge suction required by 4.1.5 and 5.1.4 is to be led to the largest available power pump, which is not a bilge, propulsion or oil pump, from a suitable low level in the machinery space and is to be fitted with a screw-down non-return valve with an extended spindle and hand wheel situated above the floor plating.

6.1.2 As an alternative to 6.1.1, or in compartments other than machinery spaces, the emergency bilge pumping arrangements may be provided by a portable submersible self-priming pump of capacity not less than that required by 8.3.5.

6.1.3 The pump referred to in 6.1.2 together with its suction and delivery hoses is to be stored in a locker marked 'For emergency use only' and is to be available for immediate use. Arrangements to facilitate safe handling under adverse conditions are to be provided. If the pump is electrically driven it is to be supplied from the emergency switchboard.

■ *Section 7*
Size of bilge suction pipes

7.1 Bilge main

7.1.1 Where a bilge main is fitted, its internal diameter d_m is to be not less than that required by the following formula:

$$d_m = 1{,}68\sqrt{L\,(B + D)} + 25 \text{ mm}$$

where

B = breadth of craft, in metres

D = moulded depth to the watertight deck, in metres

L = length of craft, in metres

The actual internal diameter of the bilge main may be rounded off to the nearest pipe size of a recognised standard, but d_m is in no case to be less than 50 mm.

7.2 Branch bilge suctions

7.2.1 The diameter d_b of branch bilge suction pipes is to be not less than that required by the following formula:

$$d_b = 2{,}15\sqrt{C\,(B + D)} + 12{,}5 \text{ mm}$$

where

B and D are as defined in 7.1.1

C = length of compartment, in metres.

The actual internal diameter of branch bilge suction pipes may be rounded off to the nearest pipe size of a recognised standard, but d_b is in no case to be less than 25 mm.

■ *Section 8*
Pumps on bilge service

8.1 Number of pumps

8.1.1 For craft fitted with a bilge main, at least two power bilge pumping units are to be provided. One of these units may be worked from the main engines and the other is to be independently driven.

8.1.2 Each unit may consist of one or more pumps connected to the main bilge line, provided that their combined capacity is not less than that required by 8.3.2.

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8.1.3 A bilge ejector in combination with a high pressure sea-water pump may be accepted as a substitute for an independent bilge pump as required by 8.1.1.

8.1.4 For craft fitted with fixed submersible bilge pumps, one pump is to be provided for each watertight compartment.

8.1.5 For the bilge pumping requirements for multi-hull craft, *see* Section 12.

8.2 General service pumps

8.2.1 The bilge pumping units or pumps required by 8.1 may also be used for ballast, fire or general service duties of an intermittent nature, but not for pumping fuel or other flammable liquids. These pumps are to be immediately available for bilge duty when required. For the use of bilge pumping units for fire-extinguishing duties, *see* Part 17.

8.3 Capacity of pumps

8.3.1 Each bilge pumping unit is to be connected to the bilge main and is to be capable of giving a speed of water through the Rule size of bilge main of not less than 2 m/s.

8.3.2 To achieve the flow velocity required by 8.3.1, the capacity Q of each bilge pumping unit or bilge pump is to be not less than that required by the following formula:

$$Q = \frac{5{,}75}{10^3} d_m^2 \text{ m}^3\text{/hour}$$

where

d_m is as defined in 7.1.1.

Q = Rule minimum capacity, in m^3/hour.

8.3.3 Where one bilge pumping unit is of slightly less than Rule capacity, the deficiency may be made good by an excess capacity of the other unit. In general, the deficiency is to be limited to 30 per cent.

8.3.4 Where fixed submersible bilge pumps are fitted, the total capacity Q_t of the pumps is to be not less than that required by the following formula:

$$Q_t = \frac{13{,}8}{10^3} d_m^2 \text{ m}^3\text{/hour}$$

where

d_m is as defined in 7.1.1.

Q_t = Rule minimum total capacity, in m^3/hour.

8.3.5 The capacity Q_n of each submersible bilge pump is to be not less than that required by the following formula:

$$Q_n = \frac{Q_t}{(N-1)} \text{ m}^3\text{/hour}$$

where

N = number of fixed submersible pumps

Q_t is as defined in 8.3.4

Q_n = Rule minimum submersible pump capacity, in m^3/hour

Q_n is in no case to be less than 8 m^3/hour.

8.4 Self-priming pumps

8.4.1 All power pumps which are essential for bilge services are to be of the self-priming type, unless an approved central priming system is provided for these pumps.

8.5 Pump connections

8.5.1 The connections at the bilge pumps are to be such that one unit may continue in operation when the other unit is being opened up for overhaul.

8.5.2 Pumps required for essential services are not to be connected to a common suction or discharge chest or pipe unless the arrangements are such that the working of any pumps so connected is unaffected by the other pumps being in operation at the same time.

8.6 Direct bilge suctions

8.6.1 The direct bilge suction in the machinery space required by 5.1.2 and referred to in 5.1.3 is to be led to an independent power pump, and the arrangements are to be such that the direct suction can be used independently of the main bilge line suctions.

8.6.2 The machinery space direct bilge suction is not to be of a diameter less than that required for the machinery space branch bilge suction and arranged as detailed in 8.6.1.

■ *Section 9* Bilge main arrangements and materials

9.1 General

9.1.1 Bilge mains, branch bilge suctions and bilge overboard discharge arrangements within machinery spaces are to be of steel or other equivalent material.

9.1.2 Where bilge suction pipework outside machinery spaces is manufactured from material sensitive to heat then the arrangements are to be such that pipe failure in one compartment will not render the bilge suction pipework in another compartment inoperable.

9.1.3 Bilge pipework is to be mounted inboard such that in the event of the maximum assumed damage the pipework will remain intact.

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9.2 Prevention of communication between compartments

9.2.1 The arrangement of valves, cocks and their connections is to be such as to prevent the possibility of one watertight compartment being placed in communication with another, or of dry cargo spaces, machinery spaces or other dry compartments being placed in communication with the sea or with tanks. For this purpose, screw-down non-return valves are to be provided in the following fittings:

- Bilge valve distribution chests
- Bilge suction hose connections, whether fitted direct to the pump or on the main bilge line.
- Direct bilge suctions and bilge pump connections to the main bilge line.

9.3 Isolation of bilge system

9.3.1 Bilge suction pipes are to be entirely separate from sea inlet pipes or from pipes which may be used for filling or emptying spaces where water or oil is carried.

9.4 Bilge suction strainers

9.4.1 The open ends of bilge suctions are to be enclosed in strum boxes having perforations of not more than 10 mm diameter, whose combined area is not less than twice that required for the suction pipe. The boxes are to be so constructed that they can be cleared without breaking any joint of the suction pipe.

■ *Section 10*
Submersible bilge pump arrangements

10.1 General

10.1.1 Arrangements are to be such that at least two automatic non-return devices are fitted between the overboard discharge and the watertight space being served by the pump.

10.1.2 One of these devices is to be an automatic non-return valve situated at or near the shell and the other may be a pipework loop taken up to the highest practicable point below the watertight deck. The arrangements are to be effective in the maximum assumed damaged condition.

■ *Section 11*
Air, overflow and sounding pipes

11.1 Air pipes

11.1.1 Air pipes are to be fitted to all tanks, cofferdams, tunnels and other compartments which are not fitted with alternative ventilation arrangements.

11.1.2 Air pipes are to be fitted at the opposite end of the tank to that which the filling pipes are placed and/or at the highest part of the tank. Where the tank top is of unusual or irregular profile, special consideration will be given to the number and position of the air pipes.

11.1.3 Air pipes to oil fuel, lubricating oil and other tanks containing flammable liquids which are located in or pass through compartments of high fire risk or on open deck are to be of steel or other equivalent material.

11.2 Termination of air pipes

11.2.1 Air pipes to double bottom tanks, deep tanks extending to the shell plating, or tanks which can be run up from the sea are to be led to above the watertight deck. Air pipes to oil fuel tanks, cofferdams and all tanks which can be pumped up are to be led to the open.

11.2.2 Air pipes from storage tanks containing lubricating or hydraulic oil may terminate in the machinery space, provided that the open ends are so situated that issuing oil cannot come into contact with electrical equipment or heated surfaces.

11.2.3 The open ends of air pipes to oil fuel tanks are to be situated where no danger will be incurred from issuing oil vapour when the tank is being filled.

11.2.4 The location and arrangement of air pipes for oil fuel service, settling and lubricating oil tanks are to be such that in the event of a broken vent pipe, this does not directly lead to the risk of ingress of sea-water or rainwater.

11.3 Gauze diaphragms

11.3.1 The open ends of air pipes to oil fuel tanks are to be fitted with a wire gauze diaphragm of non-corrodible material which can be readily removed for cleaning or renewal.

11.3.2 Where wire gauze diaphragms are fitted at air pipe openings, the area of the opening through the gauze is to be not less than the cross-sectional area required for the pipe, *see* 11.6.

11.4 Air pipe closing appliances

11.4.1 Closing appliances fitted to tank air pipes are to be of an automatic opening type which will allow the free passage of air or liquid to prevent the tanks being subjected to a pressure or vacuum greater than that for which they are designed, *see also* Pt 3, Ch 4,12.3.

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11.4.2 Air pipe closing devices are to be of a type acceptable to LR and are to be tested in accordance with a National or International Standard recognised by LR. The flow characteristic of the closing device is to be determined using water, *see* 11.6.1.

11.4.3 Wood plugs and other devices which can be secured closed are not to be fitted at the outlets.

11.4.4 Air pipe automatic closing devices shall be so designed that they will withstand both ambient conditions as indicated in Pt 9, Ch 1, 4.4 and designed working conditions, and be suitable for use at inclinations up to and including ± 40°.

11.4.5 Air pipe automatic closing devices shall be constructed to allow inspection of the closure and the inside of the casing, as well as changing the seals.

11.4.6 Efficient ball or float seating arrangements are to be provided for the closures. Bars, cages or other devices are to be provided to prevent the ball or float from contacting the inner chamber in its normal state, and made in such a way that the ball or float is not damaged when subjected to liquid impact due to a tank being overfilled.

11.4.7 Air pipe automatic closing devices are to be self-draining.

11.4.8 The clear area through an air pipe closing device in the open position shall be at least equal to the area of the inlet.

11.4.9 In the case of air pipe closing devices of the float type, suitable guides are to be provided to ensure unobstructed operation under all working conditions of heel and trim.

11.4.10 The maximum allowable tolerances for wall thickness of floats should not exceed ±10 per cent of thickness.

11.4.11 The inner and the outer chambers of an automatic air pipe head are to be of a minimum thickness of 6 mm.

11.4.12 Casings of air pipe closing devices are to be of approved metallic materials adequately protected against corrosion.

11.4.13 For galvanised steel air pipe heads, the zinc coating is to be applied by the hot method and the thickness is to be 70 to 100 microns.

11.4.14 For areas of the head susceptible to erosion (e.g. those parts directly subjected to ballast water impact when the tank is being pressed up, for example the inner chamber area above the air pipe, plus an overlap of 10° or more either side) an additional harder coating should be applied. This is to be an aluminium bearing epoxy, or other equivalent coating, applied over the zinc.

11.5 Nameplates

11.5.1 Nameplates are to be affixed to the upper ends of all air and sounding pipes.

11.6 Size of air pipes

11.6.1 For every tank which can be filled by on-board pumps, the total cross-sectional area of the air pipes and the air pipe closing devices is to be such that when the tank is overflowing at the maximum pumping capacity available for the tank, it will not be subjected to a pressure greater than that for which it is designed.

11.6.2 In all cases, whether a tank is filled by on-board pumps or other means, the total cross-sectional area of the pipes is to be not less than 25 per cent greater than the effective area of the respective filling pipe.

11.6.3 Air pipes are to be generally not less than 38 mm bore. In the case of small gravity filled tanks smaller bore pipes may be accepted but in no case is the bore to be less than 25 mm.

11.7 Overflow pipes

11.7.1 For all tanks which can be pumped up, overflow pipes are to be fitted where:

(a) The total cross-sectional area of the air pipes is less than that required by 11.6.

(b) The pressure head corresponding to the height of the air pipe is greater than that for which the tank is designed.

11.7.2 In the case of oil fuel tanks, lubricating oil tanks and other tanks containing flammable liquids, the overflow pipe is to be led to an overflow tank of adequate capacity or to a storage tank having a space reserved for overflow purposes. Suitable means is to be provided to indicate when overflowing is occurring.

11.7.3 Overflow pipes are to be self draining under normal conditions of trim.

11.7.4 Where overflow sight glasses are provided, they are to be in a vertical dropping line and designed such that the oil does not impinge on the glass. The glass is to be of heat resisting quality and be adequately protected from mechanical damage. Overflow sight glasses are not permitted in oil fuel systems for craft required to comply with the HSC Code.

11.8 Combined air and overflow systems

11.8.1 Where a combined air or overflow system is fitted, the arrangement is to be such that in the event of any one of the tanks being bilged, the other tanks cannot be flooded from the sea through combined air pipes or the overflow main. For this purpose, it will normally be necessary to lead the overflow pipe to a point above the waterline in the maximum assumed damage condition.

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11.8.2 Where a common overflow main is provided, the main is to be sized to allow any two tanks connected to that main to overflow simultaneously.

11.9 Sounding arrangements

11.9.1 Provision is to be made for sounding all tanks and the bilges of those compartments which are not at all times readily accessible. The soundings are to be taken as near the suction pipes as practicable.

11.9.2 Sounding devices of an approved type (i.e. level gauge or remote reading level device) may be used in lieu of sounding pipes.

11.9.3 Bilges of compartments which are not at all times readily accessible are to be provided with sounding pipes.

11.9.4 Where fitted, sounding pipes are to be as straight as practicable, and if curved to suit the structure of the craft, the curvature is to be sufficiently easy to permit the ready passage of the sounding rod or chain.

11.9.5 Striking plates of adequate thickness and size are to be fitted under open ended sounding pipes.

11.9.6 Where slotted sounding pipes having closed ends are employed, the closing plugs are to be of substantial construction.

11.9.7 Sounding pipes are to be not less than 32 mm bore.

11.10 Termination of sounding pipes

11.10.1 Except as permitted by 11.11, sounding pipes are to be led to positions above the bulkhead deck which are at all times accessible and, in the case of oil fuel tanks, cargo oil tanks and lubricating oil tanks, the sounding pipes are to be led to safe positions on the open deck.

11.10.2 For closing requirements, *see also* Pt 3, Ch 4,12.3.1.

11.11 Short sounding pipes

11.11.1 In machinery spaces, where it is not practicable to extend sounding pipes as mentioned in 11.10 short sounding pipes extending to readily accessible positions above the platform may be fitted.

11.11.2 Short sounding pipes are not permitted in machinery spaces for tanks containing oil fuel or other flammable oils used in power transmission systems, control and activating systems and heating systems, except as permitted by 11.13.6.

11.11.3 Short sounding pipes may be fitted to tanks used for the storage, distribution and utilisation of lubricating oil in machinery spaces. These sounding pipes are to be fitted with cocks having parallel plugs with permanently attached handles located such that, on being released, they automatically close the cocks.

11.12 Elbow sounding pipes

11.12.1 In passenger craft, elbow sounding pipes are not permitted.

11.12.2 Elbow sounding pipes are not to be used for deep tanks, unless the elbows and pipes are situated within closed cofferdams or within tanks containing similar liquids. They may, however, be fitted to other tanks and may be used for sounding bilges, provided that it is not practicable to lead them direct to the tanks or compartments, and subject to any subdivision and damage stability requirements that may apply.

11.12.3 The elbows are to be of heavy construction and adequately supported.

11.13 Sounding arrangements for oil fuel, lubricating oil and other flammable liquids

11.13.1 Safe and efficient means of ascertaining the amount of oil in any storage tank are to be provided.

11.13.2 For oil fuel, lubricating oil and other flammable liquids, closed sounding devices are preferred. Design details of such devices are to be submitted and they are to be tested after fitting on board, to the satisfaction of the Surveyors.

11.13.3 If closed sounding devices are fitted, failure of the device or over filling of the tank is not to result in the release of tank contents. In passenger craft and yachts that are 500 gt or more, such means are not to require penetration below the top of the tank.

11.13.4 Where sounding pipes are used they are not to terminate in any space where risk of ignition or spillage from the sounding pipe might arise. In particular they are not to terminate in public spaces or crew accommodation. Additionally for oil fuel tanks they are not to terminate in machinery spaces. Terminations are to be provided with a suitable means of closure and provision to prevent spillage during refuelling/refilling operations.

11.13.5 Where gauge glasses are used they are to be of the flat type of heat resisting quality, adequately protected from mechanical damage and fitted with self closing valves at the lower ends and at the top ends if these are connected to the tanks below the maximum liquid level.

11.13.6 In yachts and service craft which are not required to comply with the HSC Code, short sounding pipes extending to well-lighted, readily accessible positions above the platform may be fitted in machinery spaces and tunnels. Sounding pipes are to be fitted with cocks having parallel plugs with permanently attached handles located such that, on being released, they automatically close the cocks.

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11.13.7 For yachts that are 500 gt or more, where short sounding pipes serve tanks containing oil fuel, an additional sounding device of approved type is to be fitted. In addition, a small diameter self-closing test cock is to be fitted below the cock mentioned in 11.13.6, in order to ensure that the sounding pipe is not under pressure from oil fuel before opening up the sounding pipe.

■ *Section 12*
Requirements for multi-hull craft

12.1 General

12.1.1 The requirements of Sections 2 to 11 apply to multi-hull craft except where modified by the requirements of this Section.

12.2 Drainage of raft void spaces

12.2.1 Arrangements are to be provided for venting, sounding and draining raft void spaces generally as required by Sections 1 to 11.

12.2.2 Where the raft void space is located above the water line in the maximum assumed damage condition then it may be drained directly overboard through scuppers fitted with non-return valves.

12.2.3 Raft void spaces which are not located above the water line in the worst expected damage condition are to be provided with pumping arrangements in accordance with Section 4.

12.3 Size of bilge suction pipes

12.3.1 Where a bilge main is fitted in each hull, its internal diameter d_m is to be not less than that required by the following formula:

$$d_m = 1{,}68\sqrt{L\,(B + D)} + 25 \text{ mm}$$

where

B = breadth of a hull in metres

D = moulded depth to the watertight deck, in metres

L = length of craft, in metres

The actual internal diameter of the bilge main may be rounded off to the nearest pipe size of a recognised standard, but d_m is in no case to be less than 50 mm.

12.3.2 The diameter d_b of branch bilge suction pipes is to be not less than that required by the following formula:

$$d_b = 2{,}15\sqrt{C\,(B + D)} + 12{,}5 \text{ mm}$$

where

C = length of compartment, in metres

B and D are as defined in 12.3.1

The actual internal diameter of branch bilge suction pipes may be rounded off to the nearest pipe size of a recognised standard, but d_b is in no case to be less than 25 mm.

12.4 Capacity and number of pumps on bilge main services

12.4.1 Each power bilge pump should be capable of pumping water through the required size of bilge main at a speed of not less than 2 m/s.

12.4.2 To achieve the flow velocity required by 12.4.1, the capacity Q of each bilge pumping unit or bilge pump is to be not less than that required by the following formula:

$$Q = \frac{5{,}75}{10^3} d_m^2 \text{ m}^3\text{/hour}$$

where

d_m is as defined in 12.3.1.

12.4.3 Not less than two power bilge pumping units taking suction from the bilge main in each hull are to be provided.

12.4.4 Where the bilge system in each hull is entirely separate then two bilge pumping units in each hull are to be provided.

12.4.5 Where fixed submersible bilge pumps are fitted, the total capacity Q_t of the pumps in each hull is to be not less than that required by the following formula:

$$Q_t = \frac{13{,}8}{10^3} d_m^2 \text{ m}^3\text{/hour}$$

where

d_m is as defined in 12.3.1.

12.4.6 The capacity Q_n of each submersible pump is to be not less than that required by the following formula:

$$Q_n = \frac{Q_t}{(N - 1)} \text{ m}^3\text{/hour}$$

where

N = number of fixed submersible pumps in each hull

Q_t is as defined in 12.4.5

Q_n is in no case to be less than 8 m^3/hour.

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Section 13
Additional requirements for Passenger (B) Craft

13.1 Bilge pumping arrangements

13.1.1 At least three power bilge pumping units are to be fitted connected to the bilge main, one of which may be driven by the propulsion machinery.

13.1.2 For multi-hull craft the bilge pumping units are to be capable of taking suction from the bilge main in any hull of the craft.

13.1.3 The arrangements are to be such that at least one power bilge pump is to be available for use in all flooding conditions which the craft is required to withstand as follows:

(a) one of the required bilge pumps is to be an emergency pump of a reliable submersible type having a source of power located above the waterline after the craft has sustained the maximum assumed damage; or

(b) the bilge pumps and their sources of power are to be so distributed throughout the length of the craft that at least one pump in an undamaged compartment will be available.

13.1.4 Alternatively fixed submersible bilge pumps may be provided in accordance with the requirements of 8.3.4 for monohull craft or 12.4.5 for multihull craft.

13.1.5 Distribution boxes, cocks and valves in connection with the bilge pumping system are to be so arranged that, in the event of flooding, one of the bilge pumps may take suction from any compartment.

13.1.6 Damage to a pump or its pipe connecting to the bilge main is not to put the bilge system out of action.

13.1.7 When in addition to the main bilge pumping system an emergency bilge pumping system is provided, it is to be independent of the main system and so arranged that a pump is capable of operating in any compartment under the maximum assumed flooding conditions. In that case only the valves necessary for the operation of the emergency system need be capable of remote operation.

13.1.8 All cocks and valves referred to in 13.1.5 which can be remotely operated are to have their controls at their place of operation clearly marked and are to be provided with means to indicate whether they are open or closed.

Section 14
Requirements for small craft which are not required to comply with the HSC Code

14.1 General

14.1.1 These requirements replace Sections 1 to 10, 12 and 13 of this Chapter. In general the requirements of Section 11 are to be complied with, however 11.4.1 and 11.9.3 do not apply.

14.1.2 Bilge and cooling water pipework systems are to be of an approved material, *see* Ch 1,15.

14.2 Shell valves and fittings

14.2.1 All sea inlet and overboard discharges are to be provided with shut off valves or cocks arranged in positions where they are readily accessible at all times.

14.2.2 Where valves, cocks, inlet chests, distance pieces and other sea connections are made of steel or other approved materials of low corrosion resistance, they are to be suitably protected against wastage.

14.3 Fittings for steel and aluminium hulls

14.3.1 All suction and discharge valves and cocks secured direct to the plating are to be fitted with spigots passing through the plating, but spigots on the valves and cocks may be omitted if these fittings are attached to pads or distance pieces which themselves form spigots in way of the plating.

14.4 Fittings for wood and glass reinforced plastics hulls

14.4.1 The openings in the shell or planking are to have suitably reinforced areas or pads into which the attached fittings are to be spigoted.

14.4.2 Valves or fittings are to be secured with an external ring under the bolt heads. The ring is to be of copper nickel alloy, bronze, dezincification resistant brass or other material approved for use in sea-water.

14.4.3 Valves or cocks up to 50 mm bore may be attached to spigot pieces or hull fittings having an external collar and internal nut.

14.4.4 Valves or cocks over 50 mm bore are to be flanged and attached as per 14.4.2.

14.5 Bilge pumping arrangements

14.5.1 An efficient bilge pumping system is to be fitted having suctions and means of drainage so arranged that any water which may enter any compartment can be pumped overboard.

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14.5.2 The system is to be tested on completion of the craft to ensure that all limber holes are free and that under normal conditions of trim any bilge water can drain to an appropriate suction.

14.5.3 The arrangement of pumps, valves, cocks, pipes and sea connections is to be such as to prevent water entering the craft accidentally or the possibility of one water-tight compartment being placed in communication with another.

14.5.4 Readily accessible strum boxes are to be fitted at the open ends of tail pipes.

14.5.5 The perforations in the strum boxes are to be not greater than 10 mm diameter and the combined area is to be not less than twice that required for the bilge suction pipe.

14.5.6 Where a collision bulkhead is fitted, the fore peak dry space is to be drained either by a branch suction to the main bilge line or by a manual pump. Alternatively, it may be drained to the adjacent compartment by means of a self closing drain cock which is to be readily accessible under all conditions.

14.5.7 Where a bilge main is fitted, the internal diameter d of the main and the branch suction pipes is to be not less than that required by the following formula:

$$d = \frac{L}{1,2} + 25 \text{ mm}$$

where

L = length of craft, in metres.

14.6 Pumps on bilge service and their connections

14.6.1 Not less than one power pump and one manual bilge pump are to be provided. Both pumps are to be arranged to take suction from the bilge main or suction valve chest as applicable.

14.6.2 The power driven pumps may be used for other services such as deck washing, fire extinguishing or standby cooling water duty but not for pumping oil fuel or other flammable liquids.

14.6.3 The total capacity Q_t of the bilge pumps is to be not less than required by the following formula:

$$Q_t = 1,5\,(d - 25) - 6,7 \text{ m}^3\text{/hour}$$

where

d is as defined in 14.5.7

Q_t is in no case to be less than 3 m^3/hour.

14.6.4 A reduction in capacity of one pump may be permitted provided the deficiency is made good by an excess capacity of the other pump or by an additional pump. In no case is this deficiency to be more than 40 per cent of the Rule capacity.

14.6.5 Pumps on bilge service are to be of the self-priming type.

14.6.6 The bilge pumps are to be connected to a common bilge line provided with a branch connection to each compartment.

14.6.7 A non-return valve is to be fitted between each bilge pump and the bilge main.

14.6.8 Non-return valves are to be fitted in each branch bilge suction from the main bilge line.

14.6.9 Power pumps may be driven by the main engine, an auxiliary engine or by an electric motor.

14.6.10 The power pump is to be provided with a suction enabling it to pump directly from the engine space in addition to the suction from the main bilge line. This direct bilge suction is to be controlled by a screw down non-return valve or equivalent.

14.6.11 Manual bilge pumps are to be capable of being operated from readily accessible positions above the waterline.

14.6.12 As an alternative to fitting a bilge main, individual submersible pumps may be fitted. In this case the arrangements are to be in accordance with the requirements of Sections 8, 10 and 12 of this Chapter, as applicable.

■ *Section 15*
Requirements for yachts and service craft of 24 m or greater in length, which are not required to comply with the HSC Code

15.1 General

15.1.1 The requirements of Sections 1, 2, 3, 11 and 12 of this Chapter are generally applicable. The remaining Sections 4 to 10 of this Chapter concerning the requirements for bilge pumping and drainage systems are replaced by the requirements given in 15.2 to 15.28.

15.2 Bilge systems and pumping

15.2.1 Where it is intended to carry vehicles with fuel in their tanks having a flashpoint less than 60°C for their own propulsion and having re-fuelling facilities for such vehicles or when only providing re-fuelling facilities, a separate bilge system is to be provided.

15.2.2 The bilge system is to be designed to prevent pumping of flammable liquids through piping and pumps in machinery, accommodation or any other spaces where a source of ignition may exist.

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15.3 Drainage of compartments, other than machinery spaces

15.3.1 All craft are to be provided with efficient pumping plant having the suctions and means for drainage so arranged that any water within any compartment of the craft, or any watertight section of any compartment, can be pumped out through at least one suction when the craft is on an even keel and is either upright or has a list of not more than 5°. For this purpose, wing suctions will generally be necessary, except in short, narrow compartments where one suction can provide effective drainage under the above conditions.

15.3.2 In the case of dry compartments, the suctions required by 15.3.1 are, except where otherwise stated, to be branch bilge suctions, i.e. suctions connected to a main bilge line.

15.4 Tanks and cofferdams

15.4.1 All tanks (including double bottom tanks), whether used for water ballast, oil fuel or liquid cargoes, are to be provided with suction pipes, led to suitable power pumps, from the after end of each tank.

15.4.2 In general, the drainage arrangements are to be in accordance with 15.3. However, where the tanks are divided by longitudinal watertight bulkheads or girders into two or more tanks, a single suction pipe, led to the after end of each tank, will normally be acceptable.

15.4.3 Similar drainage arrangements are to be provided for cofferdams, except that the suctions may be led to the main bilge line.

15.5 Fore and after peaks

15.5.1 Where the peaks are used as tanks, a power pump suction is to be led to each tank, except in the case of small tanks used for the carriage of domestic fresh water, where hand pumps may be used.

15.5.2 Where the peaks are not used as tanks, and main bilge line suctions are not fitted, drainage of both peaks may be effected by hand pump suctions, provided that the suction lift is well within the capacity of the pumps. Drainage of the after peak may be effected by means of a self-closing cock fitted in a well lighted and readily accessible position.

15.5.3 Pipes piercing the collision bulkhead are to be fitted with suitable valves secured to the bulkhead. The valves are to be operable from above the freeboard deck.

15.6 Spaces above fore peaks, after peaks and machinery spaces

15.6.1 Provision is to be made for the drainage of the chain locker and watertight compartments above the fore peak tank by hand or power pump suctions.

15.6.2 Steering gear compartments or other small enclosed spaces situated above the after peak tank are to be provided with suitable means of drainage, either by hand or power pump bilge suctions.

15.6.3 The compartments referred to in 15.6.2 may be drained by scuppers of not less than 38 mm bore, discharging to the tunnel or machinery space and fitted with self-closing cocks situated in well lighted and visible positions.

15.7 Maintenance of integrity of bulkheads

15.7.1 The intactness of the machinery space bulkheads, and of tunnel plating required to be of watertight construction, is not to be impaired by the fitting of scuppers discharging to machinery space or tunnels from adjacent compartments which are situated below the bulkhead deck.

15.7.2 No drain valve or cock is to be fitted to the collision bulkhead. Drain valves or cocks are not to be fitted to other watertight bulkheads if alternative means of drainage are practicable.

15.8 Bilge drainage of machinery space

15.8.1 The bilge drainage arrangements in the machinery space are to comply with 15.3 except that the arrangements are to be such that any water which may enter this compartment can be pumped out through at least two bilge suctions when the craft is on an even keel, and is either upright or has a list of not more than 5°. One of these suctions is to be a branch bilge suction, i.e. a suction connected to the main bilge line, and the other is to be a direct bilge suction, i.e. a suction led direct to an independent power pump.

15.9 Separate machinery spaces

15.9.1 Where the machinery space is divided by watertight bulkheads to separate the auxiliary engine room(s) from the main engine room, the bilge drainage arrangements for the auxiliary engine room(s) are to be the same as for compartments, other than machinery spaces, referred to in 15.3.1.

15.9.2 In addition to the requirements of 15.9.1, at least one direct suction, led to an independent power pump, is to be fitted in each compartment.

15.10 Machinery space with double bottom

15.10.1 Where the double bottom extends the full length of the machinery space and forms bilges at the wings, it will be necessary to provide one branch and one direct bilge suction at each side.

15.10.2 Where the double bottom plating extends the full length and breadth of the compartment, one branch bilge suction and one direct bilge suction are to be led to each of two bilge wells, situated one at each side.

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15.10.3 Where there is no double bottom and the rise of floor is not less than 5°, one branch and one direct bilge suction are to be led to accessible positions as near to the centreline as practicable.

15.11 Machinery space – Emergency bilge drainage

15.11.1 In addition to the bilge suctions detailed in 15.8 and 15.9, an emergency bilge suction is to be provided in each main machinery space. This suction is to be led to the main cooling water pump from a suitable low level in the machinery space and is to be fitted with a screw-down non-return valve having the spindle so extended that the hand wheel is not less than 460 mm above the bottom platform.

15.11.2 Where two or more cooling water pumps are provided, each capable of supplying cooling water for normal power, only one pump need be fitted with an emergency bilge suction.

15.11.3 Where main cooling water pumps are not suitable for bilge pumping duties, the emergency bilge suction is to be led to the largest available power pump, which is not a bilge pump.

15.11.4 Emergency bilge suction valve nameplates are to be marked 'For emergency use only'.

15.12 Sizes of bilge suction pipes

15.12.1 The diameter, d_m, of the main bilge line is to be not less than that required by the following formula, to the nearest 5 mm, but in no case is the diameter to be less than that required for any branch bilge suction:

$$d_m = 1{,}68\sqrt{L\,(B + D)} + 25 \text{ mm}$$

where

d_m = internal diameter of main bilge line, in mm
B = greatest moulded breadth of craft, in metres
D = moulded depth to bulkhead deck, in metres
L = Rule length of craft in metres.

15.12.2 The diameter d_b, of branch bilge suction pipes to cargo and machinery spaces is to be not less than required by the following formula, to the nearest 5 mm, but in no case is the diameter of any suction to be less than 50 mm:

$$d_b = 2{,}15\sqrt{C\,(B + D)} + 25 \text{ mm}$$

where

d_b = internal diameter of branch bilge suction, in mm
C = length of compartment, in metres
B and D are as defined in 15.12.1.

15.12.3 The direct bilge suctions in the machinery space are not to be of a diameter less than that required for the main bilge line.

15.12.4 For sizes of emergency bilge suctions, *see* 15.11.

15.13 Distribution chest branch pipes

15.13.1 The area of each branch pipe connecting the bilge main to a distribution chest is to be not less than the sum of the areas required by the Rules for the two largest branch bilge suction pipes connected to that chest, but need not be greater than that required for the main bilge line.

15.14 Pumps on bilge service and their connections

15.14.1 At least two power bilge pumping units are to be provided in the machinery space. One of these units may be worked from the main engines and the other is to be independently driven.

15.14.2 Each unit may consist of one or more pumps connected to the main bilge line, provided that their combined capacity is adequate.

15.14.3 A bilge ejector in combination with a high pressure sea-water pump may be accepted as a substitute for an independent bilge pump as required by 15.14.1.

15.14.4 Special consideration will be given to the number of pumps for small craft and, in general, if there is a class notation restricting a small craft to harbour or river service, a hand pump may be accepted in lieu of one of the bilge pumping units.

15.15 General service pumps

15.15.1 The bilge pumping units, or pumps, required by 15.14 may also be used for ballast, fire or general service duties of an intermittent nature, but they are to be immediately available for bilge duty when required.

15.16 Capacity of pumps

15.16.1 Each bilge pumping unit is to be connected to the main bilge line and is to be capable of giving a speed of water through the Rule size of main bilge pipe of not less than 122 m/min.

15.16.2 The capacity of each bilge pumping unit or bilge pump is to be not less than required by the following formula:

$$Q = \frac{5{,}75}{10^3} d_m^2$$

where

d_m = Rule internal diameter of main bilge line, in mm
Q = capacity, in m^3/hour.

15.16.3 Where one bilge pumping unit is of slightly less than Rule capacity, the deficiency may be made good by an excess capacity of the other unit. In general, the deficiency is to be limited to 30 per cent.

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15.17 Self-priming pumps

15.17.1 All power pumps which are essential for bilge services are to be of the self-priming type, unless an approved central priming system is provided for these pumps. Details of this system are to be submitted.

15.17.2 Cooling water pumps having emergency bilge suctions need not be of the self-priming type.

15.18 Pump connections

15.18.1 The connections at the bilge pumps are to be such that one unit may continue in operation when the other unit is being opened up for overhaul.

15.18.2 Pumps required for essential services are not to be connected to a common suction or discharge chest or pipe unless the arrangements are such that the working of any pumps so connected is unaffected by the other pumps being in operation at the same time.

15.19 Direct bilge suctions

15.19.1 The direct bilge suctions in the machinery space are to be led to independent power pumps, and the arrangements are to be such that these direct suctions can be used independently of the main bilge line suctions.

15.20 Main bilge line suctions

15.20.1 Suctions from the main bilge line, i.e. branch bilge suctions, are to be arranged to draw water from any hold or machinery compartment within the craft, excepting small spaces such as those mentioned in 15.5 and 15.6 where manual pump suctions are accepted, and are not to be of smaller diameter than that required by the formula in 15.12.2.

15.21 Prevention of communication between compartments

15.21.1 The arrangement of valves, cocks and their connections is to be such as to prevent the possibility of one watertight compartment being placed in communication with another, or of dry cargo spaces, machinery spaces or other dry compartments being placed in communication with the sea or with tanks. For this purpose, screw-down non-return valves are to be provided in the following fittings:

- Bilge valve distribution chests.
- Bilge suction hose connections, whether fitted directly to the pump or on the main bilge line.
- Direct bilge suctions and bilge pump connections to main bilge line.

15.22 Isolation of bilge system

15.22.1 Bilge pipes which are required for draining cargo or machinery spaces are to be entirely distinct from sea inlet pipes or from pipes which may be used for filling or emptying spaces where water or oil is carried. This does not, however, exclude a bilge ejection connection, a connecting pipe from a pump to its suction valve chest, or a deep tank suction pipe suitably connected through a change-over device to a bilge, ballast or oil line.

15.23 Machinery space suctions – Mud boxes

15.23.1 Suctions for bilge drainage in machinery spaces and tunnels, other than emergency suctions, are to be led from easily accessible mud boxes fitted with straight tail pipes to the bilges and having covers secured in such a manner as to permit their being expeditiously opened or closed. Strum boxes are not to be fitted to the lower ends of these tail pipes or to the emergency bilge suctions.

15.24 Hold suctions – Strum boxes

15.24.1 The open ends of bilge suctions in holds and other compartments outside machinery spaces and tunnels are to be enclosed in strum boxes having perforations of not more than 10 mm diameter, whose combined area is not less than twice that required for the suction pipe. The boxes are to be so constructed that they can be cleared without breaking any joint of the suction pipe.

15.25 Tail pipes

15.25.1 The distance between the foot of all bilge tail pipes and the bottom of the bilge well is to be adequate to allow a full flow of water and to facilitate cleaning.

15.26 Location of fittings

15.26.1 Bilge valves, cocks and mud boxes are to be fitted at, or above, the machinery space platforms.

15.26.2 Where relief valves are fitted to pumps having sea connections, these valves are to be fitted in readily visible positions above the platform. The arrangements are to be such that any discharge from the relief valves will also be readily visible.

15.27 Bilge pipes in way of double bottom tanks

15.27.1 Bilge suction pipes are not to be led through double bottom tanks if it is possible to avoid doing so.

15.27.2 Bilge pipes which have to pass through these tanks are to have a minimum wall thickness of 6,3 mm. The thickness of pipes made from material other than steel will be specially considered.

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15.27.3 Expansion bends, not glands, are to be fitted to these pipes within the tanks, and the pipes are to be tested, after installation, to the same pressure as the tanks through which they pass.

15.28 Hold bilge non-return valves

15.28.1 Where non-return valves are fitted to the open ends of bilge suction pipes in cargo holds in order to decrease the risk of flooding, they are to be of an approved type which does not offer undue obstruction to the flow of water.

■ *Section 16*
Additional requirements for yachts that are 500 gt or more

16.1 General

16.1.1 Yachts that are 500 gt or more are to comply with Section 15 of this Chapter and in addition the following requirements.

16.2 Location of bilge pumps and bilge main

16.2.1 At least three power bilge pumps are to be provided, one of which may be operated from the main engines. Wherever practicable they are to be located in separate watertight compartments which will not readily be flooded by the same damage. If the engines are in two or more watertight compartments, the bilge pumps are to be distributed throughout these compartments so far as possible.

16.2.2 Where compliance with 16.2.1 is impractical, two independently driven bilge pumps may be accepted provided they are located in separate watertight compartments. If both pumps are necessarily located in the machinery space then one is to be of the submersible type with its source of power located above the bulkhead deck.

16.2.3 The bilge main is to be so arranged that no part is situated nearer the side of the craft than *B*/5, measured at right angles to the centreline at the level of the deepest sub-division load line, where *B* is the breadth of the craft.

16.2.4 Where any bilge pump or its pipe connection to the bilge main is situated outboard of the *B*/5 line, then a non-return valve is to be provided in the pipe connection at the junction with the bilge main.

16.2.5 Each independent bilge pump is to have a direct bilge suction from the space in which it is situated, but not more than two such suctions are required in any one space. The suctions are to be arranged such that each side of the space is fitted with at least one suction.

16.3 Prevention of communication between compartments in the event of damage

16.3.1 Provision is to be made to prevent the compartment served by any bilge suction pipe being flooded, in the event of the pipe being severed, or otherwise damaged by collision or grounding in any other compartment. For this purpose, where any part of a branch bilge pipe is situated outboard of the *B*/5 line or in a duct keel, a non-return valve is to be fitted to the pipe in the compartment containing the open end.

16.4 Arrangement and control of bilge valves

16.4.1 Distribution boxes, valves and cocks in connection with the bilge pumping arrangements are to be so arranged that, in the event of flooding, one of the bilge pumps may be operative on any compartment.

16.4.2 Where there is only one system of pipes common to all pumps, the arrangements are to be such that if the machinery space or other compartment is flooded then it is possible to operate the necessary valves and cocks in order to take suction from that compartment. For this purpose it may be necessary to arrange for remote control of the bilge suction valves from above the bulkhead deck.

16.4.3 Where, in addition to the main bilge pumping system, an emergency bilge pumping system is provided, it is to be independent of the main system and so arranged that a pump is capable of operating on any compartment under flooding conditions. In this case, only the valves and cocks necessary for the operation of the emergency system need to be capable of being operated from above the bulkhead deck.

16.4.4 All valves and cocks mentioned in 16.4.2 which can be operated from above the bulkhead deck are to have their controls at their place of operation clearly marked and provided with means to indicate whether they are open or closed.

16.5 Cross flooding arrangements

16.5.1 Where divided deep tanks or side tanks are provided with cross flooding arrangements to limit the angle of heel after side damage, the arrangements are to be self-acting where practicable. In any case, where controls to cross flooding fittings are provided, they are to be operable from above the bulkhead deck.

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■ *Section 17* Requirements for Air Cushion Vehicles

17.1 General

17.1.1 At least three copies of the following diagrammatic plans are to be submitted together with a general description of each system, indicating operating pressures and temperatures, etc., safety devices incorporated and means of protection against corrosion and contamination:

- Oil fuel.
- Lubricating oil.
- Hydraulic and pneumatic systems.
- Pumping arrangements for draining and trimming.
- Air filtering to power units.

17.1.2 Reference is to be made to the *Guidance Notes and Requirements for the Classification of Air Cushion Vehicles (ACV) 1970*.

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Section

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■ *Section 1* Application

1.1 Applicability of requirements

1.1.1 The requirements of Sections 2 to 8 of this Chapter apply to piping systems on mono-hull and multi-hull craft except where modified by Sections 9 to 11 as applicable.

1.1.2 Special requirements for multi-hull craft are given in Section 9.

1.1.3 These requirements satisfy the relevant design and construction requirements of the HSC Code. They are also applicable to yachts and service craft of more than 24 m not required to comply with the Code.

1.1.4 Requirements for Passenger (A) Craft are given in Section 10.

1.1.5 Requirements for small craft not required to comply with the HSC Code are given in Section 11.

1.1.6 In addition to the requirements of this Chapter, attention is to be given to any relevant statutory requirements of the National Authority of the country in which the craft is to be registered.

■ *Section 2* General requirements

2.1 General

2.1.1 The maximum working pressure in any part of a fluid system is not to be greater than the design pressure.

2.1.2 Where the design pressure of a system component, such as a valve or a fitting, is less than that for the pipe or tubing, the system pressure is to be limited to the lowest of the component design pressures. Every system which may be exposed to pressures higher than the design pressure is to be safeguarded by appropriate relief devices.

2.1.3 Materials used in piping systems are to be compatible with the fluid conveyed and due regard given to the risk of fire. Non-metallic piping material may be permitted in certain systems, provided the integrity of the hull and watertight decks and bulkheads is maintained.

2.1.4 The design of pipework systems is to be in accordance with the requirements of Chapter 1.

■ *Section 3* Oil fuel storage

3.1 Flash point

3.1.1 The flash point (closed cup test) of oil fuel for use in craft classed for unrestricted service is in general to be not less than 60°C. For emergency generator engines, a flash point of not less than 43°C is permissible.

3.1.2 Oil fuel with a flash point lower than 60°C may be used in craft intended for restricted service where it can be demonstrated that the temperature of machinery spaces will always be 10°C below the flash point of the oil fuel.

3.1.3 The use of oil fuel with a flash point below 43°C is not recommended. However, oil fuel with a lower flash point, but not lower than 35°C, may be used in gas turbines only subject to compliance with the provisions specified in Section 5.

3.1.4 Proposals for the use or carriage of oil fuel with a lower flash point will be specially considered.

3.2 Oil fuel storage arrangements

3.2.1 Tanks containing oil fuel are to be separated from passenger, crew and baggage compartments by vapour-proof enclosures or cofferdams which are suitably ventilated and drained.

3.2.2 Oil fuel tanks are not to be located in or adjacent to major fire hazard areas.

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3.2.3 Oil fuel is not to be carried forward of the area for which public spaces or crew accommodation are permitted.

3.2.4 No oil fuel tank is to be situated where spillage or leakage therefrom can constitute a hazard by falling on heated surfaces.

3.2.5 Safe and efficient means of ascertaining the amount of oil fuel contained in any oil fuel tank is to be provided, *see also* Ch 2,11.9 to 11.12.

3.2.6 Oil fuel tanks are to be provided with self-closing valves or cocks for draining water from the bottom of the tanks.

3.2.7 As far as practicable, all parts of the oil fuel system containing heated oil under pressure exceeding 2 bar are not to be placed in a concealed position such that defects and leakage cannot be readily observed. The machinery spaces in way of such parts of the oil fuel system are to be adequately illuminated.

3.2.8 Oil fuel tanks are to be provided with oil-tight drip trays of sufficient capacity having suitable drainage arrangements.

3.2.9 In general oil fuel tanks are not to be used for carriage of water ballast. Where this is unavoidable the fuel transfer system is to be isolated from the ballast system and either oily water separating equipment is to be installed, or discharge to shore facilities provided, in accordance with the requirements of the *International Convention for the Prevention of Pollution from Ships* in force.

3.3 Oil fuel storage arrangements for yachts and service craft of 24 m or greater in length, which are not required to comply with the HSC Code

3.3.1 Oil fuel tanks are normally to be located outside machinery spaces and other areas of major fire hazard.

3.3.2 Where structural tanks are located adjacent to machinery spaces they are to be arranged such that the area of the tank common with the machinery space is kept to a minimum. In craft constructed of aluminium or other heat sensitive material the tanks are to be suitably protected against the effect of fire in the machinery space.

3.3.3 Where free standing tanks are fitted in machinery spaces they are to be of steel or equivalent material and positioned in an oil tight drip tray of ample size having suitable drainage arrangements to a spill oil tank.

3.3.4 For yachts that are 500 gt or more, free standing oil fuel tanks are not to be fitted in machinery spaces, *see* Pt 17, Ch 3,3.17.3.

3.3.5 The requirements of 3.2.4 to 3.2.8 are to be complied with. Where free standing tanks are fitted they are to comply with the requirements of 11.3.1 to 11.3.3.

3.4 Unattended machinery

3.4.1 Where machinery is fitted with automatic or remote controls so that under normal operating conditions it does not require any manual intervention by the operators, the requirements of 3.4.2 to 3.4.5 apply.

3.4.2 Where daily service tanks are filled automatically or by remote control, means are to be provided to prevent overflow spillages.

3.4.3 Other equipment which treats flammable liquid automatically, such as oil fuel purifiers, are to have arrangements to prevent spillage of the liquid through overflow or malfunction of seals.

3.4.4 Alarms are to be provided for purifier broken water seal and high oil inlet temperature.

3.4.5 Where daily service oil fuel tanks or settling tanks are fitted with heating arrangements, a high temperature alarm is to be provided if the flash point of the oil can be exceeded. This alarm is to be separate from the temperature control system.

3.4.6 Oil fuel service tanks are to be provided with high and low level alarms. Where a common overflow tank is fitted, a high level alarm in the common overflow tank may be accepted.

3.4.7 Oil and gas dual-fired systems for boilers and engines are to be provided with indication to show which fuel is in use.

■ *Section 4* Oil fuel systems

4.1 Oil fuel supply to main and auxiliary engines

4.1.1 Two or more filters are to be fitted in the oil fuel supply lines to the main and auxiliary engines, and the arrangements are to be such that any filter can be cleaned without interrupting the supply of filtered oil fuel to the engines.

4.2 Booster pumps

4.2.1 Where an oil fuel booster pump is fitted, which is essential to the operation of the main engine, a standby pump is to be provided.

4.2.2 The standby pump is to be connected ready for immediate use, but where two or more main engines are fitted, each with its own pump, a complete spare pump may be accepted provided that it is readily accessible and can easily be installed.

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4.3 Fuel valve cooling pumps

4.3.1 Where pumps are provided for fuel valve cooling, the arrangements are to be in accordance with 4.2.1 and 4.2.2.

4.4 Transfer pumps

4.4.1 Where a power driven pump is necessary for transferring oil fuel, a standby pump is to be provided and connected ready for use. The standby pump may be a manual pump. Alternatively, emergency connections may be made to another suitable power driven pump.

4.5 Control of pumps

4.5.1 All independently driven oil fuel transfer and pressure pumps are to be capable of being stopped locally and from a position outside of the space in which they are located. The remote stop position is always to be accessible in the event of fire occurring in the space in which these pumps are located.

4.6 Relief valves on pumps

4.6.1 All pumps which are capable of developing a pressure exceeding the design pressure of the system are to be provided with relief valves. Each relief valve is to be in closed circuit, i.e. arranged to discharge back to the suction side of the pump and to effectively limit the pump discharge pressure to the design pressure of the system.

4.7 Pump connections

4.7.1 Valves or cocks are to be interposed between the pumps and the suction and discharge pipes, in order that any pump may be shut off for opening up and overhauling.

4.8 Low pressure pipes

4.8.1 Transfer, suction and other low pressure oil pipes and all pipes passing through oil storage tanks are to be suitable for a working pressure of not less than 7 bar.

4.9 Valves on deep tanks and their control arrangements

4.9.1 Every oil fuel suction pipe from a storage, settling or daily service tank situated above the double bottom, and every oil fuel levelling pipe, is to be fitted with a valve or cock secured to the tank.

4.9.2 In machinery spaces such valves and cocks are to be capable of being closed locally and from positions outside these spaces which will always be accessible in the event of fire occurring in these spaces. Instructions for closing the valves or cocks are to be indicated at the valves and cocks and at the remote control positions.

4.9.3 In the case of tanks of less than 0,5 m^3, consideration will be given to the omission of remote controls for craft not required to comply with the HSC Code.

4.9.4 Every oil fuel suction pipe which is led into the machinery spaces, from a deep tank outside these spaces, is to be fitted in the machinery space with a valve controlled as in 4.9.2 except where the valve on the tank is already capable of being closed from an accessible position above the bulkhead deck.

4.9.5 Where the filling pipes to deep oil tanks are not connected to the tanks near the top, they are to be provided with non-return valves at the tanks or with valves or cocks fitted and controlled as in 4.9.2.

4.10 Filling arrangements

4.10.1 Filling stations are to be isolated from other spaces and are to be efficiently drained and ventilated.

4.10.2 Provision is to be made against over-pressure in the filling pipelines. Any relief valve fitted for this purpose is to discharge to an overflow tank or other safe position.

4.11 Precautions against fire

4.11.1 Pipes, valves and couplings conveying flammable fluids are to be installed, screened or otherwise suitably protected, to avoid spray or leakages onto hot surfaces, into machinery air intakes, or other sources of ignition such as electrical equipment. The number of joints in such systems is to be kept to a minimum.

■ *Section 5* Low flash point fuels

5.1 General

5.1.1 For craft having oil fuel with a flash point below 43°C the arrangements for the storage, distribution and utilisation of the oil fuel are to be such that the safety of the craft and persons on board is preserved, having regard to fire and explosion hazards. The arrangements are to comply with Sections 3, 4 and 5.1.2 to 5.1.6.

5.1.2 Tanks for the storage of such oil fuel are to be located outside any machinery space and at a distance of not less than 760 mm inboard from the shell and bottom plating, and from decks and bulkheads.

5.1.3 The spaces in which oil fuel tanks are located are to be mechanically ventilated using exhaust fans providing not less than six air changes per hour. The fans are to be such as to avoid the possibility of ignition of flammable gas air mixtures. Suitable wire mesh guards are to be fitted over inlet and outlet ventilation openings. The outlets for such exhausts are to discharge to a safe position.

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5.1.4 A fixed vapour detection system is to be installed in each space through which oil fuel lines pass, with alarms provided at a continuously manned control station.

5.1.5 Safe and efficient means of ascertaining the amount of oil fuel contained in any tank is to be provided. Gauge glasses are not to be used. Other means of ascertaining the amount of oil fuel contained in any tank may be permitted if such means do not require penetration below the top of the tank, and providing their failure or overfilling of the tanks will not permit the release of oil fuel.

5.1.6 Vessel to shore oil fuel connections are to be of closed type and suitably grounded during bunkering operations.

5.1.7 Air pipes shall discharge to a safe position and terminate with flame arresters in accordance with MSC/Circ. 677.

■ *Section 6* Lubricating/hydraulic oil systems

6.1 Lubricating oil arrangements

6.1.1 The arrangements for the storage, distribution and utilisation of oil used in pressure lubrication systems in machinery spaces and, whenever practicable, in auxiliary machinery spaces are to comply with the provisions of 3.2 (except 3.2.2), 3.4 and 4.9 (except 4.9.3).

6.1.2 Tanks containing lubricating oil located within major fire hazard areas are to be of steel or other equivalent material.

6.1.3 Where lubricating oil tanks have a capacity of less than 0,5 m^3, consideration will be given to relaxing the requirements for remote controls to be fitted.

6.1.4 Where the lubricating oil for main propelling engines is circulated under pressure, provision is to be made for the efficient filtration of the oil. The filters are to be capable of being cleaned without stopping the engine or reducing supply of filtered oil to the engine. Proposals for an automatic by-pass for emergency purposes in high speed engines are to be submitted for consideration.

6.1.5 In addition, craft of 24 m or greater in length are to comply with the requirements of 4.5 to 4.7.

6.2 Arrangements for hydraulic and flammable oils

6.2.1 The requirements of this Section are applicable to flammable oils employed under pressure in power transmission, control, actuating and heating systems, and hydraulic media in systems which are providing essential services.

6.2.2 The arrangements for storage, distribution and utilisation of hydraulic and flammable oils employed in the systems defined in this sub-Section are to comply with the provisions of 6.1.

6.3 Lubricating/hydraulic oil standby arrangements

6.3.1 Where lubricating oil for the main engine(s) is circulated under pressure, a standby lubricating oil pump is to be provided where the following conditions apply:

(a) The lubricating oil pump is independently driven and the total output of the main engine(s) exceeds 500 kW.

(b) One main engine with its own pump is fitted and the output of the engine exceeds 500 kW.

(c) More than one engine each with its own lubricating oil pump is fitted and the output of each engine exceeds 500 kW.

6.3.2 The standby pump is to be of sufficient capacity to maintain the supply of oil for normal conditions with any one pump out of action. The pump is to be fitted and connected ready for immediate use, except that where the conditions referred to in 6.3.1(c) apply, a complete spare pump may be accepted. In all cases, satisfactory lubrication of the engines is to be ensured while starting and manoeuvring.

6.3.3 Similar provisions to those of 6.3.1 and 6.3.2 are to be made where separate lubricating/hydraulic oil systems are employed for piston cooling, reduction gears, oil operated couplings controllable pitch propellers and steering systems etc., unless approved alternative arrangements are provided.

6.3.4 Independently driven pumps of rotary type are to be fitted with a non-return valve on the discharge side of the pump.

6.4 Lubricating oil contamination

6.4.1 The materials used in the storage and distribution of lubricating oil are to be selected such that they do not introduce or modify the properties of the oil. The use of cadmium or zinc in lubricating oil systems where they may come into contact with the oil is not permitted.

6.4.2 Arrangements are to be made for each forced lubrication system, renovation system, ready to use tank(s) and their associated rundown lines to drain tanks to be flushed after system installation and prior to running of machinery. The flushing arrangements are to be in accordance with the equipment manufacturer's procedures and recommendations.

6.4.3 The design and construction of engine and gear box piping arrangements are to prevent as far as practicable, contamination of engine lubricating oil systems by leakage of cooling water or from bilge water where engines or gearboxes are partly installed below the lower platform.

6.4.4 Where a lubricating oil filling pipe and cap are provided for engines and other machinery, provision is to be made for the topping up oil to pass through a gauze strainer. The caps are to be capable of being secured in the closed position.

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6.4.5 Sampling points are to be provided that enable samples of lubricating oil to be taken in a safe manner. The sampling arrangements are to have the capability to provide samples when machinery is running and are to be provided with valves and cocks of the self-closing type and located in positions as far removed as possible from any heated surface or electrical equipment.

■ *Section 7*
Engine cooling water systems

7.1 General

7.1.1 The cooling arrangements provided are to be adequate to maintain all lubricating and hydraulic fluid temperatures within the manufacturer's recommended limits.

7.2 Main supply

7.2.1 Provision is to be made for an adequate supply of cooling water to the main propelling machinery and essential auxiliary engines, also to the lubricating oil and fresh water coolers and air coolers for electric propelling machinery, where these coolers are fitted. The cooling water pump(s) may be worked from the engines or be driven independently.

7.3 Standby supply

7.3.1 Provision is also to be made for a separate supply of cooling water from a suitable independent pump of adequate capacity.

7.3.2 The following arrangements are acceptable depending on the purpose for which the cooling water is intended:

(a) Where only one main engine is fitted, the standby pump is to be connected ready for immediate use.

(b) Where more than one main engine is fitted, each with its own pump, a complete spare pump of each type may be accepted.

(c) Where fresh water cooling is employed for main and/or auxiliary engines, a standby fresh water pump need not be fitted if there are suitable emergency connections from a salt water system.

(d) Where each auxiliary engine is fitted with a cooling water pump, standby means of cooling need not be provided. Where, however, a group auxiliary engine is supplied with cooling water from a common system, a standby cooling water pump is to be provided for this system.

This pump is to be connected ready for immediate use and may be a suitable general service pump.

7.4 Selection of standby pumps

7.4.1 When selecting a pump for standby purposes, consideration is to be given to the maximum pressure which it can develop if the overboard discharge valve is partly or fully closed. Where necessary, water boxes, etc., are to be protected against inadvertent over-pressure by an approved device.

7.5 Relief valves on main cooling water pumps

7.5.1 Where cooling water pumps can develop a pressure head greater than the design pressure of the system, they are to be provided with relief valves on the pump discharge to effectively limit the pump discharge pressure to the design pressure of the system.

7.6 Sea inlets

7.6.1 Not less than two sea inlets are to be provided for the pumps supplying the sea water cooling system, one for the main pump and one for the standby pump. Alternatively, the sea inlets may be connected to a suction line available to main and standby pumps.

7.6.2 Where standby pumps are not connected ready for immediate use (*see* 7.3.2(b) and (d)), the main pump is to be connected to both sea inlets.

7.6.3 The auxiliary cooling water sea inlets are to be located one on each side of the craft.

7.7 Strainers

7.7.1 Where sea water is used for the direct cooling of the main engines and essential auxiliary engines, the cooling water suction pipes are to be provided with strainers which can be cleaned without interruption to the cooling water supply.

■ *Section 8*
Miscellaneous machinery

8.1 General

8.1.1 Alarms and safeguards are indicated in Table 1.8.1.

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Table 1.8.1 Miscellaneous machinery: Alarms and safeguards

Item	Alarm	Note
Coolant tanks level	Low	—
Sludge tanks level	High	—
Feed water tanks level	Low	Service tank only
Hydraulic control system pressure	Low	—
Pneumatic control system pressure	Low	—

■ *Section 9* Special requirements for multi-hull craft

9.1 General

9.1.1 The requirements of Sections 1 to 8 are generally applicable to multi-hull craft except where these are modified by the requirements of this Section.

9.1.2 Where the machinery piping arrangements in each hull of a multi-hull craft are separate, the machinery piping and standby requirements for each hull are to be as detailed in 6.3.1(c) and 7.3.2(b), i.e. the requirements for a twin-engined mono-hull craft apply.

9.1.3 Where a multi-hull craft cannot navigate safely with the main propulsion machinery in one hull out of action, the machinery piping and standby requirements are to be as detailed in 6.3.1(a) or (b), and 7.3.2(a), i.e. the requirements for a single-engined mono-hull craft apply to the machinery in each hull.

■ *Section 10* Requirements for Passenger (A) Craft

10.1 General

10.1.1 The requirements of Sections 1 to 9 apply except that the standby machinery arrangements detailed in Sections 6 and 7 are not required.

■ *Section 11* Requirements for small craft which are not required to comply with the HSC Code

11.1 General

11.1.1 The requirements of this Section replace Sections 3.2 to 3.4 and 4, 5, 6 and 7 of this Chapter, *see also* Ch 1,15.

11.2 Oil fuel system

11.2.1 Where a power driven oil fuel transfer pump is fitted, it is to be capable of being stopped from a position outside the space which will always be accessible in the event of fire occurring in the compartment in which the pump is situated, as well as from the compartment itself.

11.2.2 Where a power driven pump is necessary for transferring oil fuel, a standby pump is to be provided and connected ready for use.

11.3 Separate oil fuel tanks

11.3.1 Except for very small tanks separate oil fuel tanks are to be not less than 3 mm in thickness. The seams are to be welded or brazed. Steel tanks are to be protected from corrosion.

11.3.2 Before installation, all tanks are to be tested by a head of water equal to the maximum to which the tanks may be subjected, but not less than 2,5 m above the crown of the tank.

11.3.3 Separate oil fuel tanks are to be securely fixed in position, and located as remote as practicable from exhaust manifolds and exhaust pipes or other hot surfaces and not above any electrical apparatus. Where this cannot be avoided, a drip tray is to be fitted under the tank and extended sufficiently to catch any drips from fittings attached to the tank.

11.3.4 Oil fuel tanks are not to be fitted above or adjacent to oil fired heaters, cooking stoves, equipment using naked flames or electrical equipment unless this is suitably constructed or enclosed.

11.4 Oil fuel filling

11.4.1 The filling pipe is to be of metallic construction and is to be a permanent fixture led from the deck and secured to the tank by an approved connection. A screwed cap and name plate inscribed 'Oil Fuel' is to be provided at the filling point.

11.4.2 Flexible hoses are not permitted as filling pipes. In wood or composite craft short lengths may be employed at the deck connection to accommodate any movement between the tank and the deck fitting.

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11.5 Oil fuel supply

11.5.1 Provision is to be made for efficient filtration of the oil fuel supply to the engine.

11.6 Oil fuel valves and cocks

11.6.1 Outlet valves or cocks are to be fitted to all deep tanks. The valves are to be fitted directly to the tank plating and are to be capable of being closed locally and from positions which will always be readily accessible in the event of fire.

11.6.2 Valve covers are to be so constructed that they will not become slack when the valves are operated.

11.6.3 Heat sensitive materials are not to be used in the construction of valves and cocks.

11.6.4 Where drain cocks or valves are fitted to oil fuel tanks they are to be of the self-closing type and suitable provision is to be made for collecting the oil discharge.

11.7 Flexible hoses for oil fuel systems

11.7.1 Where necessary, flexible pipes of approved type may be used as short joining lengths to the engine.

11.8 Pipe joints for oil fuel systems

11.8.1 Where flanged joints are used the jointing material is to be impervious to oil. Cone type joints and approved types of compression fittings may be permitted for pipes having a bore not exceeding 40 mm.

11.8.2 Soft solder is not to be used for attaching pipe fittings.

11.9 Engine cooling system

11.9.1 Where sea water is used for the direct cooling of the engine, an efficient strainer which can be cleared from inside the craft is to be fitted between the sea inlet valve and the pump.

11.9.2 Means are to be provided for cleaning the strainer without interruption to the cooling water supply, where necessary.

11.9.3 Means are to be provided for indicating the temperature of the engine cooling media.

11.9.4 Alarms for the engine cooling water system are to be provided in accordance with Part 10.

11.10 Lubricating oil system

11.10.1 Where the lubricating oil for main propelling engines is circulated under pressure, provision is to be made for the efficient filtration of the oil.

11.10.2 Where necessary, flexible pipes of approved type may be used as short joining lengths to the engine.

11.10.3 In general, joints are to be of the flanged type with jointing materials which are impervious to oil. Cone type joints and approved types of compression fittings may be permitted for pipes having a bore not exceeding 40 mm.

11.10.4 Soft solder is not to be used for attaching pipe fittings.

11.10.5 Means are to be provided for indicating the lubricating oil pressure.

11.10.6 Alarms for the lubricating oil systems are to be provided in accordance with Part 10.

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Section

1 **General requirements**

2 **Cylindrical shells subject to internal pressure**

3 **Spherical shells subject to internal pressure**

4 **Dished ends subject to internal pressure**

5 **Standpipes and branches**

6 **Unstayed circular flat end plates**

7 **Construction**

8 **Requirements for fusion welded pressure vessels**

9 **Mountings and fittings for pressure vessels**

10 **Hydraulic tests**

11 **Fibre reinforced plastics pressure vessels**

12 **Requirements for craft which are not required to comply with the HSC Code**

Section 1
General requirements

1.1 Application

1.1.1 The requirements of this Chapter are applicable to fusion welded pressure vessels and their mountings and fittings, where plans have to be submitted in accordance with 1.2.

1.1.2 Seamless pressure vessels are to be manufactured in accordance with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials) where applicable.

1.1.3 Steam raising plant and associated pressure vessels should be designed and constructed in accordance with Pt 5, Ch 10 of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships).

1.2 Details to be submitted

1.2.1 Plans of pressure vessels are to be submitted in triplicate for consideration where all the conditions in (a) or (b) are satisfied:

(a) The vessel contains vapours or gases, e.g. air receivers, hydrophore or similar vessels and gaseous CO_2 vessels for fire-fighting, and
$pV > 600$
$p > 1$
$V > 100$
V = volume (litres) of gas or vapour space

(b) The vessel contains liquefied gases for fire-fighting, or flammable liquids, and
$p > 7$
$V > 100$
V = volume (litres)
p = design pressure (bar).

1.3 Materials

1.3.1 Materials used in the construction of Class 1, 2/1 and 2/2 pressure vessels are to be manufactured, tested and certified in accordance with the requirements of the Rules for Materials. Materials used in the construction of Class 3 pressure vessels may be in accordance with the requirements of an acceptable National or International Standard. The manufacturer's certificate will be accepted in lieu of LR's material certificate for such materials.

1.3.2 The specified minimum tensile strength of carbon and carbon-manganese steel plates, pipes, forgings and castings is to be within the following general limits:

(a) For seamless and Class 1 and Class 2/1 fusion welded pressure vessels:
340 to 520 N/mm^2.

(b) For Class 2/2 and where required Class 3 fusion welded pressure vessels:
340 to 430 N/mm^2.

1.3.3 Where it is proposed to use materials other than those specified in the Rules for Materials, details of the chemical compositions, heat treatment and mechanical properties are to be submitted for approval. In such cases, the values of the mechanical properties used for deriving the allowable stress are to be subject to agreement by Lloyd's Register (hereinafter referred to as 'LR').

1.4 Classification of fusion welded pressure vessels

1.4.1 Fusion welded pressure vessels are graded as Class 1 where the shell thickness exceeds 38 mm.

1.4.2 Fusion welded pressure vessels are graded as Class 2/1 and Class 2/2 if they comply with the following conditions:

(a) where the design pressure exceeds 17,2 bar, or
(b) where the metal temperature exceeds 150°C, or
(c) where the design pressure, in bar, multiplied by the actual thickness of the shell, in mm exceeds 157, or
(d) where the shell thickness does not exceed 38 mm.

1.4.3 For Rule purposes, Class 3 pressure vessels are to have a maximum shell thickness of 16 mm, and are pressure vessels not included in Classes 1, 2/1 or 2/2.

1.5 Design pressure

1.5.1 The design pressure is the maximum permissible working pressure and is to be not less than the highest set pressure of any safety valve.

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1.6 Metal temperature

1.6.1 The metal temperature, T, used to evaluate the allowable stress, σ, is to be taken as the actual mean wall metal temperature expected under operating conditions for the pressure part concerned, and is to be stated by the manufacturer when plans of the pressure parts are submitted for consideration.

1.6.2 For fusion welded pressure vessels the minimum design temperature, T, is not to be less than 50°C.

1.7 Definition of symbols

1.7.1 The symbols used in the various formulae in Sections 2 to 6, unless otherwise stated, are defined as follows and are applicable to the specific part of the pressure vessel under consideration:

p = design pressure, in bar, *see* 1.5
r_i = inside knuckle radius, in mm
r_o = outside knuckle radius, in mm
t = minimum thickness, in mm
D_i = inside diameter, in mm
D_o = outside diameter, in mm
J = joint factor applicable to welded seams
R_i = inside radius, in mm
R_o = outside radius, in mm
T = design temperature, in °C
σ = allowable stress, in N/mm^2, *see* 1.8.

1.7.2 Where reference is made to calculated or actual plate thickness for the derivation of other values, these thicknesses are to be minus the standard Rule corrosion allowance of 0,75 mm, if not so stated.

1.8 Allowable stress

1.8.1 The term 'allowable stress', σ, is the stress to be used in the formulae for the calculation of scantlings of pressure parts.

1.8.2 The allowable stress, σ, is to be the lowest of the following values:

$$\sigma = \frac{E_t}{1,5}$$

$$\sigma = \frac{R_{20}}{2,7}$$

$$\sigma = \frac{S_R}{1,5}$$

where

E_t = specified minimum lower yield stress or 0,2 per cent proof stress at temperature, T, for carbon and carbon-manganese steels. In the case of austenitic steels, the 1,0 per cent proof stress at temperature, T, is to be used
R_{20} = specified minimum tensile strength at room temperature
S_R = average stress to produce rupture in 100 000 hours at temperature, T
T = metal temperature, *see* 1.6.

1.8.3 The allowable stress for steel castings is to be taken as 80 per cent of the value determined by the method indicated in 1.8.2, using the appropriate values for cast steel.

1.8.4 Where steels castings, which have been tested in accordance with the Rules for Materials, are also subjected to non-destructive tests, consideration will be given to increasing the allowable stress using a factor up to 90 per cent in lieu of the 80 per cent referred to in 1.8.3. Particulars of the non-destructive test proposals are to be submitted for consideration.

1.9 Joint factors

1.9.1 The following joint factors are to be used in the equations in Sections 2 to 6, where applicable. Fusion welded pressure parts are to be made in accordance with Section 8.

Class of pressure vessel	Joint factor
Class 1	1,0
Class 2/1	0,85
Class 2/2	0,75
Class 3	0,6

1.9.2 The longitudinal joints for all Classes of vessels are to be butt joints. Circumferential joints for Class 1 vessels and all classes of vessel for the production and storage of steam are also to be butt welds. Circumferential joints for Class 2/1, 2/2 and 3 vessels should also be butt joints with the following exceptions:

(a) Circumferential joints for Class 2/1, 2/2 and 3 vessels may be of the joggle type provided neither plate at the joints exceeds 16 mm thickness.
(b) Circumferential joints for Class 3 vessels may be of the lap type provided neither plate at the joint exceeds 16 mm thickness nor the internal diameter of the vessel exceeds 610 mm.

For typical acceptable methods of attaching dished ends, *see* Fig. 4.6.1.

1.10 Pressure parts of irregular shape

1.10.1 Where pressure parts are of such irregular shape that it is impracticable to design their scantlings by the application of formulae in this Chapter, the suitability of their construction is to be determined by hydraulic proof test of a prototype or by agreed alternative method.

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Section 2
Cylindrical shells subject to internal pressure

2.1 Minimum thickness

2.1.1 Minimum thickness, t, of a cylindrical shell is to be determined by the following formula:

$$t = \frac{p R_i}{10\sigma J - 0{,}5p} + 0{,}75 \text{ mm}$$

where

t, p, R_i and σ are defined in 1.7

J = the joint factor of the longitudinal joints (expressed as a fraction), *see* 1.9.1. In the case of seamless shells clear of openings, $J = 1{,}0$.

2.1.2 The formula in 2.1.1 is applicable only where the resulting thickness does not exceed half the internal radius, i.e. where R_o is not greater than $1{,}5R_i$.

2.1.3 For fusion welded pressure vessels, t, is to be not less than $3 + \frac{D_i}{1500}$ mm,

where

D_i is as defined in 1.7.

2.1.4 The minimum thickness of vessels manufactured of corrosion resistant steels will be the subject of special consideration.

2.2 Unreinforced openings

2.2.1 The maximum diameter, d, of any unreinforced isolated openings is to be determined by the following formula:

$$d = 8{,}08\,[D_o\, t\, (1 - K)]^{1/3} \text{ in mm}$$

The value of K to be used is calculated from the following formula:

$$K = \frac{p D_o}{18{,}2\sigma t} \text{ but is not to be taken as greater than } 0{,}99$$

where

p, D_o and σ are as defined in 1.7

t = actual thickness of shell, in mm.

2.2.2 For elliptical or oval holes, d, for the purposes of 2.2.1, refers to the major axis when this lies longitudinally or to the mean of the major and minor axes when the minor axis lies longitudinally.

2.2.3 No unreinforced opening is to exceed 200 mm in diameter.

2.2.4 Holes may be considered isolated if the centre distance between two holes on the longitudinal axis of a cylindrical shell is not less than:

$$d + 1{,}1\sqrt{D\,t} \text{ with a minimum } 5d$$

where

d = diameter of openings in shell (mean diameter if dissimilarly sized holes are involved)

D = mean diameter of shell

t = actual thickness of shell

Where the centre distance is less than so derived, the holes are to be fully compensated.

2.3 Reinforced openings

2.3.1 Openings larger than those permitted by 2.2 are to be compensated in accordance with Fig. 4.2.1(a) or (b). The following symbols are used in Fig. 4.2.1(a) and (b):

t_s = calculated thickness of a shell without joint or opening or corrosion allowance, in mm

t_d = thickness calculated in accordance with 3.1 without corrosion allowance, in mm

t_a = actual thickness of shell plate without corrosion allowance, in mm

t_b = actual thickness of standpipe without minus tolerances and corrosion allowance, in mm

t_r = thickness of added reinforcement, in mm

D_i = internal diameter of cylindrical shell, in mm

d_o = diameter of hole in shell, in mm

L = width of added reinforcement not exceeding D, in mm

$C = \sqrt{d_o\, t_b}$ in mm

$D = \sqrt{D_i\, t_a}$ and is not to exceed $0{,}5d_o$, in mm

σ = shell plate allowable stress, N/mm^2

σ_p = standpipe allowable stress, N/mm^2

σ_r = added reinforcement allowable stress, N/mm^2

σ_w = weld metal allowable stress, N/mm^2

NOTE

σ_p, σ_r and σ_w are not to be taken as greater than σ.

2.3.2 For elliptical or oval holes, the dimension on the meridian of the shell is to be used for d_o in 2.3.1.

2.3.3 The welds attaching standpipes and reinforcing plates to the shell are to be of sufficient size to transmit the full strength of the reinforcing areas and all other loadings to which they may be subjected.

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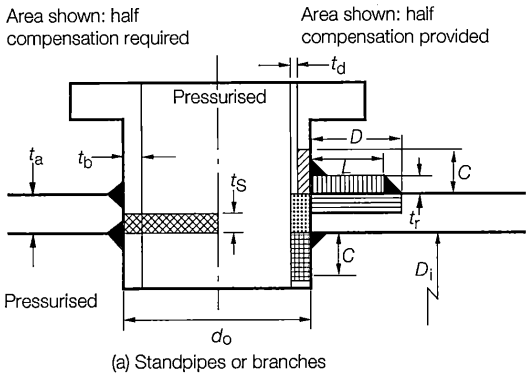
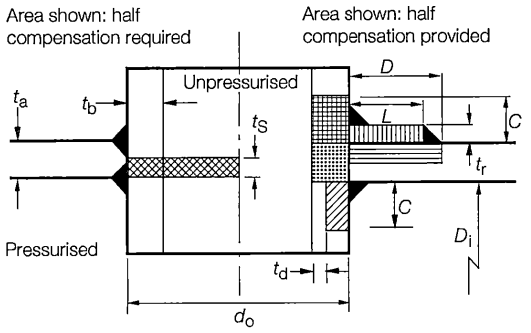


(a) Standpipes or branches



(b) Insert pieces for internal doors

Compensation required:

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A_1 = ▨ $= d_o\, t_S$ mm²

Compensation provided:

A_2 = ▤ $= 2D\,(t_a - t_S)$ mm²

A_3 = ▦ $= 2\,t_b\,t_a\,\frac{\sigma_p}{\sigma}$ mm²

A_4 = ▩ $= 2C\,t_b\,\frac{\sigma_p}{\sigma}$ mm²

A_5 = ▨ $= 2C\,(t_b - t_d)\,\frac{\sigma_p}{\sigma}$ mm²

A_6 = ▥ $= 2L\,t_r\,\frac{\sigma_r}{\sigma}$ mm²

A_7 = ◣ = (Area of fillet welds) $\frac{\sigma_w}{\sigma}$ mm²

$A_2 + A_3 + A_4 + A_5 + A_6 + A_7 \geq A_1$

Fig. 4.2.1
Compensation for welded standpipes or branches in cylindrical shells

■ *Section 3*
Spherical shells subject to internal pressure

3.1 Minimum thickness

3.1.1 The minimum thickness, t, of a spherical shell is to be determined by the following formula:

$$t = \frac{p\,R_i}{20\sigma\,J - 0{,}5p} + 0{,}75 \text{ mm}$$

where

t, p, R_i, σ and J are as defined in 1.7.

3.1.2 The formula in 3.1.1 is applicable only where the resulting thickness does not exceed half the internal radius.

3.1.3 Irrespective of the thickness determined by the formula in 3.1.1, t is to be not less than $\frac{D_i}{1500} + 3$ mm for other pressure vessels, where D_i is as defined in 1.7.

3.1.4 The minimum thickness permitted for vessels manufactured in corrosion resistant steels will be the subject of special consideration.

3.1.5 Openings in spherical shells requiring compensation are to comply, in general, with 2.3, using the calculated and actual thicknesses of the spherical shell as applicable.

■ *Section 4*
Dished ends subject to internal pressure

4.1 Minimum thickness

4.1.1 The thickness, t, of semi-ellipsoidal and hemispherical unstayed ends, and the knuckle section of torispherical ends, dished from plate, having pressure on the concave side and satisfying the conditions listed below, is to be determined by the following formula:

$$t = \frac{p\,D_o\,K}{20\sigma\,J} + 0{,}75 \text{ mm}$$

where

t, p, D_o, σ and J are as defined in 1.7

K = a shape factor, *see* 4.2 and Fig. 4.4.1.

4.1.2 For semi-ellipsoidal ends:

the external height, $H \geq 0{,}18D_o$

where

D_o = the external diameter of the parallel portion of the end, in mm.

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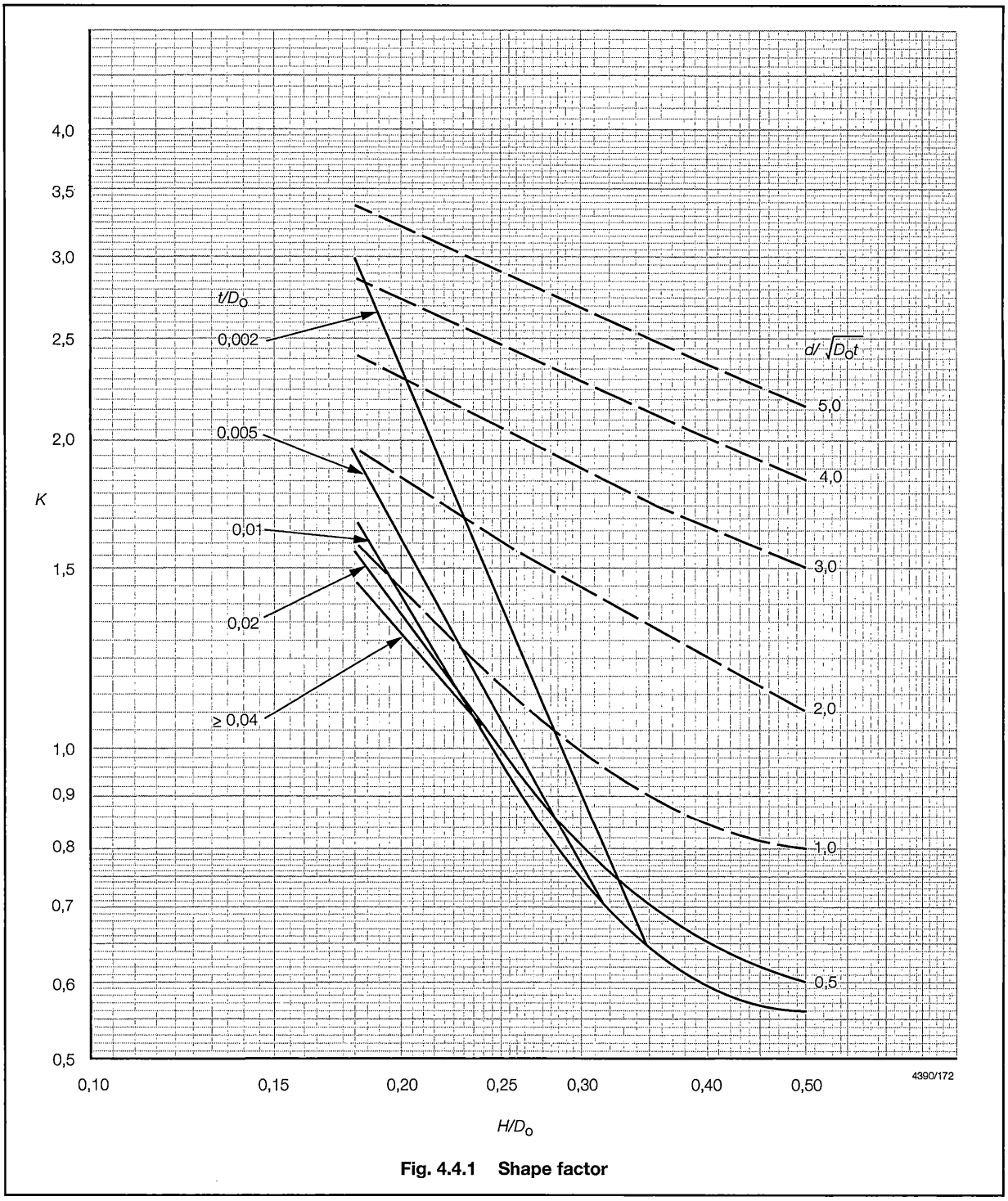

Fig. 4.4.1 Shape factor

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4.1.3 For torispherical ends:

- the internal radius, $R_i \leq D_o$
- the internal knuckle radius, $r_i \geq 0{,}1D_o$
- the internal knuckle radius, $r_i \geq 3t$
- the external height, $H \geq 0{,}18D_o$ and is determined as follows:

$$H = R_o - \sqrt{(R_o - 0{,}5D_o)(R_o + 0{,}5D_o - 2r_o)}$$

4.1.4 In addition to the formula in 4.1.1 the thickness, t, of a torispherical head, made from more than one plate, in the crown section is to be not less than that determined by the following formula:

$$t = \frac{p R_i}{20\sigma J - 0{,}5p} + 0{,}75 \quad mm$$

where

t, p, R_i, σ and J are as defined in 1.7.

4.1.5 The thickness required by 4.1.1 for the knuckle section of a torispherical head is to extend past the common tangent point of the knuckle and crown radii into the crown section for a distance not less than $0{,}5\sqrt{R_i t}$ mm, before reducing to the crown thickness permitted by 4.1.4,

where

t = the required thickness from 4.1.1.

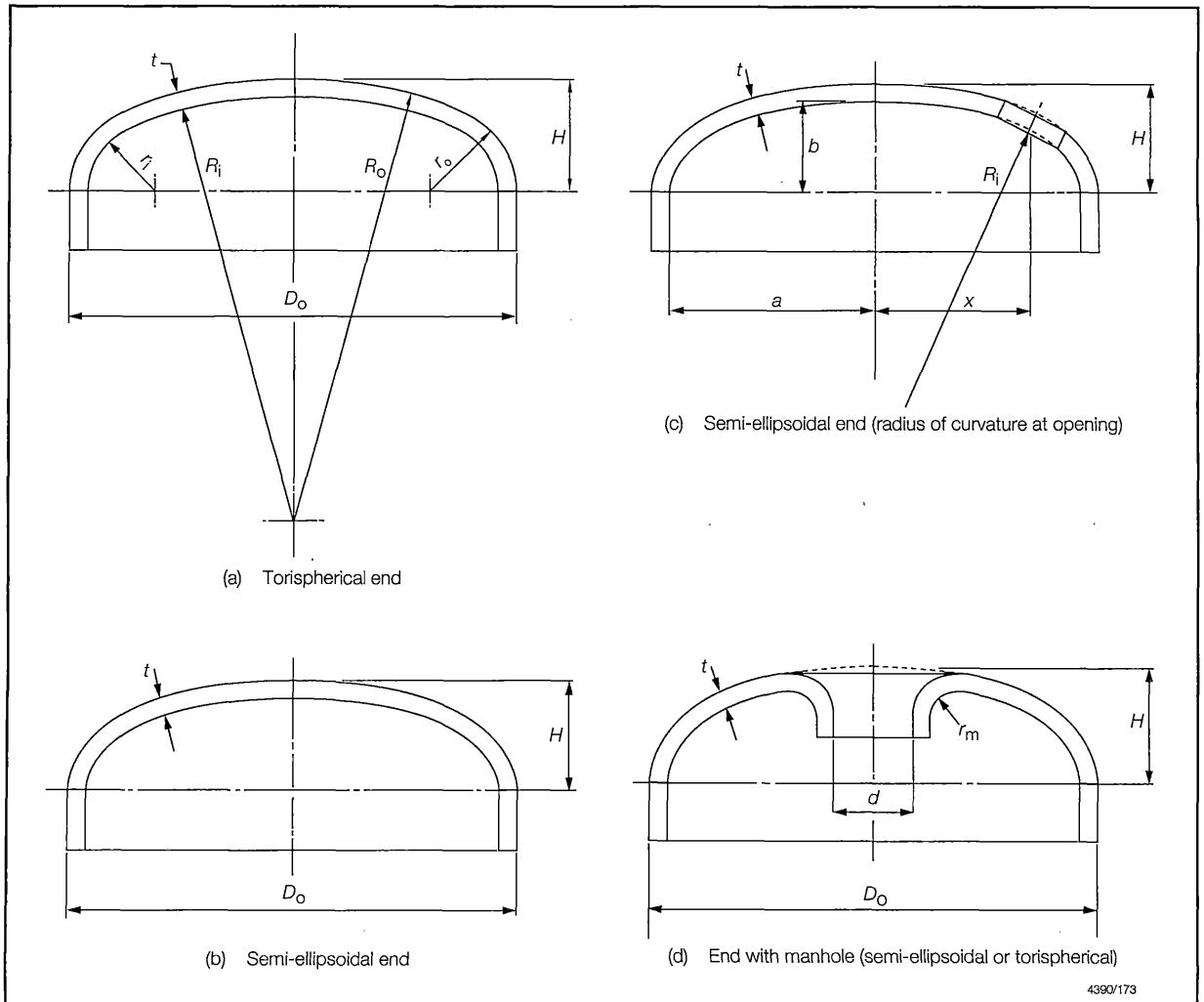
4.1.6 In all cases, H, is to be measured from the commencement of curvature, *see* Fig. 4.4.2.

4.1.7 For fusion welded pressure vessels the minimum thickness of the head, t, is to be not less than $3 + \frac{D_i}{1500}$ mm

where

D_i is as defined in 1.7.

4.1.8 For ends which are butt welded to the shell the thickness of the edge of the flange for connection to the shell is to be not less than the thickness of an unpierced seamless or welded shell, whichever is applicable, of the same diameter and material and determined by 2.1.



(a) Torispherical end

(b) Semi-ellipsoidal end

(c) Semi-ellipsoidal end (radius of curvature at opening)

(d) End with manhole (semi-ellipsoidal or torispherical)

Fig. 4.4.2 Typical dished ends

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4.2 Shape factors for dished ends

4.2.1 The shape factor, K, to be used in 4.1.1 is to be obtained from the curves in Fig. 4.4.1, and depends on the ratio of height to diameter $\frac{H}{D_o}$.

4.2.2 The lowest curve in the series provides the factor, K, for plain (i.e. unpierced) ends. For lower values of $\frac{H}{D_o}$, K depends upon the ratio of thickness to diameter, $\frac{t}{D_o}$, aswell as on the ratio $\frac{H}{D_o}$, and a trial calculation may be necessary to arrive at the correct value of K.

4.3 Dished ends with unreinforced openings

4.3.1 Openings in dished ends may be circular, obround or approximately elliptical.

4.3.2 The upper curves in Fig. 4.4.1 provide values of K, to be used in 4.1.1, for ends with unreinforced openings. The selection of the correct curve depends on the value of $\frac{d}{\sqrt{D_o t}}$ and a trial calculation is necessary to select the correct curve,
where

d = the diameter of the largest opening in the end plate, in mm (in the case of an elliptical opening, the larger axis of the ellipse)
t = minimum thickness, after dishing, in mm
D_o = outside diameter of dished end, in mm.

4.3.3 The following requirements must in any case be satisfied:

$$\frac{t}{D_o} \leq 0{,}1$$

$$\frac{d}{D_o} \leq 0{,}7$$

4.3.4 From Fig. 4.4.1 for any selected ratio of $\frac{H}{D_o}$ the curve for unpierced ends gives a value for $\frac{d}{\sqrt{D_o t}}$ as well as for K. Openings giving a value of $\frac{d}{\sqrt{D_o t}}$ not greater than the value so obtained may thus be pierced through an end designed as unpierced without any increase in thickness.

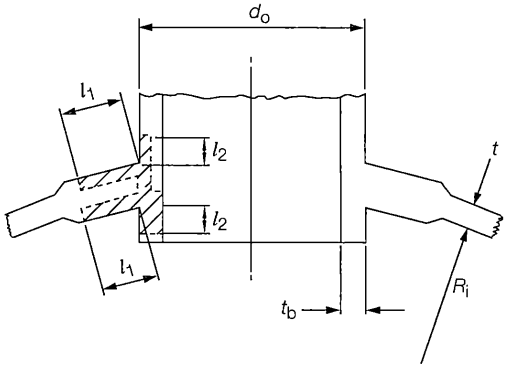
4.4 Flanged openings in dished ends

4.4.1 The requirements in 4.3 apply equally to flanged openings and to unflanged openings cut in the plate of an end. No reduction may be made in end plate thickness on account of flanging.

4.4.2 Where openings are flanged, the radius, r_m of the flanging is to be not less than 25 mm, *see* Fig. 4.4.2(d). The thickness of the flanged portion may be less than the calculated thickness.

4.5 Location of unreinforced and flanged openings in dished ends

4.5.1 Unreinforced and flanged openings in dished ends are to be so arranged that the distance from the edge of the hole to the outside edge of the plate and the distance between openings are not less than those shown in Fig. 4.4.3.



$l_1 = \sqrt{2R_i t}$ or $0{,}5d_o$ whichever is the lesser
l_2 is not to exceed $\sqrt{d_o t_b}$ 4390/179

Fig. 4.4.3 Limits for reinforcement

4.6 Dished ends with reinforced openings

4.6.1 Where it is desired to use a large opening in a dished end of less thickness than would be required by 4.3, the end is to be reinforced. This reinforcement may consist of a ring or standpipe welded into the hole, or of reinforcing plates welded to the outside and/or inside of the end in the vicinity of the hole, or a combination of both methods, *see* Fig. 4.4.4. Forged reinforcements may be used.

4.6.2 Reinforcing material with the following limits may be taken as effective reinforcement:

(a) The effective width, l_1 of reinforcement is not to exceed $\sqrt{2R_i t}$ or $0{,}5d_o$ whichever is the lesser.

(b) The effective length, l_2 of a reinforcing ring is not to exceed $\sqrt{d_o t_b}$

where

R_i = the internal radius of the spherical part of a torispherical end, in mm, or

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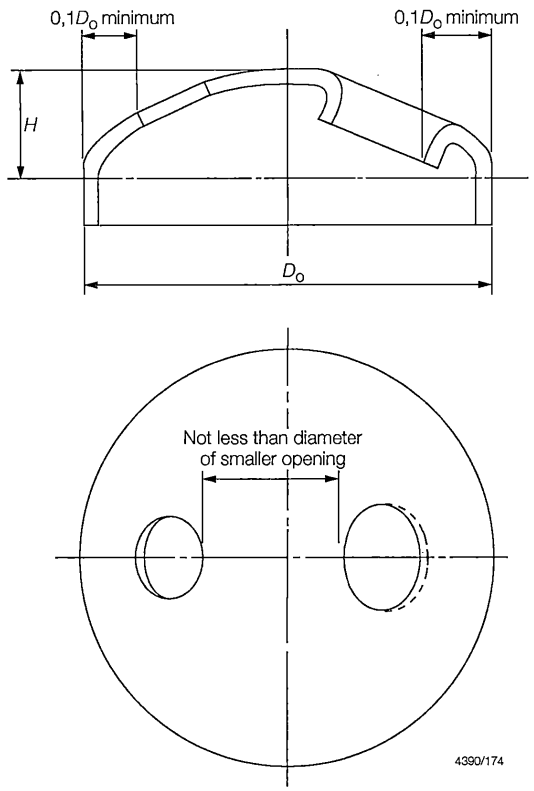

Fig. 4.4.4 Opening in dished ends

R_i = internal radius of the meridian of the ellipse at the centre of the opening, of a semi-ellipsoidal end, in mm, and is given by the following formula:

$$\frac{[a^4 - x^2\,(a^2 - b^2)]^{3/2}}{a^4\,b}$$

where

a, b and x are shown in Fig. 4.4.2(c)

d_o = external diameter of ring or standpipe, in mm

l_1 and l_2 are shown in Fig. 4.4.3

t_b = actual thickness of ring or standpipe, in mm.

4.6.3 The shape factor, K, for a dished end having a reinforced opening can be read from Fig. 4.4.1 using the value obtained from:

$$\frac{d_o - \frac{A}{t}}{\sqrt{D_o\,t}} \text{ instead of from } \frac{d}{\sqrt{D_o\,t}}$$

where

A = the effective cross-sectional area of reinforcement and is to be twice the area shown shaded on Fig. 4.4.3

As in 4.3, a trial calculation is necessary in order to select the correct curve.

4.6.4 The area shown in Fig. 4.4.3 is to be obtained as follows:

- Calculate the cross-sectional area of reinforcement both inside and outside the end plate within the length, l_1, plus the full cross-sectional area of that part of the ring or standpipe which projects inside the end plate up to a distance, l_2, plus the full cross-sectional area of that part of the ring or standpipe which projects outside the internal surface of the end plate up to a distance, l_2, and deduct the sectional area which the ring or standpipe would have if its thickness were as calculated in accordance with 5.1.

4.6.5 If the material of the ring or the reinforcing plates has an allowable stress value lower than that of the end plate, then the effective cross-sectional area, A, is to be multiplied by the ratio:

$$\frac{\text{allowable stress of reinforcing plate at design temperature}}{\text{allowable stress of end plate at design temperature}}$$

4.7 Torispherical dished ends with reinforced openings

4.7.1 If an opening and its reinforcement are positioned entirely within the crown section, the compensation requirements are to be as for a spherical shell, using the crown radius as the spherical shell radius. Otherwise, the requirements of 4.6 are to be applied.

■ *Section 5* Standpipes and branches

5.1 Minimum thickness

5.1.1 The minimum wall thickness, t, of standpipes and branches is to be not less than the greater of the two values determined by the following formulae, making such additions as may be necessary on account of bending, static loads and vibrations:

$$t = \frac{p\,D_o}{20\sigma + p} + 0{,}75 \text{ mm}$$

$$t = 0{,}015D_o + 3{,}2 \text{ mm}$$

where

t, p, D_o and σ are defined in 1.7.

If the second formula applies, the thickness need only be maintained for a length, L, from the outside surface of the vessel, but need not extend past the first connection, butt weld or flange, where:

$$L = 3{,}5\sqrt{D_o\,t} \text{ mm}$$

5.1.2 In no case does the wall thickness need to exceed that of the shell as required by 2.1, 3.1 or 4.1 as applicable.

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■ *Section 6*
Unstayed circular flat end plates

6.1 Minimum thickness

6.1.1 Ends attached by welding are to be designed such that the minimum thickness of flat end plates is to be determined by the following formula:

$$t = d_i \sqrt{\frac{pC}{\sigma}} + 0{,}75 \text{ mm}$$

where

p and σ are as defined in 1.7.

t = minimum thickness of end plate, in mm

d_i = internal diameter of circular shell, in mm

C = a constant depending on method of end attachment, *see* Fig. 4.6.1

(a) For end plates welded as shown in Fig. 4.6.1(a):

C = 0,019 for circular shells.

(b) For end plates welded as shown in Figs. 4.6.1(b) and (c):

C = 0,028 for circular shells.

6.1.2 Where flat end plates are bolted to flanges attached to the ends of headers, the flanges and end plates are to be in accordance with recognised pipe flange standards.

6.1.3 Openings in flat plates are to be compensated in accordance with Fig. 4.2.1(a) or (b) with the value of A_1, the compensation required, calculated as follows:

$$A_1 = \frac{d_o}{2{,}4} t_f \text{ mm}^2$$

where

d_o = diameter of hole in flat plate, in mm

t_f = required thickness of the flat plate in the area under consideration, in mm, calculated in accordance with 6.1.1, as applicable, without corrosion allowance

Limit D = $0{,}5d_o$.

■ *Section 7*
Construction

7.1 Access arrangements

7.1.1 Pressure vessels are to be so made that the internal surfaces may be examined. Wherever practicable, the openings for this purpose are to be sufficiently large for access and for cleaning the inner surfaces.

7.1.2 Manholes in cylindrical shells should preferably have their shorter axes arranged longitudinally.

7.1.3 Doors for manholes and sightholes are to be formed from the steel plate or of other approved construction, and all jointing surfaces are to be machined.

7.1.4 Doors of the internal type are to be provided with spigots which have a clearance of not more than 1,5 mm all round, i.e. the axes of opening are not to exceed those of the door by more than 3 mm. The width of the manhole gasket seat is not to be less than 16 mm.

7.1.5 Doors of the internal type for openings not larger than 230 x 180 mm need be fitted with only one stud, which may be forged integral with the door. Doors for openings larger than 230 mm x 180 mm are to be fitted with two studs or bolts. The strength of the attachment to the door is not to be less than the strength of the stud or bolt.

7.1.6 The crossbars or dogs for doors are to be of steel.

7.1.7 External circular flat cover plates are to be in accordance with a recognised standard.

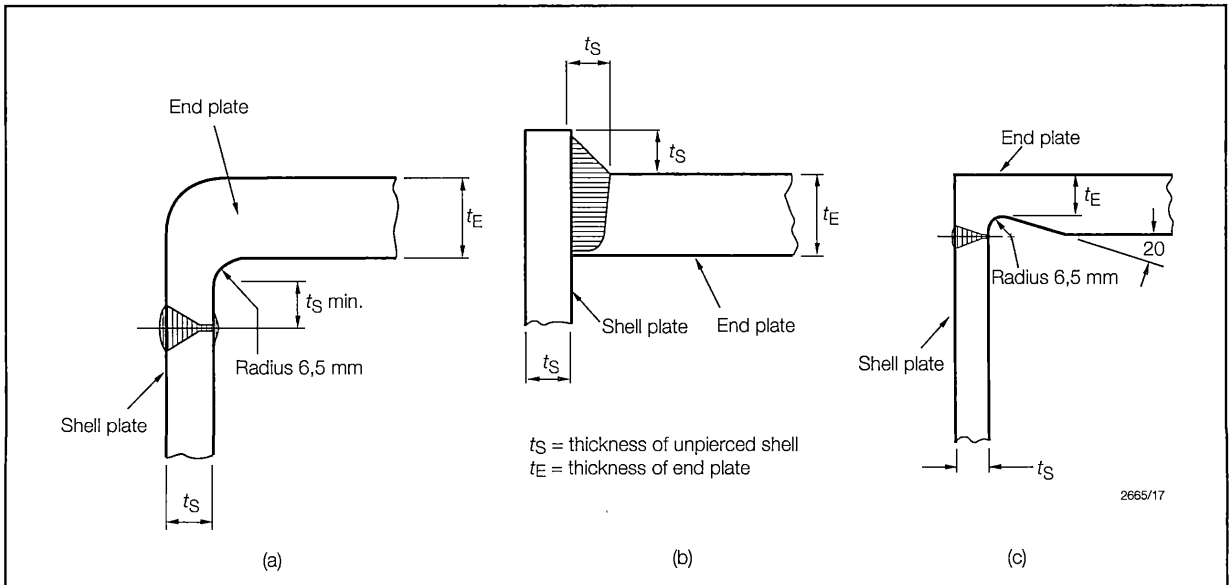

Fig. 4.6.1 Typical methods of attachment of unstayed circular flat end plates

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7.2 Torispherical and semi-ellipsoidal ends

7.2.1 For typically acceptable types of attachment for dished ends to cylindrical shells, *see* Fig. 4.7.1. Types (d) and (e) are to be made a tight fit in the cylindrical shell.

7.2.2 Where the difference in thickness is the same throughout the circumference, the thicker plate is to be reduced in thickness by machining to a taper for a distance not less than four times the offset, so that the two plates are of equal thickness at the position of the circumferential weld. A parallel portion may be provided between the end of the taper and the weld edge preparation; alternatively, if so desired, the width of the weld may be included as part of the smooth taper of the thicker plate.

7.2.3 The thickness of the plates at the position of the circumferential weld is to be not less than that of an unpierced cylindrical shell of seamless or welded construction, whichever is applicable, of the same diameter and material, *see* 2.1.

7.3 Welded-on flanges, butt welded joints and fabricated branch pieces

7.3.1 Flanges may be cut from plates or may be forged or cast. Hubbed flanges are not to be machined from plate. Flanges are to be attached to branches by welding. Alternative methods of flange attachment will be subject to special consideration.

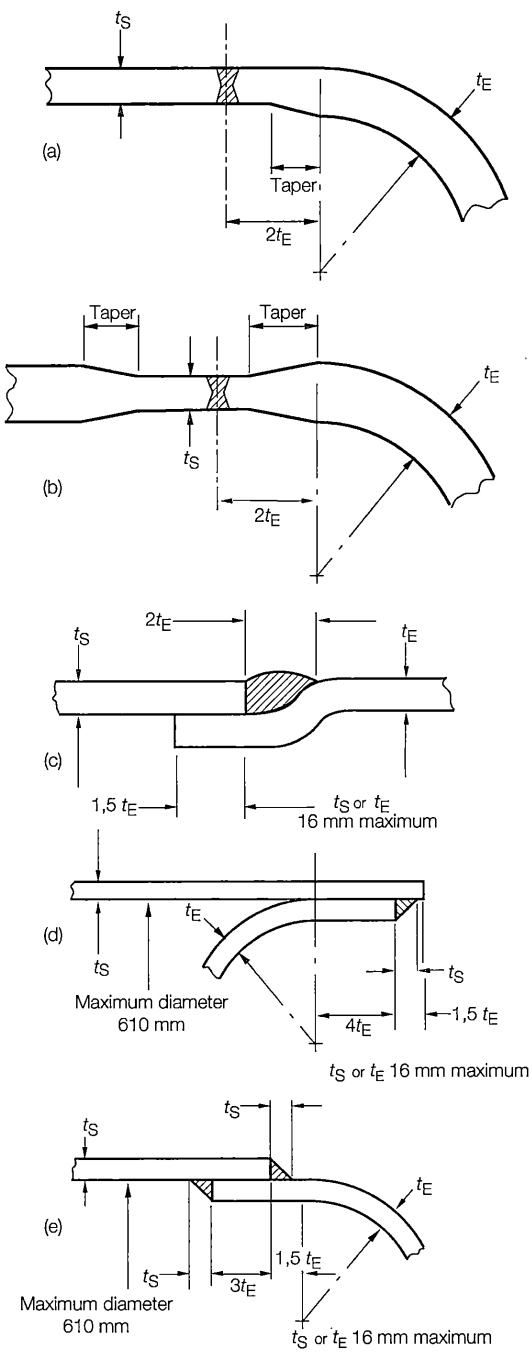
7.3.2 The types of welded-on flanges are to be suitable for the pressure, temperature and service for which the branches are intended.

7.3.3 Flange attachments and pressure-temperature ratings in accordance with materials and design of recognised standards will be accepted.

7.3.4 Typical examples of welded-on flange connections are shown in Fig. 4.7.2(a) to (f), and limiting design conditions for the flange types are shown in Table 4.7.1. In Fig. 4.7.2, t is the minimum Rule thickness of the standpipe or branch.

7.3.5 Welded-on flanges are not to be a tight fit on the branch. The maximum clearance between the bore of the flange and the outside diameter of the branch is to be 3 mm at any point, and the sum of the clearances diametrically opposite is not to exceed 5 mm.

7.3.6 Where butt welds are employed in the attachment of flange type (a), or in the construction of standpipes or branch pieces, the adjacent pieces are to be matched at the bores. This may be effected by drifting, roller expanding or machining, provided the pipe wall is not reduced below the designed thickness. If the parts to be joined differ in wall thickness, the thicker wall is to be gradually tapered to that of the thinner at the butt joint.



Type of end attachment	Acceptable for
(a) and (b)	All classes
(c)	2/1, 2/2 and 3
(d) and (e)	Class 3 only

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Fig. 4.7.1
Typical attachment of dished ends to cylindrical shell

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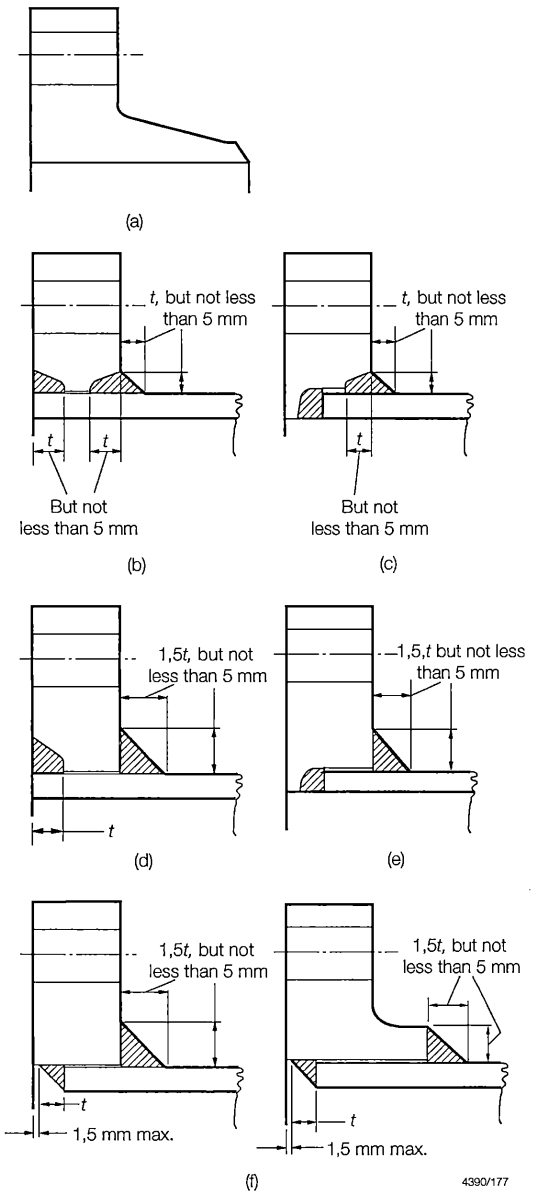

't' is the minimum Rule thickness of standpipe or branch

Fig. 4.7.2
Typical example of welded flange connections

7.3.7 Welding may be carried out by means of the shielded metal arc, inert gas metal arc, oxy-acetylene or other approved process, but in general, oxy-acetylene welding is suitable only for flange type (a) and is not to be applied to branches exceeding 100 mm diameter or 9,5 mm thick.

7.3.8 Threaded sleeve joints complying with Ch 1,5.5.1 may be used on the steam and water piping of small oil fired package boilers of the once through coil type, used for auxiliary or domestic purposes, where the feed pump capacity limits the output.

7.3.9 Socket weld joints are not to be used where fatigue, severe erosion, crevice corrosion or stress corrosion are expected to occur, for example, blow down, drain, scum and chemical dosing connections.

7.4 Welded attachments to pressure vessels

7.4.1 Unless the actual thickness of the shell or end is at least twice that required by calculation for a seamless shell or end, whichever is applicable, doubling plates with well rounded corners are to be fitted in way of attachments such as lifting lugs, supporting brackets and feet, to minimise load concentrations on pressure shells and ends. Compensating plates, pads, brackets and supporting feet are to be bedded closely to the surface before being welded, and are to be provided with a 'tell-tale' hole not greater than 9,5 mm in diameter, open to the atmosphere to provide for the release of entrapped air during heat treatment of the vessel, or as a means of indicating any leakage during hydraulic testing and in service.

7.4.2 For acceptable methods of attaching standpipes, branches, compensating plates and pads, *see* Fig. 4.7.3. Alternative methods of attachment may be accepted provided details are submitted for consideration.

7.4.3 Where fillet welds are used to attach standpipes, there are to be equal sized welds both inside and outside the vessel shell, *see* Fig. 4.7.3(a) and (l). The leg length of each of the fillet welds is to be not less than the actual thickness of the thinner of the parts being joined.

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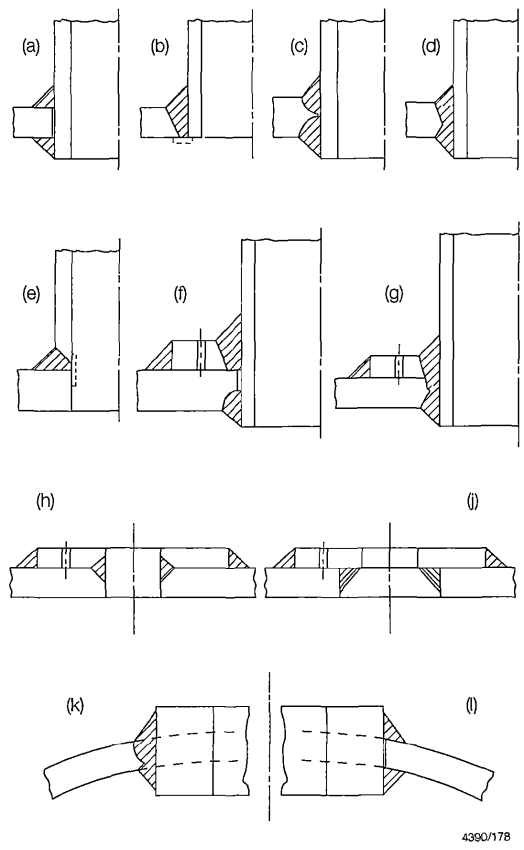
Table 4.7.1 Limiting design conditions for flanges

Flange type	Maximum pressure	Maximum temperature	Maximum pipe o.d.	Minimum pipe bore
		°C	mm	mm
(a)	Pressure temperature ratings to be in accordance with a recognised Standard	No restriction	No restriction	No restriction
(b)		No restriction	168,3 for alloy steels*	No restriction
(c)		No restriction	168,3 for alloy steels*	75
(d)		425	No restriction	No restriction
(e)		425	No restriction	75
(f)		425	No restriction	No restriction

NOTE
* *No restriction for carbon steels*



Type (a) and (l) attachments are not to be used for openings which require to be compensated. Backing rings may be used with types (b) and (e).

Fig. 4.7.3
Typical acceptable methods of attaching branches and pads

■ *Section 8*
Requirements for fusion welded pressure vessels

8.1 General requirements

8.1.1 Welded construction of pressure vessels is to be in accordance with the requirements specified in Ch 13,1 and 4 of the Rules for Materials.

8.1.2 Fusion welded pressure vessels constructed to Class 1 and Class 2/1 requirements will be accepted only if manufactured by firms equipped and competent to undertake high quality welding. In order that firms may be approved for this purpose, it will be necessary for the Surveyors to visit the works for the purpose of inspecting the welding plant equipment and procedures, and to arrange for the carrying out of preliminary tests as stated in Ch 13,4 of the Rules for Materials.

■ *Section 9*
Mountings and fittings for pressure vessels

9.1 General

9.1.1 Each pressure vessel or system is to be fitted with a stop valve situated as close as possible to the shell.

9.1.2 Adequate arrangements are to be provided to prevent over-pressure of any part of a pressure vessel which can be isolated. Pressure gauges are to be fitted in positions where they can be easily read.

9.1.3 Adequate arrangements are to be provided for draining and venting the separate parts of each pressure vessel.

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9.2 Receivers containing pressurised gases

9.2.1 Each air receiver is to be fitted with a drain arrangement at its lowest part, permitting oil and water to be blown out.

9.2.2 Each receiver which can be isolated from a relief valve is to be provided with a suitable fusible plug to discharge the contents in case of fire. The melting point of the fusible plug is to be approximately 150°C. *See also* 9.2.3 and 9.2.4.

9.2.3 Where a fixed system utilising fire-extinguishing gas is fitted, to protect a machinery space containing an air receiver(s), fitted with a fusible plug, it is recommended that the discharge from the fusible plug be piped to the open deck.

9.2.4 Receivers used for the storage of air for the control of remotely operated valves are to be fitted with relief valves and not fusible plugs.

■ *Section 10* Hydraulic tests

10.1 Fusion welded pressure vessels

10.1.1 Fusion welded pressure vessels are to be tested on completion to a pressure, p_T, determined by the following formula, without showing signs of weakness or defect:

$$p_T = 1{,}3 \frac{\sigma_{50}}{\sigma_t} \frac{t}{(t - 0{,}75)} p$$

but in no case is to exceed

$$1{,}5 \frac{t}{(t - 0{,}75)} p$$

where

p = design pressure, in bar
p_T = test pressure, in bar
t = nominal thickness of shell as indicated on the plan, in mm
σ_T = allowable stress at design temperature, in N/mm^2
σ_{50} = allowable stress at 50°C, in N/mm^2.

10.2 Mountings

10.2.1 Mountings are to be subjected to a hydraulic test of twice the approved design pressure.

■ *Section 11* Fibre reinforced plastics pressure vessels

11.1 General

11.1.1 Pressure vessels may be constructed in fibre reinforced plastics provided the manufacturer is competent and suitably equipped for this purpose.

11.1.2 Pressure vessels are to be of standard design whose suitability has been established by fatigue and burst tests on a prototype.

11.2 Prototype testing

11.2.1 For the fatigue test the pressure shall be cycled from atmospheric to design pressure 100 000 times at the design temperature.

11.2.2 For the burst test the minimum bursting pressure shall be six times the design pressure.

11.3 Production hydraulic test

11.3.1 Vessels subject to internal pressure shall be hydraulically tested to not less than 1,5 times the design pressure.

■ *Section 12* Requirements for craft which are not required to comply with the HSC Code

12.1 Fibre reinforced plastics pressure vessels

12.1.1 Fibre reinforced plastics pressure vessels, where the product of the design pressure in bar and volume in litres exceeds 600, are not to be situated in machinery spaces or high risk areas on yachts and service craft less than 24 m.

12.1.2 Small fibre reinforced plastics pressure vessels will receive special consideration in relation to their intended duty and service conditions.

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Rules and Regulations for the Classification of Special Service Craft

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Section 1 General requirements

1.1 General

1.1.1 This Chapter applies to control engineering systems on special service craft.

1.1.2 Section 2 states requirements for alarm systems, safety systems and automatic or remote controls where fitted.

1.1.3 Section 3 states requirements which shall apply where it is intended to operate the craft with machinery spaces unattended. In general, craft complying with the requirements of Section 3 will be eligible for the class notation **UMS**.

1.1.4 Section 4 states requirements which shall apply where it is intended to operate the craft with machinery spaces under continuous supervision from a centralised control station. In general, craft complying with the requirements of Section 4 will be eligible for the class notation **CCS**.

1.1.5 Lloyd's Register (hereinafter referred to as 'LR') will be prepared to give consideration to special cases or to arrangements which are equivalent to the Rules.

1.2 Plans and information

1.2.1 Plans and information as detailed in 1.2.2 to 1.2.7 are to be submitted in triplicate.

1.2.2 A description of operation with explanatory diagrams together with line diagrams of control circuits, list of monitored, control and alarm points is required for the following machinery or equipment:

- Fixed water-based local application fire-fighting systems, *see* 2.9.
- Air compressors.
- Bilge systems.
- Controllable pitch propellers.
- Electric generating plant.
- Oil fuel transfer and storage systems.
- Propulsion machinery including essential auxiliaries.
- Steam raising plant (boilers and their ancillary equipment).
- Steering systems.
- Thermal fluid heaters.
- Thrust units.
- Valve position indicating systems.
- Waterjets for propulsion purposes.
- Windlasses.

1.2.3 **Test schedules** (for both works testing and sea trials), which should include methods of testing and test facilities, *see* 6.4.1.

1.2.4 **Alarm systems**. Details of the overall alarm system linking the main control station, subsidiary control stations, the bridge area and accommodation.

1.2.5 **Programmable electronic systems**. In addition to the documentation required by 1.2.2, the following is to be submitted:

(a) System requirements specification.
(b) System integration plan, *see* 2.14.2.
(c) Failure Mode and Effects Analysis (FMEA), *see* 2.14.5.
(d) Details of the hardware configuration in the form of a system block diagram, including input/output schedules.
(e) Hardware certification details, *see* 2.10.5 and 2.13.3.
(f) Software quality plans, including applicable procedures, *see* 2.10.25.
(g) Factory acceptance, integration and sea trial test schedules for hardware and software.
(h) Details of data storage arrangements, *see* 2.10.10 and 2.13.6.

1.2.6 For wireless data communication equipment:

(a) Details of manufacturer's installation and maintenance recommendations;
(b) network plan with arrangement and type of aerials and identification of location;
(c) specification of wireless communication system protocols and management functions, *see* 2.12.4; and
(d) details of radio frequency and power levels, including details of those permitted by the National Administration.

1.2.7 **Control station**. Location and details of control stations, e.g. control panels and consoles.

1.2.8 **Fire detection systems**. Plans showing the system operation and the type and location of all machinery space fire detector heads, manual call points and the fire detector indicator panel(s). The plans are to indicate the position of the fire detectors in relation to significant items of machinery, ventilation and extraction openings.

1.2.9 **Approved system**. Where it is intended to employ a standard system which has been previously approved, plans are not required to be submitted, providing there have been no changes in the applicable Rule requirements. Details of the previous approval are to be submitted.

1.2.10 **Cables**. For details of instrumentation and control system cabling requirements, *see* Ch 2,10.

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1.3 Control, alarm and safety equipment

1.3.1 Major units of equipment associated with control, alarm and safety systems as defined in 1.2 are to be surveyed at the manufacturers' works and the inspection and testing is to be to the Surveyor's satisfaction, *see also* 1.2.2.

1.3.2 Equipment used in control, alarm and safety systems is to be suitable for its intended purpose, and accordingly, whenever practicable, be selected from the *List of Lloyd's Register Type Approved Products* published by LR.

1.3.3 Where equipment requires a controlled environment, an alternative means is to be provided to maintain the required environment in the event of a failure of the normal air conditioning system. Failure of the air conditioning system is to initiate an alarm.

1.3.4 Assessment of performance parameters, such as accuracy, repeatability, etc., are to be in accordance with an acceptable National or International Standard, e.g. IEC 60051, *Direct acting indicating analogue electrical measuring instruments and their accessories*.

1.4 Alterations and additions

1.4.1 When an alteration or addition to the approved system(s) is proposed, plans are to be submitted for approval. The alterations or additions are to be carried out under survey and the installation and testing are to be to the Surveyor's satisfaction.

1.4.2 Details of proposed software modifications are to be submitted for consideration. Where the modification may affect compliance with these Rules, proposals for verification and validation are also to be submitted.

1.4.3 Software versions are to be uniquely identified by number, date or other appropriate means. Modifications are not to be made without also changing the version identifier. A record of changes to the system since the original issue (and their identification) is to be maintained and made available to the LR Surveyor on request.

■ *Section 2*
Essential features for control, alarm and safety systems

2.1 General

2.1.1 Where it is proposed to install control, alarm and safety systems to the equipment listed in 1.2.2 the applicable features contained in this Section are to be incorporated in the system design.

2.1.2 Systems complying with ISO 17894, *Ships and marine technology – Computer applications – General principles for the development and use of programmable electronic systems in marine applications*, may be accepted as meeting the requirements of this Section in which case evidence of compliance is to be submitted for consideration.

2.2 Control stations for machinery

2.2.1 A system of alarm displays and controls is to be provided which readily ensures identification of faults in the machinery and satisfactory supervision of related equipment. This may be provided at a main control station or, alternatively at subsidiary control stations. In the latter case, a master alarm display is to be provided at the main control station showing which of the subsidiary control stations is indicating a fault condition.

2.2.2 At the main control station (if provided) or close to the subsidiary stations (if fitted) means of two way voice communication with the bridge area, the accommodation for engineering personnel and, if necessary, the machinery spaces are to be provided.

2.2.3 Provision is to be made at the main control station, or subsidiary control stations as appropriate, for the operation of an engineers' alarm which is to be clearly audible in the engineers' accommodation.

2.2.4 Provision is to be made at the main control station and any other subsidiary control station from which the main propulsion and auxiliary machinery or associated equipment may be controlled to indicate which station is in control.

2.2.5 Control of machinery and associated equipment is to be possible only from one station at a time.

2.2.6 Changeover between control stations is to be arranged so that it may only be effected with the acceptance of the station taking control. The system is to be provided with interlocks or other suitable means to ensure effective transfer of control.

2.2.7 For additional requirements where control stations incorporate visual display units and keyboard input facilities, *see* 2.10.

2.3 Alarm systems

2.3.1 Where an alarm system, which will provide warning of faults in the machinery and the safety and control systems, is to be installed, the requirements of 2.3.2 to 2.3.18 are to be satisfied.

2.3.2 Machinery, safety and control system faults are to be indicated at the relevant control stations to advise duty personnel of a fault condition. The presence of unrectified faults is to be clearly indicated at all times.

2.3.3 Alarms associated with machinery, safety and control system faults are to be clearly distinguishable from other alarms e.g. fire, general alarm.

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2.3.4 Where alarms are displayed as group alarms, provision is to be made to identify individual alarms at the main control station (if fitted) or alternatively at subsidiary control stations.

2.3.5 All alarms are to be both audible and visual. If arrangements are made to silence audible alarms they are not to extinguish visual alarms.

2.3.6 Acknowledgement of visual alarms is to be clearly indicated.

2.3.7 Acknowledgement of alarms at positions outside a machinery space is not to silence the audible alarm or extinguish the visual alarm in that machinery space.

2.3.8 If an alarm has been acknowledged and a second fault occurs prior to the first being rectified, audible and visual alarms are again to operate. Where alarms are displayed at a local panel adjacent to the machinery and with arrangements to provide a group or common fault alarm at the main control room alarm display then the occurrence of a second fault prior to the first alarm being rectified need only be displayed at the local panel, however the group alarm is to be reinitiated. Unacknowledged alarms on monitors are to be distinguished by either flashing text or a flashing marker adjacent to the text. A change of colour will not in itself be sufficient to distinguish between acknowledged and unacknowledged alarms.

2.3.9 For the detection of transient faults which are subsequently self-correcting, alarms are required to lock in until accepted.

2.3.10 The alarm system is to be arranged with automatic changeover to a standby power supply in the event of a failure of the normal power supply. Where an alarm system could be adversely affected by an interruption in power supply, changeover to the standby power supply is to be achieved without a break.

2.3.11 Failure of any power supply to the alarm system is to operate an audible and visual alarm.

2.3.12 The alarm system should be designed with self-monitoring properties. Insofar as practicable, any fault in the alarm system should cause it to fail to the alarm condition.

2.3.13 The alarm system is to be capable of being tested during normal machinery operation, *see* 6.1.2.

2.3.14 The alarm system is to be designed as far as practicable to function independently of control and safety systems such that a failure or malfunction in these systems will not prevent the alarm system from operating.

2.3.15 Disconnection or manual overriding of any part of the alarm system should be clearly indicated.

2.3.16 When alarm systems are provided with means to adjust their set point, the arrangements are to be such that the final settings can be readily identified.

2.3.17 Where monitors are provided at the station in control and, if fitted, in the duty engineer's accommodation, they are to provide immediate display of new alarm information regardless of the information display page currently selected. This may be achieved by provision of a dedicated alarm monitor, a dedicated area of screen for alarms or other suitable means.

2.3.18 Alarms are to be displayed in the order in which they occur. Alarms requiring shutdown or slowdown action are to be given visual prominence.

2.4 Safety systems, general requirements

2.4.1 Where safety systems are provided, the requirements of 2.4.2 to 2.4.12 are to be satisfied. The requirements of this sub-Section apply, where relevant, to the safety systems installed on the equipment defined in 1.2.3, including those provided in addition to those safeguards required by other Sections of the Rules.

2.4.2 Safety systems are to operate automatically in case of serious faults endangering the machinery, so that:

(a) normal operating conditions are restored, e.g. by the starting of standby machinery, or

(b) the operation of the machinery is temporarily adjusted to the prevailing conditions, e.g. by reducing the output of the machinery, or

(c) the machinery is protected from critical conditions by shutting off the fuel or power supplies thereby stopping the machinery.

2.4.3 The safety system required by 2.4.2(c) is to be designed as far as practicable to operate independently of the control and alarm systems, such that a failure or malfunction in the control and alarm systems will not prevent the safety system from operating.

2.4.4 For safety systems required by 2.4.2(a) and (b) complete independence from other control systems is not necessary.

2.4.5 Safety systems for different items of the machinery plant are to be arranged so that failure of the safety system of one part of the plant will not interfere with the operation of the safety system in another part of the plant.

2.4.6 The safety system is to be designed to 'fail safe'. The characteristics of the 'fail safe' operation are to be evaluated on the basis not only of the safety system and its associated machinery, but also the complete installation.

2.4.7 When a safety system is activated, an audible and visual alarm is to be provided to indicate the cause of the safety action.

2.4.8 The safety system is to be manually reset before the relevant machinery can be restarted.

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2.4.9 Where arrangements are provided for overriding a safety system, they are to be such that inadvertent operation is prevented. Visual indication is to be given at the relevant control station(s) when a safety override is operated. High speed craft are to be provided with arrangements for overriding automatic shutdown systems except in cases where there is a risk of complete breakdown or explosion.

2.4.10 The safety system is to be arranged with automatic changeover to a standby power supply in the event of a failure of the normal power supply.

2.4.11 Failure of any power supply to a safety system is to operate an audible and visual alarm.

2.4.12 When safety systems are provided with means to adjust their set point, the arrangements are to be such that the final settings can be readily identified.

2.5 Control systems

2.5.1 Where control systems are provided, the requirements of 2.5.2 to 2.5.11 are to be satisfied.

2.5.2 Control systems for machinery operations are to be stable throughout their operating range.

2.5.3 The control system is to be designed such that normal operation of the controls cannot induce detrimental mechanical or thermal overloads in the machinery.

2.5.4 When control systems are provided with means to adjust their sensitivity or set point, the arrangements are to be such that the final settings can be readily identified.

2.5.5 Control systems are to be designed to 'fail safe'. The characteristics of the 'fail safe' operation are to be evaluated on the basis not only of the control system and its associated machinery, but also the complete installation.

2.5.6 Failure of any power supply to a control system is to operate an audible and visual alarm.

2.5.7 Where machinery is fitted with automatic or remote controls so that under normal operating conditions it does not require any manual intervention by the operators, it is to be provided with the alarms and safety arrangements required by the appropriate Chapter(s). Alternative arrangements which provide equivalent safeguards will be considered.

2.5.8 Remote or automatic controls are to be provided with sufficient instrumentation at the relevant control stations to ensure effective control and indicate that the system is functioning correctly.

2.5.9 Where machinery is arranged to start automatically or from a remote control station, interlocks are to be provided to prevent start-up under conditions which could hazard the machinery.

2.5.10 Where machinery, controlled in accordance with 2.5.7, is required to be provided with a standby pump, the standby pump is to start automatically if the discharge pressure from the working pumps falls below a predetermined value.

2.5.11 Failure of a control system is not to result in the loss of ability to provide essential services by alternative means. This may be achieved by manual control or redundancy within the control system or redundancy in machinery and equipment, *see also* 2.13.2. Instrumentation is to be provided at local manual control stations to ensure effective operation of the machinery.

2.6 Bridge control for propulsion machinery

2.6.1 Where a bridge control system for propulsion machinery is to be fitted, the requirements of 2.6.2 to 2.6.8 are to be satisfied.

2.6.2 Means are to be provided to ensure satisfactory control of propulsion from the bridge in both the ahead and astern directions.

2.6.3 Two independent means are to be provided on the bridge to enable the watchkeeper to stop the propulsion machinery in an emergency.

2.6.4 Audible and visual alarms are to operate on the bridge and in the machinery alarm system if any power supply to the bridge control system fails. Where practicable the preset speed and direction of thrust are to be maintained until corrective action is taken.

2.6.5 Cargo (B) high speed craft are to be provided with a standby system for controlling propulsion machinery. A standby system controllable from an engine control space such as an engine control room outside the bridge is acceptable.

2.6.6 Passenger (B) high speed craft are to be provided with a standby system for controlling propulsion machinery from the bridge.

2.6.7 Passenger (B) high speed craft are to be provided with additional control of propulsion and manoeuvring at the same location as the emergency functions referred to in Ch 2,16.6.12. Such stations are to have direct communication with the bridge area.

2.6.8 For high speed craft, failure of the operating propulsion control system or of transfer of control is to bring the craft to low speed without hazarding passengers or craft.

2.7 Valve control systems

2.7.1 Where cargo, bilge, ballast, oil fuel transfer and sea valves for engine services are operated by remote or automatic control, the requirements of 2.7.2 to 2.7.5 are to be satisfied.

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2.7.2 Failure of actuator power is not to permit a valve to move to an unsafe condition.

2.7.3 Positive indication is to be provided at the remote control station for the service to show the actual valve position or alternatively that the valve is fully open or closed.

2.7.4 Equipment located in places which may be flooded is to be capable of operating when submerged.

2.7.5 A secondary means of operating the valves, which may be by local manual control, is to be provided.

2.7.6 For requirements applicable to closing appliances on scuppers and sanitary discharges, *see* Pt 3, Ch 4,9.4. For power supplies on passenger craft, *see* Ch 2,3.2.

2.8 Fire detection alarm systems

2.8.1 Where an automatic fire detection system is to be fitted in a machinery space the requirements of 2.8.2 to 2.8.14 are to be satisfied.

2.8.2 A fire detection control unit is to be located in the navigating bridge area, the fire control station, or in some other position such that a fire in the machinery spaces will not render it inoperable.

2.8.3 Fire detection indicating panels are to denote the section in which a detector or manually operated call point has operated. At least one indicating panel is to be so located that it is easily accessible to responsible members of the crew at all times. An indicating panel is to be located on the navigating bridge, together with TV monitoring in the case of high speed craft.

2.8.4 An audible fire-alarm is to be provided having a characteristic which distinguishes it from the alarm system required by 2.3 or any other alarm system. The audible fire-alarm is to be immediately audible on all parts of the navigating bridge, at the fire control station and the machinery control stations, and throughout the crew accommodation areas and the machinery spaces.

2.8.5 Facilities are to be provided in the fire detection system to manually initiate the fire alarm from the following locations:

(a) Positions adjacent to all exits from machinery spaces.
(b) Navigating bridge.
(c) Control station in engine room.
(d) Fire control station.

2.8.6 The alarm system is to be designed with self-monitoring properties and system failures are to initiate an audible and visual alarm distinguishable from the fire alarm. This alarm may be incorporated in the machinery alarm system.

2.8.7 Power supplies for the alarm system are to be in accordance with Ch 2,16.1.

2.8.8 Fire detection control units (including addressable systems), indicating panels, detector heads, manual call points and short circuit isolation units are to be Type Approved in accordance with the LR *Type Approval System*. For addressable systems, *see also* 2.10.

2.8.9 Detector heads are to be located in the machinery spaces so that all potential fire outbreak points are guarded. A combination of detectors is to be provided in order that the system will react to all possible fire characteristics.

2.8.10 When fire detectors are provided with means to adjust their sensitivity, the arrangements are to be such that the set point can be fixed and readily identified.

2.8.11 When it is intended that a particular loop is to be temporarily switched off, this state is to be clearly indicated at the fire detection indicating panels.

2.8.12 When it is intended that a particular detector(s) is (are) to be temporarily switched off locally, this state is to be clearly indicated at the local position. Reactivation of the detector(s) is to be performed automatically after a preset time.

2.8.13 The fire detector heads are to be of a type which can be tested and reset without the renewal of any component. Facilities are to be provided on the fire control panel for functional testing and reset of the system.

2.8.14 It is to be demonstrated to the Surveyor's satisfaction that detector heads are so located that air currents will not render the system ineffective at sea and in port.

2.9 Fixed water-based local application fire-fighting systems

2.9.1 Where fixed water-based local application fire-fighting systems are required to be installed by National Administration requirements, arrangements are to be in accordance with this sub-Section.

2.9.2 Systems are to be available for immediate use and arranged for manual activation from inside and outside the protected space. *See also* Ch 2,16.3.4.

2.9.3 Activation of a system is not to result in loss of electrical power or reduction of the manoeuvrability of the craft and is not to require confirmation of space evacuation or sealing, *see also* Ch 2,16.3.12.

2.9.4 System zones and protected areas are to be arranged to allow essential services to be provided by machinery and/or equipment located outside areas affected by direct spray or extended water in the event of a system activation, where the machinery and/or equipment is duplicated or otherwise replicated to provide redundancy.

2.9.5 A control panel is to be provided for managing actions such as opening of valves, starting of pumps and sounding of alarms and processing information from detectors. This panel is to be independent of the fire detection control unit required by 2.8.

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2.9.6 Alarms are to be initiated upon activation of a system and are to indicate the specific zone released at the control panel. Alarms are to be provided in each protected space, at an attended machinery control station and in the wheelhouse. The audible alarm is to be distinguishable from other safety system alarms.

2.9.7 A failure in a manual system activation switch circuit is not to prevent system activation using other installed manual system activation switches or, where installed, automatic activation. The means of activation are to be provided with self-monitoring facilities which will activate an alarm at an attended control station in the event of failure detection.

2.9.8 Where, additionally, the system is required to be capable of automatic release, the arrangements are to be in accordance with 2.9.8 to 2.9.12.

2.9.9 A minimum of two fire detectors are to be provided for each protected area. One is to be a flame detector and the other is to be a smoke or heat detector, as considered appropriate to the nature of the risk and ambient conditions. The system is to be activated upon detection by two of the detectors. A fault in one detector is to initiate an alarm at an attended control stationand is not to inhibit activation of the system under the control of the other detector or manually.

2.9.10 The fire detectors are to be arranged (located, oriented, guarded, etc.) to ensure that a fire in one protected area will not result in the inadvertent automatic activation of a system for another protected area. Guards or barriers provided to comply with this requirement are not to reduce the ability to detect a fire in the protected area.

2.9.11 A fire detection alarm system panel in accordance with 2.8 may be used for receiving fire detection signals. Separate loops are not required provided that the address of the initiating device can be identified at the control panel. The received signals are then to be sent to the control panel required by 2.9.5 for processing and action.

2.9.12 The system's fire detection systems and control units are to meet the performance criteria stipulated by the National Administration and are to be Type Approved in accordance with *Test Specification Number 1* given in LR's Type Approval System for an environmental category appropriate for the locations in which they are intended to operate.

2.10 Programmable electronic systems – General requirements

2.10.1 The requirements of this sub-Section are to be complied with where control, alarm or safety systems incorporate programmable electronic equipment. Systems for essential services and safety critical applications, systems incorporating shared data communication links and systems which are integrated are to comply with the additional requirements of 2.11, 2.13 and 2.14, as applicable. For systems complying with ISO 17894, *Ships and marine technology – Computer applications – General principles for the development and use of programmable electronic systems in marine applications, see* 2.1.2.

2.10.2 Where programmable electronic systems share resources, any components that can affect the ability to effectively provide required control, alarm or safety functions are to fulfil the requirements of 2.10 to 2.14 related to providing those required functions.

2.10.3 Programmable electronic equipment is to revert to a defined safe state on initial start up or re-start in the event of failure.

2.10.4 In the event of failure of any programmable electronic equipment, the system and any other system to which it is connected, is to fail to a defined safe state or maintain safe operation, as applicable.

2.10.5 Programmable electronic equipment is to be certified by a recognised authority as suitable for the environmental conditions in which it is intended to operate, *see also* 2.13.3.

2.10.6 Emergency stops are to be hard-wired and independent of any programmable electronic equipment. Alternatively, the system providing emergency stop functions is to comply with the requirements of 2.13.2 and/or 2.13.9.

2.10.7 Programmable electronic equipment is to be provided with self-monitoring capabilities such that hardware and functional failures will initiate an audible and visual alarm in accordance with the requirements of 2.3 and, where applicable, 3.2. Hardware failures indications are to enable faults to be identifiable at least down to the level of the lowest replaceable unit and the self-monitoring capabilities are to ensure that diagnostic information is readily available.

2.10.8 Means are to be provided to recover or replace data required for safe and effective system operation lost as a result of component failure. The submission required by 1.2.5 is to address reinstatement of system operation following data loss.

2.10.9 System configuration, programs and data are to be protected against loss or corruption in the event of failure of any power supply. For essential services and safety critical systems, *see* 2.13.6.

2.10.10 Where it is necessary to store data required for system operation in volatile memory, a back-up power supply is to be provided that prevents data loss in the event of loss of the normal power supply. The submission required by 1.2.5 is to include details of any routine maintenance necessary and the measures necessary to restore system operation in the event of data loss as a result of power supply failure.

2.10.11 Back-up power supplies required by 2.10.10 are to be rated to supply the connected load for a defined period of time that allows sufficient time to restore the supply in the event of loss of the normal power supply as a result of failure of a main source of electrical power. This period is not to be less than 30 minutes.

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2.10.12 Where regular battery replacement is required to maintain the availability of volatile memory back-up power supply required by 2.10.10, these are to be included in the schedule of batteries required by Ch 2,1.2.7 and 11.7, irrespective of battery type and size. Applicable entries in this schedule are to note that these batteries are not for safety critical systems or essential or emergency services.

2.10.13 Access to system configuration, programs and data is to be restricted by physical and/or logical means providing effective security against unauthorised alteration.

2.10.14 Where date and time information is required by the equipment, this is to be provided by means of a battery backed clock with restricted access for alteration. Date and time information is to be fully represented and utilised.

2.10.15 Displays and controls are to be protected against liquid ingress due to spillage.

2.10.16 User interfaces are to be designed in accordance with appropriate ergonomic principles to meet user needs and enable timely access to desired information or control of functions. A system overview is to be readily available.

2.10.17 The keyboard is to be divided logically into functional areas. Alphanumeric, paging and specific system keys are to be grouped separately.

2.10.18 Where a function may be accessed from more than one interface, the arrangement of displays and controls is to be consistent.

2.10.19 The size, colour and density of information displayed to the operator are to be such that information may be easily read from the normal operator position under all operational lighting conditions.

2.10.20 Display units are to comply with the requirements of an acceptable National or International Standard e.g. IEC 60950:1999, *Safety of information technology equipment,* in respect of emission of ionising radiation.

2.10.21 Symbols used in mimic diagrams are to be visually representative and are to be consistent throughout the systems' displays.

2.10.22 Where systems detect fault conditions, any affected mimic diagrams are to ensure that the status of unreliable and incorrect data is clearly identified.

2.10.23 Multi-function displays and controls are to be duplicated and interchangeable where used for the control or monitoring of more than one system, machinery item or item of equipment. At least one unit at the main control station is to be supplied from an independent uninterruptible power system (UPS).

2.10.24 The number of multi-function display and control units provided at the main control station and their power supply arrangements are to be sufficient to ensure continuing safe operation in the event of failure of any unit or any power supply.

2.10.25 Software lifecycle activities, e.g. design, development, supply and maintenance, are to be carried out in accordance with an acceptable quality management system. Software quality plans are to be submitted. These are to demonstrate that the provisions of ISO/IEC 90003:2004, *Software engineering – Guidelines for the application of ISO 9001:2000 to computer software*, or equivalent, are incorporated. The plans are to define responsibilities for the lifecycle activities, including verification, validation, module testing and integration with other components or systems.

2.11 Data communication links

2.11.1 Where control, alarm or safety systems use shared data communication links to transfer data, the requirements of 2.11.2 to 2.11.10 are to be complied with. The requirements apply to local area networks, fieldbuses and other types of data communication link which make use of a shared medium to transfer control, alarm or safety related data between distributed programmable electronic equipment or systems.

2.11.2 Data communication is to be automatically restored within 45 seconds in the event of a single component failure. Upon restoration, priority is to be given to updating safety critical data and control, alarm and safety related data for essential services. Components comprise all items required to facilitate data communication, including cables, switches, repeaters, software components and power supplies.

2.11.3 Loss of a data communication link is not to result in the loss of ability to operate any essential service by alternative means, *see also* 2.13.2.

2.11.4 The properties of the data communication link, (e.g. bandwidth, access control method, etc.), are to ensure that all connected systems will operate in a safe, stable and repeatable manner under all operating conditions. The latency of control, alarm and safety related data is not to exceed two seconds.

2.11.5 Protocols are to ensure the integrity of control, alarm and safety related data, and provide timely recovery of corrupted or invalid data.

2.11.6 Means are to be provided to monitor performance and identify hardware and functional failures. An audible and visual alarm is to operate in accordance with the requirements of 2.3 and, where applicable, 3.2 in the event of a failure of an active or standby component.

2.11.7 System self-monitoring capabilities are to be arranged to initiate transition to a defined safe state for the complete installation in the event of data communication failure, *see also* 2.5.5.

2.11.8 Means are to be provided to prevent unintended connection or disconnection of any equipment where this may affect the performance of any other systems in operation.

2.11.9 Data cables are to comply with the applicable requirements of Ch 2,10. Other media will be subject to special consideration.

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2.11.10 The installation is to provide adequate protection against mechanical damage and electromagnetic interference.

2.11.11 Components are to be located with appropriate segregation such that the risk of mechanical damage or electromagnetic interference resulting in the loss of both active and standby components is minimised. Duplicated data communication links are to be routed to give as much physical separation as is practical.

2.12 Additional requirements for wireless data communication links

2.12.1 The requirements of this sub-Section are in addition to 2.11 and apply to systems incorporating wireless data communication links.

2.12.2 Wireless data communication links are not to be used for safety critical systems or essential services that are required for the propulsion or safety of the craft, except as permitted by 2.12.3.

2.12.3 For services not required to operate continuously, wireless data communication links may be considered where an alternative means of operation that can be brought into action within an acceptable period of time is provided.

2.12.4 Wireless data communication is to employ recognised international wireless communication system protocols that incorporate the following:

(a) Message integrity: fault prevention, detection, diagnosis and correction, ensuring that the received message is not corrupted or altered when compared to the transmitted message.

(b) Configuration and device authentication: is to permit connection only of devices that are included in the system design.

(c) Message encryption: protection of the confidentiality and/or criticality of the data content.

(d) Security management: protection of network assets and prevention of unauthorised access to network assets.

2.12.5 The wireless system is to comply with the radio frequency and power level requirements of the International Telecommunications Union and any requirements of the National Administration with which the craft is registered.

2.12.6 Compliance with different port state and local regulations pertaining to the use of radio-frequency transmission that would prohibit the operation of a wireless data communication link, due to frequency and power level restrictions, is not addressed by these requirements and is the responsibility of the Owner and Operator.

2.13 Programmable electronic systems – Additional requirements for essential services and safety critical systems

2.13.1 The requirements of 2.13.2 to 2.13.10 are to be complied with where control, alarm or safety systems for essential services, as defined by Ch 2,1.5, or safety critical systems, incorporate programmable electronic equipment:

(a) Safety critical systems are those which provide functions intended to protect persons from physical hazards (e.g. fire, explosion, etc.), or to prevent mechanical damage which may result in the loss of an essential service (e.g. main engine low lubricating oil pressure shutdown).

(b) Applications that are not essential services may also be considered to be safety critical (e.g. domestic boiler low water level shutdown).

2.13.2 Alternative means of safe and effective operation are to be provided for essential services and, wherever practicable, these are to be by provision of a fully independent hard wired back-up system. Where these alternative means are not independent of any programmable electronic equipment, the software is to satisfy the requirements of LR's *Software Conformity Assessment System – Assessment Module GEN1 (1994)*.

2.13.3 Items of programmable electronic equipment used to implement control, alarm and safety functions are to satisfy the requirements of LR's *Type Approval System Test Specification Number 1* (2002).

2.13.4 The system is to be configured such that control, alarm and safety function groups are independent. A failure of the system is not to result in the loss of more than one of these function groups. Proposals for alternative arrangements providing an equivalent level of safety will be subject to special consideration.

2.13.5 For essential services, the system is to be arranged to operate automatically from an alternative power supply in the event of a failure of the normal supply.

2.13.6 Volatile memory is not to be used to store data required for:

- an essential service or safety critical functions; or
- ensuring safety or preventing damage, including during start-up or re-start.

Alternative proposals which demonstrates that an equivalent level of system integrity will be achieved may be submitted for consideration.

2.13.7 Failure of any power supply is to initiate an audible and visual alarm in accordance with the requirements of 2.3 and, where applicable, 3.2.

2.13.8 Where it is intended that the programmable electronic system implements emergency stop or safety critical functions, the software is to satisfy the requirements of LR's *Software Conformity Assessment System – Assessment Module GEN1 (1994)*. Alternative proposals providing an equivalent level of system integrity will be subject to special consideration, e.g. fully independent hard wired back-up system, redundancy with design diversity, etc.

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2.13.9 Control, alarm and safety related information is to be displayed in a clear, unambiguous and timely manner, and, where applicable, is to be given visual prominence over other information on the display.

2.13.10 Means of access to safety critical functions are to be dedicated to the intended function and readily distinguishable.

2.14 Programmable electronic systems – Additional requirements for integrated systems

2.14.1 The requirements of 2.14.2 to 2.14.7 apply to integrated systems providing control, alarm or safety functions in accordance with the Rules, including systems capable of independent operation interconnected to provide co-ordinated functions or common user interfaces. Examples include integrated machinery control, alarm and monitoring systems, power management systems and safety management systems providing a grouping of fire, passenger, crew or craft safety functions, *see* Ch 2,16 to 18.

2.14.2 System integration is to be managed by a single designated party, and is to be carried out in accordance with a defined procedure identifying the roles, responsibilities and requirements of all parties involved. This procedure is to be submitted for consideration where the integration involves control functions for essential services or safety functions including fire, passenger, crew, and craft safety.

2.14.3 The system requirements specification, *see* 1.2.5, is to identify the allocation of functions between modules of the integrated system, and any common data communication protocols or interface standards required to support these functions.

2.14.4 Reversionary modes of operation are to be provided to ensure safe and graceful degradation in the event of one or more failures. In general, the integrated system is to be arranged such that the failure of one part will not affect the functionality of other parts, except those that require data from the failed part.

2.14.5 Where the integration involves control functions for essential services or safety functions, including fire, passenger, crew and craft safety, a Failure Mode and Effects Analysis (FMEA) is to be carried out in accordance with IEC 60812, or an equivalent and acceptable National or International Standard and the report and worksheets submitted for consideration. The FMEA is to demonstrate that the integrated system will 'fail-safe', *see* 2.4.6 and 2.5.5, and that essential services in operation will not be lost or degraded beyond acceptable performance criteria where specified by these Rules.

2.14.6 The quantity and quality of information presented to the operator are to be managed to assist situational awareness in all operating conditions. Excessive or ambiguous information that may adversely affect the operator's ability to reason or act correctly is to be avoided, but information needed for corrective or emergency actions is not to be suppressed or obscured in satisfying this requirement.

2.14.7 Where information is required by the Rules or by National Administration requirements to be continuously displayed, the system configuration is to be such that the information may be viewed without manual intervention, e.g. the selection of a particular screen page or mode of operation. *See also* 2.10.23 and 2.10.24.

■ *Section 3*
Unattended machinery space(s) – UMS notation

3.1 General

3.1.1 Where it is proposed to operate the following machinery in an unattended space, no matter what period is envisaged, the controls, alarms and safeguards required by the appropriate Chapters together with those given in 3.2 to 3.7 are to be provided:

- Air compressors.
- Controllable pitch propellers.
- Electric generating plant.
- Oil fuel transfer and storage systems.
- Propulsion machinery including essential auxiliaries.
- Steam raising plant (boilers and their ancillary equipment).
- Thermal fluid heaters.

3.2 Alarm system for machinery

3.2.1 An alarm system which will provide warning of faults in the machinery is to be installed. The system is to satisfy the requirements of 2.3.

3.2.2 Audible and visual indication of machinery alarms is to be relayed to the engineers' accommodation so that engineering personnel are made aware that a fault has occurred.

3.2.3 The engineers' alarm required by 2.2.3 is to be activated automatically in the event that a machinery alarm has not been acknowledged in the space within a predetermined time.

3.2.4 Audible and visual indication of machinery alarms is to be relayed to the navigating bridge control station in such a way that the navigating officer of the watch is made aware when:

(a) a machinery fault has occurred,
(b) the machinery fault is being attended to, and
(c) the machinery fault has been rectified.

3.2.5 Group alarms may be arranged on the bridge to indicate machinery faults, but alarms associated with faults requiring speed or power reduction or the automatic shutdown of propulsion machinery are to be identified by separate group alarms or by individual alarm parameters.

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3.3 Bridge control for propulsion machinery

3.3.1 A bridge control system for the propulsion machinery is to be fitted. The system is to satisfy the requirements of 2.6.

3.4 Control stations for machinery

3.4.1 A control station(s) is to be provided in the space and on the bridge which satisfies the requirements of 2.2.

3.5 Fire detection alarm system

3.5.1 An automatic fire detection system is to be fitted in the space together with an audible and visual alarm system. The system is to satisfy the requirements of 2.8.

3.6 Bilge level detection

3.6.1 An alarm system is to be provided to warn when liquid in machinery space bilges has reached a predetermined level, and is to comply with 2.3. This level is to be sufficiently low to prevent liquid from overflowing from the bilges onto the tank top. The number and location of detectors are to be such that accumulation of liquids will be detected at all angles of heel and trim.

3.6.2 Local or remote controls of any valve within the space serving a sea inlet, a discharge below the waterline, a bilge injection or a direct bilge system, should be so sited as to be readily accessible and to allow adequate time for operation in case of influx of water to the space, having regard to the time which could be taken to reach and operate such controls.

3.6.3 Where the bilge pumps are arranged to start automatically, means are to be provided to indicate if the influx of liquids is greater than the pump capacity or, if the pump is operating more frequently than would be expected. Special attention should be given to oil pollution prevention requirements.

3.7 Supply of electric power, general

3.7.1 For craft operating with one generator set in service, arrangements are to be such that a standby generator will automatically start and connect to the switchboard in as short a time as practicable, but in any case within 45 seconds, on loss of the service generator. For craft operating with two or more generator sets in service, arrangements are to be such that on loss of one generator the remaining one(s) are to be adequate for continuity of essential services. For the detailed requirements of these arrangements, *see* Ch 2,2.2.

■ *Section 4* Machinery operated from a centralised control station – CCS notation

4.1 General requirements

4.1.1 Where it is proposed to operate the machinery as listed in 3.1.1 with continuous supervision from a centralised control station, the control station is to be such that the machinery operation will be as effective as it would be under direct supervision.

4.1.2 The arrangements are to be such that corrective actions can be taken at the control station in the event of machinery faults, e.g. stopping of machinery, starting of standby machinery, adjustment of operating parameters, etc. These actions may be effected by either remote manual or automatic control.

4.1.3 The controls, alarms and safeguards required by the appropriate Chapters and by 3.6 together with a fire detection system satisfying the requirements of 2.8 are to be provided.

4.1.4 Additional requirements for controls, alarms and safeguards are given in 4.2.

4.2 Centralised control station for machinery

4.2.1 A centralised control station is to be provided at some suitable location, which satisfies the requirements of 4.2.2 to 4.2.7.

4.2.2 A system of alarm displays and controls is to be provided which readily ensures identification of faults in the machinery and satisfactory supervision of related equipment. The alarm and control systems are to satisfy the requirements of 2.3 and 2.5, as applicable.

4.2.3 Indication of all essential parameters necessary for the safe and effective operation of the machinery is to be provided, e.g. temperatures, pressures, tank levels, speeds, powers, etc.

4.2.4 Indication of the operational status of running and standby machinery is to be provided.

4.2.5 At the centralised control station, means of communication with the bridge area, the accommodation for engineering personnel and, if necessary, the machinery space are to be provided.

4.2.6 In addition to the communication required by 4.2.5, a second means of communication is to be provided between the bridge and the centralised control station. One of these means is to be independent of the main electrical power supply.

4.2.7 Arrangements are to be provided in the centralised control station so that the normal supply of electrical power may be restored in the event of failure.

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Section 5
Requirements for craft which are not required to comply with the HSC Code

5.1 General

5.1.1 The relevant requirements of Sections 1 and 2 are to be complied with.

5.1.2 For vessels which are to be assigned or to be eligible for the **UMS** or **CCS** notations the requirements of Sections 3 and 4 are to be complied with.

5.1.3 For yachts less than 500 gt and small craft not requiring the **UMS** and **CCS** notation, the requirements of 5.2 and 5.3 apply.

5.1.4 Yachts that are 500 gt or more are to comply with the requirements of Sections 1 and 2.

5.2 Plans and information

5.2.1 Plans are required to be submitted in accordance with 1.2 only for the machinery items applicable to these craft.

5.3 Control and supervision of unattended machinery

5.3.1 Where machinery items applicable to these craft are fitted with automatic or remote controls so that under normal operating conditions they do not require any manual intervention by the operators they are to be provided with the alarms and safety arrangements specified in the appropriate Chapters of the Rules.

Section 6
Trials

6.1 General

6.1.1 Before a new installation (or any alteration or addition to an existing installation) is put into service, trials are to be carried out. These trials are in addition to any acceptance tests which may have been carried out at the manufacturers' works and are to be based on the approved test schedules list as required by 1.2.3. In the case of new construction it will be expected that most of these trials will be carried out before the official sea trials of the craft. During sea trials, system dynamic tests are to be carried out to demonstrate overall satisfactory performance of the control engineering installation.

6.1.2 Means are to be provided to facilitate testing during normal machinery operation, e.g. by the provision of three-way test valves or equivalent.

6.1.3 Acceptance tests and trials for Programmable Electronic Systems are to include verification of software life-cycle activities appropriate to the stage in the system's lifecycle at the time of system examination. The documentation required by 1.2.5 is to be in accordance with the current configuration and the testing and trials are to address software modifications and configuration management procedures to the Surveyor's satisfaction.

6.1.4 Wireless data communication links are to be operational and tested during trials. Tests are to demonstrate that radio-frequency transmission does not interfere with the operation of equipment required by this Chapter or other Sections of the Rules and does not itself malfunction as a result of electromagnetic interference during expected operating conditions. Reversionary modes are to be activated to demonstrate continued safe and effective operation in the event of fault conditions.

6.2 Unattended machinery space operation – UMS notation

6.2.1 In addition to the tests required by 6.1, the suitability of the installation for operation in the unattended mode is to be demonstrated during sea trials observing the following:

(a) Occurring alarms and the frequency of operation both during steady steaming and under manoeuvring conditions using bridge control.

(b) Any intervention by personnel in the operation of the machinery.

6.3 Operation from a centralised control station – CCS notation

6.3.1 In addition to the tests required by 6.1, the suitability of the installation for operation from the centralised control station is to be demonstrated during sea trials.

6.4 Record of trials

6.4.1 Two copies of the alarm and control equipment test schedules, as required by 1.2.3, signed by the Surveyor and Builder are to be provided on completion of the survey. One copy is to be placed on board the vessel and the other submitted to LR.

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Section

1 **General requirements**

2 **Main source of electrical power**

3 **Emergency source of electrical power**

4 **External source of electrical power**

5 **Supply and distribution**

6 **System design – Protection**

7 **Switchgear and control gear assemblies**

8 **Rotating machines**

9 **Converter equipment**

10 **Electrical cables and busbar trunking systems (busways)**

11 **Batteries**

12 **Equipment – Heating, lighting and accessories**

13 **Electrical equipment for use in explosive atmospheres**

14 **Navigation and manoeuvring systems**

15 **Electric propulsion**

16 **Fire safety systems**

17 **Crew and passenger emergency safety systems**

18 **Craft safety systems**

19 **Cargo craft, patrol and pilot craft, workboats and other similar craft of less than 500 tons gross tonnage for operation in Service Groups 1 to 3, and yachts less than 500 gt**

20 **Testing and trials**

Section 1 General requirements

1.1 General

1.1.1 The requirements of Sections 1 to 18 and 20 are, in general, applicable to all the craft types indicated in Pt 1, Ch 2,2.1, with the exception of cargo craft, patrol and pilot craft, workboats and other similar craft of less than 500 tons gross tonnage for operation in Service Groups 1 to 3, and for yachts less than 500 gt, which are covered in Section 19.

1.1.2 Whilst this Chapter applies to the electrical engineering equipment and systems on special service craft intended to be classed, attention should also be given to any relevant Statutory Regulations of the National Authority of the country in which the craft is to be registered and the Code of Safety for High Speed Craft.

1.1.3 Electrical services required to maintain the craft in a normal seagoing, operational and habitable condition are to be capable of being maintained without recourse to the emergency source of electrical power.

1.1.4 Electrical services essential for safety are to be maintained under various emergency conditions.

1.1.5 The safety of passengers, crew and craft from electrical hazards is to be ensured.

1.1.6 Consideration will be given to special cases or to arrangements which are equivalent to the Rules.

1.2 Plans

1.2.1 At least three copies of the plans and particulars in 1.2.2 to 1.2.8 are to be submitted for consideration. Single copies only are required of plans in 1.2.10 to 1.2.13. Additional copies are to be submitted when requested.

1.2.2 Single line diagram of main and emergency power and lighting systems which is to include:
(a) ratings of machines, transformers, batteries and semi-conductor converters;
(b) all feeders connected to the main and emergency switchboards;
(c) section boards and distribution boards;
(d) insulation type, size and current loadings of cables;
(e) make, type and rating of circuit breakers and fuses;
(f) details of harmonic filters (where fitted).

1.2.3 Simplified diagrams of generator circuits, inter-connector circuits and feeder circuits showing:
(a) protective devices, e.g. short circuit, overload, reverse power protection;
(b) instrumentation and synchronising devices;
(c) preference tripping;
(d) remote stops;
(e) earth fault indication/protection.

1.2.4 Calculations of short circuit currents at main and emergency switchboards and section boards including those fed from transformers, with details of circuit breaker and fuse operating times and discrimination curves showing compliance with 6.1 and 10.6.2.

1.2.5 A test schedule which is to include the method of testing and the test facilities which are provided for the general emergency alarm system and the public address system.

1.2.6 For battery installations, arrangement plans and calculations to show compliance with Section 11.

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1.2.7 A schedule of batteries fitted for use for emergency and essential services, giving details of:

- type and manufacturer's type designation;
- voltage and ampere-hour rating;
- location;
- equipment and/or system(s) served;
- maintenance/replacement cycle dates;
- date(s) of maintenance and/or replacement; and
- for replacement batteries in storage, the date of manufacture and shelf life, with accompanying battery replacement procedure documentation to show compliance with 11.7.

1.2.8 Details of electrically-operated fire, craft, crew and passenger emergency safety systems which are to include typical single line diagrams and arrangements, showing main vertical and, where applicable, horizontal fire zones and the location of equipment and cable routes, including identification of relevant high fire risk areas, to be employed for:

(a) emergency lighting;
(b) accommodation fire detection, alarm and extinction systems;
(c) fixed water-based local application fire-fighting systems;
(d) public address system;
(e) general alarm;
(f) watertight doors, shell doors and other electrically operated closing appliances; and
(g) low location lighting.

A general arrangement plan of the complete craft showing the main vertical fire zones and the location of equipment and cable routes, including identification of relevant high fire risk areas, for the above systems, is to be made available for the use of the Surveyor on board.

1.2.9 Evidence of the suitability of electrical and electronic equipment for use in protected areas and adjacent areas, as required by 16.3.11 and 16.3.12, including a schedule of electrical and electronic equipment located in protected areas and adjacent areas, and general arrangement plans showing the coverage of the protected areas and adjacent areas.

1.2.10 In order to establish compliance with 1.10.2 and 5.1.3 to 5.1.5, a general arrangement plan of the craft showing the location of major items of electrical equipment, for example:

- main and emergency generators;
- switchboards;
- section boards and distribution boards supplying essential and emergency services;
- emergency batteries;
- motors for emergency services; and
- cable routes between these items of equipment.

1.2.11 Arrangement plans of main and emergency switchboards, and section boards.

1.2.12 Schedule of normal and emergency operating loads on the system estimated for the different operating conditions expected.

1.2.13 In order to establish compliance with the requirements of 1.6.3, evidence is to be submitted to demonstrate the suitability of electrical equipment for its intended purpose in the conditions in which it is expected to operate.

1.2.14 For non-metallic cable support systems or protective casings, test evidence, details of installation procedures and manufacturer's recommendations that show compliance with 10.13.

1.3 Surveys

1.3.1 Electrical machinery and auxiliary services essential for the safety of the craft are to be installed in accordance with the relevant requirements of this Chapter, surveyed and have tests witnessed by the Surveyors.

1.3.2 The following equipment, where intended for use for essential and emergency services, is to be surveyed by the Surveyors during manufacture and testing:

- Converting equipment of 100 kW and over;
- Rotating machines of 100 kW and over;
- Switchboards and section boards; and
- UPS units of 50 kVA and over.

1.3.3 For electric propulsion systems, in addition to the equipment listed in 1.3.2, the following equipment is to be surveyed by the Surveyors during manufacture and testing:

- exciters;
- filters;
- reactors;
- dynamic braking assemblies;
- pre-magnetisation transformers; and
- slip ring assemblies.

1.3.4 All other electrical equipment, not specifically referenced in 1.3.2 and 1.3.3, intended for use for essential or emergency services is to be supplied with a manufacturer's works test certificate showing compliance with the constructional standard(s) as referenced by the relevant requirements of this Chapter.

1.4 Additions or alterations

1.4.1 No addition, temporary or permanent, is to be made to the approved load of an existing installation until it has been ascertained that the current carrying capacity and the condition of the existing equipment including cables and switchgear are adequate for the increased load.

1.4.2 Plans are to be submitted for consideration, and the alterations or additions are to be carried out under the survey, and to the satisfaction of the Surveyors.

1.4.3 When it is proposed to replace permanently installed secondary valve-regulated sealed batteries with vented batteries, details are to be submitted for consideration to ensure continued safety in the presence of the products of electrolysis and evaporation being allowed to escape freely from the cells to the atmosphere. These details are to demonstrate that there will be adequate ventilation in accordance with 11.5.9 and that the location and installation requirements of 11.3 and 11.4 are complied with.

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1.4.4 Proposed modifications to the electrical protection systems are to be developed in accordance with 6.1.4 and plans submitted are also to address the updating of approved version of the details required by 1.2.3 and 1.2.4.

1.4.5 Where it is intended to replace an existing incandescent lamp type navigation light with a light emitting diode type navigation light, details are to be submitted for consideration that demonstrate compliance with 14.3. Light emitting diode type navigation light failure detection arrangements are to satisfy the requirements of 14.3.5 and 14.3.6.

1.5 Definitions

1.5.1 Essential services are those necessary for the propulsion and safety of the craft, such as the following:

- air compressors for starting and manoeuvring essential mains and auxiliary machinery;
- air pumps:
- automatic sprinkler systems;
- ballast pumps;
- bilge pumps;
- circulating and cooling water pumps;
- communication systems;
- electric starting systems for starting and manoeuvring essential main and auxiliary machinery;
- fire detection and alarm systems;
- fire pumps;
- fuel valve cooling pumps;
- hydraulic pumps for controllable pitch propellers and those serving essential services here listed that would otherwise be directly electrically-driven;
- hydraulic pumps serving essential services here listed which would otherwise be directly electrically driven;
- lubricating oil pumps;
- lighting systems for those parts of the craft normally accessible to and used by personnel and passengers;
- navigational aids where required by Statutory Regulations;
- navigation lights and special purpose lights where required by Statutory regulations;
- oil fuel pumps and oil fuel burning units;
- pumps for fire-extinguishing systems;
- scavenge blowers;
- steering gear;
- valves which are required to be remotely operated;
- ventilating fans for engine rooms;
- watertight doors, shell doors and other electrical operated closing appliances;
- windlasses;
- power sources and supply systems for supplying the above services.

1.5.2 Services such as the following are considered necessary for minimum comfortable conditions of habitability:

- cooking;
- heating;
- domestic refrigeration;
- mechanical ventilation;
- sanitary and fresh water.

1.5.3 Services such as the following, which are additional to those in 1.5.1 and 1.5.2, are considered necessary to maintain the craft in a normal seagoing operational and habitable condition:

- cargo handling and cargo care equipment;
- hotel services, other than those required for habitable conditions;
- thruster systems for manoeuvring.

1.5.4 A 'high voltage' is a voltage exceeding 1000 V a.c. or 1500 V d.c. between conductors, *see also* 5.1.2.

1.5.5 A 'switchboard' is a switchgear and control gear assembly for the control of power generated by a source of electrical power and its distribution to electrical consumers.

1.5.6 A 'section board' is a switchgear and control gear assembly for controlling the supply of electrical power from a switchboard and distributing it to other section boards, distribution boards or final sub-circuits.

1.5.7 A 'distribution board' is an assembly of one or more protective devices arranged for the distribution of electrical power to final sub-circuits.

1.5.8 A 'final sub-circuit' is that portion of a wiring system extending beyond the final overcurrent device of a board.

1.5.9 'Special Category spaces' are those enclosed spaces above or below the bulkhead deck intended for the carriage of motor vehicles with fuel, for their own propulsion, in their tanks, into and from which such vehicles can be driven, and to which passengers have access.

1.5.10 'Machinery spaces of Category A' are those spaces and trunks to such spaces which contain:

(a) internal combustion machinery used for main propulsion; or

(b) internal combustion machinery used for purposes other than main propulsion where such machinery has in the aggregate a total power output of not less than 375 kW; or

(c) any oil-fired boiler or oil fuel unit.

1.5.11 'Dead craft condition' means that the entire machinery installation, including the power supply, is out of operation and that the auxiliary services for bringing the main propulsion systems into operation (e.g. compressed air, starting current from batteries, etc.) and for the restoration of the main power supply are not available. Means are to be available at all times to start the emergency generator, *see* Pt 10, Ch 1,7.6.

1.5.12 Protected space is a machinery space where a fixed water-based local application fire-fighting system is installed.

1.5.13 Protected areas are areas within a protected space which is required to be protected by a fixed water-based local application fire-fighting system.

1.5.14 Adjacent areas are areas, other than protected areas, exposed to direct spray or other areas where water may extend when a fixed water-based local application fire-fighting system is activated.

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1.6 Design and construction

1.6.1 Equipment for services essential for the safety of the craft are to be constructed in accordance with the relevant requirements of this Chapter.

1.6.2 The design and installation of other equipment is to be such that risk of fire due to its failure is minimised. It is to, as a minimum, comply with a National or International Standard revised where necessary for ambient conditions.

1.6.3 Electrical equipment is to be suitable for its intended purpose and accordingly, whenever practicable to be selected from the *List of Type Approved Products* published by Lloyd's Register's (hereinafter referred to as 'LR'). A copy of the Procedure for LR Type Approval System will be supplied on application.

1.7 Quality of power supplies

1.7.1 All electrical equipment supplied from the main and emergency sources of electrical power and electrical equipment for essential and emergency services supplied from d.c. sources of electrical power is to be so designed and manufactured that it is capable of operating satisfactorily under normally occurring variations of voltage and frequency.

1.7.2 Unless specified otherwise, a.c. electrical equipment is to operate satisfactorily with the following simultaneous variations, from their nominal value, when measured at the consumer input terminals. Alarms are to be provided for High and Low Voltage and Low Frequency.

(a) Voltage:
- permanent variations +6 per cent, –10 per cent
- transient variations due to step changes in load ±20 per cent
- recovery time 1,5 seconds.

(b) Frequency:
- permanent variations ±5 per cent
- transient variations due to step changes in load ±10 per cent
- recovery time 5 seconds.

A maximum rate of change of frequency not exceeding ±1,5 Hz per second during cyclic frequency fluctuations.

1.7.3 Harmonics. Unless specified otherwise, the total harmonic distortion (THD) of the voltage waveform at any a.c. switchboard or section-board is not to exceed 8 per cent of the fundamental for all frequencies up to 50 times the supply frequency and no voltage at a frequency above 25 times supply frequency is to exceed 1,5 per cent of the fundamental of the supply voltage. THD is the ratio of the rms value of the harmonic content to the rms value of the fundamental, expressed in per cent and may be calculated using the expression:

$$THD = \frac{\sqrt{\sum_{h=2}^{\infty} V_h^2}}{V_1} \times 100$$

where

V_h = rms amplitude of a harmonic voltage of order h

V_1 = rms amplitude of the fundamental voltage.

1.7.4 Unless specified otherwise, d.c. electrical equipment is to operate satisfactorily with the following simultaneous variations, from their nominal value, when measured at the consumer input terminals:

(a) When supplied by d.c. generator(s) or a rectified a.c. supply:
Voltage tolerance (continuous) ±10 per cent
Voltage cyclic variation deviation 5 per cent
Voltage ripple 10 per cent
(a.c. rms over steady state d.c. voltage);

(b) When supplied by batteries:
(i) Equipment connected to the batteries during charging:
Voltage tolerance +30 per cent, –25 per cent;
(ii) Equipment not connected to batteries during charging:
Voltage tolerance +20 per cent, –25 per cent

Different voltage variations as determined by the charging/discharging characteristics, including ripple voltage from the charging device, may be considered. When battery chargers/battery combinations are used as d.c. power supply systems adequate measures are to be taken to keep the voltage within the specified limits during charging, boost charging and discharging of the battery.

1.8 Ambient reference and operating conditions

1.8.1 The rating for classification purposes of essential electrical equipment intended for installation in craft to be classed for unrestricted (geographical) service is to be based on an engine room ambient temperature of 45°C, and a seawater temperature at the inlet of 32°C. The equipment manufacturer is not expected to provide simulated ambient reference conditions at a test bed.

1.8.2 In the case of craft to be classed for restricted service, the rating is to be suitable for the ambient conditions associated with the geographical limits of the restricted service which are part of the class notation.

1.8.3 Main and essential auxiliary machinery and equipment is to operate satisfactorily under the conditions shown in Pt 9, Ch 1,4.4. Electrical equipment satisfying alternative ambient operating condition requirements for installation on ships contained in an acceptable and relevant national or international standard may be considered to satisfy this requirement.

NOTE

Details of local environmental conditions are stated in Annex B of IEC 60092: *Electrical installations in ships – Part 101: Definitions and general requirements.*

1.8.4 Where electrical equipment is installed within environmentally controlled spaces, the ambient temperature for which the equipment is suitable for operation at its rated capacity may be reduced to a value not less than 35°C provided:
- the equipment is not for use for emergency services and is located outside of machinery space(s);
- temperature control is achieved by at least two cooling units so arranged that, in the event of loss of one cooling unit, for any reason, the remaining unit(s) will be capable of satisfactorily maintaining the design temperature;

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- the equipment is able to be initially set to work safely within a 45°C ambient temperature until such a time that the lesser ambient temperature may be achieved; the cooling equipment is to be rated for an ambient temperature of not less than 45°C; and
- alarms are provided, at a continually attended control station, to indicate any malfunction of the cooling units.

See also Ch 1,1.3.3.

1.8.5 Where equipment is to comply with 1.8.4, it is to be ensured that electrical cables for their entire length are adequately rated for the maximum ambient temperature to which they are exposed along their length.

1.8.6 Equipment used for cooling and maintaining the lesser ambient temperature in accordance with 1.8.4 are considered essential services and are to satisfy the requirements of 5.2.

1.9 Inclination of craft

1.9.1 Emergency and essential electrical equipment is to operate satisfactorily under the conditions as shown in Table 1.4.1 in Pt 9, Ch 1.

1.10 Location and construction

1.10.1 All electrical equipment is to be constructed or selected, and installed such that:

(a) live parts cannot be inadvertently touched, unless they are supplied at the safety voltage specified in 1.11.2(h);
(b) it does not cause injury when handled or touched in the normal manner; and
(c) it is unaffected by any water, steam or oil and oil vapour to which it is likely to be exposed.

Electrical equipment having, as a minimum, the degrees of protection as specified in IEC 60092-201 for the relevant location will satisfy these requirements.

1.10.2 Switchboards, section boards and distribution boards supplying essential and emergency services, as well as cables from the respective generators to and between these boards, are to be arranged to avoid areas of high fire risk and elevated temperatures, for example, in close proximity to incinerators and boilers.

1.10.3 Electrical equipment, as far as is practicable, is to be located:

(a) such that it is accessible for the purpose of maintenance and survey;
(b) clear of flammable material;
(c) in spaces adequately ventilated to remove the waste heat liberated by the equipment under full load conditions, at the ambient conditions specified in 1.8;
(d) where flammable gases cannot accumulate. If this is not practicable, electrical equipment is to be of the appropriate 'safe-type', *see* Section 13;
(e) where it is not exposed to the risk of mechanical injury or damage from water, steam or oil.

1.10.4 Equipment design and the choice of materials are to reduce the likelihood of fire, ensuring that:

(a) where the electrical energised part can cause ignition and fire, it is contained within the bounds of the enclosure of the electrotechnical product;
(b) the design, material(s) and construction of the enclosure minimises, as far as is practicable, any internal ignition causing ignition of adjacent materials; and
(c) where surfaces of the electrotechnical products can be exposed to external fire, they do not, as far as practicable, contribute to the fire growth.

NOTE
Compliance with IEC 60695: *Fire hazard testing*, or an alternative and acceptable Standard, will satisfy this requirement, *see also* 1.14.4.

1.10.5 Insulating materials and insulated windings are to be resistant to tracking, moisture, sea air, oil and oil vapour unless special precautions are taken to protect them.

1.10.6 The minimum creepage and clearance distances provided for electrical connections, terminals and similar bare live parts are to be in accordance with a relevant International or National Standard for the equipment or apparatus concerned. In cases where the rated voltage is outside that given in the Standard or where no Standard is available, the minimum creepage and clearance distances provided are to be in accordance with 7.5. Details of alternatives proposals including supporting design rationale and demonstration may be submitted for consideration.

1.10.7 Studs, screw-type or spring-type clamp terminations, satisfactory for the normal operating currents and voltages, are to be provided in electrical equipment for the connection of external cable, or bus-bar conductors, as appropriate, *see also* 10.15. There is to be adequate space and access for the terminations.

1.10.8 Equipment is not to remain alive through the control circuits and/or pilot lamps when switched off by the control switch. This does not apply to synchronising switches and/or plugs.

1.10.9 The operation of all electrical equipment and the lubrication arrangements are to be efficient under such conditions of vibration and shock as arise in normal practice.

1.10.10 All nuts, screws and clamping devices used in connection with current-carrying, supporting and working parts are to be provided with means to ensure that they cannot work loose by vibration and shock as arise in normal practice.

1.10.11 Conductors and equipment are to be placed at such a distance from the magnetic compasses, or are to be so disposed, that the interfering magnetic field is negligible when circuits are switched on and off.

1.10.12 Where electrical power is used for propulsion, the equipment is to be so arranged that it will operate satisfactorily in the event of partial flooding by bilge water above the tank top up to the bottom floor plate level, under the normal angles of inclination given in 1.9 for essential electrical equipment, *see* Pt 15, Ch 2.

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1.11 Earthing of non-current carrying parts

1.11.1 Except where exempted by 1.11.2, all non-current carrying exposed metal parts of electrical equipment and cables are to be earthed.

1.11.2 The following parts may be exempted from the requirements of 1.11.1:

(a) lamp-caps, where suitably shrouded;
(b) shades, reflectors and guards supported on lampholders or light fittings constructed of, or shrouded in, non-conducting material;
(c) metal parts on, or screws in or through, non-conducting materials, which are separated by such material from current-carrying parts and from earthed non-current carrying parts in such a way that in normal use they cannot become live or come into contact with earthed parts;
(d) apparatus which is constructed in accordance with the principle of double insulation;
(e) bearing housings which are insulated in order to prevent circulation of current in the bearings;
(f) clips for fluorescent lamps;
(g) cable clips and short lengths of pipes for cable protection;
(h) apparatus supplied at a safety voltage not exceeding 50 V d.c. or 50 V a.c., between conductors, or between any conductor and earth in a circuit isolated from the supply. Autotransformers are not to be used for the purpose of achieving the alternating current voltage;
(j) apparatus or parts of apparatus which although not shrouded in insulating material is nevertheless otherwise so guarded that it cannot be touched and cannot come in contact with exposed metal.

1.11.3 Where extraneous-conductive parts (i.e. parts not forming part of the electrical installation and liable to introduce an electric potential) are not bonded by separate earthing conductors, details are to be submitted that demonstrate that a permanent, metal-to-metal connection of negligible impedance, which will not degrade due to corrosion or vibration, will be achieved.

1.11.4 Armouring, braiding and other metal coverings of cables are to be effectively earthed. Where the armouring, braiding and other metal coverings are earthed at one end only, they are to be adequately protected and insulated at the unearthed end with the insulation being suitable for the maximum voltage that may be induced. *See* 13.1 for earthing of cables in hazardous zones or spaces.

1.11.5 The electrical continuity of all metal coverings of cables throughout the length of the cable, particularly at joints and tappings, is to be ensured.

1.11.6 Metal parts of portable appliances, other than current-carrying parts and parts exempted by 1.11.2 are to be earthed by means of an earth-continuity conductor in the flexible cable or cord through the associated plug and socket-outlet.

1.11.7 Earthing conductors are to be of copper or other corrosion-resistant material and be securely installed and protected where necessary against damage and also, where necessary, against electrolytic corrosion. Connections are to be so secured that they cannot work loose under vibration.

1.11.8 The nominal cross-section areas of copper earthing conductors are, in general to be equal to the cross-section of the current-carrying conductor up to 16 mm^2. Above this figure they are to be equal to at least half the cross-section of the current-carrying conductor with a minimum of 16 mm^2. Every other earthing conductor is to have a conductance not less than that specified for an equivalent copper earthing conductor.

1.11.9 The connection of the earthing conductor to the hull of the craft is to be made in an accessible position, and is to be secured by a screw or stud of diameter not less than 6 mm which is to be used for this purpose only. Bright metallic surfaces at the contact areas are to be ensured immediately before the nut or screw is tightened and, where necessary, the joint is to be protected against electrolytic corrosion. The connection is to remain unpainted.

1.12 Electrical bonding for the control of static electricity

1.12.1 In non-metallic craft, all metallic parts of the craft are to be electrically bonded together, as far as possible, in consideration of galvanic corrosion between dissimilar metals, to ensure an earth return path and to connect the craft to the water when water-borne. This does not apply to isolated components which cannot become live, nor require control of static electricity.

1.12.2 Bonding straps for the control of static electricity are required for piping systems, including pressure refuelling points, which are not electrically continuous throughout their length and for flammable products, which are not permanently connected to the hull of the craft either directly or via their bolted or welded supports and where the resistance between them and the hull exceeds 1MΩ.

1.12.3 Where bonding straps are required for the control of static electricity, they are to be robust, that is, having a cross-sectional area of about 10 mm^2, and are to comply with 1.11.7 and 1.11.9.

1.13 Alarms

1.13.1 Where alarms are required by this Chapter they are to be arranged in accordance with Ch 1,2.3. Sound signal equipment, fire and general alarm bells are not required to be supplemented by visual alarms, except in areas having high levels of background noise, such as machinery spaces.

1.13.2 The alarms in this Chapter are additional to those required by Chapter 1. They may however form part of the alarm system that is required by Chapter 1.

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1.13.3 Cables for emergency alarms and their power sources are to be in accordance with 1.14.

1.13.4 Electrical equipment and cables for emergency alarms are to be so arranged that the loss of alarms in any one area due to localised fire, collision, flooding or similar damage is minimised, *see* 1.14.

1.14 Operation under fire conditions

1.14.1 As a minimum, the following emergency services and their emergency power supplies, are required to be capable of being operated under fire conditions:

- Emergency fire pump.
- Fire safety stops, *see also* 16.6.
- Control and power systems to power-operated fire doors and their status indication.
- Control and power systems to power-operated water-tight doors and their status indication.
- Emergency lighting.
- Fire and general alarms.
- Fire detection systems.
- Fire-extinguishing systems and fire-extinguishing media release alarms.
- Low location lighting, *see also* 17.4.3.
- Public address systems.

1.14.2 Where cables for services that are required to be capable of being operated under fire conditions, including their power supplies, pass through high fire risk areas, main vertical or horizontal fire zones or decks other than those which they serve, they are to be of a fire resistant type complying with 10.5.3, and:

(a) in the case of the emergency services: the fire resistant cable is to extend, at least, from the control/monitoring panel to the nearest local junction box serving the relevant deck/area; and

(b) in the case of power supplies: the fire resistant cable is to extend, at least, from the distribution point within the space containing the emergency source of electrical power to the nearest local distribution panel serving the relevant deck/area.

1.14.3 Electrical cables for the above services required to be capable of being operated under fire conditions, including their power supplies, are to be run as directly as is practicable, having regard to any special installation requirements, for example those concerning minimum bend radii.

1.14.4 In addition to 1.10.4, materials used for electrical equipment, cables and accessories within passenger accommodation areas are not to be capable of producing excessive quantities of smoke and toxic products, when tested in accordance with an acceptable and relevant Standard.

1.15 Lightning protection

1.15.1 In order to minimise the risks of damage to the craft and its electrical installation due to lightning, crafts having non-metallic masts or topmasts are to be fitted with lightning conductors in accordance with the applicable requirements of IEC 60092-401 *Electrical installations in ships. Part 401: Installation and test of completed installation* or an alternative and relevant National Standard.

1.15.2 In addition to the primary protection requirements in 1.15.1, precautions are to be taken to protect essential electronic equipment that may be susceptible to damage from voltage pulses attributable to the secondary effects of lightning. This may be achieved by suitable design and/or the use of additional protective devices, such as surge arrestors. Resultant induced voltages may be further reduced by the use of earthed metallic screened cables.

1.16 Programmable electronic systems

1.16.1 Where programmable electronic systems are implemented and used to control the electrical installation, or to provide safety functions in accordance with the requirements of this Chapter (e.g. electric propulsion, circuit-breaker settings, switchgear and control gear controllers, etc.), the arrangements are to satisfy the applicable requirements of Ch 1,2.10 to 2.13.

1.16.2 Where 1.16.1 applies, proposed modifications to software and acceptance testing and trials are to be in accordance with Ch 1,1.4 and Section 7 as applicable.

■ *Section 2*
Main source of electrical power

2.1 General

2.1.1 The main source of electrical power is to comply with the requirements of this Section without recourse to the emergency source of electrical power.

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2.2 Number and rating of generators and converting equipment

2.2.1 Under seagoing conditions, the number and rating of service generating sets and converting sets, such as transformers and semi-conductor converters, when any one generating set or converting set is out of action, are:

(a) to be sufficient to ensure the operation of electrical services for essential equipment and habitable conditions;

(b) to have sufficient reserve capacity to permit the starting of the largest motor without causing any motor to stall or any device to fail due to excessive voltage drop on the system;

(c) to be capable of providing the electrical services necessary to start the main propulsion machinery from a 'dead craft condition'. The emergency source of electrical power may be used to assist if it can provide power at the same time to those services required to be supplied by Section 3, *see also* 2.3.2.

2.2.2 The arrangement of the craft's main source of power is to be such that the operation of electrical services for essential equipment and habitable conditions can be maintained regardless of the speed and direction of the propulsion machinery shafting.

2.2.3 Where the electrical power requirement to maintain the craft in a normal operational and habitable condition is usually supplied by one generating set, arrangements are to be provided to prevent overloading of the running generator, *see* 6.9. On loss of power there is to be provision for automatic starting and connecting to the main switchboard of the standby set in as short a time as practicable, but in any case within 45 seconds, and automatic sequential restarting of essential services, *see* 1.5.1, in as short a time as practicable.

NOTE

Where the prime mover starting time will result in exceeding this starting and connection time, details are to be submitted for consideration.

2.3 Starting arrangements

2.3.1 The starting arrangements of the generating sets' prime movers are to comply with the requirements of Pt 10, Ch 1 and 2 as applicable.

2.3.2 Where the emergency source of electrical power is required to be used to restore propulsion from a 'dead craft condition', the emergency generator is to be capable of providing initial starting energy for the propulsion machinery within 30 minutes of the 'dead craft condition'. The emergency generator capacity is to be sufficient for restoring propulsion in addition to supplying those services in 3.2.7(a), 3.2.7(b), 3.2.7(c) for passenger craft and yachts greater than 500gt; or 3.3.7(a), 3.3.7(b), 3.3.7(c) and 3.3.7(d)(i) and (vi) for craft required to comply with HSC code; or 3.4.3(a) to (e) and (f) (i) as applicable. *See* Pt 10, Ch 1,7.1.1 and Ch 2,6.1.1 for starting arrangements.

2.4 Prime mover governors

2.4.1 The governing accuracy of the generating sets' prime movers is to meet the requirements of Pt 10, Ch 1 and Ch 2.

2.4.2 The maximum electrical step load switched on or off is not to cause the frequency variation of the electrical supply to exceed the parameters given in 1.7.2, *see also* Pt 10, Ch 1 and Ch 2.

2.5 Main propulsion driven generators not forming part of the main source of electrical power

2.5.1 Generators and generator systems, having the craft's propulsion machinery as their prime mover but not forming part of the craft's main source of electrical power may be used whilst the craft is at sea to supply electrical services required for normal operational and habitable conditions provided that the requirements of 2.5.2 to 2.5.4 are satisfied.

2.5.2 Within the declared operating range of the generators and/or generator system, the specified voltage and frequency variations of the Rules are to be met.

2.5.3 Where there is remote control of the propulsion machinery, arrangements are to ensure that essential machinery power supplies are maintained during manoeuvring conditions in order to prevent a blackout situation.

2.5.4 In addition to the requirements of 2.2.3, arrangements are to be fitted to automatically start one of the generators forming the main source of power should the frequency variations exceed those permitted by the Rules.

■ *Section 3* Emergency source of electrical power

3.1 General

3.1.1 The requirements of this Section apply to passenger craft, to yachts that are 500 gt or more, to cargo craft, patrol and pilot craft, workboats and other similar craft of 500 tons gross tonnage and above, and to cargo craft, patrol and pilot craft, workboats and other similar craft of less than 500 tons gross tonnage for operation in Service Groups 4 and 5. For other craft, *see* Section 19.

3.1.2 Passenger craft and cargo craft constructed in compliance with the HSC Code are to comply with 3.3. Other specified craft are to comply with 3.2 or 3.4 as applicable.

3.1.3 The emergency source of power for other craft will be the subject of special consideration, with due regard to the size and the intended service of the craft.

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3.1.4 Where the main source of electrical power is located in two or more compartments which are not contiguous, each of which has its own self-contained systems, including power distribution and control systems, completely independent of each other and such that a fire or other casualty in any one of the spaces will not affect the power distribution from the others, or to the services required by 3.2, 3.3 or 3.4, the requirements of this Section may be considered satisfied without an additional emergency source of electrical power, provided that:

(a) there is at least one generating set of sufficient capacity to meet the requirements of 3.2, 3.3 or 3.4 in each of at least two non-contiguous spaces;

(b) the generator sets referred to in 3.1.4(a) and their self-contained systems are installed such that a source of electrical power remains available at all times to supply emergency services after damage or flooding in any one compartment.

3.1.5 Non-passenger type craft of 300 tons gross tonnage and above are to comply with 3.7.

3.2 Emergency source of electrical power in passenger craft and for yachts that are 500 gt or more

3.2.1 A self-contained emergency source of electrical power is to be provided.

3.2.2 The emergency source of electrical power, associated transforming equipment, if any, transitional source of emergency power, emergency switchboard and emergency lighting switchboard are to be located above the waterline in the final condition of damage, be operable in that condition, and be readily accessible from the open deck. They are not to be located forward of the collision bulkhead, if fitted. Consideration may also be given to alternative arrangements, such as 3.1.4, which provide an equivalent degree of safety from fire and flooding.

3.2.3 The location of:

- the emergency source of electrical power and associated transforming equipment, if any;
- the transitional source of emergency power;
- the emergency switchboard; and
- the emergency lighting switchboard;

in relation to:

- the main source of electrical power, associated transforming equipment, if any; and
- the main switchboard;

is to be such as to ensure that a fire or other casualty in spaces containing:

- the main source of electrical power, associated transforming equipment, if any, and the main switchboard; or
- in any machinery space of Category A;

will not interfere with the supply, control and distribution of emergency electrical power.

3.2.4 The space containing:

- the emergency source of electrical power, associated transforming equipment, if any;
- the transitional source of emergency electrical power; and
- the emergency switchboard;

is not to be contiguous to the boundaries of machinery spaces of Category A or those spaces containing:

- the main source of electrical power, associated transforming equipment, if any; or
- the main switchboard.

3.2.5 Where compliance with 3.2.3 or 3.2.4 is not practicable, details of the proposed arrangements are to be submitted.

3.2.6 Provided that suitable measures are taken for safeguarding independent emergency operation under all circumstances, the emergency generator may be used exceptionally, and for short periods, to supply non-emergency circuits. Failure of the emergency switchboard when being used in other than an emergency is not to put at risk the operation of the craft or yacht.

3.2.7 The electrical power available is to be sufficient to supply all those services that are essential for safety in an emergency, due regard being paid to such services as may have to be operated simultaneously. The emergency source of electrical power is to be capable, having regard to starting currents and the transitory nature of certain loads, of supplying simultaneously at least the following services for the periods specified hereinafter, if they depend upon an electrical source for their operation:

(a) for a period of 36 hours, emergency lighting:
  (i) at every lifeboat or liferaft preparation station, muster and embarkation station and oversides;
  (ii) in alleyways, stairways and exits, giving access to the muster and embarkation stations;
  (iii) in all service and accommodation alleyways, stairways and exits and personnel lift cars;
  (iv) in the machinery spaces, and main generating stations including their control positions;
  (v) in all control stations, machinery control rooms, and at each main and emergency switchboard;
  (vi) at the stowage positions for firemen's outfits and life saving appliances;
  (vii) at the steering gear; and
  (viii) at the fire pump, the sprinkler pump and the emergency bilge pump and at the starting position of their motors.

(b) for a period of 36 hours:
  (i) the navigation lights, and other lights as required by the International Regulations for Preventing Collisions at Sea in force; and
  (ii) the radiocommunications, as required by statutory regulations.

(c) for a period of 36 hours:
  (i) all internal communication equipment required in an emergency;
  (ii) the navigational equipment as required by statutory regulations; where such provision is unreasonable or impracticable this requirement may be waived for craft of less than 5000 tons gross;
  (iii) the fire detection, fire alarm and general alarm system, manual alarms, and the fire door holding and release system; and

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(iv) the intermittent operation of the daylight signalling lamps, the craft's whistle, the manually-operated call points and all internal signals that are required in an emergency;

unless such services have an independent supply for the period of 36 hours from an accumulator battery, suitably located for use in an emergency;

(d) for a period of 36 hours:
- (i) emergency fire pump;
- (ii) the automatic sprinkler pump, if fitted;
- (iii) the emergency bilge pump and all the equipment essential for the operation of electrically powered remote controlled bilge valves; and
- (iv) essential electrically powered instruments and control for propulsion machinery, if alternate sources of power are not available for such devices.

(e) for a period of 10 min, power drives for directional control devices including those required to direct thrust forward and astern, unless there is a manual alternative complying with Pt 14, Ch 1,6.1.4;

(f) for a period of half an hour;
- (i) any watertight doors required by Chapter 2 to be power operated together with their control, indication and alarm signals;
- (ii) the emergency arrangements to bring the lift cars to deck level for the escape of persons. The passenger lift cars may be brought to deck level sequentially in an emergency;

(g) where applicable, the services required by 2.3.2; and

(h) where applicable, the air compressors for breathing apparatus cylinders referred to in 16.10.1.

3.2.8 The emergency source of electrical power may be either a generator or an accumulator battery, which is to comply with the following:

(a) Where the emergency source of electrical power is a generator it is to be:
- (i) driven by a suitable prime mover with an independent supply of fuel having a flash point (closed cup test) of not less than 43°C;
- (ii) started automatically upon failure of the electrical supply from the main source of electrical power and is to be automatically connected to the emergency switchboard; those services referred to in 3.2.7 are then to be transferred automatically to the emergency generating set. The automatic starting system and the characteristics of the prime mover are to be such as to permit the emergency generator to carry its full rated load as quickly as is safe and practicable, subject to a maximum of 45 seconds; and
- (iii) provided with a transitional source of emergency electrical power according to 3.2.9.

(b) Where the emergency source of electrical power is an accumulator battery, it is to be capable of:
- (i) carrying the emergency electrical load without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage;
- (ii) automatically connecting to the emergency switchboard in the event of failure of the main source of electrical power; and
- (iii) immediately supplying at least those services specified in 3.2.9.

3.2.9 The transitional source of emergency electrical power required by 3.2.8 may consist of an accumulator battery suitably located for use in an emergency which is to operate without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage and be of sufficient capacity and so arranged as to supply automatically in the event of failure of either the main or emergency source of electrical power for half an hour at least the following services, if they depend upon an electrical source for their operation:

(a) (i) the lighting required by 3.2.7(a) and (b);
- (ii) the services required by 3.2.7(c)(i), (iii) and (iv) unless such services have an independent supply for the period specified from an accumulator battery suitably located for use in an emergency;

(b) with respect to watertight doors:
- (i) power to operate the watertight doors but not necessarily simultaneously, unless an independent temporary source of stored energy is provided. The power source should have sufficient capacity to operate each door at least three times i.e. closed-open-closed, against an adverse list of 15°;
- (ii) power to the control, indication and alarm circuits for the watertight doors.

3.2.10 The emergency switchboard is to be installed as near as is practicable to the emergency source of electrical power.

3.2.11 Where the emergency source of electrical power is a generator, the emergency switchboard is to be located in the same space unless the operation of the emergency switchboard would thereby be impaired.

3.2.12 No accumulator battery fitted in accordance with this Section, unless for engine starting, is to be installed in the same space as the emergency switchboard. An indicator is to be mounted in a suitable place on the main switchboard or in the machinery control room to indicate when the batteries constituting either the emergency source of electrical power or the transitional source of emergency electrical power are being discharged, and provision is to be made to charge them *in situ* from a reliable on board supply.

3.2.13 The emergency switchboard is to be supplied during normal operation from the main switchboard by an interconnector feeder which is to be adequately protected at the main switchboard against overload and short circuit and which is to be disconnected automatically at the emergency switchboard upon failure of the main source of electrical power. Where the system is arranged for feedback operation, the interconnector feeder is also to be protected at the emergency switchboard at least against short circuit.

3.2.14 In order to ensure the ready availability of the emergency source of electrical power to supply circuits required to provide emergency services, arrangements are to be made, where necessary, to automatically disconnect non-emergency circuits from the emergency switchboard in the event of overloading to ensure that electrical power is available to the emergency circuits.

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3.2.15 Provision is to be made for the periodic testing of the complete emergency system and is to include the testing of automatic starting arrangements.

3.2.16 In addition to the emergency lighting required by 3.2.7(a) passenger craft with roll on–roll off cargo spaces or special category spaces, are to be provided with the following:

(a) in all passenger public spaces and alleyways supplementary electric lighting that can operate for at least three hours when all other sources of electric power have failed and under any condition of heel. The illumination provided is to be such that the approach to the means of escape can be readily seen. The source of power for the supplementary lighting is to consist of accumulator batteries within the lighting units that are continuously charged where practicable, from the emergency switchboard. Consideration may be given to other means of lighting which is at least as effective. The supplementary lighting is to be such that any failure of the lamp will be immediately apparent. Any accumulator battery provided is to be replaced at intervals having regard to the specified service life in the ambient conditions that they are subject to in service.

(b) A portable rechargeable battery operated lamp is to be provided in every crew space alleyway, recreational space and every working space which is normally occupied unless supplementary emergency lighting, as required by (a) is provided.

3.2.17 A lesser period than the 36 hour period specified in 3.2.7, but not less than 18 hours, may be considered for yachts of 500 gt or more when in accordance with the relevant Statutory Regulations of the National Authority of the country in which the craft is to be registered.

3.3 Emergency source of electrical power in craft required to comply with the HSC Code

3.3.1 The arrangements for the emergency source of electrical power are to satisfy the requirements of this sub-Section and, additionally, 3.2.1, 3.2.6, 3.2.8, 3.2.11 and 3.2.13 to 3.2.15.

3.3.2 The emergency source of electrical power, associated transforming equipment, if any, transitional source of emergency power, emergency switchboard and emergency lighting switchboard are to be located above the waterline in the final condition of damage, be operable in that condition, and be readily accessible from the open deck. They are not to be located forward of the collision bulkhead, if fitted.

3.3.3 The location of:

- the emergency source of electrical power and associated transforming equipment, if any;
- the transitional source of emergency power;
- the emergency switchboard; and
- the emergency lighting switchboard;

in relation to:

- the main source of electrical power, associated transforming equipment, if any, and;
- the main switchboard;

is to be such as to ensure that a fire or other casualty in spaces containing:

- the main source of electrical power, associated transforming equipment, if any, and the main switchboard;
- or in any machinery space;

will not interfere with the supply, control and distribution of emergency electrical power.

3.3.4 The space containing:

- the emergency source of electrical power, associated transforming equipment, if any;
- the transitional source of emergency electrical power; and
- the emergency switchboard;

is not to be contiguous to the boundaries of machinery spaces and those spaces containing:

- the main source of electrical power, associated transforming equipment, if any; or
- the main switchboard.

3.3.5 Where compliance with 3.3.3 or 3.3.4 is not practicable, details of the proposed arrangements are to be submitted.

3.3.6 For passenger craft with the restrictive notation Passenger (A), the emergency source of power is to be capable of supplying simultaneously the services referred to in 3.3.7(a), 3.3.7(b) and 3.3.7(d)(ii) and (vi), for a period of 5 hours, the services referred to in 3.3.7(c) and (e) for the periods specified, and, additionally, the 'Not under command' lights for a period of 12 hours.

3.3.7 The electrical power available is to be sufficient to supply all those services that are essential for safety in an emergency, due regard being paid to such services as may have to be operated simultaneously. The emergency source of electrical power is to be capable, having regard to starting currents and the transitory nature of certain loads, of supplying simultaneously at least the following services for the periods specified hereinafter, if they depend upon an electrical source for their operation:

(a) for a period of 12 hours, emergency lighting:
  (i) at the stowage positions of life-saving appliances and, additionally, for passenger craft at the preparation, launching and deployed positions of survival craft and equipment for embarkation into those craft;
  (ii) at all escape routes, such as alleyways, stairways, exits from accommodation and service spaces, embarkation points, etc.;
  (iii) in the passenger compartments or public spaces, if any;
  (iv) in the machinery spaces, and main emergency generating spaces including their control positions;
  (v) in control stations;
  (vi) at the stowage positions for fireman's outfits; and
  (vii) at the steering gear;

(b) for a period of 12 hours:
  (i) the navigation lights, and other lights required by the *International Regulations for Preventing Collisions at Sea* in force;
  (ii) electrical internal communication equipment for announcements during evacuation;
  (iii) fire detection and general alarm system and manual fire-alarms; and

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(iv) remote control devices of fire-extinguishing systems if electrical;

(c) for a period of four hours of intermittent operation:
  (i) the daylight signalling lamps, if they have no independent supply from their own accumulator battery; and
  (ii) the craft's whistle or siren, if electrically driven;

(d) for a period of 12 hours:
  (i) the navigational equipment as required by statutory Regulations; where such provision is unreasonable or impracticable, this requirement may be waived for craft of less than 5000 gross tonnage;
  (ii) essential electrically powered instruments and controls for propulsion machinery, if alternate sources of power are not available for such devices;
  (iii) emergency fire pump;
  (iv) the automatic sprinkler pump and drencher pump, if fitted;
  (v) the emergency bilge pump and all the equipment essential for the operation of electrically powered remote controlled bilge valves; and
  (vi) the craft radio facilities required to be available in an emergency;

(e) for a period of 10 minutes:
  (i) power drives for directional control devices including those required to direct thrust forward and astern, unless there is a manual alternative complying with Pt 14, Ch 1,6.1.4;

(f) for Passenger (B) craft only, for a period of half an hour:
  (i) power operated sliding watertight doors together with their indicators and warning signals.

(g) for any passenger high speed craft with lifts, for a period of half an hour:
  (i) the emergency arrangements to bring the lift cars to deck level for the escape of persons. The passenger lift cars may be brought to deck level sequentially in an emergency.

3.3.8 The emergency source of electrical power may be either a generator or an accumulator battery, which is to comply with the following:

(a) Where the emergency source of electrical power is a generator it is to be:
  (i) driven by a suitable prime mover with an independent supply of fuel, having a flashpoint (closed cup test) of not less than 43° C;
  (ii) started automatically upon failure of the main source of electrical power supply unless a transitional source of emergency electrical power complying with 3.3.9 is provided; where the emergency generator is automatically started, it is to be automatically connected to the emergency switchboard; those services referred to in 3.3.9 are to be connected automatically to the emergency generator; and
  (iii) provided with a transitional source of emergency electrical power as specified in 3.3.9, except on cargo craft where it may be omitted when an emergency generator is provided capable both of supplying the services mentioned in that paragraph and of being automatically started and supplying the required load as quickly as is safe and practicable subject to a maximum of 45 seconds.

(b) Where the emergency source of electrical power is an accumulator battery it is to be capable of:
  (i) carrying the emergency electrical load without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage;
  (ii) automatically connecting to the emergency switchboard in the event of failure of the main source of electrical power; and
  (iii) immediately supplying at least those services specified in 3.3.9.

3.3.9 The transitional source of emergency electrical power where required by 3.3.8 is to consist of an accumulator battery suitably located for use in an emergency which is to operate without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage and be of sufficient capacity and is to be so arranged as to supply automatically in the event of failure of either the main or the emergency source of electrical power for half an hour at least the following services if they depend upon an electrical source for their operation:

(a) the lighting required by 3.3.7(a) and (b). For this transitional phase, the required emergency electric lighting, in respect of the machinery space and accommodation and service spaces, may be provided by permanently fixed, individual, automatically charged, relay operated accumulator lamps; and

(b) the services required by 3.3.7(b) and (c);

(c) with respect to watertight doors:
  (i) power to operate the watertight doors but not necessarily simultaneously, unless an independent temporary source of stored energy is provided. The power source should have sufficient capacity to operate each door at least three times, i.e. closed-open-closed, against an adverse list of 15°; and
  (ii) power to the control, indication and alarm circuits for the watertight doors.

Alternatively, the above services may have independent supplies, for the period specified, from accumulator batteries suitably located for use in an emergency.

3.3.10 For passenger craft, propulsion and direction system instruments and controls power supplies are to be arranged to provide an uninterruptible supply of emergency power.

3.3.11 No accumulator battery fitted in accordance with this Section, unless for engine starting, is to be installed in the same space as the emergency switchboard. An indicator is to be mounted in a suitable place in the craft's operating compartment to indicate when the batteries constituting either the emergency source of electrical power or the transitional source of electrical power are being discharged, and provision is to be made to charge them *in situ* from a reliable on board supply.

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3.3.12 In addition to the emergency lighting required by 3.3.5(a) to (c), passenger craft with roll on-roll off spaces are to be provided with the following:

(a) in all passenger public spaces and alleyways supplementary electric lighting that can operate for at least three hours when all other sources of electric power have failed and under any condition of heel. The illumination provided is to be such that the approach to the means of escape can be readily seen. The source of power for the supplementary lighting is to consist of accumulator batteries within the lighting units that are continuously charged, where practicable, from the emergency switchboard. Consideration may be given to other means of lighting which is at least as effective. The supplementary lighting is to be such that any failure of the lamp will be immediately apparent. Any accumulator battery provided is to be replaced at intervals having regard to the specified service life in the ambient conditions that they are subject to in service; and

(b) a portable rechargeable battery operated lamp is to be provided in every crew space alleyway, recreational space and every working space which is normally occupied unless supplementary emergency lighting, as required by (a) is provided.

3.4 Emergency source of electrical power in cargo craft, patrol and pilot craft, workboats and other similar craft of 500 tons gross tonnage and above; and cargo craft, patrol and pilot craft, workboats and other similar craft of less than 500 tons gross tonnage for operation in Service Groups 4 to 6

3.4.1 The arrangements for the emergency source of electrical power are to satisfy the requirements of this sub-Section and, additionally, 3.2.1, 3.2.3, 3.2.6 and 3.2.10 to 3.2.15.

3.4.2 The emergency source of electrical power, associated transforming equipment, if any, transitional source of emergency power, emergency switchboard and emergency lighting switchboard are to be located such that the emergency generator and the main generators together meet the requirements of 3.1.4(a) and (b).

3.4.3 The electrical power available is to be sufficient to supply all those services that are essential for safety in an emergency, due regard being paid to such services as may have to be operated simultaneously. The emergency source of electrical power is to be capable, having regard to starting currents and the transitory nature of certain loads, of supplying simultaneously at least the following services for the periods specified hereinafter, if they depend upon an electrical source for their operation:

(a) for a period of three hours, emergency lighting at every survival craft preparation station, muster and embarkation station and over the sides;

(b) for a period of 12 hours, emergency lighting:
  (i) at the stowage positions of life-saving appliances:
  (ii) at all escape routes, such as alleyways, stairways, exits from accommodation and service spaces, embarkation points, etc.;
  (iii) in the public spaces, if any;
  (iv) in the machinery spaces, and main emergency generating spaces including their control positions;
  (v) in control stations;
  (vi) at the stowage positions for fireman's outfits;
  (vii) at the steering gear; and
  (viii) at the emergency fire pump, at the sprinkler pump, if any, and at the emergency bilge pump, if any, and at the starting positions of their motors;

(c) for a period of 12 hours:
  (i) the navigation lights, and other lights required by the *International Regulations for Preventing Collisions at Sea* in force; and
  (ii) the radio communications, as required by statutory regulations;

(d) for a period of 12 hours:
  (i) electrical internal communication equipment for announcements during evacuation;
  (ii) fire detection and general alarm system and manual fire alarms; and
  (iii) remote control devices of fire-extinguishing systems if electrical;

  unless such services have an independent supply for a period of 12 hours from an accumulator battery, suitably located for use in an emergency;

(e) for a period of four hours of intermittent operation:
  (i) the daylight signalling lamps, if they have no independent supply from their own accumulator battery; and
  (ii) the craft's whistle or siren, if electrically driven;

(f) for a period of 12 hours:
  (i) the navigational equipment as required by statutory regulations; where such provision is unreasonable or impracticable, this requirement may be waived for craft of less than 5000 tons gross tonnage;
  (ii) essential electrically powered instruments and controls for propulsion machinery, if alternate sources of power are not available for such devices;
  (iii) emergency fire pump;
  (iv) the automatic sprinkler pump and drencher pump, if fitted; and
  (v) the emergency bilge pump and all the equipment essential for the operation of electrically powered remote controlled bilge valves;

(g) for a period of 10 min:
  (i) power drives for directional control devices including those required to direct thrust forward and astern, unless there is a manual alternative complying with Pt 14, Ch 1,6.1.4.

(h) for a period of half an hour:
  (i) any watertight doors required by Chapter 2 to be power-operated together with their indicators and warning signals; and

(j) where applicable, the services required by 2.4.2.

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3.4.4 The emergency source of electrical power may be either a generator or an accumulator battery, which is to comply with the following:

(a) Where the emergency source of electrical power is a generator it is to be:
  (i) driven by a suitable prime mover with an independent supply of fuel, having a flash point (closed cup test) of not less than 43°C;
  (ii) started automatically upon failure of the main source of electrical power supply unless a transitional source of emergency electrical power in accordance with 3.4.5 is provided; where the emergency generator is automatically started, it is to be automatically connected to the emergency switchboard; those services referred to in 3.4.5 are to be connected automatically to the emergency generator; and
  (iii) provided with a transitional source of emergency electrical power as specified in 3.4.5 unless an emergency generator is provided capable both of supplying the services mentioned in that paragraph and of being automatically started and supplying the required load as quickly as is safe and practicable subject to a maximum of 45 seconds.

(b) Where the emergency source of electrical power is an accumulator battery it is to be capable of:
  (i) carrying the emergency electrical load without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage;
  (ii) automatically connecting to the emergency switchboard in the event of failure of the main source of electrical power; and
  (iii) immediately supplying at least those services specified in 3.4.5.

3.4.5 The transitional source of emergency electrical power where required by 3.4.4 is to consist of an accumulator battery suitably located for use in an emergency which is to operate without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage and be of sufficient capacity and is to be so arranged as to supply automatically in the event of failure of either the main or the emergency source of electrical power for half an hour at least the following services if they depend upon an electrical source for their operation:

(a) the lighting required by 3.4.3(a) to (c). For this transitional phase, the required emergency electric lighting, in respect of the machinery space and accommodation and service spaces may be provided by permanently fixed, individual, automatically charged, relay operated accumulator lamps, and

(b) all services required by 3.4.3(d)(i) to (iii) and (e) unless such services have an independent supply for the period specified from an accumulator battery suitably located for use in an emergency.

(c) with respect to watertight doors:
  (i) power to operate the watertight doors but not necessarily simultaneously, unless an independent temporary source of stored energy is provided. The power source should have sufficient capacity to operate each door at least three times i.e. closed-open-closed, against an adverse list of 15°;
  (ii) power to the control, indication and alarm circuits for the watertight doors for half an hour.

3.5 Starting arrangements

3.5.1 Where the emergency source of power is a generator, the starting arrangements are to comply with the requirements given in Part 10.

3.6 Prime mover governor

3.6.1 Where the emergency source of power is a generator, the governor is to comply with 2.4.

3.7 Radio installation

3.7.1 Every radio installation as required by statutory regulations is to be provided with reliable, permanently arranged electrical lighting, independent of the main and emergency sources of electrical power, for the adequate illumination of the radio controls for operating the radio installation.

3.7.2 A reserve source or sources of energy is to be provided on every craft, for the purpose of conducting distress and safety radio-communications, in the event of failure of the craft's main and emergency sources of electrical power. The reserve source or sources of energy is to be capable of simultaneously operating the VHF radio installation and, as appropriate for the sea or sea area for which the craft is equipped, either the MF radio installation, the MF/HF radio installation, or the INMARSAT 'ship to earth' station and any of the additional loads mentioned in 3.7.4, 3.7.5 and 3.7.7 for a period of at least one hour. The reserve source or sources of energy need not supply independent HF and MF radio installations at the same time.

3.7.3 The reserve source or sources of energy is to be independent of the propelling power of the craft and the craft's electrical system.

3.7.4 Where, in addition to the VHF radio installation, two or more of the other radio installations, referred to in 3.7.2, can be connected to the reserve source or sources of energy, the reserve source or sources are to be capable of simultaneously supplying, for the period specified by 3.7.2, the VHF radio installation and:

(a) all other radio installations which can be connected to the reserve source or sources of energy at the same time; or

(b) whichever of the other radio installations will consume the most power, if only one of the other radio installations can be connected to the reserve source or sources of energy at the same time as the VHF radio installation.

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3.7.5 The reserve source or sources of energy may be used to supply the electrical lighting required by 3.7.1.

3.7.6 Where a reserve source of energy consists of a rechargeable accumulator battery or batteries a means of automatically charging the batteries is to be provided which is to be capable of recharging them to minimum capacity requirements within 10 hours.

3.7.7 If an uninterrupted input of information from the craft's navigational or other equipment to a radio installation as referred to in 3.7.2 is needed to ensure its proper performance, means are to be provided to ensure the continuous supply of such information in the event of failure of the craft's main or emergency source of electrical power.

■ *Section 4*
External source of electrical power

4.1 Temporary external supply (shore supply)

4.1.1 Where arrangements are made for the supply of electricity from a source on shore or elsewhere, a connection box is to be installed in a position suitable for the convenient reception of flexible cables from the external source and containing a circuit-breaker or isolating switch and fuses and terminals including one earthed, of ample size and suitable shape to facilitate a satisfactory connection of three-phase external supplies with earthed neutrals.

4.1.2 Suitable cables, permanently fixed, are to be provided, connecting the terminals in the connection box to a linked switch and/or a circuit-breaker at the main switchboard. An indicator is to be provided at the main switchboard in order to show when the cables are energised.

4.1.3 Means are to be provided for checking the phase sequence of the incoming supply.

4.1.4 At the connection box a notice is to be provided giving full information on the system of supply, the normal voltage and frequency of the installation's system and the procedure for carrying out the connection.

4.1.5 Alternative arrangements may be submitted for consideration.

4.2 Permanent external supply

4.2.1 Details are to be submitted.

■ *Section 5*
Supply and distribution

5.1 Systems of supply and distribution

5.1.1 The following systems of generation and distribution are acceptable:

(a) d.c., two-wire;
(b) a.c., single-phase, two-wire;
(c) a.c., three-phase;
three-wire;
four-wire with neutral solidly earthed but without hull return.

5.1.2 System voltages for both alternating current and direct current in general are not to exceed:

(a) 15 000 V for propulsion purposes;
(b) 500 V for power, cooking and heating equipment permanently connected to fixed wiring;
(c) 250 V for lighting, heaters in cabins and public rooms, and other applications not mentioned above;
(d) Voltages exceeding these will be the subject of special consideration.

5.1.3 The arrangement of the main system of supply is to be such that a fire or other casualty in any space containing the main source of electrical power, associated converting equipment, if any, the main switchboard or the main lighting switchboard will not render inoperable any emergency service, other than those located within the space where the fire or casualty has occurred.

5.1.4 The main switchboard is to be so placed relative to the main source of power that, as far as is practicable, the integrity of the main system of supply will be affected only by a fire or other casualty in one space.

5.1.5 The arrangement of the emergency system of supply is to be such that a fire or other casualty in spaces containing the emergency source of electrical power, associated converting equipment, if any, the emergency switchboard and the emergency lighting switchboard, will not cause loss of services required to maintain the propulsion and safety of the craft.

5.1.6 Distribution systems required in an emergency are to be so arranged that a fire in any main vertical zone will not interfere with the emergency distribution in any other such zone.

5.1.7 Feeders from the main and the emergency sources of electrical power are to be separated both vertically and horizontally as widely as is practicable.

5.1.8 For Passenger (A) or Passenger (B) Craft or cargo craft of 500 tons gross tonnage and over, and in any case where the total installed electrical power of the main generating sets is in excess of 3 MW or is supplied at high voltage, arrangements are to be made so that it is possible to split the switchboard, by a multipole linked circuit-breaker, disconnector or switch-disconnector, into at least two independent sections, each supplied by at least one generator.

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5.1.9 Where 5.1.8 is applicable and the essential services which are duplicated are supplied from a section board, arrangements are to be made so that it is possible to split the section board into at least two independent sections each supplied by an independent section of the main switchboard either directly or through a transformer.

5.1.10 For Passenger (B) high speed craft, each part of the main busbars with its associated generators is to be arranged in separate compartments.

5.2 Essential services

5.2.1 Essential services that are required to be duplicated are to be served by individual circuits, separated in their switchboard or section board and throughout their length as widely as is practicable without the use of common feeders, protective devices, control circuits or control gear assemblies, so that any single fault will not cause the loss of both services.

5.2.2 Where 5.2.1 is applicable the main busbars of the switchboard, or section boards, are to be capable of being split, by removable links or other means, into at least two independent sections, each supplied by at least one generator, either directly or through a converter. The essential services are to be equally divided, as far as is practicable, between the independent sections.

5.2.3 Where 5.1.8 is applicable provision is to be made to transfer to a temporary circuit those essential services which are not required to be, and have not been, duplicated in the event of loss of their normal section of switchboard or section board.

5.2.4 Where the loss of the electrical supply to a particular essential service which is not duplicated would cause serious risk to the craft, it is to be fed by two independent supplies complying with 5.2.1. Such circuits are to be provided with short circuit protection and an overload and phase-failure alarm. Failure of either supply is not to cause risk to the craft during switching to the alternative supply.

5.3 Isolation and switching

5.3.1 The incoming and outgoing circuits from every switchboard or section board are to be provided with a means of isolation and switching to permit each circuit to be switched off:

(a) on load;
(b) for mechanical maintenance;
(c) in an emergency to prevent or remove danger.

Precautions are to be taken to minimise the risk of inadvertent or accidental switching.

5.3.2 Isolation and switching is to be by means of a circuit breaker or switch arranged to open and close simultaneously all insulated poles. Where a switch is used as the means of isolation and switching, it is to be capable of:

(a) switching off the circuit on load;
(b) withstanding, without damage, the overcurrents which may arise during overloads and short circuit.

In addition, these requirements do not preclude the provision of single pole control switches in final sub-circuits, for example light switches. For circuit-breakers, *see* 6.5 and 7.3.

5.3.3 Provision is to be made, in accordance with one of the following, to prevent any circuit being inadvertently energised:

(a) the circuit breaker or switch can be withdrawn, or locked in the open position;
(b) the operating handle of the circuit breaker or switch can be removed;
(c) the circuit fuses, where fitted, can be readily removed and retained by authorised personnel.

5.3.4 All lighting and power circuits installed in unattended spaces are to be controlled by multipole linked switches situated outside such spaces. Provision is to be made for the complete isolation of these circuits and locking the means of control in the off position.

5.3.5 Where arrangements are in place for automatic changeover between two or more supplies of electrical power in the event of failure of one supply, the arrangements are to be such that a fault in one feeder does not result in the loss of all supplies to the automatic changeover switch.

5.3.6 Where a section board, distribution board or item of equipment can be supplied by more than one circuit, a switching device is to be provided to permit each incoming circuit to be isolated and the supply transferred to the alternative circuit.

5.3.7 The switching device required by 5.3.6 is to be situated within or adjacent to the section board, distribution board or item of equipment. Where necessary, interlocking arrangements are to be provided to prevent circuits being inadvertently energised.

5.3.8 A notice is to be fixed to any section board, distribution board or item of equipment to which 5.3.5 applies warning personnel before gaining access to live parts of the need to open the appropriate circuit breakers or switches, unless an interlocking arrangement is provided so that all circuits concerned are isolated before access is gained.

5.4 Insulated distribution systems

5.4.1 A device(s) is to be installed for every insulated distribution system, whether primary or secondary, for power, heating and lighting circuits, to continuously monitor the insulation level to earth and to operate an alarm in the event of an abnormally low level of insulation resistance.

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5.4.2 Where any insulated lower voltage system is supplied through transformers from a high voltage system, adequate precautions are to be taken to prevent the low voltage system being charged by capacitive leakage from the high voltage system.

5.4.3 Where filters are fitted, for example to reduce EMC susceptibility, these are not to cause distribution systems to be unintentionally connected to earth.

5.5 Earthed distribution systems

5.5.1 No fuse, non-linked switch or non-linked circuit-breaker is to be inserted in an earthed conductor. Any switch or circuit-breaker fitted is to operate simultaneously in the earthed conductor and the insulated conductors. These requirements do not preclude the provision (for test purposes) of an isolating link to be used only when the other conductors are isolated.

5.5.2 For high speed craft, earthed electrical distribution systems are not to be used, with the exception of earthed intrinsically safe circuits, in areas where an explosive gas atmosphere may arise from the presence of fuel with a flash point below 43°C, *see* Pt 15, Ch 3,3.1.

5.5.3 For high voltage systems, where the earthed neutral system of generation and primary distribution is used, earthing is to be through an impedance in order to limit the total earth fault current to a magnitude which does not exceed that of the three phase short circuit current for which the generators are designed.

5.5.4 Generator neutrals may be connected in common, provided that the third harmonic content of the voltage waveform of each generator does not exceed five per cent.

5.5.5 Where a switchboard is split into sections operated independently or where there are separate switchboards, neutral earthing is to be provided for each section or for each switchboard. Means are to be provided to ensure that the earth connection is not removed when generators are isolated.

5.5.6 A means of isolation is to be fitted in the earthing connection of each generator so that generators can be completely isolated for maintenance.

5.5.7 All earthing impedances are to be connected to a common earth connection/bar. The connections to the common earth connection/bar are to be so arranged that any circulating currents in the earth connections do not interfere with radio, radar, communication and control equipment circuits.

5.6 Diversity factor

5.6.1 Circuits supplying two or more final sub-circuits are to be rated in accordance with the total connected load subject, where justified, to the application of a diversity factor. Where spare ways are provided on a section or distribution board, an allowance for future increase of load is to be added to the total connection load before application of any diversity factor.

5.6.2 A diversity factor may be applied to the calculation for size of cable and rating of switchgear and fusegear, taking into account the duty cycle of the connected loads and the frequency and duration of any motor starting loads.

5.6.3 For winches and crane motors the diversity factor is to be calculated and submitted when required.

5.7 Lighting circuits

5.7.1 Lighting circuits are to be supplied by final sub-circuits separate from those for heating and power. This does not preclude the supply from a lighting circuit supplying a single fixed appliance, such as a cabin fan, a dry shaver, a wardrobe or anti-condensation heater, taking a maximum current of 2 A. (This does not apply to cabin and wardrobe heaters).

5.7.2 Lighting for machinery spaces, control stations, normal working spaces, large galleys, corridors, stairways leading to boat decks and in public rooms is to be supplied from at least two final sub-circuits in such a way that failure of any one of the circuits does not leave the space in darkness. One of these circuits may be the emergency circuit, provided it is normally energised.

5.7.3 Lighting for enclosed hazardous spaces is to be supplied from at least two final sub-circuits to permit light from one circuit to be retained while maintenance is carried out on the other.

5.7.4 Emergency lighting is to be fitted in accordance with Section 3, *see also* Section 17.

5.8 Motor circuits

5.8.1 A separate final sub-circuit is to be provided for every motor for essential services, *see* 1.5.1.

5.9 Motor control

5.9.1 Every electric motor is to be provided with efficient means for starting and stopping so placed as to be easily operated by the person controlling the motor. Every motor above 0,5 kW is to be provided with control apparatus as given in 5.9.2 to 5.9.4.

5.9.2 Means to prevent undesired restarting after a stoppage due to low volts or complete loss of volts are to be provided. This does not apply to motors where a dangerous condition might result from the failure to restart automatically, e.g. steering gear motor.

5.9.3 Means for automatic disconnection of the supply in the event of excess current due to mechanical overloading of the motor are to be provided, *see also* 6.9.

5.9.4 Motor control gear is to be suitable for the starting current and for the full load rated current of the motor.

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Section 6
System design – Protection

6.1 General

6.1.1 Installations are to be protected against over-currents including short-circuits, and other electrical faults. The tripping/fault clearance times of the protective devices are to provide complete and co-ordinated protection to ensure:

(a) availability of essential and emergency services under fault conditions through discriminative action of the protective devices; as far as practicable the arrangements are also to secure the availability of other services;

(b) elimination of the fault to reduce damage to the system and hazard of fire.

6.1.2 Short-circuit and overload protection are to be provided in each non-earthed line of each system of supply and distribution, unless exempted under the provisions of any paragraph in this Section.

6.1.3 The protection of circuits is to be such that a fault in a circuit does not cause the interruption of supplies used to provide emergency or essential services other than those dependent on the circuit where the fault occurred. For circuits used to provide essential services which need not necessarily be in continuous operation to maintain propulsion and steering but which are necessary for maintaining the vessel's safety, arrangements that ensure that a fault in a circuit does not cause the sustained interruption of supply to healthy circuits may be accepted. Such arrangements are to ensure the supply to healthy circuits is automatically re-established in sufficient time after a fault in a circuit.

6.1.4 Protection systems are to be developed using a systematic design procedure incorporating verification and validation methods to ensure successful implementation of the requirements above. Details of the procedures used are to be submitted when requested. An approved copy of the details required by 1.2.3 and 1.2.4 is to be retained on board and made available to the Surveyor on request.

6.1.5 Short-circuit protection is to be provided for each source of power and at each point at which a distribution circuit branches into two or more subsidiary circuits.

6.1.6 Where protection for generator power circuits is provided at the associated switchboard, the cabling between generator and switchboard is to be of a type, and installed in a manner such as to minimise the risk of short-circuit.

6.1.7 Protection for battery circuits is to be provided at a position external and adjacent to the battery compartments. Where arrangements comply with 11.3.5, the protection may be installed at a suitable location in the battery compartment.

6.1.8 Protection may be omitted from the following:

(a) Engine starting battery circuits.

(b) Circuits for which it can be shown that the risk resulting from spurious operation of the protective device may be greater than that resulting from a fault.

6.1.9 Short-circuit protection may be omitted from cabling or wiring to items of equipment internally protected against short-circuit or where it can be shown that they are unlikely to fail to a short-circuit condition or it is impractical for operational reasons (e.g. within battery compartments), and where the cabling or wiring is installed in a manner such as to minimise the risk of short-circuit.

6.1.10 Overload protection may be omitted from the following:

(a) one line of circuits of the insulated type;

(b) circuits supplying equipment incapable of being overloaded, or overloading the associated supply cable, under normal conditions, and unlikely to fail to an overload condition.

6.2 Protection against short-circuit

6.2.1 Protection against short-circuit currents is to be provided by circuit-breakers or fuses.

6.2.2 The rated short-circuit making and breaking capacity of every protective device is to be adequate for the prospective fault level at its point of installation; the requirements for circuit breakers and fuses are detailed in 6.4 and 6.5 respectively.

6.2.3 The prospective fault current is to be calculated for the following set of conditions:

(a) all generators, motors and, where applicable, all transformers, connected as far as permitted by any interlocking arrangements;

(b) a fault of negligible impedance close up to the load side of the protective device.

6.2.4 In the absence of precise data, the prospective fault current may be taken to be:

(a) for alternating current systems at the main switchboard: 10 x f.l.c. (rated full load current) for each generator that may be connected, or, if the subtransient direct axis reactance, X"d,of each generator is known, $\frac{\text{f.l.c}}{X''_d\ (\text{p.u.})}$ for each generator and 3 x f.l.c. for motors simultaneously in service;
The value derived from the above is an approximation to the r.m.s. symmetrical fault current; the peak asymmetrical fault current may be estimated to be 2,5 times this figure (corresponding to a fault power factor of approximately 0,1).

(b) battery-fed direct current systems at the battery terminals:
  (i) 15 times ampere hour rating of the battery for vented lead-acid cells, or of alkaline type intended for discharge at low rates corresponding to a battery duration exceeding three hours, or
  (ii) 30 times ampere hour rating of the battery for sealed lead-acid cells having a capacity of 100 ampere hours or more, or of alkaline type intended for discharge at high rates corresponding to a battery duration not exceeding three hours and,
  (iii) 6 x f.l.c. for motors simultaneously in service, if applicable.

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6.3 Protection against overload

6.3.1 Fuses, circuit breakers and other protective devices provided for overload protection are to have fusing/tripping characteristics ensuring the protection of cabling and electrical machinery against overheating resulting from mechanical or electrical overload.

6.3.2 Fuses of a type intended for short-circuit protection only (e.g. fuse links complying with IEC 60269-1, of type "a") are not to be used for overload protection.

6.4 Protection against earth faults

6.4.1 Every distribution system that has an intentional connection to earth, by way of an impedance, is to be provided with a means to continuously monitor and indicate the current flowing in the earth connection.

6.4.2 If the current in the earth connection exceeds 5 A there is to be an alarm and the fault current is to be automatically interrupted or limited to a safe value.

6.4.3 The rated short circuit capacity of any device used for interrupting earth fault currents is to be not less than the prospective earth fault current at its point of installation.

6.4.4 Insulated neutral systems with harmonic distortion of the voltage waveform, which may result in earth fault currents exceeding the level given in 6.4.2 because of capacitive effects, are to be provided with arrangements to isolate the faulty circuit(s).

6.5 Circuit-breakers

6.5.1 Circuit-breakers for alternating current systems are to satisfy the following conditions:

(a) the r.m.s. symmetrical breaking current for which the device is rated is to be not less than the r.m.s. value of the a.c. component of the prospective fault current, at the instant of contact separation (i.e. first half cycle, or time of interruption where an intentional time delay is provided to ensure suitability);

(b) the peak asymmetrical making current for which the device is rated is not to be less than the peak value of the prospective fault current at the first half cycle, allowing for maximum asymmetry;

(c) the power factor at which the device short circuit ratings are assigned is to be no greater than that of the prospective fault current; alternatively for high voltage, the rated percentage d.c. component of the short-circuit breaking current of the device is to be not less than that of the prospective fault current.

6.5.2 Circuit-breakers for d.c. systems are to have a breaking current not less than the initial prospective fault current. The time constant of the fault current is not to be greater than that for which the circuit-breaker was tested.

6.5.3 The fault ratings considered in 6.5.1 and 6.5.2, are to be assigned on the basis that the device is suitable for further use after fault clearance.

6.5.4 Circuit- breaker selection is, and ratings are, to be in accordance with the relevant requirements of IEC 60092-202: *Electrical installations in ships – System design – Protection*. Alternative methods acceptable to LR of selecting suitable circuit-breakers may be considered.

6.6 Fuses

6.6.1 Fuses for a.c. systems are to have a breaking current rating not less than the initial r.m.s. value of the a.c. component of the prospective fault current.

6.6.2 Fuses for d.c. systems are to have a d.c. breaking current rating not less than the initial value of the prospective fault current.

6.7 Circuit-breakers requiring back-up by fuse or other device

6.7.1 The use of a circuit-breaker having a short-circuit current capacity less than the prospective short-circuit current at the point of installation is permitted, provided that it is preceded by a device having at least the necessary short-circuit capacity. The generator circuit breakers are not to be used for this purpose.

6.7.2 The same device may back-up more than one circuit-breaker provided that no essential or emergency service is supplied from there, or that any such service is duplicated by arrangements unaffected by tripping of the device.

6.7.3 The combination of back-up device and circuit-breaker is to have a short circuit performance at least equal to that of a single circuit-breaker satisfying the requirements of 6.5.

6.7.4 Evidence of testing of the combination is to be submitted for consideration; alternatively, consideration may be given to arrangements where it can be shown that:

(a) the takeover current, above which the back-up device would clear a fault, is not greater than the rated short-circuit breaking capacity of the circuit-breaker and;

(b) the characteristics of the back-up device, and the prospective fault level, are such that the peak fault current rating of the circuit-breaker cannot be exceeded and;

(c) the Joule integral of the let-through current of the back-up device does not exceed that corresponding to the rated breaking current and opening time of the circuit-breaker.

6.8 Protection of generators

6.8.1 The protective gear required by 6.8.2 and 6.8.3 is to be provided as a minimum.

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6.8.2 Generators not arranged to run in parallel are to be provided with a circuit-breaker arranged to open simultaneously, in the event of short-circuit, overload or under-voltage, all insulated poles. In the case of generators rated at less than 50 kW, a multiple linked switch with a fuse, complying with 5.3.2, in each insulated pole will be acceptable.

6.8.3 Generators arranged to operate in parallel are to be provided with a circuit-breaker arranged to open all insulated poles simultaneously in the event of a short-circuit, an overload or an under-voltage. This circuit-breaker is to be provided with reverse power protection with time delay, selected or set within the limits of two per cent to 15 per cent of full load to a value fixed in accordance with the characteristics of the prime mover. A fall of 50 per cent in the applied voltage is not to render the reverse power mechanism inoperative, although it may alter the amount of reverse power required to open the breakers.

6.8.4 The generator circuit-breaker short-circuit and overload tripping arrangements, or fuse characteristics, are to be such that the machine's thermal withstand capability is not exceeded.

6.8.5 Generators having a capacity of 1500 kVA or above are to be equipped with a protective device which, in the event of a short-circuit in the generator or in the cable between the generator and its circuit breaker, will instantaneously open the circuit breaker and de-excite the generator.

6.8.6 The voltage and time delay settings of the under-voltage release mechanism(s) required by 6.8.2 and 6.8.3 are to be chosen to ensure that the discriminative action required by 6.1.1(a) is maintained.

6.9 Load management

6.9.1 Arrangements are to be made to disconnect automatically, after an appropriate time delay, circuits of the categories noted below, when the generator(s) is/are overloaded; sufficient to ensure the connected generating set(s) is/are not overloaded:

(a) non-essential circuits;
(b) circuits feeding services for habitability, *see* 1.5.2;
(c) in cargo craft, circuits for cargo refrigeration.

NOTE
For emergency generators *see* 3.2.14, with 3.3.1 or 3.4.1 where applicable.

6.9.2 If required, this load switching may be carried out in one or more stages, in which case the non-essential circuits are to be included in the first group to be disconnected.

6.9.3 An alarm is to be provided to indicate when such switching has taken place.

6.9.4 Consideration is to be given to providing means to inhibit automatically the starting of large motors, or the connection of other large loads, until sufficient generating capacity is available to supply them.

6.9.5 When the electric generating plant is fitted with automatic or remote controls so that under normal operating conditions it does not require any manual intervention by the operators, it is to be provided with audible and visual alarms for:

(a) Busbar voltage; high or low.
(b) Busbar frequency; low.
(c) Operating of load switching.
(d) Generator cooling air temperature high; closed air circuit machines only.

6.10 Feeder circuits

6.10.1 Isolation and protection of each feeder circuit is to be ensured by a multiple circuit-breaker or linked switch with a fuse in each insulated conductor. Protection is to be in accordance with 6.2 and 6.3. The protective devices are to allow excess current to pass during the normal accelerating period of motors.

6.11 Motor circuits

6.11.1 Motors of rating exceeding 0,5 kW and all motors for essential services are to be protected individually against overload and short circuit. For motors which for essential services are duplicated, the overload protection may be replaced by an overload alarm; arrangements for steering unit motors are to comply with 14.1.

6.11.2 Protection for both the motor and its supply cable may be provided by the same device, provided that due account is taken of any differences between ratings of cable and motor.

6.11.3 Where operation of an item of equipment is dependent upon a number of motors, consideration may be given to the provision of a common means of short-circuit protection.

6.11.4 For motors for intermittent service, the characteristics of the arrangements for overload protection are to be chosen in relation to the load factor(s) of the motor(s).

6.11.5 Where fuses are used to protect polyphase motor circuits, means are to be provided to protect the motor from unacceptable overcurrent in the case of single phasing.

6.12 Protection of transformers

6.12.1 Short circuit protection for transformers is to be provided by circuit breakers or fuses in the primary circuit and in addition, overload protection is to be provided either in the primary or secondary circuit.

6.12.2 Arrangements are to be made to prevent the primary windings of transformers being inadvertently energised from their secondary side when disconnected from their source of supply.

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Section 7
Switchgear and control gear assemblies

7.1 General requirements

7.1.1 Switchgear and control gear assemblies and their components are to comply with one of the following standards amended where necessary for ambient temperature and other environmental conditions:

(a) IEC 60439: *Low voltage switchgear and control gear assemblies*;
(b) IEC 62271-200: *AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV*;
(c) IEC 60466: *AC insulated-enclosed switchgear for rated voltages above 1 kV and up to and including 38 kV*;
(d) IEC 60255: *Electrical relays*;
(e) acceptable and relevant National Standard.

In addition, the requirements of 7.2 to 7.18 are to be complied with.

7.2 Busbars

7.2.1 Busbars and their connections are to be of copper or aluminium, all connections being so made as to inhibit corrosion/oxidation between current-carrying mating faces, which may result in poor electrical contact giving rise to overheating. Busbars and their supports are to be designed to withstand the mechanical stresses which may arise during short-circuits. A test report or calculation to verify the short-circuit withstand strength of the busbar system is to be submitted for consideration when required.

7.2.2 The maximum permissible temperature rise for bare conductors is 45°C. A test report or calculation to verify the rated current assigned to the busbar system is to be submitted for consideration when required.

7.3 Circuit-breakers

7.3.1 Circuit-breakers are to comply with one of the following standards amended where necessary for ambient temperature:

(a) IEC 60947-2: *Low voltage switchgear and Control gear Pt 2: circuit breakers*;
(b) IEC 60056: *High voltage alternating-current circuit-breakers*;
(c) acceptable and relevant National Standard.

Type test reports to verify the characteristics of a circuit-breaker are to be submitted for consideration when required.

7.3.2 Circuit-breakers are to be capable of isolation.

7.3.3 Circuit-breakers are to be of the trip free type and, where applicable, be fitted with anti-pumping control.

7.3.4 High-voltage circuit-breakers are to be of the withdrawable type or with equivalent means or arrangements permitting safe maintenance whilst the busbars are live.

7.3.5 Where the means of setting adjustable protection characteristics are not durably marked and locked in position and cannot be visually inspected (e.g. electronic storage), the settings of characteristics are to be recorded and a copy of the records included in the details retained on board, *see* 6.1.4.

7.4 Contactors

7.4.1 High-voltage contactors are to comply with one of the following standards amended where necessary for ambient temperature.

(a) IEC 60470: *High-voltage alternating current contactors*.
(b) acceptable and relevant National Standard.

Type test reports to verify the characteristics of a contactor are to be submitted for consideration when required.

7.4.2 High-voltage contactors are to be of the withdrawable type or with equivalent means or arrangements permitting safe maintenance whilst the busbars are live.

7.5 Creepage and clearance distances

7.5.1 The shortest distances between conductive parts and between conductive parts and earth in air or along the surface of an insulating material, are to be suitable for the rated voltage having regard to the nature of the insulating material and the transient over voltages developed by switching and fault conditions. This requirement may be satisfied by subjecting each assembly type to an impulse voltage test in accordance with its constructional Standard or, alternatively, maintaining the minimum distances for bare conductive parts in switchgear and control gear assemblies given in Table 2.7.1.

Table 2.7.1 Minimum clearance distances

Rated voltage V	Minimum clearance (mm) between phases and earth		Minimum clearance (mm) between phases
	Earthed neutral	Insulated neutral	
≤ 660	16	19	19
1000	25	25	25
3600	55	55	55
7200	70	100	100
12000	85	140	140
15000	100	165	165

7.5.2 Suitable shrouding or barriers are to be provided in way of connections to equipment, where necessary, to maintain the minimum distances in Table 2.7.1.

7.5.3 Creepage distances cannot be accurately specified as they depend upon the insulating material, dust deposits, humidity, etc. They are to be not less than the clearance distances given in Table 2.7.1, or less than 16 mm per 1000 V (rated voltage), whichever is the greater.

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7.6 Degree of protection

7.6.1 Low voltage assemblies where the rated voltage between conductors or to earth exceeds 55 V a.c. or 250 V d.c. are to be of the deadfront or enclosed type. High-voltage assemblies are to be of the enclosed type.

7.6.2 Where switchboards or section boards are required to comply with 5.2.2, barriers are to be installed to provide protection for the independent sections against contamination due to the products of arcing, which may result in a fault.

7.7 Distribution boards

7.7.1 Distribution boards are to be suitably enclosed unless they are installed in a cupboard or compartment to which only authorised persons have access in which case the cupboard may serve as an enclosure. *See* 7.16.4.

7.8 Earthing of high-voltage switchboards

7.8.1 High-voltage switchboards are to be provided with suitable means to earth isolated circuits so that they are discharged and so maintained that they are safe to touch.

7.9 Fuses

7.9.1 Fuses are to comply with one of the following standards amended where necessary for ambient temperature.

(a) IEC 60269: *Low-voltage fuses*;
(b) IEC 60282-1: *High voltage fuses Pt 1: Current-limiting fuses*;
(c) acceptable and relevant National Standard for enclosed current-limiting fuses.

Type test reports to verify the characteristics of a fuse are to be submitted for consideration when required.

7.10 Handrail or handles

7.10.1 All main and emergency switchboards are to be provided with an insulated handrail or insulated handles suitably fitted on the front of the switchboard. Where access to the rear is required, a horizontal insulated handrail is to be suitably fitted on the rear of the switchboard.

7.11 Instruments for alternating current generators

7.11.1 For alternating current generators not operated in parallel, each generator is provided with at least one voltmeter, one frequency meter, and one ammeter with an ammeter switch to enable the current in each phase to be read, or an ammeter in each phase. Generators above 50 kVA are also to be provided with a wattmeter.

7.11.2 For alternating current generators operated in parallel, each generator is to be provided with a wattmeter, and one ammeter with an ammeter switch to enable the current in each phase to be read, or an ammeter in each phase.

7.11.3 For parallelling purposes, two voltmeters, two frequency meters and two synchronising devices, of which one at least is to be a synchroscope or a set of lamps are to be provided. One voltmeter and one frequency meter are to be connected to the busbars, the other voltmeter and frequency meter are to be switched to enable the voltage and frequency of any generator to be measured. Where the electrical power requirement to maintain the ship in a normal operational and habitable condition is usually supplied by two or more generators operating in parallel, the two synchronising devices are to be independent of each other, *see also* 2.2.1.

7.11.4 The indicators and displays required by 7.11.1 to 7.11.3 are to be located and arranged such that they may be viewed at a single operating position. Where manual paralleling is provided, it is to be possible to adjust voltage and frequency at this position.

7.11.5 Where the indications of voltage, frequency, current and power are displayed digitally, the indications are to be separately displayed.

7.12 Instrument scales

7.12.1 The upper limit of the scale of every voltmeter is to be approximately 120 per cent of the nominal voltage of the circuit, and the nominal voltage is to be clearly indicated.

7.12.2 The upper limit of the scale of every ammeter is to be approximately 130 per cent of the normal rating of the circuit in which it is installed. Normal full load is to be clearly indicated.

7.12.3 Kilowatt meters for use with alternating current generators which may be operated in parallel are to be capable of indicating 15 per cent reverse power.

7.12.4 Where the indications provided by the instrumentation required by 7.11 are displayed digitally, nominal voltage, over voltage, over current and reverse power indications are to be indicated by an appropriate means. The information provided is to be clearly visible and immediately available.

7.13 Labels

7.13.1 The identification of individual circuits and their devices is to be made on labels of durable material. The ratings of fuses and settings of protective devices are also to be indicated. Section and distribution boards are to be marked with the rated voltage.

7.14 Protection

7.14.1 For details of the electrical protection required of switchgear and control gear, *see* Section 6.

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7.15 Wiring

7.15.1 Insulated wiring connecting components are to be stranded, flame retardant and manufactured in accordance with a relevant and acceptable National Standard.

7.16 Position of switchboards

7.16.1 An unobstructed space not less than 1 m wide is to be provided in front of switchboards and section boards. When switchboards and section boards contain withdrawable equipment the unobstructed space is to be not less than 0,4 m wide with this equipment in its fully withdrawn position.

7.16.2 Where necessary, the space at the rear of switchboards and section boards is to be ample to permit maintenance and in general not less than 0,6 m except that this may be reduced to 0,5 m in way of stiffeners or frames.

7.16.3 The spaces defined in 7.16.1 and 7.16.2 are to have non-slip surfaces. Where access to live parts within switchboards and section boards is normally possible the surface is, in addition, to be electrically insulated.

7.16.4 So far as practicable, pipes are not to be installed directly above or in front of or behind switchboards, section boards and distribution boards. If such placing is unavoidable, suitable protection is to be provided in these positions, *see* Pt 15, Ch 2,2.4.

7.16.5 For switchgear and control gear assemblies, for rated voltages above 1 kV, arrangements are to be made to protect personnel in the event of gases or vapours escaping under pressure as the result of arcing due to an internal fault. Where personnel may be in the vicinity of the equipment when it is energised, this may be achieved by an assembly that has been tested in accordance with Annex A of IEC 62271-200 and qualified for classification **IAC** (internal arc classification).

7.17 Switchboard auxiliary power supplies

7.17.1 Where the operation of a protective device relies upon a power supply, an alarm is to be provided to indicate failure of the power supply, unless its failure causes automatic tripping of the protected circuit.

7.18 Testing

7.18.1 Tests in accordance with 7.18.2 to 7.18.4 are to be satisfactorily carried out on all assemblies, complete or in sections, at the manufacturer's premises, and a test report issued by the manufacturer.

7.18.2 A high voltage test, *see* Section 20.

7.18.3 Calibration of protective devices and indicating instruments is to be verified by means of current and/or voltage injection.

7.18.4 Demonstration of the satisfactory operation of protection circuits, control circuits and interlocks by means of simulated functional tests.

7.18.5 For switchgear and control gear assemblies, for rated voltages above 1 kV, type tests are to be carried out, in accordance with Annex A of IEC 62271-200 and **IAC** (internal arc classification) assigned, to verify that the assembly will withstand the effects of an internal arc occurring within the enclosure at a prospective fault level equal to, or in excess of, that of the installation.

7.19 Disconnectors and switch-disconnectors

7.19.1 Disconnectors, switch-disconnectors and their components are to comply with one of the following standards, amended where necessary for ambient temperature and other environmental conditions:

(a) IEC 60947-3: *Low voltage switchgear and control gear Part 3: switches, disconnectors, switch-disconnectors and fuse combination units*.

(b) IEC 60129: *Alternating current disconnectors (isolators) and earthing switches*.

(c) Acceptable and relevant National Standard.

Type test reports to verify the characteristics of a disconnector or switch-disconnector are to be submitted for consideration when required.

■ *Section 8* Rotating machines

8.1 General requirements

8.1.1 Rotating machines are to comply with the relevant part of IEC 60092, or an acceptable and relevant National Standard, and the requirements of this Section.

8.1.2 For all the rotating machines a manufacturer's test certificate is to be provided, *see also* 1.3.

8.1.3 Shafts for rotating machines are to be forged or rolled and are to comply with the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

8.1.4 Where welding is applied to shafts of machines for securing arms or spiders, stress relieving is to be carried out after welding. The finalised assembly is to be visually examined by the Surveyors, crack detection carried out by an appropriate method and the finished welds found sound and free from cracks.

8.1.5 The rotating parts of machines are to be so balanced that when running at any speed in the normal working range the vibration does not exceed the levels of IEC 60034: *Rotating electrical machines*, Part 14.

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8.1.6 The lubrication arrangement for bearings are to be effective under all operating conditions including the maximum craft inclinations defined by 1.9 and there are to be effective means provided to ensure that lubricant does not reach the machine windings or other conductors and insulators.

8.1.7 Means are to be taken to prevent the ill effects of the flow of currents circulating between the shaft and machine bearings or bearings of connected machinery.

8.1.8 Alternating current machines are to be constructed such that, under any operating conditions, they are capable of withstanding the effects of a sudden short-circuit at their terminals without damage.

8.2 Rating

8.2.1 Generators, including their excitation systems, and continuously rated motors are to be suitable for continuous duty at their full rated output at maximum cooling air or water temperature for an unlimited period, without the limits of temperature rise in 8.3 being exceeded. Generators are to be capable of an overload power of not less than 10 per cent at their rated power factor for a period of 15 minutes without injurious heating. Other machines are to be rated in accordance with the duty which they have to perform and, when tested under rated load conditions, the temperature rise is not to exceed the values in 8.3.

8.2.2 When a rotating machine is connected to a supply system with harmonic distortion the rating of the machine is to allow for the increased heating effect of the harmonic loading.

8.2.3 The design and construction of smoke extraction fan motors are to be suitable for the ambient temperature and operating time required. Type test reports to verify the performance of the electric motor are to be submitted for consideration.

8.3 Temperature rise

8.3.1 The limits of temperature rise specified in Table 2.8.1, are based on the cooling air temperature and cooling water temperature given in 1.8.

8.3.2 If it is known that the temperature of cooling medium exceeds the values given in 1.8 the permissible temperature rise is to be reduced by an amount equal to the excess temperature of the cooling medium.

8.3.3 If it is known that the temperature of cooling medium will be permanently less than the values given in 1.8 the permissible temperature rise may be increased by an amount equal to the difference between the declared temperature and that given in 1.8 up to a maximum of 15°C.

8.4 Generator control

8.4.1 Each alternating current generator, unless of the self-regulating type, is to be provided with automatic means of voltage regulation; voltage build-up is not to require an external source of power. Provision is to be made to safeguard the distributing system should there be a failure of the voltage regulating system resulting in a high voltage.

8.4.2 The voltage regulation of any alternating current generator with its regulating equipment is to be such that at all loads, from zero to full load at rated power factor, the rated voltage is maintained within ±2,5 per cent under steady conditions. There is to be provision at the voltage regulator to adjust the generator no load voltage.

8.4.3 Generators, and their excitation systems, when operating at rated speed and voltage on no-load are to be capable of absorbing the suddenly switched, balanced, current demand of the largest motor or load at a power factor not greater than 0,4 with a transient voltage dip which does not exceed 15 per cent of rated voltage. The voltage is to recover to rated voltage within a time not exceeding 1,5 seconds.

8.4.4 The transient voltage rise at the terminals of a generator is not to exceed 20 per cent of rated voltage when rated kVA at a power factor not greater than 0,8 is thrown off.

8.4.5 Generators and their voltage regulation systems are to be capable of maintaining, without damage, under steady state short circuit conditions a current of at least three times the full load rated current for a duration of at least two seconds or where precise data is available for the duration of any time delay which may be provided by a tripping device for discrimination purposes.

8.4.6 Generators required to run in parallel are to be stable from no load (kW) up to the total combined full load (kW) of the group, and load sharing is to be such that the load on any generator does not normally differ from its proportionate share of the total load by more than 15 per cent of the rated output (kW) of the largest machine or 25 per cent of the rated output (kW) of the individual machine, whichever is less.

8.4.7 When generators are operated in parallel, the kVA loads of the individual generating sets are not to differ from the proportionate share of the total kVA load by more than 5 per cent of the rated kVA output of the largest machines.

8.5 Overloads

8.5.1 Machines are to withstand on test, without injury, the following momentary overloads:

(a) **Generators.** An excess current of 50 per cent for 15 seconds after attaining the temperature rise corresponding to rated load, the terminal voltage being maintained as near the rated value as possible. The forgoing does not apply to the overload torque capacity of the prime mover.

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Table 2.8.1 Limits of temperature rise of machines cooled by air

Limits of temperature rise of machines cooled by air, °C						
Part of machine	Method of temperature measurement	Insulation class				
		A	E	B	F	H
1. (a) a.c. windings of machines having output of 5000 kVA or more	ETD R	55 50	— —	75 70	95 90	115 110
(b) a.c. windings of machines having output of less than 5000 kVA	ETD R	55 50	— 65	80 70	100 95	115 110
2. Windings of armatures having commutators	R T	50 40	65 55	70 60	95 75	115 95
3. Field windings of a.c. and d.c. machines having d.c. excitation other than those in item 4	R T	50 40	65 55	70 60	95 75	115 95
4. (a) Field windings of synchronous machines with cylindrical rotors having d.c. excitation	R	—	—	80	100	125
(b) Stationery field windings of d.c. machines having more than one layer	R T	50 40	65 55	70 60	95 75	115 95
(c) Low resistance field windings of a.c. and d.c. machine and compensating windings of d.c. machines having more than one layer	R, T	50	65	70	90	115
(d) Single-layer windings of a.c. and d.c. machines with exposed bare or varnished metal surfaces and single-layer compensating windings of d.c. machines	R, T	55	70	80	100	125
5. Permanently short-circuited insulated windings	T	50	65	70	90	115
6. Permanently short-circuited uninsulated windings	T	The temperature rise of these parts shall in no case reach such a value that there is a risk to any insulation or other materials on adjacent parts or to the item itself				
7. Magnetic cores and other parts not in contact with windings	T					
8. Magnetic cores and other parts in contact with windings	T	50	65	70	90	110
9. Commutators and slip-rings open and enclosed	T	50	60	70	80	90

NOTES
1. Where water cooled heat exchangers are used in the machine cooling circuit the temperature rises are to be measured with respect to the temperature of the cooling water at the inlet to the heat exchanger and the temperature rises given in Table 2.8.1 shall be increased by 10°C provided the inlet water temperature does not exceed the values given in 1.8.
2. T = thermometer method
   R = resistance method
   ETD = embedded temperature detector
3. Temperature rise measurements are to use the resistance method whenever practicable.
4. The ETD method may only be used when the ETDs are located between coil sides in the slot.

(b) **Motors**. At rated speed or, in the case of a range of speeds, at the highest and lowest speeds, under gradual increase of torque, the appropriate excess torque given below. Synchronous motors and synchronous induction motors are required to withstand the excess torque without falling out of synchronism and without adjustment of the excitation circuit preset at the value corresponding to rated load:

d.c. motors 50 per cent for 15 seconds;
polyphase a.c. synchronous motors 50 per cent for 15 seconds;
polyphase a.c. synchronous induction motors 35 per cent for 15 seconds;
polyphase a.c. induction motors 60 per cent for 15 seconds.

8.6 Machine enclosure

8.6.1 Where water cooled heat exchangers are used in the machine cooling circuit there is to be provision for the detection of water leakage and the system is to be arranged so as to prevent the entry of water into the machine.

8.6.2 An alarm is to be provided to indicate high cooling water temperature.

8.7 Direct current machines

8.7.1 The final running position of brushgear is to be clearly and permanently marked.

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8.7.2 Direct current machines are to work with fixed brush setting from no load to the momentary overload specified without injurious sparking.

8.8 Survey and testing

8.8.1 On machines for essential services tests are to be carried out and a certificate furnished by the manufacturer. The tests are to include temperature rise, momentary overload, high voltage, and commutation. The insulation resistance and the temperature at which it was measured are to be recorded.

8.8.2 In the case of duplicate machines, type tests of temperature rise, excess current and torque and commutation taken on a machine identical in rating and in all other essential details may be accepted in conjunction with abbreviated tests on each machine. Type tests for propulsion machines will be specially considered. For the abbreviated tests, each machine is to be run and is to be found electrically and mechanically sound and is to have a high voltage test and insulation resistance recorded.

8.8.3 A high voltage test, in accordance with Section 20, is to be applied to new machines, preferably at the conclusion of the temperature rise test. Where both ends of each phase are brought out to accessible separate terminals each phase is to be tested separately.

8.8.4 An impulse test is to be carried out on the coils of high voltage machines in order to demonstrate a satisfactory withstand level of the inter-turn insulation to voltage surges. The test is to be carried out on all coils after they have been inserted in the slots and after wedging and bracing. Each coil shall be subjected to at least five impulses of injected voltage, the peak value of the injected voltage being given by the formula:

$V_{peak} = 2{,}45V$

where

V = rated line voltage r.m.s.

Alternative proposals to demonstrate the withstand level of inter-turn insulation will be considered.

■ *Section 9* Converter equipment

9.1 Transformers

9.1.1 Paragraphs 9.1.2 to 9.1.11 apply to transformers rated for 5 kVA upwards.

9.1.2 Transformers are to comply with the requirements of IEC 60076: *Power transformers*, or an acceptable and relevant National Standard amended where necessary for ambient temperature, *see* 1.8.

9.1.3 Transformers may be of the dry type, encapsulated or liquid filled type.

9.1.4 The temperature rise of the winding of transformers above the ambient temperatures given in 1.8, when measured by resistance during continuous operation at the maximum rating, is not to exceed:

(a) For dry type transformers, air cooled:
- insulation of Class A – 50°C
- insulation of Class E – 60°C
- insulation of Class B – 70°C
- insulation of Class F – 90°C
- insulation of Class H – 110°C

(b) For liquid filled transformers:
- 50°C – where air provides cooling of the fluid
- 65°C – where water provides cooling of the fluid.

9.1.5 When a transformer is connected to a supply system with harmonic distortion, the rating of the transformer is to allow for the increased heating effect of the harmonic loading. Special attention is to be given to transformers connected for the purpose of reducing harmonic distortion.

9.1.6 The inherent regulation of transformers at their rated output is to be such that the total voltage drop to any point in the installation does not exceed that allowed by 1.7.

9.1.7 Transformers, except those for motor starting, are to be double wound.

9.1.8 Liquid fillings for transformers are to be non-toxic and of a type which does not readily support combustion. Liquid filled transformers are to have a pressure relief-device with an alarm and there is to be a suitable means provided to contain any liquid which may escape from the transformer due to the operation of the relief device or damage to the tank.

9.1.9 All transformers are to be capable of withstanding for two seconds, without damage, the thermal and mechanical effects of a short-circuit at the terminals of any winding.

9.1.10 When forced cooling is used, whether air or liquid, there is to be monitoring of the cooling medium and transformer winding temperatures with an alarm should these exceed preset limits. There are to be arrangements so that the load may be reduced to a level commensurate with the cooling available.

9.1.11 Where water cooled heat exchangers are used in transformer cooling circuits, there is to be provision for the detection of water leakage and the system is to be arranged so as to prevent the entry of water into the transformer.

9.1.12 The following tests are to be carried out on all transformers at the manufacturer's works, and a certificate of tests issued by the manufacturer, *see also* 1.3.2 and 1.3.3:

(a) measurement of winding resistances, voltage ratio, impedance voltage, short circuit impedance, insulation resistance, load loss, no load loss and current;
(b) dielectric tests;
(c) temperature rise test on one transformer of each size and type; and
(d) where evidence of compliance with 9.1.9 is not submitted for consideration, short-circuit withstand on one transformer of each size and type.

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9.2 Semiconductor equipment

9.2.1 The requirements of 9.2.2 to 9.2.18 apply to semiconductor equipment rated for 5 kW upwards.

9.2.2 Semiconductor equipment is to comply with the requirements of IEC 60146: *Semiconductor converters*, or an acceptable and relevant National Standard amended where necessary for ambient temperature, *see* 1.8.

9.2.3 Semiconductor static power converter equipment is to be rated for the required duty having regard to peak loads, system transients and overvoltage.

9.2.4 Converter equipment may be air or liquid cooled and is to be so arranged that it cannot remain loaded unless effective cooling is maintained. Alternatively the load may be automatically reduced to a level commensurate with the cooling available.

9.2.5 Liquid cooled converter equipment is to be provided with leakage alarms and there is to be a suitable means provided to contain any liquid which may leak from the system in order to ensure that it does not cause an electrical failure of the equipment. Where the semiconductors and other current carrying parts are in direct contact with the cooling liquid, the liquid is to be monitored for satisfactory resistivity and an alarm initiated at the relevant control station should the resistivity be outside the agreed limits.

9.2.6 Where forced cooling is used there is to be temperature monitoring of the heated cooling medium with an alarm and shutdown when the temperature exceeds a preset value.

9.2.7 Cooling fluids are to be non-toxic and of low flammability.

9.2.8 Converter equipment is to be so arranged that the semiconductor devices, fuses, control and firing circuit boards may be readily removed from the equipment for repair or replacement.

9.2.9 Test and monitoring facilities are to be provided to permit identification of control circuit faults and faulty components.

9.2.10 Protection devices fitted for converter equipment protection are to ensure that, under fault conditions, the protective action of circuit breakers, fuses or control systems is such that there is no further damage to the converter or the installation.

9.2.11 Converter equipment, including any associated transformers, reactors, capacitors and filters, if provided, is to be so arranged that the harmonic distortion, and voltage spikes, introduced into the craft's electrical system are within the limits of 1.7.3 or restricted to a lower level necessary to ensure that it causes no malfunction of equipment connected to the electrical installation.

9.2.12 Overvoltage spikes or oscillations caused by commutation or other phenomena, are not to result in the supply voltage waveform deviating from a superimposed equivalent sine wave by more than 10 per cent of the maximum value of the equivalent sine wave.

9.2.13 When converter equipment is operated in parallel, load sharing is to be such that under normal operating conditions overloading of any unit does not occur and the combination of paralleled equipment is stable throughout the operating range.

9.2.14 When converter equipment has parallel circuits there is to be provision to ensure that the load is distributed uniformly between the parallel paths.

9.2.15 Transformers, reactors, capacitors and other circuit devices associated with converter equipment, or associated filters, are to be suitable for the distorted voltage and current waveforms to which they may be subjected and filter circuits are to be provided with facilities to ensure that their capacitors are discharged before the circuits are energised.

9.2.16 Any regenerated power developed during the operation of converter equipment is not to result in disturbances to the supply system voltage and frequency which exceeds the limits of 1.7.

9.2.17 Where control systems form an integral part of semiconductor equipment, they are to be designed and manufactured with regard to the environmental conditions to which they will be exposed in service and their performance is to be demonstrated during the test and trials programme.

9.2.18 Tests at the manufacturer's works of converter equipment and any associated reactors or filters are to include the high voltage test of 20.1, a temperature rise test, on one of each size and type of converter equipment, and such other tests as may be necessary to demonstrate the suitability of the equipment for its intended duty. Details of tests are to be submitted for consideration when required, *see also* 1.3.2.

9.3 Uninterruptible power systems

9.3.1 Where uninterruptible power systems (UPS) are required to maintain essential services or provide emergency services, the requirements of this Sub-Section apply. This sub-Section is in addition to the requirements of 9.1 and 9.2 and Section 11, as applicable.

9.3.2 UPS units are to be constructed in accordance with IEC 62040: *Uninterruptible power systems (UPS)*, or an acceptable and relevant National or International Standard.

9.3.3 The operation of a UPS is not to depend upon external services.

9.3.4 The type of UPS unit employed, whether off-line, line-interactive or on-line, is to be appropriate to the power supply requirements of the connected load equipment.

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9.3.5 An external bypass, that is hardwired and manually operated, is to be provided for UPS to allow isolation of UPS for safety during maintenance and maintain continuity of load power.

9.3.6 UPS units are to be monitored and an audible and visual alarm is to be initiated in the navigating bridge or the engine control room, or an equivalent attended location for:

- power supply failure (voltage and frequency) to the connected load;
- earth fault;
- operation of battery protective device;
- battery discharge; and
- bypass in operation for on-line UPS units.

9.3.7 UPS units required to provide emergency services are to be suitably located for use in an emergency.

9.3.8 UPS units utilising valve-regulated sealed batteries may be located in compartments with standard marine or industrial electrical equipment provided that the arrangements comply with 11.3.5. Ventilation arrangements in accordance with IEC 62040: *Uninterruptible power systems (UPS),* or an acceptable and relevant National or International Standard, may be considered to satisfy the requirements of 11.5.10.

9.3.9 Output power is to be maintained for the duration required for the connected equipment.

9.3.10 The UPS battery capacity is, at all times, to be capable of supplying the designated loads for the time specified. Where it is proposed that additional circuits are connected to the UPS unit, details verifying that the UPS unit has adequate capacity are to be submitted for consideration, *see* 1.4.

9.3.11 On restoration of the input power, the rating of the charge unit is to be sufficient to recharge the batteries while maintaining the output supply to the load equipment.

9.3.12 Tests at the manufacturer's works are to include such tests necessary to demonstrate the suitability of a UPS unit for its intended duty and location. This is expected to include as a minimum the following tests:

- a temperature rise test and battery capacity test on one of each size and type of UPS;
- the high voltage test of 20.1;
- a ventilation rate test; and
- functional testing, including operation of alarms.

Details of tests are to be submitted for consideration when required, *see also* 1.3.2.

9.3.13 Where the supply is to be maintained without a break following a power input failure, this is to be verified after installation by practical testing.

Section 10
Electrical cables and busbar trunking systems (busways)

10.1 General

10.1.1 The requirements of 10.1 to 10.16 apply to all electric cables for fixed wiring unless otherwise exempted. The requirements of 10.16 apply to busbar trunking systems (busways) where they are used in place of electric cables.

10.1.2 Electric cables for fixed wiring are to be designed, manufactured and tested in accordance with the relevant IEC Standard stated in Table 2.10.1 or an acceptable and relevant National Standard.

Table 2.10.1 Electric cables

Application	IEC Standard	Title
General constructional and testing requirements	60092–350	Low-voltage shipboard power cables. General construction and test requirements
Fixed power and control circuits	60092–353	Single and multicore non-radial field power cables with extruded solid insulation for rated voltages 1kV and 3kV
Fixed power circuits	60092–354	Single and three-core power cables with extruded solid insulation for rated voltages 6kV, 10kV and 15kV
Instrumentation, control and communication circuits up to 60 V	60092–375	Shipboard telecommunication cables and radio frequency cables – General instrumentation, control and communication cables
Control circuits up to 250 V	60092–376	Shipboard multicore cables for control circuits
Mineral insulated	60702	Mineral insulated cables with a rated voltage not exceeding 750 V

10.1.3 Electric cables for electric propulsion systems are to be Type Approved in accordance with LR's *Type Approval System Test Specification Number 3* or, alternatively, surveyed by the Surveyors during manufacture and testing to assess compliance with the applicable International or National Standards and application of an acceptable quality management system.

10.1.4 Provided that adequate flexibility of the finished cable is assured, conductors of nominal cross-section area 2,5 mm^2 and less need not be stranded.

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10.1.5 Electric cables for non-fixed wiring applications are to comply with an acceptable and relevant Standard.

10.1.6 For the purpose of this Section, pipes, conduits, trunking or any other system for the additional mechanical protection of cables are hereafter referred to under the generic name 'protective casings'.

10.2 Testing

10.2.1 Routine tests, consisting of at least:
(a) measurement of electrical resistance of conductors;
(b) high voltage test, *see also* Section 20;
(c) insulation resistance measurement;
(d) for high voltage cables, partial discharge tests are to be made in accordance with the requirements of the relevant publication or National Standard referred to in 10.1.2 at the manufacturer's works prior to despatch.

Evidence of successful completion of routine tests is to be provided by the manufacturer.

10.2.2 Particular, special and type tests are to be made, when required, in accordance with the requirements of the relevant publication or National Standard referred to in 10.1.2 and a test report issued by the manufacturer.

10.3 Voltage rating

10.3.1 The rated voltage of any electric cable is to be not lower than the nominal voltage of the circuit for which it is used. The maximum sustained voltage of the circuit is not to exceed the maximum voltage for which the cable has been designed.

10.3.2 Electric cables used in unearthed systems are to be suitably rated to withstand the additional stresses imposed on the insulation due to an earth fault.

10.4 Operating temperature

10.4.1 The maximum rated conductor temperature of the insulating material for normal operation is to be at least 10°C higher than the maximum ambient temperature liable to be produced in the space where the cable is installed.

10.4.2 The maximum rated conductor temperatures for normal and short-circuit operation, for the insulating materials included within the Standards referred to in 10.1.2 is not to exceed the values stated in Table 2.10.2.

10.4.3 Electric cables constructed of an insulating material not included in Table 2.10.2 are to be rated in accordance with the National Standard chosen in compliance with 10.1.2.

10.5 Construction

10.5.1 Electric cables are to be at least of a flame-retardant type. Compliance with IEC 60332-1-2: *Tests on electric and optical fibre cables under fire conditions – Part 1-2: Test for vertical flame propagation for a single insulated wire or cable – Procedure for 1kW pre-mixed flame*, will be acceptable.

Table 2.10.2 Maximum rated conductor temperature

Type of Insulating compound	Maximum rated conductor temperature °C	
	Normal operation	Short-circuit
Thermoplastics:		
• Based upon polyvinyl chloride or co-polymer of vinyl chloride and vinyl acetate	70	150
Elastomeric or thermosetting:		
• Ethylene-propylene rubber or similar (EPM or EPDM)	90	250
• High modulus or hard grade ethylene propylene rubber	90	250
• Cross-linked polyethylene	90	250
• Ethylene-propylene rubber or similar (EPM or EPDM) halogen-free	90	250
• High modulus or hard grade halogen-free ethylene propylene rubber	90	250
• Halogen-free cross-linked polyethylene	90	250
• Cross-linked polyolefin material for halogen-free cables	90	250
• Silicon rubber	95	350
• Halogen-free silicone rubber	95	350

10.5.2 Exemption from the requirements of 10.5.1 for applications such as radio frequency or digital communication systems, which require the use of particular types of cable, will be subject to special consideration.

10.5.3 Where electric cables are required to be of a 'fire resistant type', they are in addition to be easily distinguishable and to comply with the performance requirements of the appropriate part of IEC 60331:*Tests for electric cables under fire conditions - Circuit integrity*, when tested with a minimum flame application time of 90 minutes, as follows:
IEC 60331-21: *Procedures and requirements – Cables of rated voltage up to and including 0.6/1.0kV;*
IEC 60331-23: *Procedures and requirements – Electric data cables;*
IEC 60331-25: *Procedures and requirements – Optical fibre cables*.

10.5.4 Where electric cables are installed in locations exposed to the weather, in damp and in wet situations, in machinery compartments, refrigerated spaces or exposed to harmful vapours including oil vapour they are to have the conductor insulating materials enclosed in an impervious sheath of material appropriate to the expected ambient conditions.

10.5.5 Where it is required that the construction of electrical cables includes metallic sheaths, armouring or braids are to be provided with an overall impervious sheath or other means to protect the metallic elements against corrosion, *see also* 10.8.7 and 10.8.8.

10.5.6 Where cables are installed in an area where contamination by oil is likely to occur, the oversheath is to be of an enhanced oil resistance grade.

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10.5.7 Where single core electric cables are used in circuits rated in excess of 20 Amps and are armoured the armour is to be of a non-magnetic material.

10.5.8 Electric cables are to be constructed such that they are capable of withstanding the mechanical and thermal effects of the maximum short-circuit current which can flow in any part of the circuit in which they are installed, taking into consideration not only the time/current characteristics of the circuit protective device but also the peak value of the prospective short-circuit current. Where electric cables are to be used in circuits with a maximum short circuit current in excess of 70 kA, evidence is to be submitted for consideration when required demonstrating that the cable construction can withstand the effects of the short circuit current.

10.5.9 All high voltage electric cables are to be readily identified by suitable marking.

10.6 Conductor size

10.6.1 The maximum continuous load carried by a cable is not to exceed its continuous current rating. It is to be chosen such that the maximum rated conductor temperature for normal operation for the insulation is not exceeded. In assessing the current rating the correction factors in 10.7 may be applied as required.

10.6.2 The cross-sectional area of the conductors is to be sufficient to ensure that, under short-circuit conditions, the maximum rated conductor temperature for short-circuit operation is not exceeded, taking into consideration the time current characteristics of the circuit protective device and the peak value of the prospective short-circuit current.

10.6.3 The cable current ratings given in Tables 2.10.3 and 2.10.4 are based on the maximum rated conductor temperatures given in Table 2.10.2. When cable sizes are selected on the basis of precise evaluation of current rating based upon experimental and calculated data, details are to be submitted for consideration. Alternative short-circuit temperature limits, other than those given in Table 2.10.4, may be applied using the data provided in:

- IEC 60724: *Short-circuit temperature limits of electric cables with rated voltages of 1kV (Um=1,2kV) and 3kV (Um=3,6kV)*; or
- IEC 60986: *Short-circuit temperature limits of electric cables with rated voltages from 6kV (Um=7,2kV) and up to 30kV (Um=36kV)*.

Alternative short-circuit temperature limits provided in an acceptable and relevant National Standard may also be considered.

10.6.4 The cross-sectional area of the conductors is to be sufficient to ensure that at no point in the installation will the voltage variations stated in 1.7 be exceeded when the conductors are carrying the maximum current under their normal conditions of service.

10.6.5 The size of earth conductors is to comply with 1.11.8.

10.6.6 The cross-sectional area of conductors used in circuits supplying cyclic or non-continuous loads is to be sufficient to ensure that the cable's maximum rated conductor temperature for normal operation is not exceeded when the conductors are operating under their normal conditions of service, *see* 10.7.4.

10.7 Correction factors for cable current rating

10.7.1 The correction factors of 10.7.2 to 10.7.5 provide a guide for general applications in assessing a current rating. A more precise evaluation based upon experimental and calculated data may be submitted for consideration.

10.7.2 Bunching of cables. Where more than six electric cables, which may be expected to operate simultaneously at their full rated capacity, are laid close together in a cable bunch in such a way that there is an absence of free air circulation around them, a correction factor of 0,85 is to be applied. Signal cables may be exempted from this requirement.

10.7.3 Ambient temperature. The current ratings of Table 2.10.3 are based on an ambient temperature of 45°C. For other values of ambient temperature the correction factors shown in Table 2.10.5 are to be applied.

10.7.4 Short time duty. When the load is not continuous i.e. operates for periods of half an hour or one hour and the periods of no load are longer than three times the cable's time constant T in minutes, the cable's continuous rating may be increased by a duty factor, calculated in accordance with:

$$\text{Duty factor} = \sqrt{\frac{1{,}12}{1 - e^{\frac{-t_s}{T}}}}$$

When the load is not continuous, is repetitive and has periods of no-loads less than three times the cable's time constant, so that the cable has insufficient time to cool down between the applications of load, the cable's continuous rating may be increased by an intermittent factor, calculated in accordance with:

$$\text{Intermittent factor} = \sqrt{\frac{1 - e^{\frac{-t_p}{T}}}{1 - e^{\frac{-t_s}{T}}}}$$

where

T = $0{,}245d^{1{,}35}$ where d is the overall diameter of the cable, in mm

t_s = the service time of the load current, in minutes

t_p = the intermittent period in minutes, i.e. the total period of load and no-load before the cycle is repeated.

10.7.5 Diversity. Where cables are used to supply two or more final sub-circuits account may be taken of any diversity factors which may apply, *see* 5.6.

10.8 Installation of electric cables

10.8.1 Electric cable runs are to be as far as practicable fixed in straight lines and in accessible positions.

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Table 2.10.3 Electric cable current ratings, normal operation, based on ambient 45°C

Nominal cross-section (mm^2)	Continuous r.m.s current rating, in amperes								
	Thermoplastic (70°C)			Elastomeric (90°C)			Elastomeric or thermosetting, based on silicon rubber (95°C)		
	Single core	2 core	3 or 4 core	Single core	2 core	3 or 4 core	Single core	2 core	3 or 4 core
0,75	10	8	7	15	13	11	17	14	12
1	12	10	8	18	15	13	20	17	14
1,25	13	11	9	21	18	14	23	20	16
1,5	15	13	11	23	20	16	26	22	18
2	18	15	12	28	24	19	31	26	22
2,5	21	18	15	40	26	21	32	27	22
3,5	26	22	18	37	32	26	39	33	28
4	29	25	20	51	34	28	43	37	30
5,5	35	30	24	49	42	35	52	44	37
6	37	31	26	52	44	36	55	47	39
8	44	37	31	62	53	44	66	56	46
10	51	43	36	72	61	50	76	65	53
14	62	53	44	88	75	62	94	80	66
16	68	58	48	96	82	67	102	87	71
22	83	70	58	117	100	82	124	106	87
25	90	77	63	127	108	89	135	115	95
30	101	85	70	142	121	100	151	128	106
35	111	94	78	157	133	110	166	141	116
38	117	99	82	165	140	116	175	149	122
50	138	117	97	196	167	137	208	177	146
60	155	132	109	220	187	154	233	198	163
70	171	145	120	242	206	169	256	218	179
80	186	158	130	263	224	184	278	237	195
95	207	176	145	293	249	205	310	264	217
100	213	181	149	302	257	212	320	272	224
120	239	203	167	339	288	237	359	305	251
125	245	209	172	348	295	243	368	313	258
150	275	234	193	389	331	272	412	350	288
185	313	266	219	444	377	311	470	400	329
200	329	280	230	466	396	326	494	420	346
240	369	314	258	522	444	365	553	470	387
300	424	360	297	601	511	421	636	541	445

10.8.2 Bends in fixed electric cable runs are to be in accordance with the cable manufacturer's recommendations. The minimum internal radius of bend for the installation of fixed electric cables is to be chosen according to the construction and size of the cable and is not to be less than the values given in Table 2.10.6.

10.8.3 The installation of electric cables across expansion joints in any structure is to be avoided. Where this is not practicable, a loop of electric cable of length sufficient to accommodate the expansion of the joint is to be provided. The internal radius of the loop is to be at least 12 times the external diameter of the cable.

10.8.4 Electric cables for essential and emergency services are to be arranged, so far as is practicable, to avoid galleys, machinery spaces and other enclosed spaces and areas of high fire risk except as is necessary for the service being supplied. Such cables are also, so far as reasonably practicable, to be routed clear of bulkheads to preclude their being rendered unserviceable by heating of the bulkheads that may be caused by a fire in an adjacent space.

10.8.5 Electric cables having insulating materials with different maximum rated conductor temperatures are to be so installed that the maximum rated conductor temperature for normal operation of each cable is not exceeded.

10.8.6 Electric cables having a protective covering which may damage the covering of other cables are not to be bunched with those other cables.

10.8.7 Cables having an exposed metallic screen, braid or armour are to be installed in such a manner that galvanic corrosion by contact with other metals is prevented. Sufficient measures are also to be taken to prevent damage to exposed galvanised coatings during installation.

10.8.8 Protection is to be provided for cable oversheaths in areas where cables are likely to be exposed to damaging substances under normal circumstances or areas where the spillage or release of harmful substances is likely.

10.8.9 Electric cables are to be as far as practicable installed remote from sources of heat. Where installation of cables near sources of heat cannot be avoided and where there is consequently a risk of damage to the cables by heat, suitable shields, insulation or other precautions are to be installed between the cables and the heat source. The free air circulation around the cables is not to be impaired.

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Table 2.10.4 Electric cable current ratings, r.m.s. short-circuit current

Nominal cross-section (mm^2)	Fault current (kA) at 150°C			Fault current (kA) at 250°C			Fault current (kA) at 350°C		
	1 s duration	0,5 s duration	0,1 s duration	1 s duration	0,5 s duration	0,1 s duration	1 s duration	0,5 s duration	0,1 s duration
0,75	0,1	0,1	0,3	0,1	0,2	0,3	0,1	0,2	0,4
1	0,1	0,2	0,3	0,1	0,2	0,5	0,2	0,2	0,5
1,25	0,1	0,2	0,4	0,2	0,3	0,6	0,2	0,3	0,7
1,5	0,2	0,2	0,5	0,2	0,3	0,7	0,3	0,4	0,8
2	0,2	0,3	0,7	0,3	0,4	0,9	0,3	0,5	1,1
2,5	0,3	0,4	0,9	0,4	0,5	1,1	0,4	0,6	1,4
3,5	0,4	0,5	1,2	0,5	0,7	1,6	0,6	0,8	1,9
4	0,4	0,6	1,4	0,6	0,8	1,8	0,7	1,0	2,2
5,5	0,6	0,8	1,9	0,8	1,1	2,5	0,9	1,3	3,0
6	0,7	0,9	2,1	0,9	1,2	2,7	1,0	1,5	3,2
8	0,9	1,2	2,8	1,1	1,6	3,6	1,4	1,9	4,3
10	1,1	1,5	3,5	1,4	2,0	4,5	1,7	2,4	5,4
14	1,5	2,2	4,8	2,0	2,8	6,3	2,4	3,4	7,6
16	1,7	2,5	5,5	2,3	3,2	7,2	2,7	3,9	8,7
22	2,4	3,4	7,6	3,1	4,5	10,0	3,8	5,3	11,9
25	2,7	3,9	8,6	3,6	5,1	11,3	4,3	6,0	13,5
30	3,3	4,6	10,4	4,3	6,1	13,6	5,1	7,3	16,2
35	3,8	5,4	12,1	5,0	7,1	15,8	6,0	8,5	18,9
38	4,1	5,9	13,1	5,4	7,7	17,2	6,5	9,2	20,6
50	5,5	7,7	17,3	7,2	10,1	22,6	8,6	12,1	27,1
60	6,5	9,3	20,7	8,6	12,1	27,1	10,3	14,5	32,5
70	7,6	10,8	24,2	10,0	14,2	31,7	12,0	16,9	37,9
80	8,7	12,3	37,6	11,4	16,2	36,2	13,7	19,4	43,3
95	10,4	14,7	32,8	13,6	19,2	43,0	16,3	23,0	51,4
100	10,9	15,4	34,5	14,3	20,2	45,2	17,1	24,2	54,1
120	13,1	18,5	41,4	17,2	24,3	54,3	20,5	29,0	64,9
125	13,6	19,3	43,1	17,9	25,3	56,6	21,4	30,2	67,6
150	16,4	23,2	51,8	21,5	30,4	67,9	25,7	36,3	81,2
185	20,2	28,6	63,9	26,5	37,4	83,7	31,7	44,8	100,1
200	21,8	30,9	69,0	28,6	40,5	90,5	34,2	48,4	108,2
240	26,2	37,0	82,8	34,3	48,6	108,6	41,1	58,1	129,9
300	32,7	46,3	103,6	42,9	60,7	135,7	51,3	72,6	162,3

10.8.10 Where single cables, or bundles of cables grouped in accordance with Table 1.10.8, run parallel with cables or bundles of cables of a different group for a distance greater than 1 m, a minimum separation distance of 0,1 m is to be ensured to reduce mutual interference.

10.8.11 Where electric cables are installed in bunches, provision is to be made to limit the propagation of fire. This requirement is considered satisfied when cables of the bunch have been tested in accordance with the requirements of IEC 60332:*Tests on electric cables under fire conditions, Part 3-22, Test for vertical flame spread of vertically-mounted bunched wires or cables – Category A*, and are installed in the same configuration(s) as are used for the test(s). If the cables are not so installed, information is to be submitted to satisfactorily demonstrate that suitable measures have been taken to ensure that an equivalent limit of fire propagation will be achieved for the configurations to be used. Particular attention is to be given to cables in:

- atria or equivalent spaces; and
- vertical runs in trunks and other restricted spaces.

In addition, cables that comply with the requirements of IEC 60332-3-22 are also required to meet the requirements of IEC 60332-1-2.

10.8.12 Electric cables are not to be coated or painted with materials which may adversely affect their sheath or their fire performance.

10.8.13 Where electric cables are installed in refrigerated spaces they are not to be covered with thermal insulation but may be placed directly on the face of the refrigeration chamber, provided that precautions are taken to prevent the electric cables being used as casual means of suspension.

10.8.14 All metal coverings of electric cables are to be earthed in accordance with 1.11.

10.8.15 High voltage cables may be installed as follows:

(a) in the open, e.g. on carrier plating, when they are to be provided with a continuous metallic sheath or armour which is effectively bonded to earth to reduce danger to personnel. The metallic sheath or armour may be omitted provided that the cable sheathing material has a longitudinal electric resistance high enough to prevent sheath currents which may be hazardous to personnel;

(b) contained in earthed metallic protective casings when the cables may be as in (a) or the armour or metal sheath may be omitted. In the latter case care is to be taken to ensure that protective casings are electrically continuous and that short lengths of cable are not left unprotected.

10.8.16 High voltage electric cables are not to be run in the open through accommodation spaces.

10.8.17 High voltage electric cables are to be segregated as far as is practicable from electric cables operating at lower voltages.

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Table 2.10.5 Correction factors

Insulation material	Correction factor for ambient air temperature of °C										
	35	40	45	50	55	60	65	70	75	80	85
Thermoplastic (70°C)	1,18	1,10	1,00	0,89	0,77	0,63	—	—	—	—	—
Elastomeric or thermosetting (90°C)	1,10	1,05	1,00	0,94	0,88	0,82	0,74	0,67	0,58	0,47	—
Elastomeric or thermosetting, based on silicone rubber (90°C)	1,10	1,05	1,00	0,95	0,89	0,84	0,77	0,71	0,63	0,55	0,45

Table 2.10.6 Minimum internal radii of bends in cables for fixed wiring

Cable construction		Overall diameter of cable	Minimum internal radius of bend (times overall diameter of cable)
Insulation	Outer covering		
Thermoplastic and elastomeric 600/1000 V and below	Metal sheathed Armoured and braided	Any	6*D*
	Other finishes	≤ 25 mm > 25 mm	4*D* 6*D*
Mineral	Hard metal sheathed	Any	6*D*
Thermoplastic and elastomeric above 600/1000 V – single core	Any	Any	12*D*
– multicore	Any	Any	9*D*

10.8.18 a.c. wiring is to be carried out using multicore cables wherever reasonably practicable. Where it is necessary to install single core electric cables for alternating current circuits in excess of 20 Amps the requirements of 10.14 are to be complied with, *see also* 10.5.7.

10.8.19 Electric cables are to be, so far as reasonably practicable, installed remote from sources of mechanical damage. Where necessary, the cables are to be protected in accordance with the requirements of 10.9.

10.8.20 Electric cables, with the exception of those for portable appliances and those installed in protective casings, are to be fixed securely in accordance with the requirements of 10.10.

10.8.21 Where electric cables penetrate bulkheads and decks, the requirements of 10.11 are to be complied with.

10.8.22 Where electric cables are installed in protective casings, the requirements of 10.12 are to be complied with.

10.9 Mechanical protection of cables

10.9.1 Where electric cables are exposed to risk of mechanical damage they are to be protected by suitable protective casings unless the protective covering (e.g. armour or sheath) is sufficient to withstand the possible cause of damage.

10.9.2 Electric cables installed in spaces where there is exceptional risk of mechanical damage such as holds, storage spaces, cargo spaces, etc., are to be suitably protected by metallic protective casings, even when armoured, unless the craft's structure affords adequate protection.

10.9.3 Metal protective casings are to be efficiently protected against corrosion, and effectively earthed in accordance with 1.11.

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10.10 Cable support systems

10.10.1 Electric cables are to be effectively supported and secured, without being damaged, to the craft's structure, either indirectly by a cable support system, or directly by means of clips, saddles or straps to bulkheads, etc., *see* 10.8.4.

10.10.2 Cable support systems, which may be in the form of trays or plates, separate support brackets, hangers or ladder racks, together with their fixings and accessories, are to be robust and are to be of corrosion-resistant material or suitably corrosion inhibited before erection. The cable support system is to be effectively secured to the craft's structure, the spacing of the fixings taking account of the probability of vibration and any heavy external forces, e.g. where located in areas subject to impact by sea-water.

10.10.3 The distances between the points at which the cable is supported (e.g. distances between ladder rungs, support brackets, hangers, etc.) are to be chosen according to the construction of cable (i.e. size and rigidity) and the probability of vibration and are to be generally in accordance with those given in Table 2.10.7.

10.10.4 Where the cables are laid on top of their support system, the spacings of fixings may be increased beyond those given in Table 2.10.7, but should take account of the probability of movement and vibration and in general is not to exceed 900 mm. This relaxation is not to be applied where cables can be subjected to heavy external forces, e.g. where they are run on, or above, open deck or in areas subject to impact by sea-water.

10.10.5 Single core electric cables are to be firmly fixed, using supports of strength adequate to withstand forces corresponding to the values of the peak prospective short-circuit current.

10.11 Penetration of bulkheads and decks by cables

10.11.1 Where electric cables pass through watertight, fire insulated or gas tight bulkheads, the arrangements are to be such as to ensure the integrity of the bulkhead or deck is not impaired. The arrangements chosen are to ensure that the cables are not adversely affected.

10.11.2 Where cables pass through non-watertight bulkheads or structural steel, the holes are to be bushed with suitable material. If the steel is at least 6 mm thick, adequately rounded edges may be accepted as the equivalent of bushing.

10.11.3 Electric cables passing through decks are to be protected by deck tubes or ducts.

10.11.4 Where cables pass through thermal insulation they are to do so at right angles, in tubes sealed at both ends.

Table 2.10.7 Maximum spacing of supports or fixings for securing cables

External diameter of cable		Non-armoured cables	Armoured cables
Exceeding	Not exceeding		
mm	mm	mm	mm
—	8	200	250
8	13	250	300
13	20	300	350
20	30	350	400
30	—	400	450

10.12 Installation of electric cables in protective casings

10.12.1 Protective casings are to be mechanically continuous across joints and effectively supported and secured to prevent damage to the electric cables.

10.12.2 Protective casings are to be suitably smooth on the interior and have their ends shaped or bushed in such a manner as not to damage the cables.

10.12.3 The internal radius of bends of protective casings are to be not less than that required for the largest cable installed therein, *see* 10.8.2.

10.12.4 The space factor (ratio of the sum of the cross sectional areas corresponding to the external diameters of the cables to the internal cross sectional area of the protective casings) is not to exceed 0,4.

10.12.5 Where necessary, ventilation openings are to be provided at the highest and lowest points of protective casings to permit air circulation and to prevent accumulation of water.

10.12.6 Expansion joints are to be provided in protective casings where necessary.

10.12.7 Protective casings containing high voltage electric cables are not to contain other electric cables and are to be clearly identified, defining their function and voltage.

10.13 Non-metallic cable support systems, protective casings and fixings

10.13.1 Where it is proposed to use non-metallic cable support systems, protective casings or fixings, the additional requirements of this sub-Section apply. For high voltage installations, metallic protective casings are required where 10.8.15(b) applies.

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10.13.2 Non-metallic cable support systems and protective casings are to be installed in accordance with the manufacturer's recommendations. The support systems and protective casings are to have been tested in accordance with an acceptable test procedure for:

(a) ambient operating temperatures;
(b) safe working load;
(c) impact resistance;
(d) flame retardancy;
(e) smoke and toxicity; and
(f) use in explosive gas atmospheres or in the presence of combustible dusts, electrical conductivity;

with satisfactory results.

10.13.3 Non-metallic cable support systems, protective casings and fixings installed on the open deck are to be protected from degradation caused by exposure to solar radiation.

10.13.4 Where the cable support system, protective casing or fixings are manufactured from a material other than metal, suitable supplementary metallic fixings or straps spaced at regular distances are to be provided such that, in the event of a fire or failure, the cable support system, protective casing and the affixed cables are prevented from falling and causing an injury to personnel and/or an obstruction to any escape route. Alternatively, the cables may be routed away from such areas.

10.13.5 The load on non-metallic cable support systems or protective casings is not to exceed the tested safe working load.

10.13.6 When a cable support system or protective casing is secured by means of clips or straps manufactured from a material other than metal the fixings are to be supplemented by suitable metal clips or straps spaced at regular distances each not exceeding 2 m and, for non-metallic cable support systems or protective casing, that used during safe working load testing.

10.13.7 Non-metallic fixings are to be flame retardant in accordance with the requirements of IEC 60092-101, or an alternative, relevant National or International Standard.

10.14 Single core electric cables for alternating current

10.14.1 When installed in protective casings, electric cables belonging to the same circuit are to be installed in the same casing, unless the casing is of non-magnetic material.

10.14.2 Cable clips are to include electric cables of all phases of a circuit unless the clips are of non-magnetic material.

10.14.3 Single-core cables of the same circuit are to be in contact with one another, as far as possible. In any event the distance between adjacent electric cables is not to be greater than one cable diameter.

10.14.4 If single-core cables of current rating greater than 250 A are installed near a steel bulkhead, the clearance between the cables and the bulkhead is to be at least 50 mm unless the cables belonging to the same a.c. circuit are installed in trefoil formation.

10.14.5 Magnetic material is not to be used between single core cables of a group. Where cables pass through steel plates, all the conductors of the same circuit are to pass through a plate or gland, so made that there is no magnetic material between the cables, and the clearance between the cables and the magnetic material is not to be less than 75 mm, unless the cables belonging to the same a.c. circuit are installed in trefoil formation.

10.14.6 Electric cables are to be installed such that the induced voltages, and any circulating currents, in the sheath or armour are limited to safe values.

10.15 Electric cable ends

10.15.1 Where screw-clamp or spring-clamp type terminations are used in electrical apparatus for external cable connections (*see* 1.10.7), cable conductors of the solid or stranded type may be inserted directly into the terminals. Where flexible conductors are used, a suitable termination is to be fitted to the cable conductor to prevent 'whiskering' of the strands.

10.15.2 If compression type conductor terminations are used on the cable ends, they are to be of a size to match the conductor and to be made with a compression type tool with the dies selected to suit the termination and conductor sizes and having a ratchet action to ensure completion of the compression action.

10.15.3 Soldered sockets may be used in conjunction with non-corrosive fluxes provided that the maximum conductor temperature at the joint, under short circuit conditions, does not exceed 160°C.

10.15.4 High voltage cables of the radial field type, i.e. having a conducting layer to control the electric field within the insulation, are to have terminations which provide electrical stress control.

10.15.5 Electric cables having hygroscopic insulation (e.g. mineral insulated) are to have their ends sealed against ingress of moisture.

10.15.6 Cable terminations are to be of such a design and dimensions that the maximum current likely to flow through them will not result in degradation of the contacts or damage to insulation as the result of overheating.

10.15.7 The fixing of conductors in terminals at joints and at tappings is to be capable of withstanding the thermal and mechanical effects of short circuit currents.

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10.16 Joints and branch circuits in cable systems

10.16.1 If a joint is necessary it is to be carried out so that all conductors are adequately secured, insulated and protected from atmospheric action. The flame retardant properties or fire resisting properties of the cable are to be retained, the continuity of metallic sheath, braid or armour is to be maintained and the current carrying capacity of the cable is not to be impaired.

10.16.2 Tappings (branch circuits) are to be made in suitable boxes of such a design that the conductors remain suitably insulated, protected from atmospheric action and fitted with terminals or busbars of dimensions appropriate to the current rating.

10.16.3 Cables of a fire-resistant type, *see* 10.5.3, are to be installed so that they are continuous throughout their length, without any joints or tappings.

10.17 Busbar trunking systems (bustrunks)

10.17.1 Where busbar trunking systems are used in place of electric cables, they are to comply with the requirements of 10.17.2 to 10.17.6, in addition to the applicable requirements in Section 7.

10.17.2 The busbar trunking, or enclosure system, is to have a minimum ingress protection of IP54, according to IEC60529: *Degrees of protection provided by enclosures* (IP Code).

10.17.3 The internal and external arrangements of the busbar trunking, or enclosure system, are to ensure that the fire and/or watertight integrity of any structure through which it passes is not impaired.

10.17.4 Where the busbar trunking system is employed for circuits on and below the bulkhead deck, arrangements are to be made to ensure that circuits on other decks are not affected in the event of partial flooding under the normal angles of inclination given in 1.9 for essential electrical equipment.

10.17.5 Supports and accessories are to be robust and are to be of corrosion-resistant material or suitably corrosion inhibited before erection. The support system is to effectively secure the busbar trunking system to the craft's structure.

10.17.6 When accessories are fixed to the busbar system by means of clips or straps manufactured from a material other than metal, the fixings are to be supplemented by suitable metal clips or straps, such that, in the event of a fire or failure, the accessories are prevented from falling and causing injury to personnel and/or an obstruction to any escape route. Alternatively, the busbar system may be routed away from such areas.

■ *Section 11* Batteries

11.1 General

11.1.1 The requirements of this Section apply to permanently installed secondary batteries of the vented and valve-regulated sealed type.

11.1.2 A vented battery is one in which the cells have a cover provided with an opening through which the products of electrolysis and evaporation are allowed to escape freely from the cells to the atmosphere.

11.1.3 A valve-regulated sealed battery is one in which the cells are closed but have an arrangement (valve) which allows the escape of gas if the internal pressure exceeds a predetermined value. The electrolyte cannot normally be replaced.

11.2 Construction

11.2.1 Batteries are to be constructed so as to prevent spilling of the electrolyte due to motion and to minimise the emission of electrolyte spray.

11.3 Location

11.3.1 Vented batteries connected to a charging device with a power output of more than 2 kW, calculated from the maximum obtainable charging current and the nominal voltage of the battery, are to be housed in an adequately ventilated compartment assigned to batteries only, or in an adequately ventilated suitable box on open deck.

11.3.2 Vented batteries connected to a charging device with a power output within the range 0,2 kW to 2 kW, calculated from the maximum obtainable charging current and the nominal voltage of the battery, are to be installed in accordance with 11.3.1, or may be installed within a well ventilated machinery or similar space.

11.3.3 Vented batteries connected to a charging device with a power output of less than 0,2 kW, calculated from the maximum obtainable charging current and the nominal voltage of the battery, may be installed in an open position or in a battery box in any suitable space.

11.3.4 Where more than one charging device is installed for any battery or group of batteries in one location, the total power output is to be used to determine the installation requirements of 11.3.1, 11.3.2 or 11.3.3.

11.3.5 Valve-regulated sealed batteries may be located in compartments with standard marine or industrial electrical equipment provided that the ventilation requirements of 11.5.10 and the charging requirements of 11.6.4 and 11.6.5 are complied with. Equipment that may produce arcs, sparks or high temperatures in normal operation is not to be in close proximity to battery vent plugs or pressure relief valve outlets.

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11.3.6 Where lead-acid and nickel-cadmium batteries are installed in the same compartment precautions are to be taken, such as the provision of screens, to prevent possible contamination of electrolytes.

11.3.7 Where batteries may be exposed to the risk of mechanical damage or falling objects they are to be suitably protected.

11.3.8 Batteries installed in crew and passenger cabins, together with their associated corridors, are to be of the hermetically sealed type.

11.3.9 A permanent notice prohibiting smoking and the use of naked lights or equipment, capable of creating a source of ignition, is to be prominently displayed adjacent to the entrances of all compartments containing batteries.

11.3.10 Only electrical equipment necessary for operational reasons and for the provision of lighting is to be installed in compartments provided in compliance with 11.3.1. Such electrical equipment is to be certified for group IIC gases and temperature Class T1 in accordance with IEC 60079: *Electrical apparatus for explosive gas atmospheres*, or an acceptable and relevant National Standard.

11.3.11 A permanent notice is to be prominently displayed adjacent to battery installations advising personnel that replacement batteries are to be of an equivalent performance type. For valve-regulated sealed batteries, the notice is to advise of the requirement for replacement batteries to be suitable with respect to products of electrolysis and evaporation being allowed to escape from cells to the atmosphere, *see also* 1.4.3.

11.4 Installation

11.4.1 Batteries are to be arranged such that each cell or crate of cells is accessible from the top and at least one side and it is to be ensured that they are suitably secured to move with the craft's motion. For high speed craft, the securing arrangements for batteries are to, as far as practicable, prevent excessive movement during the accelerations due to grounding or collision.

11.4.2 The materials used in the construction of a battery rack or stand are to be resistant to the battery electrolyte or suitably protected by paint or a coating.

11.4.3 Measures are to be taken to minimise the effect of any electrolyte spillage and leakage, for example the use of rubber capping around the top of the cells and the provision of a tray of electrolyte-resistant material below the cells, unless the deck is suitably protected with paint or a coating.

11.4.4 The interiors of all compartments for batteries, including crates, trays, boxes, shelves and other structural parts therein, are to be of an electrolyte-resistant material or suitably protected, for example with paint or a coating.

11.4.5 High speed craft are to be provided with an alarm to indicate that immediate action is required in the event of thermal runaway of any nickel cadmium battery.

11.5 Ventilation

11.5.1 Battery compartments and boxes are to be ventilated to avoid accumulation of dangerous concentrations of flammable gas. The ventilation openings are to be of a non-closeable type, with the exception of closing devices in accordance with 11.5.2, and a permanent notice is to be prominently displayed adjacent to them, stating:

THIS VENTILATOR OPENING IS NOT TO BE CLOSED OR BLOCKED AT ANY TIME – EXPLOSIVE GAS.

11.5.2 Closing devices in battery compartment ventilation openings are to be provided with a means to be locked open. A permanent notice is to be prominently displayed adjacent to each one to make clear that the closing device is to be closed only in the event of a fire.

11.5.3 Ducted natural ventilation may be employed for battery installations connected to a charging device with a power output of 2 kW or less, provided the exhaust duct can be run directly from the top of the compartment or box to the open air above, with no part of the duct more than 45° from the vertical. A suitable opening is also to be provided below the level of the top of the batteries, so as to ensure a free ventilation air flow. The ventilation duct is to have an area not less than 50 cm^2 for every 1 m^3 of battery compartment or box volume.

11.5.4 Where natural ventilation is impracticable or insufficient, mechanical ventilation is to be provided, with the air inlet located near the floor and the exhaust at the top of the compartment.

11.5.5 Mechanical exhaust ventilation complying with 11.5.9 is to be provided for battery installations connected to a charging device with a total maximum power output of more than 2 kW and also, to minimise the possibility of oxygen enrichment, compartments and spaces containing batteries with boost charging facilities are to be provided with mechanical exhaust ventilation irrespective of the charging device power output.

11.5.6 The ventilation system for battery compartments and boxes, other than boxes located on open deck or in spaces to which 11.3.2, 11.3.3 and 11.3.5 refer, is to be separate from other ventilation systems. The exhaust ducting is to be led to a location in the open air, where any gases can be safely diluted, away from possible sources of ignition and openings into spaces where gases may accumulate.

11.5.7 Fan motors associated with exhaust ducts from battery compartments are to be placed external to the ducts and the compartments.

11.5.8 Ventilating fans for battery compartments are to be so constructed and be of material such as to minimise risk of sparking in the event of the impeller touching the casing. Non-metallic-impellers are to be of an anti-static material.

11.5.9 Battery boxes are to be provided with sufficient ventilation openings located so as to avoid accumulation of flammable gas whilst preventing the entrance of rain or spray.

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11.5.10 The ventilation arrangements for all installations of vented type batteries are to be such that the quantity of air expelled is at least equal to:

$Q = 110In$

where

n = number of cells in series

I = maximum current delivered by the charging equipment during gas formation, but not less than 25 per cent of the maximum obtainable charging current in amperes

Q = quantity of air expelled in litres/hr.

11.5.11 The ventilation rate for compartments containing valve-regulated sealed batteries may be reduced to 25 per cent of that given in 11.5.10.

11.6 Charging facilities

11.6.1 Charging facilities are to be provided for all secondary batteries such that they may be completely charged from the completely discharged state in a reasonable time having regard to the service requirements.

11.6.2 Suitable means, including an ammeter and a voltmeter, are to be provided for controlling and monitoring charging of batteries, and to protect them against discharge into the charging circuits.

11.6.3 For floating circuits or any other conditions where the load is connected to the battery whilst it is on charge, the maximum battery voltage is not to exceed the safe value for any connected apparatus.

11.6.4 Where valve-regulated sealed batteries are installed, the charging facilities are to incorporate independent means such as overvoltage protection to prevent gas evolution in excess of the manufacturer's design quantity.

11.6.5 Boost charge facilities, where provided, are to be arranged such that they are automatically disconnected should the battery compartment ventilation system fail.

11.7 Recording of batteries for emergency and essential services

11.7.1 A schedule of batteries fitted for use for essential and emergency services is to be compiled and maintained.

11.7.2 Procedures are to be put in place and documented to ensure that, where batteries are replaced, they are of an equivalent performance type, *see also* 1.4.3.

11.7.3 When additions or alterations are proposed to the existing batteries for essential and emergency services, the schedule and replacement procedure documentation are to be updated to reflect the proposed installation and submitted in accordance with 1.4.2.

11.7.4 The schedule and replacement procedure documentation are to be made available to the LR Surveyor on request.

11.8 Cables

11.8.1 Where it is impracticable to provide electrical protective devices for certain cables supplied from batteries, e.g. within battery compartments and in engine starting circuits, unprotected cable runs are to be kept as short as possible and special precautions should be taken to minimise risk of faults, e.g., use of single core cables with additional sleeve over the insulation of each core, with shrouded terminals.

Section 12
Equipment – Heating, lighting and accessories

12.1 Heating and cooking equipment

12.1.1 The construction of heaters is to give a degree of protection according to IEC 60529: *Degrees of protection provided by enclosures (IP Code)*, or an acceptable and relevant National Standard, suitable for the intended location.

12.1.2 Heating elements are to be suitably guarded.

12.1.3 Heating and cooking equipment is to be installed such that adjacent bulkheads and decks are not subjected to excessive heating.

12.2 Lighting – General

12.2.1 Lampholders are to be constructed of flame retarding non-hygroscopic materials.

12.2.2 Lighting fittings are to be so arranged as to prevent temperature rises which overheat or damage surrounding materials. They must not impair the integrity of fire divisions.

12.3 Incandescent lighting

12.3.1 Tungsten filament lamps and lampholders are to be in accordance with Table 2.12.1.

12.3.2 Lampholders of type E40 are to be provided with a means of locking the lamp in the lampholder.

12.4 Fluorescent lighting

12.4.1 Fluorescent lamps and lampholders are to be in accordance with Table 2.12.1.

12.4.2 Fittings, reactors, capacitors and other auxiliaries are not to be mounted on surfaces which are subject to high temperatures. If mounted separately they are additionally to be enclosed in an earthed conductive casing.

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Table 2.12.1 Lamps and lampholders

Designation	Maximum lamp rating		Maximum lampholder current, A
	Voltage, V	Power, W	
Screw cap lamps			
E40	250	3000	16
E27	250	200	4
E14	250	15	2
E10	24	—	2
Bayonet cap lamps			
B22	250	200	4
B15d	250	15	2
B15s	55	15	2
Tubular fluorescent lamps			
G13	250	80	—
G5	250	13	—

12.4.3 Where capacitors of 0,5 microfarads and above are installed, means are to be provided to promptly discharge the capacitors on disconnection of the supply.

12.5 Discharge lighting

12.5.1 Discharge lamps operating in excess of 250 V are only acceptable as fixed fittings. Warning notices calling attention to the voltage are to be permanently displayed at points of access to the lamps and where otherwise necessary.

12.6 Socket outlets and plugs

12.6.1 The temperature rise on the live parts of socket outlet and plugs is not to exceed 30°C. Socket outlets and plugs are to be so constructed that they cannot be readily short-circuited whether the plug is in or out, and so that a pin of the plug cannot be made to earth either pole of the socket outlet.

12.6.2 All socket outlets of current rating in excess of 16 A are to be provided with a switch, and be interlocked such that the plug cannot be inserted or withdrawn when the switch is in the 'on' position.

12.6.3 Where it is necessary to earth the non-current carrying parts of portable or transportable equipment, an effective means of earthing is to be provided at the socket outlet.

12.6.4 On weather decks, galleys, laundries, machinery spaces and all wet situations socket outlets and plugs are to be effectively shielded against rain and spray and are to be provided with means of maintaining this quality after removal of the plug.

12.7 Enclosures

12.7.1 Enclosures for the containing and mounting of electrical accessories are to be of metal, effectively protected against corrosion, or of flame-retardant insulating materials.

■ *Section 13* Electrical equipment for use in explosive atmospheres

13.1 General

13.1.1 Electrical equipment is not to be installed in areas where an explosive atmosphere may be present, except where necessary for operational and/or safety purposes, when the equipment is to be of a certified safe type as listed below and details of the equipment and installation are to be submitted for consideration. The construction and type testing is to be in accordance with IEC 60079: *Electrical Equipment for Explosive Gas Atmospheres* or an acceptable and relevant National Standard.

Intrinsically safe – Ex 'i'
Increased safety – Ex 'e'
Flameproof – Ex 'd'
Pressurised enclosure – Ex 'p'
Powder filled – Ex 'q'
Encapsulated – Ex 'm'

13.1.2 The installation of electrical equipment in spaces and locations in which flammable mixtures are liable to collect, e.g. areas containing flammable gas or vapour and/or combustible dust, are, to comply with the relevant requirements of Pt 6, Ch 2,13 of the *Rules and Regulations for the Classification of Ships*.

13.1.3 Where cables are installed in hazardous areas, precautions are to be taken against risks being introduced in the event of an electrical fault.

13.1.4 For craft with spaces for carrying vehicles with fuel in their tanks for their own propulsion, the following requirements are also applicable:

(a) electrical equipment fitted within a height of 45 cm above the vehicle deck, or any platform on which vehicles are carried, or within the exhaust ventilation trunking for the space, is to be of a safe type;

(b) electrical equipment situated elsewhere within the space is to have an enclosure of ingress protection rating of at least IP55, if not of a safe type. (*See* IEC 60529: *Classification of Degrees of Protection Provided by Enclosures*). Smoke and gas detector heads are exempt from this requirement.

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Section 14
Navigation and manoeuvring systems

14.1 Steering systems

14.1.1 The requirements of 14.1.2 to 14.1.7 are to be read in conjunction with those in Pt 14, Ch 1.

14.1.2 Two exclusive circuits, fed from the main source of electrical power and each having adequate capacity to supply all the motors which may be connected to it simultaneously are to be provided for each electric or electrohydraulic steering unit arrangement consisting of one or more electric motors. One of these circuits may pass through the emergency switchboard. For high speed craft, one of these circuits is to be fed either from the emergency source of electric power or from an independent power source located in such a position as to be unaffected by fire or flooding affecting the main source of power. *See also* Pt 14, Ch 1,6.

14.1.3 The main and auxiliary steering unit motors are to be capable of being started from a position on the navigating bridge and also arranged to restart automatically when power is restored after a power failure.

14.1.4 The motor of an associated auxiliary electric or electrohydraulic power unit may be connected to one of the circuits supplying the main steering unit.

14.1.5 Only short circuit protection is to be provided for each main and auxiliary steering unit motor circuit.

14.1.6 In craft of less than 1600 gross tonnage, if an auxiliary steering unit is not electrically powered or is powered by an electric motor primarily intended for other services, the main steering unit may be fed by one circuit from the main switchboard. Consideration would be given to other protective arrangements other than described in 14.1.5 for such a motor primarily intended for other services.

14.1.7 Each main and auxiliary steering unit electric control system which is to be operated from the navigating bridge is to be served with electric power by a separate circuit supplied from the associated steering gear power circuit, from a point within the steering unit compartment, or directly from the same section of switchboard busbars, main or emergency, to which the associated steering unit power circuit is connected. Each separate circuit is to be provided with short circuit protection only.

14.2 Thruster systems for manoeuvring

14.2.1 Where a tunnel or athwartship thruster is fitted solely for the purpose of manoeuvring, and is electrically driven, its starting and operation is not to cause the loss of any essential services.

14.2.2 In order to ensure that the thruster system is not tripped inadvertently whilst manoeuvring the craft, overload protection in the form of an alarm is to be provided for the electric motor and any associated supply converters, in lieu of tripping.

14.2.3 The thruster electric motor is not to be disconnected as part of a load management switching operation.

14.3 Navigation lights

14.3.1 Navigation lights are to be connected separately to a distribution board reserved for this purpose only and accessible to the officer of the watch. This distribution board is to be connected directly or through transformers to the emergency source of electrical power in compliance with, for passenger craft, 3.2.7(b)(i) and (ii) and 3.2.9(a) or, for cargo craft, 3.3.8(b)(i) and (ii) and 3.3.8(a). An alarm is to be activated in the event of failure of a power supply from the distribution board.

14.3.2 Each navigation light is to be controlled and protected in each insulated pole by a switch and fuse or circuit-breaker mounted on the distribution board.

14.3.3 Provision is to be made on the navigating bridge for the navigation lights to be transferred to an alternative circuit fed from the main source of electrical power.

14.3.4 Each navigation light is to be provided with an automatic indicator giving audible and/or visual indication of failure of the light. If an audible device alone is fitted, it is to be connected to an independent source of supply, e.g. a battery, with means provided to test this supply. If a visual signal is used connected in series with the navigation light, means are to be provided to prevent extinction of the navigation light due to failure of the signal. The requirements of this paragraph do not apply to pilot boats, fishing boats and similar small vessels.

14.3.5 For navigation lights using light emitting diodes (consisting of multiple light sources) means to ensure that the overall luminous intensity of the navigation light is sufficient are to be provided in addition to the alarm to indicate the complete loss of the navigation light illumination required by 14.3.4. For replacement navigation lights, *see* 1.4.5.

14.3.6 To satisfy 14.3.5, an audible and visual alarm is to be activated to notify the Officer of the Watch that the luminous intensity of the light reduces below the level required by the IMO Convention on the International Regulations for Preventing Collisions at Sea. Alternative measures to ensure continuing acceptable performance of navigation lights using light emitting diodes may be considered that are in accordance with:

- IMO Res. MSC.253(83), *Performance Standards for Navigation Lights, Navigation Light Controllers and associated Equipment*, and
- EN 14744, *Inland navigation vessels and sea-going vessels – Navigation light*, or a relevant National or International Standard.

Where alternative measures are proposed that require periodic verification by personnel of the luminous intensity of navigation lights using light emitting diodes, details of the

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inspection implementation in the ships safety management system and acceptance by the National Administration requirements are to be submitted for consideration.

14.3.7 Navigation light power supply units installed to convert, control and/or monitor the distribution board power supply required by 14.3.1 above for connection to the light source(s) (e.g. for LED type navigation lights) are, in the event of a short-circuit on the unit output, are to disconnect or limit the supply to prevent further damage and activate an alarm in the event of a short-circuit on the unit output side.

14.3.8 Navigation light power supply units are to be self-checking, detecting failures of the unit itself and activating an alarm. These are to include:

- detection of system lock-ups (program hangs);
- means to detect whether navigation light switching command input circuits or links; and
- means to detect failure of the navigation light monitoring arrangements required to provide the alarms required by 14.3.4 and 14.3.5, as applicable.

14.3.9 The navigation light power supply failure alarms required by 14.3.1 are not to be displayed as a group alarm. Other navigation light alarms may be grouped for each navigation light where means are provided for personnel to determine the cause of the alarm. Activation of more than one of the navigation light alarms as a result of a single failure is to be prevented.

14.3.10 Any statutory requirements of the country of registration are to be complied with and may be accepted as an alternative to the above.

14.4 Navigational aids

14.4.1 Navigational aids as required by statutory regulations are to be fed from the emergency source of electrical power. *See also* 3.2.7(d)(i) and 3.3.7(d)(i).

14.5 Stabilisation

14.5.1 Where the stabilisation of a craft is essentially dependent upon a single device which in turn is dependent upon a continuous supply of electrical power, the supply arrangements are to comply with 5.2.3.

14.5.2 Where such systems are not dependent upon the continuous availability of electrical power, but one or more alternative systems not dependent upon the electrical supply are installed, a single circuit may be provided, with the protection and alarms required by 5.2.3.

■ *Section 15*
Electric propulsion

15.1 General

15.1.1 Where electric propulsion is proposed, details are to be submitted and the arrangements will be subject to special consideration.

■ *Section 16*
Fire safety systems

16.1 Fire detection and alarm systems

16.1.1 Fire detection and alarm systems are to be provided with at least two power supplies. One supply is to be connected to the main source of electrical power and another supply is to be connected to the emergency source of electrical power required by 3.2, 3.3 or 3.4, or an accumulator battery capable of supplying power for the same period of time as the emergency source of electrical power. All power supply feeders for fire detection and alarm systems are to be in accordance with 10.6.4.

16.1.2 Automatic changeover facilities in accordance with 5.3.5 are to be located in, or adjacent to, the main fire control panel. Power supply changeover is to be achieved without adverse effect. Failure of any power supply is to operate an audible and visual alarm. *See also* 1.13 and 1.14.

16.1.3 Where an accumulator battery provides a power supply, on restoration of the main source of electrical power, the rating of the charge unit is to be sufficient to recharge the battery while maintaining the output supply to the fire detection and alarm system.

16.1.4 Power supplies from the main and emergency switchboards are to be supplied by separate feeders that are reserved solely for this purpose. Where the emergency feeder for the electrical equipment used in the operation of the fixed fire detection and fire alarm system is supplied from the emergency switchboard, it is to be run from this switchboard to the automatic changeover switch without passing through any other switchboard.

16.1.5 For machinery spaces the requirements of Ch 1,2.8 are applicable.

16.1.6 Fire detection systems within the accommodation spaces and cabin balconies are, in addition to the requirements of Chapter 1, as applicable, to comply with 16.1.7 to 16.1.20.

16.1.7 The fire control panel is to be located on the navigating bridge or in a central fire control station and may form part of that panel specified in Ch 1,2.8.2. In passenger craft carrying more than 36 passengers, the fire control panel is to be located in the continuously manned central control station.

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16.1.8 Detectors and manually operated call points are to be grouped into sections. The activation of any detector or manually operated call point is to initiate a visual and audible fire signal at the control panel and indicating units. If the signals have not received attention within two minutes an audible alarm is to be automatically sounded throughout the crew accommodation and service spaces, control stations and machinery spaces of Category A. For craft required to comply with the HSC Code, there is to be no time delay for the audible alarms in crew accommodation areas when all the control stations are unattended. This alarm sounder system need not be an integral part of the detection system.

16.1.9 In yachts, the fixed fire detection and fire alarm system is to be capable of remotely and individually identifying each detector and manually operated call point. On other craft, indicating units are to denote, as a minimum, the section in which a detector or manually operated call point has operated. At least one unit is to be so located that it is easily accessible to responsible members of the crew. One indicating unit is to be located on the navigating bridge if the control panel is located in the central control station.

16.1.10 Clear information is to be displayed on or adjacent to each indicating unit about the spaces covered and the location of the section and, for yachts, each detector and manually operated call point.

16.1.11 Where the fire detection system does not include means of remotely identifying each detector and manually operated call point individually no section covering more than one deck within accommodation, service spaces and control stations is normally to be permitted except a section which covers an enclosed stairway. The number of enclosed spaces in each section are to be limited to the minimum considered necessary in order to avoid delay in identifying the source of fire. In no case are more than fifty spaces permitted in any section.

16.1.12 In passenger craft other than yachts, where the fire detection system does not include means of remotely identifying each detector individually a section of detectors is neither to serve spaces on both sides of the craft nor on more than one deck except when permitted by 16.1.17.

16.1.13 A section of fire detectors and manually operated call points which covers a control station, a service space or an accommodation space is not to include a machinery space of Category A.

16.1.14 The fire detection system is not to be used for any other purpose, except that closing of fire doors and similar functions may be permitted at the control panel. For craft required to comply with the HSC Code, the control panel may be used to activate a paging system, fan stops, closure of fire doors, closure of fire and smoke dampers, and/or a sprinkler system.

16.1.15 A loop circuit of an addressable fire detection system, capable of remotely identifying from either end of the loop, individually each detector and manually operated call point served by the circuit, may serve spaces on both sides of the craft and on several decks, but is not to be situated in more than one main vertical or horizontal fire zone, nor is a loop circuit which covers an accommodation space, service space and/or control station to include a machinery space of Category A.

16.1.16 A loop circuit of an addressable fire detection system may comprise one or more sections of detectors and manually operated call points. Where the loop comprises more than one section, the sections are to be separated by devices which will ensure that if a short-circuit occurs anywhere in the loop, only the affected section of detectors and manually operated call points will be isolated from the control panel. No section of detectors and manually operated call points is in general to include more than 50 detectors.

16.1.17 A section of fire detectors and manually operated call points is not to be situated in more than one main vertical or horizontal fire zone. Additionally, for craft required to comply with the HSC Code, a section of detectors and manually operated call points section of detectors of an addressable fire detection system is neither to serve spaces on both sides of the craft nor on more than one deck, except that:

(a) a section of detectors and manually operated call points may serve spaces on more than one deck if those spaces are located in either the fore or aft end of the craft, or they constitute common spaces occupying several decks, i.e. public spaces, enclosed stairways, etc.

(b) in craft of less than 20 m in breadth, a section of detectors and manually operated call points may serve spaces on both sides of the craft.

16.1.18 The wiring for each section of detectors and manually operated call points in an addressable fire detector system is to be separated as widely as practicable from that of all other sections on the same loop. When this is not practical, such as in large public spaces, the part of the loop which by necessity passes through the space for a second time is to be installed at the maximum possible distance from other parts of the loop.

16.1.19 Where it is intended that detectors be installed in external locations, e.g. cabin balconies, in addition to meeting the requirements for an environmental category suitable for open decks (*see* Ch 1,2.8.8), they are also to be tested for sun irradiation and ultraviolet exposure with satisfactory results.

16.1.20 Detectors fitted in cabins on yachts, when activated, are also to be capable of emitting, or cause to be emitted, an audible alarm within the space where they are located.

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16.2 Automatic sprinkler system

16.2.1 Any electrically driven power pump, provided solely for the purpose of continuing automatically the discharge of water from the sprinklers, is to be brought into action automatically by the pressure drop in the system before the standing fresh water charge in the pressure tank is completely exhausted.

16.2.2 For passenger craft, electrically driven sea-water pumps for automatic sprinkler systems are to be served by not less than two circuits reserved solely for this purpose, one fed from the main source of electrical power and one from the emergency source of electrical power. Such feeders are to be connected to an automatic change-over switch situated near the sprinkler pump and the switch is to be normally closed to the feeder from the main source of electrical power. No other switches are permitted in the feeders. The switches on the main and emergency switchboards are to be clearly labelled and normally kept closed.

16.2.3 The automatic alarm and detection system is to be fed by exclusive feeders from two sources of electrical power, one of which is to be an emergency source, with automatic change-over facilities located in, or adjacent to, the main alarm and detection panel.

16.2.4 Feeders for the sea-water pump and the automatic alarm and detection system are to be arranged so as to avoid galleys, machinery spaces and other enclosed spaces of high fire risk, except in so far as it is necessary to reach the appropriate switch boards. The cables are to be of a fire resistant type where they pass through such high risk areas.

16.3 Fixed water-based local application fire-fighting systems

16.3.1 Where fixed water-based local application fire-fighting system pressure sources are reliant on external power they need only be supplied by the main source of electrical power.

16.3.2 The fire detection, control and alarm systems are to be provided with an emergency source of electrical power required by 3.2, 3.3 or 3.4 and are also to be connected to the main source of electrical power. Separate feeders, reserved solely for this purpose, with automatic changeover facilities located in, or adjacent to, the main control panel are to be provided.

16.3.3 Failure of any power supply is to operate an audible and visual alarm. *See also* 1.13 and 1.14.

16.3.4 Means to activate a system are to be located at easily accessible positions inside and outside the protected space. Arrangements inside the space are to be situated such that they will not be cut off by a fire in the protected areas and are suitable for activation in the event of escape. Where it is proposed to install local activation means outside of the protected space, details are to be submitted for consideration.

16.3.5 For the electrical safety of electrical and electronic equipment in areas protected by fixed water-based local application, fire-fighting systems and adjacent areas where water may extend, the requirements of 16.3.6 to 16.3.10 apply.

16.3.6 As far as is practicable, electrical and electronic equipment is not to be located within protected areas or adjacent areas. The system pump, its electrical motor and the sea valve if any, may be in a protected space provided that they are outside areas where water or spray may extend.

16.3.7 High voltage equipment and their enclosures are not to be installed in protected areas or adjacent areas. For high voltage generators enclosures which cannot be fully located outside of adjacent areas due to close proximity, a technical justification, including proposed degree of protection ratings that are normally not to be lower that IP54, may be submitted for consideration that demonstrates the overall safety of the installation in the event of system operation.

16.3.8 In addition to the degree of protection requirements of 1.10.1, electrical and electronic equipment enclosures located within protected areas and within adjacent areas are to provide adequate protection in the event of system operation.

16.3.9 To demonstrate compliance with 16.3.8, evidence of the suitability of electrical and electronic equipment for use in protected areas and adjacent areas is to be submitted in accordance with 1.2.9. The evidence is to demonstrate that additional precautions have been taken, where necessary, in respect of:

(a) satisfying 16.3.6 and 16.3.7;
(b) personnel protection against electric shock;
(c) cooling airflow, where necessary, for equipment required to operate during system operation; and
(d) maintenance requirements for equipment before return to operation following system activation.

Any test evidence submitted is to consider the overall installation, including equipment types, system configuration and nozzles and the potential effects of airflows in the protected space.

16.3.10 The evidence required by 16.3.9 is to demonstrate the safe and effective operation of the overall arrangements in the event of system operation. This evidence is to demonstrate that exposure to system spray and/or water:

- cannot result in loss of essential services (e.g. unintended activation of automatic machinery shut-down);
- cannot result in loss of availability of emergency services;
- will not affect the continued safe and effective operation of electrical and electronic equipment required to operate during the required period of system operation;
- does not present additional electrical or fire hazards; and
- would require only identified readily replaceable components to be repaired or replaced.

The installation of electrical and electronic equipment required to provide essential or emergency services in enclosures with a degree of protection less than IP44 within areas exposed to direct spray is to be acceptable to LR, and evidence of suitability is to be submitted accordingly.

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16.3.11 Fixed water-based local application fire-fighting system electrically-driven pumps may be shared with:

- equivalent automatic sprinkler systems;
- equivalent main machinery space fire-fighting systems; or
- local fire-fighting systems for deep-fat cooking equipment;

provided that the shared use is accepted by the National Administration as complying with applicable statutory regulations and the arrangements comply with the requirements of 16.3.12 to 16.3.14.

16.3.12 Shared electrically-driven sea-water pumps are to be served by not less than two circuits reserved solely for this purpose, one fed from the main source of electrical power and one from the emergency source of electrical power. Such feeders are to be connected to an automatic changeover switch situated near the pumps and the switch is to be normally closed to the feeder from the main source of electrical power. No other switches are permitted in the feeders. The switches on the main and emergency switchboards are to be clearly labelled and normally kept closed.

16.3.13 Failure of a component in the power and control system is not to result in a reduction of the total available pump capacity below that required by any of the areas which the system is required to protect. For equivalent automatic sprinkler systems, a failure is not to prevent automatic release or reduce sprinkler pump capacity by more than 50 per cent.

16.3.14 Where fire-fighting systems share fire-fighting pumps, failure of one system is not to prevent activation of the pumps by any other system.

16.4 Fire pumps

16.4.1 When the emergency fire pump is electrically driven, the power is to be supplied by a source other than that supplying the main fire pumps. This source is to be located outside the machinery spaces containing the main fire pumps and their source of power and drive units.

16.4.2 The cables to the emergency fire pump are not to pass through the machinery spaces containing the main fire pumps and their source of power and drive units. The cables are to be of a fire resistant type where they pass through other high fire risk areas.

16.5 Refrigerated liquid carbon dioxide systems

16.5.1 Where there are electrically driven refrigeration units for carbon dioxide fire-extinguishing systems, one unit is to be supplied by the main source of electrical power and the other unit from the emergency source of electrical power.

16.5.2 Each electrically driven carbon dioxide refrigerating unit is to be arranged for automatic operation in the event of loss of the alternative unit.

16.6 Fire safety stops

16.6.1 In order to limit the fire growth potential in every space of the craft, means for controlling the air supply to the spaces and flammable liquids within the spaces are to be provided.

16.6.2 To control air supply, a means of stopping all forced and induced draught fans, and all ventilation fans serving accommodation spaces, service spaces, control stations and machinery spaces from an easily accessible position outside of the space being served is to be provided. The position is not to be readily cut off in the event of a fire in the spaces served by the fans.

16.6.3 In passenger craft carrying more than 36 passengers, a second means of stopping ventilation fans serving accommodation spaces, service spaces and control stations is to be provided at a position as far apart from the position required by 16.6.2 as is practicable. At both positions, the controls are to be grouped so that all fans can be stopped from either of the two positions.

16.6.4 A second means of stopping ventilation fans serving machinery spaces is to be provided at a position as far apart from the position required by 16.6.2 as is practicable. At both positions the controls are to be grouped so that all fans are operable from either of the two positions. The means for stopping machinery space ventilation fans are to be entirely separate from the means for stopping fans serving all other spaces.

16.6.5 In passenger craft, the means of stopping machinery ventilation fans required by 16.6.2 is to be located at the central control station which is to have safe access from the open deck. The central control station is to be provided with ventilation fan OFF status indications, together with a means for restarting the ventilation fans.

16.6.6 In passenger craft carrying 36 passengers or more with main laundries, electrically operated fire dampers fitted at the lower end of the laundry exhaust ducts required to comply with relevant statutory regulations are to be fitted with additional remote-control arrangements for shutting off the exhaust fans and supply fans and operating the fire dampers from within the space.

16.6.7 To control flammable liquids, a means of stopping all fuel oil, lubricating oil, hydraulic oil, cargo oil and thermal oil pumps and oil purifiers from outside the spaces being served is to be provided. The position is not to be cut off in the event of a fire.

16.6.8 Means of cutting off all electrical power to the galley except lighting circuits, in the event of a fire, are to be provided outside the galley exits, at positions which will not readily be rendered inaccessible by such a fire.

16.6.9 Following activation of any fire safety stops, a manual reset is to be provided in order to restart the associated equipment.

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16.6.10 Fire safety stop systems are to be designed on the fail-safe principle or alternatively the power supplies to, and the circuits of, the fire safety stop systems are to be continuously monitored and an alarm initiated in the event of a fault. Cables are to be of a fire-resistant type, *see* 10.5.3. *See also* 5.2.1.

16.6.11 High speed craft bridge areas are to be provided with suitable emergency means to:

(a) close ventilation openings and stop ventilating machinery supplying spaces covered by fixed fire-extinguishing systems;

(b) shut off fuel supplies to machinery in main and auxiliary machinery spaces; and

(c) stop main engine(s) and auxiliary machinery.

NOTE

These emergency means are to be sited in conjunction with required fixed fire extinguishing system activation means.

16.6.12 Additionally, Passenger (B) high speed craft are to be provided with the means required by 16.6.11 at one or more alternative stations separate from the bridge area. *See also* Ch 1,2.6.7.

16.7 Fire doors

16.7.1 The electrical power required for the control, indication and alarm circuits of fire doors is to be provided by an emergency source of electrical power as required by 3.2. In passenger craft carrying more than 36 passengers an alternative supply fed from the main source of electrical power, with automatic change-over facilities, is to be provided at the central control station. Failure of any power supply is to operate an audible and visual alarm, *see also* 1.13 and 1.14.

16.7.2 The control and indication systems for the fire doors are to be designed on the fail-safe principle with the release system having a manual reset.

16.8 Fire dampers

16.8.1 The electrical power required for the control and indication circuits of fire dampers is to be supplied from the emergency source of electrical power.

16.8.2 The control and indication systems for the fire dampers are to be designed on the fail-safe principle with the release system having a manual reset.

16.8.3 In passenger craft carrying 36 passenger or more with main laundries, where electrically operated fire dampers are required to comply with relevant statutory regulations to be fitted at the lower end of exhaust ducts from any main laundries, they are to be capable of automatic and remote operation.

16.8.4 For craft required to comply with the HSC Code with galley range exhaust ducts, electrically operated fire dampers fitted in the lower or upper end of the duct are to be remotely operated and, additionally, the fire damper at the lower end of the duct is to be automatically operated.

16.9 Fire-extinguishing media release alarms

16.9.1 Where it is required that alarms be provided to warn of the release of a fire extinguishing medium, and these are electrically operated, they are to be provided with an emergency source of electrical power, as required by 3.2, 3.3 or 3.4 and also connected to the main source of electrical power, with automatic changeover facilities located in, or adjacent to, the fire-extinguishing media release panel, *see also* 1.13. Failure of any power supply is to operate an audible and visual alarm, *see also* 1.13 and 1.14.

16.10 Electrically powered air compressors for breathing air cylinders

16.10.1 In yachts that are 500 gt or more carrying more than 36 passengers where electrically powered air compressors are installed as part of the means required by the National Administration, for recharging breathing apparatus air cylinders for fire-fighter's outfits, the compressors are to be supplied by the main and emergency sources of electrical power. Details of the emergency supply electrical load, supply changeover arrangements and operation under fire conditions are to be submitted for consideration. The arrangements are to be to the satisfaction of the National Administration with which the craft is registered.

■ *Section 17*
Crew and passenger emergency safety systems

17.1 Emergency lighting

17.1.1 For the purpose of this Section emergency lighting, transitional emergency lighting and supplementary emergency lighting are hereafter referred to under the generic name 'emergency lighting'.

17.1.2 Emergency lighting provided in compliance with Section 3 is to be arranged so that a fire or other casualty in the spaces containing the emergency source of electrical power, associated transforming equipment and the emergency lighting switchboard does not render the main lighting system inoperative.

17.1.3 The level of illumination provided by the emergency lighting is to be adequate to permit safe evacuation in an emergency, having regard to the possible presence of smoke, *see* 17.4.

17.1.4 The exit(s) from every main compartment occupied by passengers or crew is to be continuously illuminated by an emergency lighting fitting.

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17.1.5 Switches are not to be installed in the final sub-circuits to emergency light fittings unless the light fittings are serving normally unmanned spaces, e.g. storage-rooms, cold rooms, etc., or they are normally required to be extinguished for operational reasons, e.g. for night visibility from the navigating bridge. Where switches are fitted they are to be accessible only to craft crew with provision made to ensure that the emergency lighting is energised when such spaces are manned and/or during emergency conditions.

17.1.6 Where emergency lighting fittings are connected to dimmers, provision is to be made, upon the loss of the main lighting, to automatically restore them to their normal level of illumination.

17.1.7 Fittings are to be specially marked to indicate that they form part of the emergency lighting system.

17.2 General emergency alarm system

17.2.1 An electrically operated bell or klaxon or other equivalent warning system installed in addition to the craft's whistle or siren, for sounding the general emergency alarm signal, is to comply with the *International Life-saving Appliances (LSA) Code* and with the requirements of this Section, *see also* 1.13 and 1.14.

17.2.2 The general emergency alarm system is to be provided with an emergency source of electrical power as required by 3.2, 3.3, 3.4 or 19.10 and also connected to the main source of electrical power with automatic changeover facilities located in, or adjacent to, the main alarm signal distribution panel. Failure of any power supply is to operate an audible and visual alarm, *see also* 1.13.

17.2.3 The general emergency alarm distribution system is to be so arranged that a fire or casualty in any one main vertical zone, as defined by SOLAS Reg. II-2/A, Reg. 3.9, other than the zone in which the public address control station is located, will not interfere with the distribution in any other such zone.

17.2.4 There are to be segregated cable routes to public rooms, alleyways, stairways, control stations and on passenger craft on open decks, so arranged that any single electrical fault, localised fire or casualty will not cause the loss of the facility to sound the general emergency alarm in any public rooms, alleyways, stairways, control stations and on passenger craft on open decks, albeit at a reduced capacity.

17.2.5 Where the special alarm fitted to summon the crew, operated from the navigation bridge, or fire control station, forms part of the craft's general alarm system, it is to be capable of being sounded independently of the alarm to the passenger spaces.

17.2.6 The sound pressure levels are to be measured during a practical test and documented, *see* 20.2.

17.3 Public address system

17.3.1 Public address systems are to comply with the *International Life-saving Appliances (LSA) Code* and the requirements of this Section.

17.3.2 The public address system is to be provided with an emergency source of electrical power as required by 3.2, 3.3, 3.4 or 19.10 and also connected to the main source of electrical power with automatic changeover facilities located adjacent to the public address system. Failure of any power supply is to operate an audible and visual alarm, *see also* 1.13 and 1.14.

17.3.3 The public address system is to have multiple amplifiers having their power supplies so arranged that a single fault will not cause the loss of the facility to broadcast emergency announcements in public rooms, alleyways, stairways and control stations, albeit at a reduced capacity.

17.3.4 The public address distribution system is to be so arranged that a fire or casualty in any one main vertical zone, as defined by SOLAS Reg. II-2/A, Reg.3.9, other than the zone in which the public address control station is located, will not interfere with the distribution in any other such zone.

17.3.5 There are to be segregated cable routes to public rooms, alleyways, stairways, and control stations so arranged that any single electrical fault, fire or casualty will not cause the loss of the facility to broadcast emergency announcements in any public rooms, alleyways, stairways, and control stations, albeit at a reduced capacity.

17.3.6 Amplifiers are to be continuously rated for the maximum power that they are required to deliver into the system for audio and, where alarms are to be sounded through the public address system, for tone signals.

17.3.7 Loudspeakers are to be continuously rated for their proportionate share of amplifier output and protected against short-circuits.

17.3.8 Amplifiers and loudspeakers are to be selected and arranged to prevent feedback and other interference. There are also to be means to automatically override any volume controls, so as to ensure the specified sound pressure levels are met.

17.3.9 Where the public address system is used for sounding the general emergency alarm and the fire-alarm, the following requirements are to be met in addition to those of 17.2:

(a) The emergency system is given automatic priority over any other system input.

(b) More than one device is provided for generating the sound signals for the emergency alarms.

17.3.10 Where more than one alarm is to be sounded through the public address system, they are to have recognisably different characteristics and additionally be arranged, so that any single electrical failure which prevents the sounding of any one alarm will not affect the sounding of the remaining alarms.

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17.3.11 The sound pressure levels are to be measured during a practical test using speech and, where applicable, tone signals, and documented, *see* 20.2.

17.4 Escape route or low location lighting (LLL)

17.4.1 Where required escape route or low location lighting (LLL) is satisfied by electric illumination, the LLL system is to comply with the requirements of this sub-Section.

17.4.2 The LLL system is to be provided with an emergency source of electrical power and also be connected to the main source of electrical power, with automatic changeover facilities located adjacent to the control panel, *see also* 1.14.

17.4.3 The power supply arrangements to the LLL are to be arranged so that a single fault or a fire in any one fire zone or deck does not result in loss of the lighting in any other zone or deck. This requirement may be satisfied by the power supply circuit configuration, use of fire-resistant cables complying with 10.5.3, and/or the provision of suitably located power supply units having integral batteries adequately rated to supply the connected LLL for a minimum period of 60 minutes, *see* 11.3.7.

17.4.4 The performance and installation of lights and lighting assemblies are to comply with ISO standard 15370: *Ships and marine technology – Low location lighting on passenger ships*.

■ *Section 18*
Craft safety systems

18.1 Watertight doors

18.1.1 The electrical power required for power-operated sliding watertight doors is to be separate from any other power circuit and supplied from the emergency switchboard either directly or by a dedicated distribution board situated above the waterline in the final condition of damage or above the bulkhead deck as applicable. The associated control, indication and alarm circuits are to be supplied from the emergency switchboard either directly or by a dedicated distribution board situated above the waterline in the final condition of damage or above the bulkhead deck as applicable and for passenger craft be capable of being automatically supplied by the transitional source of emergency electrical power required by 3.2.9 or, where applicable, 3.3.9 in the event of failure of either the main or emergency source of electrical power.

18.1.2 A single failure in the power operating or control system of power-operated sliding watertight doors is not to result in a closed door opening or prevent the hand operation of any door.

18.1.3 Availability of the power supply is to be continuously monitored at a point in the electrical circuit adjacent to the door operating equipment. Loss of any such power supply is to activate an audible and visual alarm at the central operating console at the navigating bridge.

18.1.4 Electrical power, control, indication and alarm circuits are to be protected against fault in such a way that a failure in one door circuit will not cause a failure in any other door circuit. Short circuits or other faults in the alarm or indicator circuits of a door are not to result in a loss of power operation of the door. Arrangements are to be such that leakage of water into the electrical equipment located below the bulkhead deck will not cause the door to open.

18.1.5 The enclosures of electrical components necessarily situated below the waterline in the final condition of damage or below the bulkhead deck as applicable are to provide suitable protection against the ingress of water with ratings as defined in IEC 60529 or an acceptable and relevant national standard, as follows:

(a) Electrical motors, associated circuits and control components, protected to IPX7 Standard.

(b) Door position indicators and associated circuit components protected to IPX8 Standard, where the water pressure testing of the enclosures is to be based on the pressure that may occur at the location of the component during flooding for a period of 36 hours.

(c) Door movement warning signals, protected to IPX6 Standard.

18.1.6 Watertight door electrical controls including their electric cables are to be kept as close as is practicable to the bulkhead in which the doors are fitted and so arranged that the likelihood of them being involved in any damage which the craft may sustain is minimised.

18.1.7 An audible alarm, distinct from any other alarm in the area, is to sound whenever the door is closed remotely by power and sound for at least five seconds but no more than ten seconds before the door begins to move and is to continue sounding until the door is completely closed. The audible alarm is to be supplemented by an intermittent visual signal at the door in passenger areas and areas where the noise level exceeds 85 dB(A).

18.1.8 A central operating console is to be fitted on the navigating bridge and is to be provided with a 'master-mode' switch having:

(a) a 'local control' mode for normal use which is to allow any door to be locally opened and locally closed after use without automatic closure, and;

(b) a 'doors closed' mode for emergency use which is to allow any door that is opened to be automatically closed whilst still permitting any doors to be locally opened but with automatic reclosure upon release of the local control mechanism.

18.1.9 The 'master mode' switch is to be arranged to be normally in the 'local control' mode position; be clearly marked as to its emergency function and be Type Approved in accordance with LR's Procedure for Type Approved Products.

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18.1.10 The central operating console at the navigating bridge is to be provided with a diagram showing the location of each door, with visual indicators to show whether each door is open or closed. A red light is to indicate a door is fully open and a green light, a door fully closed. When the door is closed remotely a red light is to indicate the intermediate position by flashing. The indicating circuit is to be independent of the control circuit for each door.

18.1.11 The arrangements are to be such that it is not possible to remotely open any door from the central operating console.

18.2 Shell doors, loading doors and other closing appliances

18.2.1 Where it is required that indicators be provided for shell doors, loading doors and other closing appliances, which are intended to ensure the watertight integrity of the craft's structure in which they are located, the indicator system is to be designed on the fail-safe principle. The system is to indicate if any of the doors or closing appliances are open or are not fully closed or secured.

18.2.2 Where such doors and appliances are to be operated at sea, the requirements of 18.1 are to be complied with as far as is practicable.

18.2.3 The electrical power supply for the indicator system is to be independent of any electrical power supply for operating and securing the doors.

Section 19
Cargo craft, patrol and pilot craft, workboats and other similar craft of less than 500 tons gross tonnage for operation in Service Groups 1 to 3, and yachts less than 500 gt

19.1 General requirements

19.1.1 The requirements of this Section are applicable to electrical installations where the voltage of supply does not exceed 440 V a.c. or d.c.

19.1.2 The electrical installations for propulsion and auxiliary service where the voltage of supply exceeds 440 volts are to be constructed and installed in accordance with Sections 1 to 18.

19.1.3 Cargo craft of 300 tons gross tonnage and above are also to comply with 3.7.

19.1.4 Alternative arrangements, including those in accordance with IEC 60092-507:2008-01, *Electrical installations in ships – Small vessels*, or a relevant International or National Standard acceptable to LR may be considered.

19.2 Plans

19.2.1 At least three copies of the plans and particulars in 19.2.2 to 19.2.6 are to be submitted for consideration. Single copies only are required of plans in 19.2.7.

19.2.2 Single line diagram of main power and lighting systems which is to include:
(a) rating of machines; transformers; batteries and semi-conductor converters;
(b) all feeders connected to the main switchboard;
(c) section boards and distribution boards;
(d) insulation type, size and current loadings of cables;
(e) make, type and rating of circuit breakers and fuses.

19.2.3 Simplified diagrams of generator circuits and feeder circuits showing:
(a) protective devices;
(b) instrumentation and control devices;
(c) preference tripping;
(d) earth fault indication/protection.

19.2.4 Calculations of short circuit currents at main switchboard and distribution boards, details of circuit breaker and fuse operating times and discrimination curves.

19.2.5 For battery installation, arrangement plans and calculations are to show compliance with 19.12.

19.2.6 Details of electrically operated personnel safety systems which are to include single line diagrams and a general arrangement plan of the vessel showing location and cable routes of:
(a) fire detection, alarm and extinction systems;
(b) internal communication and alarm systems.

19.2.7 Schedule of normal operating loads on the system.

19.3 Survey

19.3.1 The installation is to be inspected and tested by the Surveyors, in accordance with the requirements of Section 20, as appropriate, and is to be to their satisfaction.

19.4 Addition or alterations

19.4.1 No addition, temporary or permanent is to be made to an approved installation until it has been ascertained that the current carrying capacity and the condition of the existing equipment, including cables and switchgear, are adequate for the increased load.

19.4.2 Plans are to be submitted for consideration, and the alterations or additions are to be carried out under the survey and to the satisfaction of the Surveyors.

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19.5 Location and construction of equipment

19.5.1 Electrical equipment is to be accessibly placed, clear of flammable material in well ventilated, adequately lighted spaces, in which flammable gases cannot accumulate and where it is not exposed to risk of mechanical damage or damage from water, steam or oil. Where necessarily exposed to such risks, the equipment is to be suitably constructed or enclosed. Equipment is to be accessible for maintenance.

19.5.2 Insulating materials and insulated windings are to be flame retardant, and resistant to tracking, moisture, sea air and oil vapour unless special precautions are taken to protect them.

19.5.3 Securing arrangements used in connection with current carrying parts are to be effectively locked.

19.5.4 The operation of all electrical equipment is to be satisfactory under such conditions of vibrations, movements and shock as may arise in normal practice.

19.5.5 The design and installation of electrical equipment is to be such that the risk of fire due to its failure is minimised. It is, as a minimum, to comply with a National or International Standard revised where necessary for ambient conditions. Equipment is to be tested at the manufacturer's works and a certificate of tests issued by the manufacturer.

19.6 Systems of distribution

19.6.1 The following systems of generation and distribution are acceptable:

(a) two wire insulated;
(b) two wire with one pole earthed;
(c) three phase three wire insulated neutral;
(d) three phase, four wire with neutral earthed but without hull return.

19.6.2 A device(s) is to be installed for every insulated distribution system, whether primary or secondary, for power, heating and lighting circuits to continuously monitor the insulation level to earth.

19.7 Earthing

19.7.1 Except where exempted by 19.7.2 all non-current carrying exposed metal parts of electrical equipment and cables are to be earthed.

19.7.2 The following parts may be exempted from the requirements of 19.7.1:

(a) lamp-caps, where suitably shrouded;
(b) shades, reflectors and guards supported in lampholders or light fittings constructed of, or shrouded in, non-conducting material;
(c) metal parts on, or screws in or through, non-conducting materials, which are separated by such material from current-carrying parts and from earthed non-current carrying parts in such a way that in normal use they cannot become live or come into contact with earthed parts;
(d) apparatus which is constructed in accordance with the principle of double insulation;
(e) bearing housings which are insulated in order to prevent circulation of current in the bearings;
(f) clips for fluorescent lamps;
(g) cable clips and short lengths of pipes for cable protection;
(h) apparatus supplied at a voltage not exceeding 55V direct current or 55V root mean square, between conductors, or between any conductor and earth in a circuit isolated from the supply. Autotransformers are not to be used for the purpose of achieving the alternating current voltage;
(j) apparatus or parts of apparatus which although not shrouded in insulating material is nevertheless otherwise so guarded that it cannot be touched and cannot come in contact with exposed metal.

19.7.3 With wood and other non-metallic hull constructions earthing connections are to be made to the generator frame, engine bedplate and earthing plate. Earthing connections are not to be made to hull sheathing, skin fittings or plumbing.

19.8 Protection

19.8.1 Installations are to be protected against over-currents including short circuits. The tripping/fault clearance times of protective devices are to provide complete and co-ordinated protection to ensure:

(a) availability of services not affected by the faulty circuit;
(b) elimination of the fault to reduce damage to the system and hazard of fire.

19.8.2 Short circuit protection and a means of complete isolation is to be provided for each source of power.

19.8.3 Protection for battery circuits is to be provided at a position external and adjacent to the battery compartments; batteries used solely for engine starting may be provided with only a means of isolation.

19.8.4 Short circuit and overload protection together with a means of isolation is to be provided in each non-earthed outgoing circuit of the main switchboard and each distribution board.

19.8.5 Each final sub-circuit is to be provided with short circuit protection and a means of isolation in each non-earthed line.

19.8.6 Lighting circuits are to be supplied by circuits separate from those for power.

19.8.7 Control circuits for engine monitoring and other services are to be provided with short circuit protection.

19.8.8 Protective devices are not to be fitted in any earthed line of a distribution system.

19.8.9 Circuit breakers and fuses are to have a certified fault rating adequate for the installation and are to comply with a National or International Standard.

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19.8.10 In the absence of precise data the calculation methods given in 6.2.4 are to be used for evaluation of short circuit currents.

19.8.11 Generators for a.c. systems are to be provided, as a minimum, with the protective gear required by 6.8.2 and 6.8.3 and additionally provided with the instrumentation required by 7.11.

19.9 Quality of power supplies

19.9.1 Unless specified otherwise electrical equipment, other than that supplied by battery systems, is to operate satisfactorily with the following simultaneous variations, from their nominal value, when measured at the consumer input terminals:

(a) Voltage:
- Permanent variations +6 per cent, –10 per cent
- Transient recovery +20 per cent, –15 per cent
- Recovery time 1,5 seconds.

(b) Frequency:
- Permanent variations ±5 per cent
- Transient variations ±10 per cent
- Recovery time five seconds.

19.9.2 Generator voltage regulators and engine governors are to be such as to ensure that the above supply variations are not exceeded.

19.10 Sources of electrical power

19.10.1 Under sea-going conditions where electrical power is required for services for the propulsion, navigation and safety of the craft and crew, it is to be provided by either a generator(s) having a rating sufficient to ensure the operation of these services or by an engine-driven charging system in conjunction with a battery(ies).

19.10.2 Under emergency conditions where electrical power is required for lighting to enable persons to evacuate the craft, for navigational lights, fire detection and alarm systems and internal communication and alarm systems, it is to be provided by alternative source(s) of electrical power located separately from the source(s) of power in 19.10.1 and suitably located for use in an emergency. This source(s) of electrical power is to be adequate to permit evacuation and to supply the navigation lights, fire detection and alarm systems and internal communication and alarm systems, for a period of 5 hours duration.

19.10.3 Where electrical power is required for services for the propulsion, navigation and safety of the yacht or craft and for the safety of the crew it is to be provided by:

(a) for **non-passenger type yachts of scantling length between 24 m and 50 m**, at least two generators having ratings sufficient to ensure the operation of these services when any one generator is out of action; or

(b) for **non-passenger type service craft for Service Groups 1 to 3**, a generator(s) having a rating sufficient to ensure the operation of these services without being overloaded.

19.10.4 Additionally, for **non-passenger type yachts of scantling length between 24 m and 50 m**:

(a) generators fitted to satisfy the requirements of 19.10.3(a) may be driven by the main engine provided the requirements of 19.9.1 are satisfied for all main engine speed and load conditions and that there is at least one of the remaining generators driven by a prime mover independent of the main engine; and

(b) any batteries provided for the duty, referred to in 19.10.2, are to be rated for at least 5 hours duration.

19.10.5 Additionally, for **non-passenger type service craft for Service Groups 1 to 3**, in a single generator installation, or where in a multiple generator installation with one generator out of action the remaining generator(s) is not capable of supplying the circuits serving any safety, essential lighting and communication equipment, an alternative source of electrical power of 5 hours duration is to be provided for these services.

19.11 Cables

19.11.1 Cables and cable installations are to be in accordance with the requirements of Section 10.

19.12 Batteries

19.12.1 Batteries and battery installations are to be in accordance with the requirements of Section 11.

19.13 Lightning conductors

19.13.1 Lightning conductors complying with IEC 60092-401 are to be fitted to each mast of all wood, composite and steel craft having wooden masts or topmasts. They need not be fitted to steel craft having steel masts.

19.14 Fire detection and alarm systems

19.14.1 Where a fire detection and alarm system is fitted, it is to be in accordance with the requirements of 16.1.

19.15 Internal communication and alarm systems

19.15.1 Where internal communication and alarm systems are provided for use in an emergency, they are to comply with the requirements of 17.2 and 17.3 as appropriate.

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■ *Section 20*
Testing and trials

20.1 Testing

20.1.1 Tests in accordance with 20.1.2 to 20.1.4 are to be satisfactorily carried out on all electrical equipment, complete or in sections, at the manufacturer's premises and a test report issued by the manufacturer.

20.1.2 A high voltage at any frequency between 25 and 100 Hz is to be applied between:
(a) all current carrying parts connected together and earth;
(b) all current carrying parts of opposite polarity or phase.
For rotating machines the value of test voltage is to be 1000 V plus 2 x rated voltage with a minimum of 2000 V, and for other electrical equipment, it is to be in accordance with Table 2.20.1. Items of equipment included in the assembly for which a test voltage lower than the above is specified may be disconnected during the test and tested separately at the appropriate lower test voltage. The test is to be commenced at a voltage of about one-third the test voltage and is to be increased to full value as rapidly as is consistent with its value being indicated by the measuring instrument. The full test voltage is then to be maintained for one minute, and then reduced to one-third full value before switching off. The assembly is considered to have passed the test if no disruptive discharge occurs.

Table 2.20.1 Test voltage

Rated voltage, U_n U_n V	Test voltage a.c. (r.m.s.), V
$U_n \leq 60$	500
$60 < U_n \leq 1000$	$2 \times U_n + 1000$
$1000 < U_n \leq 2500$	6500
$2500 < U_n \leq 3500$	10000
$3500 < U_n \leq 7200$	20000
$7200 < U_n \leq 12000$	28000
$12000 < U_n \leq 15000$	38000

20.1.3 When it is desired to make additional high voltage tests on equipment which has already passed its tests, the voltage of such additional tests is to be 80 per cent of the test voltage the equipment has already passed.

20.1.4 Immediately after the high voltage test, the insulation resistance is to be measured using a direct current insulation tester, between:
(a) all current carrying parts connected together and earth;
(b) all current carrying parts of different polarity or phase.
The minimum values of test voltage and insulation resistance are given in Table 2.20.2.

20.1.5 Tests in accordance with the standard with which the equipment complies may be accepted as an alternative to the above.

Table 2.20.2 Test voltage and minimum insulation

Rated voltage U_n V	Minimum voltage of the tests, V	Minimum insulation resistance, MΩ
$U_n \leq 250$	$2 \times U_n$	1
$250 < U_n \leq 1000$	500	1
$1000 < U_n \leq 7200$	1000	$\frac{U_n}{1000} + 1$
$7200 < U_n \leq 15000$	5000	$\frac{U_n}{1000} + 1$

20.2 Trials

20.2.1 Before a new installation, or any alteration or addition to an existing installation, is put into service the applicable trials in 20.2.2 to 20.2.7 are to be carried out. These trials are in addition to any acceptance tests which may have been carried out at the manufacturer's works.

20.2.2 The insulation resistance is to be measured of all circuits and electrical equipment, using a direct current insulation tester, between:
(a) all current carrying parts connected together and earth; and, so far as is reasonably practicable,
(b) all current carrying parts of different polarity or phase;
The minimum values of test voltage and insulation resistance are given in Table 2.20.2. The installation may be subdivided and appliances may be disconnected if initial tests produce results less than these figures.

20.2.3 Tests are to be made to verify the effectiveness of:
(a) earth continuity conductor;
(b) the earthing of non-current carrying exposed metal parts of electrical equipment and cables not exempted by 1.11.2 or 19.7.2;
(c) bonding for the control of static electricity.

20.2.4 It is to be demonstrated that the Rules have been complied with in respect of:
(a) satisfactory performance of each generator throughout a run at full rated load;
(b) temperature of joint, connections, circuit-breakers and fuses;
(c) the operation of engine governors, synchronising devices, overspeed trips, reverse-current, reverse-power and over-current trips and other safety devices;
(d) voltage regulation of every generator when full rated load is suddenly thrown off and when starting the largest motor connected to the system;
(e) voltage drop;
(f) harmonic distortion of the voltage waveform;
(g) satisfactory parallel operation, and kW and KVA load sharing of all generators capable of being operated in parallel at all loads up to normal working load;
(h) alarm sound pressure levels; and
(j) all essential and other important equipment are to be operated under service conditions, though not necessarily at full load or simultaneously, for a sufficient length of time to demonstrate that they are satisfactory.

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20.2.5 Voltage drop is to be measured, where necessary, to verify that this is not in excess of that specified in 1.7 or 19.9. Where necessary, measurements are to be taken as part of the trials specified in 20.2.4 (c), (d), (e) and (f), to verify that the installation will provide a quality of power supply in accordance with the values listed in 1.7.

20.2.6 It is to be demonstrated by practical tests that the Rules have been complied with in respect of fire, crew and passenger emergency and craft safety systems.

20.2.7 On completion of the general emergency alarm system and public address system tests, the Surveyor is to be provided with two copies of the test schedule, detailing the measured sound pressure levels. Such schedules are to be signed by the Surveyor and the Builder.

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LIFE MATTERS

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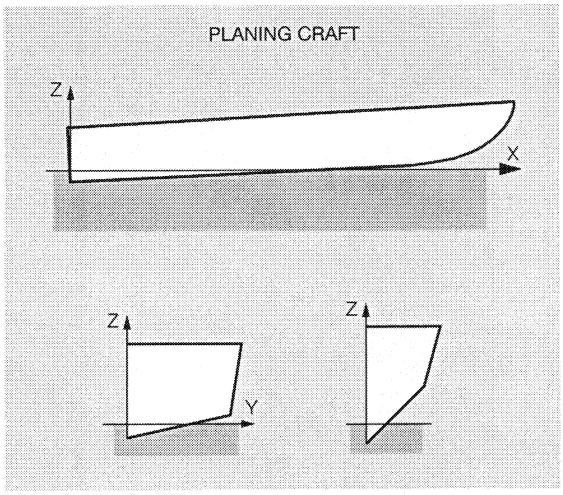
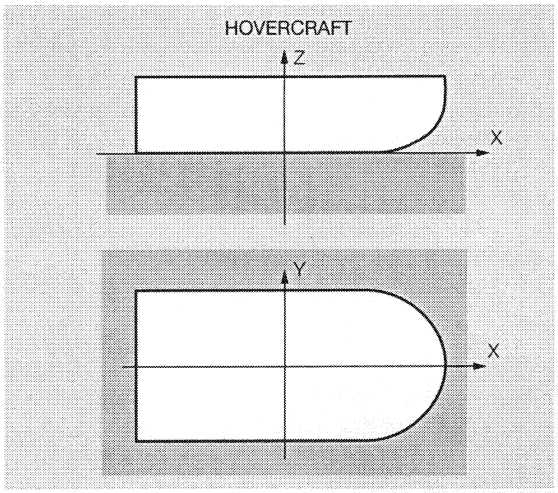
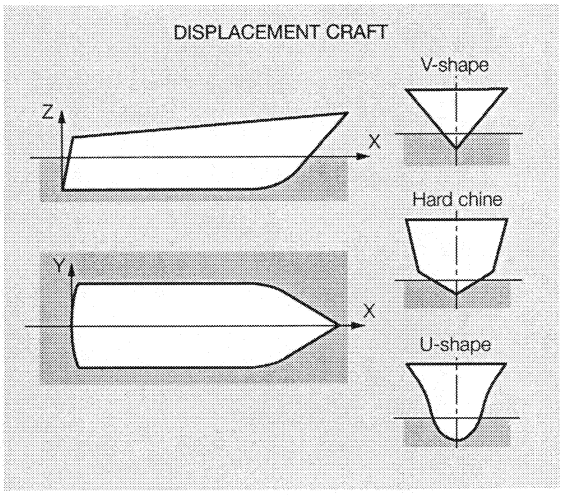
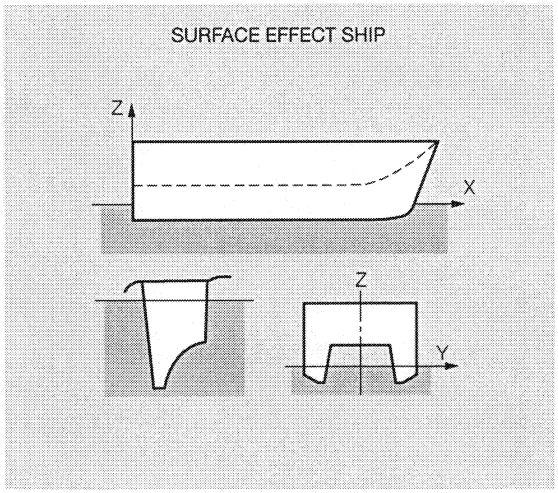
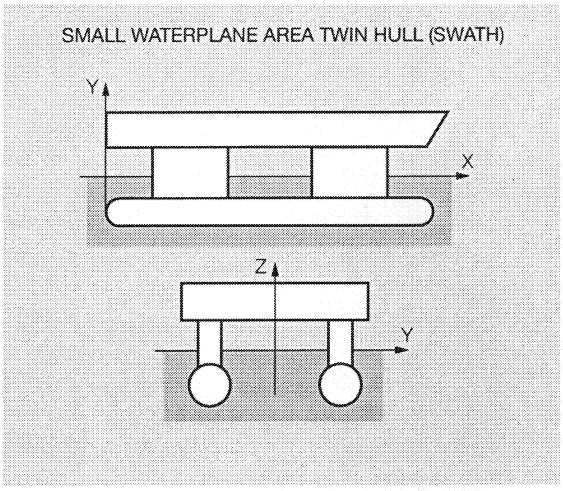
DIFFERENT TYPES OF HULL FORMS COVERED BY THE SPECIAL SERVICE CRAFT RULES

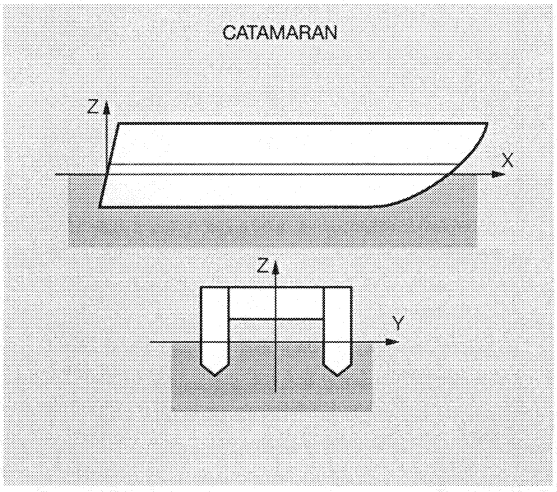












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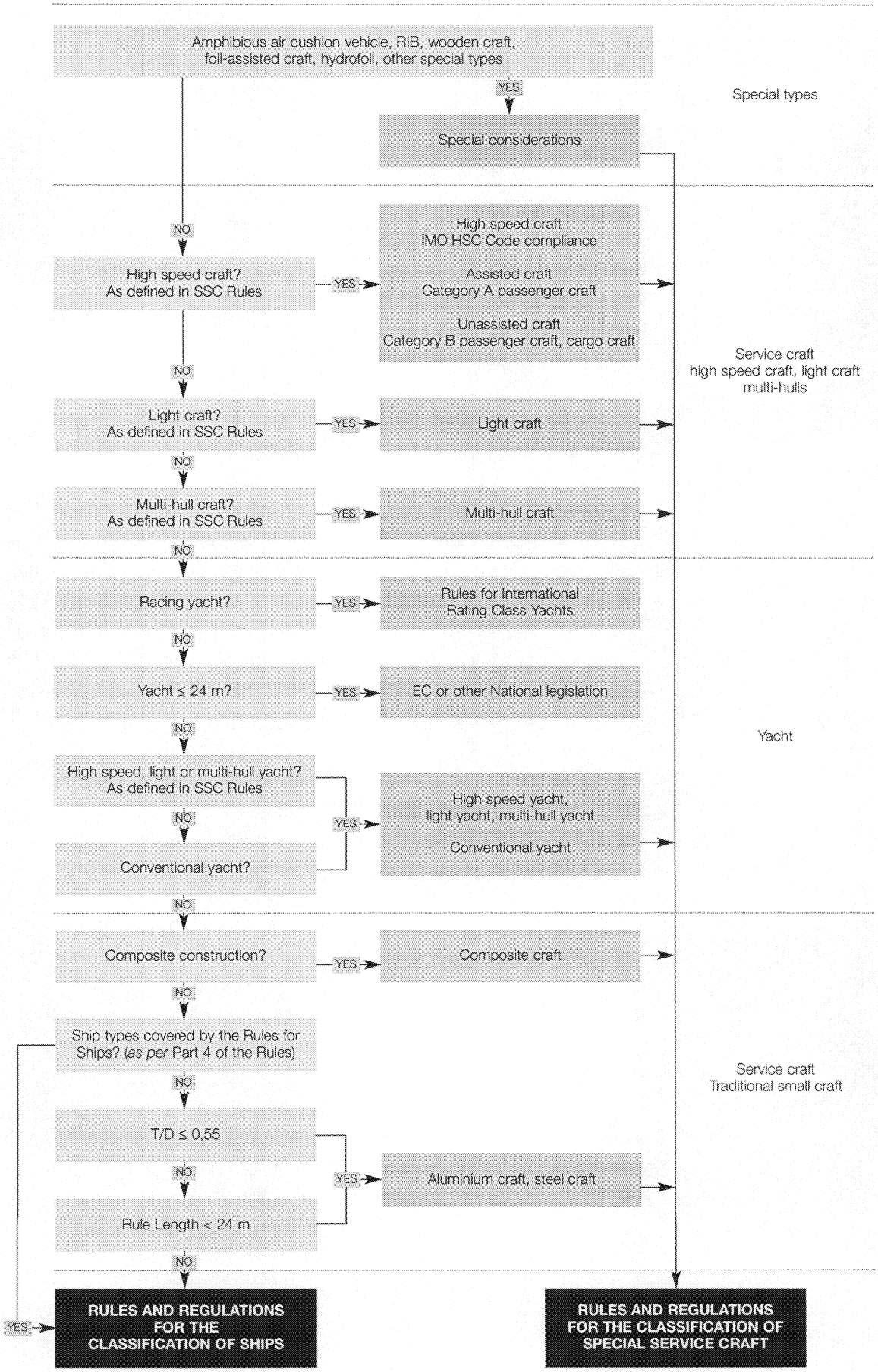
DIFFERENT TYPES OF CRAFT COVERED BY THE SPECIAL SERVICE CRAFT RULES



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Section

1 **General requirements**

2 **Definitions**

Section 1 General requirements

1.1 Application

1.1.1 The requirements of this Part apply to yachts with an overall length, L_{OA} (as defined in Pt 3, Ch 1,6.2.4) of 24 m or greater, 3000 gross registered tonnage or less, and intended for the carriage of 12 passengers or less, and service craft (*see also* 1.1.2(c)) built in accordance with these Rules.

1.1.2 Consideration will be given to the acceptance of fire safety measures:

(a) which, for Service Craft, have been prescribed and approved by the Government of the Flag State;

(b) which, for yachts, have been prescribed and approved by the Government of the Flag State, provided that these are shown to be equivalent to those required by the MCA LY2 Code as amended; or

(c) where the arrangements are considered equivalent to those required by these Rules as a result of risk assessment studies; or

(d) where the arrangements are considered acceptable compared to those required by these Rules, due cognisance having been taken of any restricted service limits.

1.1.3 Special consideration, consistent with the fire hazard involved, will be given to construction or arrangements not covered by this Chapter.

1.1.4 High speed cargo craft of 500 gross tons and over on international voyages and high speed passenger craft on international voyages are to be provided with the fire safety measures required by the *International Convention for the Safety of Life at Sea, 1974* as amended (SOLAS 74), Chapter X – Safety Measures for High Speed Craft (*International Code of Safety for High Speed Craft*).

1.1.5 High speed cargo craft of 500 gross tons and over employed on national voyages and high speed passenger craft employed on national voyages are to comply with the fire safety measures of the Government of the Flag State.

1.1.6 High speed cargo craft of less than 500 gross tons employed on national or international voyages are to comply with the fire safety measures of the Government of the Flag State.

1.1.7 It is the responsibility of the Government of the Flag State to give effect to the fire safety measures of 1.1.4, 1.1.5 and 1.1.6. However, Lloyd's Register (hereinafter referred to as LR) will undertake to do this in cases where:

(a) Contracting Governments have authorised LR to apply the requirements of SOLAS 74 and issue the appropriate certification on their behalf; or

(b) the Government of the Flag State is not a signatory to SOLAS 74; or

(c) the craft is to be classed for restricted or special service in national waters and the Government of the Flag State has no National requirements.

1.1.8 When implementing the provisions of 1.1.7, LR will apply the fire safety measures required by SOLAS 74 Chapter X – Safety Measures for High Speed Craft (*International Code of Safety for High Speed Craft*). However, due consideration will be given to arrangements deemed to provide an equivalent level of fire safety, taking due cognisance of the circumstances of the restricted or special service.

1.2 Submission of plans and information

1.2.1 The plans and information detailed in 1.2.2 to 1.2.4, where applicable, are to be submitted at least in triplicate for approval, together with all additional information such as gross tonnage and number of passengers/guests.

1.2.2 For fire protection, the following plans and information are to be submitted:

(a) Structural fire protection plan showing extent of materials used in construction, steel, aluminium, or alternative forms of construction, together with details of the thermal characteristics of the alternative forms of construction that include the temperature at which the material starts to lose its strength, and proposals for protection, etc.

(b) A general arrangement plan showing the main fire zones, escape stairways and the fire compartmentation bulkheads and decks within the main fire zones, including engine rooms, galleys, bonded stores, paint stores, navigating bridge, radio room, fire-fighting control room, emergency generator rooms and battery locker, helicopter arrangements, including re-fuelling and petrol stowage arrangements.

(c) A plan showing the details of construction of the fire protection bulkheads and decks and particulars of any surface laminates employed.

(d) Copies of Certificates of Approval by National Authorities and Fire Test Reports in respect of all 'A' and 'B' Class fire divisions, non-combustible materials and materials having low flame-spread characteristics, etc., which are to be used but have not been approved by LR. Copies of Certificates issued by other recognised approval bodies may be submitted for consideration.

(e) A ventilation plan showing ducts and any dampers in them, closing appliances and the position of the controls for stopping the system.

(f) A plan showing the fire detection and alarm system.

(g) A plan showing the remote control system for fire doors, if applicable.

(h) A fire control plan meeting the requirements of Ch 4,5.

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1.2.3 For fire-extinguishing the following plans are to be submitted:

(a) A general arrangement plan showing the disposition of all the fire-fighting equipment including the fire main, the fixed fire-extinguishing systems; the disposition of the portable and non-portable extinguishers and the types used; and the position and details of the firemen's outfits.

(b) A plan showing the layout and construction of the fire main, including the main and emergency fire pumps, isolating valves, pipe sizes and materials, and the cross connections to any other system.

(c) A plan showing details of each fixed fire-fighting system, including calculations for the quantities of the media used and the proposed rates of application.

1.2.4 Fire-control plans as required by Ch 4,5 are to be submitted.

1.2.5 For yachts, where fire plans and the information listed above have been appraised, approved and verified on board by the Flag Administration in compliance with the MCA LY2 Code as amended, Lloyd's Register will only acknowledge the aforementioned and therefore no further appraisal, approval or survey should be provided.

■ *Section 2* Definitions

2.1 Materials

2.1.1 **Non-combustible material** means a material which neither burns nor gives off flammable vapours in sufficient quantity for self-ignition when heated to approximately 750°C, according to an established test procedure, *see* IMO *International Code for Application of Fire Test Procedures* (FTP Code), Annex 1, Part 1. Any other material is a **combustible material**.

2.1.2 **Steel or other equivalent material**. Where the words 'steel or other equivalent material' occur, 'equivalent material' means any non-combustible material which, by itself, or due to insulation provided, has structural and integrity properties equivalent to steel at the end of the applicable fire exposure to the standard fire test (e.g. aluminium with appropriate insulation).

2.1.3 **Alternative forms of construction** means any combustible material may be accepted if it can be demonstrated that the material, which by itself or due to insulation provided has structural and fire integrity properties equivalent to 'A' or 'B' class divisions, or steel, as applicable, at the end of the applicable fire exposure to the standard fire test.

2.2 Fire test

2.2.1 A **standard fire test** is one in which the specimens of the relevant bulkheads and decks are exposed in a test furnace to temperatures corresponding approximately to the standard time-temperature curve. The test methods are to be in accordance with the IMO FTP Code, Annex 1, Part 3.

2.3 Flame spread

2.3.1 **Low flame spread** means that the surface thus described will adequately restrict the spread of flame, having regard to the risk of fire in the spaces concerned, this being determined by an acceptable test procedure, *see* IMO FTP Code, Annex 1, Part 5.

2.3.2 **Not readily ignitable** means that the surface thus described will not continue to burn for more than 20 seconds after the removal of a suitable impinging test flame.

2.4 Ship divisions and spaces

2.4.1 **'A' Class divisions** are those divisions formed by bulkheads and decks, and:

(a) Are to be constructed of steel or other equivalent material.

(b) Are to be suitably stiffened.

(c) Are to be so constructed as to be capable of preventing the passage of smoke and flame up to the end of the one-hour standard fire test, *see* 2.2.1.

(d) Are to be insulated with approved non-combustible materials such that the average temperature of the unexposed side will not rise more than 140°C above the original temperature, nor will the temperature, at any one point, including any joint, rise more than 180°C above the original temperature, within the time listed below:

Class 'A-60' 60 minutes.
Class 'A-30' 30 minutes.
Class 'A-15' 15 minutes.
Class 'A-0' 0 minutes.

(e) May be required to demonstrate that they meet the above requirements for integrity and temperature rise, through a test.

2.4.2 **'B' Class divisions** are those divisions formed by bulkheads, decks, ceilings or linings and:

(a) Are to be so constructed as to be capable of preventing the passage of flame to the end of the first half hour of the standard fire test, *see* IMO FTP Code, Annex 1, Part 3.

(b) Are to be insulated such that the average temperature of the unexposed side will not rise more than 140°C above the original temperature, nor will the temperature at any one point, including any joint, rise more than 225°C above the original temperature, within the time listed below:

Class 'B-15' 15 minutes.
Class 'B-0' 0 minutes.

(c) Are to be constructed of approved non-combustible materials and all materials entering into the construction and erection of 'B' Class divisions are to be non-combustible, except where permitted by other requirements of this Chapter.

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(d) May be required to ensure that they meet the above requirements for integrity and temperature rise through a test of a prototype division.

2.4.3 **'C' Class divisions** are divisions to be constructed of approved non-combustible materials. They need to meet neither requirements relative to the passage of smoke and flame nor limitations relative to the temperature rise. Combustible veneers are permitted provided they meet other requirements of this Chapter.

2.4.4 **Continuous 'B' Class ceilings or linings** are those 'B' Class ceilings or linings which terminate only at an 'A' or 'B' Class division.

2.4.5 **Accommodation spaces** are those spaces used for public spaces, corridors, lavatories, cabins, offices, hospitals, cinemas, games and hobbies rooms, pantries containing no cooking appliances and similar spaces.

2.4.6 **Service spaces** are those used for galleys, pantries containing cooking appliances, stores, mail and specie rooms, store rooms, lockers, workshops other than those forming part of the machinery spaces and similar spaces and trunks to such spaces.

2.4.7 **Cargo spaces** are all spaces used for cargo (including cargo oil tanks) and trunks to such spaces.

2.4.8 **Machinery spaces of Category A** are those spaces and trunks to such spaces which contain:

(a) internal combustion machinery used for main propulsion; or

(b) internal combustion machinery used for purposes other than main propulsion where such machinery has in the aggregate a total power output of not less than 375 kW; or

(c) any oil-fired boiler or oil fuel unit.

2.4.9 **Machinery spaces** are all machinery spaces of Category 'A' and all other spaces containing propelling machinery, boilers, oil fuel units, steam and internal combustion engines, generators and major electrical machinery, oil filling stations, refrigerating, stabilising, ventilation and air conditioning machinery, and similar spaces; and trunks to such spaces.

2.4.10 **Control stations** are those spaces in which the craft's radio or main navigating equipment or the emergency source of power is located or where the fire recording or fire-control equipment is centralised.

2.4.11 **Cargo area** is that part of the craft that contains cargo tanks, slop tanks and cargo pump rooms including pump rooms, cofferdams, ballast and void spaces adjacent to cargo tanks and also deck areas throughout the entire length and breadth of the part of the craft over the above-mentioned spaces.

2.4.12 **Main vertical zones** are those sections into which the hull, superstructure and deck houses are divided by 'A' Class divisions, the mean length and width of which on any one deck does not, in general, exceed 48 m.

2.5 Equipment

2.5.1 **Oil fuel unit** is the equipment used for the preparation of oil fuel for delivery to an oil-fired boiler, or equipment used for the preparation for delivery of heated oil to an internal combustion engine, and includes any oil pressure pumps, filters and heaters dealing with oil at a pressure of more than 1,8 bar (1,8 kgf/cm^2) gauge.

2.6 Craft types

2.6.1 For the purpose of this Part the definitions of craft types given in 2.6.2 and 2.6.3 apply.

2.6.2 A **passenger craft** is a craft which carries more than twelve passengers.

2.6.3 A **yacht** is a recreational craft used for sport or pleasure and may be propelled mechanically, by sail or by a combination of both.

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Fire Protection, Detection and Extinction — Service Craft

Section

1 **General requirements**

2 **Fire safety measures for service craft**

Section 1 General requirements

1.1 Application

1.1.1 The requirements of this Chapter apply to service craft built in accordance with these Rules.

1.1.2 Where service craft incorporate fire hazards not covered in this Part, appropriate fire protection, detection and extinction arrangements are to be provided. Details are to be submitted for approval.

Section 2 Fire safety measures for service craft

2.1 General

2.1.1 Table 2.2.1 is a guide to the major requirements of this Section. The Table is intended as a quick reference to the requirements and is not to be used in isolation when designing the fire safety arrangements.

Table 2.2.1 General fire protection, detection and extinction requirements

Form of construction, *see* 2.2	Steel or equivalent, or alternative forms of construction may be accepted, subject to requirements in high fire risk areas
Passive fire protection, *see* 2.3 to 2.6	Category 'A' machinery spaces: • For craft >150 gross tons: A-30/A-0 • For craft <150 gross tons: A-0 Galleys: • For craft >50 gross tons: B-15
Means of escape, *see* 2.7: • Machinery spaces • Accommodation, etc.	} 2
Fixed fire detection system, *see* 2.13	• Fitted in all machinery spaces • Fitted in stairways, service spaces, machinery spaces, control stations and accommodation spaces of craft >50 gross tons with sleeping accommodation
Fire pumps, *see* 2.14	• 1 fixed power pump + 1 portable pump • For craft <150 gross tons: 1 portable pump
Fire-extinguishing arrangements in machinery spaces, *see* 2.15	• A fixed fire-extinguishing system • A minimum of 2, but need not exceed 5 portable foam extinguishers or equivalent
Portable fire-extinguishers in accommodation, *see* 2.18	Sufficient to ensure that at least one will be readily available in every compartment

2.2 Forms of construction – Structure

2.2.1 The hull, superstructure, structural bulkheads, decks and deckhouses may be constructed of steel, other equivalent material, *see* Ch 1,2.1.2, or be of alternative forms of construction, *see* Ch 1,2.1.3.

2.2.2 The structure in way of Category 'A' machinery spaces, galleys containing appliances of significant fire risk, *see* 2.4.2, and other high risk areas is to be protected such that the material by itself or due to insulation provided can maintain its required strength at the end of 30 minutes exposure to the standard fire test.

2.2.3 Details of the method of construction, supported by calculations and/or fire test data, demonstrating compliance with 2.2.2, are to be submitted.

2.2.4 For aluminium alloy structures, the insulation is to be such that the temperature of the structural core does not rise more than 200°C above the ambient temperature at any time during the specified fire exposure.

2.2.5 For composite structures, the insulation is to be such that the temperature of the laminate does not rise more than the minimum temperature of deflection under load of the resin at any time during the specified fire exposure. The temperature of deflection under load is to be determined as in Ch 14,3.7 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

2.2.6 For structures in contact with sea-water, the required insulation should extend to at least 300 mm below the lightest waterline, *see also* 2.6.1.

2.3 Forms of construction – Fire divisions

2.3.1 Fire divisions required by 2.4 are to be constructed in accordance with the remaining paragraphs of this sub-Section.

2.3.2 Fire divisions using steel equivalent or alternative forms of construction may be accepted if it can be demonstrated that the material by itself, or due to insulation provided, has the fire resistance properties equivalent to 'A' or 'B' class divisions.

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2.3.3 Insulation required by 2.3.2 is to be such that the temperature of the structural core does not rise above the point at which the structure would begin to lose its strength at any time during the applicable exposure to the standard fire test. For 'A' class divisions, the applicable exposure is 60 minutes, and for 'B' Class divisions, the applicable exposure is 30 minutes.

2.3.4 For aluminium alloy structures the insulation is to be such that the temperature of the structural core does not rise more than 200°C above the ambient temperature at any time during the applicable fire exposure.

2.3.5 For composite structures, the insulation is to be such that the temperature of the laminate does not rise more than the minimum temperature of deflection under load of the resin at any time during the applicable fire exposure. The temperature of deflection under load is to be determined as in Ch 14,3.7 of the Rules for Materials.

2.4 Structural fire protection

2.4.1 Category 'A' machinery spaces are to be enclosed by A-30 Class divisions where adjacent to accommodation spaces, or control positions and A-0 Class divisions elsewhere. For craft below 150 gross tons, Category 'A' machinery spaces are to be enclosed by A-0 Class divisions, regardless of adjacent space use.

2.4.2 For craft greater than 50 gross tons, galleys are to be enclosed by B-15 Class divisions unless the cooking appliances contained therein have an insignificant fire risk.

(a) For the purposes of this Chapter, coffee automats, toasters, dishwashers, microwave ovens, water boilers and similar appliances each with a maximum power of 5 kW may be regarded as having an insignificant fire risk. Electrically-heated cooking plates and hot plates for keeping food warm, each of them having a maximum power of 2 kW and a surface temperature not above 150°C may also be regarded as having insignificant fire risk. If spaces containing this equipment are lockable, then means of cutting-off the power to the space are to comply with Pt 16, Ch 2,16.6.7.

(b) Other equipment such as fat fryers, open flame cookers, etc., are to be regarded as having a significant fire risk.

2.4.3 Openings in 'A' Class divisions are to be provided with permanently attached means of closing that are to be at least as effective for resisting fires as the divisions in which they are fitted.

2.4.4 Interior stairways serving machinery spaces, accommodation spaces, service spaces or control stations are to be of steel or other equivalent material.

2.4.5 Doors are to be self-closing in way of Category 'A' machinery spaces.

2.4.6 Where 'A' Class divisions are penetrated for the passage of electric cables, pipes, trunks, ducts, etc., or for girders, beams or other structural members, arrangements are to be made to ensure that the fire resistance is not impaired.

2.4.7 Where the structure or 'A' Class divisions are required to be insulated, it is to be ensured that the heat from a fire is not transmitted through the intersections and terminal points of the divisions or penetrations to uninsulated boundaries. Where the insulation installed does not achieve this, arrangements are to be made to prevent this heat transmission by insulating the horizontal and vertical boundaries or penetrations for a distance of 450 mm.

2.5 Materials

2.5.1 Paints, varnishes and other finishes used on exposed interior surfaces are not to be capable of producing excessive quantities of smoke, toxic gases or vapours and are to be of the low flame spread type. Reference is also to be made to the IMO FTP Code, Annex 1, Parts 2 and 5.

2.5.2 Except in refrigerated compartments of service space, all insulation (e.g. fire and comfort) is to be of non-combustible materials.

2.5.3 Pipes penetrating 'A' Class divisions are to be of approved materials having regard to the temperature such divisions are required to withstand.

2.5.4 Pipes conveying oil or combustible liquids through accommodation and service spaces are to be of approved materials having regard to the fire risk.

2.5.5 Materials readily rendered ineffective by heat are not to be used for overboard scuppers, sanitary discharges, and other outlets which are close to the waterline and where the failure of the material in the event of fire would give rise to danger of flooding.

2.5.6 Primary deck coverings within accommodation spaces, service spaces and control stations are to be of a type that will not readily ignite, or give rise to toxic or explosive hazards at elevated temperatures. Reference is also to be made to the IMO FTP Code, Annex 1, Parts 2 and 6.

2.5.7 Vapour barriers and adhesives used in conjunction with insulation, as well as insulation of pipe fittings for cold service systems need not be non-combustible, but they are to be kept to the minimum quantity practicable and their exposed surfaces are to have low flame spread characteristics.

2.5.8 All waste receptacles are to be constructed of non-combustible materials with no openings in the sides or bottom.

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2.6 Surface of insulation

2.6.1 In spaces where penetration of oil products is possible, the surface of insulation is to be impervious to oil or oil vapours. Insulation boundaries are to be arranged to avoid immersion in oil spillages.

2.7 Means of escape

2.7.1 Stairways, ladders and corridors serving crew spaces and other spaces to which the crew normally have access are to be arranged so as to provide ready means of escape to a deck from which disembarkation may be effected.

2.7.2 Where reasonable and practicable, and having regard to the number of crew and size of space, at least two means of escape, as widely separated as possible, are to be provided from each section of accommodation spaces, service spaces and control stations:

(a) The normal means of access to the accommodation and service spaces below the open deck is to be arranged so that it is possible to reach the open deck without passing through intervening spaces containing a possible source of fire.

(b) The second means of escape may be through portholes, or hatches of adequate size, leading to the open deck.

(c) No dead-end corridors having a length of more than 7 m will be accepted. A 'dead-end corridor' is a corridor or part of a corridor from which there is only one escape route.

2.7.3 At least two means of escape are to be provided from machinery spaces, except where the small size of the machinery space makes it impractical. Escape is to be by steel ladders that are as widely separated as possible.

2.8 Ventilation systems

2.8.1 Ventilation fans are to be capable of being stopped, and main inlets and outlets of ventilation systems closed, from outside the spaces being served, *see also* Pt 16, Ch 2,16.6.

2.8.2 Ventilation ducts for Category 'A' machinery spaces and exhaust ducts for galleys of significant fire risk are not to pass through accommodation spaces, service spaces or control stations unless the ducts are constructed of steel and arranged to preserve the integrity of the division.

2.8.3 Ventilation ducts for accommodation spaces, service spaces or control stations are not to pass through Category 'A' machinery spaces unless the ducts are constructed of steel and arranged to preserve the integrity of the division.

2.8.4 Store-rooms containing highly flammable products are to be provided with ventilation arrangements that are separate from other ventilation systems. Ventilation is to be arranged to prevent the build-up of flammable vapours at high and low levels. The inlets and outlets of ventilators are to be positioned so that they do not draw from or vent into an area which would cause undue hazard, and are to be fitted with spark arrestors.

2.8.5 Ventilation systems serving Category 'A' machinery spaces are to be independent of systems serving other spaces.

2.8.6 All enclosed spaces containing free-standing fuel tanks are to be ventilated independently of systems serving other spaces.

2.8.7 Ventilation is to be provided to prevent the accumulation of dangerous concentrations of flammable gas that may be emitted from batteries. The requirements of Pt 16, Ch 2,11.5 are to be complied with.

2.8.8 Ventilation openings may be fitted in and under the lower parts of cabin and public space doors in corridor bulkheads. Ventilation grills are to be of non-combustible material. The total net area of any such openings is not to exceed 0,05 m^2. Bridging ducts are not allowed in fire divisions.

2.8.9 For additional requirements for the ventilation of domestic gaseous fuel, *see* 2.11.

2.9 Fuel arrangements

2.9.1 In service craft in which oil fuel is used, the arrangements for the storage, distribution and utilisation of the oil fuel are to be such as to ensure the safety of the service craft and persons on board. For details, *see* Pt 15, Ch 3.

2.9.2 Oil fuel tanks situated within the boundaries of Category 'A' machinery spaces are not to contain oil fuel having a flashpoint of less than 60°C.

2.9.3 Oil fuel, lubricating oil and other flammable oils are not to be carried in fore peak tanks.

2.10 Special arrangements in machinery spaces and, where necessary, other spaces

2.10.1 Openings are to be provided with closing appliances constructed so as to maintain the fire integrity of the machinery space boundaries.

2.10.2 The type of equipment installed and the layout of the craft are to take account of the risk and spread of fire. Special attention is to be paid to the surroundings of open flame devices, hot areas and main and auxiliary machinery, oil and fuel overflows, and uncovered oil and fuel pipes.

2.10.3 Fuel filling, storage, venting and supply systems are to be installed so as to minimise the risk of fire and explosion.

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2.10.4 Machinery components and accessories that require frequent maintenance and inspection are to be readily accessible.

2.10.5 Windows are not to be fitted in machinery space boundaries. This does not preclude the use of glass in control rooms within the machinery spaces.

2.10.6 In Category 'A' machinery spaces means of control are to be provided for:

(a) closure of openings which normally allow exhaust ventilation, and closure of ventilator dampers;
(b) permitting the release of smoke;
(c) stopping ventilating fans; and
(d) stopping forced and induced draught fans, oil fuel transfer pumps, oil fuel unit pumps and other similar fuel pumps.

2.10.7 The controls required in 2.10.6 are to be located outside the space concerned, in a position where they will not be cut off in the event of fire in the space they serve. Such controls and the controls for any required fire-extinguishing system are to be situated at one control position or grouped in as few positions as possible. Such positions are to have a safe access from the open deck. *See also* Pt 15, Ch 3,4.5.1 and 4.9.2.

2.11 Arrangements for gaseous fuel for domestic purposes

2.11.1 Where gaseous fuel is used for domestic purposes, the arrangements for the storage, distribution and utilisation of the fuel are to be such that, having regard to the hazards of fire and explosion which the use of such fuel may entail, the safety of the service craft and the persons onboard is preserved. The installation is to be in accordance with recognised National or International Standards.

2.11.2 Storage lockers for gas cylinders are to be provided with:

(a) effective ventilation;
(b) an outward-opening door accessible directly to the open deck; and
(c) gas-tight boundaries, including doors and other means of closing any openings therein, which form boundaries between such lockers and adjoining spaces.

2.11.3 Arrangements for storage on open deck will be specially considered.

2.12 Space heaters

2.12.1 Space heaters, if used, are to be fixed in position and so constructed as to reduce fire risks to a minimum. The design and location of these units are to be such that clothing, curtains or other similar materials cannot be scorched or set on fire by heat from the unit.

2.13 Fixed fire detection and fire-alarm systems

2.13.1 A fixed fire detection and fire-alarm system is to be installed in all Category 'A' machinery spaces and is to comply with the requirements of Pt 16, Ch 1,2.8.

2.13.2 In craft over 50 gross tons, where sleeping accommodation is provided on board, a fixed fire detection and fire-alarm system is to be installed in all stairways, service spaces, machinery spaces, control stations and accommodation spaces (except toilets, bathrooms, void spaces, etc.). The fixed fire detection and fire-alarm system is to be installed in accordance with Ch 4,2.

2.14 Fire pumps and fire main system

2.14.1 **Application:**

(a) Every service craft is to be provided with a fire pump(s), fire mains, hydrants and hoses as required by this Chapter.
(b) For very small service craft, where it is not considered possible to fit a fire pump, the arrangements will be specially considered.

2.14.2 **Capacity of fire pumps.** The capacity of the fixed main fire pump(s) is not to be less than:

$$Q = (0{,}15\,(L_R\,(B + D))^{1/2} + 2{,}25)^2$$

but need not exceed 25 m^3/hour

where

B = greatest moulded breadth of craft, in metres
D = moulded depth to bulkhead deck, in metres
L_R = Rule length of craft, as defined in Pt 3, Ch 1,6.2.1, in metres
Q = total capacity in m^3/hours.

2.14.3 **Fire pumps:**

(a) In service craft of 150 tons gross or more, a minimum of one fixed power pump and one portable pump, complying with 2.14.4, are to be provided.
(b) For service craft of less than 150 tons gross, one portable pump or alternative as required by 2.14.4, is to be provided.
(c) Sanitary, ballast, bilge or general service pumps may be accepted as fire pumps, provided that they are not normally used for pumping oil, and that, if they are subject to occasional duty for the transfer or pumping of fuel oil, suitable changeover arrangements are fitted.
(d) In service craft classed for navigation in ice, the fire pump sea inlet valves are to be provided with ice clearing arrangements, *see* Pt 1, Ch 2,3.8.1.
(e) Relief valves are to be provided in conjunction with any fire pumps if the pump is capable of developing a pressure exceeding the design pressure of the water service pipes, hydrants and hoses. These valves are to be so placed and adjusted as to prevent excessive pressure in any part of the fire main system.
(f) Where centrifugal pumps are provided in order to comply with this Section, a non-return valve is to be fitted in the pipe connecting each pump to the fire main.

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2.14.4 **Portable fire pumps:**

(a) Except for electric pumps, which will be specially considered, portable fire pumps are to comply with the following:
  (i) The pump is to be self priming.
  (ii) The suction head in operation is not to exceed 4,5 m.
  (iii) The portable fire pump is to be fitted with a length of discharge hose and nozzle capable of maintaining a pressure sufficient to produce a jet throw of at least 12 m, or that required to enable a jet of water to be directed on any part of the engine room or the exterior boundary of the engine room and casing, whichever is the greater. The jet throw required need not exceed the length of the craft.
  (iv) The pump set is to have its own fuel tank of sufficient capacity to operate the pump for three hours.
  (v) Details of the fuel type and storage location are to be submitted. If the fuel type has a flashpoint below 60°C, further consideration will be given to the fire safety aspects.
  (vi) The pump set is to be stored in a secure, safe and enclosed space, accessible from open deck and clear of the Category 'A' machinery space.
  (vii) The pump set is to be easily moved and operated by two persons and be readily available for immediate use.
  (viii) Arrangements are to be provided to secure the pump at its anticipated operating position(s).
  (ix) The overboard suction hose is to be non-collapsible and of sufficient length to cater for the craft's motion under all operational conditions. A suitable strainer is to be fitted at the inlet end of the hose.
  (x) Any diesel-driven power source for the pump is to be capable of being readily started in its cold condition down to a temperature of 0°C by hand (manual) cranking.

(b) If it is not possible to comply with the requirements of 2.14.4(a), an additional fixed fire pump will be required, which is to comply with the following:
  (i) The pump, its source of power and sea connection are to be located in accessible positions outside the Category 'A' machinery space, or in a different space to the main fire pump, if the main fire pump is located outside the Category 'A' machinery space. In the case of craft defined in 2.14.3(b), the pump may be situated in the Category 'A' machinery space, if so desired.
  (ii) The sea valve is to be capable of being operated from a position near the pump.
  (iii) The space where the fire pump prime mover is located is to be illuminated from the emergency source of electrical power, except for craft defined in 2.14.3(b), and is to be well ventilated.
  (iv) If the pump is required to supply water for a fixed fire-extinguishing system in the space where the main fire pumps are situated, it is to be capable of simultaneously supplying water to this system and the fire main at the required rates.
  (v) The pump may also be used for other suitable purposes, subject to approval in each case.
  (vi) The pressure and quantity of water delivered by the pump is to be sufficient to produce a jet of water at any nozzle of not less than 12 m.
  (vii) In the case of craft defined in 2.14.3(b), a fire main, hydrants and hoses are to be installed in accordance with 2.14.5 to 2.14.10.

(c) Means to illuminate the stowage area of the portable pump and its necessary areas of operation are to be provided from the emergency source of electrical power.

(d) If preferred, a pump complying with 2.14.4(b) may be fitted instead of a portable pump complying with 2.14.4(a).

2.14.5 **Fire main:**

(a) The diameter of the fire main is to be based on the required capacity of the fixed main fire pump(s). The diameter of the water service pipes are to be sufficient to ensure an adequate supply of water for the operation of at least one fire-hose.

(b) The wash deck line may be used as a fire main provided that the requirements of this Section are satisfied.

(c) All exposed water pipes for fire-extinguishing are to be provided with drain valves for use in frosty weather. The valves are to be located where they will not be damaged by cargo.

2.14.6 **Pressure in the fire main.** When the fixed main fire pump, or the fire pump described in 2.14.4(b), is delivering the quantity of water required by 2.14.2 through the fire main, fire hoses and nozzles, the pressure maintained at any hydrant is to be sufficient to produce a jet throw at any nozzle of not less than 12 m.

2.14.7 **Number and position of hydrants.** The number and position of the hydrants are to be such that at least one jet of water is to reach any part normally accessible to the crew while the service craft is being navigated and any part of any cargo space when empty. Furthermore, such hydrants are to be positioned near the accesses to the protected spaces. At least one hydrant is to be provided in each machinery space.

2.14.8 **Pipes and hydrants:**

(a) Materials readily rendered ineffective by heat are not to be used for fire mains. Where steel pipes are used, they are to be galvanised internally and externally. Cast iron pipes are not acceptable. The pipes and hydrants are to be so placed that the fire-hoses may be easily coupled to them. The arrangements of pipes and hydrants is to be such as to avoid the possibility of freezing. In service craft where deck cargo may be carried, the positions of the hydrants are to be such that they are always readily accessible and the pipes are to be arranged, as far as practicable, to avoid risk of damage by such cargo. Unless one hose and nozzle is provided for each hydrant in the service craft, there is to be complete interchange-ability of hose couplings and nozzles.

(b) A valve is to be fitted at each fire hydrant so that any fire-hose may be removed while the fire pumps are at work.

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(c) Where an additional fixed fire pump is fitted in accordance with 2.14.4(b) or 2.14.4(d):
  (i) An isolating valve is to be fitted in the fire main so that all the hydrants in the service craft, except those in the Category 'A' machinery space containing the main fire pump, can be supplied with water by the additional fixed fire pump. The isolating valve is to be located in an easily accessible and tenable position outside the Category 'A' machinery space; and
  (ii) The fire main is not to re-enter the machinery space downstream of the isolating valve.

2.14.9 **Fire-hoses**:

(a) Fire-hoses are to be of approved non-perishable material. The hoses are to be sufficient in length to project a jet of water to any of the spaces in which they may be required to be used. Their length, in general, is not to exceed 18 m. Each hose is to be provided with a nozzle and the necessary couplings. Fire-hoses, together with any necessary fittings and tools, are to be kept ready for use in conspicuous positions near the water service hydrants or connections.

(b) The number of fire-hoses to be provided, each complete with couplings and nozzles, is to be one for each 15 m length of the service craft, or part thereof, but need not exceed the number of hydrants provided. This number does not include any hoses required in any engine room. If necessary, the number of hoses is to be increased so as to ensure that hoses in sufficient numbers are available and accessible at all times.

2.14.10 **Nozzles**:

(a) For the purpose of this Chapter, standard nozzle sizes are to be 12 mm, 16 mm or 19 mm, or as near thereto as possible, so as to make full use of the maximum discharge capacity of the fire pump(s).

(b) For accommodation and service spaces, the nozzle size need not exceed 12 mm.

(c) The size of nozzles intended for use in conjunction with a portable fire pump need not exceed 12 mm.

(d) All nozzles are to be of an approved dual purpose type (i.e. spray/jet type) incorporating a shut-off.

2.15 Fire-extinguishing arrangements in Category 'A' machinery spaces

2.15.1 Except where provided for in 2.15.2, Category 'A' machinery spaces are to be provided with:

(a) one of the fixed fire-extinguishing systems given in Ch 4,3; and

(b) at least two portable foam extinguishers or equivalent, *see* Ch 4,6.3.2. Where internal combustion machinery is installed, an additional portable extinguisher is to be provided for every 375 kW of power output, but the total number of such additional extinguishers need not exceed five.

2.15.2 Where the size of the machinery space precludes access under normal operating conditions, provision is to be made such that a manually-released extinguishing medium, of a type allowed in Chapter 4, can be remotely discharged into the space. Such arrangements may utilise a portable extinguisher of adequate size. Details of the arrangements with supporting calculations are to be submitted for approval.

2.16 Fire-extinguishing appliances in other machinery spaces

2.16.1 Where a fire hazard exists in any machinery space for which no specific provisions for fire-extinguishing appliances are prescribed in 2.15 and 2.17, there is to be provided in, or adjacent to, that space a satisfactory number of approved portable fire-extinguishers or other approved means of fire-extinction.

2.17 Machinery spaces in craft which are constructed mainly or wholly of alternative forms of construction

2.17.1 Machinery spaces in craft which are constructed mainly or wholly with alternative forms of construction that contain internal combustion machinery, are to comply with the fire-extinguishing requirements for Category 'A' machinery spaces, *see* 2.15.1.

2.18 Fixed fire-extinguishing systems not required by this Chapter

2.18.1 Where a fixed fire-extinguishing system not required by this Chapter is installed, the arrangement is to comply with the relevant requirements of this Chapter.

2.19 Portable fire-extinguishers

2.19.1 All portable fire-extinguishers are to comply with the requirements of Ch 4,6.

2.19.2 The portable fire-extinguishers are to be stowed in readily accessible positions.

2.19.3 One of the portable fire-extinguishers intended for use in any space is to be stowed near the entrance to that space.

2.19.4 At least one portable fire-extinguisher is to be located so that it can easily be reached from the main steering position of the craft.

2.19.5 Accommodation spaces, service spaces and control stations are to be provided with a sufficient number of portable fire-extinguishers to ensure that at least one extinguisher will be readily available for use in every compartment.

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2.19.6 Where cooking facilities are provided a portable fire-extinguisher of a type appropriate to the energy source used is to be located in a position readily accessible for use in the event of a fire.

2.20 Fire blanket

2.20.1 A fire blanket is to be installed in all galleys.

2.21 Protection of paint lockers and flammable liquid lockers

2.21.1 Paint lockers and flammable liquid lockers with a deck area 4 m^2 or over are to be provided with a fixed fire-extinguishing system enabling the crew to extinguish a fire without entering the space. One of the following systems is to be provided:

- A carbon dioxide system designed for 40 per cent of the gross volume of the space.
- A dry powder system designed to discharge 0,5 kg powder per cubic metre of gross volume of the space.
- A water spray system designed to give a coverage of 5 litres per square metre of deck area per minute. Water spray systems may be connected to the fire main.

2.21.2 Consideration will be given to the acceptance of other arrangements which provide equivalent protection.

2.21.3 Lockers having a deck area of less than 4 m^2 may be protected by carbon dioxide or dry powder portable extinguishers located near the entrance to the locker.

2.22 Arrangements where deep-fat cooking equipment is installed

2.22.1 Where deep-fat cooking equipment is installed in high speed craft, all installations are to be fitted with:

(a) an automatic or manual fixed extinguishing system type approved in accordance with ISO 15371, *Ships and marine technology – Fire extinguishing systems for protection of galley deep-fat cooking equipment – Fire tests*, or an acceptable alternative National or International Standard, for protection of the deep-fat cooking equipment;

(b) a primary and back up thermostat with an alarm to alert the operator in the event of failure of either thermostat;

(c) means to automatically shut off the deep-fat cooking equipment electrical power upon activation of the fire-extinguishing system;

(d) an alarm for indicating operation of the fire-extinguishing system in the galley where the equipment is installed; and

(e) controls for manual operation of the fire-extinguishing system which are clearly labelled for ready use by the crew.

Control and electrical engineering arrangements are to be in accordance with the requirements of Pt 16, Ch 1 and Ch 2, as applicable.

2.23 Helicopter decks

2.23.1 The requirements of IMO Resolution A.855(20) are to be complied with having due regard to the hazards involved.

2.23.2 If a helicopter hangar is not provided and if two fireman's outfits are supplied as per 2.24.1, then the fireman's outfits required by IMO Resolution A.855(20) need not be provided.

2.24 Fireman's outfit

2.24.1 All service craft of 350 gross tons or more and having enclosed spaces which are normally accessible, are to carry at least two fireman's outfits complying with the requirements of Ch 4,4.

2.25 Fire-control plans

2.25.1 Fire-control plans are to meet the requirements of Ch 4,5.

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Fire Protection, Detection and Extinction — Yachts

Section

1 **General requirements**

2 **Fire safety measures for yachts of overall length greater than 24 m but less than 500 gt**

3 **Fire safety measures for yachts 500 gt or more**

■ *Section 1* General requirements

1.1 Application

1.1.1 The requirements of this Chapter apply to yachts with an overall length, L_{OA} (as defined in Pt 3, Ch 1,6.2.4) of 24 m or greater built in accordance with the Rules.

1.1.2 Where yachts incorporate fire hazards not covered in this Part, appropriate fire protection, detection and extinction arrangements are to be provided. Details are to be submitted for approval.

1.1.3 For yachts with an overall length of 24 m or more, and less than 500 gt, the fire safety measures are to comply with Section 2.

1.1.4 For yachts 500 gt or more, the fire safety measures are to comply with Section 3.

■ *Section 2* Fire safety measures for yachts of overall length greater than 24 m but less than 500 gt

2.1 General

2.1.1 Table 3.2.1 is a guide to the major requirements of this Section. The Table is intended as a quick reference to the requirements and is not to be used in isolation when designing the fire safety arrangements.

2.2 Forms of construction – Structure

2.2.1 The hull, superstructure, structural bulkheads, decks and deckhouses may be constructed of steel, other equivalent material, *see* Ch 1,2.1.2, or be of alternative forms of construction, *see* Ch 1,2.1.3.

2.2.2 The structure in way of Category 'A' machinery spaces, galleys containing appliances of significant fire risk, *see* 2.4.2, and other high risk areas is to be protected such that the material by itself or due to insulation provided can maintain its required strength at the end of 30 minutes exposure to the standard fire test.

Table 3.2.1 General fire protection, detection and extinction requirements

Form of construction, *see* 2.2	Steel or equivalent, or alternative forms of construction may be accepted subject to requirements
Passive fire protection, *see* 2.3 to 2.6	• Category 'A' machinery spaces 'A-30'/'A-0' • Galleys: 'B-15' where significant fire risk • Bulkheads in escape route corridors greater than 7 m in length: 'B-0' • Stairway enclosures: 'B-0'
Means of escape, *see* 2.7 • Category 'A' machinery spaces • Accommodation, etc.	} 2
Fixed fire detection system, *see* 2.13	• Fitted in machinery spaces • Fitted in service spaces, control stations and accommodation spaces
Fire pumps, *see* 2.14	1 fixed power pump + 1 portable pump
Fire extinguishing arrangements in Category 'A' machinery spaces, *see* 2.15	• A fixed fire-extinguishing system • A minimum of 2 and maximum of 5 portable foam extinguishers or equivalent
Portable fire-extinguishers in accommodation, *see* 2.18	At least 3
Automatic sprinkler system or equivalent, *see* 2.16	Fitted in yachts >350 gross tons

2.2.3 Details of the method of construction, supported by calculations and/or fire test data, demonstrating compliance with 2.2.2 are to be submitted.

2.2.4 For aluminium alloy structures, the insulation is to be such that the temperature of the structural core does not rise more than 200°C above the ambient temperature at any time during the specified fire exposure.

2.2.5 For composite structures, the insulation is to be such that the temperature of the laminate does not rise more than the minimum temperature of deflection under load of the resin at any time during the specified fire exposure. The temperature of deflection under load is to be determined as in Ch 14,3.7 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

2.2.6 For structures in contact with sea-water, the required insulation should extend to at least 300 mm below the lightest waterline, *see also* 2.6.1.

2.3 Forms of construction – Fire divisions

2.3.1 Fire divisions required by 2.4 are to be constructed in accordance with the remaining paragraphs of this sub-Section.

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2.3.2 Fire divisions using steel equivalent, or alternative forms of construction may be accepted if it can be demonstrated that the material by itself, or due to insulation provided, has the fire resistance properties equivalent to 'A' or 'B' Class divisions.

2.3.3 Insulation required by 2.3.2 is to be such that the temperature of the structural core does not rise above the point at which the structure would begin to lose its strength at any time during the applicable exposure to the standard fire test. For 'A' Class divisions, the applicable exposure is 60 minutes, and for 'B' Class divisions, the applicable exposure is 30 minutes.

2.3.4 For aluminium alloy structures, the insulation is to be such that the temperature of the structural core does not rise more than 200°C above the ambient temperature at any time during the applicable fire exposure.

2.3.5 For composite structures, the insulation is to be such that the temperature of the laminate does not rise more than the minimum temperature of deflection under load of the resin at any time during the applicable fire exposure. The temperature of deflection under load is to be determined as in Ch 14,3.7 of the Rules for Materials.

2.4 Structural fire protection

2.4.1 Category 'A' machinery spaces, spaces containing vehicles or craft with fuel in their tanks, or lockers storing such fuels, are to be enclosed by 'A-30' Class divisions where adjacent to accommodation or service spaces, control positions or each other, and 'A-0' Class divisions elsewhere.

2.4.2 Galleys are to be enclosed by 'B-15' Class divisions, unless the cooking appliances contained therein have an insignificant fire risk:

(a) For the purposes of this Chapter, coffee automats, toasters, dishwashers, microwave ovens, water boilers and similar appliances each with a maximum power of 5 kW may be regarded as having an insignificant fire risk. Electrically-heated cooking plates and hot plates for keeping food warm, each of them having a maximum power of 2 kW and a surface temperature not above 150°C may also be regarded as having insignificant fire risk. If spaces containing this equipment are lockable, then means of cutting-off the power to the space are to comply with Pt 16, Ch 2,16.6.7.

(b) Other equipment such as fat fryers, open flame cookers, etc., would be regarded as having a significant fire risk.

2.4.3 Where forming escape routes, corridor bulkheads and ceilings may be constructed of combustible materials provided they have a non-combustible core such that the 'B-0' Class standard fire test criteria are met.

2.4.4 Stairways connecting spaces below the main deck to the deck above are to be protected at one level by at least 'B-0' Class divisions and self-closing doors.

2.4.5 Lift and dumbwaiter trunks are to be enclosed by at least 'B-0' Class divisions and self-closing doors.

2.4.6 Openings in 'A' and 'B' Class divisions are to be provided with permanently attached means of closing that are to be at least as effective for resisting fires as the divisions in which they are fitted.

2.4.7 Interior stairways serving machinery spaces, accommodation spaces, service spaces or control stations are to be of steel, or other equivalent material.

2.4.8 Where 'A' Class divisions are penetrated for the passage of electric cables, pipes, trunks, ducts, etc., or for girders, beams or other structural members, arrangements are to be made to ensure that the fire resistance is not impaired.

2.4.9 Where 'B' Class divisions are penetrated for the passage of electric cables, pipes, trunks, ducts, etc., or for the fitting of ventilation terminals, lighting fixtures and similar devices, arrangements are to be made to ensure that the fire resistance is not impaired.

2.4.10 Where the structure or 'A' Class divisions are required to be insulated, it is to be ensured that the heat from a fire is not transmitted through the intersections and terminal points of the divisions or penetrations to uninsulated boundaries. Where the insulation installed does not achieve this, arrangements are to be made to prevent this heat transmission by insulating the horizontal and vertical boundaries or penetrations for a distance of 450 mm.

2.5 Materials

2.5.1 Except in refrigerated compartments of service spaces, all insulation other than fire insulation is to be of not-readily ignitable type. Fire insulation is to be of the non-combustible type.

2.5.2 Pipes penetrating 'A' or 'B' Class divisions are to be of approved materials having regard to the temperature such divisions are required to withstand.

2.5.3 Pipes conveying oil or combustible liquids through accommodation and service spaces are to be of approved materials having regard to the fire risk.

2.5.4 Materials readily rendered ineffective by heat are not to be used for overboard scuppers, sanitary discharges and other outlets which are close to the waterline and where the failure of the material in the event of fire would give rise to danger of flooding.

2.5.5 Primary deck coverings within accommodation spaces, service spaces and control stations are to be of a type that will not readily ignite, or give rise to toxic or explosive hazards at elevated temperatures. Reference is also to be made to the IMO FTP Code, Annex 1, Parts 2 and 6.

2.5.6 Vapour barriers and adhesives used in conjunction with insulation, as well as insulation of pipe fittings for cold service systems need not be non-combustible, but they are to be kept to the minimum quantity practicable and their exposed surfaces are to have low flame spread characteristics.

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2.5.7 All waste receptacles are to be constructed of non-combustible materials with no openings in the sides or bottom.

2.6 Surface of insulation

2.6.1 In spaces where penetration of oil products is possible, the surface of the insulation is to be impervious to oil or oil vapours. Insulation boundaries are to be arranged to avoid immersion in oil spillages.

2.7 Means of escape

2.7.1 Stairways, ladders and corridors serving all spaces normally accessible are to be arranged so as to provide ready means of escape to a deck from which embarkation into survival craft may be effected.

2.7.2 Where reasonable and practicable, and having regard to the number of personnel involved and size of space, at least two means of escape, as widely separated as possible, are to be provided from each section of accommodation and service spaces and control stations:

(a) The normal means of access to the accommodation and service spaces below the open deck are to be arranged so that it is possible to reach the open deck without passing through intervening spaces containing a possible source of fire.

(b) Where accommodation arrangements are such that access to compartments is through another compartment, as is often the case with an Owner's suite, a second means of escape is to be provided. The second escape route is to be as remote as possible from the main escape route.

(c) This second means of escape may be through portholes, or hatches of adequate size, leading to the open deck.

(d) No dead-end corridors having a length of more than 7 m will be accepted. A 'dead-end corridor' is a corridor or part of a corridor from which there is only one escape route.

2.7.3 At least one of the means of escape from each space referred to in 2.7.2 is to be enclosed by 'B-0' Class divisions, unless it gives access directly to the open decks from the space.

2.7.4 At least two means of escape are to be provided from machinery spaces, except where the small size of the machinery space makes it impracticable. Escape is to be by steel ladders that are as widely separated as possible.

2.7.5 Lifts are not considered as forming a means of escape.

2.8 Ventilation systems

2.8.1 Ventilation fans are to be capable of being stopped, and main inlets and outlets of ventilation systems closed, from outside the spaces being served, *see* Pt 16, Ch 2,16.6.

2.8.2 Ventilation ducts for Category 'A' machinery spaces, exhaust ducts for galleys of significant fire risk, spaces containing vehicles or craft with fuel in their tanks, or lockers storing such fuels, are not to pass through accommodation spaces, service spaces or control stations unless the ducts are constructed of steel and arranged to preserve the integrity of the division.

2.8.3 Ventilation ducts for accommodation spaces, service spaces or control stations are not to pass through Category 'A' machinery spaces, spaces containing vehicles or craft with fuel in their tanks, or lockers storing such fuels, unless the ducts are constructed of steel and arranged to preserve the integrity of the division.

2.8.4 Store-rooms containing highly flammable products are to be provided with ventilation arrangements that are separate from other ventilation systems. Ventilation is to be arranged to prevent the build up of flammable vapours at high and low levels. The inlets and outlets of ventilators are to be positioned so that they do not draw from or vent into an area which would cause undue hazard, and are to be fitted with spark arresters.

2.8.5 Ventilation systems serving Category 'A' machinery spaces are to be independent of systems serving other spaces.

2.8.6 All enclosed spaces containing free-standing fuel tanks are to be ventilated independently of systems serving other spaces.

2.8.7 Ventilation is to be provided to prevent the accumulation of dangerous concentrations of flammable gas which may be emitted from batteries. The requirements of Pt 16, Ch 2,11.5 are to be complied with.

2.8.8 Ventilation openings may be fitted in and under the lower parts of cabin and public space doors in corridor bulkheads. The total net area of any such openings is not to exceed 0,05 m^2. Bridging ducts are not allowed in fire divisions.

2.8.9 For spaces containing vehicles or craft with fuel in their tanks or lockers storing such fuels, *see* 2.20.1(d). For additional requirements for the ventilation of domestic gaseous fuel, *see* 2.11.

2.9 Fuel arrangements

2.9.1 In yachts in which oil fuel is used, the arrangements for the storage, distribution and utilisation of the oil fuel are to be such as to ensure the safety of the yacht and persons on board. For details, *see* Pt 15, Ch 3.

2.9.2 Oil fuel tanks situated within the boundaries of Category 'A' machinery spaces are not to contain oil fuel having a flashpoint of less than 60°C.

2.9.3 Oil fuel, lubricating oil and other flammable oils are not to be carried in fore peak tanks.

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2.10 Special arrangements in Category 'A' machinery spaces and, where necessary, other machinery spaces

2.10.1 Openings are to be provided with closing appliances constructed so as to maintain the fire integrity of the machinery space boundaries.

2.10.2 The type of equipment installed and the layout of the yacht are to take account of the risk and spread of fire. Special attention is to be paid to the surroundings of open flame devices, hot areas and main and auxiliary machinery, oil and fuel overflows, and uncovered oil and fuel pipes.

2.10.3 Fuel filling, storage, venting and supply systems are to be installed so as to minimise the risk of fire and explosion.

2.10.4 Machinery components and accessories that require frequent maintenance and inspection are to be readily accessible.

2.10.5 Windows are not to be fitted in machinery space boundaries. This does not preclude the use of glass in control rooms within the machinery spaces.

2.10.6 Means of control are to be provided for:

(a) closure of openings which normally allow exhaust ventilation, and closure of ventilator dampers;
(b) permitting the release of smoke;
(c) stopping ventilating fans; and
(d) stopping forced and induced draught fans, oil fuel transfer pumps, oil fuel unit pumps and other similar fuel pumps.

2.10.7 The controls required in 2.10.6 are to be located outside the space concerned, where they will not be cut off in the event of fire in the space they serve. Such controls and the controls for any required fire-extinguishing system are to be situated at one control position or grouped in as few positions as possible. Such positions are to have a safe access from the open deck. *See also* Pt 15, Ch 3,4.5.1 and 4.9.2.

2.11 Arrangements for gaseous fuel for domestic purposes

2.11.1 Where gaseous fuel is used for domestic purposes, the arrangements for the storage, distribution and utilisation of the fuel are to be such that, having regard to the hazards of fire and explosion which the use of such fuel may entail, the safety of the yacht and the persons onboard is preserved. The installation is to be in accordance with recognised National or International Standards.

2.11.2 Storage lockers for gas cylinders are to be provided with:

(a) effective ventilation;
(b) an outward-opening door accessible directly to the open deck; and
(c) gas-tight boundaries, including doors and other means of closing any openings therein, which form boundaries between such lockers and adjoining spaces.

2.11.3 Arrangements for storage on open deck will be specially considered.

2.12 Space heaters

2.12.1 Space heaters, if used, are to be fixed in position and so constructed as to reduce fire risks to a minimum. The design and location of these units are to be such that clothing, curtains or other similar materials cannot be scorched or set on fire by heat from the unit.

2.13 Fixed fire detection and fire-alarm systems

2.13.1 A fixed fire detection and fire-alarm system are to be installed in all Category 'A' machinery spaces and are to comply with the requirements of Pt 16, Ch 1,2.8.

2.13.2 A fixed fire detection and fire-alarm system are to be fitted in all stairways (including lift and dumbwaiter trunks), service spaces, control stations and accommodation spaces (except toilets, bathrooms, void spaces, etc.). The fixed fire detection and fire-alarm system are to be installed in accordance with Ch 4,2.

2.13.3 All yachts at all times when at sea, or in port (except when out of service), are to be so equipped as to ensure that any initial fire-alarm is immediately received by a responsible member of the crew.

2.13.4 A special alarm, operated from the navigating bridge or fire-control station, is to be fitted to summon the crew.

2.14 Fire pumps and fire main system

2.14.1 **Application.** Every yacht is to be provided with a fire pump(s), fire mains, hydrants and hoses as required by this Section.

2.14.2 **Capacity of fire pumps.** The capacity of the fixed main fire pump(s) is not to be less than:

$$Q = (0{,}15\,(L_R\,(B + D))^{1/2} + 2{,}25)^2$$

but need not exceed 25 m^3/hour.

where

B = greatest moulded breadth of yacht, in metres
D = moulded depth to bulkhead deck, in metres
L_R = Rule length of yacht, as defined in Pt 3, Ch 1,6.2.1, in metres
Q = total capacity in m^3/hour.

2.14.3 **Fire pumps:**

(a) A minimum of one fixed power pump and one portable pump or alternative, complying with 2.14.4, are to be provided.
(b) Sanitary, ballast, bilge or general service pumps may be accepted as fire pumps, provided that they are not normally used for pumping oil, and that, if they are subject to occasional duty for the transfer or pumping of fuel oil, suitable changeover arrangements are fitted.

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(c) In yachts classed for navigation in ice, the fire pump sea inlet valves are to be provided with ice clearing arrangements, *see* Pt 1, Ch 2,3.8.1.

(d) Relief valves are to be provided in conjunction with any fire pump if the pump is capable of developing a pressure exceeding the design pressure of the water service pipes, hydrants and hoses. These valves are to be so placed and adjusted as to prevent excessive pressure in any part of the fire main system.

(e) Where centrifugal pumps are provided in order to comply with this Section, a non-return valve is to be fitted in the pipe connecting each pump to the fire main.

2.14.4 **Portable fire pumps**:

(a) Except for electric pumps, which will be specially considered, portable fire pumps are to comply with the following:
  (i) The pump is to be self priming.
  (ii) The suction head in operation is not to exceed 4,5 m.
  (iii) The portable fire pump is to be fitted with a length of discharge hose and nozzle capable of maintaining a pressure sufficient to produce a jet throw of at least 12 m or that required to enable a jet of water to be directed on any part of the engine room or the exterior boundary of the engine room and casing, whichever is the greater.
  (iv) The pump set is to have its own fuel tank of sufficient capacity to operate the pump for three hours.
  (v) Details of the fuel type and storage location are to be submitted. If the fuel type has a flashpoint below 60°C, further consideration will be given to the fire safety aspects.
  (vi) The pump set is to be stored in a secure, safe and enclosed space, accessible from open deck and clear of the Category 'A' machinery space.
  (vii) The pump set is to be easily moved and operated by two persons and be readily available for immediate use.
  (viii) Arrangements are to be provided to secure the pump at its anticipated operating position(s).
  (ix) The overboard suction hose is to be non-collapsible and of sufficient length to cater for the yacht's motion under all operational conditions. A suitable strainer is to be fitted at the inlet end of the hose.
  (x) Any diesel driven power source for the pump is to be capable of being readily started in its cold condition down to a temperature of 0°C by hand (manual) cranking.

(b) If it is not possible to comply with the requirements of 2.14.4(a), an additional fixed fire pump will be required, which is to comply with the following:
  (i) The pump, its source of power and sea connection are to be located in accessible positions outside the Category 'A' machinery space, or in a different space to the main fire pump, if the main fire pump is located outside the Category 'A' machinery space.
  (ii) The sea valve is to be capable of being operated from a position near the pump.
  (iii) The room where the fire pump prime mover is located is to be illuminated from the emergency source of electrical power and is to be well ventilated.
  (iv) If the pump is required to supply water for a fixed fire-extinguishing system in the space where the main fire pumps are situated, it is to be capable of simultaneously supplying water to this system and the fire main at the required rates.
  (v) The pump may also be used for other suitable purposes, subject to approval in each case.
  (vi) The pressure and quantity of water delivered by the pump are to be sufficient to produce a jet of water at any nozzle of not less than 12 m.

(c) Means to illuminate the stowage area of the portable pump and its necessary areas of operation are to be provided from the emergency source of electrical power.

(d) If preferred, a pump complying with 2.14.4(b) may be fitted instead of a portable pump complying with 2.14.4(a), *see also* 2.14.8(c).

2.14.5 **Fire main**:

(a) The diameter of the fire main is to be based on the required capacity of the fixed main fire pump(s). The diameter of the water service pipes is to be sufficient to ensure an adequate supply of water for the operation of at least one fire-hose.

(b) The wash deck line may be used as a fire main provided that the requirements of this Section are satisfied.

(c) All exposed water pipes for fire-extinguishing are to be provided with drain valves for use in frosty weather. The valves are to be located where they will not be damaged.

2.14.6 **Pressure in the fire main**. When the fixed main fire pump, or the fire pump described in 2.14.4(b), is delivering the quantity of water required by 2.14.2 through the fire main, fire-hoses and nozzles, the pressure maintained at any hydrant is to be sufficient to produce a jet throw at any nozzle of not less than 12 m.

2.14.7 **Number and position of hydrants**. The number and position of the hydrants are to be such that at least one jet of water is to reach any part normally accessible to any person while the yacht is being navigated. Furthermore, such hydrants are to be positioned near the accesses to the protected spaces. At least one hydrant is to be provided in each Category 'A' machinery space.

2.14.8 **Pipes and hydrants**:

(a) Materials readily rendered ineffective by heat are not to be used for fire mains. For the use of aluminium alloy *see* Pt 15, Ch 1,10.1.4. Where steel pipes are used, they are to be galvanised internally and externally. Cast iron pipes are not acceptable. The pipes and hydrants are to be so placed that the fire-hoses may be easily coupled to them. The arrangement of pipes and hydrants is to be such as to avoid the possibility of freezing. Unless one hose and nozzle is provided for each hydrant in the yacht, there is to be complete interchangeability of hose couplings and nozzles.

(b) A valve is to be fitted at each fire hydrant so that any fire-hose may be removed while the fire pump is at work.

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(c) Where an additional fixed fire pump is fitted in accordance with 2.14.4(b) or 2.14.4(d):
  (i) An isolating valve is to be fitted in the fire main so that all the hydrants in the yacht, except those in the Category 'A' machinery space containing the main fire pump, can be supplied with water by the additional fixed fire pump. The isolating valve is to be located in an easily accessible and tenable position outside the Category 'A' machinery space; and
  (ii) the fire main is not to re-enter the machinery space downstream of the isolating valve.

2.14.9 **Fire-hoses**:
(a) Fire-hoses are to be of approved non-perishable material. The hoses are to be sufficient in length to project a jet of water to any of the spaces in which they may be required to be used. Their length, in general, is not to exceed 18 m. Each hose is to be provided with a nozzle and the necessary couplings. Fire-hoses, together with any necessary fittings and tools, are to be kept ready for use in conspicuous positions near the water service hydrants or connections.
(b) A minimum of three fire-hoses are to be provided, each complete with couplings and nozzles. These numbers do not include any hoses required in any engine room. If necessary, the number of hoses is to be increased so as to ensure that hoses in sufficient number are available and accessible at all times.

2.14.10 **Nozzles**:
(a) For the purpose of this Chapter, standard nozzle sizes are to be 12 mm, 16 mm or 19 mm, or as near thereto as possible, so as to make full use of the maximum discharge capacity of the fire pump or pumps.
(b) For accommodation and service spaces, the nozzle size need not exceed 12 mm.
(c) The size of nozzles intended for use in conjunction with a portable fire pump need not exceed 12 mm.
(d) All nozzles are to be of an approved dual purpose type (i.e. spray/jet type) incorporating a shut-off.

2.15 Fire-extinguishing arrangements in machinery spaces

2.15.1 **Category 'A' machinery spaces** are to be provided with:
(a) One of the fixed fire-extinguishing systems given in Ch 4,3; and
(b) at least two portable foam extinguishers or equivalent, *see* Ch 4,6.3.2. Where internal combustion machinery is installed, an additional portable extinguisher is to be provided for every 375 kW of power output, but the total number of such additional extinguishers need not exceed five.

2.15.2 **Fire-extinguishing appliances in other machinery spaces.** Where a fire hazard exists in any machinery space for which no specific provisions for fire-extinguishing appliances are prescribed in 2.15.1 or 2.15.3 there is to be provided in or adjacent to that space, a satisfactory number of approved portable fire-extinguishers or other approved means of fire-extinction.

2.15.3 **Machinery spaces, other than Category 'A', in yachts which are constructed mainly or wholly with alternative forms of construction.** In yachts that are constructed mainly or wholly with alternative forms of construction, machinery spaces, other than Category 'A', containing internal combustion machinery, are to comply with the fire-extinguishing requirements for Category 'A' machinery spaces, *see* 2.15.1.

2.16 Automatic sprinkler, fire detection and fire-alarm system

2.16.1 A fixed automatic sprinkler must be fitted in yachts over 350 gross tons, fire detection and fire-alarm system, or equivalent system (e.g. watermist), are to be fitted in all stairways, service spaces, control stations and accommodation spaces, except in general, in spaces which afford no fire risk such as void spaces.

2.16.2 The arrangements are to be in accordance with Ch 4,1, particular attention should be given to Ch 4,1.2.16 and 1.2.17.

2.17 Fixed fire-extinguishing systems not required by this Section

2.17.1 Where a fixed fire-extinguishing system not required by this Chapter is installed, the arrangement is to comply with the relevant requirements of this Chapter.

2.18 Portable fire-extinguishers

2.18.1 All portable fire-extinguishers are to comply with the requirements of Ch 4,6.

2.18.2 The portable fire-extinguishers are to be stowed in readily accessible positions.

2.18.3 One of the portable fire-extinguishers intended for use in any space is to be stowed near the entrance to that space.

2.18.4 At least one portable fire-extinguisher is to be located so that it can easily be reached from the main steering position of the yacht.

2.18.5 Accommodation spaces, service spaces and control stations are to be provided with a sufficient number of portable fire-extinguishers to ensure that at least one extinguisher will be readily available for use in every compartment. In any case, their number is to be not less than three.

2.18.6 Where cooking facilities are provided, a portable fire-extinguisher of a type appropriate to the energy source used is to be located in a position readily accessible for use in the event of a fire.

2.19 Fire blanket

2.19.1 A fire blanket is to be installed in all galleys.

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2.20 Protection of spaces containing vehicles or craft with fuel in their tanks or lockers storing such fuels

2.20.1 Spaces containing vehicles or craft with fuel in their tanks, or lockers storing such fuels, are to be provided with the following:

(a) A fixed fire detection and fire-alarm system complying with the requirements of Pt 16, Ch 1,2.8.

(b) A manually-operated water spray deluge system having a water application rate of 5 litres per square metre of deck area per minute. Where the deck height does not exceed 2,5 m, an application rate of 3,5 litres per square metre of deck area per minute will be accepted. Adequate drainage of the protected spaces is to be provided generally in accordance with the requirements for vehicle or cargo spaces, *see* Pt 3, Ch 4,9.4.4. The drainage piping and connection for the space are to be non-combustible. Other fixed fire-extinguishing systems may be permitted, provided they are not less effective in controlling the type of fire likely to occur.

(c) At least two portable foam extinguishers or equivalent.

(d) An independent mechanical ventilation system, which is entirely separate from other ventilation systems, providing at least six air changes per hour. The ducted air is not to pass through other spaces, except as allowed under 2.8.2, or vent into areas where it could be drawn into accommodation areas or cause undue hazard.

(e) Electrical equipment of a safe type is to be provided, *see* Pt 16, Ch 2,13.

(f) Prominently displayed 'No Smoking' signs.

(g) 'A-30' Class divisions where adjacent to Category 'A' machinery spaces, accommodation or service spaces, or control positions and 'A-0' Class divisions elsewhere.

2.20.2 Such spaces are not to give access to any space other than the fuel store or lockers for use within the space. Lockers storing fuel are to be accessed from an exterior location, unless the locker is within the space containing the vehicles or craft. Exceptionally, where the engine room escape cannot be routed elsewhere, it may exit into the space providing that:

(a) the connecting door is self-closing;

(b) no door hold back devices are fitted;

(c) an audible and visual alarm is fitted on the bridge to signify when the door is open; and

(d) a notice is posted at the door stating that the door is to remain closed and that the area beside the door is an escape route and is to be kept clear.

2.20.3 The requirements of 2.9 are to be complied with, as appropriate.

2.21 Protection of paint lockers and flammable liquid lockers

2.21.1 Paint lockers and flammable liquid lockers with a deck area of 4 m^2 or more are to be provided with a fixed fire-extinguishing system enabling the crew to extinguish a fire without entering the space. One of the following systems is to be provided:

- A carbon dioxide system designed for 40 per cent of the gross volume of the space.
- A dry powder system designed to discharge 0,5 kg powder per cubic metre of gross volume of the space.
- A water spray system designed to give a coverage of 5 litres per square metre of deck area per minute. Water spray systems may be connected to the fire main.

2.21.2 Consideration will be given to the acceptance of other arrangements which provide equivalent protection.

2.21.3 Lockers having a deck area of less than 4 m^2 may be protected by carbon dioxide or dry powder portable extinguishers located near the entrance to the locker.

2.22 Helicopter decks

2.22.1 The requirements of IMO Resolution A.855(20) are to be complied with having due regard to the hazards involved.

2.22.2 If a helicopter hangar is not provided and if two fireman's outfits are supplied as in 2.23.1, then the fireman's outfits required by IMO Resolution A.855(20) need not be provided.

2.23 Fireman's outfit

2.23.1 All yachts of 350 gross tons or more are to carry at least two fireman's outfits complying with the requirements of Ch 4,4.

2.24 Fire-control plans

2.24.1 Fire control plans are to meet the requirements of Ch 4,5.

■ *Section 3* Fire safety measures for yachts 500 gt or more

3.1 General

3.1.1 Table 3.3.1 is a guide to the major requirements of this Section. The Table is intended as a quick reference to the requirements and is not to be used in isolation when designing the fire safety arrangements.

3.2 Forms of construction – Structure

3.2.1 The hull, superstructure, structural bulkheads, decks and deckhouses may be constructed of steel, other equivalent material, *see* Ch 1,2.1.2 or be of alternative forms of construction, *see* Ch 1,2.1.3.

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Table 3.3.1 General fire protection, detection and extinction requirements

Form of construction, *see* 3.2	Steel or equivalent, or alternative forms of construction may be accepted subject to extensive insulation requirements
Passive fire protection, *see* 3.3 to 3.12	*See* Table 3.3.2 and Table 3.3.3
Means of escape, *see* 3.15: • Category 'A' machinery spaces • Accommodation, etc.	2
Fixed fire detection system, *see* 3.24	• Fitted in machinery spaces • Fitted in service spaces, control stations and accommodation spaces
Fire pumps, *see* 3.25.1 to 3.25.10	• In general, 2 independent power pumps • For yachts of ≥4000 gross tons: 3 independent power pumps • A fire in any one compartment is not to put all the fire pumps out of action
International shore connection, *see* 3.25.11	At least 1
Fire extinguishing arrangements in Category 'A' machinery spaces, *see* 3.26. *See also* 3.27 for oil fuel units	• A fixed fire extinguishing system • Portable air-foam equipment • 45 litre foam extinguisher • Portable foam extinguishers within 10 m walking distance
Portable fire-extinguishers in accommodation, *see* 3.32	Sufficient to ensure that at least one will be readily available in every compartment, but a minimum of five
Automatic sprinkler system or equivalent, *see* 3.29	Fitted in all yachts
Fireman's outfits, *see* 3.38	At least 2

3.2.2 The structure in way of Category 'A' machinery spaces, galleys containing appliances of significant fire risk and other high risk areas is to be protected such that the material by itself or due to insulation provided can maintain its required strength at the end of 60 minutes exposure to the standard fire test.

3.2.3 Details of the method of construction, supported by calculations and/or fire test data, demonstrating compliance with 3.2.2 are to be submitted.

3.2.4 For aluminium alloy structures, the insulation is to be such that the temperature of the structural core does not rise more than 200°C above the ambient temperature at any time during the specified fire exposure.

3.2.5 For composite structures, the insulation is to be such that the temperature of the laminate does not rise more than the minimum temperature of deflection under load of the resin at any time during the specified fire exposure. The temperature of deflection under load is to be determined as in Ch 14,3.7 of the Rules for Materials.

3.2.6 For structures in contact with sea-water, the required insulation should extend to at least 300 mm below the lightest waterline, *see also* 2.6.1.

3.3 Forms of construction – Fire divisions

3.3.1 Fire divisions required by 3.4 are to be constructed in accordance with the remaining paragraphs of 3.3.

3.3.2 Fire divisions using steel equivalent, or alternative forms of construction, may be accepted if it can be demonstrated that the material by itself due to insulation provided, has the fire resistance properties equivalent to 'A' or 'B' Class divisions.

3.3.3 Insulation required by 3.3.2 is to be such that the temperature of the structural core does not rise above the point at which the structure would begin to lose its strength at any time during the applicable exposure to the standard fire test. For 'A' Class divisions, the applicable exposure is 60 minutes, and for 'B' Class divisions, the applicable exposure is 30 minutes.

3.3.4 For aluminium alloy structures, the insulation is to be such that the temperature of the structural core does not rise more than 200°C above the ambient temperature at any time during the applicable fire exposure.

3.3.5 For composite structures, the insulation is to be such that the temperature of the laminate does not rise more than the minimum temperature of deflection under load of the resin at any time during the applicable fire exposure. The temperature of deflection under load is to be determined as in Ch 14,3.7 of the Rules for Materials.

3.4 Structural fire protection – Main vertical zones and horizontal zones

3.4.1 The hull, superstructure and deckhouses in way of accommodation and service spaces are to be subdivided into main vertical zones by 'A' Class divisions, *see* Ch 1,2.4.12. These divisions are to have insulation values in accordance with Tables 3.3.2 and 3.3.3.

3.4.2 As far as practicable, the bulkheads forming the boundaries of the main vertical zones above the bulkhead deck are to be in line with watertight subdivision bulkheads situated immediately below the bulkhead deck.

3.4.3 The bulkheads mentioned in 3.4.2 are to extend from deck to deck and to the shell or other boundaries.

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Table 3.3.2 Fire integrity of bulkheads separating adjacent spaces

Spaces		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Control stations	(1)	'A-0' *See* Note 3	'A-0'	'A-60'	'A-0'	'A-15'	'A-60'	'A-15'	'A-60'	*See* Note 7
Corridors	(2)	—	C *See* Note 4	'B-0' *See* Note 4	'A-0' *See* Note 1 'B-0' *See* Note 4	'B-0' *See* Note 4	'A-60'	'A-0'	'A-15' 'A-0' *See* Note 6	*See* Note 7
Accommodation spaces	(3)	—	—	C *See* Note 4	'A-0' *See* Note 1 'B-0' *See* Note 4	'B-0' *See* Note 4	'A-60'	'A-0'	'A-15' 'A-0' *See* Note 6	*See* Note 7
Stairways	(4)	—	—	—	'A-0' *See* Note 1 'B-0' *See* Note 4	'A-0' *See* Note 1 'B-0' *See* Note 4	'A-60'	'A-0'	'A-15' 'A-0' *See* Note 6	*See* Note 7
Service spaces (low risk)	(5)	—	—	—	—	C *See* Note 4	'A-60'	'A-0'	'A-0'	*See* Note 7
Machinery spaces of Category 'A' and spaces containing vehicles or craft with fuel in their tanks or lockers storing such fuels	(6)	—	—	—	—	—	'A-60' *See* Note 2	'A-0'	'A-60'	*See* Note 7
Other machinery spaces	(7)	—	—	—	—	—	—	'A-0' *See* Note 2	'A-0'	*See* Note 7
Service spaces (high risk)	(8)	—	—	—	—	—	—	—	'A-0' *See* Note 2	*See* Note 7
Open decks	(9)	—	—	—	—	—	—	—	—	—

NOTES
1. For clarification as to which applies, *see* 3.7.
2. Where spaces are of the same numerical category and Note 2 appears, a bulkhead or deck of the ratings shown in the Table is only required when the adjacent spaces are for a different purpose, e.g. in category (8), a galley next to a galley does not require a bulkhead, but a galley next to a paint room requires an 'A-0' Class bulkhead.
3. Bulkheads separating the wheelhouse and chartroom from each other may be 'B-0' rating.
4. For the application of 3.4.1 all 'B-0' and 'C' Class bulkheads where appearing in this Table are to be taken as 'A-0' Class.
5. Fire insulation need not be fitted if the machinery space of category (7) has little or no fire risk.
6. Where the spaces are protected by the sprinkler system on both sides of the division, the division may be 'A-0' Class. Where the sprinkler system only protects a space on one side of the division the rating is to be the higher of the two values given.
7. The division is to be of steel, other equivalent material, or alternative forms of construction, but is not required to be of 'A' Class standard. However, where decks, except open decks, are penetrated for the passage of electric cables, pipes and vent ducts, such penetrations are to be made tight to prevent the passage of flame and smoke.
8. For requirements for main vertical zones, *see* 3.4.1.

3.5 Structural fire protection of bulkheads within a main vertical zone

3.5.1 All such divisions may be faced with combustible materials.

3.5.2 When continuous 'B' Class ceilings and/or linings are fitted on both sides of the bulkhead, the portion of the bulkhead behind the continuous ceiling or lining is to be of material which in thickness and composition is acceptable in the construction of 'B' Class divisions but which may meet 'B' Class standards only insofar as is reasonable and practicable.

3.5.3 All bulkheads required to be 'B' Class divisions, except corridor bulkheads prescribed in 3.5.2, are to extend from deck to deck and to the shell or other boundaries unless continuous 'B' Class ceilings or linings fitted on both sides of the bulkhead are at least of the same fire resistance as the bulkhead, in which case the bulkhead may terminate at the continuous ceiling or lining.

3.6 Structural fire protection – Fire integrity of bulkheads and decks

3.6.1 In addition to complying with the specific provisions for fire integrity of bulkheads and decks mentioned elsewhere in this Section the minimum fire integrity of bulkheads and decks are to be as prescribed in Tables 3.3.2 and Table 3.3.3.

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Table 3.3.3 Fire integrity of decks separating adjacent spaces

		Space above								
Space below		*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*
Control stations	*(1)*	'A-0'	'A-0'	'A-0'	'A-0'	'A-0'	'A-60'	'A-0'	'A-0'	*See* Note 3
Corridors	*(2)*	'A-0'	*See* Note 3	*See* Note 3	'A-0'	*See* Note 3	'A-60'	'A-0'	'A-0'	*See* Note 3
Accommodation spaces	*(3)*	'A-60'	'A-0'	*See* Note 3	'A-0'	*See* Note 3	'A-60'	'A-0'	'A-0'	*See* Note 3
Stairways	*(4)*	'A-0'	'A-0'	'A-0'	*See* Note 3	'A-0'	'A-60'	'A-0'	'A-0'	*See* Note 3
Service spaces (low risk)	*(5)*	'A-15'	'A-0'	'A-0'	'A-0'	*See* Note 3	'A-60'	'A-0'	'A-0'	*See* Note 3
Machinery spaces of Category 'A' and spaces containing vehicles or craft with fuel in their tanks or lockers storing such fuels	*(6)*	'A-60'	'A-60'	'A-60'	'A-60'	'A-60'	'A-60'	'A-60' *See* Note 1	'A-60'	*See* Note 3
Other machinery spaces	*(7)*	'A-15'	'A-0'	'A-0'	'A-0'	'A-0'	'A-0'	*See* Note 3	'A-0'	*See* Note 3
Service spaces (high risk)	*(8)*	'A-60' 'A-0' *See* Note 2	'A-30' 'A-0' *See* Note 2	'A-30' 'A-0' *See* Note 2	'A-30'	'A-0'	'A-60'	'A-0'	'A-0'	*See* Note 3
Open decks	*(9)*	*See* Note 3	*See* Note 3	*See* Note 3	*See* Note 3	*See* Note 3	*See* Note 3	*See* Note 3	*See* Note 3	—

NOTE
1. Fire insulation need not be fitted if the machinery space of category (7) has little or no fire risk.
2. Where the spaces are protected by the sprinkler system on both sides of the division, the division may be 'A-0' Class. Where the sprinkler system only protects a space on one side of the division the rating is to be the higher of the two values given.
3. The division is to be of steel, other equivalent material, or alternative forms of construction, but is not required to be of 'A' Class standard. However, where decks, except open decks, are penetrated for the passage of electric cables, pipes and vent ducts, such penetrations are to be made tight to prevent the passage of flame and smoke.

3.6.2 For determining the appropriate fire integrity standards to be applied to divisions between adjacent spaces, such spaces are classified in Table 3.3.2 and Table 3.3.3 according to their fire-risk as shown in space categories ***(1)*** to ***(9)***. The title of each category is intended to be typical (general) rather than restrictive. The number in parentheses preceding each space category refers to the applicable column or row in the Tables.

(1) Control stations:
- Spaces containing emergency sources of power and lighting.
- Wheelhouse and chartroom.
- Spaces containing the ship's radio equipment.
- Fire-extinguishing rooms, fire-control stations and fire recording stations.
- Control room for propulsion machinery when located outside the machinery space.
- Spaces containing centralised fire-alarm equipment.

(2) Corridors:
- Guest and crew corridors and lobbies.

(3) Accommodation spaces:
- Spaces as defined in Ch 1,2.4.5 excluding corridors.

(4) Stairways:
- Interior stairways, lifts and escalators (other than those wholly contained within the machinery spaces) and enclosures thereto.
- In this connection, a stairway which is enclosed only at one level is to be regarded as part of the space from which it is not separated by a fire door.

(5) Service spaces (low risk):
- Lockers and store-rooms having areas of less than 4 m^2, drying rooms and laundries.

(6) Category 'A' machinery spaces, spaces containing vehicles or craft with fuel in their tanks, or lockers storing such fuels:
- Spaces as defined in Ch 1,2.4.8.

(7) Other machinery spaces:
- Spaces as defined in Ch 1,2.4.9 excluding Category 'A' machinery spaces.

(8) Service spaces (high risk):
- Galleys, pantries containing cooking appliances, paint and lamp rooms, lockers and store-rooms having areas of 4 m^2 or more, spaces for the storage of flammable liquids, bonded stores and workshops other than those forming part of the machinery spaces.

(9) Open decks:
- Open deck spaces and enclosed promenades having no fire-risk. Air spaces (the space outside superstructures and deckhouses).

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3.6.3 Continuous 'B' Class ceilings or linings, in association with the relevant decks or bulkheads, may be accepted as contributing, wholly or in part, to the required insulation and integrity of a division.

3.7 Structural fire protection – Protection of stairways and lifts in accommodation and service spaces

3.7.1 All stairways are to be of steel construction except where the use of other equivalent material is specially approved, and are to be within enclosures formed of 'A' Class divisions, with positive means of closure at all openings, except that:

(a) A stairway connecting only two decks need not be enclosed, provided that the integrity of the deck is maintained by proper bulkheads or doors at one level to at least 'B-0' Class. When a stairway is closed at one level, the stairway enclosure is to be protected in accordance with Tables 3.3.2 and 3.3.3; and

(b) Stairways may be fitted in the open in a public space, provided that they lie wholly within such public space.

3.7.2 Stairway enclosures are to have a direct access to the corridors and to be of sufficient area to prevent congestion, having in view the number of persons likely to use them in an emergency. Within the perimeter of such stairway enclosures, only toilets and lockers of non-combustible material providing storage for safety equipment are permitted. Only public spaces, corridors, other escape stairways required by 3.15.1(e), pantries containing cooking appliances with an insignificant fire risk, *see* 2.4.2, and external areas are to have direct access to these stairway enclosures. Small corridors or lobbies may be used to separate an enclosed stairway from other spaces.

3.7.3 Lift trunks are to be so fitted as to prevent the passage of smoke and flame from one 'tween deck to another and are to be provided with means of closing so as to permit the control of draught and smoke.

3.8 Structural fire protection – Openings in 'A' Class divisions

3.8.1 The construction of all doors and door frames in 'A' Class divisions, and the means of securing them when closed, is to provide resistance to fire as well as to the passage of smoke and flame, as far as practicable, equivalent to that of the bulkheads in which the doors are situated. Such doors and door frames are to be constructed of steel or other equivalent material. Steel watertight doors need not be insulated.

3.8.2 It is to be possible for each door to be opened and closed from each side of the bulkhead by one person only.

3.8.3 Fire doors in main vertical zone bulkheads and stairway enclosures are to satisfy the following requirements:

(a) The doors shall be self-closing and be capable of closing with an angle of inclination of up to 3,5° opposing closure. The approximate time of closure for hinged fire-doors is to be no more than 40 s and not less than 10 s from the beginning of their movement with the ship in the upright position. The approximate uniform rate of closure for sliding fire doors is to be no more than 0,2 m/s and no less than 0,1 m/s with the ship in the upright position.

(b) Remote-controlled sliding or power-operated doors are to be equipped with an alarm that will sound not less than 5 s but no more than 10 s before the door begins to move and will continue to sound until the door is completely closed. Doors designed to re-open upon contacting an object in its path are to re-open sufficiently to allow a clear passage of at least 0,75 m but not more than 1 m.

(c) All doors are to be capable of remote and automatic release from the continuously manned central control station, either simultaneously or in groups and also individually from a position at both sides of the door. Indication is to be provided at the fire control panel in the continuously manned central control station whether each of the remotely-controlled doors are closed. The release mechanism is to be so designed that the door will automatically close in the event of disruption of the control system or central power supply. Release switches shall have an on-off function to prevent automatic resetting of the system. Hold-back devices not subject to central control station release are not permitted.

(d) Local power accumulators for power-operated doors are to be located in the immediate vicinity of the doors. They are to have the capacity to enable the doors to be fully opened and closed at least 10 times using local controls.

(e) Double-leaf doors dependent on a latch to maintain their fire integrity are to be arranged so that the latch is automatically activated by the action of the closing doors.

(f) Doors which are power-operated and automatically closed, giving direct access to special category spaces need not be equipped with the alarms and remote release mechanisms required by (b) and (c).

(g) The components of the local control system are to be accessible for maintenance and adjusting.

3.8.4 Where 'A' Class divisions are penetrated for the passage of electric cables, pipes, trunks, ducts, etc., or for girders, beams or other structural members, arrangements are to be made to ensure that the fire resistance is not impaired.

3.9 Structural fire protection – Openings in steel outer boundaries

3.9.1 The requirements for steel or other equivalent material on the outer boundaries of a yacht do not apply to glass partitions, windows and sidescuttles. The requirements of 3.11.2 for such boundaries to have 'A' class integrity are to be adhered to.

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3.10 Structural fire protection – Openings in 'B' Class divisions

3.10.1 Doors and door frames in 'B' Class divisions and means of securing them are to provide a method of closure which has resistance to fire as far as practicable equivalent to the divisions they serve, except that ventilation openings may be permitted in the lower portion of such doors. Where such openings are in or under a door the total net area of any such opening or openings is not to exceed 0,05 m^2. When such an opening is cut in a door it is to be fitted with a grill made of non-combustible material. Bridging ducts are not allowed in fire divisions.

3.10.2 Cabin doors in 'B' class divisions are to be self-closing. Hold-backs are not permitted.

3.10.3 Where 'B' Class divisions are penetrated for the passage of electric cables, pipes, trunks, ducts, etc., or for the fitting of ventilation terminals, lighting fixtures and similar devices, arrangements are to be made to ensure that the fire resistance is not impaired.

3.11 Structural fire protection – Windows and side scuttles

3.11.1 Notwithstanding the requirements of Table 3.3.2 and Table 3.3.3, all windows and side scuttles in bulkheads separating accommodation and service spaces and control stations from weather are to be constructed with frames of steel or other suitable material. The glass is to be retained by a metal glazing bead or angle. Alternative forms of construction and retention will be considered.

3.11.2 Glass is not to be installed as an interior main vertical zone or stairway enclosure bulkhead.

3.11.3 For yachts having a freeboard length of 85 m and over, windows and side scuttles situated in the yacht's side shell below the life raft and escape slide embarkation areas and below lifeboat embarkation areas are to have fire integrity of at least equal to 'A-0' Class.

3.12 Structural fire protection – Details of construction

3.12.1 In accommodation and services spaces, control stations, corridors and stairways, air spaces enclosed behind ceilings, panelling or linings are to be suitably divided by close-fitting draught stops not more than 7 m apart. In the vertical direction, such spaces, including those behind linings of stairways, trunks, etc., are to be closed at each deck.

3.12.2 The draught stops are to be non-combustible and are to form a continuation above the ceiling of the bulkhead below or the other side of the panelling or lining to the bulkhead, as far as possible.

3.12.3 Where the structure or 'A' Class divisions are required to be insulated, it is to be ensured that the heat from a fire is not transmitted through the intersections and terminal points of the divisions or penetrations to uninsulated boundaries. Where the insulation installed does not achieve this, arrangements are to be made to prevent this heat transmission by insulating the horizontal and vertical boundaries or penetrations for a distance of 450 mm.

3.13 Structural fire protection – Materials

3.13.1 Except in cargo spaces, mail rooms, baggage rooms, or refrigerated compartments, of service spaces, all insulation (e.g. fire and comfort) is to be of non-combustible materials. Partial bulkheads or decks used to subdivide a space for utility or artistic treatment are to have a non-combustible core.

3.13.2 The use of combustible materials is to be kept to a minimum.

3.13.3 Pipes penetrating 'A' or 'B' Class divisions are to be of approved materials having regard to the temperature such divisions are required to withstand.

3.13.4 Pipes conveying oil or combustible liquids through accommodation and service spaces are to be of approved materials having regard to the fire risk.

3.13.5 Materials readily rendered ineffective by heat are not to be used for overboard scuppers, sanitary discharges and other outlets which are close to the waterline and where the failure of the material in the event of fire would give rise to danger of flooding.

3.13.6 Primary deck coverings within accommodation spaces, service spaces and control stations are to be of a type which will not readily ignite, or give rise to toxic or explosive hazards at elevated temperatures. Reference is also to be made to the IMO FTP Code, Annex 1, Parts 2 and 6.

3.13.7 Vapour barriers and adhesives used in conjunction with insulation, as well as insulation of pipe fittings for cold service systems need not be non-combustible, but they shall be kept to the minimum quantity practicable and their exposed surfaces shall have low flame spread characteristics.

3.13.8 All waste receptacles are to be constructed of non-combustible materials with no openings in the sides or bottom.

3.13.9 Furniture in the stairway enclosures is to be limited to seating. If required, it is to be fixed, limited to four seats on each deck in each stairway enclosure and is not to obstruct the escape route. Additional seating may be permitted in the main reception area within a stairway enclosure provided it is fixed and does not obstruct the escape route. Furniture is not permitted in corridors forming escape routes in cabin areas. Lockers for the storage of safety equipment may be permitted.

3.14 Structural fire protection – Surface of insulation

3.14.1 In spaces where penetration of oil products is possible, the surface of insulation is to be impervious to oil or oil vapours. Insulation boundaries are to be arranged to avoid immersion in oil spillages so far as is practicable.

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3.15 Structural fire protection – Means of escape

3.15.1 Stairways and ladders are to be arranged to provide ready means of escape to the survival craft embarkation deck from all guest and crew spaces and from spaces in which the crew is normally employed, other than machinery spaces. In particular, the following provisions are to be complied with:

(a) Below the bulkhead deck, two means of escape, at least one of which is to be independent of watertight doors, are to be provided for each watertight compartment or similarly restricted space or group of spaces. One of these means of escape may be dispensed with, due regard being paid to the nature and the location of spaces concerned, and to the number of persons who normally might be accommodated or employed there.

(b) Above the bulkhead deck, there are to be at least two practical means of escape from each main vertical zone or similarly restricted space or group of spaces, at least one of which is to give access to a stairway forming a vertical escape.

(c) If a radio-telegraph station has no direct access to the open deck, two means of escape from or access to such station are to be provided, one of which may be a port-hole or window of sufficient size or other satisfactory means to provide an emergency escape.

(d) A corridor, lobby, or part of a corridor from which there is only one route of escape is not to exceed 7 m. Where accommodation arrangements are such that access to compartments is through another compartment, as is often the case with an Owner's suite, a second means of escape is to be provided. The second escape route is to be as remote as possible from the main escape route. The second means of escape may be through portholes or hatches of adequate size, leading to the open deck.

(e) At least one of the means of escape required by (a) or (b) is to be by means of a readily accessible enclosed stairway, which will provide continuous fire shelter from the level of its origin to the appropriate survival craft embarkation decks, or the uppermost weather deck if the embarkation deck does not extend to the main vertical zone being considered. In the latter case, direct access to the embarkation deck by external open stairways and passageways is to be provided and is to have emergency lighting and slip-free surfaces underfoot. Boundaries facing external open stairways and passageways forming part of an escape route and boundaries in such a position that their failure during a fire would impede escape to the embarkation deck, are to have fire integrity and insulation values in accordance with Tables 3.3.2 and 3.3.3. The widths, number and continuity of escape routes are to be as follows:

  (i) Stairways are to be not less than 900 mm clear width between handrails. Stairways are to be fitted with handrails on each side. The minimum clear width of stairways is to be increased by 10 mm for every person provided for in excess of 90 persons. The maximum clear width between handrails where stairways are wider than 900 mm is to be 1800 mm. The total number of persons to be evacuated by such stairways is to be two-thirds of the crew and total number of passengers in the areas served by such stairways.

  (ii) Stairways with a clear width in excess of 900 mm are to be aligned in a fore-and-aft direction.

  (iii) Doorways, corridors and intermediate landings included in the means of escape are to have widths sized in the same manner as the stairways.

  (iv) Stairways are not to exceed 3,5 m vertical rise without the provision of a landing and are not to have angle of inclination greater than 45° to the horizontal.

  (v) Landings at each deck level are to be not less than 2 m^2 in area and are to be increased by 1 m^2 for every 10 persons provided for in excess of 20 persons but need not exceed 16 m^2, except for those landings serving public spaces having direct access onto the stairway enclosure.

(f) Protection of access from the stairway enclosures to the survival craft embarkation areas are to comply with the requirements of Tables 3.3.2 and 3.3.3.

(g) Where public spaces span three or more open decks, contain combustibles such as furniture and give access to other enclosed spaces, each level within the space is to have two means of escape, one of which is to give direct access to an enclosed vertical means of escape meeting the requirements of (e).

(h) Where a dispensation has been granted under the provisions of (a), a safe means of escape is to be provided. Stairways are to be provided with handrails on both sides and are to have a clear width between handrails of not less than 800 mm.

3.15.2 Two means of escape are to be provided from each machinery space. In particular, the following provisions are to be complied with:

(a) Where the space is below the bulkhead deck the two means of escape are to consist of either:

  (i) Two sets of steel ladders and walkways as widely separated as possible, leading to doors in the upper part of the space similarly separated and from which access is provided to the appropriate survival craft embarkation decks. One of these ladders is to provide continuous fire shelter from the lower part of the space to a safe position outside the space. This shelter is to be of steel or equivalent material, insulated where necessary, and provided with a self closing door of steel or equivalent material at the lower end. If access is provided at other levels each level is to be provided with a door of steel or equivalent material; or

  (ii) one steel ladder leading to a door in the upper part of the space from which access is provided to the embarkation deck and additionally, in the lower part of the space and in a position well separated from the ladder referred to, a steel or equivalent material door capable of being operated from each side and which provides access to a safe escape route from the lower part of the space to the embarkation deck.

(b) Where the space is above the bulkhead deck, the two means of escape are to be as widely separated as possible and the doors leading from such means of escape are to be in positions from which access is provided to the appropriate survival craft embarkation decks. Where such means of escape require the use of ladders these are to be of steel.

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3.15.3 One of the means of escape from any such space required by 3.15.2 may be dispensed with, so long as either a door or a steel ladder and walkways provides a safe escape route to the embarkation deck, due regard being paid to the nature and location of the space and whether persons are normally employed in that space.

3.15.4 Two means of escape are to be provided from a machinery control room located inside a machinery space, at least one of which is to provide continuous fire shelter to a safe position outside the machinery space.

3.15.5 Adequate deck area is to be provided at muster stations and embarkation areas having due regard to the expected number of persons.

3.16 Ventilation systems

3.16.1 Ventilation ducts are to be of non-combustible material. Short lengths of ducts not exceeding 2 m in length and with a cross-section not exceeding 0,02 m^2 need not be non-combustible, subject to these ducts being:

(a) of a material that has low flame spread characteristics;
(b) used at the end of the ventilation device; and
(c) situated not less than 600 mm, measured along the duct, from an opening in an 'A' or 'B' Class division including continuous 'B' Class ceilings.

3.16.2 Where the ventilation ducts with a free cross-sectional area exceeding 0,02 m^2 pass through Class 'A' bulkheads or decks, the openings are to be lined with a steel sheet sleeve unless the ducts passing through the bulkheads or decks are of steel in the vicinity of passage through the deck or bulkhead and the ducts and sleeves are to comply in this part with the following:

(a) Steel ducts, or sleeves lining such ducts, are to have a thickness of at least 3 mm and a length of at least 900 mm. When passing through bulkheads, this length is to be divided preferably into 450 mm on each side of the bulkhead. These ducts, or sleeves lining such ducts, are to be provided with fire insulation. The insulation is to have at least the same fire integrity as the bulkhead or deck through which the duct passes.
(b) Steel ducts with a free cross-sectional area exceeding 0,075 m^2 are to be fitted with fire dampers in addition to the requirements of (a). The fire damper is to operate automatically but is also to be capable of being closed manually from both sides of the bulkhead or deck. The damper is to be provided with an indicator which shows whether the damper is open or closed. Fire dampers are not required, however, where ducts pass through spaces surrounded by 'A' Class divisions, without serving those spaces, provided those ducts have the same fire integrity as the divisions which they pierce.
(c) Compliance with 3.8.4.

3.16.3 Ventilation ducts with a free cross-sectional area exceeding 0,02 m^2 passing through 'B' Class bulkheads are to be lined with steel sheet, or other equivalent material, sleeves of 900 mm in length divided preferably into 450 mm on each side of the bulkheads unless the duct is of steel for this length, *see also* 3.10.3.

3.16.4 Ducts provided for the ventilation of Category 'A' machinery spaces, galleys, spaces containing vehicles or craft with fuel in their tanks or lockers storing such fuels, are not to pass through accommodation spaces, service spaces or control stations unless the ducts are:

(a) either:
  (i) constructed of steel having a thickness of at least 3 mm and 5 mm for ducts the widths or diameters of up to and including 300 mm and 760 mm and over respectively and, in the case of such ducts, the widths or diameters of between 300 mm and 760 mm having a thickness to be obtained by interpolation;
  (ii) suitably supported and stiffened;
  (iii) fitted with automatic fire dampers close to the boundaries penetrated; and
  (iv) insulated to 'A-60' Class standard from the machinery spaces, galleys, spaces containing vehicles or craft with fuel in their tanks or lockers storing such fuels, to a point at least 5 m beyond each fire damper;
(b) or:
  (i) constructed of steel in accordance with (a)(i) and (ii); and
  (ii) insulated to 'A-60' Class standard throughout the accommodation spaces, service spaces or control stations;

except that penetrations of main zone divisions are also to comply with 3.16.8.

3.16.5 Ducts provided for ventilation to accommodation spaces, service spaces or control stations are not to pass through such spaces, unless, where they pass through Category 'A' machinery space, galleys, spaces containing vehicles or craft with fuel in their tanks or lockers storing such fuels, the ducts:

(a) either:
  (i) are constructed of steel in accordance with 3.16.4(a)(i) and (ii);
  (ii) are fitted with automatic fire dampers close to the boundaries penetrated; and
  (iii) have the integrity of boundaries of the machinery space, galley, spaces containing vehicles or craft with fuel in their tanks, or lockers storing such fuels, maintained at the penetrations;
(b) or:
  (i) are constructed of steel in accordance with 3.16.4(a)(i) and (ii); and
  (ii) are insulated to 'A-60' Class standard within the machinery space, galley or spaces containing vehicles or craft with fuel in their tanks or lockers storing such fuels;

except that penetration of main zone divisions is also to comply with 3.16.8.

3.16.6 Such measures as are practicable are to be taken in respect of control stations outside machinery spaces in order to ensure that ventilation, visibility and freedom from smoke are maintained, so that in the event of fire the machinery and equipment contained therein may be supervised and continue to function effectively. Alternative and separate means of air supply are to be provided; air inlets of the two sources of supply are to be so disposed that the risk of both inlets drawing in smoke simultaneously is minimised. Such requirements need not apply to control stations situated on,

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and opening on to, an open deck, or where local closing arrangements would be equally effective.

3.16.7 Where they pass through accommodation spaces or spaces containing combustible materials, the exhaust ducts from galley ranges are to comply with 3.16.4. Such exhaust ducts are to be fitted with:

(a) a grease trap readily removable for cleaning;
(b) a fire damper located in the lower end of the duct;
(c) arrangements, operable from within the galley, for shutting off the exhaust fans; and
(d) fixed means for extinguishing a fire within the duct.

3.16.8 Where it is necessary that a ventilation duct passes through a main vertical zone division, a fail-safe automatic closing fire damper is to be fitted adjacent to the division. The damper is also to be capable of being manually closed from each side of the division. The operating position is to be readily accessible and be marked in red light-reflecting colour. The duct between the division and the damper is to be of steel or other equivalent material and, if necessary, insulated to comply with 3.8.4. The damper is to be fitted on at least one side of the division with a visible indicator showing whether the damper is in the open position.

3.16.9 Where public spaces span three or more open decks and contain combustibles such as furniture and other enclosed spaces, the space is to be equipped with a smoke extraction system. The smoke extraction system is to be activated by the smoke detection system required by Ch 4,2 and is to be capable of manual control. The fans are to be capable of exhausting the entire volume within the space in not more than 10 min.

3.16.10 The main inlets and outlets of all ventilation systems are to be capable of being closed from outside the spaces being ventilated.

3.16.11 Power ventilation of accommodation spaces, service spaces, control stations and machinery spaces is to be capable of being stopped from an easily accessible position outside the space being served. This position should not be readily cut off in the event of a fire in the spaces served. The means provided for stopping the power ventilation of the machinery spaces is to be entirely separate from the means provided for stopping ventilation of other spaces, *see also* Pt 16, Ch 2,16.6.

3.16.12 Reference is also made to 2.8.4 to 2.8.7, 2.8.9 and 3.10.1.

3.16.13 Ducts provided for exhaust ventilation from laundries are to be fitted with suitably located cleaning and inspection openings.

3.16.14 Fire dampers required by 3.16.2, 3.16.4, 3.16.5 and 3.16.8, including relevant means of operation are to be fire tested. Reference is also to be made to IMO FTP Code, Annex 1, Part 3.

3.17 Oil fuel arrangements

3.17.1 In a yacht in which oil fuel is used, the arrangements for the storage, distribution and utilisation of the oil fuel are to be such as to ensure the safety of the yacht and persons on board. For details, *see* Pt 15, Ch 3.

3.17.2 As far as practicable, oil fuel tanks are to be part of the yacht's structure and are to be located outside Category 'A' machinery spaces.

3.17.3 Where oil fuel tanks, other than double bottom tanks, are necessarily located adjacent to or within Category 'A' machinery spaces, at least one of their vertical sides is to be contiguous to the machinery space boundaries, and is preferably to have a common boundary with the double bottom tanks, and the area of the tank boundary common with the machinery spaces is to be kept to a minimum. Where the vertical boundary of a tank directly exposed to a machinery space meets the yacht's side plating at an acute angle, a small horizontal surface at the base of the tank, necessary to accommodate practical constructional considerations may be permitted. If the arrangement of the machinery is such that a tank with a large horizontal surface at the base is necessary then a cofferdam with suitable ventilation arrangements, to protect the base of the tank from the effect of a machinery space fire, will be specially considered. *See also* Pt 15, Ch 3. Oil fuel tanks situated within the boundaries of Category 'A' machinery spaces are not to contain oil fuel having a flashpoint of less than 60°C. The use of free-standing oil fuel tanks is prohibited.

3.18 Lubricating oil arrangements

3.18.1 The arrangements for the storage, distribution and utilisation of oil used in pressure lubrication systems are to be such as to ensure the safety of the yacht and persons on board, *see also* Pt 15, Ch 3.

3.19 Arrangements for other flammable oils

3.19.1 The arrangements for the storage, distribution and utilisation of other flammable oils employed under pressure in power transmission systems, control and activating systems and heating systems are to be such as to ensure the safety of the ship and persons on board, *see also* Pt 15, Ch 3.

3.20 Prohibition of carriage of flammable oils in forepeak tanks

3.20.1 Oil fuel, lubricating oil and other flammable oils are not to be carried in forepeak tanks.

3.21 Special arrangements in Category 'A' machinery spaces

3.21.1 Openings are to be provided with closing appliances constructed so as to maintain the fire integrity of the machinery space boundaries.

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3.21.2 Doors other than power operated watertight doors, are to be so arranged that positive closure is assured in case of fire in the space, by power-operated closing arrangements or by the provision of self-closing doors capable of closing against an inclination of 3,5° opposing closure and having a fail-safe hook-back facility, provided with a remotely operated release device.

3.21.3 Windows are not to be fitted in machinery space boundaries. This does not preclude the use of glass in control rooms within the machinery spaces.

3.21.4 Means of control are to be provided for:
(a) closure of openings which normally allow exhaust ventilation, and closure of ventilator dampers;
(b) permitting the release of smoke;
(c) closing power-operated doors or actuating release mechanism on doors other than power-operated watertight doors;
(d) stopping ventilating fans; and
(e) stopping forced and induced draught fans, oil fuel transfer pumps, oil fuel unit pumps and other similar fuel pumps.

3.21.5 The controls required in 3.21.4 are to be located outside the space concerned, where they will not be cut off in the event of fire in the space they serve. Such controls and the controls for any required fire-extinguishing system are to be situated at one control position or grouped in as few positions as possible. Such positions are to have a safe access from the open deck, *see also* Pt 15, Ch 3,4.5.1 and 4.9.2.

3.21.6 When access to any Category 'A' machinery space is provided at a low level from an adjacent space there is to be provided near the watertight door, a light steel fire-screen door operable from each side.

3.22 Arrangements for gaseous fuel for domestic purposes

3.22.1 Where gaseous fuel is used for domestic purposes, the arrangements for the storage, distribution and utilisation of the fuel is to be such that, having regard to the hazards of fire and explosion which the use of such fuel may entail, the safety of the yacht and the persons on board is preserved. The installation is to be in accordance with recognised National or International Standards.

3.22.2 Storage lockers for gas cylinders are to be provided with:
(a) effective ventilation;
(b) an outward-opening door accessible directly to the open deck; and
(c) gas-tight boundaries, including doors and other means of closing any openings therein, which form boundaries between such lockers and adjoining enclosed spaces.

3.23 Space heaters

3.23.1 Space heaters, if used, are to be fixed in position and so constructed as to reduce fire risks to a minimum. The design and location of these units are to be such that clothing, curtains or other similar materials cannot be scorched or set on fire by heat from the unit.

3.24 Fixed fire detection and fire-alarm systems

3.24.1 A fixed fire detection and fire-alarm system is to be installed in any machinery space and is to comply with the requirements of Pt 16, Ch 1,2.8.

3.24.2 A fixed fire detection and fire-alarm system is to be fitted in all stairways (including lift and dumbwaiter trunks), service spaces, control stations and accommodation spaces (except toilets, bathrooms, void spaces, etc.). The fixed fire detection and fire-alarm system is to be installed in accordance with Ch 4,2.

3.24.3 All yachts at all times when at sea, or in port (except when out of service), are to be so equipped as to ensure that any initial fire-alarm is immediately received by a responsible member of the crew.

3.24.4 A special alarm, operated from the navigating bridge or fire-control station, is to be fitted to summon the crew.

3.24.5 For yachts having a freeboard length of 85 m or more, a public address system is to be available throughout the accommodation spaces, service, and control stations and open decks. The arrangements are to comply with Pt 16, Ch 2,17.3.

3.25 Fire pumps and fire main system

3.25.1 **Application**. Every yacht is to be provided with fire pumps in accordance with this Section. Fire mains, hydrants and hoses are also to be provided as required by this Section.

3.25.2 **Capacity of fire pumps**:
(a) The fire pumps required are to be capable of delivering for fire-fighting purposes a quantity of water, at the pressure specified in 3.25.5 of not less than two-thirds of the quantity required to be dealt with by the bilge pumps when employed for bilge pumping. For number and capacity of bilge pumps, *see* Pt 15, Ch 2.
(b) As an alternative to (a) the capacity of fire pumps may be determined by hydrostatic calculations based on the requirement of 3.25.5(a).
(c) Where more pumps than the minimum number of required pumps are installed the capacity of such additional pumps will be specially considered.

3.25.3 **Fire pumps**:
(a) In yachts of 4000 tons gross or more, at least three independently driven fire pumps are to be provided and, in yachts of less than 4000 tons gross, at least two such fire pumps.
(b) Sanitary, ballast, bilge or general service pumps may be accepted as fire pumps, provided that they are not normally used for pumping oil, and that, if they are subject to occasional duty for the transfer or pumping of fuel oil, suitable changeover arrangements are fitted.

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(c) In yachts classed for navigation in ice, the fire pump sea inlet valves are to be provided with clearing arrangements, *see* Pt 1, Ch 2,3.8.1.

(d) The arrangements of sea connections, fire pumps and their sources of power are to be such as to ensure that in the event of a fire in any one compartment, all the fire pumps will not be put out of action.

(e) The arrangements for the ready availability of water supply are to be as follows:

(i) In yachts of 1000 gross tons or more, or any yacht of an alternative form of construction, the arrangements are to be such that at least one effective jet of water is immediately available from any hydrant in an interior location and so as to ensure the continuation of the output of water by the automatic starting of a required fire pump.

(ii) Yachts not provided with arrangements complying with (i), but to which a UMS notation is to be assigned, are to have remote starting of a required fire pump from the navigating bridge and fire-control station, if any.

(f) Relief valves are to be provided in conjunction with any fire pump if the pump is capable of developing a pressure exceeding the design pressure of the water service pipes, hydrants and hoses. These valves are to be so placed and adjusted as to prevent excessive pressure in any part of the fire main system.

(g) Where centrifugal pumps are provided in order to comply with this sub-Section, a non-return valve is to be fitted in the pipe connecting the pump to the fire main.

3.25.4 **Fire main**:

(a) The diameter of the fire main is to be based on the required capacity of two fire pumps, and the diameter of the water service pipes are to be sufficient to ensure an adequate supply of water for the simultaneous operation of at least two fire-hoses. In general, the diameter of the fire main is to be not less than:

$$d = (L_{pp}/1,2) + 25 \text{ mm}$$

but need not exceed 180 mm in yachts, and is in no case to be less than 50 mm

where

d = internal diameter of the fire main, in mm

L_{pp} = length of yacht measured between perpendiculars, in metres, as defined in Pt 3, Ch 1,6.2.2.

(b) The wash deck line may be used as a fire main provided that the requirements of this sub-Section are satisfied.

(c) All exposed water pipes for fire-extinguishing are to be provided with drain valves for use in frosty weather. The valves are to be located where they will not be damaged.

3.25.5 **Pressure in the fire main**:

(a) The fire pumps, associated piping and fire main are to be so designed that the following minimum pressures will be maintained at all hydrants under conditions where two fire pumps required by 3.25.3 are simultaneously delivering water to the fire main of the size required by 3.25.4 through adjacent nozzles of sizes required by 3.25.9:

4000 tons gross and over — 4 bar (0,4 N/mm^2)

Less than 4000 tons gross — 3 bar (0,3 N/mm^2)

(b) The maximum pressure at any hydrant shall not exceed that at which the effective control of a fire-hose can be demonstrated.

3.25.6 **Number and position of hydrants**:

(a) The number and position of the hydrants are to be such that at least two jets of water not emanating from the same hydrant, one of which is to be from a single length of hose, may reach any part of the yacht normally accessible to the guests and crew while the yacht is being navigated. In yachts of 1000 tons gross or more, at least two hydrants are to be provided in the machinery spaces; in smaller yachts one hydrant will be accepted.

(b) In the accommodation, service and machinery spaces, the number and position of hydrants are to be such that the requirements of (a) may be complied with when all watertight doors and all doors in main vertical zone bulkheads are closed.

(c) Where access is provided to a machinery space of Category 'A' at a low level, two hydrants are to be provided external to, but near the entrance, to that machinery space.

3.25.7 **Pipes and hydrants**:

(a) Materials readily rendered ineffective by heat are not to be used for fire mains. Where steel pipes are used, they are to be galvanised internally and externally. Cast iron pipes are not acceptable. The pipes and hydrants are to be so placed that the fire-hoses may be easily coupled to them. The arrangement of pipes and hydrants is to be such as to avoid the possibility of freezing. Unless one hose and nozzle is provided for each hydrant in the yacht, there is to be complete interchangeability of hose couplings and nozzles.

(b) A valve is to be fitted at each fire hydrant so that any fire-hose may be removed while the fire pump is at work.

(c) Isolating valve(s) to isolate the section of the fire main within the Category 'A' machinery space containing the main fire pump(s) from the rest of the fire main are to be fitted in an easily accessible and tenable position outside the Category 'A' machinery space. The fire main is to be so arranged that when the isolating valve(s) is shut, all the hydrants on the yacht, except those in the Category 'A' machinery space referred to above, can be supplied with water by a fire pump not located in this Category 'A' machinery space through pipes which do not enter this space.

3.25.8 **Fire-hoses**:

(a) Fire-hoses are to be of approved non-perishable material. The hoses are to be sufficient in length to project a jet of water to any of the spaces in which they may be required to be used. Their length, in general, is not to exceed 18 m. Each hose is to be provided with a nozzle and the necessary couplings. Fire-hoses, together with any necessary fittings and tools, are to be kept ready for use in conspicuous positions near the water service hydrants or connections.

(b) There is to be at least one fire-hose for each of the hydrants required by 3.25.6.

3.25.9 **Nozzles**:

(a) For the purpose of this Chapter, standard nozzle sizes are to be 12 mm, 16 mm or 19 mm, or as near thereto as possible, so as to make full use of the maximum discharge capacity of the fire pumps.

(b) For accommodation and service spaces, the nozzle size need not exceed 12 mm.

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(c) For machinery spaces and exterior locations, the nozzle size is to be such as to obtain the maximum discharge possible from two jets at the pressure indicated in 3.25.5 from the smallest pump, however a nozzle size greater than 19 mm need not be used.
(d) All nozzles are to be of an approved dual purpose type (i.e. spray/jet type) incorporating a shut-off.

3.25.10 **Location and arrangement of water pumps, etc., for other fire-extinguishing systems.** Pumps required for the provision of water for other fire-extinguishing systems required by this Chapter are to have their sources of power and their controls installed outside the space or spaces protected by such systems and are to be so arranged that a fire in the space or spaces protected will not put any such system out of action.

3.25.11 **International shore connection**. At least one international shore connection is to be provided.

3.26 Fire-extinguishing arrangements in spaces containing internal combustion machinery

3.26.1 Category 'A' machinery spaces containing internal combustion machinery are to be provided with:
(a) one of the fire-extinguishing systems described in Ch 4,3;
(b) at least one set of portable air-foam equipment complying with 3.29;
(c) in each such space approved foam type fire-extinguishers, each of at least 45 litres capacity or equivalent, sufficient in number to enable foam or its equivalent to be directed on to any part of the fuel and lubricating oil pressure systems, gearing and other fire hazards; and
(d) a sufficient number of portable foam extinguishers or equivalent are to be located so that no point in the space is more than 10 m walking distance from an extinguisher and that there are at least two such extinguishers in each such space.

3.26.2 Machinery spaces in yachts which are constructed mainly or wholly with alternative forms of construction, containing internal combustion machinery, are to comply with the requirements of 3.26.1.

3.27 Fire-extinguishing arrangements in spaces containing oil fuel units

3.27.1 Category 'A' machinery spaces containing oil fuel units are to be provided with one of the fixed fire-extinguishing systems described in Ch 4,3.

3.27.2 There are to be at least two portable foam extinguishers or equivalent in each space in which a part of the oil fuel unit is situated.

3.28 Limitations on the use of oil as a fuel

3.28.1 For the limitations of the use of oil as a fuel, *see* Pt 15, Ch 3.

3.29 Automatic sprinkler, fire detection and fire-alarm system

3.29.1 A fixed automatic sprinkler, fire detection and fire-alarm system, or equivalent system (e.g. watermist), is to be fitted in all stairways, service spaces, control stations and accommodation spaces except spaces which afford no fire risk such as void spaces.

3.29.2 The arrangements are to be in accordance with Ch 4,1.

3.30 Fixed fire-extinguishing systems not required by this Section

3.30.1 Where a fixed fire-extinguishing system not required by this Section is installed, the arrangement is to comply with the relevant requirements of this Chapter.

3.31 Portable foam applicator

3.31.1 A portable foam applicator unit is to consist of an air foam nozzle of an inductor type capable of being connected to the fire main by a fire-hose, together with a portable tank containing at least 20 litres of foam-making liquid and one spare tank. The nozzle is to be capable of producing effective foam, suitable for extinguishing an oil fire, at the rate of at least 1,5 m^3/min.

3.32 Portable fire-extinguishers

3.32.1 All fire-extinguishers are to comply with the requirements of Ch 4,6.

3.32.2 The extinguishers are to be stowed in readily accessible positions.

3.32.3 One of the portable fire-extinguishers, or the portable fire-extinguisher, dedicated for use in any space is to be stowed near the entrance to that space.

3.32.4 At least one portable fire-extinguisher is to be located so that it can easily be reached from the main steering position of the yacht.

3.32.5 Accommodation spaces, service spaces and control stations are to be provided with a sufficient number of portable fire-extinguishers to ensure that at least one extinguisher will be readily available for use in every compartment. In any case, their number is to be not less than five.

3.32.6 Where cooking facilities are provided, a portable fire-extinguisher of a type appropriate to the energy source used is to be located in a position readily accessible for use in the event of a fire.

3.33 Fire blanket

3.33.1 A fire blanket is to be installed in all galleys.

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3.34 Protection of spaces containing vehicles or craft with fuel in their tanks, or lockers storing such fuels

3.34.1 Spaces containing vehicles or craft with fuel in their tanks, or lockers storing such fuels, are to be provided with the following:

(a) A fixed fire detection and fire-alarm system complying with the requirements of Pt 16, Ch 1,2.8.

(b) A manually-operated water spray deluge system having a water application rate of 5 litres per square metre of deck area per minute. Where the deck height does not exceed 2,5 m, an application rate of 3,5 litres per square metre of deck area per minute will be accepted. Adequate drainage of the protected spaces is to be provided generally in accordance with the requirements for vehicle or cargo space, *see* Pt 3, Ch 4,9.4.4. The drainage piping and connections for the space are to be non-combustible. Other fixed fire-extinguishing systems may be permitted, provided they are not less effective in controlling the type of fire likely to occur.

(c) At least two portable foam extinguishers, or equivalent;

(d) An independent mechanical ventilation system , which is entirely separate from other ventilation systems, providing at least six air changes per hour. The ducted air is not to pass through other spaces, except as allowed under 3.16.4, or vent into areas where it could be drawn into accommodation areas or cause undue hazard.

(e) Electrical equipment of a safe type is to be provided, *see* Pt 16, Ch 2,13.

(f) Prominently displayed 'No Smoking' signs; and

(g) Structural fire protection as required by Table 3.3.2 and Table 3.3.3.

3.34.2 Such spaces are not to give access to any space other than the fuel store or lockers for use within the space. Lockers storing fuel are to be accessed from an exterior location, unless the locker is within the space containing the vehicles or craft. Exceptionally, where the engine room escape cannot be routed elsewhere, it may exit into the space providing that:

(a) the connecting door is self-closing;

(b) no door hold-back devices are fitted;

(c) an audible and visual alarm is fitted on the bridge to signify when the door is open; and

(d) a notice is posted at the door stating that the door is to remain closed and that the area beside the door is an escape route and is to be kept clear.

3.34.3 The requirements of 3.17 are to be complied with, as appropriate.

3.35 Protection of paint lockers and flammable liquid lockers

3.35.1 Paint lockers and flammable liquid lockers of deck area 4 m^2 or more are to be provided with a fixed fire-extinguishing system enabling the crew to extinguish a fire without entering the space. One of the following systems is to be provided:

- A carbon dioxide system designed for 40 per cent of the gross volume of the space.
- A dry powder system designed to discharge 0,5 kg powder per cubic metre of gross volume of the space.
- A water spray system designed to give a coverage of 5 litres per square metre of deck area per minute. Water spray systems may be connected to the fire main.

3.35.2 Consideration will be given to the acceptance of other arrangements which provide equivalent protection.

3.35.3 Lockers having a deck area less than 4 m^2 may be protected by carbon dioxide or dry powder portable extinguishers located near the entrance to the locker.

3.36 Arrangements where deep fat cooking equipment is installed

3.36.1 Where deep-fat cooking equipment is installed, all installations are to be fitted with:

(a) an automatic or manual fixed extinguishing system type approved in accordance with ISO 15371, *Ships and marine technology – Fire extinguishing systems for protection of galley deep-fat cooking equipment – Fire tests*, or an acceptable alternative National or International Standard, for protection of the deep-fat cooking equipment;

(b) a primary and back up thermostat with an alarm to alert the operator in the event of failure of either thermostat;

(c) arrangements for automatically shutting off the deep-fat cooking equipment electrical power upon activation of the fire-extinguishing system;

(d) an alarm for indicating operation of the fire-extinguishing system in the galley where the equipment is installed; and

(e) controls for manual operation of the fire-extinguishing system which are clearly labelled for ready use by the crew.

Control and electrical engineering arrangements are to be in accordance with the requirements of Pt 16, Ch 1 and Ch 2, as applicable.

3.36.2 For fryers of up to 15 litres cooking oil capacity, the provision of a suitably sized extinguisher of a suitable type located for specific use on the cooking equipment together with manual isolation of the electrical power supply may be considered an acceptable alternative to 3.36.1 provided the arrangements are to the satisfaction of the National Administration.

3.37 Helicopter decks

3.37.1 The requirements of IMO Resolution A.855(20) are to be complied with having due regard to the hazards involved.

3.37.2 If a helicopter hangar is not provided and if two fireman's outfits are supplied as per 3.38.1, then the fireman's outfits required by IMO Resolution A.855(20) need not be provided.

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3.38 Fireman's outfit

3.38.1 Each yacht is to carry at least two fireman's outfits complying with Ch 4,4. Additional fireman's outfits are to be provided as applicable to ensure that at least two fireman's outfits are stored in each main vertical zone.

3.38.2 The fireman's outfits are to be so stored as to be easily accessible and ready for use. Where more than two fireman's outfits are required, they are to be located in widely separated positions. At least two fireman's outfits are to be available at any one position.

3.38.3 Additional sets of personal equipment and breathing apparatus, may be required, having due regard to the size of the yacht.

3.39 Fire-control plans

3.39.1 Fire-control plans are to meet the requirements of Ch 4,5.

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Section

1 **Automatic sprinkler, fire detection and fire-alarm systems**

2 **Fixed fire detection and fire-alarm systems**

3 **Fixed fire-extinguishing systems in machinery spaces**

4 **Fireman's outfits**

5 **Fire-control plans**

6 **Fire-extinguishers (portable and non-portable)**

Section 1
Automatic sprinkler, fire detection and fire-alarm systems

1.1 General

1.1.1 Any required automatic water sprinkler and fire-alarm and fire detection system is to be designed for immediate use at any time. Where such a system is fitted, it is to be of the wet pipe type. Any part of the system which may be subjected to freezing temperatures in service are to be suitably protected against freezing. It is to be kept charged at the necessary pressure and have provision for a continuous supply of water.

1.1.2 As an alternative to the system specified in 1.1.1, any one of the following systems may be considered:

(a) **Dry pipe system**. A sprinkler system employing automatic sprinklers attached to a piping system containing air or nitrogen under pressure, the release of which (as from the opening of a sprinkler) permits the water pressure to open a valve known as a dry pipe valve. The water then flows into the piping system and out of the opened sprinklers.

(b) **Pre-action system**. A sprinkler system employing automatic sprinklers attached to a piping system containing air that may or may not be under pressure, with a supplemental detection system installed in the same area as the sprinklers. Actuation of the detection system opens a valve that permits water to flow into the sprinkler piping system and to be discharged from any sprinklers that may be open.

(c) **Deluge system**. A sprinkler system employing open sprinklers attached to a piping system connected to a water supply through a valve that is opened by the operation of a detection system installed in the same areas as the sprinklers. When this valve opens water flows into the piping system and discharges from all sprinklers attached thereto.

1.2 Wet pipe type

1.2.1 Any required automatic sprinkler, fire detection and fire-alarm system is to comply with the requirements of Pt 16, Ch 2,16.2.

1.2.2 Sprinklers are to be grouped into separate sections, each of which is to contain not more than 200 sprinklers. Any section of sprinklers is not to serve more than two decks nor be situated in more than one main vertical zone, except where it is satisfactorily shown that the protection of the yacht against fire will not thereby be reduced.

1.2.3 Each section of sprinklers is to be capable of being isolated by one stop valve only. The stop valve in each section is to be readily accessible and its location is to be clearly and permanently indicated. Means are to be provided to prevent the operation of the stop valves by any unauthorised person.

1.2.4 A gauge indicating the pressure in the system is to be provided at each section stop valve and at a central station.

1.2.5 The sprinklers are to be resistant to corrosion by marine atmosphere. In accommodation and service spaces the sprinklers are to come into operation within the temperature ranges from 68°C to 79°C, except that in locations such as drying rooms, where high ambient temperatures might be expected, the operating temperature may be increased by not more than 30°C above the maximum deck head temperature.

1.2.6 A list or plan is to be displayed at each indicating unit showing the spaces covered and the location of the zone in respect of each section. Suitable instructions for testing and maintenance are to be available.

1.2.7 Sprinklers are to be placed in an overhead position and spaced in a suitable pattern to maintain an average application rate of not less than 5 litres per square metre per minute over the nominal area covered by the sprinklers. The use of sprinklers providing other amounts of water suitably distributed, will be considered provided they are shown to be not less effective.

1.2.8 A pressure tank having a volume equal to at least twice that of the charge of water specified in 1.2.9 is to be provided.

1.2.9 The tank is to contain a standing charge of fresh water, equivalent to the amount of water which would be discharged in one minute by the pump referred to in 1.2.12, and the arrangements are to provide for maintaining such air pressure in the tank to ensure that where the standing charge of fresh water in the tank has been used the pressure will be not less than the working pressure of the sprinkler, plus the pressure exerted by a head of water measured from the bottom of the tank to the highest sprinkler in the system. Suitable means of replenishing the air under pressure and of replenishing the fresh water charge in the tank are to be provided. A glass gauge suitably protected is to be provided to indicate the correct level of the water in the tank.

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1.2.10 Means are to be provided to prevent the passage of sea water into the tank.

1.2.11 An independent power pump is to be provided solely for the purpose of automatically continuing the discharge of water from the sprinklers. The pump is to be brought into action automatically by the pressure drop in the system before the standing fresh water charge in the pressure tank is completely exhausted.

1.2.12 The pump and the piping system are to be capable of maintaining the necessary pressure at the level of the highest sprinkler to ensure a continuous output of water sufficient for the simultaneous coverage of a minimum area of the maximum width of the craft squared or 280 m^2 whichever is the less, at the application rate specified in 1.2.7.

1.2.13 The pump is to have fitted on the delivery side a test valve with a short open-ended discharge pipe. The effective area through the valve and pipe is to be adequate to permit the release of the required pump output while maintaining the pressure in the system specified in 1.2.9.

1.2.14 The sea inlet to the pump is to be, wherever possible, in the space containing the pump and is to be so arranged that when the vessel is afloat it will not be necessary to shut off the supply of sea water to the pump for any purpose other than the inspection or repair of the pump.

1.2.15 The sprinkler pump and tank are to be situated in a position reasonably remote from any machinery space of Category 'A' and not in any space required to be protected by the sprinkler system.

1.2.16 Where the arrangement precludes locating the pump and tank in accordance with 1.2.15, for yachts of not greater than 50 m Rule length, the sprinkler pump and tank required by Ch 3,2.16 may be situated within Category 'A' machinery spaces, but not within the spaces that are protected by the system.

1.2.17 For yachts of not greater than 50 m Rule length and all service craft, the sources of electrical power supply for the sea-water pump may be fed from the main source of electrical power.

1.2.18 There are to be not less than two sources of power supply for the sea water pump and automatic alarm and detection system. Where one of the sources of power for the pump is an internal combustion engine it is to be so situated that a fire in any protected space will not affect the air supply to the machinery, in addition to complying with 1.2.15. When the sources of power for the pump are electrical, *see* Pt 16, Ch 2,2 and Pt 16, Ch 2,3.

1.2.19 The sprinkler system is to have a connection from the vessel's fire main by way of a lockable screw-down non-return valve at the connection which will prevent a backflow from the sprinkler system to the fire main.

1.2.20 A test valve is to be provided for testing the automatic alarm for each section of sprinklers by a discharge of water equivalent to the operation of one sprinkler. The test valve for each section is to be situated near the stop valve for that section.

1.2.21 Means are to be provided for testing the automatic operation of the pump, on reduction of pressure in the system.

1.2.22 Each section of sprinklers is to include means for giving a visual and audible alarm signal automatically at one or more indicating units whenever any sprinkler comes into operation. Such alarm systems are to be arranged to indicate if any fault occurs in the system. Such units are to indicate in which section, served by the system, fire has occurred and are to be centralised on the navigation bridge. In addition, visible and audible alarms from the unit are to be located in a position other than on the navigation bridge, so as to ensure that the indication of fire is immediately received by the crew. Switches are to be provided at one of these indicating positions, which will enable the alarm and the indicators for each section of sprinklers to be tested.

1.2.23 Spare sprinkler heads are to be provided as specified in Table 4.1.1. The spare sprinkler heads are to be stowed in boxes or holders provided for that purpose, together with a tool suitable for removing and installing sprinkler heads. The boxes or holders are to be situated near the control valve for the section, and are to be clearly and permanently marked to indicate their contents.

Table 4.1.1 Spares requirements

Number of sprinkler heads provided	Number of spare sprinkler heads required
300	One spare sprinkler head is to be provided for each 50 sprinkler heads fitted, with a minimum of one spare being provided for each type fitted
301 to 1000	12
>1000	24

1.3 Arrangements which will be accepted as an alternative to 1.2

1.3.1 The alternative system is to be tested, type approved and installed in accordance with IMO Resolution A.800(19). The following exceptions to Section 3 of the Annex may be applied:

(a) Where the arrangement precludes locating the pump and tank in accordance with 1.2.15, for yachts not greater than 50 m Rule length, the sprinkler pump and tank required by Ch 3,2.16 may be situated within Category 'A' machinery spaces, but not within the spaces that are protected.

(b) Pumps and alternative supply components are to be sized so as to be capable of maintaining the required flow to the hydraulically most demanding area of not less than the maximum width of the craft squared or 280 m^2 whichever is the less.

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1.3.2 Spare nozzles are to be provided as specified in Table 4.1.2. The spare nozzles are to be stowed in boxes or holders provided for that purpose, together with a tool suitable for removing and installing nozzles. The boxes or holders are to be situated near the control valve for the section, and are to be clearly and permanently marked to indicate their contents.

Table 4.1.2 Spares requirements

Number of nozzles provided	Number of spare nozzles required
300	One spare nozzle is to be provided for each 50 nozzles fitted, with a minimum of one spare being provided for each type fitted
301 to 1000	12
>1000	24

■ *Section 2* Fixed fire detection and fire-alarm systems

2.1 General requirements

2.1.1 Any required fixed fire detection and fire-alarm system with manually operated call points is to be capable of immediate operation at all times.

2.1.2 Fire detection systems are to comply with the requirements of Pt 16, Ch 2,16.1 in addition to the requirements of this Section.

2.1.3 Detectors are to be operated by heat, smoke or other products of combustion, flame, or any combination of these factors. Detectors operated by other factors indicative of incipient fires may be considered provided that they are no less sensitive than such detectors. Flame detectors are only to be used in addition to smoke or heat detectors.

2.1.4 Suitable instructions for testing and maintenance are to be provided.

2.1.5 For each type of detector installed, one spare detector head is to be provided for every 10 heads or part thereof. They are to be stowed in a suitable container at the control station.

2.1.6 The function of the detection system is to be periodically tested by means of equipment producing hot air at the appropriate temperature, or smoke or aerosol particles having the appropriate range of density or particle size, or other phenomena associated with incipient fires to which the detector is designed to respond. All detectors are to be of a type such that they can be tested for correct operation and restored to normal surveillance without the renewal of any component.

2.2 Installation requirements

2.2.1 Manually operated call points are to be installed throughout the accommodation spaces, service spaces and control stations. One manually operated call point is to be located at each exit. Manually operated call points are to be readily accessible in the corridors of each deck such that no part of the corridor is more than 20 m from a manually operated call point.

2.2.2 Smoke detectors are to be installed in all stairways, corridors and escape routes within accommodation spaces.

2.2.3 Where a fixed fire detection and fire-alarm system is required for the protection of spaces other than those specified in 2.2.2, at least one detector complying with 2.1.3, is to be installed in each such space.

2.2.4 Detectors are to be located for optimum performance. Positions near beams and ventilation ducts or other positions where patterns of air flow could adversely affect performance and positions where impact or physical damage is likely are to be avoided. In general, detectors which are located overhead are to be a minimum distance of 0,5 m away from bulkheads.

2.2.5 The maximum spacing of detectors is to be in accordance with Table 4.2.1. Other spacings based upon test data which demonstrate the characteristics of the detectors may be required or permitted.

Table 4.2.1 Maximum spacing of detectors

Maximum		Maximum	
Maximum floor		Distance apart between centres, in metres	Distance away from bulkheads, in metres
Type of detector	Area per detector, m^2		
Heat	37	9	4,5
Smoke	74	11	5,5

2.2.6 Electrical wiring which forms part of the system is to be so arranged as to avoid galleys, machinery spaces of Category 'A', and other enclosed spaces of high fire-risk except where it is necessary to provide for fire detection or fire-alarm in such spaces or to connect to the appropriate power supply. *See also* Pt 16, Ch 2.

2.3 Design requirements

2.3.1 Smoke detectors required by 2.2.2 are to be certified to operate before the smoke density exceeds 12,5 per cent obscuration per metre, but not until the smoke density exceeds two per cent obscuration per metre. Smoke detectors to be installed in other spaces are to operate within satisfactory sensitivity limits having regard to the avoidance of detector insensitivity or oversensitivity.

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2.3.2 Heat detectors are to be certified to operate before the temperature exceeds 78°C but not until the temperature exceeds 54°C, when the temperature is raised to those limits at a rate less than 1°C per minute. At higher rates of temperature rise, the heat detector is to operate within satisfactory temperature limits having regard to the avoidance of detector insensitivity or oversensitivity.

2.3.3 The permissible temperature of operation of heat detectors may be increased to 30°C above the maximum deckhead temperature in drying rooms and similar spaces of a normal high ambient temperature.

2.4 Requirements for machinery spaces

2.4.1 The arrangements of the fixed fire detection and fire-alarm system in machinery spaces are to comply with the requirements of Pt 16, Ch 1,2.8.

■ *Section 3* Fixed fire-extinguishing systems in machinery spaces

3.1 Gas fire-extinguishing systems

3.1.1 The use of a fire-extinguishing medium which, either by itself or under expected conditions of use, gives off toxic gases in such quantities as to endanger persons is not permitted.

3.1.2 New installations that use fire-extinguishing media, which have ozone-depleting properties under the Montreal Protocol, are not permitted.

3.1.3 The necessary pipes for conveying a fire-extinguishing medium into protected spaces are to be provided with control valves which are to be so placed that they will be easily accessible and not readily cut off from use by an outbreak of fire. The control valves are to be so marked as to indicate clearly the spaces to which the pipes are led. Suitable provision is to be made to prevent inadvertent admission of the medium to any space. Where pipes pass through accommodation spaces they are to be seamless and the number of pipe joints is to be kept to a minimum and made by welding.

3.1.4 The piping for the distribution of fire-extinguishing medium is to be of adequate size and so arranged, and discharge nozzles so positioned that a uniform distribution of medium is obtained. All pipes are to be arranged to be self draining and where led into refrigerated spaces, the arrangement will be specially considered. A means whereby the individual pipes to all protected spaces can be tested using compressed air is to be provided. Distribution pipes are to extend at least 50 mm beyond the last nozzle.

3.1.5 Steel pipes fitted in spaces where corrosion is likely to occur are to be galvanised, at least internally.

3.1.6 Distribution pipes for carbon dioxide are not to be smaller than 20 mm bore.

3.1.7 Means are to be provided to close all openings which may admit air into, or allow gas to escape from, a protected space.

3.1.8 The volume of starting air receivers, converted to free air volume, is to be added to the gross volume of the machinery space when calculating the necessary quantity of extinguishing medium. Alternatively a discharge pipe from the safety valves may be fitted and led directly to the open air.

3.1.9 Means are to be provided for automatically giving audible and visual warning of the release of fire-extinguishing medium into any space in which personnel normally work or to which they have access. The alarm is to operate for a suitable period before the medium is released.

3.1.10 Where pneumatically operated alarms are fitted which require periodic testing, carbon dioxide is not to be used as an operating medium. Air operated alarms may be used provided that the air supply is clean and dry.

3.1.11 Where electrically operated alarms are used, the arrangements are to be such that the electric operating mechanism is located outside hazardous spaces.

3.1.12 The means of control of any fixed gas fire-extinguishing system is to be readily accessible and simple to operate and shall be grouped together in as few locations as possible at positions not likely to be cut off by a fire in a protected space. At each location there is to be clear instructions relating to the operation of the system having regard to the safety of personnel. Two separate controls are to be provided for releasing carbon dioxide into a protected space and each is to ensure the activation of the alarm. One control is to be used to discharge the gas from its storage cylinder(s). A second control is to be used for opening the valve of the piping which conveys the gas into the protected space. The two controls are to be located inside a release box clearly identified for the particular space. If the box containing the controls is to be locked, a key to the box is to be in a break-glass type enclosure conspicuously located adjacent to the box. There is to be a dedicated release box for each protected space, in which personnel normally work or to which they have access, *see also* 3.1.9. The space served is to be identified at the release box.

3.1.13 Automatic release of fire-extinguishing medium is not permitted.

3.1.14 Where the quantity of extinguishing medium is required to protect more than one space, the quantity of medium available need not be more than the largest quantity required for any one space so protected.

3.1.15 Means are to be provided for the crew to safely check the quantity of medium in the containers.

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3.1.16 Containers for the storage of fire-extinguishing media and associated pressure components are to be designed and tested to Codes of Practice recognised by Lloyd's Register (hereinafter referred to as 'LR') having regard to their locations and the maximum ambient temperatures expected in service.

3.1.17 The fire-extinguishing medium is to be stored outside a protected space, in a room which is situated in a safe and readily accessible position and effectively ventilated. Any entrance to such a storage room is to preferably be from the open deck and in any case be independent of the protected space. Access doors are to open outwards, and bulkheads and decks including doors and other means of closing any opening therein, which form the boundaries between such rooms and adjoining enclosed spaces are to be gastight. Such storage rooms are to be treated as control stations.

3.1.18 In systems where containers discharge into a common manifold, non-return valves are to be provided at the connections of the container discharge pipes to the manifold to allow any container to be disconnected without preventing the use of other containers in the system and to prevent the discharge of extinguishing medium into the container storage room in the event of the system being operated. Manifolds are to be tested by hydraulic pressure to 1,5 times the design pressure. The design pressure is the maximum gauge pressure to which the system may be subjected and is not to be less than the gauge pressure corresponding to the maximum ambient temperature expected in service. The design pressure need not be greater than the maximum setting of the manifold pressure relief valve. After the hydraulic test, manifolds are to be carefully cleaned and dried before the non-return valves are finally fitted.

3.1.19 For craft on unrestricted service, spare parts for the system are to be stored on board. As a minimum these are to consist of:

- 1 actuator;
- 1 flexible hose (cylinder to manifold); and
- the cylinder bursting discs and sealing washers for all cylinders.

3.2 Carbon dioxide systems

3.2.1 Carbon dioxide systems are to comply with 3.1 in addition to the remaining requirements of this sub-Section.

3.2.2 For the purpose of this paragraph the volume of free carbon dioxide is to be calculated at 0,56 m^3/kg.

3.2.3 For machinery spaces:

(a) The quantity of carbon dioxide carried is to be sufficient to give a minimum volume of free gas equal to the larger of:
   - 40 per cent of the gross volume of the largest machinery space so protected, the volume to exclude that part of the casing above the level at which the horizontal area of the casing is 40 per cent or less of the horizontal area of the space concerned taken midway between the tank top and the lowest part of the casing; or
   - 35 per cent of the gross volume of the largest machinery space protected, including the casing.

(b) The above mentioned percentages may be reduced to 35 per cent and 30 per cent respectively for craft less than 2000 gross tons.

(c) The fixed piping system is to be such that 85 per cent of the gas can be discharged into the space within two minutes.

(d) The distribution arrangements are to be such that approximately 15 per cent of the required quantity of carbon dioxide is led to the bilge areas.

3.2.4 Two separate controls are to be provided for releasing carbon dioxide into a protected space and each is to ensure the activation of the alarm. One control is to be used to discharge the gas from its storage cylinder(s). A second control is to be used for opening the valve of the piping which conveys the gas into the protected space. The two controls are to be located inside a release box clearly identified for the particular space. If the box containing the controls is to be locked, a key to the box is to be in a break-glass type enclosure conspicuously located adjacent to the box. There is to be a dedicated release box for each protected space in which personnel normally work or to which they have access, *see also* 3.1.8. The space served is to be identified at the release box.

3.3 High-expansion foam systems

3.3.1 Any required fixed high-expansion foam system in machinery spaces is to be capable of rapidly discharging through fixed discharge outlets a quantity of foam sufficient to fill the greatest space to be protected at a rate of at least 1 m in depth per minute. The quantity of foam-forming liquid available is to be sufficient to produce a volume of foam equal to five times the volume of the largest space to be protected.

3.3.2 The expansion ratio of the foam is not to exceed 1000 to 1.

3.3.3 Alternative arrangements and discharge rates will be permitted provided that equivalent protection is achieved.

3.3.4 Supply ducts for delivering foam, air intakes to the foam generator and the number of foam producing units are to be such as will provide effective foam production and distribution.

3.3.5 The arrangement of the foam generator delivery ducting is to be such that a fire in the protected space will not affect the foam-generating equipment.

3.3.6 The foam generator, its sources of power supply, foam-forming liquid and means of controlling the system are to be readily accessible and simple to operate and are to be grouped in as few locations as possible at positions not likely to be cut off by fire in the protected space. Such spaces are to be treated as control stations.

3.3.7 Foam concentrates are to be of an approved type.

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3.4 Pressure water-spraying systems

3.4.1 Any required fixed pressure water-spraying fire-extinguishing system in machinery spaces is to be provided with spraying nozzles of an approved type.

3.4.2 The number and arrangement of the nozzles is to be such as to ensure an effective average distribution of water of at least five litres per square metre per minute in the spaces to be protected. Where increased application rates are considered necessary, these will be specially considered. Nozzles are to be fitted above bilges, tank tops and other areas over which oil fuel is liable to spread and also above other specific fire hazards in the machinery spaces.

3.4.3 The system may be divided into sections, the distribution valves of which are to be operated from easily accessible positions outside the spaces to be protected and which will not be readily cut off by fire in the protected space.

3.4.4 The system is to be kept charged at the necessary pressure, and the pump supplying the water for the system is to be put automatically into action by a pressure drop in the system.

3.4.5 The pump is to be capable of simultaneously supplying, at the necessary pressure, all sections of the system in any one compartment to be protected. The pump and its controls are to be installed outside the space or spaces to be protected. It is not to be possible for a fire in the space or spaces protected by the water-spraying system to put the system out of action.

3.4.6 The pump may be driven by independent internal combustion type machinery but if it is dependent upon power being supplied from the emergency generator, that generator is to be arranged to start automatically in case of main power failure so that power for the pump required by 3.4.5 is immediately available. When the pump is driven by independent internal combustion machinery it is to be so situated that a fire in the protected space will not affect the air supply to the machinery.

3.4.7 Precautions are to be taken to prevent the nozzles from becoming clogged by impurities in the water or corrosion of the piping, nozzles, valves and pump.

3.5 Arrangements which will be accepted as an alternative to 3.4

3.5.1 The system is to be tested, type approved and installed in accordance with MSC/Circ. 668 as amended by IMO MSC/Circ. 728.

3.6 Other systems

3.6.1 Other fixed fire-extinguishing systems will be specially considered.

3.6.2 The use of steam as a fire-extinguishing medium in fixed fire-extinguishing systems is not permitted.

■ *Section 4* Fireman's outfits

4.1 Components

4.1.1 A fireman's outfit is to consist of:

(a) Personal equipment comprising:
  (i) Protective clothing of material to protect the skin from the heat radiating from the fire and from burns and scalding by steam. The outer surface is to be water-resistant.
  (ii) Boots and gloves of rubber or other electrically non-conducting material.
  (iii) A rigid helmet providing effective protection against impact.
  (iv) An electric safety lamp (hand lantern) of an approved type with a minimum burning period of three hours.
  (v) An axe with an insulated handle.

(b) A self contained breathing apparatus of an approved type. The volume of air contained in the cylinders of which is to be at least 1200 litres or other self contained breathing apparatus which is to be capable of functioning for a period of at least 30 minutes. Spare bottles are to be provided which are to be maintained fully charged except where facilities for re-charging the bottles are available on board. At least two spare charges for each breathing apparatus are to be provided, and all air cylinders for breathing apparatus are to be interchangeable.

4.1.2 For each breathing apparatus a fireproof life-line of sufficient length and strength is to be provided capable of being attached by means of a snaphook to the harness of the apparatus or to a separate belt in order to prevent the breathing apparatus becoming detached when the life-line is operated.

■ *Section 5* Fire-control plans

5.1 Description of plans

5.1.1 General arrangement plans are to be permanently exhibited for the guidance of the ship's officers, using graphical symbols in accordance with IMO Resolution A.654(16), which show clearly for each deck the control stations, the various fire sections enclosed by steel or 'A' and 'B' Class divisions, together with particulars of:

- the fire detection and fire-alarm system;
- any sprinkler installation;
- the fire-extinguishing appliances;
- the means of access to different compartments, decks, etc.;
- the position of the fireman's outfits;
- the ventilating system, including particulars of the fan control positions, the position of dampers and identification numbers of the ventilating fans serving each section; and

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- the location and arrangement of the emergency stop(s) for pumps, and for remote closing the valves on the pipes from tanks, for oil fuel, lubricating oil and other flammable oils.

5.1.2 Alternatively, the details required by 5.1.1 may be set out in a booklet, a copy of which is to be supplied to each officer, and one copy is at all times to be available on board in an accessible position.

5.1.3 The plans and booklets are to be kept up to date, any alterations being recorded thereon as soon as practicable. Description in such plans and booklets is to be in the official language of the flag state. If the language is neither English nor French, a translation into one of those languages is to be included. In addition, instructions concerning the maintenance and operation of all the equipment and installations on board for the fighting and containment of fire are to be kept under one cover, readily available in an accessible position.

5.1.4 A duplicate set of fire-control plans or a booklet containing such plans is to be permanently stored in a prominently marked weathertight enclosure outside the deckhouse for the assistance of shoreside fire-fighting personnel.

■ *Section 6* Fire-extinguishers (portable and non-portable)

6.1 Approved types

6.1.1 All fire-extinguishers are to be of approved types and designs.

6.2 Extinguishing medium

6.2.1 The extinguishing media employed are to be suitable for extinguishing fires in the compartments in which they are intended to be used.

6.2.2 The extinguishers required for use in the machinery spaces using oil as fuel are to be of a type suitable for extinguishing oil fires.

6.2.3 Fire-extinguishers containing an extinguishing medium which, either by itself or under expected conditions of use, gives off toxic gases in such quantities as to endanger persons, are not permitted.

6.3 Capacity

6.3.1 The capacity of required portable fluid extinguishers is to be not more than 13,5 litres but not less than nine litres. Other extinguishers are to be at least as portable as the 13,5 litre fluid extinguishers and are to have a fire-extinguishing capability at least equivalent to a 9,0 litre fluid extinguisher.

6.3.2 The following capacities may be taken as equivalents:

- 9 litre fluid extinguisher;
- 4,5 kg dry powder;
- 5 kg carbon dioxide.

6.4 Spare charges

6.4.1 A spare charge is to be provided for each required portable fire-extinguisher which can be readily re-charged on board. If this cannot be done, duplicate extinguishers are to be provided.

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Guidance Notes for the Classification of Special Service Craft

Calculation Procedures for Composite Construction

July 2011

Lloyd's Register

LIFE MATTERS

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CALCULATION PROCEDURES FOR COMPOSITE CONSTRUCTION

		Introduction
Chapter	**1**	**Design Procedures**
	2	**Design of Single Skin Hull Laminates**
	3	**Design of Sandwich Panel Laminates**
	4	**Design of Stiffening Members**

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Introduction

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Application of procedures

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■ Application of procedures

To clarify the procedures contained in the *Rules and Regulations for the Classification of Special Service Craft* (hereinafter referred to as the Rules for Special Service Craft) a series of typical calculation procedures are contained in these 'Guidance Notes'. The procedures describe the fundamental principles contained in Part 8 of the Rules for Special Service Craft and the associated computer software.

The procedures contained in these Guidance Notes are for:
(a) Design of single skin hull laminates.
(b) Design of sandwich panel laminates.
(c) Design of typical stiffening members.

■ Alternative procedures

The procedures describe the Rule method of calculating the various stresses in laminates. Where alternative theoretical methods are to be adopted they are to be in addition to the Rule calculation procedures and the designer is to submit full details of their assumptions and calculation procedures such that the submitted calculations may be validated.

■ Symbols and definitions

All symbols and definitions are as indicated in Pt 8, Ch 3 of the Rules for Special Service Craft.

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Design Procedures

Chapter 1

Sections 1 to 4

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1 **General**

2 **Structural analysis**

3 **Fibre composites**

4 **Fibre reinforced composite construction**

5 **Direct calculation**

■ *Section 1* General

1.1 This Section outlines the Rule approach to the design of structural members to be built in FRP and provides example calculations.

1.2 The procedures contained in these Guidance Notes are for:

(a) Design of single skin hull laminates.
(b) Design of sandwich panel laminates.
(c) Design of typical stiffening members.

■ *Section 2* Structural analysis

2.1 The Rules for Special Service Craft provide scantling requirements for a basic structural configuration for both mono and multi-hull craft with multi-deck or single deck hulls which include a double bottom, or a single bottom arrangement. The structural configuration may also include a single or multiple arrangement of cargo hatch openings. The Rules for Special Service Craft provide for both longitudinal and transverse framing systems. Alternative types of framing systems will be specially considered on the basis of the Rules for Special Service Craft.

2.2 Every effort has been taken to make the Rules for Special Service Craft scantling formulae as transparent as possible, and to achieve this objective the following approach has been adopted:

- lay down requirements,
- specify modelling considerations,
- indicate limit states,
- state constraints in an explicit manner.

2.3 This approach will enable the designers and Builders to decide for themselves the suitability of the Rules for Special Service Craft for their project. Further and perhaps more importantly changes may be easily made to the requirements based upon experience gained, discussions with interested parties and as development progresses. This is similar to the current Rule development process which is continually updating and 'tailoring' Rule requirements.

■ *Section 3* Fibre composites

3.1 Part 8 of the Rules for Special Service Crafts apply to craft constructed of fibre reinforced plastics using hand lay-up, mechanical deposition, contact moulding techniques or vacuum assisted techniques. Construction may be either single-skin or sandwich construction, or a combination of both. Where moulding techniques and methods of construction differing from those assumed to be used within the Rules for Special Service Craft are proposed, details are required to be submitted for consideration.

3.2 For the purposes of the Rules for Special Service Craft a 'plastic' is regarded as an organic substance which may be thermosetting or thermoplastic and which, in its finished state, may contain reinforcements or additives. The quantities of such additives are strictly limited by the Rules for Special Service Craft.

3.3 The resins used in production are to be of a type which have been approved by Lloyd's Register (hereinafter referred to as LR) for marine construction purposes. Samples of the resin batches being used in the construction may require to be taken for limited quality control examinations.

3.4 All fibre reinforcements are to be of a type approved by LR. The other materials used in the construction of the craft are also to be manufactured and tested in accordance with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials), of the Rules for Special Service Craft, with particular reference to Chapter 14 for plastics materials.

■ *Section 4* Fibre reinforced composite construction

4.1 The properties of composite sections and laminates are to be determined from the results of test data. The mechanical properties to be used for scantling calculation purposes are to be 90 per cent of the mean first ply/resin cracking failure values determined from accepted mechanical tests. All test pieces are to be representative of the product to be manufactured. This is particularly important since the material of construction is 'manufactured' on site, at the same time as the product.

4.2 The mechanical properties of the materials are also to be estimated from the appropriate procedures and formulae contained within the Rules for Special Service Craft. The acceptable design values for glass reinforced polyester resin laminates are not to be greater than those contained with the Rules for Special Service Craft unless agreed otherwise by LR. Additional information on the application of the various formulae is given in these Guidance Notes.

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4.3 The various formulae referred to above require that sufficient input data be available which relates to each of the proposed materials. Where it is proposed to use design values greater than the nominal value indicated in the Rules for Special Service Craft the designers and/or Builders should agree the values for use in the scantling analysis with LR at the design stage and prior to the submission of plans and data for appraisal.

4.4 Strength calculations for all advanced fibre composites are to be based on the Rules values and the results of testing of truly representative sections of the proposed design. The sections are to be manufactured under typical production conditions using the same materials, fibre contents, methods of lay-up and time delays. Mechanical testing is, in general, to be based upon the requirements specified in Chapter 14 of the Rules for Materials.

4.5 A through ply analysis is required to be conducted for both plate and stiffener elements and the resultant stresses compared with the allowable stress limits for the particular element. Example procedures are described in these Guidance Notes.

Section 5
Direct calculations

5.1 Direct calculations may be specifically required by the Rules for Special Service Craft. They may be required for craft having novel design features, or may be submitted in support of alternative arrangements and scantlings. LR may, when requested, undertake calculations on behalf of designers or Builders and make recommendations with regard to the suitability of any required model tests. Where model testing is undertaken to complement direct calculations details would normally be required to be submitted indicating the schedule of tests, details of test equipment, input data, analysis and calibration procedures together with tabulated and plotted output.

5.2 All direct calculations are to be submitted for examination. Where calculation procedures other than those available within the Rules for Special Service Craft are employed, supporting documentation is to be submitted for appraisal and this is to include details of the following:

- calculation methods,
- assumptions and references,
- loading data,
- structural modelling,
- design criteria.

5.3 LR will consider the use of Builder's and/or designer's programs for direct calculations in the following cases:

- where it can be established that the program has previously been satisfactorily used to perform a direct calculation similar to that now submitted,
- where sufficient information and evidence of satisfactory performance is submitted to substantiate the validity of the computation performed by the program.

5.4 Where items are of a novel or unconventional design or manufacture, it is the responsibility of the Builder and/or designer to demonstrate their suitability and equivalence to the Rule requirements. Alternative arrangements, which are in accordance with the requirements of a National Authority, may be accepted as equivalent to the requirements of the Rules for Special Service Craft.

5.5 These Guidance Notes are published to enable designers/Builders to carry out the Rule calculations without using the Rules for Special Service Craft software.

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Design of Single Skin Hull Laminates

Section

1 **Calculation procedure**

2 **Concluding remarks**

Section 1 Calculation procedure

1.1 The stress in individual plies of a laminate is calculated in accordance with Pt 8, Ch 3,1.12 of the Rules for Special Service Craft, based on bending moment (*see* 1.9) and the laminate stiffness of a 1 cm wide elemental strip of material.

1.2 Considering the model shown in Figs. 2.1.1 and 2.1.2 of a typical single skin hull laminate. Assume a pressure of 33 kN/m^2 and that there is no significant panel curvature.

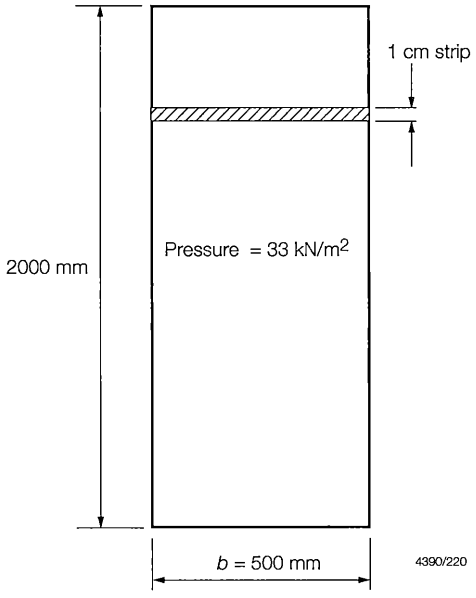

Fig. 2.1.1 Single skin example model

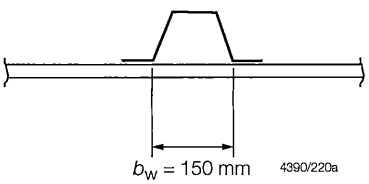

Fig. 2.1.2 'Top-hat' stiffener used in model

1.3 In this example the maximum bending moment is determined from Pt 8, Ch 3,1.9 of the Rules for Special Service Craft and occurs under the web at the base of the stiffener. It should be noted that no reduction in the bending moment, M_b, due to aspect ratio effect is given since the panel aspect ratio, i.e. panel length/panel breadth is greater than 2. *See* Pt 8, Ch 3,1.10.1 of the Rules for Special Service Craft.

$$\gamma = \frac{b_w}{b} = \frac{150}{500} = 0,3$$

$$k = \frac{\gamma^3 + 1}{\gamma + 1} = 0,79$$

$$M_b = \frac{k\,p\,b^2}{12} \times 10^{-5} \text{ Nm}$$

$$= \frac{0,79}{12} \times 33 \times 500^2 \times 10^{-5}$$

$$= 5,43 \text{ Nm.}$$

1.4 The laminate section modulus calculation is shown in Table 2.1.1 at the end of this Section. From Fig. 2.1.3 it will be noted that there will be positions where tension and compression considerations will apply. Such calculations are ideally suited to computer based investigation.

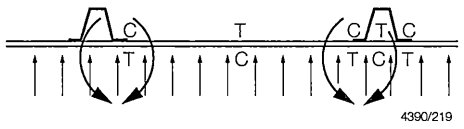

Fig. 2.1.3
Regions of tension (T) and compression (C) in example model

1.5 In order to apply a more detailed investigation it is necessary to establish the position of the neutral axis. However, in relatively balanced laminates this may be assumed to be at mid-depth. The procedure is simply to carry out the calculations assuming compressive properties on one face and tensile properties on the other face. Subsequently, the properties should be reversed and the layer stress calculations repeated. The calculated values should then be compared with the appropriate ultimate properties, i.e., dependent upon whether tension or compression considerations apply.

1.6 In the example the moments were evaluated about the base, which was taken to be the outer (wet) surface. The stiffness, EI, per 1 cm width, about the neutral axis, is determined using the parallel axis theorem:
In general:

$$I_{na} = I_{xx} - Ay^2$$

$$EI_{sect} = \Sigma\, EI_{base} - (\Sigma\, Et) \times 10 \times y^2$$

where

y = distance of neutral axis above the base (mm).

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Table 2.1.1 Tabulation of single skin laminate calculations

	Ply No.	Description	G_c	Weight (g/m^2)	t (mm)	Lever @ base, x (mm)	E (N/mm^2)	$E.t$	$E.t.x$	I @ base	EI @ base
Dry, *see* Note	1	CSM	0,33	600	1,250	10,149	7200	9000	91341	1289,2	9281917
	2	CSM	0,33	600	1,250	8,899	7200	9000	80091	991,5	7139017
	3	CSM	0,33	600	1,250	7,649	7200	9000	68841	733,0	5277367
	4	CSM	0,33	600	1,250	6,399	7200	9000	57591	513,5	3696967
	5	WR	0,5	600	0,734	5,407	14000	10276	55562	214,9	3008869
	6	CSM	0,33	600	1,250	4,415	6950	8688	38355	245,3	1704699
	7	CSM	0,33	600	1,250	3,165	6950	8688	27496	126,8	881558
	8	WR	0,5	600	0,734	2,173	14500	10643	23127	35,0	507333
	9	CSM	0,33	600	1,250	1,181	6950	8688	10260	19,1	132482
Wet (*see* Note)	10	CSM	0,286	225	0,556	0,278	6290	3497	972	0,6	3604
TOTALS					10,774			86479	453637		31633812

NOTE
'Dry' indicates the inner surface of the hull and 'wet' the outside of the shell laminate.

Position of neutral axis above base = $\frac{453637}{86479}$ = 5,246 mm

Tensile modulus of section = $\frac{86479}{10,774}$ = 8027 N/mm^2

Stiffness EI about neutral axis = 783,8 N cm^4/mm^2 (based on 1 cm wide strip)

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1.7 A factor of 10 (width in mm) is introduced to correct the value of area used in the parallel axis theorem, since a 1 cm wide strip of material is considered in the calculations.
From the tabulation:

EI_{sect} = 31633812 – (86479 x 10 x 5,246^2)
= 7837614 Nmm^4/mm^2
= 783,8 Ncm^4/mm^2.

1.8 From Pt 8, Ch 3,1.12 of the Rules for Special Service Craft the individual layer stresses (tensile consideration) are determined from:

$$\sigma_{ti} = \frac{E_{ti}\, y_i\, M}{\Sigma\,(E_i\, I_i)} \times 10^{-1} \quad N/mm^2$$

1.9 More generally, the calculation of the stresses in individual layers becomes:

$$\sigma_{ti} = \frac{5,43}{783,8} \times E_i\, y_i \times 10^{-1} \quad N/mm^2$$

$$= 693 \times 10^{-6} \times E_i\, y_i \quad N/mm^2$$

where

E_i = E_{ti} or E_{ci} for the ply relative to its position above or below the neutral axis
y_i = distance from the neutral axis to the outer extremity of an individual ply, *i*, in mm.

1.10 Consider the following typical arrangement and the associated stresses for a single shell panel outside of the slamming zone:

Consider the outer (wet) surface:
Consider the 225g/m^2 chopped strand mat reinforcement in tension:

σ_{ti} = 693 x 10^{-6} x $E_i\, y_i$
= 693 x 10^{-6} x 6290 x 5,246
= 22,9 N/mm^2.

From Pt 8, Ch 3, Table 3.1.1 of the Rules for Special Service Craft.
$\sigma_{ult\ tension}$ = 82,2 N/mm^2 for CSM at G_c =0,286
Hence, stress fraction = 22,9/82,2 = 0,278.

1.11 From Table 7.3.1 in Pt 8, Ch 7 of the Rules for Special Service Craft, the limiting tensile stress fraction is 0,33 for the side shell outside of the slamming zone. Hence, the calculated stress fraction is lower than the limiting stress factor and is therefore acceptable.

1.12 Similarly, consider the 600g/m^2 woven roving reinforcement in tension:

σ_{ti} = 693 x 10^{-6} x $E_i\, y_i$
= 693 x 10^{-6} x 14500 x (5,246–0,556–1,25)
= 34,6 N/mm^2
$\sigma_{ult\ tension}$ = 190 N/mm^2 for woven roving at G_c = 0,5
Stress fraction = 34,6/190 = 0,182
Hence acceptable.

1.13 Consider the inner (dry) surface:
The 600 g/m^2 chopped strand mat reinforcements at the inner surface in compression:

σ_{ci} = 693 x 10^{-6} x $E_i\, y_i$
= 693 x 10^{-6} x 7200 x (10,774–5,246)
= 27,6 N/mm^2
$\sigma_{ult\ comp}$ = 122 N/mm^2 for CSM at G_c = 0,33
Stress fraction = 27,6/122 = 0,226
Hence acceptable.

Section 2
Concluding remarks

2.1 From the example, the highest stress factor occurs in the outer 225 g/m^2 chopped strand mat reinforcement (in tension) but this is significantly lower than the limiting stress fraction required by the Rules. The bending moment at the centre of the panel is smaller than that at the boundary and consequently, the stress factor will be correspondingly reduced. The design may be optimised by sequentially removing plies, changing reinforcement weights and/or by providing receiving strips under the base of the 'top-hat' stiffeners.

2.2 For the design of side shell laminates there are no shear and deflection criteria to be fulfilled. In this example a significant reserve exists between the actual and the ultimate stresses.

2.3 It is of paramount importance that the strain compatibility of the component materials is carefully considered.

2.4 Consider typical values of apparent strain, ε_a, at failure for the following materials in laminate form:

	Tension	Compression
'E' glass	1,3%	1,05%
Carbon fibre	0,9%	0,55%
Aramid fibre	1,3%	0,60%

2.5 The actual strain permissible is controlled by the material with the lowest apparent strain. The level of strain depends upon whether the reinforcements are in tension or compression and depends on their relative positions within the laminate. Consequently if, for example, a carbon fibre reinforcement is used in the outer plies of laminate then the strain must be constrained to a maximum of 0,33 x 0,9 per cent, i.e., 0,297 per cent. Therefore, the corresponding allowable stress in the other reinforcements must be related to the strain in the reinforcement relative to its position away from the neutral axis and that of the carbon fibre reinforcement, e.g.:

$$\varepsilon_{limitCSM} = \frac{\varepsilon_{allowable\ carbon} \times y_{CSM}}{y_{carbon}}$$

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2.6 Where aramid reinforcements are being used, special consideration must be given to the compressive properties. For comparison purposes aramid reinforcements, at a fibre content of 0,45 (by weight), typically have the following properties:

	Tension	Compression
Ultimate strength (N/mm^2)	300	100
Elastic modulus (N/mm^2)	21000	17000

2.7 The radical reduction in ultimate compressive strength may prove to be unacceptable on the inside at the panel boundaries or on the outside at the panel centre. Designs which feature aramid fibres in the outer plies, in an attempt to make use of the superior impact properties, must be checked at the panel centre for compression in the individual layers. This also applies to hybrid reinforcements containing aramid fibres. These reinforcements have one off properties of higher than one of the constituent fibres however, in service the individual allowable strains for each fibre reinforcement should not be exceeded.

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Design of Sandwich Panel Laminates

Section

1 **Calculation procedure**

2 **Deflection of sandwich panel**

3 **Bending moment applied**

4 **Stresses in facings**

Section 1
Calculation procedure

1.1 Consider the model of a side shell sandwich panel having dimensions 700 mm x 2000 mm shown in Fig. 3.1.1. Assume a design pressure of 50 kN/m^2 and a panel of negligible curvature.

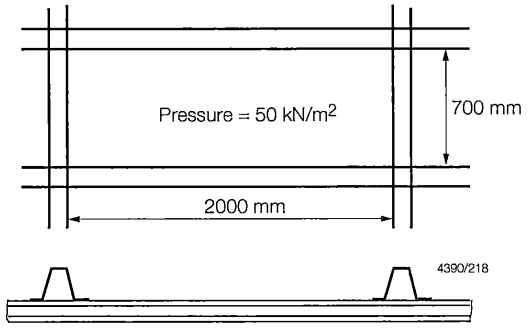

Fig. 3.1.1 Sandwich panel laminate example model

1.2 The panel is to be designed in accordance with the requirements of Pt 8, Ch 3 of the Rules for Special Service Craft. Firstly it is necessary to estimate the core thickness using Pt 8, Ch 3,1.13.2 of the Rules for Special Service Craft assuming a nominal value of tensile modulus of 11000 N/mm^2 for sandwich panel facings:

$$t_s = \phi\, k_s\, b \sqrt[3]{\frac{p}{E_{tpS}}} \quad \text{mm}$$

$$= 0{,}144 \times 700 \times \sqrt[3]{\frac{50}{11000}}$$

$$= 16{,}7 \text{ mm}$$

Hence, select 20 mm core as a typically available size.

1.3 From Pt 8, Ch 3,1.13.9 of the Rules for Special Service Craft the maximum core shear at the mid-point along the edge of the sandwich panel is given by:

$$\tau_c = \frac{p\, b\, k_S}{2t_c} \times 10^{-3} \quad \text{N/mm}^2$$

$$= \frac{50 \times 700 \times 1}{2 \times 20} \times 10^{-3}$$

$$= 0{,}875 \text{ N/mm}^2$$

1.4 The panel aspect ratio correction factor is given in Pt 8, Ch 3,1.13.9 of the Rules for Special Service Craft. $A_R = 2000/700 = 2{,}86$, hence $k_S = 1$.
No correction factor applied since $A_R > 2$.

1.5 To achieve an allowable shear stress fraction of 0,30, *see* Pt 8, Ch 7,3.5 of the Rules for Special Service Craft, this design would require the selection of 200 kg/m^3 foam core. Clearly being unacceptable the conclusion is to adopt a 50 mm thick core to reduce the core shear stress. The stress varies inversely with core thickness:

$$\tau_{50} = \tau_{20} \times \frac{20}{50} = 0{,}35 \quad \text{N/mm}^2.$$

1.6 To achieve the required allowable shear stress fraction the foam core must have a core shear strength of 0,35/0,30 = 1,17 N/mm^2. This may be achieved using a 100 kg/m^3 foam core using 90 per cent of the manufacturer's quoted value.

1.7 However, there are numerous solutions to achieve an acceptable arrangement. The options include:
(a) Repositioning the stiffeners to reduce panel sizes.
(b) Inclusion of shear ties in accordance with Pt 8, Ch 3,1.13.10 of the Rules for Special Service Craft.
(c) Accept the higher density core solution.

1.8 From Pt 8, Ch 3,1.13.3 of the Rules for Special Service Craft the skin thicknesses may be re-calculated allowing for the change in core thickness:

$$t_S = \phi_2 \frac{p\, b^3}{E_{tps}\, t_c^2} \times 10^{-3} \quad \text{mm}$$

$$t_{inner} = 0{,}446 \times \frac{50}{11000} \times \frac{700^3}{50^2} \times 10^{-3} = 0{,}28 \text{ mm}$$

$$t_{outer} = 0{,}594 \times \frac{50}{11000} \times \frac{700^3}{50^2} \times 10^{-3} = 0{,}37 \text{ mm}$$

Clearly, the increase in core thickness gives a substantial increase in panel stiffness. Consequently the skin thicknesses default to the minimum requirement quoted in Pt 8, Ch 3,3.5.5 of the Rules for Special Service Craft. The minimum side shell sandwich skin thicknesses are:

Outer 4 mm
Inner 3 mm.

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1.9 The minimum skin thicknesses relate to an assumed fibre content, f_c, of 0,5. Where the fibre content by weight is less than 0,5 the required minimum thickness are to be determined from Pt 8, Ch 3,2.4.2 of the Rules for Special Service Craft.

1.10 In order to comply with the Rules for Special Service Craft, chopped strand mat reinforcements are required against the core. The initial proposal to meet the requirement, features such CSM reinforcements together with a CSM against the gel coat surface.

1.11 The proposed sandwich skin laminate schedule for the outer skin is:

1 x 450 g/m^2 CSM @ G_c = 0,286	= 1,112 mm
3 x 600 g/m^2 WR @ G_c = 0,5	= 2,202 mm
1 x 300 g/m^2 CSM @ G_c = 0,33	= 0,625 mm
Total outer skin thickness	= 3,94 mm
Total reinforcement weight	= 2550 g/m^2

1.12 By transforming the relationship given in Pt 8, Ch 3,1.6.1 of the Rules for Special Service Craft the equivalent fibre content by weight, f_c, is 0,42.
The adjusted minimum skin thickness for the outer skin is:

$$t_{outer} = t_{0,5}\,(1,65 - 1,3f_c)$$
$$= 4 \times (1,65 - 1,3 \times 0,42)$$
$$t_{outer} = 4,42 \text{ mm}.$$

1.13 The proposed outer skin is deficient by 4,42 – 3,94 = 0,48 mm. Hence one additional woven roving reinforcement may be added to achieve the minimum requirement. The actual thickness of outer skin is 4,67 mm.

1.14 The proposed sandwich skin laminate schedule for the inner skin is:

1 x 300 g/m^2 CSM @ G_c = 0,33	= 0,625 mm
4 x 600 g/m^2 WR @ G_c = 0,5	= 2,936 mm
Total inner skin thickness	= 3,56 mm
Total reinforcement weight	= 2700 g/m^2

The equivalent overall fibre content of the inner skin is 0,473.
The adjusted minimum skin thickness for the inner skin is:

$$t_{inner} = t_{0,5}\,(1,65 - 1,3f_c)$$
$$= 3 \times (1,65 - 1,3 \times 0,473)$$
$$t_{inner} = 3,1 \text{ mm}.$$

1.15 The proposed arrangement which meets both core shear and minimum sandwich skin requirements is given in Table 3.1.1.

Section 2
Deflection of sandwich panel

2.1 Consider the revised model shown in Fig. 3.2.1:

E_{ms}	= 12086 N/mm^2 from Table 3.1.1
b	= breadth in direction of bending = 700 mm
G	= shear modulus for 100 kg/m^3 core = 36 N/mm^2 being 90 per cent of the manufacturer's quoted value
t_s	= mean skin thickness (3,56 + 4,67)/2 = 4,11 mm
$(1 - v_f^2)$	= unity (approximately)

Calculation of deflection in accordance with Pt 8, Ch 3, 1.13.15 of the Rules for Special Service Craft

$$\delta = \frac{p\,b^2}{8t_c}\left(\frac{b^2}{24E_{ms}\,t_s\,t_c} + \frac{1}{G}\right) \times 10^{-3} \text{ mm}$$

$$= \frac{50 \times 700^2}{8 \times 50}\left(\frac{700^2}{24 \times 12086 \times 4,11 \times 50} + \frac{1}{36}\right) \times 10^{-3} \text{ mm}$$

$$= 61,25 \times (0,00822 + 0,0278)$$
$$= 2,2 \text{ mm} \quad \text{total deflection.}$$

2.2 The total deflection comprises 23 per cent due to bending and 77 per cent due to shear.
The deflection criterion is given in Table 7.2.1 in Pt 8, Ch 7 of the Rules for Special Service Craft.

$$\delta_{RULE} < \frac{b}{100} \quad \text{where} \quad \frac{b}{100} = 7 \text{ mm}$$

Hence the 2,2 mm total deflection is acceptable.

Table 3.1.1 Tabulation of sandwich panel calculations

	Ref No.	Description	G_c	Weight (g/m^2)	t (mm)	Lever @ base, x (mm)	E (N/mm^2)	$E.t$	$E.t.x$	I @ base	EI @ base
Inner skin	1	WR	0,5	600	0,734	57,87	14000	10276	594641	24579	344105690
	2	WR	0,5	600	0,734	57,13	14000	10276	587099	23959	335431718
	3	WR	0,5	600	0,734	56,40	14000	10276	579556	23348	326868472
	4	WR	0,5	600	0,734	55,67	14000	10276	572014	22744	318415951
	5	CSM	0,33	300	0,625	54,99	7200	4500	247435	18896	136054699
Core	6	100 kg/m^3	–	–	50,000	29,67	83,7	4185	124182	544410	45567128
	7	CSM	0,33	300	0,625	4,36	6950	4344	18941	119	827333
	8	WR	0,5	600	0,734	3,68	14500	10643	39177	100	1446879
	9	WR	0,5	600	0,734	2,95	14500	10643	31365	64	929103
	10	WR	0,5	600	0,734	2,21	14500	10643	23553	36	526005
Outer skin	11	WR	0,5	600	0,734	1,48	14500	10643	15741	16	237588
	12	CSM	0,286	450	1,112	0,56	6290	6994	3889	5	28830
TOTALS					58,23			103699	2837592		1510439396

Inner skin in compression/outer skin in tension.

Position of neutral axis above base = $\frac{2837592}{103699}$ = 27,36 mm

Tensile modulus of elasticity of section = $\frac{103699 - 4185}{58,234 - 50} = \frac{99514}{8,234}$ = 12086 N/mm^2

Stiffness EI about neutral axis = 73397 N cm^4/mm^2 per 1 cm wide strip

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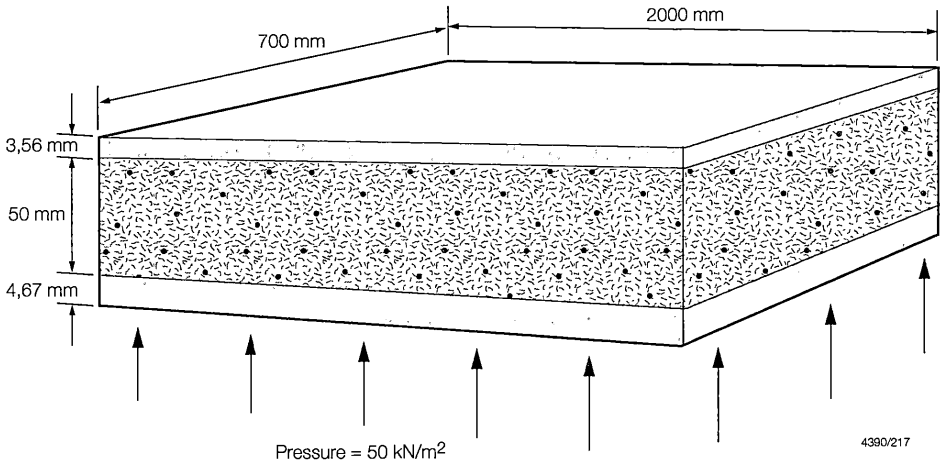

Fig. 3.2.1 Sandwich panel example model

■ *Section 3* Bending moment applied

3.1 The bending moment to be applied at 1 cm width of the sandwich panel is given by Pt 8, Ch 3,1.9 of the Rules for Special Service Craft. In this example it is evident that the maximum bending moment and hence maximum stress occurs under the base of the stiffener. Due to the high aspect ratio no correction factor needs to be applied to modify the applied bending moment.

$$\gamma = \frac{b_w}{b} = \frac{150}{700} = 0{,}2143$$

$$k = \frac{\gamma^3 + 1}{\gamma + 1} = 0{,}8316$$

$$M_b = \frac{k\,p\,b^2}{12} \times 10^{-5} \text{ Nm}$$

$$= \frac{0{,}8316}{12} \times 50 \times 700^2 \times 10^{-5}$$

$$= 17 \text{ Nm.}$$

■ *Section 4* Stresses in facings

4.1 Consider the revised model, *see* Fig 3.4.2, with 50 mm thick and 100 kg/m^3 density core having the proposed side shell sandwich skins which comply with the Rules for Special Service Craft minimum requirements. As indicated in Fig. 3.4.1 there will be positions where tension and compression considerations will apply. The relevant elastic modulus has been applied to the element dependent upon its relative position in the sandwich. The proposed schedule together with the tabular calculations are given in Table 3.1.1. Such calculations are ideally suited to computer based investigation.

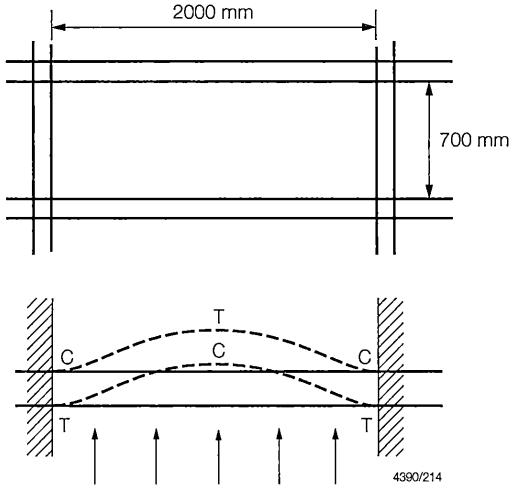

Fig. 3.4.1
Regions of tension (T) and compression (C) in example model

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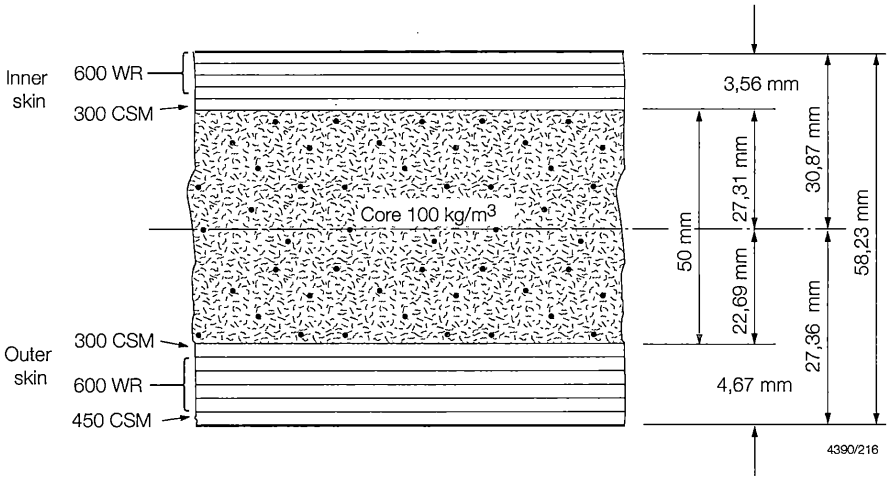

Fig. 3.4.2 Sandwich skin laminate details

4.2 The stiffness, EI, per 1 cm width is determined using the parallel axis theorem:
In general,

$$I_{na} = I_{xx} - Ay^2$$
$$EI_{sect} = \Sigma EI_{base} - (\Sigma Et) \times 10 \times y^2$$

where

y = distance of neutral axis above base (mm).

4.3 It should be noted that the factor 10 (width in mm) is introduced to correct the value of area used in the parallel axis theorem, since a 1 cm wide strip of material is considered in the calculations.

From the tabulated calculations the overall stiffness of the section is calculated:

$$EI_{sect} = 1510439396 - (103699 \times 10 \times 27{,}36^2)$$
$$= 1510439396 - 776259189 \quad Nmm^4/mm^2$$
$$= 734200000 \quad Nmm^4/mm^2$$
$$= 73{,}4 \times 10^3 \quad Ncm^4/mm^2.$$

4.4 From Pt 8, Ch 3,1.13.7 of the Rules for Special Service Craft the individual layer stresses are determined from:

$$\sigma_{ti} = \frac{E_{ti}\, y_i\, M}{\Sigma (E_i\, I_i)} \times 10^{-1} \quad N/mm^2$$

The calculation of the tensile stress in the individual layers becomes:

$$\sigma_{ti} = \frac{17{,}0}{73{,}4 \times 10^3} \times E_{ti}\, y_i \times 10^{-1} \quad N/mm^2$$

$$\sigma_{ti} = 23{,}2 \times 10^{-6} \times E_i\, y_i \quad N/mm^2$$

where

E_i = modulus of elasticity of layer (N/mm^2)
y_i = distance of layer from the neutral axis (mm).

4.5 Consider the model as shown in Fig. 3.4.1.

4.5.1 Consider wet surface in tension at the panel boundary:

(a) Consider the CSM reinforcement in the outer ply (450 g/m^2 and $G_c = 0{,}286$)

$$\sigma_{CSMult} = 82{,}2 \quad N/mm^2$$
$$E_t = 6290 \quad N/mm^2$$
$$y_i = 27{,}36 \text{ mm}$$
$$\sigma_{CSM} = 23{,}2 \times 10^{-6}\, E_t\, y_i \quad N/mm^2$$
$$= 23{,}2 \times 10^{-6} \times 6290 \times 27{,}36 \quad N/mm^2$$
$$= 3{,}99 \quad N/mm^2$$

Stress factor = 3,99/82,2 = 0,05 < 0,33 hence accept.

(b) Consider the WR reinforcement in the in outer plies (600 g/m^2 and $G_c = 0{,}5$)

$$\sigma_{WRult} = 190 \quad N/mm^2$$
$$E_t = 14500 \quad N/mm^2$$
$$y_i = 27{,}36 - 1{,}112 = 26{,}25 \text{ mm}$$
$$\sigma_{WR} = 23{,}2 \times 10^{-6}\, E_t\, y_i \quad N/mm^2$$
$$= 23{,}2 \times 10^{-6} \times 14500 \times 26{,}25 \quad N/mm^2$$
$$= 8{,}83 \quad N/mm^2$$

Stress factor = 8,83/190 = 0,046 < 0,33 hence accept.

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4.5.2 Consider inner surface in compression at the panel boundary:

(a) Consider top WR reinforcement in compression (600 g/m^2 and G_c = 0,5)

σ_{WRult} = 147 N/mm^2
E_c = 14000 N/mm^2
y_i = 58,23 – 27,36 = 30,87 mm
σ_{WR} = 23,2 x 10^{-6} E_c y_i N/mm^2
= 23,2 x 10^{-6} x 14000 x 30,87 N/mm^2
= 10,03 N/mm^2

Stress factor = 10,03/147 = 0,068 < 0,33 hence accept.

(b) Consider CSM reinforcement in compression (300 g/m^2 and G_c = 0,33)

σ_{CSMult} = 122 N/mm^2
E_c = 7200 N/mm^2
y_i = 30,87 – (4 x 0,734) = 27,93 mm
σ_{CSM} = 23,2 x 10^{-6} E_c y_i N/mm^2
= 23,2 x 10^{-6} x 7200 x 27,93 N/mm^2
= 4,67 N/mm^2

Stress fraction = 4,67/122 = 0,038 < 0,33 hence accept.

4.6 Stress fractions in this example are considerably lower than those required by the Rules for Special Service Craft and it is evident that the design is controlled by and core shear considerations and minimum skin thickness requirements.

4.7 As indicated in Chapter 2, Sections 2.4 to 2.7 of these Guidance Notes for Single Skin Laminates, consideration must be given to the strain compatibility of the reinforcements incorporated in the sandwich skins.

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Design of Stiffening Members

Section

1 **Calculation procedure**

2 **Bending moment at fixed end of stiffener**

3 **Web thickness to meet shear requirement**

4 **Calculation of deflection**

Section 1 Calculation procedure

1.1 Assume a design pressure of 70 kN/m^2 applied to a fully fixed bottom longitudinal located outside of the slamming zone as shown in Fig. 4.1.1.

1.2 The bending moment is determined from Pt 8, Ch 3,1.14.1 of the Rules for Special Service Craft. For a fully fixed stiffener the maximum bending moment coefficient from Table 3.1.5(a) in Pt 8, Ch 3 of the Rules for Special Service Craft is 1/12.

1.3 Hence, maximum bending moment, M_s, is given by:

$$M_s = \frac{s\, l_e^2\, p}{12} \text{ Nm}$$

$$M_s = \frac{500 \times l^2 \times 70}{12} \text{ Nm}$$

$$M_s = 2917 \text{ Nm}$$

Assumed shell laminate:

5 x 800/300 combination mats

G_c = 0,5 (WR in combination mat)
t_{WR} = 0,979 mm
E_t = 14500 N/mm^2

G_c = 0,33 (CSM in combination mat)
t_{CSM} = 0,625 mm
E_t = 6950 N/mm^2

1 x 450 CSM adjacent to gel coat

G_c = 0,286
t_{CSM} = 1,112 mm
E_t = 6290 N/mm^2

Total thickness, t_p = 9,132 mm

The effective width of attached plating $2b_1$ from Pt 8, Ch 3,1.7.1 of the Rules for Special Service Craft for single skin construction is:

$b_1 = 0{,}5b_w + 10t_{ap}$
$= 0{,}5 \times 120 + 10 \times 9{,}132$
$= 151$ mm

Hence, apply 302 mm attached plating.

Consider typical layup over 'top hat' stiffener:

450 g/m^2 CSM @ G_c = 0,33 – first ply over former
800 g/m^2 WR @ G_c = 0,5
800 g/m^2 WR @ G_c = 0,5
600 g/m^2 UDT @ G_c = 0,54
600 g/m^2 UDT @ G_c = 0,54
800 g/m^2 WR @ G_c = 0,5
800 g/m^2 WR @ G_c = 0,5 – top ply

1.4 Consider the idealised section shown in Fig. 4.1.2.

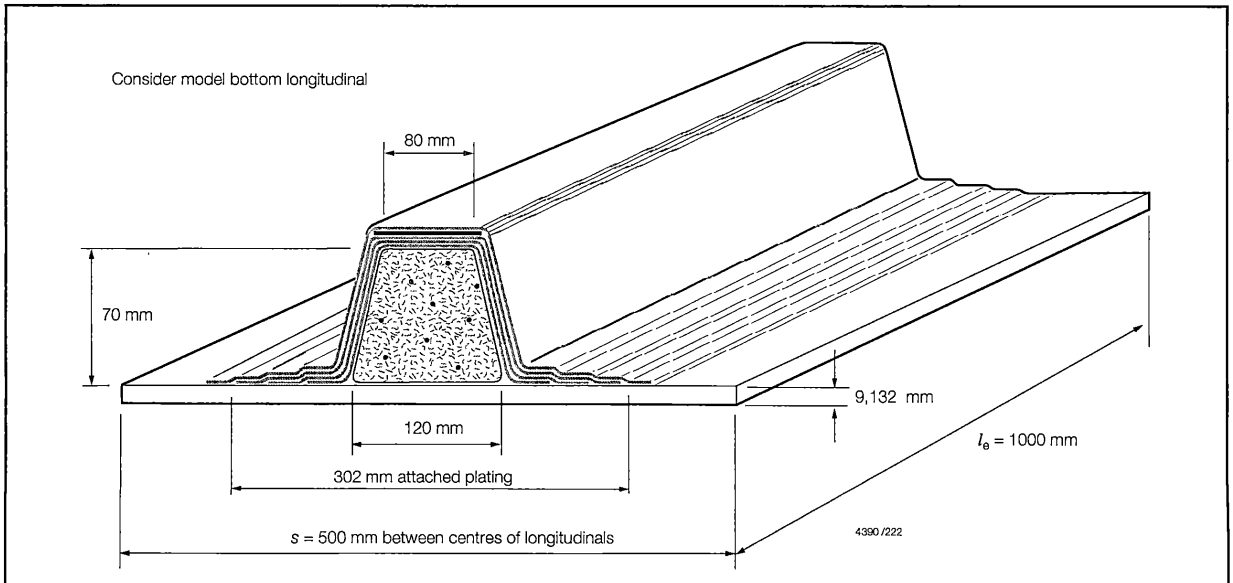

Fig. 4.1.1 'Top-hat' stiffener example model

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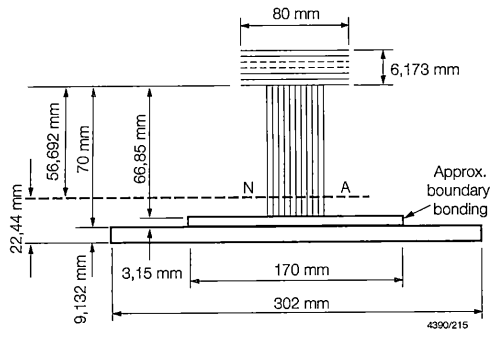

Fig. 4.1.2 Idealised section

1.5 The stiffener bonding is to be in accordance with Pt 8, Ch 3,1.18.6 of the Rules for Special Service Craft and a typical arrangement is shown in Fig. 4.1.3. To simplify the calculation of the stiffness of the overall section the tapered bonding is assumed to be an effective constant thickness. The effective thickness of the bonding is calculated as:

$$t_{bb} = \frac{(4{,}853 \times 25) + (4 + 3 + 2 + 1) \times 0{,}079 \times 15}{25 + (4 \times 15)}$$

$$t_{bb} = \frac{268{,}2}{85} = 3{,}15 \text{ mm}$$

The boundary bonding may be approximated to a thickness of 3,15 mm over an (85 x 2) mm width to account for both flanges. The majority of the flange comprises of woven rovings and it may be assumed that the tensile modulus is 145000 N/mm^2. The discrepancy is negligible since the element is very close to the neutral axis.

The effective depth and width of the web used in the idealised section are:

d_{web} = 70 – effective thickness on bonding
= 70 – 3,15
= 66,85 mm

t_{web} = 2 x (0,937 + 4 x 0,979)
= 2 x 4,853
= 9,706 mm

Now the web consists of two types of reinforcements, namely one ply of CSM and four plies of woven rovings. The majority of the web will be in compression and the overall modulus of elasticity may be calculated in accordance with Pt 8, Ch 3,1.13.5 of the Rules for Special Service Craft.

$$E_{web} = \frac{\Sigma (E_{ci}\, t_i)}{\Sigma\, t_i}$$

$$E_{web} = \frac{(0{,}937 \times 7200) + (0{,}979 \times 4 \times 14000)}{0{,}937 + (0{,}979 \times 4)}$$

E_{web} = 12687 N/mm^2

The web may now be treated as a single laminate item having an overall compressive modulus, given above.

1.6 The laminate section modulus calculation is shown in Table 4.1.1. The tabulation consists of each element having the compressive moduli in the section above the neutral axis and tensile moduli below. The actual breadth of each element must be entered to calculate the overall section properties. The tabulation corresponds to the idealised section in Fig. 4.1.2.

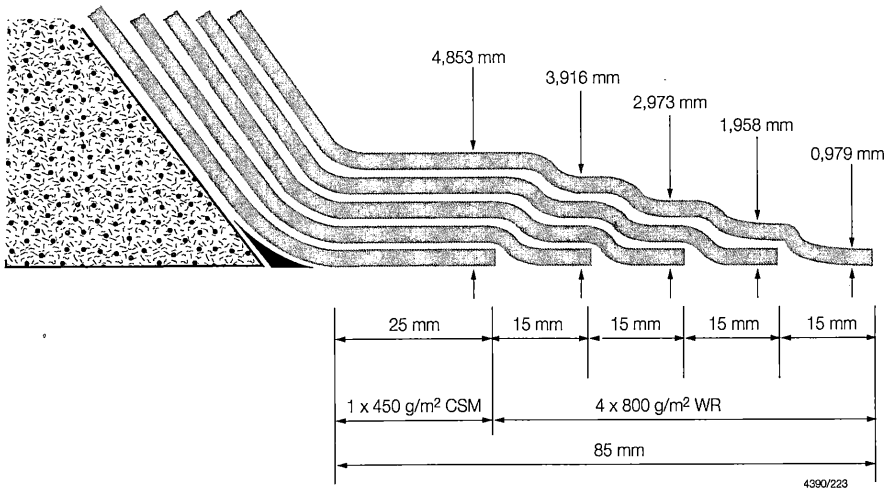

Fig. 4.1.3 Typical stiffener bonding arrangement

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Table 4.1.1 Initial tabulation of 'top-hat' stiffener calculations

	Ply No.	Description	G_c	Weight (g/m^2)	t (mm)	Breadth, b (mm)	Lever @ base, x (mm)	E (N/mm^2)	$t.b$	$E.t.b$	$E.t.b.x$	I @ base	EI @ base
Dry, *see* Note	1	WR	0,5	800	0,979	80	84,816	14000	78,32	1096480	92998499	563414,4	7887801805
	2	WR	0,5	800	0,979	80	83,837	14000	78,32	1096480	91925046	550483,0	7706761655
	3	UDT	0,54	600	0,660	80	83,017	20748	52,80	1095494	90944659	363890,1	7549992490
	4	UDT	0,54	600	0,660	80	82,357	20748	52,80	1095494	90221632	358127,2	7430422738
	5	WR	0,5	800	0,979	80	81,538	14000	78,32	1096480	89404238	520706,1	7289885632
	6	WR	0,5	800	0,979	80	80,559	14000	78,32	1096480	88330784	508277,4	7115883045
	7	CSM	0,33	450	0,937	80	79,601	7200	74,96	539712	42961345	474970,0	3419784035
	8	Web	0,5	–	66,85	9,706	45,707	12687	648,85	8231910	376255932	1597160,7	20263177372
	9	bonding	0,5	–	3,15	170	10,707	14500	535,50	7764750	83137178	61832,4	896570245
	10	WR	0,5	800	0,979	302	8,643	14500	295,66	4287041	37050752	22107,1	320553529
	11	CSM	0,33	300	0,625	302	7,840	6950	188,75	1311813	10285266	11609,3	80684330
	12	WR	0,5	800	0,979	302	7,039	14500	295,66	4287041	30174338	14670,7	212724485
	13	CSM	0,33	300	0,625	302	6,236	6950	188,75	1311813	8181119	7347,4	51064249
	14	WR	0,5	800	0,979	302	5,435	14500	295,66	4287041	23297924	8755,5	126954976
	15	CSM	0,33	300	0,625	302	4,632	6950	188,75	1311813	6076971	4056,7	28194272
	16	WR	0,5	800	0,979	302	3,831	14500	295,66	4287041	16421511	4361,7	63245002
	17	CSM	0,33	300	0,625	302	3,028	6950	188,75	1311813	3972824	1737,3	12074400
	18	WR	0,5	800	0,979	302	2,227	14500	295,66	4287041	9545097	1489,3	21594564
	19	CSM	0,33	300	0,625	302	1,424	6950	188,75	1311813	1868677	389,2	2704632
Wet, *see* Note	20	CSM	0,286	450	1,112	302	0,556	6290	335,82	2112333	1174457	138,4	870664
TOTALS					85,305				4436,05	53219882	1194228249		70480944121

NOTE
The crown of the stiffener is considered to be in compression in this example. 'Dry' indicates the face of the stiffener within the hull and 'wet' the outside of the shell laminate, *see* Fig. 4.1.4.

Position of neutral axis above base = $\frac{1194228249}{53219882}$ = 22,44 mm above base

Tensile modulus of elasticity of section = $\frac{53219882}{4436,05}$ = 11997 N/mm^2

Stiffness EI of section about NA = 4368304 N cm^4/mm^2

001717

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1.7 The tabulation considers the entire section and calculates all moments about the base, which is taken to be the outer (wet) surface. The stiffness, EI, of the entire section, about the neutral axis, is determined using the parallel axis theorem:

In general,

$I_{na} = I_{xx} - Ay^2$

$EI_{sect} = \Sigma EI_{base} - (\Sigma Etb) \times y^2$

where

y = distance of neutral axis above the base (mm)

From the tabulation:

$EI_{sect} = 70480944121 - 53219882 \times (22,44)^2$

$= 4368304336$ Nmm^4/mm^2

$EI_{sect} = 4,368 \times 10^6$ Ncm^4/mm^2

From Pt 8, Ch 3,1.15 of the Rules for Special Service Craft the individual layer stresses are determined from:

$$\sigma_{ti} = \frac{E_{ti}\, y_i\, M}{\Sigma (E_i\, I_i)} \times 10^{-1} \text{ N/mm}^2$$

The calculation of the stresses in individual layers becomes:

$$\sigma_{ti} = \frac{2917}{4,368 \times 10^6} \times E_i\, y_i \times 10^{-1} \text{ N/mm}^2$$

$\sigma_{ti} = 66,8 \times 10^{-6} \times E_i\, y_i$ N/mm^2

where

E_i = modulus of elasticity of layer (N/mm^2)

y_i = distance of layer from the neutral axis (mm)

The 'top-hat' stiffener is subjected to a load model shown in Fig. 4.1.4. The diagram indicates the areas of tension and compression that exist on either side of the stiffener.

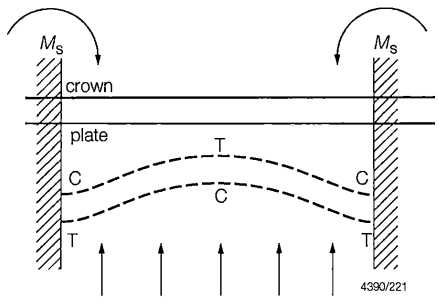

Fig. 4.1.4
Regions of tension (T) and compression (C) in example model

Section 2
Bending moment at fixed end of stiffener

2.1 The generalised stress equation is:

$\sigma_i = 66,8 \times 10^{-6} \times E_i\, y_i$ N/mm^2

The ultimate material properties may be found from Tables 3.1.1 and 3.1.2 in Pt 8, Ch 3 of the Rules for Special Service Craft and the limiting stress fractions from Table 7.3.1 in Pt 8, Ch 3 of the Rules for Special Service Craft.

2.1.1 Consider the crown of the stiffener:

(a) Consider the WR ($G_c = 0,5$) in compression:

$E_c = 14000$ N/mm^2

$y_i = 85,305 - 22,44$

$= 62,865$ mm

$\sigma_{WR\ comp} = 66,8 \times 10^{-6} \times 14000 \times 62,865$

$= 58,8$ N/mm^2

$\sigma_{WR\ ucs} = 147$ N/mm^2

Stress fraction = 58,8/147 = 0,40 hence reject.

(b) Consider the UDT ($G_c = 0,54$) in compression:

$E_c = 20748$ N/mm^2

$y_i = 85,305 - 22,44 - (2 \times 0,979)$

$= 60,907$ mm

$\sigma_{UDT\ comp} = 66,8 \times 10^{-6} \times 20748 \times 60,907$

$= 84,4$ N/mm^2

$\sigma_{UDT\ ucs} = 279$ N/mm^2

Stress fraction = 84,4/279 = 0,303 hence acceptable.

(c) Consider the CSM ($G_c = 0,33$) over the stiffener former in compression:

$E_c = 7200$ N/mm^2

$y_i = (85,305 - 22,44) - (4 \times 0,979) - (2 \times 0,66)$

$= 57,629$ mm

$\sigma_{CSM\ comp} = 66,8 \times 10^{-6} \times 7200 \times 57,629$

$= 27,7$ N/mm^2

$\sigma_{CSM\ ucs} = 122$ N/mm^2

Stress fraction = 27,7/122 = 0,227 hence acceptable.

2.1.2 Consider the loaded face of the shell:

(a) Consider the wet surface CSM ($G_c = 0,286$) in tension:

$E_t = 6290$ N/mm^2

$y_i = 22,44$ mm

$\sigma_{CSM\ tension} = 66,8 \times 10^{-6} \times 6290 \times 22,44$

$= 9,4$ N/mm^2

$\sigma_{CSM\ uts} = 91$ N/mm^2

Stress fraction = 9,4/91 = 0,10 hence acceptable.

Due to such a low stress fraction the adjacent CSM ($G_c = 0,33$) will also be acceptable.

(b) Consider the WR ($G_c = 0,5$) in tension:

$E_t = 14500$ N/mm^2

$y_i = 22,44 - 1,112 - 0,625$

$= 20,703$ mm

$\sigma_{WR\ tension} = 66,8 \times 10^{-6} \times 14500 \times 20,703$

$= 20,05$ N/mm^2

$\sigma_{WR\ uts} = 190$ N/mm^2

Stress fraction = 20,05/190 = 0,105 hence acceptable.

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2.2 However, the conclusion is that the compressive stress fraction in the WR in the crown of the stiffener is unacceptable. A number of options exist, which include:

(a) The use of higher strength materials such as carbon fibre or aramid reinforcements.
(b) Add UDT reinforcements in the crown of the stiffener.
(c) Laminate local collars at the end of the stiffeners to increase the section stiffness. This is usually labour intensive and not weight efficient.

2.3 Logically, for this example, the easiest solution is to add UDT reinforcements in the crown of the stiffener. Two additional UDT reinforcements have been included in the revised arrangement. The effect on the section stiffness of the revised schedule is shown in Table 4.2.1.

2.4 Recalculation of stress in the WR reinforcement in the stiffener crown using the revised section stiffness of 5200996 Ncm/mm^2:

$$\sigma_{ti} = \frac{2917}{5200996} \times E_i y_i \times 10^{-1} \text{ N/mm}^2$$

$$\sigma_{ti} = 56{,}09 \times 10^{-6} \times E_i y_i \text{ N/mm}^2$$

Consider the WR (G_c = 0,5) in the crown of the stiffener in compression:

E_c = 14000 N/mm^2
y_i = 86,625 – 24,926
= 61,7 mm
$\sigma_{WR\ comp}$ = 56,09 x 10^{-6} x 14000 x 61,7
= 48,4 N/mm^2
$\sigma_{WR\ ucs}$ = 147 N/mm^2

Stress fraction = 48,4/147 = 0,329 hence acceptable.

2.5 Re-consider the outermost UDT (G_c = 0,54) in compression:

E_c = 20748 N/mm^2
y_i = 86,625 – 24,926 – 0,979
= 60,720 mm
$\sigma_{UDT\ comp}$ = 56,07 x 10^{-6} x 20748 x 60,720
= 70,66 N/mm^2
$\sigma_{UDT\ ucs}$ = 279 N/mm^2

Stress fraction = 70,66/279 = 0,25 hence acceptable.

2.6 The example demonstrates that the additional two UDT's in the crown increases the section stiffness by 19 per cent and is accompanied by a movement in the neutral axis from 22,44 – 24,926 mm above the base. The stress fraction in the woven roving in the crown is reduced from 0,4 to 0,329 and meets the Rule requirement of 0,33.
Considerable care must be exercised when additional material radically affects the position of the neutral axis. For this reason the stress in the outermost UDT's has also been recalculated and found to be satisfactory.

2.7 Where aramid reinforcements are being used then special consideration must be given to the compressive properties. For comparison purposes aramid reinforcements, at a fibre content of 0,45, typically have the following properties:

	Tension	Compression
Ultimate strength (N/mm^2)	300	100
Elastic modulus (N/mm^2)	21000	17000

2.8 The radical reduction in ultimate compressive strength may prove to be unsuitable in the crown of the stiffener at the end or in the panel at mid span. Designs which feature aramid fibres in the outer plies of the panel, in an attempt to make use of the superior impact properties, must be checked at mid span for compression in the individual layers. This also applies to hybrid reinforcements containing aramid fibres. These reinforcements have one off properties of higher than one of the constituent fibres however, in service the individual allowable strains for each fibre reinforcement should not be exceeded.

2.9 In accordance with Pt 8,Ch 3,1.5.1 of the Rules for Special Service Craft, it is of paramount importance that the strain compatibility of the component materials is carefully considered.

2.10 Consider typical values of apparent strain, ε_a, at failure for the following materials in laminate form:

	Tension	Compression
'E' glass	1,3%	1,05%
Carbon fibre	0,9%	0,55%
Aramid fibre	1,3%	0,60%

2.11 The actual strain permissible is controlled by the material with the lowest apparent strain. The level of strain depends upon whether the reinforcements are in tension or compression and depends on their relative positions within the laminate. Consequently if, for example, a carbon fibre reinforcement is used in the crown of the stiffener then the compression strain must be constrained to a maximum of 0,33 x 0,55 per cent, i.e., 0,297 per cent. Therefore, the corresponding allowable stress in the other reinforcements must be related to the strain in the reinforcement relative to its position away from the neutral axis and that of the carbon fibre reinforcement, e.g.:

$$\varepsilon_{limitWR} = \frac{\varepsilon_{allowable\ carbon} \times y_{WR}}{y_{carbon}}$$

2.12 Other materials incoporated into stiffening members requiring strain compability consideration are plywoods, timbers, etc., which have very differing strains at failure dependent upon the direction of the grain.

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Table 4.2.1 Revised tabulation of 'top-hat' stiffener calculations including additional uni-directional reinforcements

	Ply No.	Description	G_c	Weight (g/m^2)	t (mm)	Breadth, b (mm)	Lever @ base, x (mm)	E (N/mm^2)	$t.b$	$E.t.b$	$E.t.b.x$	I @ base	EI @ base
Dry, *see* Note	1	WR	0,5	800	0,979	80	86,136	14000	78,32	1096480	94445853	581087,7	8135228350
	2	UDT	0,54	600	0,660	80	85,316	20748	52,80	1095494	93463200	384323,6	7973946157
	3	WR	0,5	600	0,979	80	84,497	14000	78,32	1096480	92648722	559184,3	7828580341
	4	UDT	0,54	600	0,660	80	83,677	20748	52,80	1095494	91667685	369699,1	7670516637
	5	UDT	0,54	600	0,660	80	83,017	20748	52,80	1095494	90944659	363890,1	7549992490
	6	WR	0,5	800	0,979	80	82,198	14000	78,32	1096480	90127915	529169,8	7408376853
	7	UDT	0,54	600	0,660	80	81,378	20748	52,80	1095494	89149143	349663,5	7254818749
	8	WR	0,5	800	0,979	80	80,559	14000	78,32	1096480	88330784	508277,4	7115883045
	9	CSM	0,33	450	0,937	80	79,601	7200	74,96	539712	42961345	474970,0	3419784035
	10	web	0,5	–	66,850	9,706	45,707	12687	648,85	8231910	376255932	1597160,7	20263177372
	11	bonding	0,5	–	3,150	170,000	10,707	14500	535,50	7764750	83137178	61832,4	896570245
	12	WR	0,5	800	0,979	302	8,643	14500	295,66	4287041	37050752	22107,1	320553529
	13	CSM	0,33	300	0,625	302	7,840	6950	188,75	1311813	10285266	11609,3	80684330
	14	WR	0,5	800	0,979	302	7,039	14500	295,66	4287041	30174338	14670,7	212724485
	15	CSM	0,33	300	0,625	302	6,236	6950	188,75	1311813	8181119	7347,4	51064249
	16	WR	0,5	800	0,979	302	5,435	14500	295,66	4287041	23297924	8755,5	126954976
	17	CSM	0,33	300	0,625	302	4,632	6950	188,75	1311813	6076971	4056,7	28194272
	18	WR	0,5	800	0,979	302	3,831	14500	295,66	4287041	16421511	4361,7	63245002
	19	CSM	0,33	300	0,625	302	3,028	6950	188,75	1311813	3972824	1737,3	12074400
	20	WR	0,5	800	0,979	302	2,227	14500	295,66	4287041	9545097	1489,3	21594564
	21	CSM	0,33	300	0,625	302	1,424	6950	188,75	1311813	1868677	389,2	2704632
Wet, *see* Note	22	CSM	0,286	450	1,112	302	0,556	6290	335,82	2112333	1174457	138,4	870664
TOTALS					86,625				4541,65	55410871	1381181352		86437539378

NOTE: 'Dry' indicates the face of the stiffener within the hull and 'wet' the outside of the shell laminate, *see* Fig. 4.1.4. Consider the crown of the stiffener in compression.

Position of neutral axis above base = $\frac{1381181352}{55410871}$ = 24,926 mm above base

Tensile modulus of elasticity of section = $\frac{55410871}{4541,65}$ = 12201 N/mm^2

Stiffness EI of section about NA = 5200996 N cm^4/mm^2

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Section 3
Web thickness to meet shear requirement

3.1 Ultimate shear stress from Table 3.1.2 in Pt 8, Ch 3 of the Rules for Special Service Craft. From the web thickness (4,853 mm) given in 1.5 and the web laminate schedule given in Fig. 4.1.3 (i.e. total weight of 3650 g/m^2) the effective glass content may be calculated, by transforming the relationship given in Pt 8, Ch 4,1.6.1 of the Rules for Special Service Craft. The effective glass content of the web is therefore 0,47.

$\tau_S = 80\,G_c + 38 = 76$ N/mm^2

From Pt 8, Ch 7, Table 7.3.1 of the Rules for Special Service Craft.
Limiting shear stress fraction = 0,33
Limiting shear stress = 0,33 x 76 = 25,08 N/mm^2.

3.2 The shear stress requirement is given in Pt 8, Ch 3,1.14.3 of the Rules for Special Service Craft. By setting the shear stress to the limiting shear stress the equation may be rearranged:

$t_w = F_S/(2 \times d_w \times \tau_S)$ mm

The actual shear load is given in Pt 8, Ch 3,1.14.2 of the Rules for Special Service Craft.

$F_s = \phi_S\, p\, s\, l_e$ N

The shear stress coefficient is obtained from Table 3.1.5 in Pt 8, Ch 3 of the Rules for Special Service Craft.

$F_s = 0{,}5 \times 70 \times 500 \times 1 = 17500$ N

Consequently, the minimum web thickness to meet the Rule requirement is:

$t_w = 17500/(2 \times 70 \times 25{,}08) = 4{,}98$ mm

The actual web thickness is 4,853 mm. The deficiency is only 0,127 mm and is considered acceptable.

3.3 Finally, check the minimum Rule requirement for web thickness. From Pt 8, Ch 3,1.16.2 of the Rules for Special Service Craft.

$$t_w = \frac{0{,}025\, d_w + 1{,}1}{1{,}3\, f_w + 0{,}61}$$

For a web depth of 70mm and fibre content of 0,47 the minimum web thickness is 2,33 mm. Hence the minimum requirement is fulfilled.

Section 4
Calculation of deflection

4.1 The deflection is calculated from Pt 8, Ch 3,1.14.5 of the Rules for Special Service Craft. From the tabulation the overall section stiffness is $(EI)_s = 5200996$ Ncm^4/mm^2

$$\delta_s = \frac{\phi_S\, p\, s\, l^4}{(EI)_s} \times 10^5 \text{ mm}$$

$$\delta_s = \frac{1}{348}\ \frac{70 \times 500 \times 1^4}{5200996} \times 10^5 \text{ mm}$$

$\delta_s = 1{,}93$ mm.

4.2 The limiting span/deflection ratio is given in Table 7.2.1 in Pt 8, Ch 7 of the Rules for Special Service Craft and typically for a bottom longitudinal (not in the slamming zone) the ratio required is 150.

Span/deflection ratio = length/mid-point deflection
= 1000/1,7
= 588 hence acceptable.

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Guidance Notes for the Classification of Special Service Craft

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GUIDANCE NOTES ON DESIGN DETAILS

Chapter 1 General Introduction

2 Guidance for Designers for Steel/Aluminium Construction

3 Construction Tolerances and Defect Correction Procedures for Steel/Aluminium Construction

4 Detail Design Improvement for Steel/Aluminium Construction

5 Detail Design Improvement for Composite Construction

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Section

1 **Introduction**

2 **Fatigue - General considerations**

Section 1 Introduction

1.1 Purpose of the Guidance Notes

1.1.1 With the advent of novel and high speed craft types the need for good structural detail has never been more important. Most structural failures that occur in the service life of a craft result from fatigue. A considerable amount of published data exists for more conventional steel vessels, however, little or no such data exists for the novel or high speed craft constructed from aluminium alloy or composite materials. Lloyd's Register (hereinafter referred to as LR) has amassed considerable knowledge in respect of structural detail which has demonstrated satisfactory service experience in resisting structural failure from fatigue. The details contained within these Guidance Notes are therefore provided to assist Builders and designers in identifying a minimum level of design detail which has provided acceptable levels of resistance to structural failure arising from fatigue.

1.1.2 It is not intended that the details contained within these Guidance Notes are the only solution to a particular structural design. Alternative structural details that have demonstrated satisfactory service experience will be acceptable.

1.2 General

1.2.1 Quality of detail design is fundamental if the craft's envisaged design life is to be attained. Experience over the past two decades, when structural concepts were revolutionised and aspects such as speed greatly increased, clearly indicated that areas of detail design became more prone to fatigue cracking with the traditional structural arrangements for details being used at that time.

1.2.2 Service experience has shown that provided the general concepts of a structural design are adequate then success or failure in structural terms will depend on the quality of detail design.

1.2.3 In general, the problems associated with aspects of detail design are those relating to fatigue ageing and failure.

1.2.4 Fatigue is failure under repeated loads. There are three phases in a fatigue fracture: crack initiation, crack propagation, and fracture. These phases are not completely separable. The process may be described as the formation of a crack, because of repeated local plasticity, its progression until a critical size is reached, where upon the structure fails. Fatigue accounts for a large percentage of all service failures.

1.2.5 A structural element can be subjected to various kinds of loading conditions, including fluctuating stress/strain, fluctuating temperature (thermal stress/strain), or any of these in a corrosive environment or at elevated temperatures. Most service failures occur as a result of tensile stresses.

1.2.6 Fatigue cracks generally initiate at high stress locations such as structural discontinuities, weld toes, matting in connections, etc. As these cracks propagate the ultimate load carrying capability of the structure is reduced until sufficient fatigue damage is accumulated for the structure to fail at normal working loads. Since fatigue cracks can be possible points of initiation for catastrophic failures or costly craft repairs, it is essential that fatigue is given more detailed consideration in the design of the structure.

1.2.7 Fatigue ageing of structural components is an accumulative process which is largely due to the environment and the loads experienced. An important realisation is that it is inevitable and where stress concentrations are present in association with significant magnitudes of stress variation then fatigue cracking will, in general, occur. Factors which influence performance, in that they affect the magnitude of stress ranges and provide stress concentrations, are as follows:

(a) The loading experienced.
(b) The quality of detail design.
(c) The selecting of the type and grade of material.
(d) The standard of workmanship in the craft construction.
(e) Corrosion rates and magnitudes (metallic structures).
(f) Erosion rates and magnitudes (composite structures).

1.2.8 Since the fatigue properties of higher tensile strength metallic materials are, in general, similar to those of the basic grade materials, the higher allowable stress magnitudes could entail a shorter fatigue life in standard details. Assuming that the fatigue life is a function of the stress range to the third power, it is clear that detail design requires special consideration to reduce the effects of stress concentrations. If higher tensile strength materials are incorporated and hence higher stress levels are accepted, then structural details, which would have been acceptable in mild steel structure manufactured from the basic grade material, might not be adequate.

1.2.9 The occurrence of cracking in craft is of prime concern from both a safety and maintenance point of view. Experience has shown that fatigue cracks in craft structures are normally of a self limiting nature. However, the existence of fatigue cracking may, if not repaired, render the structure susceptible to subsequent brittle or fast fracture. Thus both types of cracks are significant from a maintenance point of view. Fatigue cracks, if not repaired, may also initiate catastrophic failure as a consequence of the more extensive use of structural optimisation leading to a decrease in the level of structural redundancy.

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Section 2
Fatigue – General considerations

2.1 Basis of the Guidance Notes

2.1.1 In assessing fatigue performance, the effect of cyclic loading should be taken into consideration. The types of cyclic loading experienced in service, will, in general, depend upon the size, type and speed of the craft. Cyclic wave induced loads created by the passage of waves along the craft sides and the associated local structural response create the highest risk for fatigue damage and cracking for large craft whereas, the major consideration for small high speed craft will relate to impact considerations, hard spots and discontinuities in the structure, etc.

2.1.2 Loading associated with bottom structures, in terms of hull girder response and local pressure variation, are heavily influenced by the length of waves and their direction in relation to the craft length and draught. Similarly, the deck structure is exposed to hull girder loads in response to relatively longer waves and cargo local loads arising from craft responses. Alternatively, these can be associated with structural discontinuities and slamming in shorter waves.

2.1.3 Deck and bottom longitudinal structure require attention to detail design and structural continuity to reduce the effects of stress concentration. Depending on the type of craft, the side shell structure may be exposed to dynamic loading from the internal pressure head from storage of consumables or cargo, in association with wave induced pressure variations, resulting in high cycle local bending stresses applied to the longitudinals and connection details at the transverse bulkhead stiffeners. This may transfer moments resulting in further increased stresses in the side longitudinals.

2.1.4 Every stress concentration and welded joint is a potential source of fatigue cracking and the design, taking note of symmetry, should reflect this. To ensure the structural integrity of the stiffening members particular attention should be given to the detail design. This document provides initial design guidance on fatigue and includes recommendations for the improvement of welded joint fatigue strength, or the bonded joint fatigue strength in the case of composite structures.

2.1.5 The fatigue strength of a structural detail is dependent on the following factors:

(a) The direction of the fluctuating stress relative to the detail.
(b) The location of initiating crack in the detail.
(c) The geometrical arrangements and relative proportion of the detail.

It may also depend on:

(d) The material (unless welded).
(e) The method of fabrication.
(f) The degree of inspection.

2.2 Fatigue mechanism

2.2.1 Fatigue damage starts prior to the initiation of a crack. With repeated loading, localised regions of slip (plastic deformation) develop. These deformations are accentuated by repeated loading, until a discernable crack finally appears.

2.2.2 The initial cracks form along slipped planes. The crack is crystallographically oriented along the slip plane for a short distance. This is sometimes referred to as Stage I crack growth. Eventually the crack propagation direction becomes macroscopically normal to the maximum tensile stress. This is referred to as Stage II crack propagation, and it comprises most of the crack propagation life.

2.2.3 The relative cycles for crack initiation and propagation depend on the applied stress. As the stress increases, the crack initiation phase decreases. At very low stresses (high cycle fatigue), therefore, most of the fatigue life is utilised to initiate a crack. At very high stresses (low cycle fatigue), cracks form very early. The separation of high and low cycle fatigue is not clear-cut. Generally, the low cycle region is that which results from stresses that are often high enough to develop significant plastic strains. It is usually assumed that the separation zone for low and high cycles is of the order of $10^4 - 10^5$ cycles to failure.

2.2.4 There are visual differences between high cycle (low stress) and low cycle (high stress) fatigue. In the latter, deformation resembles that seen with unidirectional loading. Strain hardening can occur and the slip bands are coarse. In high cycle fatigue, the slip bands are usually very fine.

2.3 Allowable stresses

2.3.1 For a particular craft component the allowable stresses should be in accordance with the requirements of LR's *Rules and Regulations for the Classification of Special Service Craft* (hereinafter referred to as the Rules for Special Service Craft).

2.4 Design loads

2.4.1 Applied design loads must take into consideration the appropriate environmental and dynamic conditions. Such loads are indicated in Part 5 of the Rules for Special Service Craft.

2.4.2 Realistic assessment of the fatigue loading is crucial to the estimation of fatigue life. Little or no published data for loading exists for the types of craft covered by the Rules for Special Service Craft. LR is conducting research in this field, the results of which will form the basis of Rules for Special Service Craft requirements in the future.

2.5 Stress concentrations

2.5.1 The design, fabrication and construction of all structural details should be based on procedures and processes to minimise stress concentrations.

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2.5.2 Fatigue strength is seriously reduced by the introduction of a stress raiser such as a notch, of the method of termination of stiffeners and brackets, etc., or a hole. Since actual hull structure elements invariably contain stress raisers like fillet welds, end brackets, cut-outs, etc., it is not surprising to find that fatigue cracks in structural parts usually start at such geometrical irregularities. One of the most effective ways of minimising fatigue failure is by the reduction of avoidable stress raisers through careful design and the prevention of accidental stress raisers by careful processing and fabrication. While this section is concerned with stress concentrations resulting from geometrical discontinuities, stress concentration can also arise from surface roughness and metallurgical stress raisers such as porosity, inclusions, local overheating in grinding and decarburisation, etc., as appropriate to the construction material.

2.5.3 The effect of stress raisers on fatigue under uniaxial loading is that;

(a) there is an increase or concentration of stress at the root of the notch,
(b) a stress gradient is set up from the root of the notch,
(c) a triaxial state of stress is produced.

2.5.4 The ratio of the maximum stress to the nominal stress is the Stress Concentration Factor.

2.5.5 Values of the stress concentration factor will vary depending upon:

(a) the severity of the notch,
(b) the type of notch,
(c) the material,
(d) the type of loading, and
(e) the stress level.

2.6 Stiffness

2.6.1 Abrupt changes in stiffness of the structure should be avoided as they can induce local stress concentrations and reductions of fatigue life.

2.7 Vibration

2.7.1 If possible, precautions should be taken in the design against the possibility of excessive structural vibration being induced, for example, by machinery. This would entail investigation of the natural frequencies of the panel members and of the sources of excitation.

2.8 Potential modes of failure

2.8.1 The potential modes of fatigue failure are dependent upon the direction of the applied stress relative to the position of the weld and the position of stress concentrations due to structural discontinuities.

2.8.2 For longitudinal butt welds in plates, dressed flush, and lying parallel to the direction of applied stress, the initiation of potential fatigue failures is expected to be found at weld defect locations. In the 'as-welded' condition, fatigue cracks may be initiated at the weld start-stop positions or, weld surface ripples.

2.8.3 For transverse butt welds in plates, essentially perpendicular to the direction of applied stress, the fatigue strength depends largely upon the shape of the weld profile. Fatigue cracks normally initiate at the weld toe.

2.8.4 Cruciform fillet weld joints associated with the four way connection of plate or stiffeners, may be separated into two distinct types depending on whether or not the fillet weld transmits direct load i.e. non-load carrying or load carrying cruciform joints. In the case of the non-load carrying cruciform joint, the fatigue crack will initiate at the weld toe and propagate through the thickness of the load bearing plate in a plane perpendicular to the direction of the applied stress.

2.8.5 In load carrying cruciform joints, in addition to the weld toe, acute stress concentration occurs at the root of the fillet weld and generally fatigue cracks are initiated at the root of the weld and propagate through the weld throat. The fatigue life of such connections can be improved either by increasing the throat size of the fillet weld or by requiring improved weld penetration. In high stress regions however, such measures may not be adequate and there is then a need to specify a full penetration weld in order to achieve the necessary fatigue life for the joint.

2.8.6 Tee joints, since they represent a semi-cruciform joint in a three way connection of plates or stiffeners, would be expected to demonstrate similar fatigue characteristics to the load bearing cruciform joint. However, if bending stresses are induced in the base plate material of the tee, which are of a similar or greater magnitude than the direct stress in the tee, then a fatigue crack may initiate in the base plate at the toe of the fillet weld and propagate through the base plate.

2.8.7 Where tee or cruciform connections employ full penetration welds, and the plate material is subject to significant strains in a direction perpendicular to the rolled surfaces, it is recommended that consideration be given to the use of special plate material with specific through thickness properties, as detailed in Ch 3,8 of the *Rules for Manufacture, Testing and Certification of Materials* (hereinafter referred as the Rules for Materials).

2.8.8 For welded stiffeners and girders, fatigue cracks can be expected to be initiated at weld toes and may be associated with local stress concentrations at the weld ends of connecting end brackets or stiffeners.

2.8.9 The most common sites for potential fatigue cracks therefore are:

(a) Toes and roots of fusion welds.
(b) Machined corners.
(c) Drilled holes, cut-outs or other openings.

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2.8.10 The main conditions affecting fatigue performance are:

(a) High ratios of dynamic to static loads.
(b) Loading frequency.
(c) Material selection.
(d) Welding.
(e) Complexity of joint detail.
(f) Environment.

2.8.11 For craft operating for long periods in low air temperatures, or high temperatures for composites, the material of exposed structures will need to be specially considered.

2.9 Welds

2.9.1 Some commonly used weld details have low fatigue strength. This applies not only to joints between members, but also to any attachment to a loaded member, whether or not the resulting connections are considered to be structural.

2.9.2 The heat-affected zone (HAZ) is of great importance to the fatigue strength of welds because this is usually the region where a fatigue crack will develop. Moreover, when the reinforcement of a butt weld is not removed, or when fillet welds are used, a resulting sudden change of section occurs, and stress concentrations occur at the weld toe.

2.9.3 For the specification of welding and structural details, *see* Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft for steel and aluminium alloy craft respectively.

2.10 S-N curves

2.10.1 A material's fatigue characteristics are fatigue strength and fatigue limit.

2.10.2 The fatigue strength is the stress value beyond which the material will fail at a specified number of stress cycles.

2.10.3 The fatigue limit is the fatigue strength corresponding to an infinite number of stress cycles.

2.10.4 The S-N curve represents the dependence of the life of the 'specimen' in a number of cycles, N, to the maximum applied stress, S. N is usually taken (unless specified otherwise) as the number of stress cycles to cause a complete fracture in the 'specimen'.

2.10.5 Usually no distinction is made between the number of cycles to initiate a crack and the number of cycles to propagate the crack completely through the specimen, although it can be appreciated that the number of cycles for crack propagation will vary with the dimensions of the specimen. Fatigue tests for high cycle fatigue are usually carried out for $10^5 - 10^7$ cycles and sometimes to 5×10^8 cycles for non-ferrous metals. For a few important engineering materials such as steel and titanium, the S-N curve becomes horizontal at a certain limiting stress. Below this limiting stress, which is called the fatigue limit, or endurance limit, the material can presumably endure an infinite number of cycles without failure.

2.11 Complexity of joint detail

2.11.1 Complex joints frequently lead to high stress concentrations due to local variations on stiffness and load path. Whilst these may have little effect on the ultimate static capacity of the joint they can have a severe effect on fatigue resistance.

2.11.2 If fatigue control is the dominant criteria, the member cross-sectional shape should be selected to ensure smoothness and simplicity of joint design, so that stresses can be calculated and adequate standards of fabrication and inspection assured.

2.11.3 The best fatigue behaviour will be obtained by ensuring that the structure is detailed and constructed so that stress concentrations are kept to a minimum and that, where possible, the elements may deform without introducing secondary deformations and stresses due to local restraints.

2.11.4 Stresses may be reduced by increasing the thickness of the parent metal and this would theoretically increase fatigue life due to a reduction of the nominal stresses. However, it should be borne in mind that fatigue strength decreases, in general, with increasing thickness.

2.12 Surface properties

2.12.1 Since fatigue failure is dependent on the condition of the surface, anything that changes the fatigue strength of the surface material will greatly alter the fatigue properties.

2.12.2 As an example most mechanically finished metallic parts have a shallow surface layer in residual compression. Aside from the effect on surface roughness, the final surface finishing process will be beneficial to fatigue when it increases the depth and intensity of the compressively stressed layer and detrimental when it decreases or removes this desirable layer. Thus sandblasting, glass bead peening, burnishing, and other similar operations generally improve fatigue properties.

2.13 Residual stress

2.13.1 Residual stresses arise when plastic deformation is not uniform throughout the entire cross section of the detail being deformed. They therefore comprise a system of internal stresses in the material balanced within the material itself and can exist in the absence of any external loading. Thus if there is an area of tensile residual stress in any cross section at one part of a material there must be a residual compressive stress at some other point. There would in addition be a variation of stress through the thickness of the material, particularly for thicker sections.

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2.13.2 In a welded joint residual stresses are induced as a consequence of local heating and cooling cycles associated with the welding procedure and in particular the shrinkage of the weld metal. The actual situation in a welded joint is complicated by practical factors such as the type and size of joint, the welding process used and the weld procedure. In a butt weld for example, high residual tensile stress will exist in the direction of the weld and at right angles to it. In the case of multi-pass or high energy welding these residual stresses may reach the level of the yield strength of the material. As such tensile residual stresses can occur in locations where fatigue cracks are likely to initiate, it will be appreciated that they can lead to a proportional reduction in the fatigue strength of a joint when it is subjected to additional dynamic tensile loads.

2.14 Compressive residual stress

2.14.1 The formation of a favourable compressive residual-stress pattern at the surface is probably the most effective method of increasing fatigue performance. As indicated in 2.13, residual stresses are locked-in stresses which are present in a part which is not subjected to an external force. Only macro-stresses, which act over regions which are large compared with the grain size, are considered here.

2.14.2 In general, for a situation where part of the cross section is deformed plastically while the rest undergoes elastic deformation, the region which was plastically deformed in tension will have a compressive residual stress after unloading, while the region which was deformed plastically in compression will have a tensile residual stress when the external force is removed. The maximum value of residual stress which can be produced is equal to the elastic limit of the metal.

2.14.3 The high compressive residual stresses at the surface must be balanced by tensile residual stresses over the interior of the cross section.

2.14.4 The improvement in fatigue performance, which results from the introduction of surface compressive residual stress, will be greater when the loading is one in which a stress gradient exists than the case when no stress gradient is present.

2.14.5 It is important to recognise that improvements in fatigue properties do not automatically result from the use of shot peening or surface rolling. It is possible to damage the surface by excessive peening or rolling.

2.14.6 In order for the desirable effect of surface cold working to be maintained, the cold-working process must be accomplished in the final heat-treated condition and subsequent thermal treatment eliminated when feasible and closely controlled when essential. Exposure of cold-worked surfaces to elevated temperature initially results in stress relief of the plastically deformed zone and ultimately in recovery or perhaps re-crystallisation of the work-hardened area, with complete loss of the desirable residual stress gradient.

2.15 Grinding

2.15.1 There are some processes that are capable of developing high localised surface temperatures which are often difficult to detect and occasionally are responsible for a failure in service. Grinding can be one of these processes.

2.15.2 The rapid quenching of the material immediately below the grinding wheel by the large mass of cold metal can produce cracks or 'check'. High strength steels (for which grinding is most often used) are particularly sensitive to grinding techniques.

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Guidance for Designers for Steel/Aluminium Construction

Section

1 **Introduction**

2 **Fatigue strength improvement methods**

■ *Section 1* Introduction

1.1 Definition

1.1.1 **Critical areas** can be defined as locations that, by reason of stress concentration, alignment/discontinuity and corrosion will have a higher probability of failure during the life of the craft than the surrounding structures. **Critical locations** are defined as the specific locations within the critical area that can be prone to fatigue damage for which design improvements are provided.

1.2 General

1.2.1 In order to assist the designer to minimise fatigue failures, LR has developed an extensive database on structural detail design aspects.

1.2.2 Utilising the results from detailed finite element analyses for an extensive range of structural details it has been possible to examine a variety of configurations for each detail thereby enabling a grading to be made of their relative fatigue performance.

1.2.3 The outcome from some of this work has been condensed into these Guidance Notes. It is intended as a conservative approach to improving the fatigue life performance of structural details.

1.2.4 The designer may therefore, using these Guidance Notes, readily upgrade the detail design arrangements to provide a higher fatigue performance configuration.

1.2.5 It is intended that the detail design database given in Chapter 4 will be extended to incorporate further detail arrangements, to reflect in-service experience of their fatigue performance, design and construction practice, as well as any significant data made available from research studies.

1.2.6 In addition, guidance is provided to the designer and Builder on other methods to improve the fatigue life performance of the structural detail such as detail geometry, construction tolerances, welding sequence, weld defect, weld dressing, etc.

1.3 Application

1.3.1 The detail design improvements provided in these Guidance Notes are applicable to all grades of steel, commonly used aluminium alloys and composite structures. This is because the fatigue life improvement will be achieved through the suggested change of **geometry** which will reduce the stress concentrations and the **improved construction** requirements which will improve the performance throughout the design lifetime of the structural detail under the expected stress variations.

1.3.2 In areas where **mild steel** and basic grade aluminium may be used a number of the suggested detail improvements may not be necessary due to the lower stress ranges that the details are designed to experience. However, in areas where **higher tensile steel** (HTS) or higher strength grade aluminium are used, the operating stresses will generally be higher. Therefore the detail improvements suggested may become necessary in order to meet the fatigue strength of the structure.

1.3.3 **Alternative structural arrangements** will, in general, be acceptable provided it can be demonstrated, that a satisfactory fatigue life performance will be maintained throughout the design life span. In addition the structural arrangements and scantlings are to satisfy the Rules for Special Service Craft.

1.3.4 Where suggested values are indicated regarding geometries or scantlings, these are given as guidance.

■ *Section 2* Fatigue strength improvement methods

2.1 General

2.1.1 In general, the presence of a weld or a bonded joint in a structural component represents a possible weakness with regard to both brittle fracture and fatigue life. The low fatigue life of welded details can be considered as a limiting factor for the design of more efficient structures, in particular, since the fatigue strength of steel and aluminium materials does not increase with the yield strength.

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2.1.2 Upgrading of the fatigue life of a structural detail can be achieved in a number of ways as follows:

Design Stage
- By adopting good detail design configuration, i.e., by the provision of soft connections, the geometrical stress concentration factor due to the geometrical discontinuity may be reduced to a satisfactory level.
- By increasing the local scantlings, in particular those of the plate in which the potential crack sites are located, to reduce the local hot spot stresses.
- By modifying the structural load path and/or reducing the structural load level by the provision of additional load carrying members.

Fabrication Stage
- By improving the fatigue life of the detail by using an improvement method.

2.1.3 It is LR's intention to promote the Design Stage method for fatigue strength improvement of a craft's structural details. Fabrication stage improvement methods should only be considered as remedial measures, and subjected to strict quality control procedures. Where a fabrication stage improvement method is planned at the design stage, it is to be specially considered by LR to ensure that a satisfactory level of fatigue strength improvement is achieved.

2.2 Significant variables affecting fatigue strength improvement methods

2.2.1 The significant variables affecting the fatigue strength of a craft's structural details are reviewed:
- The geometrical notch at the weld toe region is normally the most fatigue critical area. Welded joints inherently contain a number of defects, most of which are so sharp that they start growing as fatigue cracks when the structure is subjected to dynamic loads, thus eliminating the crack initiation stage of the fatigue life.
- The fatigue crack is most likely to initiate and propagate in the Heat Affected Zone (HAZ) region, since local metallurgical changes may affect the local fatigue properties of the material, and defects are usually concentrated in this area.
- Residual stresses are set up in and near the weld due to the contraction of the weld metal during the cooling phase. These local residual stresses due to welding may reach yield stress magnitude, and affect the fatigue properties in a similar manner to externally imposed loads. Tensile residual stresses tend to reduce the fatigue strength, while compressive residual stresses may improve the fatigue strength. Attention to residual stresses is not only limited to the welding process, residual stresses may arise due to the restraints applied to the prefabricated units, the forcing of the prefabricated units during assembly, or uneven thermal expansion creating long range residual stresses acting over large areas. These long range residual stresses tend not to be relaxed by the occurrence of peak loads resulting in the so called shakedown process, or local treatment of the structural detail. However, they are generally of small magnitude compared to welding residual stresses.

2.3 Design stage fatigue strength improvement methods

2.3.1 It is clear that the most efficient method to improve the fatigue strength of welded structural details is at the design stage. To this effect, there are four factors which need to be specially considered to improve the fatigue strength of ship structural details as follows:
- Nominal stress level.
- Geometrical stress concentration due to the structural detail geometry.
- Weld geometry and construction tolerances.
- Residual stresses and construction procedure.

Each item outlined above is presented in the following Sections.

2.3.2 Nominal stress level

The most efficient way to improve fatigue strength is to increase the local scantling to reduce the nominal stress level, and hence the hot spot stress for a given structural detail. In general, structural details on higher tensile steel and aluminium require improvement in detail design over the mild steel and the base grade aluminium equivalent structural detail by virtue of the higher stress level and the constant fatigue strength for material of various yield strength.

The advantages and disadvantages of this fatigue strength improvement method are summarised in Table 2.3.1.

Table 2.3.1 Nominal stress level

Advantages	Disadvantages
• Reduce stress level. • Increase static strength. • Potential decrease in number of structural components and/or complexity required over that for a structural detail in higher tensile strength material.	• Increase structure weight.

2.3.3 Geometrical stress concentration

The adoption of a good detail design configuration by the provision of soft connections reduces the geometrical stress concentration factor due to the geometrical discontinuity to a satisfactory level. Typical detail design improvements for the critical areas are provided in Chapters 4 and 5 of these Guidance Notes for steel/aluminium alloy and composite construction respectively. These detail design improvements have been developed from the consolidation of service experience and finite element analysis.

The advantages and disadvantages of the subject fatigue improvement method are summarised in Table 2.3.2.

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Table 2.3.2 Geometrical stress concentration

Advantages	Disadvantages
• Reduce hot spot stress level by reducing the local geometrical stress concentration. • Most effective fatigue strength improvement technique. • May provide additional structural redundancy.	• May increase structural weight if additional pieces are required. • Requires good workmanship where soft toe/heel are required.

2.3.4 Weld geometry and construction tolerances

At the design stage, special attention may be given to achieving a favourable geometry and smooth transition at the weld toe, and minimising secondary stress concentration which may arise from the fit up and misalignment. Since the weld notch stress concentration is a direct function of the weld flank angle and the weld toe radius, critical structural details may be specified with an enhanced weld procedure and construction tolerances.

In view of the size and hull form of special service craft, additional considerations must, in general, be given to the accessibility for welding. This should include the selection of the depth, geometry and orientation of the stiffening members to provide the necessary access to carry out the required welding sequences, with the type and size of welding equipment available to the Builder.

The advantages and disadvantages of the subject fatigue improvement method are summarised in Table 2.3.3.

Table 2.3.3 Weld geometry and construction tolerances

Advantages	Disadvantages
• The improvement may be introduced at the design stage. • The improvement is performed in the welding process itself. • Subject to well defined inspection plan and hence higher reliability.	• Improvement can be subject to large scatter if not controlled under QA survey conditions i.e., Fatigue Control Plan.

2.3.5 Residual stresses, and construction procedures

The minimising of residual stresses through the adoption of appropriate welding procedures and sequences, the use of adequate unit size, and appropriate sequence of erection of the prefabrication unit do not constitute in themselves a fatigue strength improvement procedure. Nevertheless careful planning should be considered at the design stage to ensure that detrimental effects will not be introduced during the construction process.

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Construction Tolerances and Defect Correction Procedures for Steel/Aluminium Construction

Section

1 **Introduction**

2 **Construction tolerances**

3 **Defect correction procedures**

■ *Section 1* Introduction

1.1 General

1.1.1 The fatigue life of structural details can be adversely affected by a variety of imperfections. The most common type of imperfections are:

(a) Misalignment of structural members, poor fit-up.
(b) Welding defects.
(c) Material defects.
(d) Poor manufacture and fabrication procedures resulting in stress concentrations.
(e) Unfairness of plating.

1.1.2 The actual influence on fatigue life will depend on the number, location and size of such imperfections.

1.1.3 Where design calculations highlight regions of stress concentration then experience clearly indicates that such regions will have a higher probability of failure during the life of the craft than surrounding structures. Hence in such locations there is a need to introduce standards that will reduce or eliminate the number or type of imperfections present.

1.1.4 Basic requirements concerning welding and structural details are given in Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft for steel and aluminium alloy craft respectively. The individual standards employed by Builders are normally based on individual national standards, e.g. British Standards, and these supplement the Rule requirements.

1.1.5 Construction and erection criteria in accordance with such standards must inevitably be taken into account in the fatigue life calculation for any structural detail. Whilst it may be anticipated that such criteria may, in general, in association with an acceptable detail arrangement, provide for adequate fatigue life, there may well be instances where there is a specific need to introduce construction tolerances that are more rigorous.

1.1.6 The LR Surveyors will be required to confirm that the work is carried out in accordance with the approved construction tolerances. Where the approved tolerances are exceeded then corrective action to the satisfaction of the Surveyor will be required. Details of the construction tolerances and defect correction procedures to be applied are indicated in Pt 3, Ch 1 of the Rules for Special Service Craft.

■ *Section 2* Construction tolerances

2.1 General

2.1.1 Construction tolerances are to comply with Pt 3, Ch 1 of the Rules for Special Service Craft. The additional guidance given in this Chapter should also be complied with where practicable.

2.2 Defects in steel/aluminium products

2.2.1 Where defects are found in materials after delivery to the Builder, any rectification should be agreed with the LR Surveyor and should generally be in accordance with Ch 3,1.10 or Ch 8,1.10 of the Rules for Materials and aluminium respectively.

2.2.2 If lamination is found during plate preparation the extent of the lamination should be ascertained by ultrasonic examination. Renewal of the affected material is normally recommended.

2.3 Construction standards

2.3.1 Construction standards (including preparation of material, joint alignment, type of welded joint, fit-up prior to welding, steps to be taken for rectification of defects, etc.) are to be agreed between LR and the Builder. Such standards will be recorded and kept on file by LR. In a number of countries national standards exist in respect of the acceptable shipbuilding standards.

2.3.2 In shipyards certified under the LR Quality Assurance Scheme, the standards will have received general approval as part of the certification procedures and their application to particular craft will be included in the quality plan submitted to LR for approval.

2.3.3 In considering critical locations and their construction standards it also has to be borne in mind that craft construction is a traditional process with alignment standards based on heel lines. In addition, therefore, to establishing the more critical joints in terms of fatigue life, consideration of the thicknesses to be employed in these joints should be a fundamental factor. If the heel line principle is maintained at the toes of, for example, primary member end brackets, where increased thicknesses are employed, the arrangements will in reality, be out of line, even though perfect alignment is attained to the standard, *see* Fig. 3.2.1(a). It is therefore recommended, particularly for aluminium, that a median line principle is employed at this local area so that an improved alignment can be more easily attained. From LR's point of view the various thicknesses of plating at structural joints, particularly the higher stress joints, is an important consideration. In this respect the gradient of load through the through-thickness loaded plate should be controlled to a maximum of one in three, *see* Fig. 3.2.1(b).

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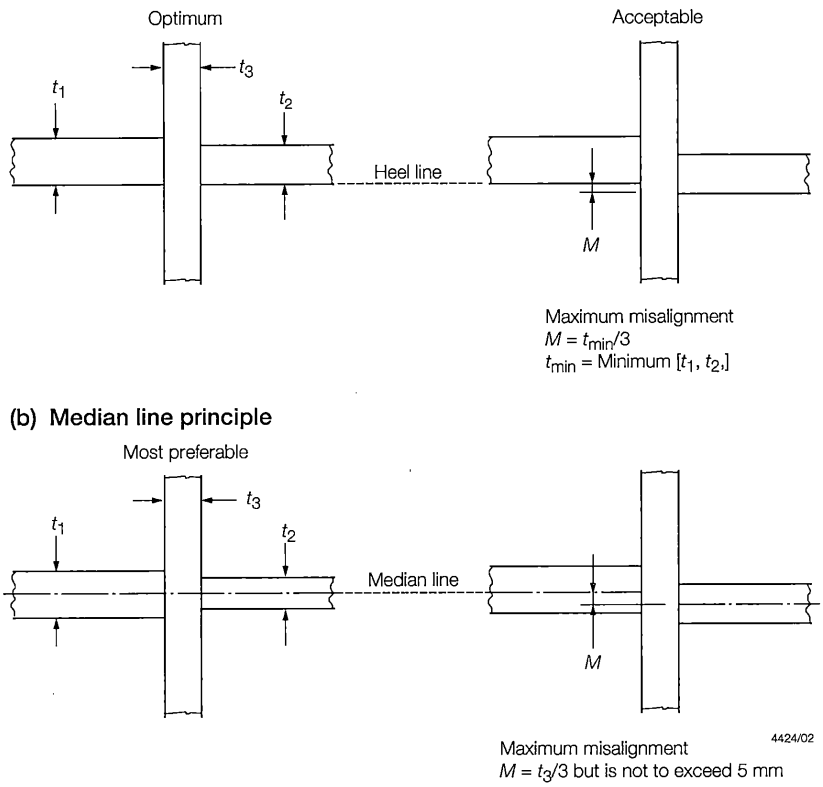

Fig. 3.2.1 Recommended alignment of primary members

2.3.4 In addition to cruciform joint misalignment, the alignment of secondary stiffening and associated brackets is also important. Recommendations are made in Fig. 3.2.1 and Fig. 3.2.2. Where centreline alignment is recommended the tolerance guideline in Fig. 3.2.2 should be followed.

2.3.5 Whenever possible the plate thicknesses, t_1 and t_2, (see Fig. 3.2.1) should be kept as close as possible in order to minimise the potential difficulties associated with a median line alignment.

2.4 Prefabrication

2.4.1 Throughout the preparation of material and assembly of prefabrication units, the workmanship is to be inspected in order to ensure that correct procedures are being followed. By attention in the early stages of construction, undesirable procedures and faulty workmanship can be avoided, or their consequences minimised. When the existence of such defects is noticed prompt and suitable measures are to be taken for rectification.

2.4.2 Examination of structure will normally be carried out during the prefabrication of units, and liaison between the LR Surveyor and the Builder's drawing offices and quality control departments will ensure that attention is also given to details which may not have been included on approved plans (air and drainage holes, etc.) during early material preparation stages.

2.4.3 It should be borne in mind that visual examination of welds and plating of a finished structure does not necessarily ensure a complete and satisfactory survey. Procedures are to be such as to ensure that adequate inspection is made of joint preparation before welding. Attention is drawn to the guidance on welding and structural details in Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft for steel and aluminium alloy craft respectively. Regular examination by the LR Surveyor, in conjunction with the Builder, of non-destructive examination and other Quality records provides a check on the quality of welding operations and any decline in standards should be investigated, including additional tests as considered desirable.

2.4.4 It is essential that a good standard of cleaning be achieved for these inspections. Special attention, as indicated in Pt 7, Ch 2,3.11.5 of the Rules for Special Service Craft, are to be applied for aluminium. For steel structures welding slag should be removed and rusting of weld deposits should be removed by wire brushing.

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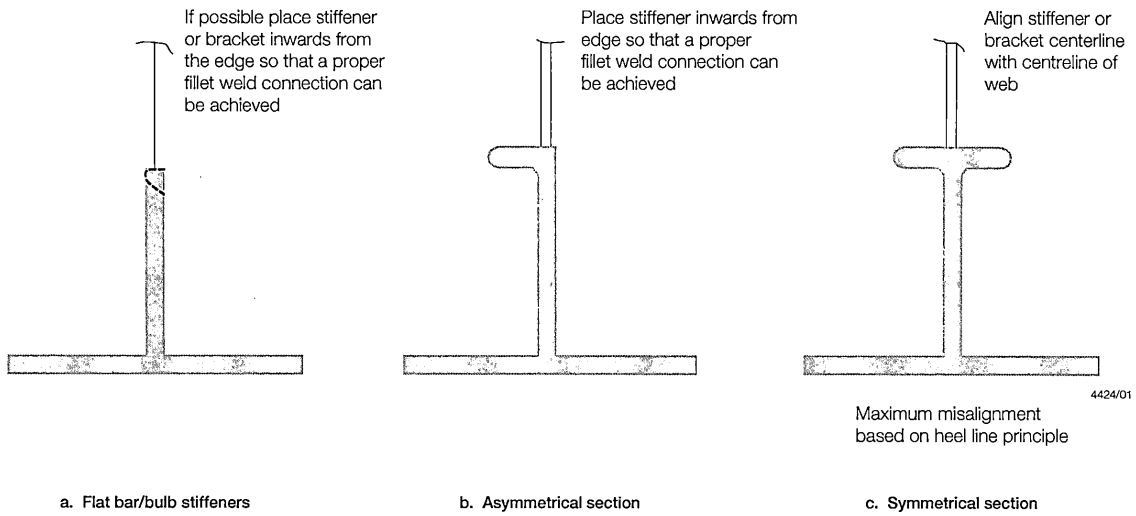

Fig. 3.2.2 Recommended alignment of secondary stiffening members

2.5 Assembly of units

2.5.1 The Builder and the LR Surveyors must ensure by regular and systematic examination that the control exercised up to the stage of block assembly is maintained by the efficient erection of blocks at the berth. It is particularly necessary at this point to ensure that fit-up, alignment, adjustment and welding of blocks is in accordance with the approved plans and building standards. Attention is to be given to the sequence of erection and of welding. Particular attention should be given to length allowance for unwelded stiffening member alignment.

2.5.2 With the assembly of large blocks careful attention should be paid to the areas in way of lifting lugs. It is not unusual to find small cracks in the vicinity of the weld area after removal of lugs. Where lugs are removed the dressing of the plate must be thorough and examination by means of crack detection of the finished surface is good practice. Repair of any cracks found must be carried out by skilled welders under strict control.

2.5.3 Any unusual incidents during construction, such as fracturing of plates, should be noted and brought to the attention of the LR Surveyor. It will be necessary to have full information on the circumstances affecting such cases, such as position and extent of the fracture relative to adjacent structure and welds, atmospheric temperature, details of joints, precise stage and sequence of welding, type of electrode filler wire used, whether or not pre-heating was used, grades of steel or aluminium alloy involved and any other factors considered to have had a possible influence. Test details of affected plates and proposals for remedial measures should also be made available. Where doubt exists in establishing the source of such incidents, the assistance of LR's staff at Headquarters, should be sought.

■ *Section 3* Defect correction procedures

3.1 Inspection and testing

3.1.1 The fabrication specification should state the extent of visual inspection and non-destructive examination along with details of the techniques and the appropriate acceptance criteria.

3.1.2 All non-destructive examination should be in accordance with written procedures. (*See also* Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft for steel and aluminium craft respectively).

3.1.3 Quality control levels for weld flaws found by radiographs, ultrasonic testing, magnetic particle and dye penetrant inspection, as appropriate, are to be approved by LR and shall be imposed during fabrication as a means of quality control.

3.1.4 Welded joints critical to the integrity of the structure should be subjected to radiographic examination and/or, where applicable, surface examination during construction. This non-destructive examination should be carried out prior to delivery, after the completion of welding and prior to any coating which would adversely effect the type of non-destructive examination being undertaken. Any repairs resulting from the testing are be re-examined.

3.1.5 Any necessary repairs and corrective actions are to be carried out to the satisfaction of the LR Surveyor and in accordance with an agreed procedure.

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Detail Design Improvement for Steel/Aluminium Construction

Section

1 **Identification of critical areas**

2 **Structural details**

Section 1 Identification of critical areas

1.1 General

1.1.1 LR has applied direct calculation procedures in the structural appraisal and approval of new buildings and in various investigations on special service craft of both steel and aluminium alloy construction. Through these procedures and the wealth of information collected on the LR fleet database, a number of locations have been identified where good design, workmanship and alignment during construction are particularly important. These are usually locations where high stress variations can be experienced during the lifetime of the craft. These are referred to to as **critical locations** and are highlighted in this Chapter.

1.1.2 This Chapter identifies the **critical areas** within various structural elements of the hull structure and transverse bulkheads.

1.1.3 In Section 2 the structural **detail design improvements** that can be applied to increase the fatigue life of the structural components are provided. These detail improvements are intended to give the designer guidance for meeting the design criteria for structural detail components.

1.1.4 The application of 2 and 3-dimensional finite element analyses techniques to the hull structure enables the global and local capabilities of the hull structure to withstand static and dynamic loadings to be assessed. Such analyses will enable those high stress locations and joints within the craft to be readily identified. Such locations will then, by their very nature, be at risk to fatigue damage unless appropriate measures are taken at the design stage and subsequently during construction.

1.1.5 Extensive 'in service' experience of the performance of existing craft structures, already provide an awareness of those critical locations which merit particular attention either due to stress or alignment difficulties.

1.2 Critical areas

1.2.1 Stress concentrations occur in both the primary and secondary structures of all craft and are identified during the design process by such means as finite element calculations. The designer will modify the detail to alleviate the stress concentration either by redesign or increase in scantlings. However, even after modification that area will still, in general, be exposed throughout the life of the craft to stresses higher than in surrounding areas.

1.2.2 At the design appraisal stage, a plan of the structure should, where appropriate, be prepared indicating by the Builder or designer these regions, and consideration can then be given, by the production team, into the appropriate methods of construction and the tolerances to be applied in order to remain within the assigned design parameters.

1.3 Misalignment during construction

1.3.1 The very nature of steel/aluminium construction requires the assembly of a multitude of structural components into blocks within an assembly shop and then the erection of these blocks within a building dock or on a building berth. The welded interface between structural components in sub-assembly areas can be reasonably controlled; however, the welded connections between large prefabricated blocks in the building dock or on the building berth cannot be so easily controlled due to the sheer size of the blocks being handled.

1.3.2 The most critical type of joint is the welded cruciform joint where it is subjected to high magnitudes of tensile stress normal to the table member of the joint.
The double bottom construction lends itself to the block construction. The interfaces between these blocks and those formed by the primary transverse structure may lie in areas of high stress. Critical cruciform joints are also found within the prefabricated blocks and also require close attention to alignment, but this is more easily achieved.

1.3.3 It can readily be seen that the combination of stress concentration and misalignment is to be avoided if the fatigue strength is to be satisfactory during the service life of the craft.

1.4 Fatigue considerations

1.4.1 The bottom shell area of high speed craft is subjected to the highest cyclic loading throughout the life of such craft.

1.4.2 The fatigue fractures in bottom longitudinal end-connections of higher tensile steel and aluminium alloy has been well documented, and constructional details in way of these connections, designed to increase fatigue life, are now incorporated by many Builders as standard. It is, therefore, important that due consideration be given to this detail at the design stage to reduce the risk of fatigue cracking during service.

1.4.3 Detailed recommendations are given herein for the critical areas, *see* Section 2.

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Section 2
Structural details

2.1 Detail design improvement

2.1.1 For the purposes of these Guidance Notes, structural locations have been divided into three separate groups, with a series of examples of critical structural areas together with alternative associated detail design improvements.

2.1.2 A summary of the data presented is given in Table 4.2.1 whilst the full details are given in Figs. 1 to 29 as contained in this Section.

2.1.3 Generally, where alternative structural detail design improvements are provided, the details shown will provide improved fatigue strength.

2.1.4 Where asymmetrical sections are shown, the same requirements apply to bulb plate stiffeners and flat bars.

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Detail Design Improvement for Steel/Aluminium Construction

Table 4.2.1

Group	Application	Area	Item	Fig. No
	High speed craft			
1		Hull structure	Chine to frame connection	1
		Hull structure	Chine and chine bar details (1)	2
		Hull structure	Chine and chine bar details (2)	3
		Hull internal structure	Frame to beam connection (radiused)	4
		Hull internal structure	Frame to beam connection (continuous bracket)	5
		Hull internal structure	Lug connections between secondary stiffeners and primary stiffener webs (1)	6
		Hull internal structure	Lug connections between secondary stiffeners and primary stiffener webs (2)	7
		Watertight/oiltight bulkheads	Shell longitudinals collared, brackets aligned	8
		Watertight/oiltight bulkheads	Shell longitudinal (fitted brackets)	9
		Watertight/oiltight bulkheads with boundary bar	Shell longitudinal (fitted brackets)	10
		Watertight/oiltight bulkheads	Collar inserts in way of secondary stiffening members	11
		Watertight/oiltight bulkheads	Collar inserts in way of primary stiffening members	12
		Cross-deck structure, multi-hulls	Inner side web frame to deck transverse connection	13
		Cross-deck structure	Deck transverse to watertight bulkhead connection	14
		Multi-hull structure	Cross-deck beam to bulkhead connection	15
	Low speed craft			
2		Hull internal structure	Floor to frame connection (bracketed)	16
		Hull internal structure	Frame to beam connection	17
		Watertight/oiltight bulkheads with boundary bar	Shell longitudinals (lapped brackets)	18
		Watertight/oiltight bulkheads	Shell longitudinals (lapped brackets)	19
		Watertight/oiltight bulkheads	Shell longitudinals collared, brackets lapped	20
		Cross-deck structure, multi-hulls	Connection between cross-deck beams and side hulls	21
	General detail			
3		Cross-deck structure, multi-hulls	Connection between cross-deck beams and side hulls	22
		Hull centreline structure	Bar and plate keels	23
		Hull centreline structure	Bar keels	24
		Hull centreline structure	Fabricated plate keel/skeg	25
		Hull centreline structure	Round bar and flat bar stems	26
		Hull centreline structure	Fabricated and plate stems	27
		Hull internal structure	Floors to frame connection (radiused)	28
		Hull internal structure	Web frame to tank boundary connection	29

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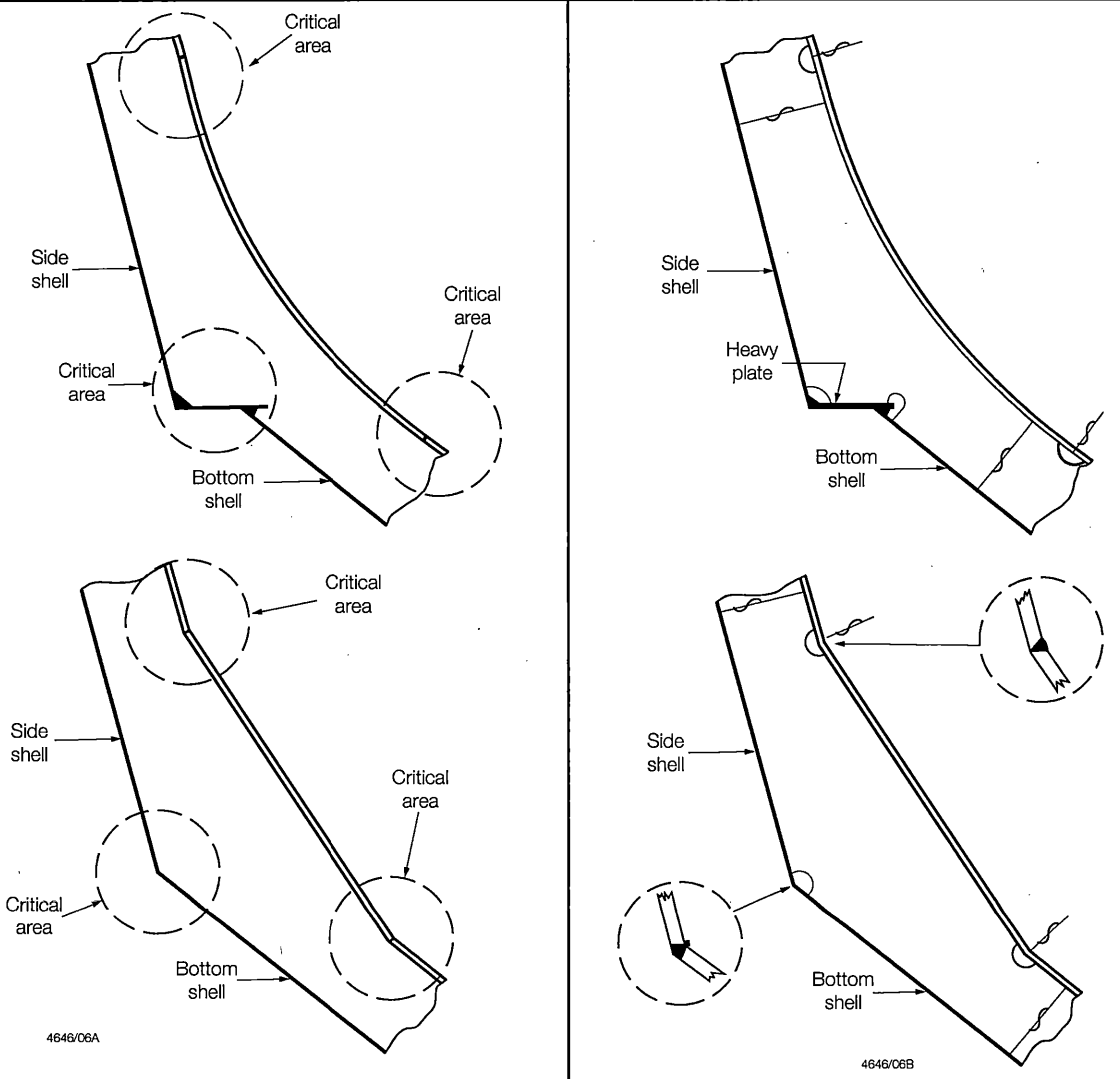
Detail Design Improvement for Steel/Aluminium Construction

AREA: Hull structure

ITEM: Chine to frame connection

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT



NOTES

Failure Mechanism	Fatigue fractures from areas of tri-axial stress.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. All welding between chine bars and shell plating is to be full penetration type. Butts in web plating and face flats are to be staggered.

GROUP 1	GUIDANCE NOTES FOR DESIGN DETAILS STEEL/ALUMINIUM CONSTRUCTION	FIGURE 1

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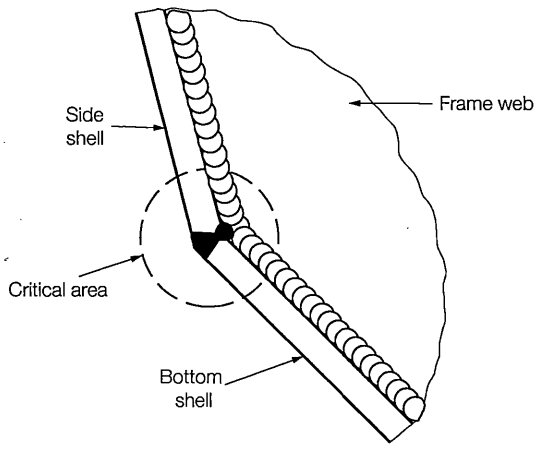
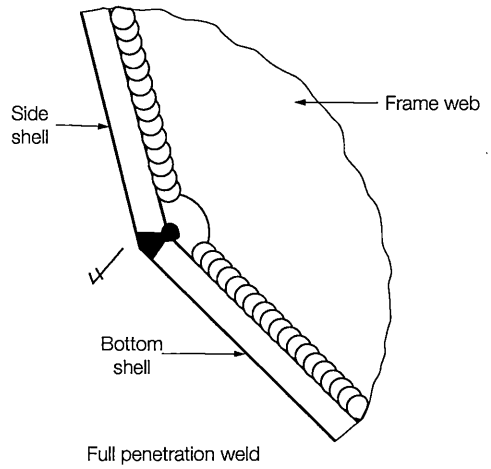
Detail Design Improvement for Steel/Aluminium Construction

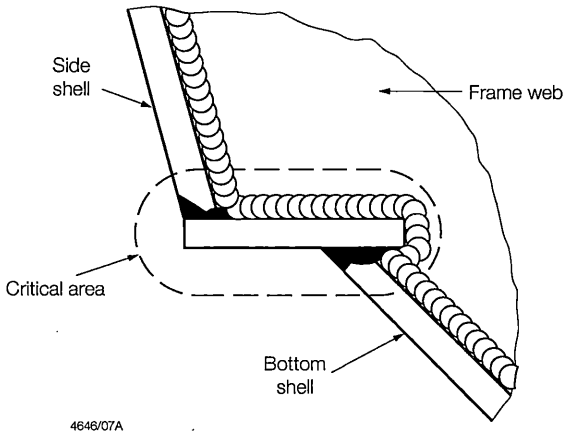
AREA: Hull structure

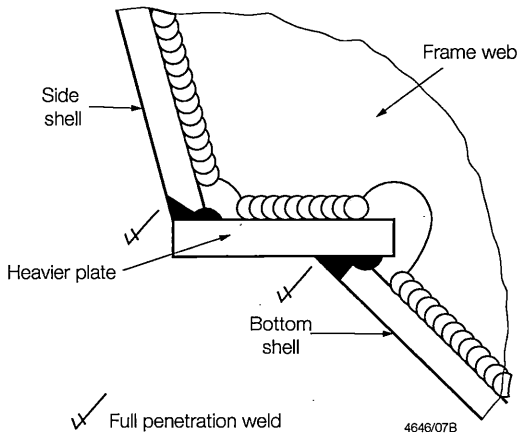
ITEM: Chine and chine bar details (1)

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT









NOTES

Failure Mechanism	Fatigue fractures from areas of tri-axial stress.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. All welding in way of shell plating and between chine bar and shell plating is to be full penetration type. Welds are to be returned around scallops.

GROUP 1	GUIDANCE NOTES FOR DESIGN DETAILS STEEL/ALUMINIUM CONSTRUCTION	FIGURE 2

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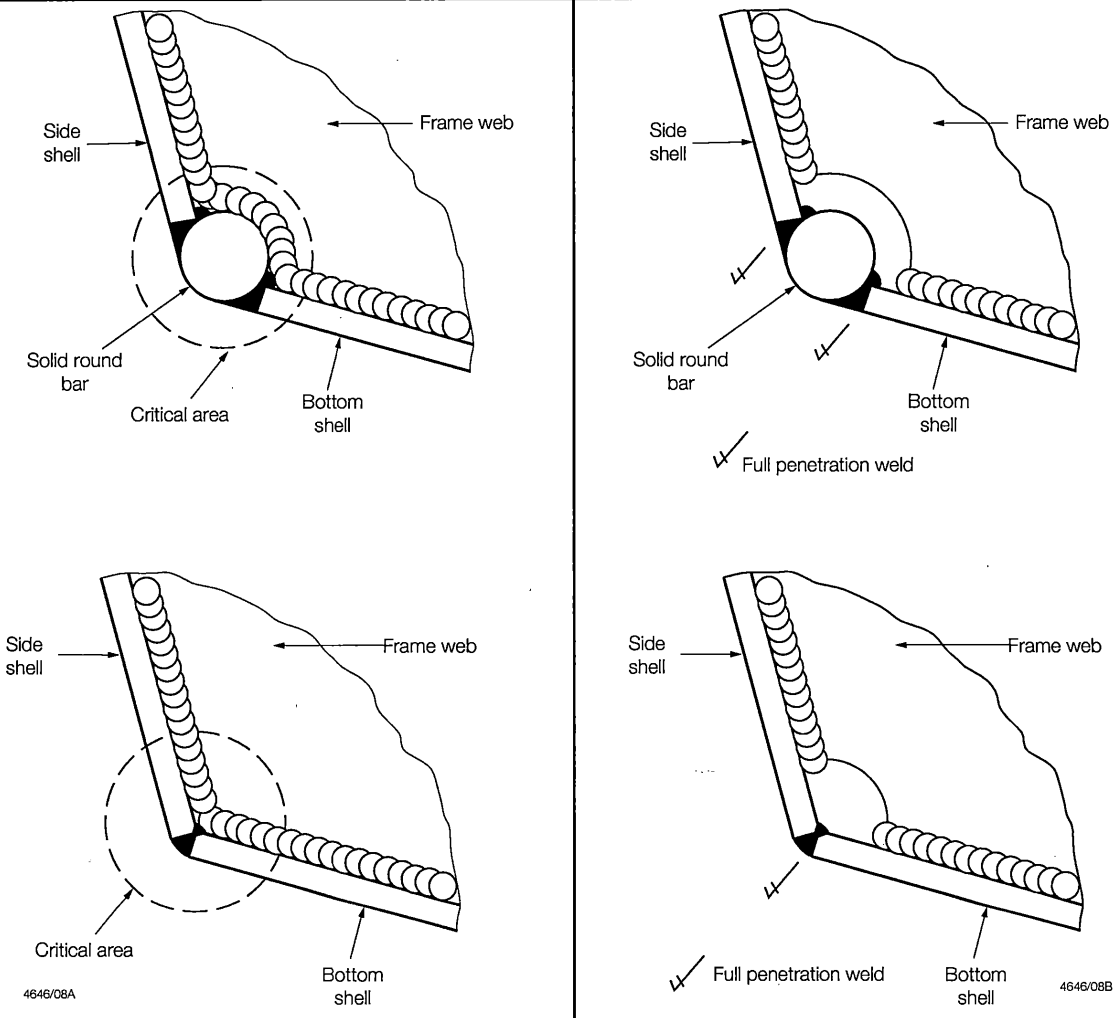
Detail Design Improvement for Steel/Aluminium Construction

AREA: Hull structure

ITEM: Chine and chine bar details (2)

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT



NOTES

Failure Mechanism	Fatigue fractures from areas of tri-axial stress.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. All welding in way of shell plating and between chine bar and shell plating is to be full penetration type. Welds to be returned around scallops.

GROUP 1	GUIDANCE NOTES FOR DESIGN DETAILS STEEL/ALUMINIUM CONSTRUCTION	FIGURE 3

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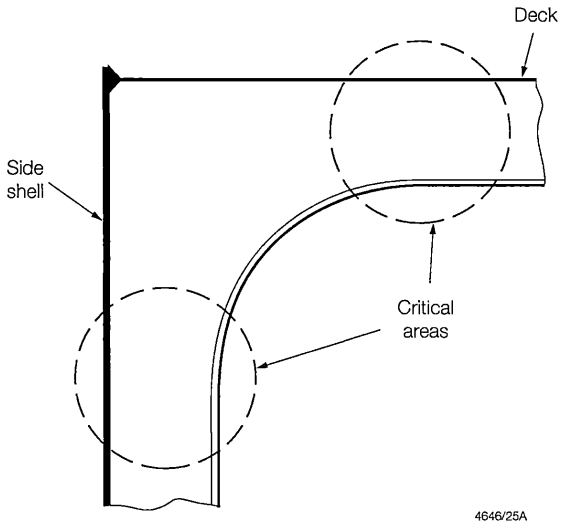
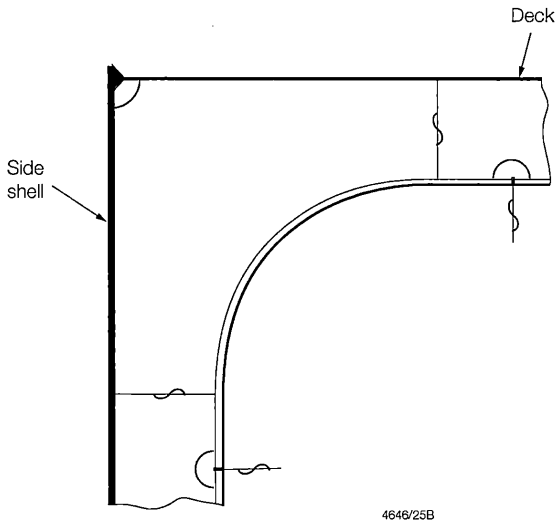
Detail Design Improvement for Steel/Aluminium Construction

AREA: Hull internal structure

ITEM: Frame to beam connection (radiused)

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT





NOTES

Failure Mechanism	Fatigue fractures in way of welds.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. Webs to be accurately aligned. Butts in webs are to be staggered from the butts in face flats. All welds to be returned around scallops.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
1	STEEL/ALUMINIUM CONSTRUCTION	4

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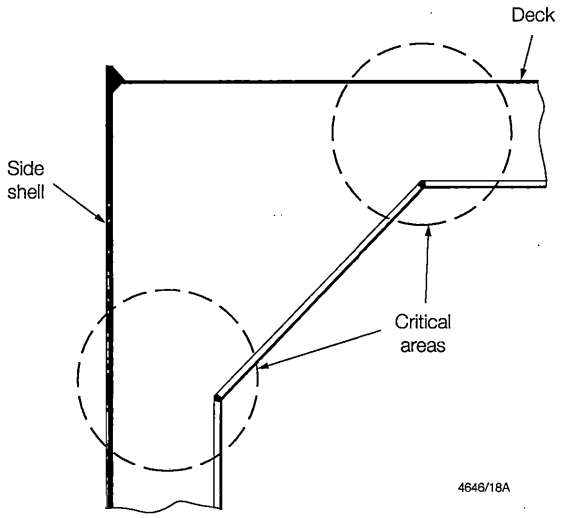
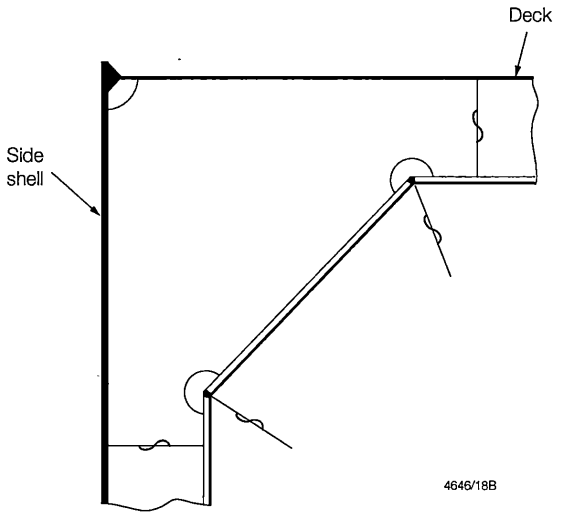
Detail Design Improvement for Steel/Aluminium Construction

AREA: Hull internal structure

ITEM: Frame to beam connection (continuous bracket)

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT





NOTES

Failure Mechanism	Fatigue fractures in way of welds.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. Webs to be carefully aligned. Butts in webs are to be staggered from the butts in face flats. All welds to be returned around scallops.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
1	STEEL/ALUMINIUM CONSTRUCTION	5

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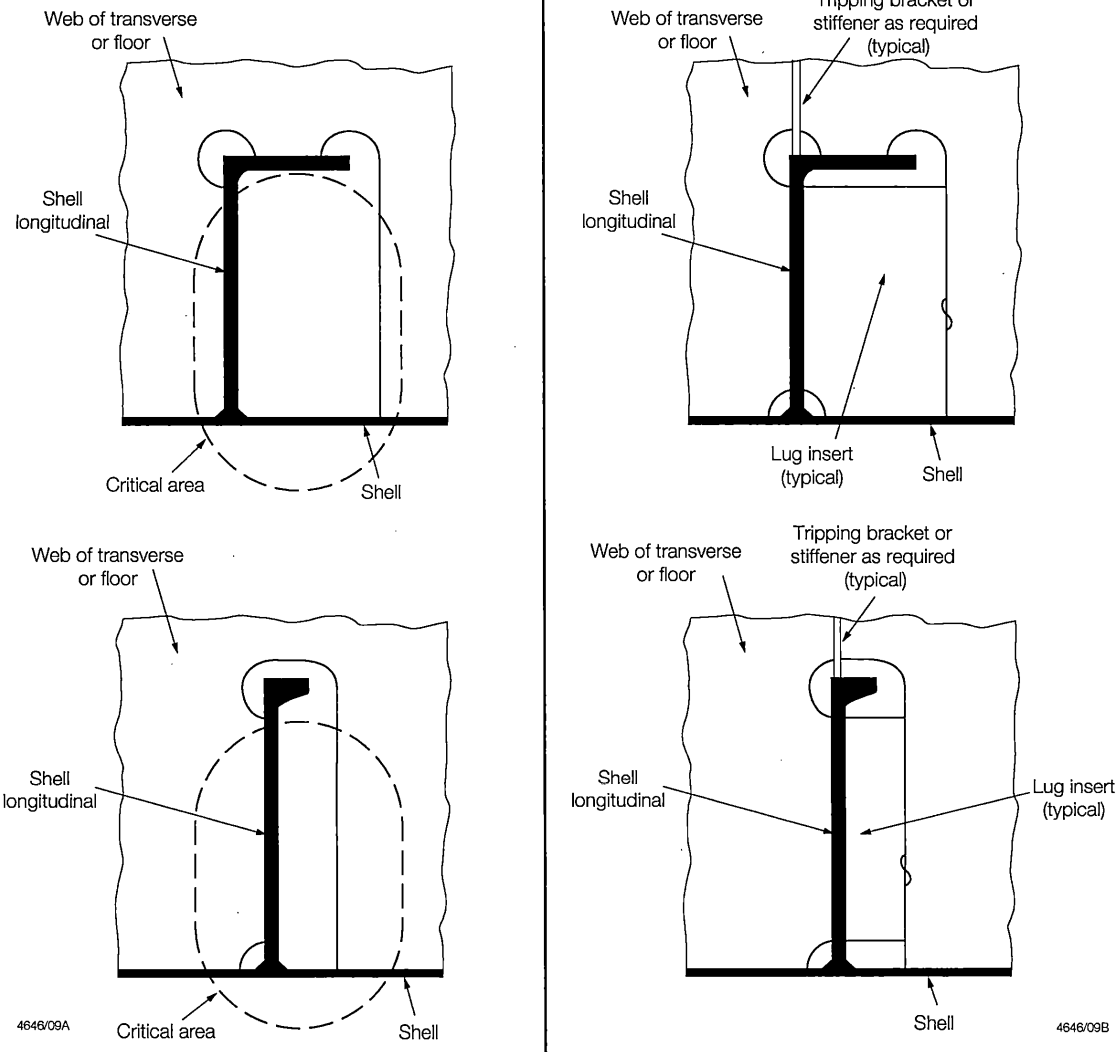
Detail Design Improvement for Steel/Aluminium Construction

AREA: Hull internal structure

ITEM: Lug connections between secondary stiffeners and primary stiffener webs (1)

Lloyd's Register

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT



NOTES

Failure Mechanism	Fatigue cracking of shell plate in way of hardspot, buckling and shear failure of the web of the primary member.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. All welding in way of lugs is to be double continuous. Welds to be returned around scallops. Lug inserts to align with primary stiffener web plating or floor.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
1	STEEL/ALUMINIUM CONSTRUCTION	6

Document Released Under the Access to Information Act / Document divulgué en vertu de la Loi sur l'accès à l'information.

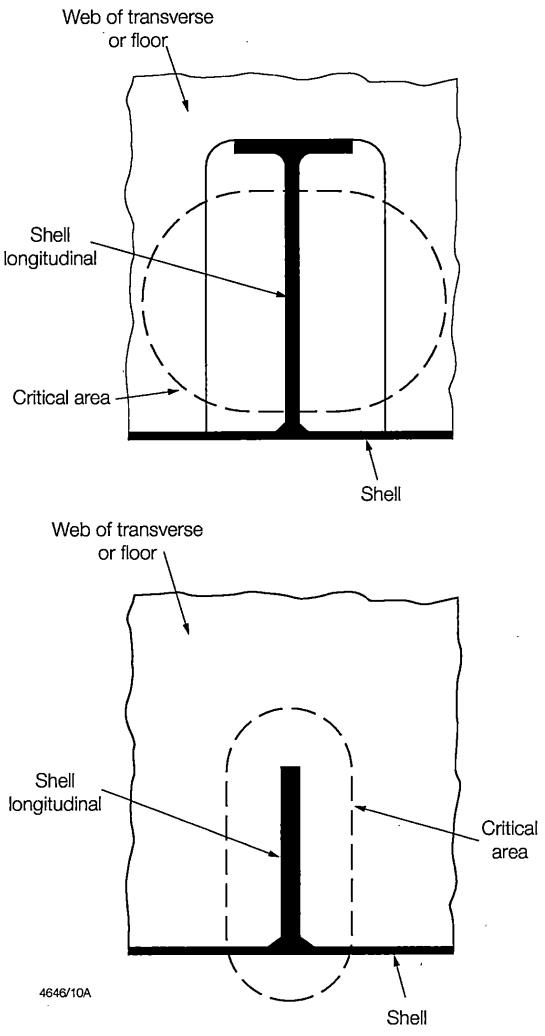
Detail Design Improvement for Steel/Aluminium Construction

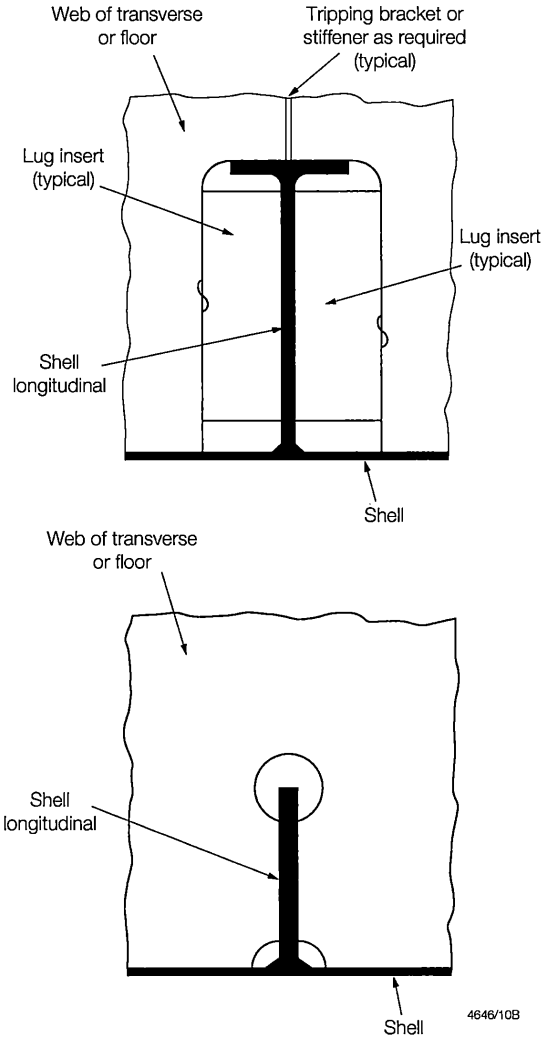
AREA: Hull internal structure

ITEM: Lug connections between secondary stiffeners and primary stiffener webs (2)

Lloyd's Register

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT





NOTES

Failure Mechanism	Fatigue cracking of shell plate in way of hardspot, buckling and shear failure of the web of the primary member.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. All welding in way of lugs is to be double continuous. Welds to be returned around scallops. Lug inserts to align with primary stiffener web plating or floor.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
1	STEEL/ALUMINIUM CONSTRUCTION	7

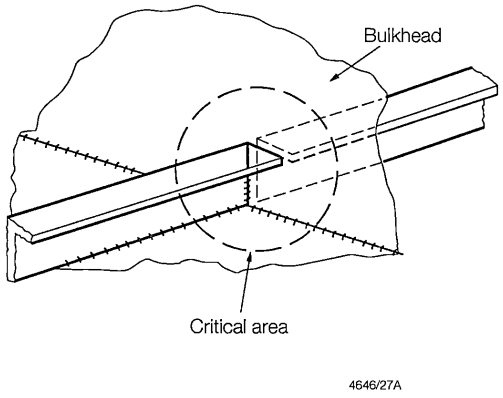
Document Released Under the Access to Information Act / Document divulgué en vertu de la Loi sur l'accès à l'information.

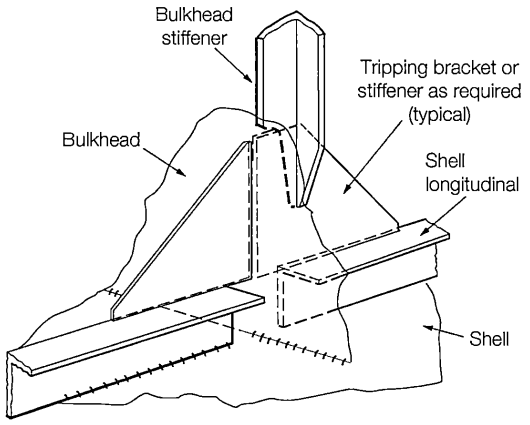
Detail Design Improvement for Steel/Aluminium Construction

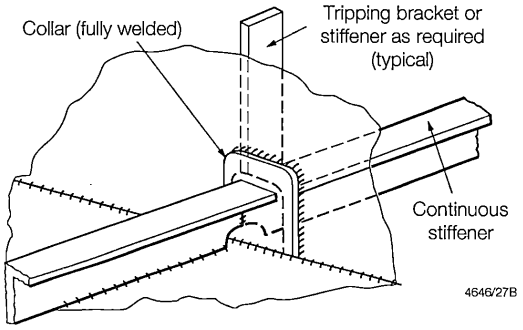
AREA: Watertight/oiltight bulkheads

ITEM: Shell longitudinals collared, brackets aligned

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT







NOTES

Failure Mechanism	Fractures in bulkhead plating arising from stress concentrations in way of longitudinal stiffener end connections.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. All welding in way of collar and stiffener end connections is to be double continuous type. Welds to be returned around scallops.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
1	STEEL/ALUMINIUM CONSTRUCTION	8

Document Released Under the Access to Information Act / Document divulgué en vertu de la Loi sur l'accès à l'information.

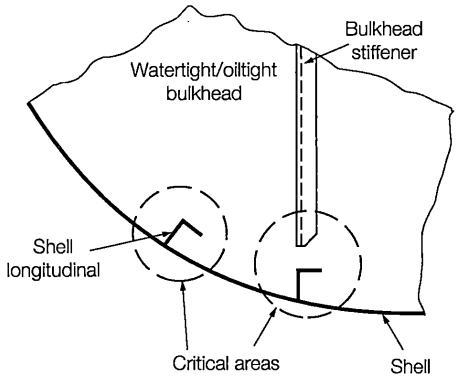
Detail Design Improvement for Steel/Aluminium Construction

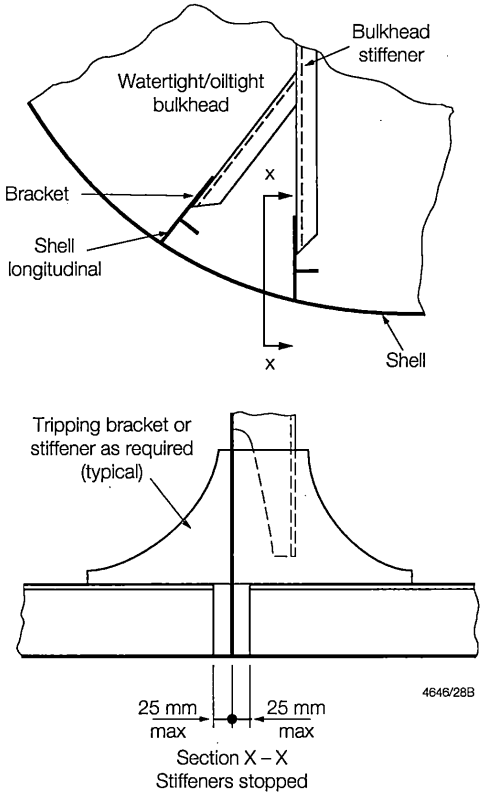
AREA: Watertight/oiltight bulkheads

ITEM: Shell longitudinals (fitted brackets)

Lloyd's Register

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT





NOTES

Failure Mechanism	Fractures in bulkhead plating arising from stress concentrations in way of longitudinal stiffener end connections.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. Webs of brackets are to be accurately aligned through the bulkhead plating and with the webs of the longitudinal stiffeners. All welding in way of brackets and stiffener end connections is to be double continuous type.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
1	STEEL/ALUMINIUM CONSTRUCTION	9

Document Released Under the Access to Information Act / Document divulgué en vertu de la Loi sur l'accès à l'information.

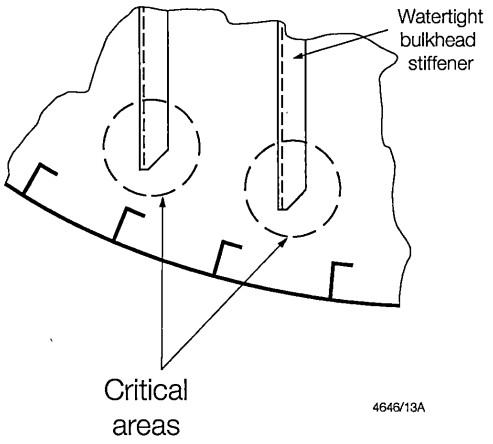
Detail Design Improvement for Steel/Aluminium Construction

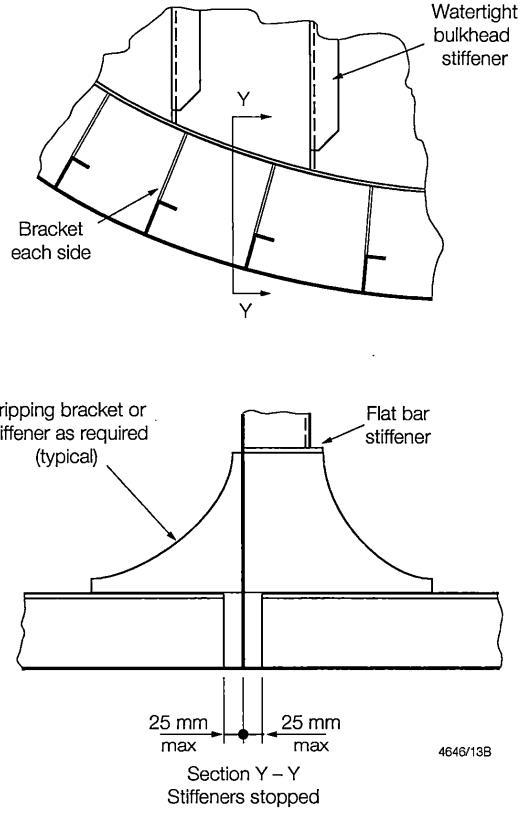
AREA: Watertight/oiltight bulkheads with boundary bar

ITEM: Shell longitudinals (fitted brackets)

Lloyd's Register

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT





NOTES

Failure Mechanism	Fractures in bulkhead plating arising from stress concentrations in way of longitudinal stiffener end connections.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. Webs of brackets are to be accurately aligned through the bulkhead plating and with the webs of the longitudinal stiffeners. All welding in way of brackets and stiffener end connections is to be double continuous type.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
1	STEEL/ALUMINIUM CONSTRUCTION	10

Document Released Under the Access to Information Act / Document divulgué en vertu de la Loi sur l'accès à l'information.

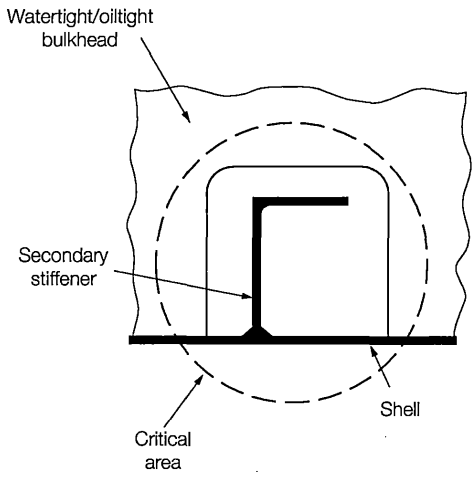
Detail Design Improvement for Steel/Aluminium Construction

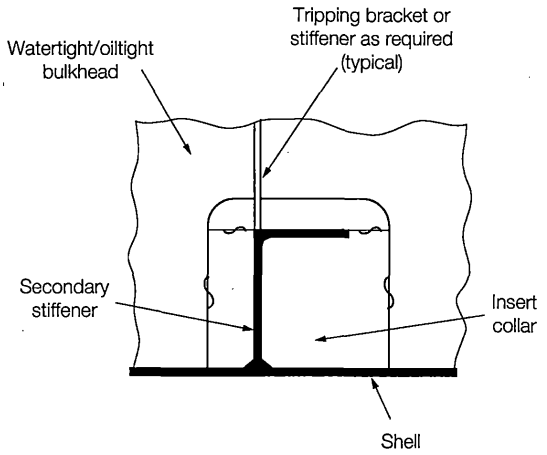
AREA: Watertight/oiltight bulkheads

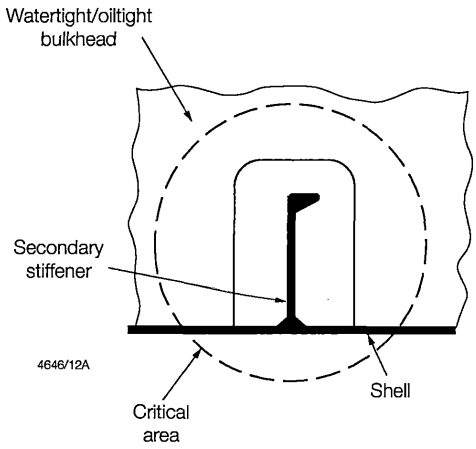
ITEM: Collar inserts in way of secondary stiffening members

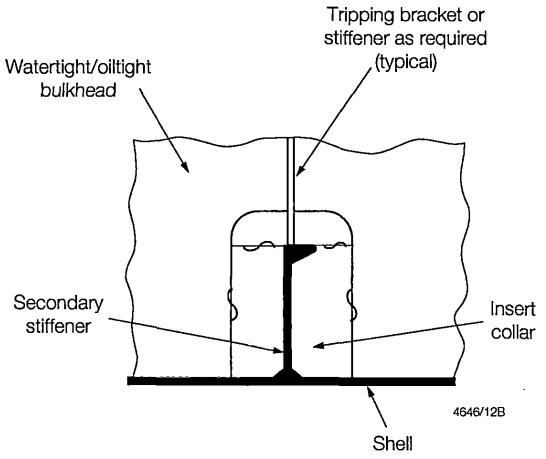
Lloyd's Register

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT









NOTES

Failure Mechanism	Fatigue fractures and leakage.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. Inserts to align with watertight/oiltight bulkhead plating. All welding in way of collar inserts and stiffener end connections is to be double continuous type.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
1	STEEL/ALUMINIUM CONSTRUCTION	11

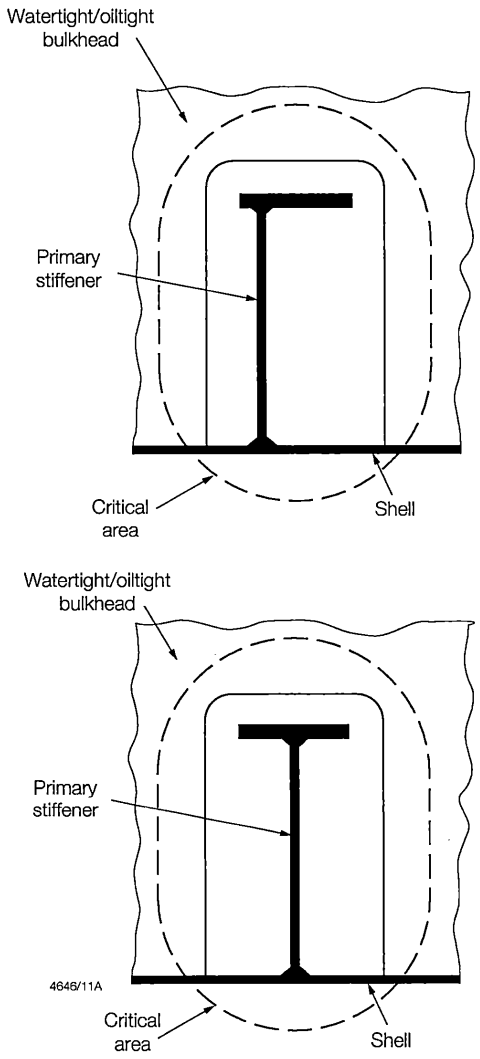
Document Released Under the Access to Information Act / Document divulgué en vertu de la Loi sur l'accès à l'information.

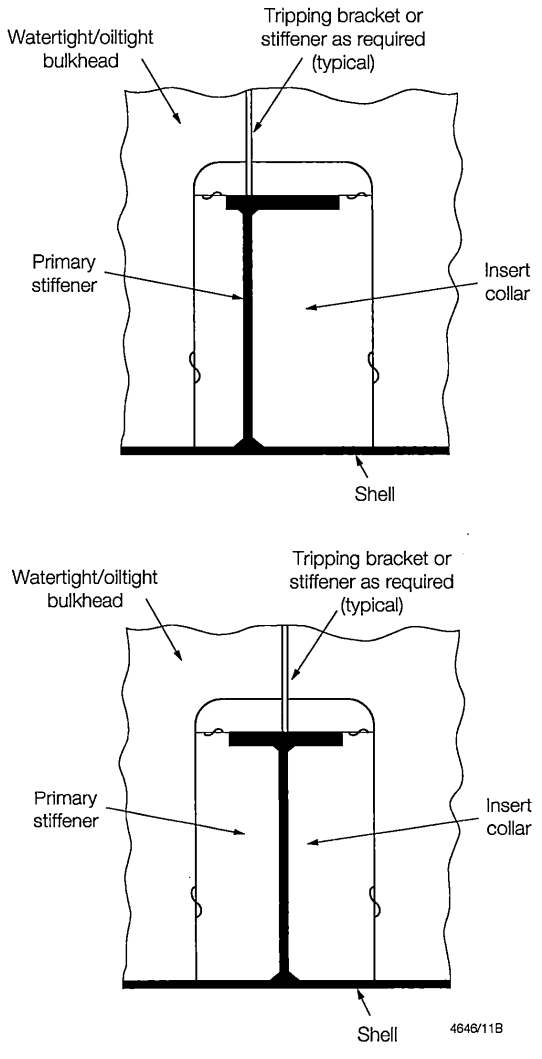
Detail Design Improvement for Steel/Aluminium Construction

AREA: Watertight/oiltight bulkheads

ITEM: Collar inserts in way of primary stiffening members

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT





NOTES

Failure Mechanism	Fatigue fractures and leakage.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. Inserts to align with watertight/oiltight bulkhead plating. All welding in way of collar inserts and stiffener end connections is to be double continuous type.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
1	STEEL/ALUMINIUM CONSTRUCTION	12

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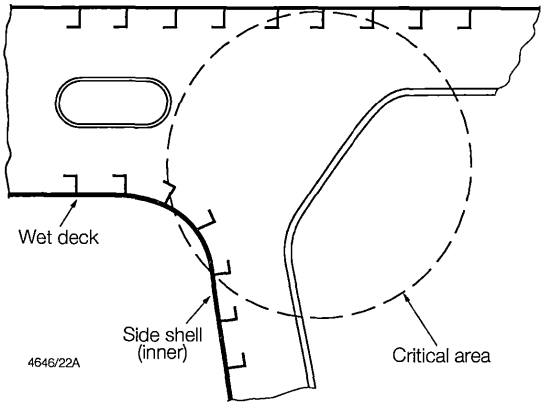
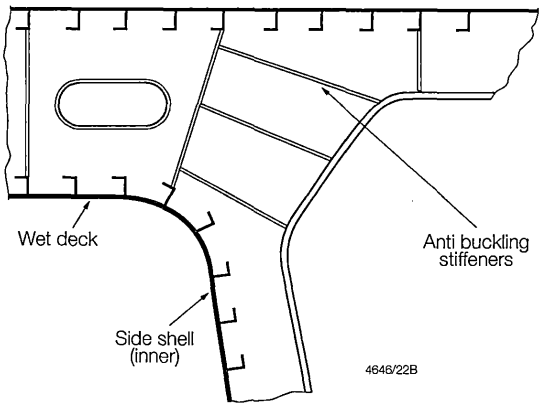
Detail Design Improvement for Steel/Aluminium Construction

AREA: Cross-deck structure, multi-hulls

ITEM: Inner side web frame to deck transverse connection

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT





NOTES

Failure Mechanism	Buckling of deep webs.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively.

GROUP 1	GUIDANCE NOTES FOR DESIGN DETAILS STEEL/ALUMINIUM CONSTRUCTION	FIGURE 13

Document Released Under the Access to Information Act / Document divulgué en vertu de la Loi sur l'accès à l'information.

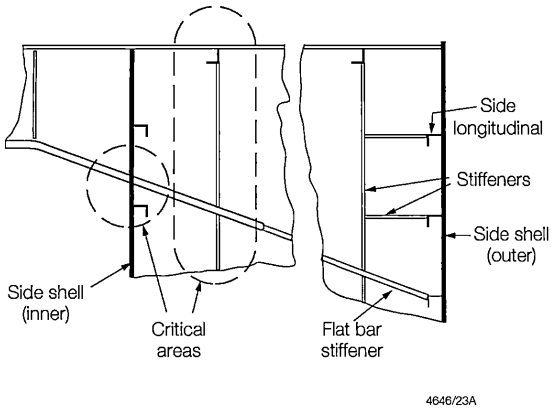
Detail Design Improvement for Steel/Aluminium Construction

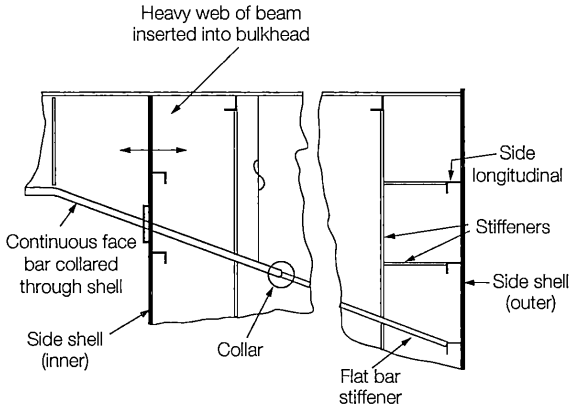
AREA: Cross-deck structure

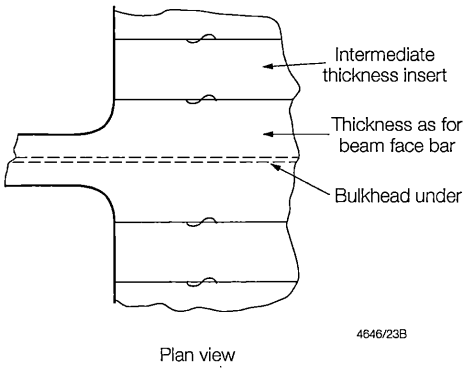
ITEM: Deck transverse to watertight bulkhead connection

Lloyd's Register

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT







Plan view

NOTES

Failure Mechanism	Failure fractures in areas of high stress, cracking due to both stress concentrations and tri-axial stress.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. All welds in way of shell penetration are to be full penetration type.

GROUP 1	GUIDANCE NOTES FOR DESIGN DETAILS STEEL/ALUMINIUM CONSTRUCTION	FIGURE 14

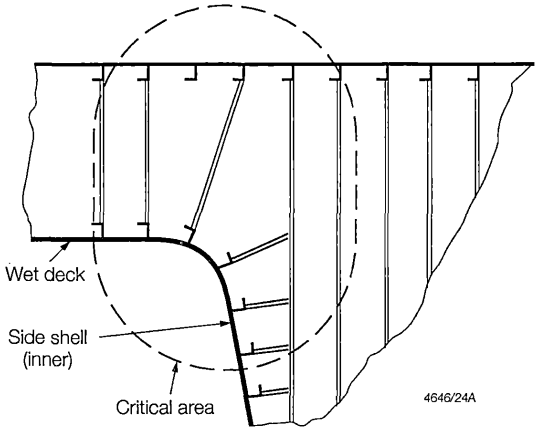
Document Released Under the Access to Information Act / Document divulgué en vertu de la Loi sur l'accès à l'information.

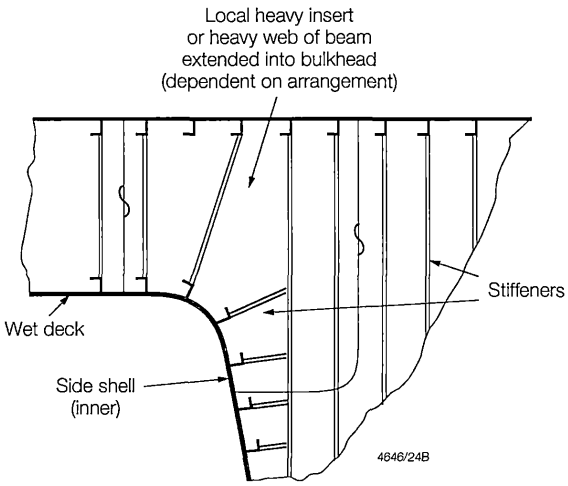
Detail Design Improvement for Steel/Aluminium Construction

AREA: Multi-hull structure

ITEM: Cross-deck beam to bulkhead connection

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT





NOTES

Failure Mechanism	Buckling of deep webs and bulkhead in way of connection.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. Webs of deep transverses are to be accurately aligned with the bulkhead plating. All welding in way of end connection is to be double continuous type.

GROUP 1	GUIDANCE NOTES FOR DESIGN DETAILS STEEL/ALUMINIUM CONSTRUCTION	FIGURE 15

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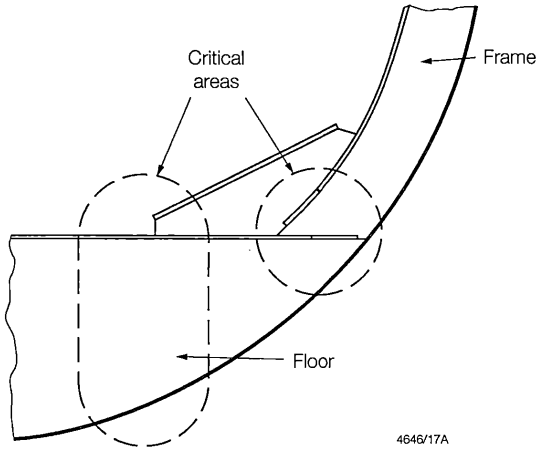
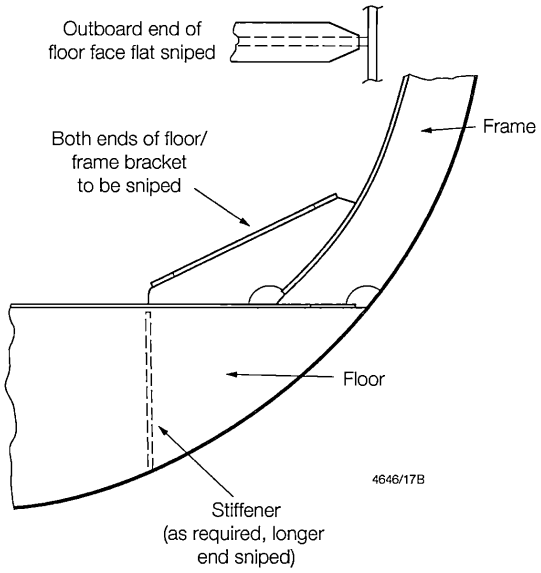
Detail Design Improvement for Steel/Aluminium Construction

AREA: Hull internal structure

ITEM: Floor to frame connection (bracketed)

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT





NOTES

Failure Mechanism	Buckling of floor under bracket toe. Fracturing of frame and floor structure in way of end connections.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. All welding in way of brackets and end connections is to be double continuous type. All welds to be returned around scallops. Webs of frames to be accurately aligned with floor plating.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS STEEL/ALUMINIUM CONSTRUCTION	FIGURE
2		16

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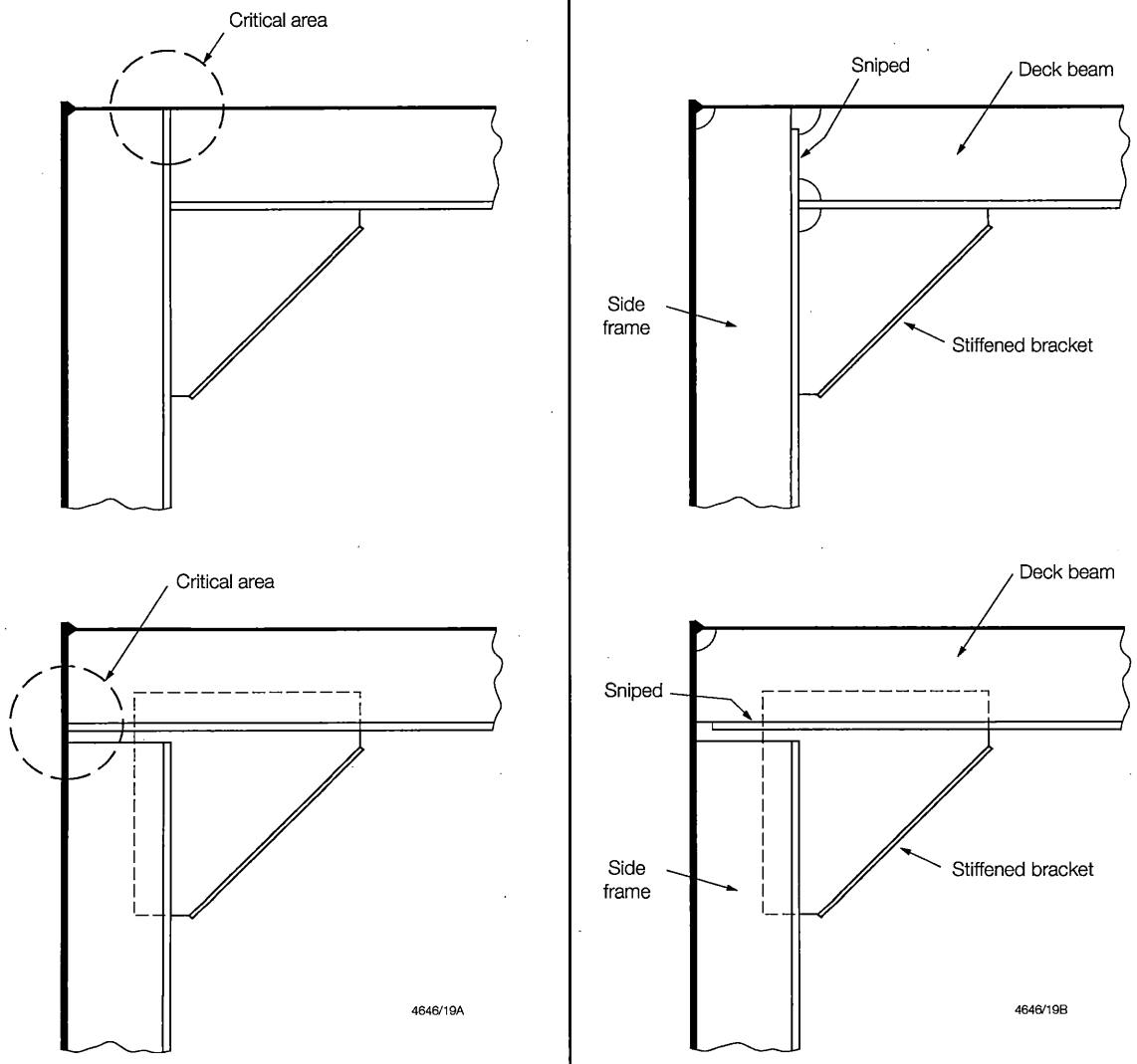
Detail Design Improvement for Steel/Aluminium Construction

AREA: Hull internal structure

ITEM: Frame to beam connection

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT



NOTES

Failure Mechanism	Fractures in the shell and deck plating due to stress concentration arising from hard spots.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. Webs of deck beam to be accurately aligned with webs of frames. All welding in way of end connections and brackets is to be double continuous type. All welds to be returned around scallops.

GROUP 2	GUIDANCE NOTES FOR DESIGN DETAILS STEEL/ALUMINIUM CONSTRUCTION	FIGURE 17

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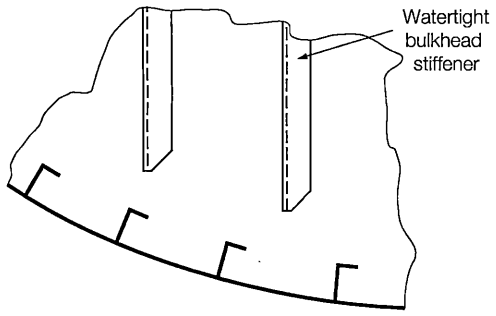
Detail Design Improvement for Steel/Aluminium Construction

AREA: Watertight/oiltight bulkheads with boundary bar

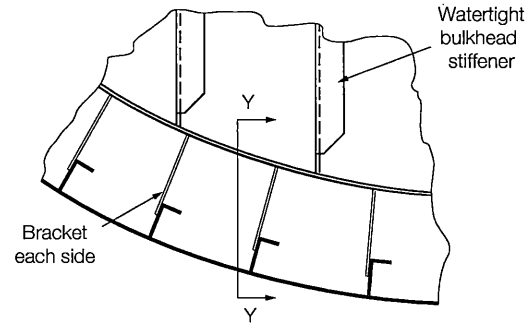
ITEM: Shell longitudinals (lapped brackets)

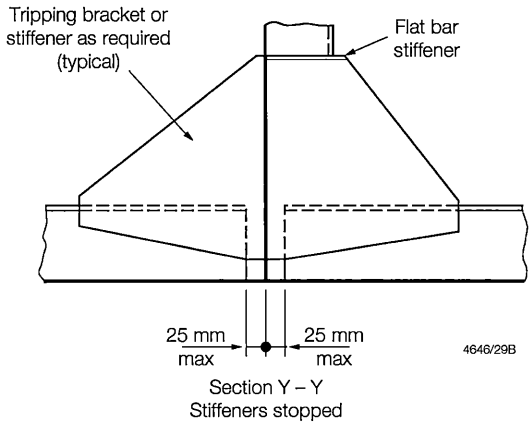
Lloyd's Register

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT



4646/29A





4646/29B

Section Y – Y
Stiffeners stopped

NOTES

Failure Mechanism	Fractures in bulkhead plating arising from stress concentrations in way of longitudinal stiffener end connections.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. Webs of brackets are to be accurately aligned through the bulkhead platings. All welding in way of brackets and stiffener end connections is to be double continuous type.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
2	STEEL/ALUMINIUM CONSTRUCTION	18

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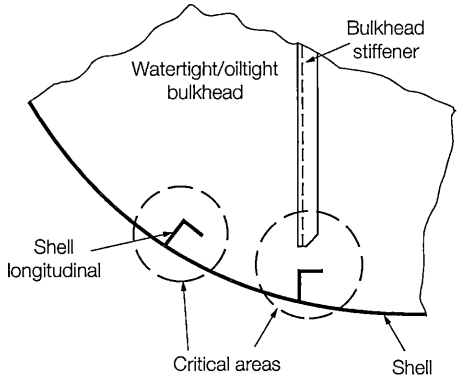
Detail Design Improvement for Steel/Aluminium Construction

AREA: Watertight/oiltight bulkheads

ITEM: Shell longitudinals (lapped brackets)

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT



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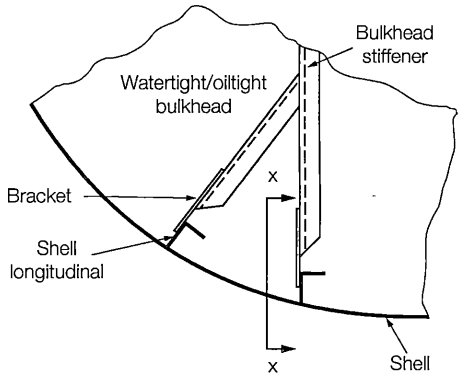

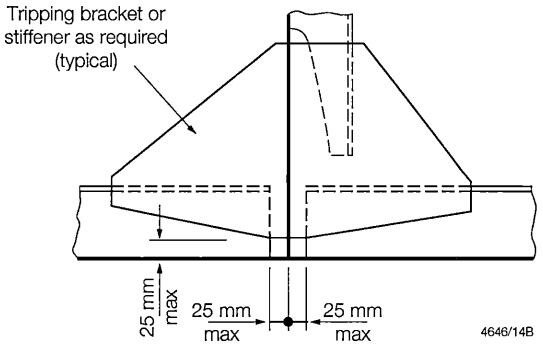

4646/14B

Section X – X

NOTES

Failure Mechanism	Fractures in bulkhead plating arising from stress concentrations in way of longitudinal stiffener end connections.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. Webs of brackets are to be accurately aligned through the bulkhead platings. All welding in way of brackets and end connections of stiffeners is to be double continuous type.

GROUP 2	GUIDANCE NOTES FOR DESIGN DETAILS STEEL/ALUMINIUM CONSTRUCTION	FIGURE 19

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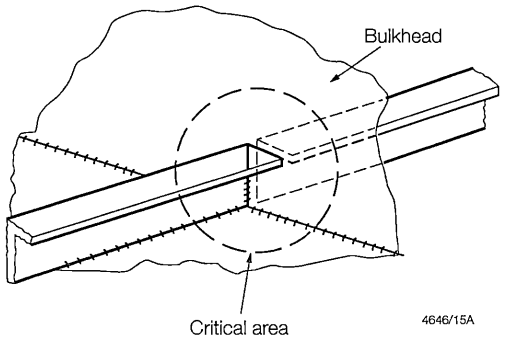
Detail Design Improvement for Steel/Aluminium Construction

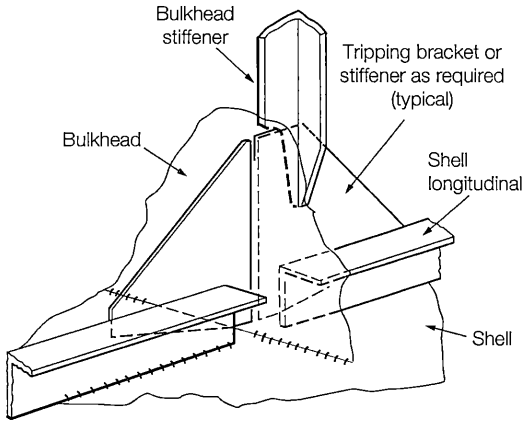
AREA: Watertight/oiltight bulkheads

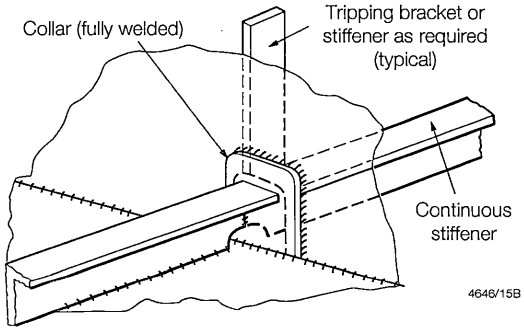
ITEM: Shell longitudinals collared, brackets lapped

Lloyd's Register

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT







NOTES

Failure Mechanism	Fractures in bulkhead plating arising from stress concentrations in way of longitudinal stiffener end connections.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. All welding in way of collar and stiffener end connections is to be double continuous type. Welds are to be returned around scallops.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
2	STEEL/ALUMINIUM CONSTRUCTION	20

Document Released Under the Access to Information Act / Document divulgué en vertu de la Loi sur l'accès à l'information.

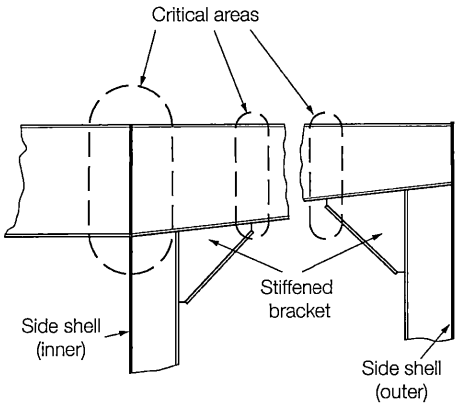
Detail Design Improvement for Steel/Aluminium Construction

AREA: Cross-deck structure, multi-hulls

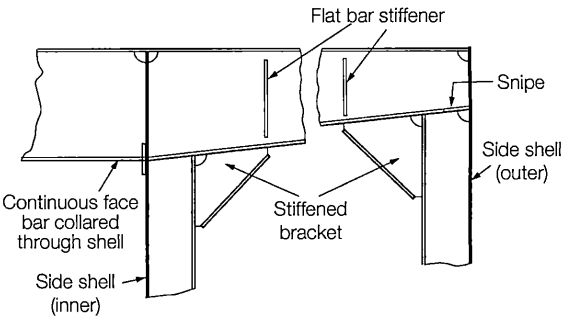
ITEM: Connection between cross-deck beams and side hulls

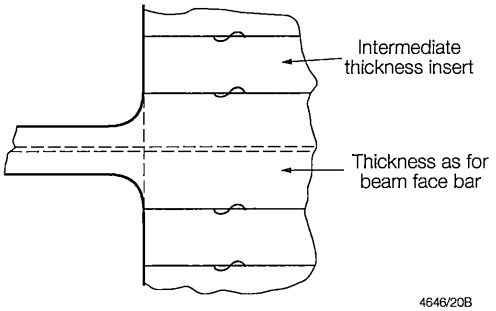
Lloyd's Register

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT



4646/20A





4646/20B

Plan view

NOTES

Failure Mechanism	Buckling of webs of cross-deck beams, and fracturing of deck plating in way of end connection due to hard spot.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. Webs of frames to be accurately aligned with webs of cross-deck beams. All welds in way of end connection of frames are to be double continuous type. Webs of transverse beams are to be accurately aligned.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
2	STEEL/ALUMINIUM CONSTRUCTION	21

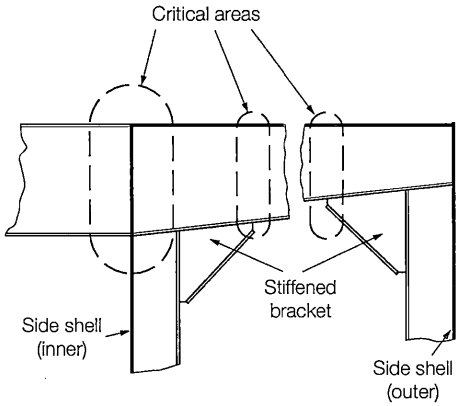
Document Released Under the Access to Information Act / Document divulgué en vertu de la Loi sur l'accès à l'information.

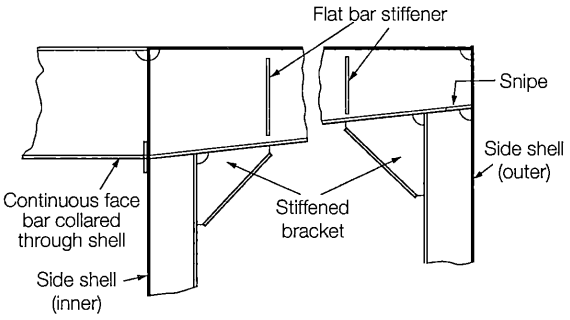
Detail Design Improvement for Steel/Aluminium Construction

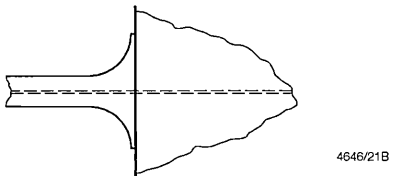
AREA: Cross-deck structure, multi-hulls

ITEM: Connection between cross-deck beams and side hulls

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT







Plan view

NOTES

Failure Mechanism	Buckling of webs of cross-deck beams, and fracturing of deck plating in way of end connection due to hard spot.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. Webs of frames to be accurately aligned with webs of cross-deck beams. All welds in way of end connections to be double continuous type. Webs of transverse beams are to be accurately aligned.

GROUP 3	GUIDANCE NOTES FOR DESIGN DETAILS STEEL/ALUMINIUM CONSTRUCTION	FIGURE 22

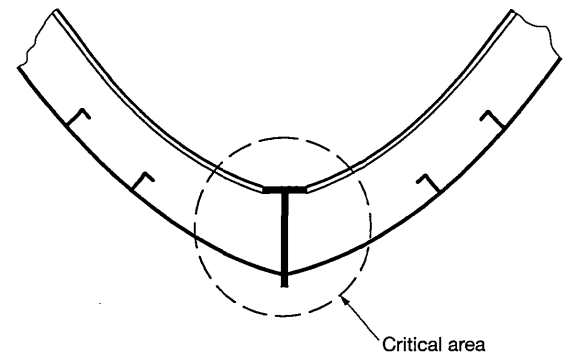
Document Released Under the Access to Information Act / Document divulgué en vertu de la Loi sur l'accès à l'information.

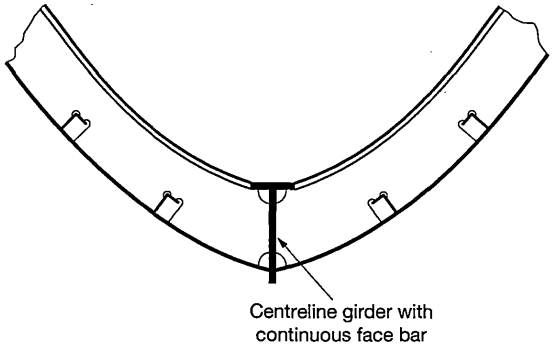
Detail Design Improvement for Steel/Aluminium Construction

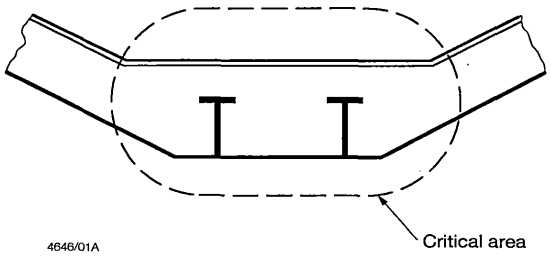
AREA: Hull centreline structure

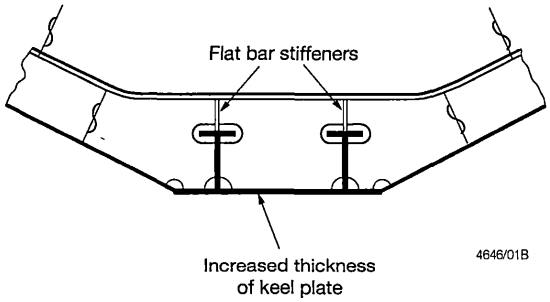
ITEM: Bar and plate keels

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT









NOTES

Failure Mechanism	Fracturing of centre girder(s), buckling of keel plate and floors.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. Butts in webs are to be staggered from butts in face flats.

GROUP 3	GUIDANCE NOTES FOR DESIGN DETAILS STEEL/ALUMINIUM CONSTRUCTION	FIGURE 23

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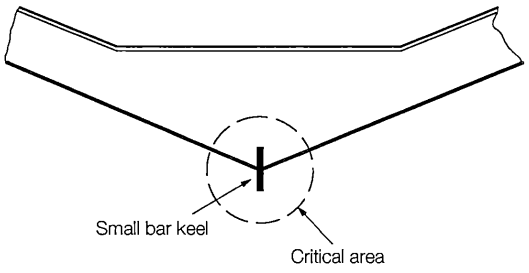
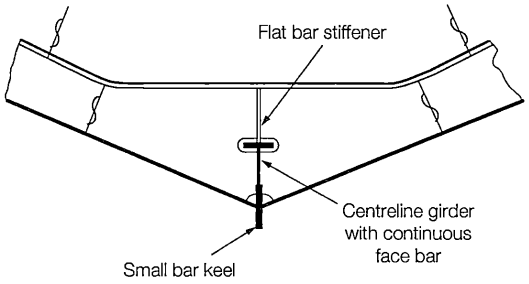
Detail Design Improvement for Steel/Aluminium Construction

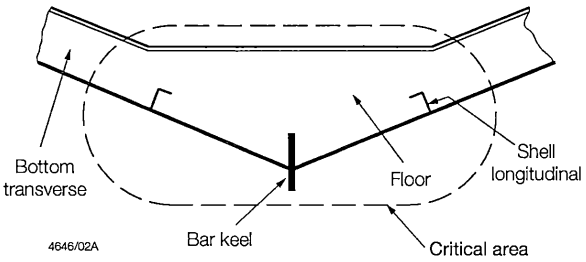
AREA: Hull centreline structure

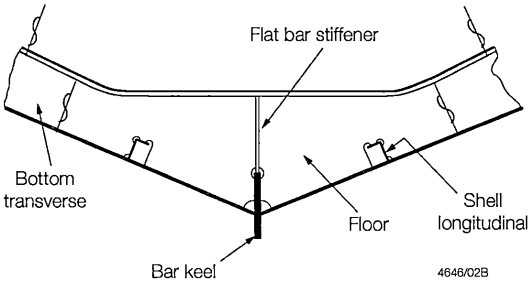
ITEM: Bar keels

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT









NOTES

Failure Mechanism	Buckling of bar keel, shell plate and floors.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. Butts in webs are to be staggered from butts in face flats.

GROUP 3	GUIDANCE NOTES FOR DESIGN DETAILS STEEL/ALUMINIUM CONSTRUCTION	FIGURE 24

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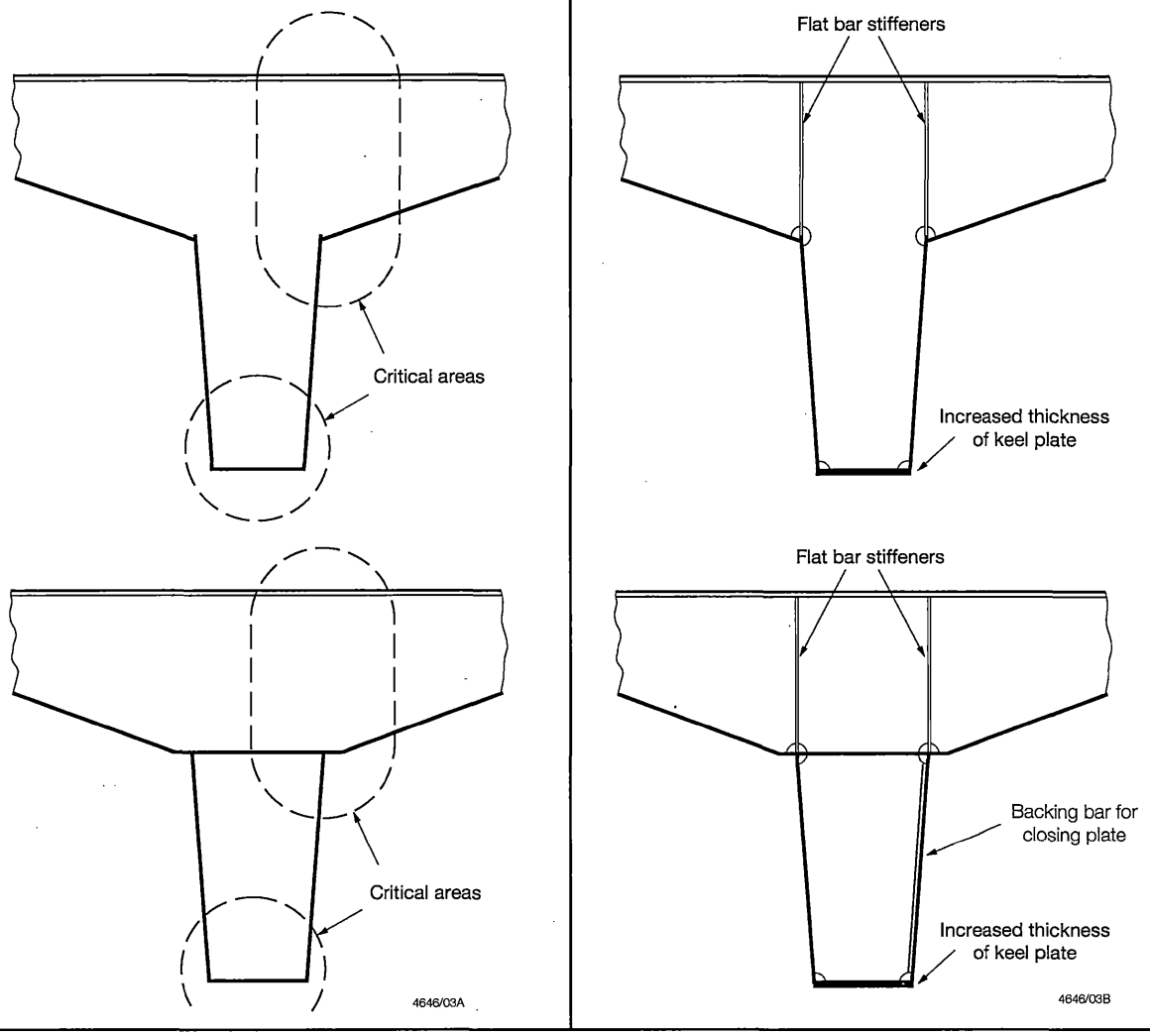
Detail Design Improvement for Steel/Aluminium Construction

AREA: Hull centreline structure

ITEM: Fabricated plate keel/skeg

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT



NOTES

Failure Mechanism	Buckling of keel plate, shell and floor. Fractures from stress concentrations.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively.

GROUP 3	GUIDANCE NOTES FOR DESIGN DETAILS STEEL/ALUMINIUM CONSTRUCTION	FIGURE 25

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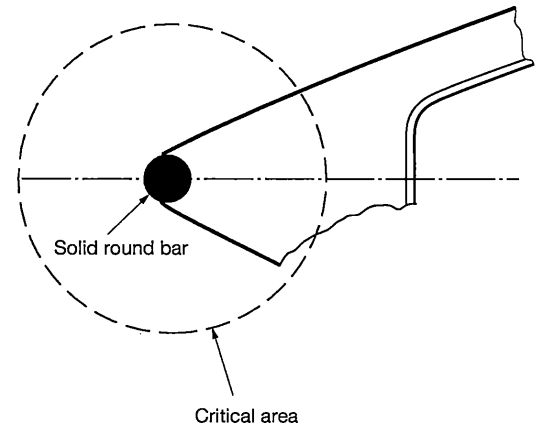
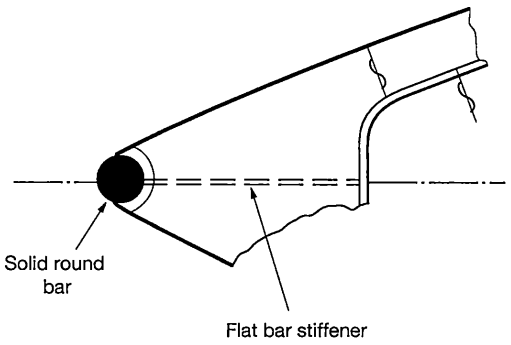
Detail Design Improvement for Steel/Aluminium Construction

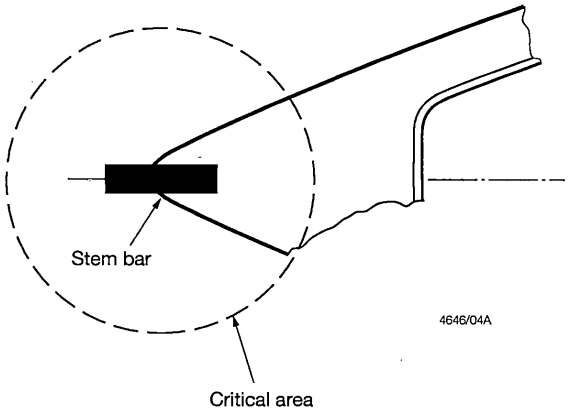
AREA: Hull centreline structure

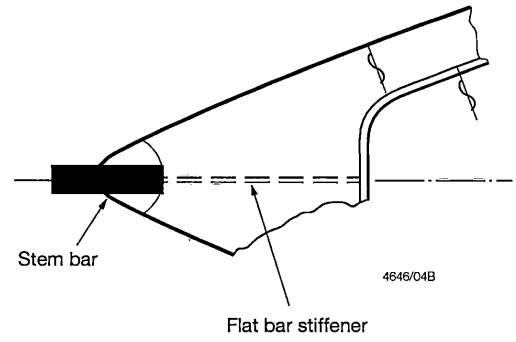
ITEM: Round bar and flat bar stems

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT









NOTES

Failure Mechanism	Buckling of stem plating due to collision and impact with floating debris.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. All welding between stem bar and shell plating to be full penetration type. Butts in webs are to be staggered from butts in face flats.

GROUP 3	GUIDANCE NOTES FOR DESIGN DETAILS STEEL/ALUMINIUM CONSTRUCTION	FIGURE 26

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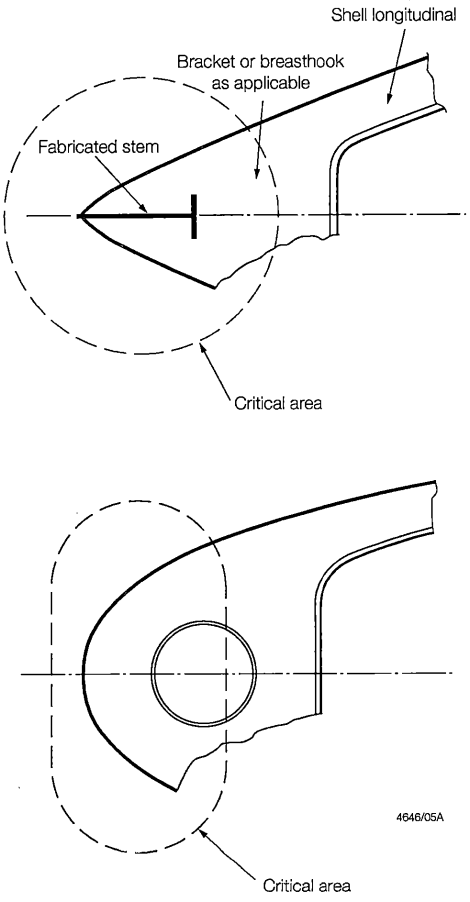
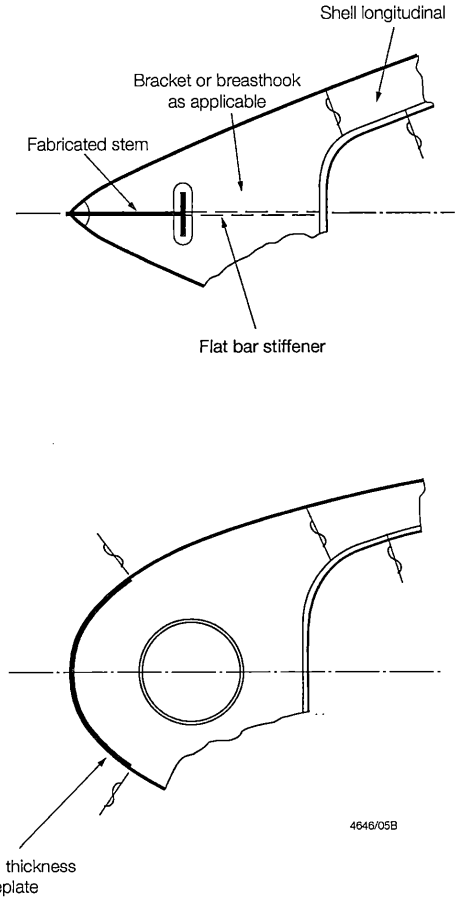
Detail Design Improvement for Steel/Aluminium Construction

AREA: Hull centreline structure

ITEM: Fabricated and plate stems

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT





NOTES

Failure Mechanism	Buckling of stem plating due to collision and impact with floating debris.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. All welding between stem and shell plating to be full penetration type. Butts in webs are to be staggered from the butts in face flats.

GROUP 3	GUIDANCE NOTES FOR DESIGN DETAILS STEEL/ALUMINIUM CONSTRUCTION	FIGURE 27

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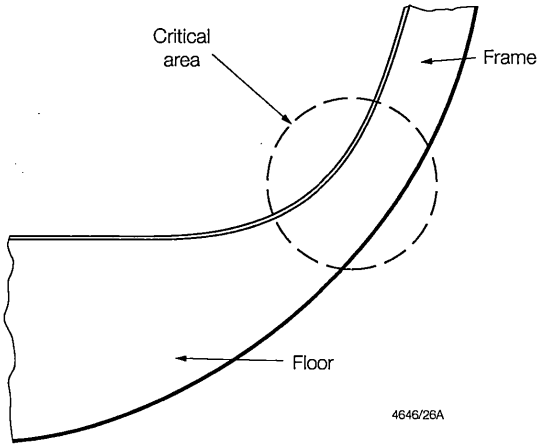
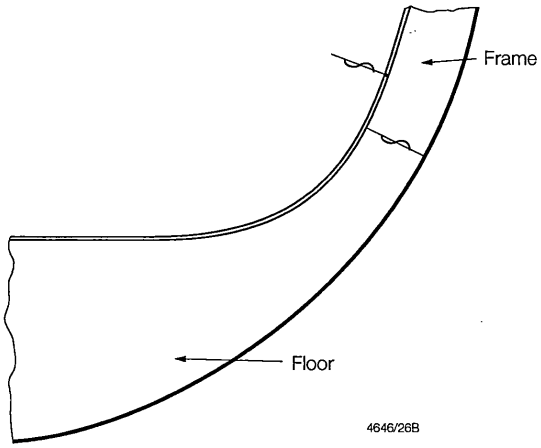
Detail Design Improvement for Steel/Aluminium Construction

AREA: Internal hull structure

ITEM: Floor to frame connection (radiused)

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT
	

NOTES

Failure Mechanism	Fatigue fractures in way of welds.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. Webs and face flats are to be accurately aligned with butts between face flats staggered from the butts in the frame webs.

GROUP 3	GUIDANCE NOTES FOR DESIGN DETAILS STEEL/ALUMINIUM CONSTRUCTION	FIGURE 28

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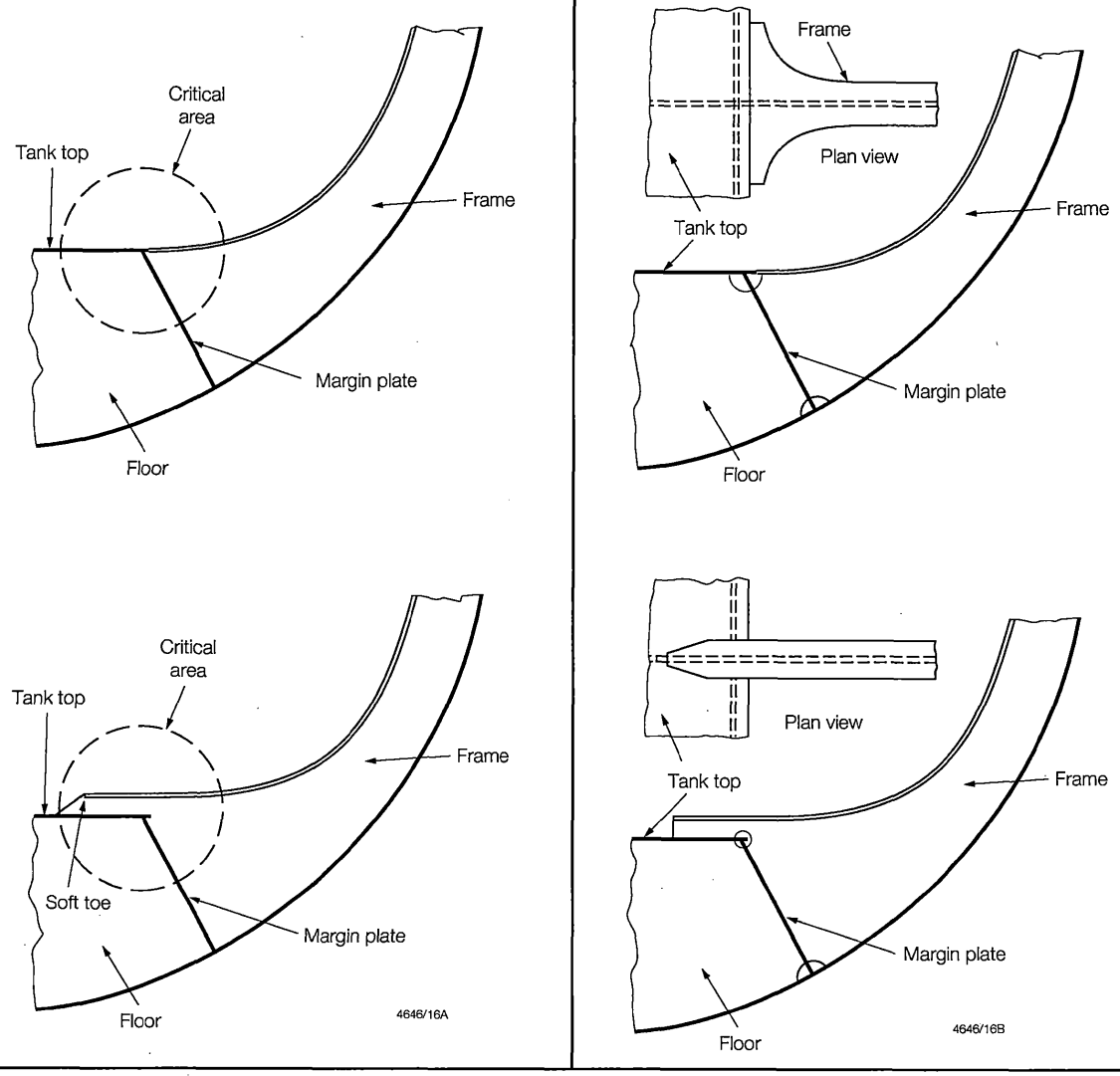
Detail Design Improvement for Steel/Aluminium Construction

AREA: Hull internal structure

ITEM: Web frame to tank boundary connection

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT



NOTES

Failure Mechanism	Fractures arising from stress concentrations.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. Webs of frames to be accurately aligned with floor plating. All welds in way of end connection of frames are to be double continuous type.

GROUP 3	GUIDANCE NOTES FOR DESIGN DETAILS STEEL/ALUMINIUM CONSTRUCTION	FIGURE 29

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Detail Design Improvement for Composite Construction

Section

1 **Identification of critical areas**

2 **Structural details**

■ *Section 1* Identification of critical areas

1.1 General

1.1.1 LR has applied direct calculation procedures in the structural appraisal and approval of new buildings and in various investigations on special service craft of composite construction. Through these procedures and the wealth of information collected on the LR fleet database, a number of locations have been identified where good design, workmanship and alignment during construction are particularly important. These are usually locations where high stress variations can be experienced during the lifetime of the craft. These are referred to to as **critical locations** and are highlighted in this Chapter.

1.1.2 This Chapter identifies the **critical areas** within various structural elements of the hull structure and transverse bulkheads.

1.1.3 In Section 2 the structural **detail design improvements** that can be applied to increase the fatigue life of the structural components are provided. These detail improvements are intended to give the designer guidance for meeting the design criteria for structural detail components.

1.1.4 The application of 2 and 3-dimensional finite element analyses techniques to the hull structure enables the global and local capabilities of the hull structure to withstand static and dynamic loadings to be assessed. Such analyses will enable those high stress locations and joints within the craft to be readily identified. Such locations will then, by their very nature, be at risk to fatigue damage unless appropriate measures are taken at the design stage and subsequently during construction.

1.1.5 Extensive 'in-service' experience of the performance of existing craft structures, already provide an awareness of those critical locations which merit particular attention either due to stress or alignment difficulties.

1.2 Critical areas

1.2.1 Stress concentrations occur in both the primary and secondary structures of all craft and are identified during the design process by such means as finite element calculations. The designer will modify the detail to alleviate the stress concentration either by redesign or increase in scantlings. However, even after modification that area will still, in general, be exposed throughout the life of the craft to stresses higher than in surrounding areas.

1.2.2 At the design appraisal stage, a plan of the structure should, where appropriate, be prepared by the Builder or designer indicating these regions, and consideration can then be given, by the production team, into the appropriate methods of construction and the tolerances to be applied in order to remain within the assigned design parameters.

1.3 Misalignment during construction

1.3.1 The very nature of composite construction involves the manufacture of the material at the same time as the product and therefore, the alignment of the moulds and formers is one of the major considerations. The bonded interface between structural components in sub-assembly areas, prefabrication stages must also be carefully controlled to ensure accurate alignment and to achieve a satisfactory bond.

1.3.2 The most critical type of joint is the bonded 'tee joint' where it is subjected to high magnitudes of tensile and shear stresses. Particular attention must also be given to the transition between different types of stiffener members i.e., top-hat to plate laminates.

1.3.3 It can readily be seen that the combination of stress concentration and misalignment is to be avoided if the fatigue strength is to be satisfactory during the service life of the craft.

1.4 Fatigue considerations

1.4.1 The bottom shell area of high speed craft is subjected to the highest cyclic loading throughout the life of such craft.

1.4.2 The fatigue cracks in bottom shell laminates in way of internal hard spots, and in way of longitudinal end-connections, has been well documented. Constructional details in way of these areas, designed to increase fatigue life, are now incorporated by many Builders as standard. It is, therefore, important that due consideration be given to these details at the design stage to reduce the risk of fatigue cracking during service.

1.4.3 Detailed recommendations are detailed herein for the critical areas, *see* Section 2.

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Section 2
Structural details

2.1 Detail design improvement

2.1.1 For the purposes of these Guidance Notes, structural locations have been divided into five separate groups, with a series of examples of critical structural areas together with alternative associated detail design improvements.

2.1.2 A summary of the data presented is given in Table 5.2.1 whilst the full details are given in Figs. 1 to 30 as contained in this Section.

2.1.3 Generally, where alternative structural detail design improvements are provided, the details shown will provide improved fatigue strength.

2.1.4 Where 'top-hat' sections are shown, the same requirements apply to plate and other stiffening members sections.

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Detail Design Improvement for Composite Construction

Table 5.2.1

Group	Application	Area	Item	Fig. No
	High speed craft			
1	Sandwich	Chine in way of side shell and bottom shell connection	Chine reinforcement	1
		Stem	Stem reinforcement	2
		Hull bottom structure	Bulkhead to hull connection	3
		Hull bottom structure	Bulkhead to hull connection	4
2	Single skin	Hull structure	Spray rails	5
		Hull structure	Spray rails	6
		Chine in way of side shell and bottom shell connection	Chine reinforcement	7
		Hull internal structure	Bulkhead to hull connection	8
		Hull internal structure	Bulkhead to hull connection	9
	Low speed craft			
3	Sandwich	Hull internal structure	Bulkhead to hull connection	10
		Hull internal structure	Bulkhead to hull connection	11
4	Single skin	Hull bottom structure	Bulkhead to hull connection	12
		Hull bottom structure	Bulkhead to hull connection	13
5	General detail	Hull centreline structure	Keel/stem reinforcement and keel stiffening	14
		Hull centreline structure	Keel/stem reinforcement and keel stiffening	15
		Hull structure	Deck to hull connection	16
		Hull structure	Transom boundary	17
		Hull structure	Deck to hull connection	18
		Hull bottom structure	Limber holes	19
		Hull bottom structure	Machinery seating, tapping plates	20
		Hull internal structure	Deep girders and floors	21
		Hull internal structure	'Top-hat' stiffeners penetrating tank boundaries	22
		Hull internal structure	Lower deck/tank top to bottom shell connection	23
		Hull internal structure	Integral tanks access manholes	24
		Skeg (open type)	Skeg stiffening and reinforcement	25
		Skeg (closed type)	Skeg diaphragm plates and sealing laminate	26
		Deck structure	Well deck, lower/sole deck to hull connection	27
		Deck structure	Well deck, lower/sole deck to hull connection	28
		Deck	Bulkhead to deck connection	29
		Deck	Deckhouse to deck connection	30

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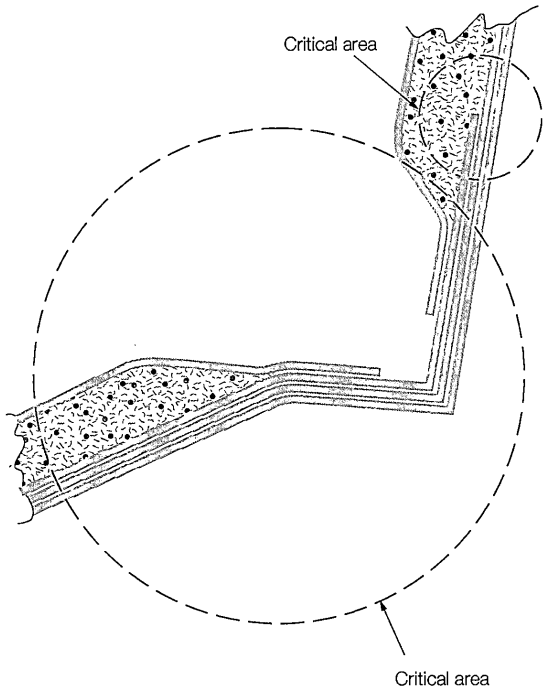
Detail Design Improvement for Composite Construction

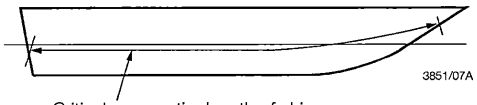
AREA: Chine in way of side shell and bottom shell connection

ITEM: Chine reinforcement

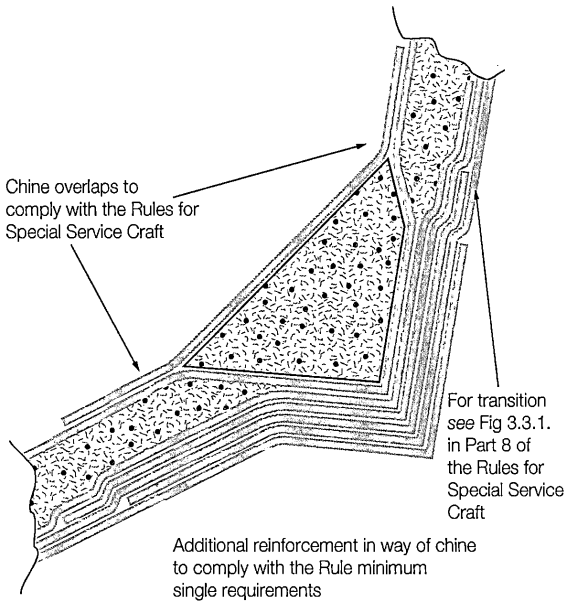
CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

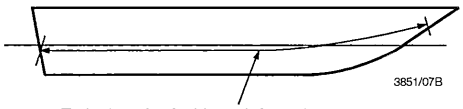
Sandwich construction





Critical area, entire length of chine





Entire length of chine reinforced to comply with the Rules for Special Service Craft

NOTES

Failure Mechanism	Excess loads due to grounding, docking, slinging, hydrodynamic and other types of impact.
Building Tolerance	All FRP materials to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
1	COMPOSITE CONSTRUCTION	1

Document Released Under the Access to Information Act / Document divulgué en vertu de la Loi sur l'accès à l'information.

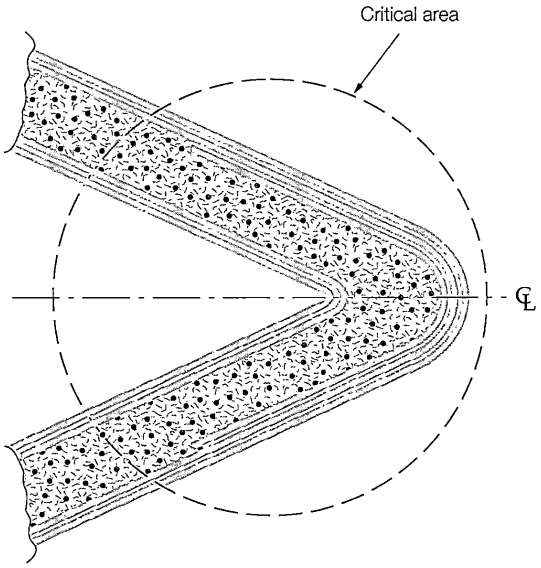
Detail Design Improvement for Composite Construction

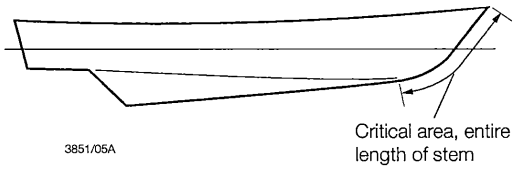
AREA: Stem

ITEM: Stem reinforcement

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

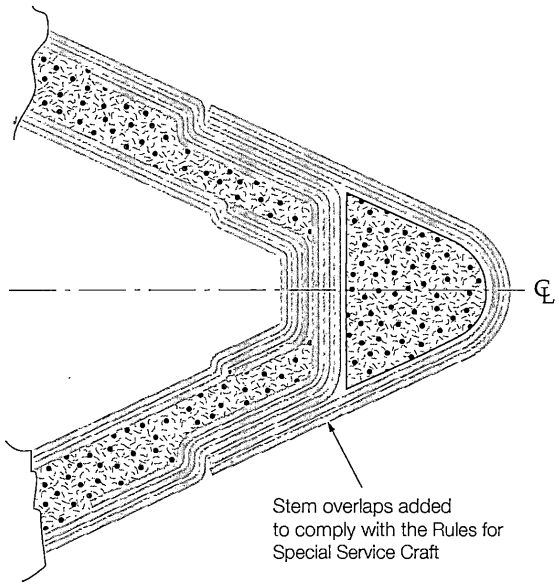
Sandwich construction

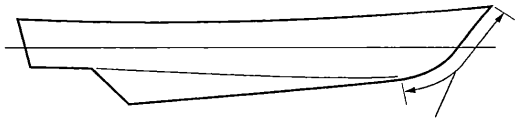




3851/05A

Critical area, entire length of stem





3851/05A

Entire length of stem reinforced to comply with the Rules for Special Service Craft

NOTES

Failure Mechanism	Excess loads due to collision and impact with floating debris.
Building Tolerance	All FRP materials to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
1	COMPOSITE CONSTRUCTION	2

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Detail Design Improvement for Composite Construction

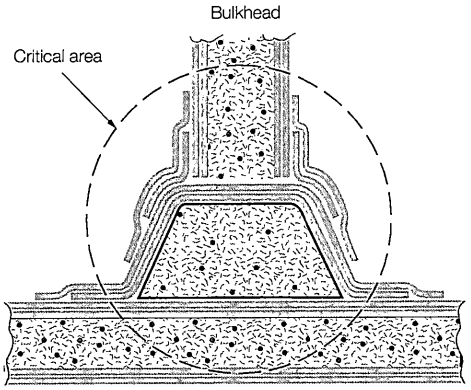
AREA: Hull bottom structure

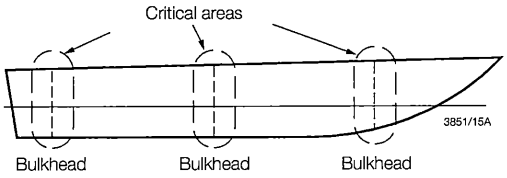
ITEM: Bulkhead to hull connection

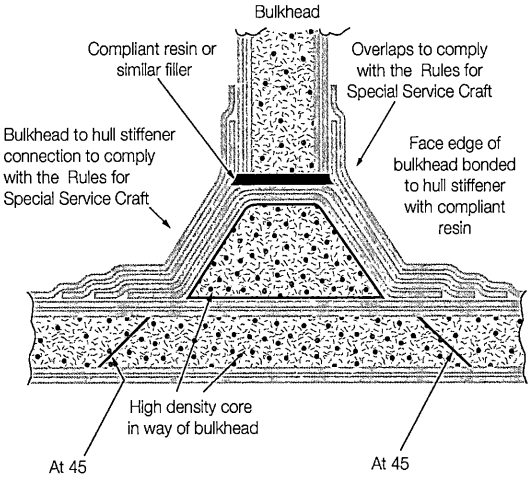
Lloyd's Register

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

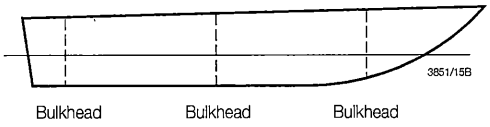
Sandwich construction, high speed







All bulkhead hull connections to comply with the Rules for Special Service Craft



NOTES

Failure Mechanism	Crushing of the sandwich core under the bulkhead, and delamination of the sandwich bulkhead due to excess loads arising from berthing, slinging, impact and racking.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
1	COMPOSITE CONSTRUCTION	3

Document Released Under the Access to Information Act / Document divulgué en vertu de la Loi sur l'accès à l'information.

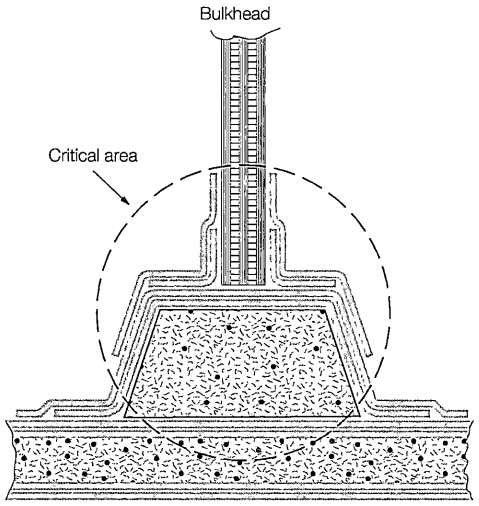
Detail Design Improvement for Composite Construction

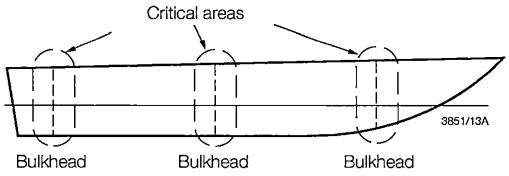
AREA: Hull bottom structure

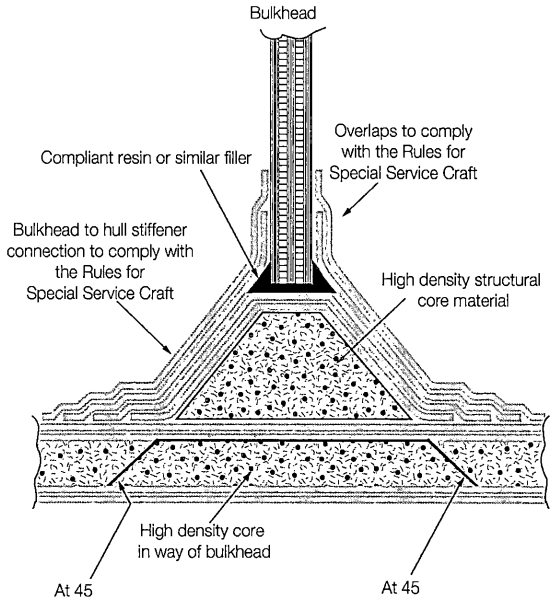
ITEM: Bulkhead to hull connection

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

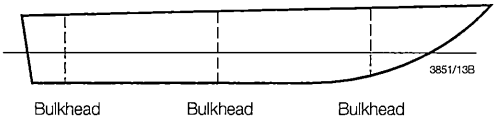
Sandwich construction, high speed







All bulkhead hull connections to comply with the Rules for Special Service Craft



NOTES

Failure Mechanism	Crushing of the sandwich core under the bulkhead due to excess loads arising from berthing, slinging, impact and racking.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
1	COMPOSITE CONSTRUCTION	4

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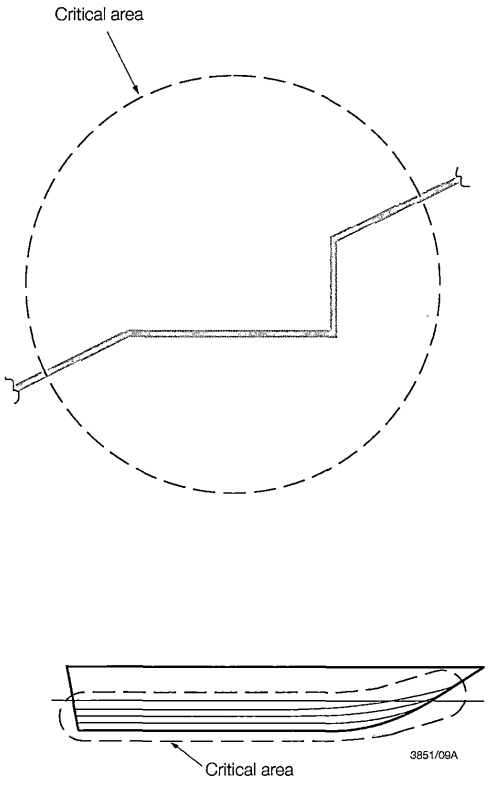
Detail Design Improvement for Composite Construction

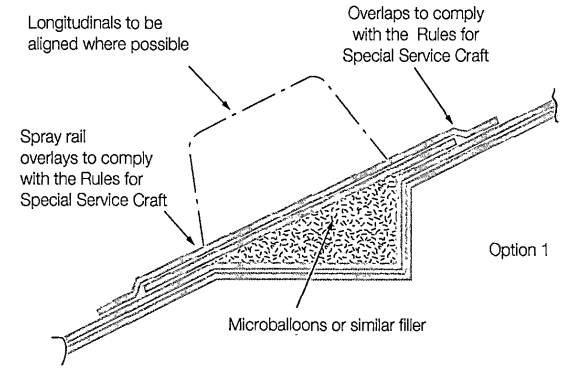
AREA: Hull structure

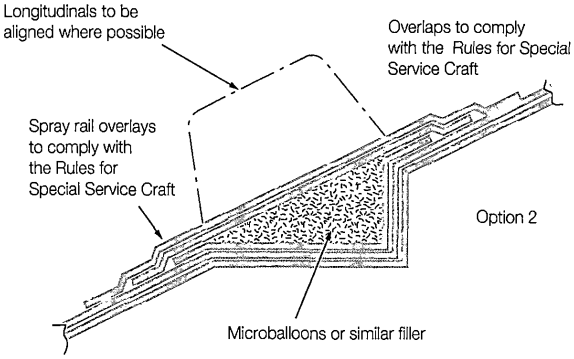
ITEM: Spray rails

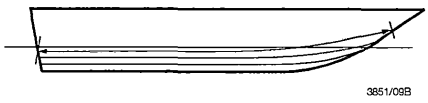
CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

Single skin construction









Entire length of spray rails overlaid to comply with the Rules for Special Service Craft

NOTES

Failure Mechanism	Excess loads due to grounding and impact.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
2	COMPOSITE CONSTRUCTION	5

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Detail Design Improvement for Composite Construction

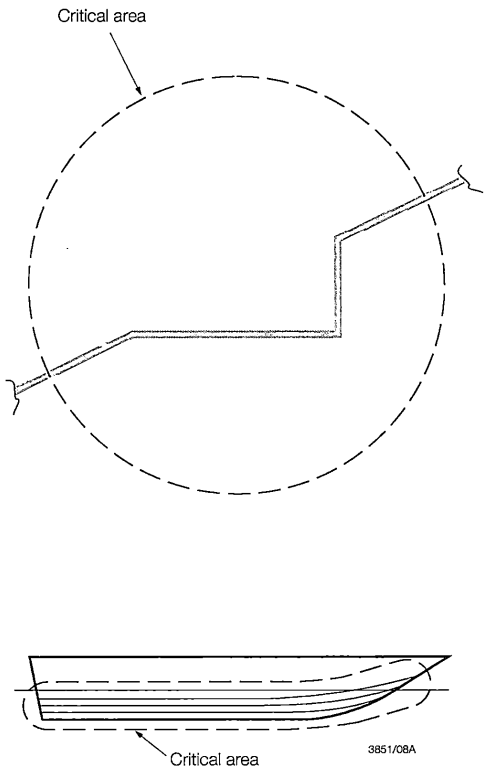
AREA: Hull structure

ITEM: Spray rails

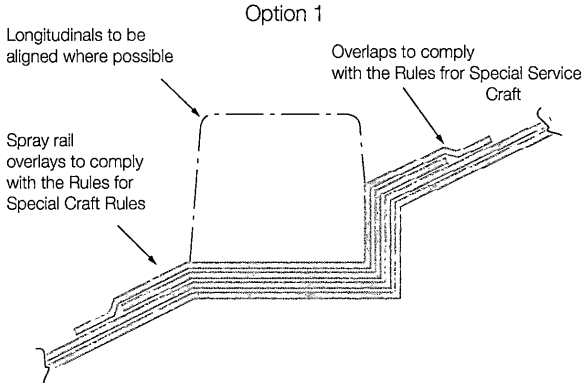
Lloyd's Register

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

Single skin construction



Option 1



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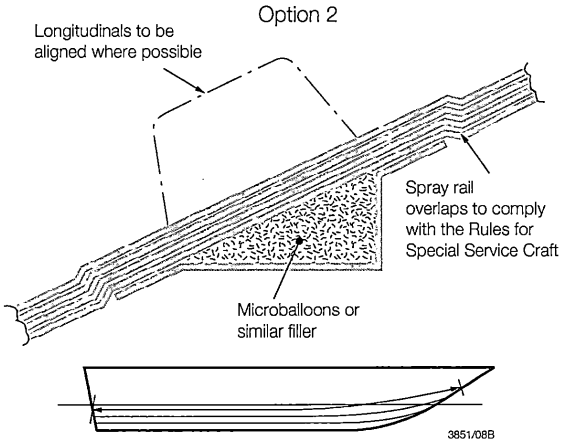

Entire length of spray rails overlaid to comply with the Rules for Special Service Craft

NOTES

Failure Mechanism	Excess loads due to grounding and impact.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with the Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
2	COMPOSITE CONSTRUCTION	6

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Detail Design Improvement for Composite Construction

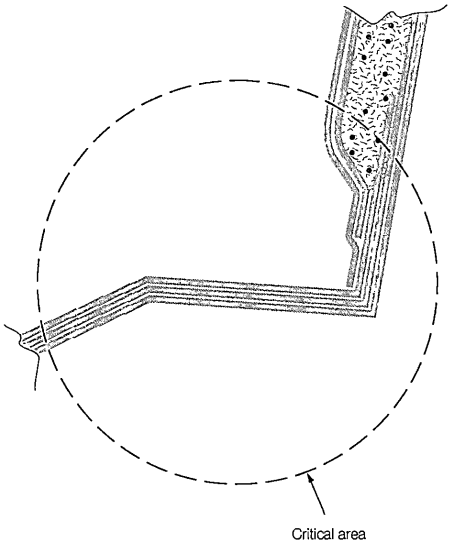
AREA: Chine in way of side shell and bottom shell connection

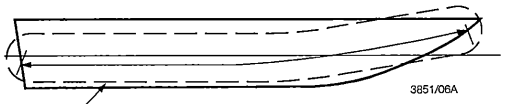
ITEM: Chine reinforcement

Lloyd's Register

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

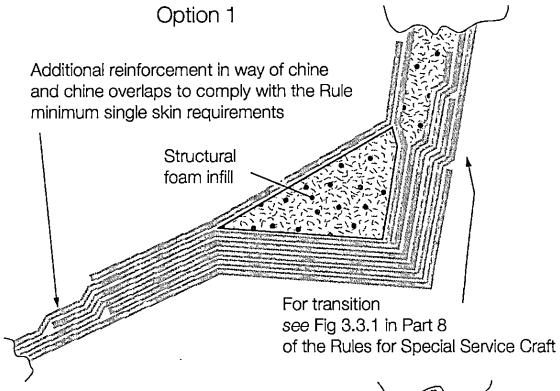
Sandwich side and single skin bottom





Critical area, entire length of chine

Option 1



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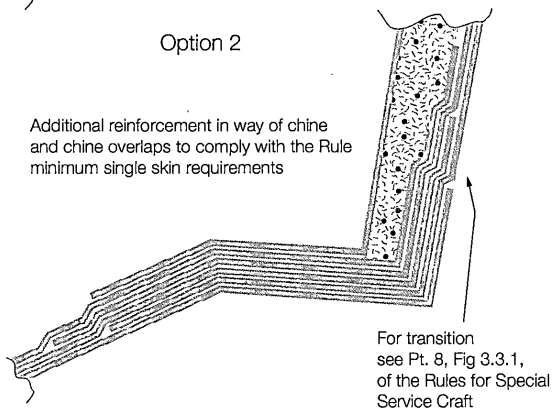

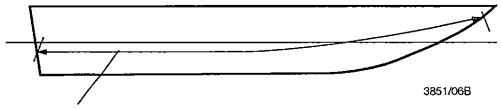

Entire length of chine reinforced to comply with the Rules for Special Service Craft

NOTES

Failure Mechanism	Excess loads due to grounding, docking, slinging and hydrodynamic impact.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft
Laminating Requirements	To be in accordance with the Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
2	COMPOSITE CONSTRUCTION	7

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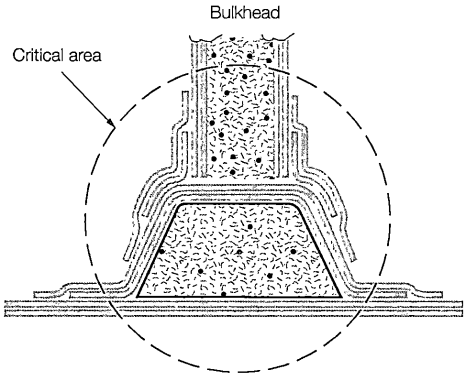
Detail Design Improvement for Composite Construction

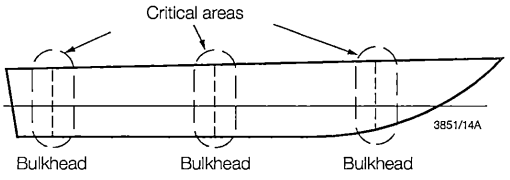
AREA: Hull internal structure

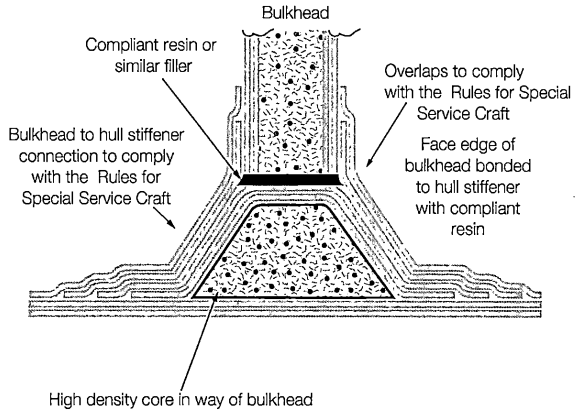
ITEM: Bulkhead to hull connection

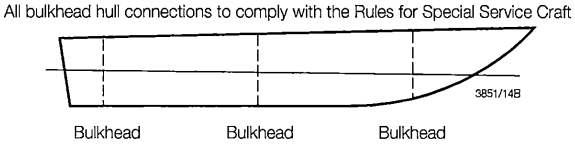
CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

Single skin construction, high speed









NOTES

Failure Mechanism	Excess loads due to berthing, slinging, impact and racking.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with the Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
2	COMPOSITE CONSTRUCTION	8

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Detail Design Improvement for Composite Construction

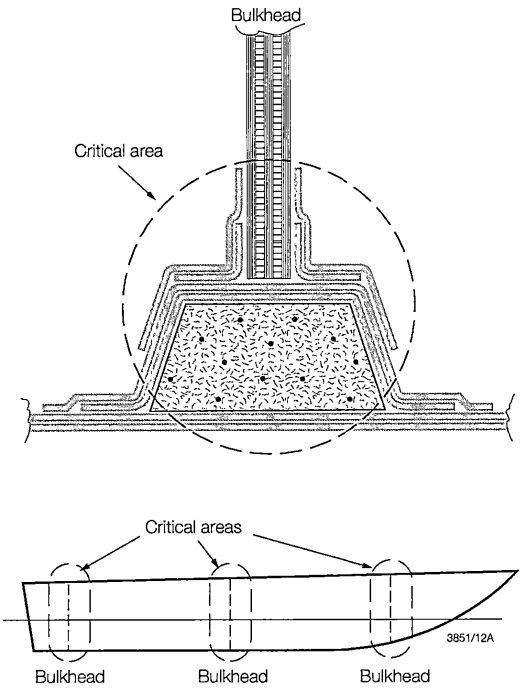
AREA: Hull internal structure

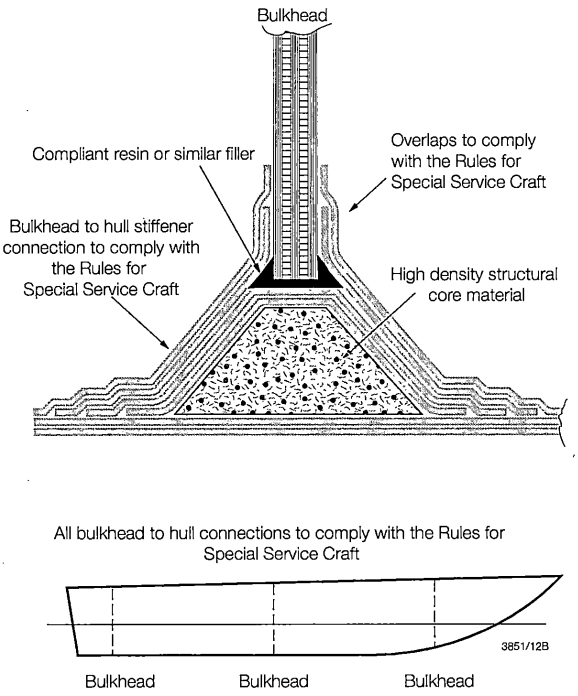
ITEM: Bulkhead to hull connection

Lloyd's Register

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

Single skin construction, high speed





NOTES

Failure Mechanism	Excess loads due to berthing, slinging, impact and racking.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
2	COMPOSITE CONSTRUCTION	9

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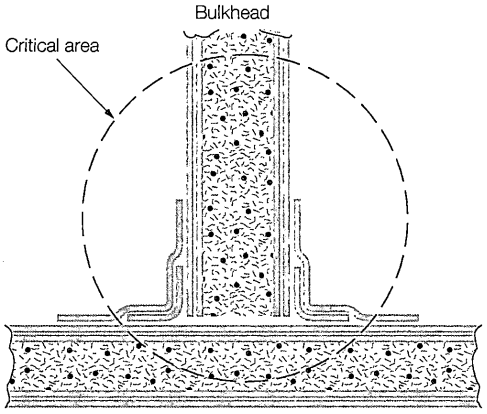
Detail Design Improvement for Composite Construction

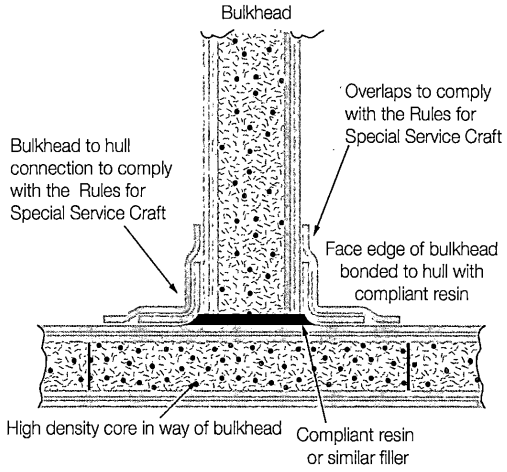
AREA: Hull internal structure

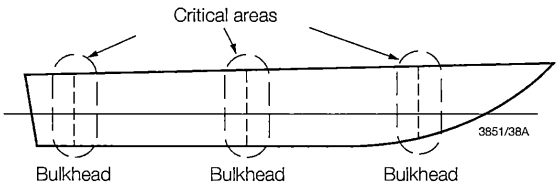
ITEM: Bulkhead to hull connection

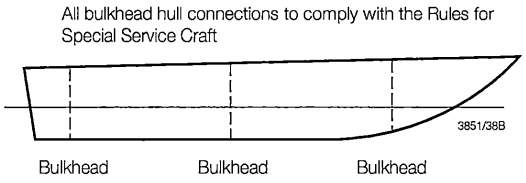
CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

Sandwich construction, low speed









NOTES

Failure Mechanism	Crushing of the sandwich core under the bulkhead, and delamination of the sandwich bulkhead due to excess loads arising from berthing, slinging, impact and racking.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
3	COMPOSITE CONSTRUCTION	10

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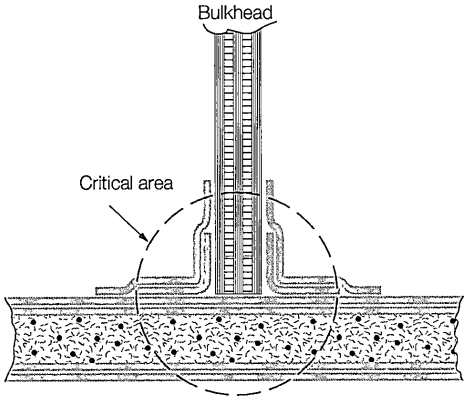
Detail Design Improvement for Composite Construction

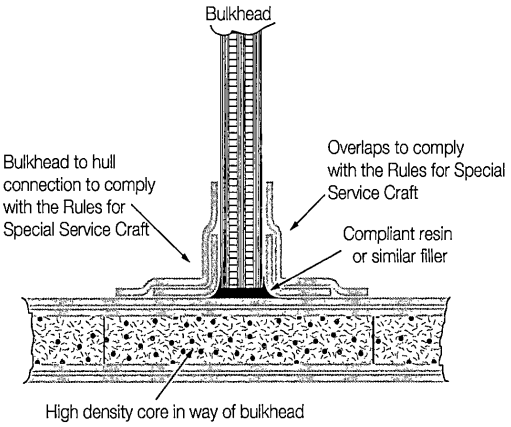
AREA: Hull internal structure

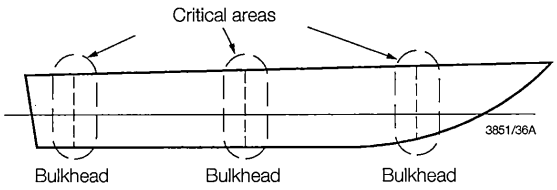
ITEM: Bulkhead to hull connection

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

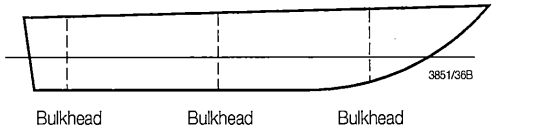
Sandwich construction, low speed







All bulkhead hull connections to comply with the Rules for Special Service Craft



NOTES

Failure Mechanism	Crushing of the sandwich core under the bulkhead due to excess loads arising from berthing, slinging, impact and racking.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
3	COMPOSITE CONSTRUCTION	11

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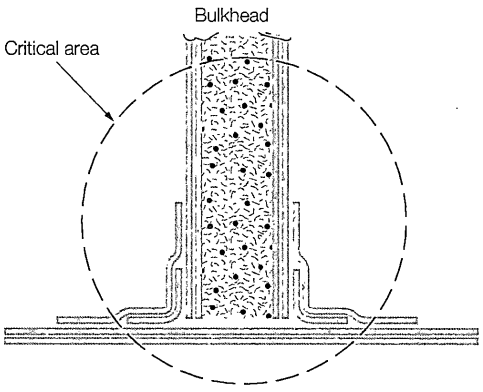
Detail Design Improvement for Composite Construction

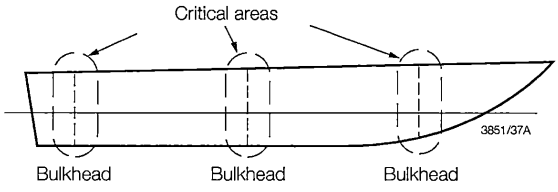
AREA: Hull bottom structure

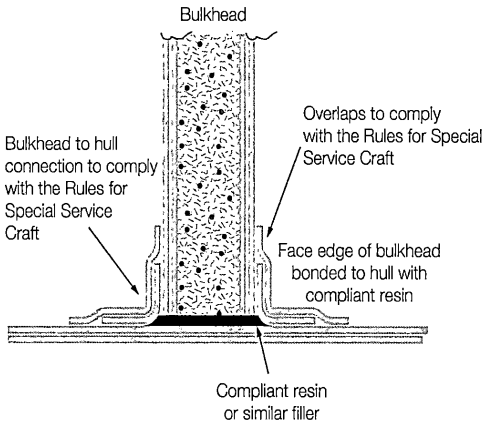
ITEM: Bulkhead to hull connection

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

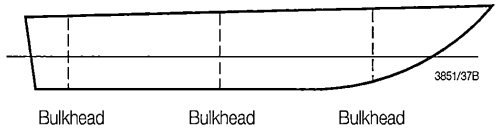
Single skin construction, low speed







All bulkhead hull connections to comply with the Rules for Special Service Craft



NOTES

Failure Mechanism	Excess loads due to berthing, slinging, impact and racking.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
4	COMPOSITE CONSTRUCTION	12

Document Released Under the Access to Information Act / Document divulgué en vertu de la Loi sur l'accès à l'information.

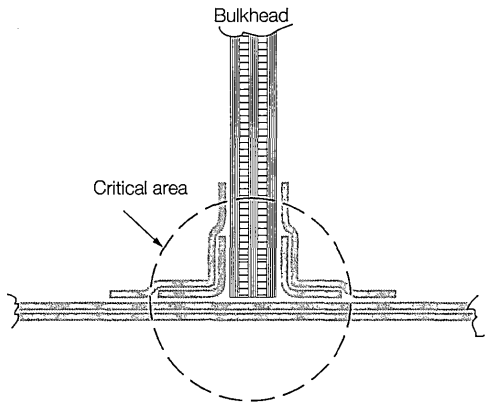
Detail Design Improvement for Composite Construction

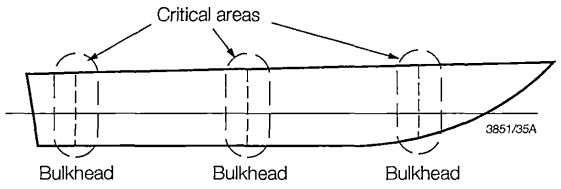
AREA: Hull bottom structure

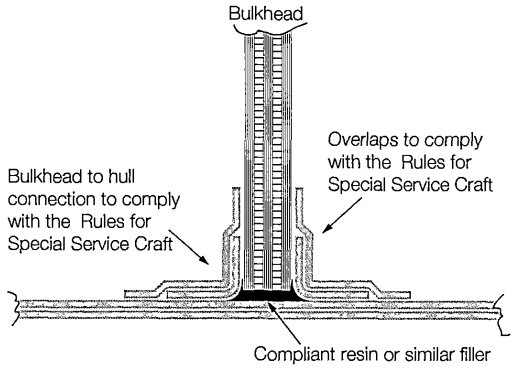
ITEM: Bulkhead to hull connection

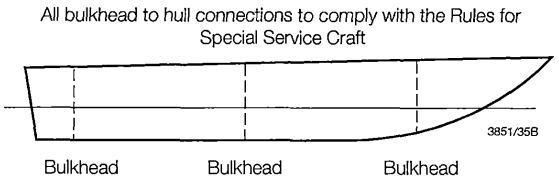
CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

Single skin construction, low speed









NOTES

Failure Mechanism	Excess loads due to berthing, slinging, impact and racking.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP 4	GUIDANCE NOTES FOR DESIGN DETAILS COMPOSITE CONSTRUCTION	FIGURE 13

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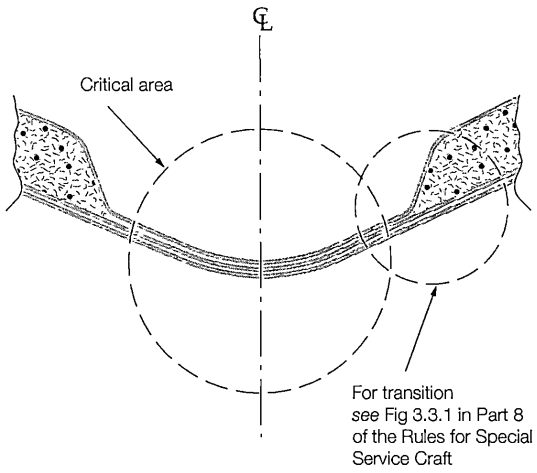
Detail Design Improvement for Composite Construction

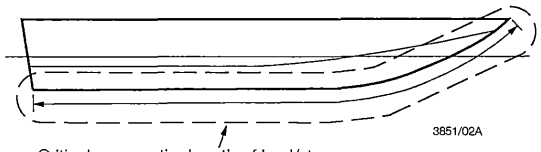
AREA: Hull centreline structure

ITEM: Keel/stem reinforcement and keel stiffening

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

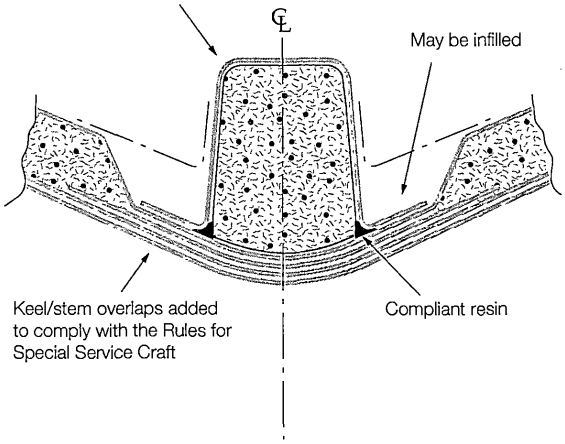
Sandwich construction

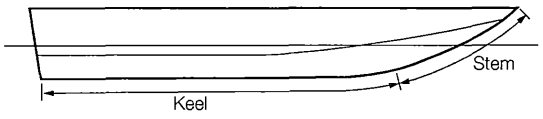




Critical area, entire length of keel/stem

Centre line stiffener/girder added in way of keel to accomodate docking, grounding and slinging loads





Entire length of keel/stem reinforced to comply with the Rules for Special Service Craft

NOTES

Failure Mechanism	Excess loads due to grounding, docking and slinging.
Building Tolerance	All FRP materials to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with the Part 8 of the Rules for Special Service Craft.

GROUP 5	GUIDANCE NOTES FOR DESIGN DETAILS COMPOSITE CONSTRUCTION	FIGURE 14

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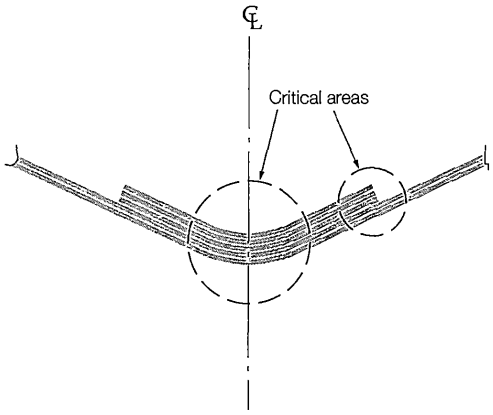
Detail Design Improvement for Composite Construction

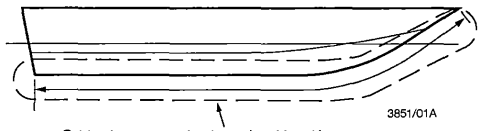
AREA: Hull centreline structure

ITEM: Keel/stem reinforcement and keel stiffening

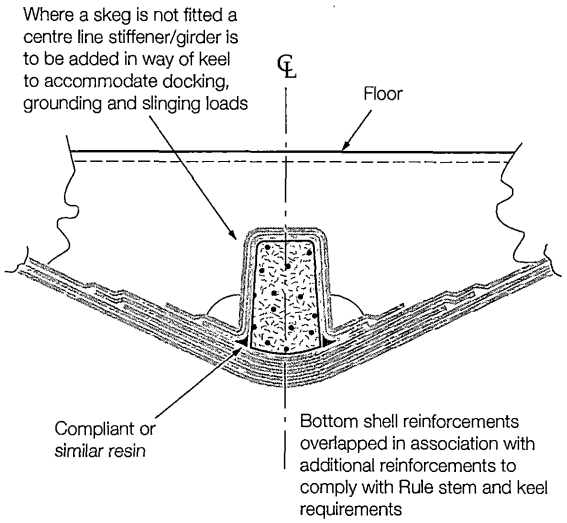
CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

Single skin construction





Critical area, entire length of keel/stem



Entire Length of keel/stem reinforced to comply with the Rules for Special Service Craft

NOTES

Failure Mechanism	Excess loads due to grounding, docking and slinging.
Building Tolerance	All FRP materials to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP 5	GUIDANCE NOTES FOR DESIGN DETAILS COMPOSITE CONSTRUCTION	FIGURE 15

Document Released Under the Access to Information Act / Document divulgué en vertu de la Loi sur l'accès à l'information.

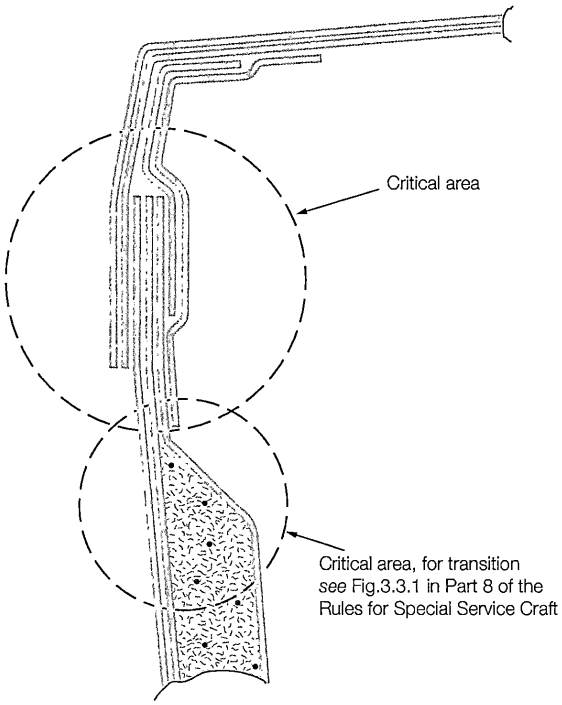
Detail Design Improvement for Composite Construction

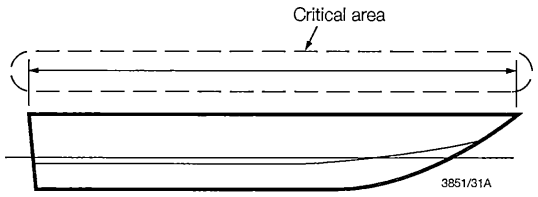
AREA: Hull structure

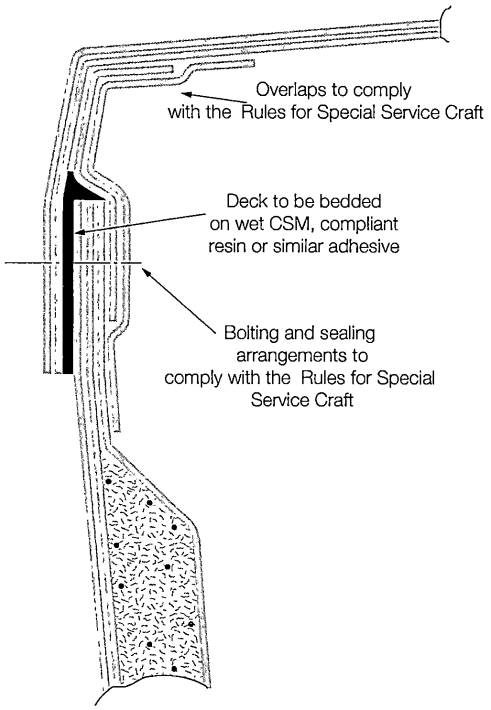
ITEM: Deck to hull connection

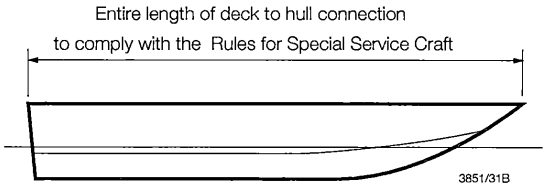
CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

Sandwich construction









NOTES

Failure Mechanism	Excess loads due to berthing, slinging, impact from green seas and other loadings arising from heavy weather.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
5	COMPOSITE CONSTRUCTION	16

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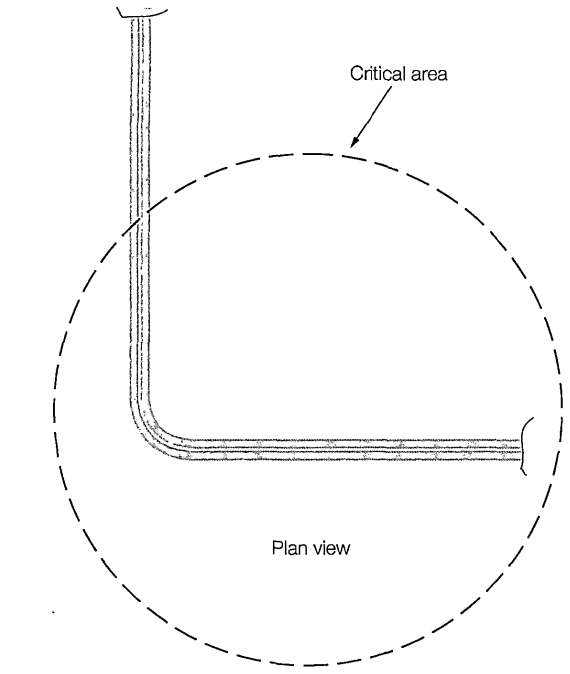
Detail Design Improvement for Composite Construction

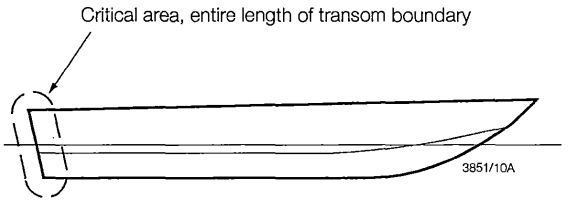
AREA: Hull structure

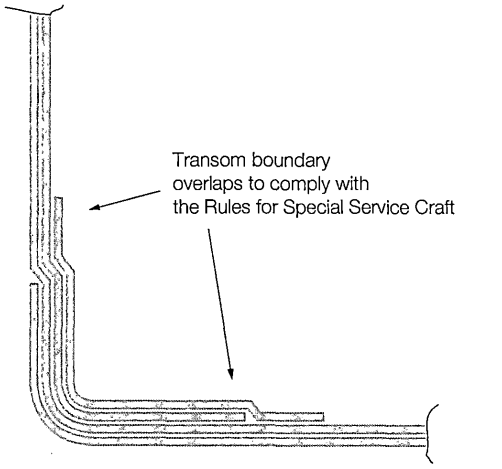
ITEM: Transom boundary

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

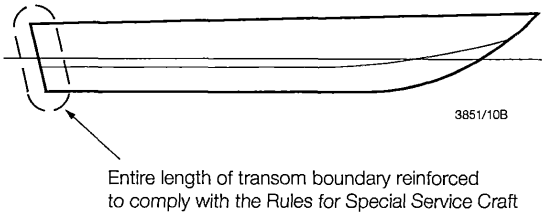
Single skin construction







Additional reinforcement in way of *transom boundary to comply with the* Rules for Special Service Craft



NOTES

Failure Mechanism	Excess loads due to docking and impact due to berthing.
Building Tolerance	All FRP materials to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP 5	GUIDANCE NOTES FOR DESIGN DETAILS COMPOSITE CONSTRUCTION	FIGURE 17

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Detail Design Improvement for Composite Construction

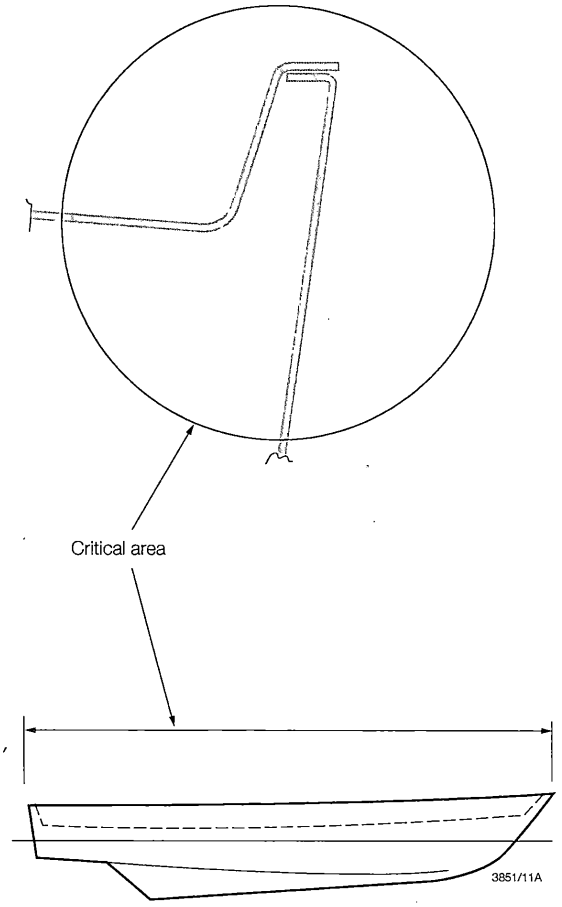
AREA: Hull structure

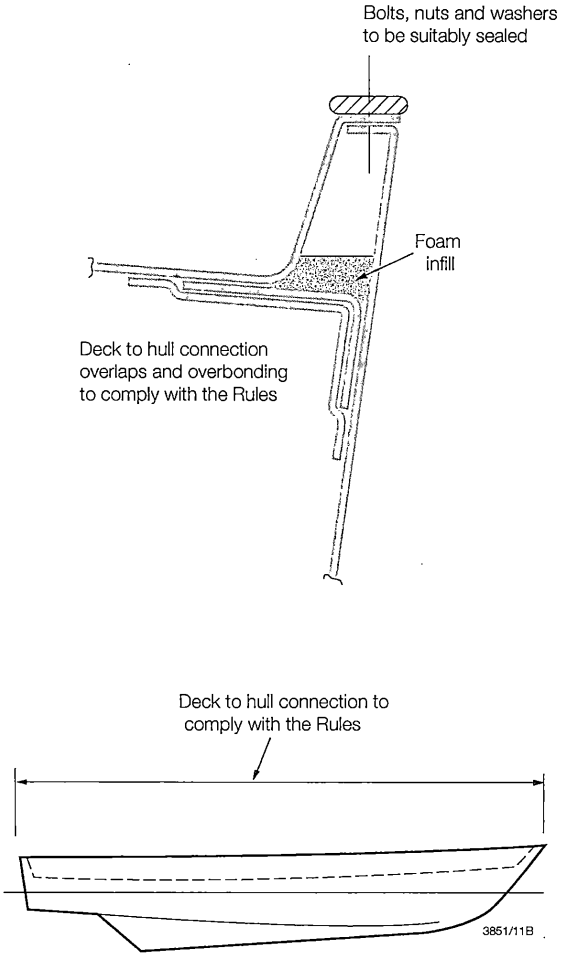
ITEM: Deck to hull connection

Lloyd's Register

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

Single skin construction





NOTES

Failure Mechanism	Excess loads due to berthing, slinging, impact from green seas and other loadings arising from heavy weather.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
5	COMPOSITE CONSTRUCTION	18

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Detail Design Improvement for Composite Construction

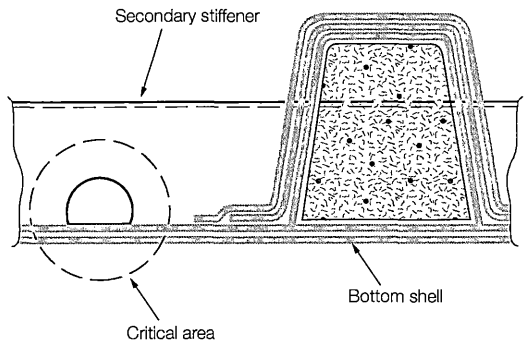
AREA: Hull bottom structure

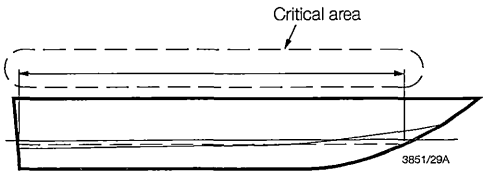
ITEM: Limber holes

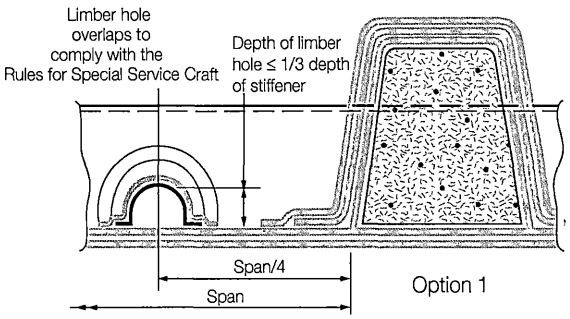
Lloyd's Register

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

Single skin construction

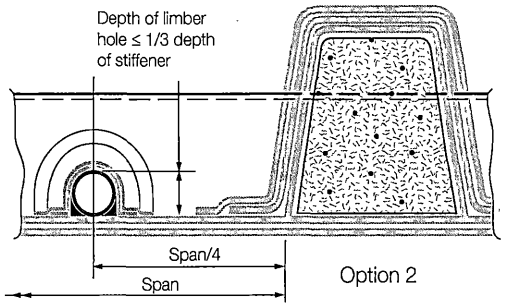




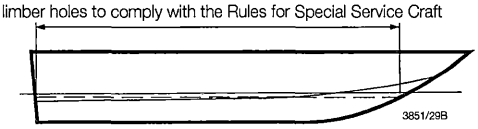


FRP preform bonded to shell and stiffener with compliant resin adhesive

NOTE: PVC preforms to be overlaminated to shell before installation of stiffener



All limber holes to comply with the Rules for Special Service Craft



NOTES

Failure Mechanism	Excess loads due to hydrodynamic impact, grounding, docking and slinging leading to stiffener web failure.
Building Tolerance	All FRP materials to be in accordance with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
5	COMPOSITE CONSTRUCTION	19

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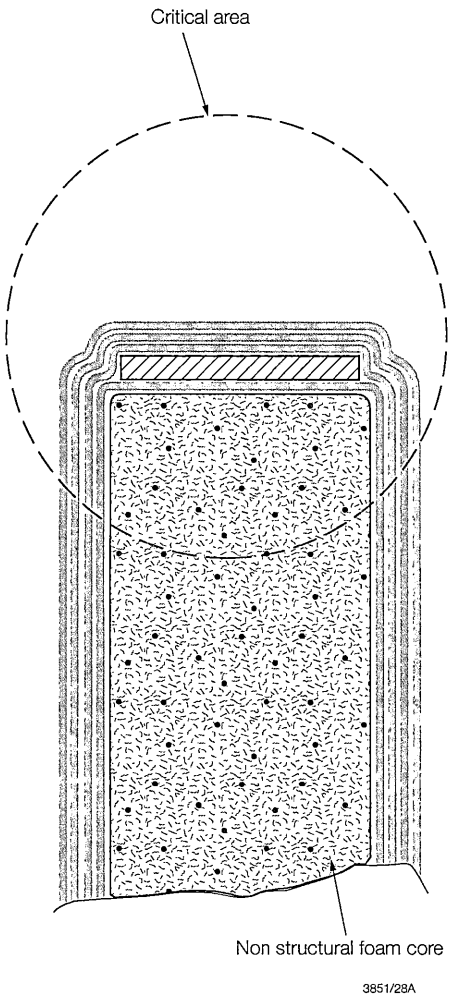
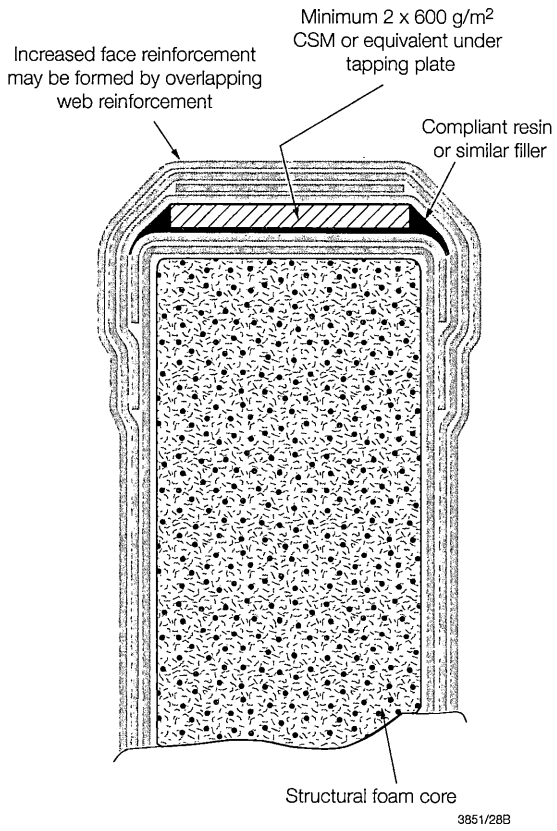
Detail Design Improvement for Composite Construction

AREA: Hull bottom structure

ITEM: Machinery seating, tapping plates

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT





Tapping plate is to be suitably abraded, all sharp edges removed and all corners radiused prior to encapsulating

NOTES

Failure Mechanism	Engine loadings arising from thrust, torque and mass.
Building Tolerance	All FRP materials to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
5	COMPOSITE CONSTRUCTION	20

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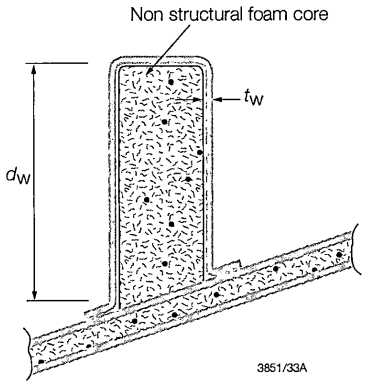
Detail Design Improvement for Composite Construction

AREA: Hull internal structure

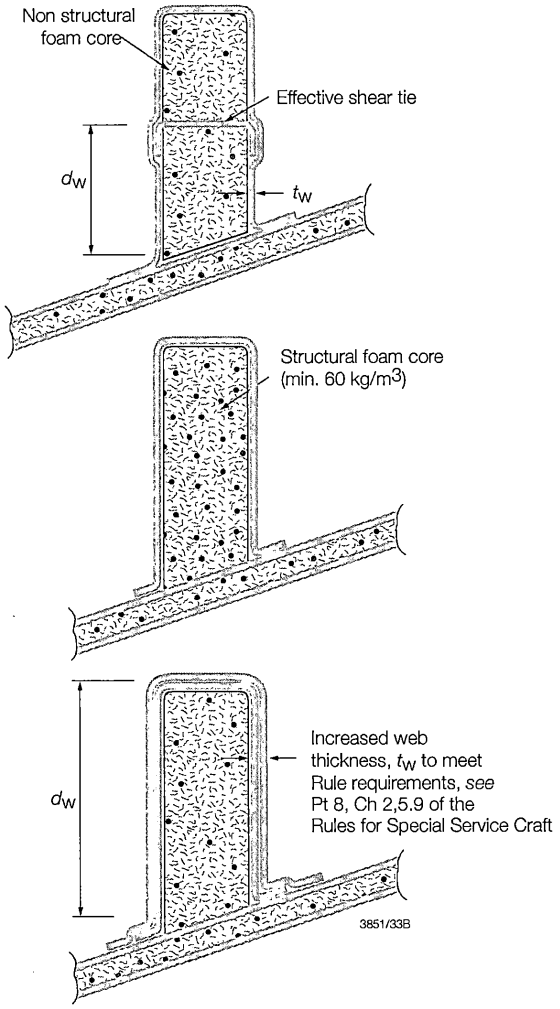
ITEM: Deep girders and floors

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT
Sandwich construction/single skin construction	



t_W is to satisfy the Rule requirement for d_W, *see* Pt 8, Ch 2,5.9 of the Rules for Special Service Craft

d_W = unsupported web depth
t_W = web thickness



NOTES

Failure Mechanism	Web buckling under design load, docking and berthing loads.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP 5	GUIDANCE NOTES FOR DESIGN DETAILS COMPOSITE CONSTRUCTION	FIGURE 21

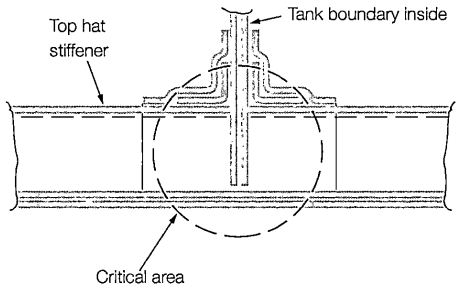
Document Released Under the Access to Information Act / Document divulgué en vertu de la Loi sur l'accès à l'information.

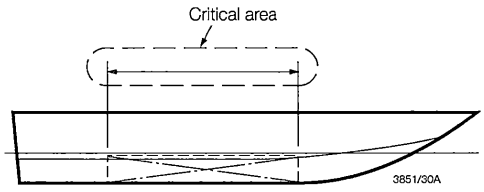
Detail Design Improvement for Composite Construction

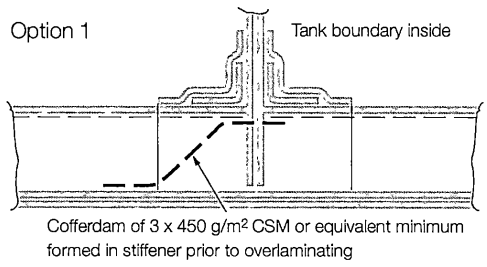
AREA: Hull internal structure

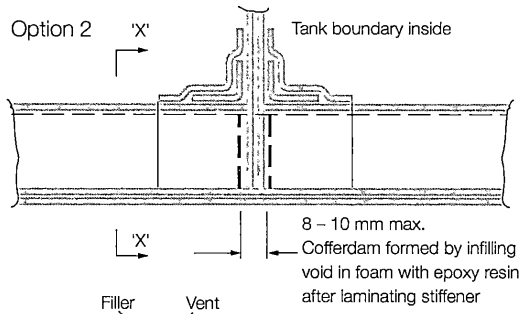
ITEM: 'Top-hat' stiffeners penetrating tank boundaries

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT









NOTES

Failure Mechanism	Ingress and permeation of fluid along stiffener.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft. Fit-up is to be very good.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
5	COMPOSITE CONSTRUCTION	22

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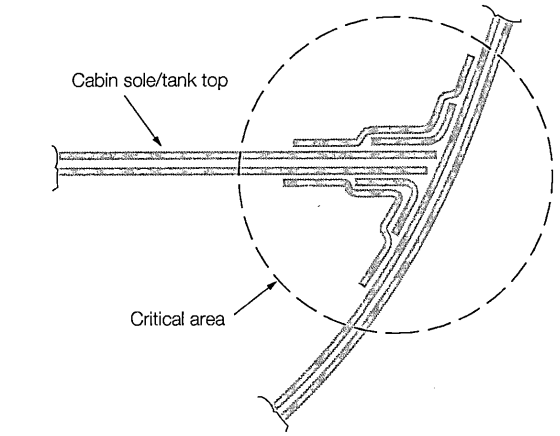
Detail Design Improvement for Composite Construction

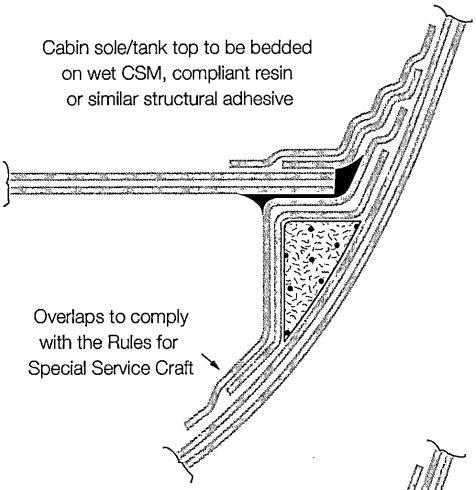
AREA: Hull internal structure

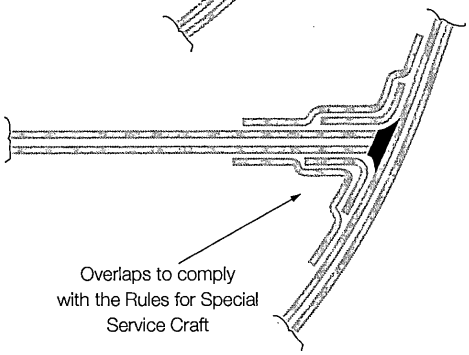
ITEM: Lower deck/tank top to bottom shell connection

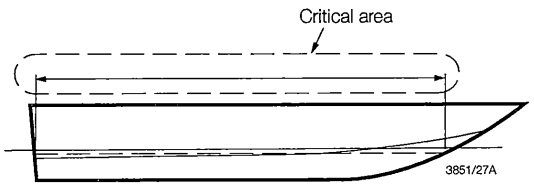
CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

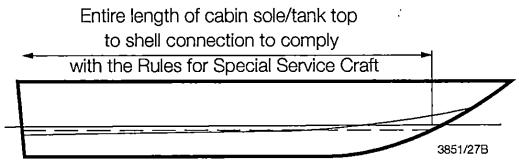
Single skin construction











NOTES

Failure Mechanism	Excess loads due to impact also hydrostatic pressure where the internal structure forms the boundary of an integral tank.
Building Tolerance	All FRP materials to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP 5	GUIDANCE NOTES FOR DESIGN DETAILS COMPOSITE CONSTRUCTION	FIGURE 23

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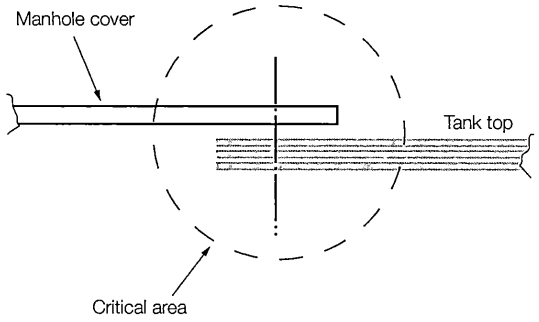
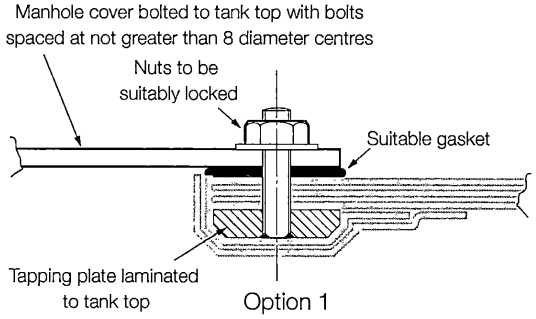
Detail Design Improvement for Composite Construction

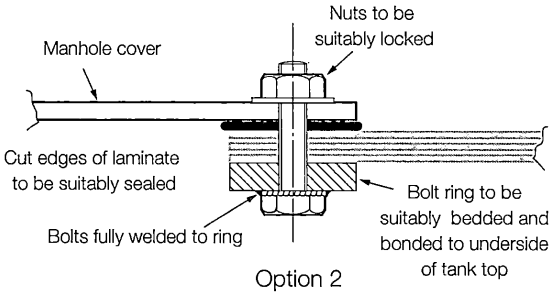
AREA: Hull internal structure

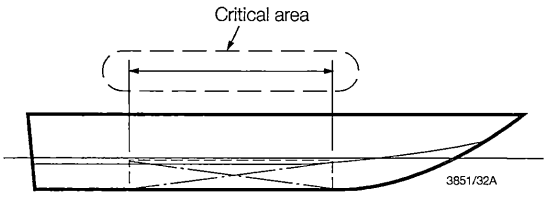
ITEM: Integral tanks access manholes

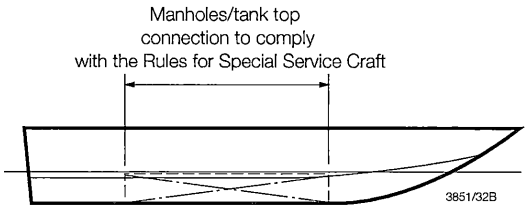
CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT











NOTES

Failure Mechanism	Leakage under hydrostatic pressure.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
5	COMPOSITE CONSTRUCTION	24

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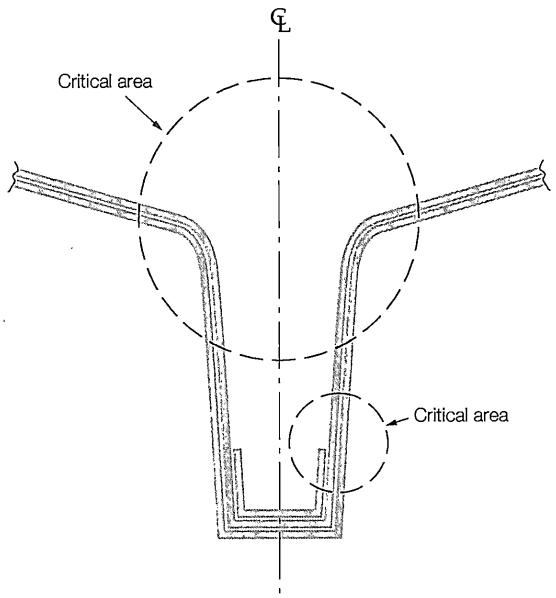
Detail Design Improvement for Composite Construction

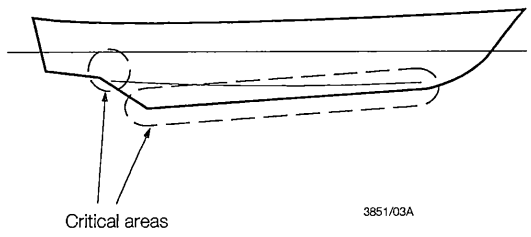
AREA: Skeg (open type)

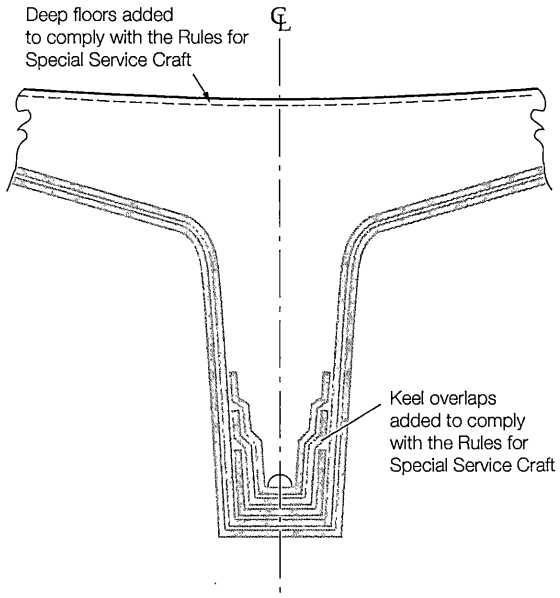
ITEM: Skeg stiffening and reinforcement

Lloyd's Register

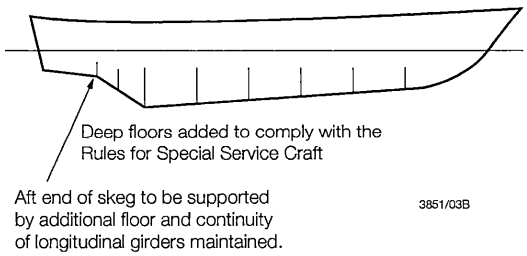
CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT







Note : Where the hull is moulded in two halves, the bottom shell laminate is to be reinstated across ℄ prior to additional reinforcements to comply with the Rule keel requirements.



NOTES

Failure Mechanism	Excess loads due to grounding, docking, slinging and hydrostatic pressure.
Building Tolerance	All FRP materials to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
5	COMPOSITE CONSTRUCTION	25

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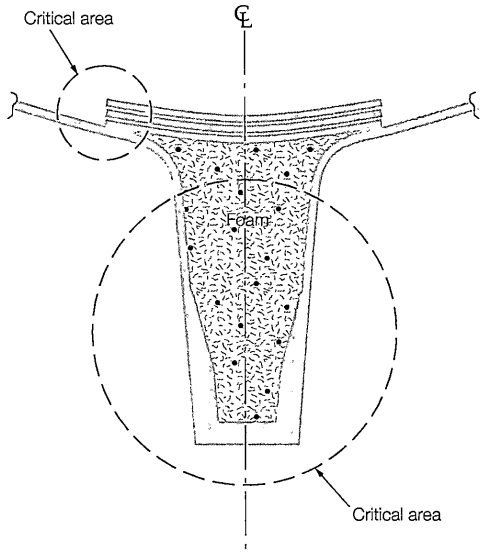
Detail Design Improvement for Composite Construction

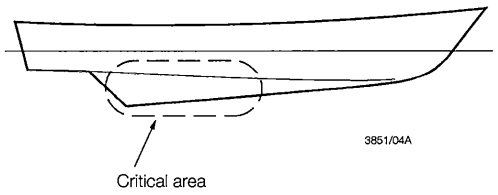
AREA: Skeg (closed type)

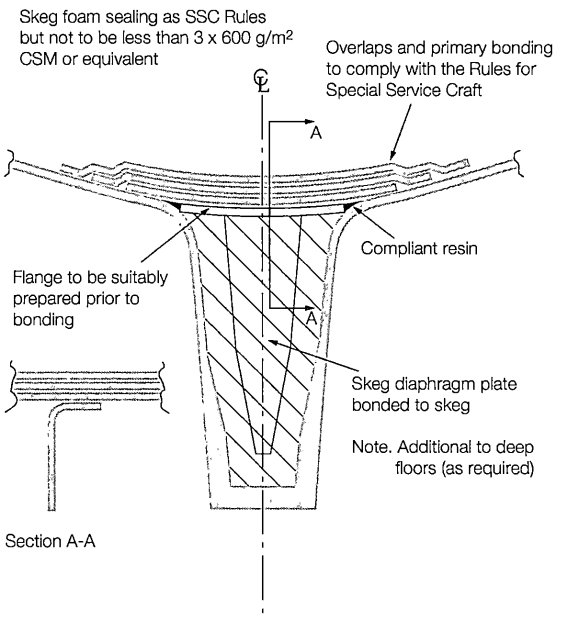
ITEM: Skeg diaphragm plates and sealing laminate

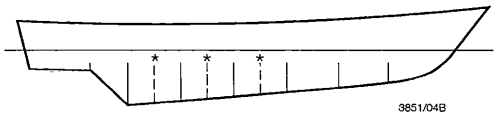
Lloyd's Register

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT









* Skeg diaphragm plates added as required to ensure that skeg panel sizes comply with the Rules for Special Service Craft

NOTES

Failure Mechanism	Excess loads due to grounding, docking, slinging and hydrostatic pressure both externally and internally in the case of integral tanks.
Building Tolerance	To align with bottom framing. All FRP materials to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
5	COMPOSITE CONSTRUCTION	26

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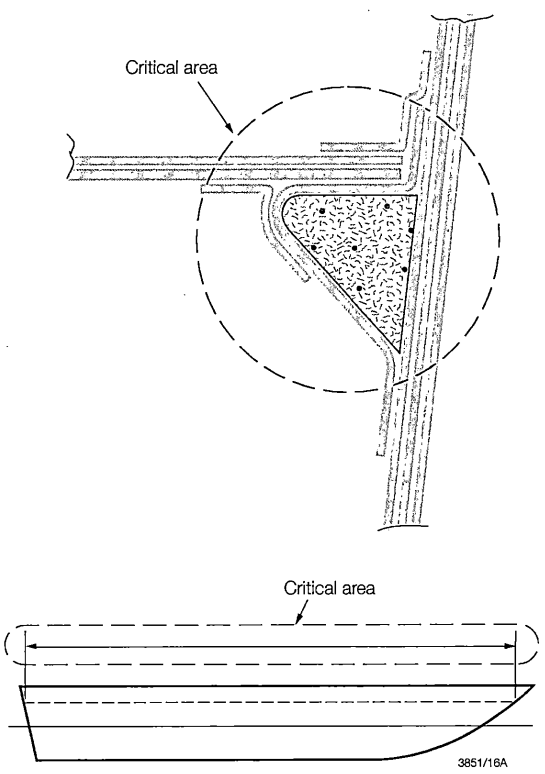
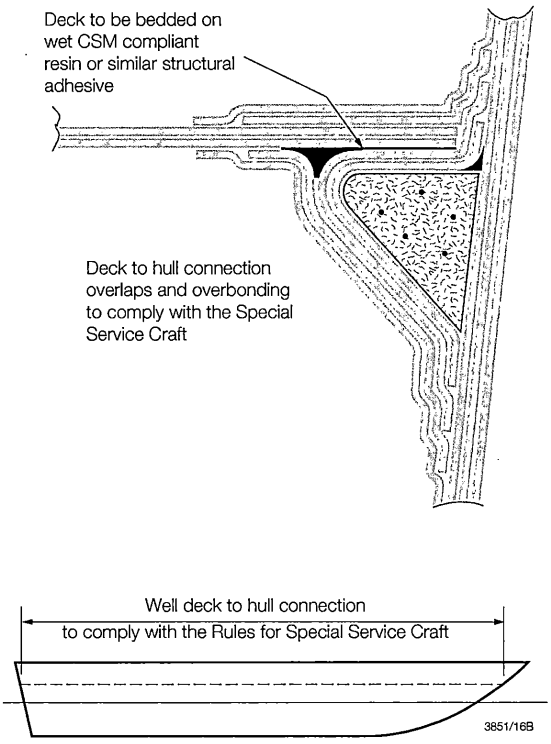
Detail Design Improvement for Composite Construction

AREA: Deck structure

ITEM: Well deck, lower/sole deck to hull connection

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT





NOTES

Failure Mechanism	Excess loads due to berthing and slinging.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
5	COMPOSITE CONSTRUCTION	27

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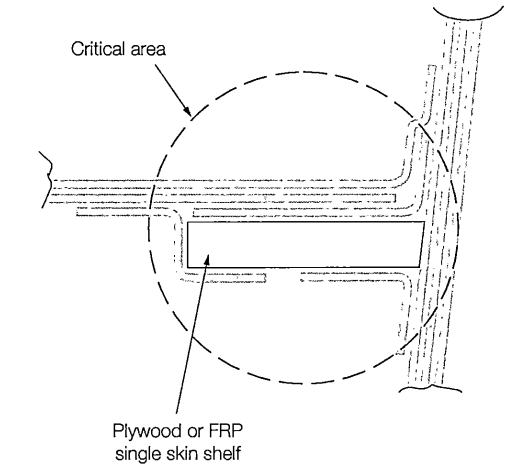
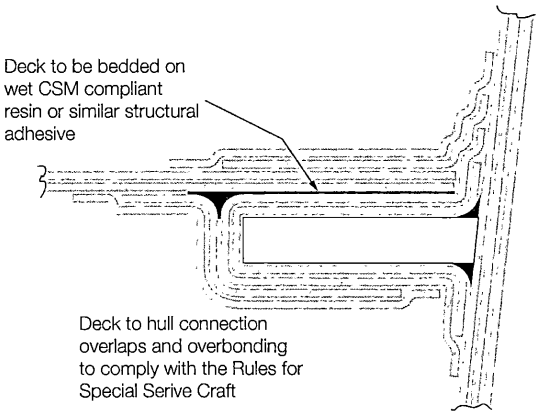
Detail Design Improvement for Composite Construction

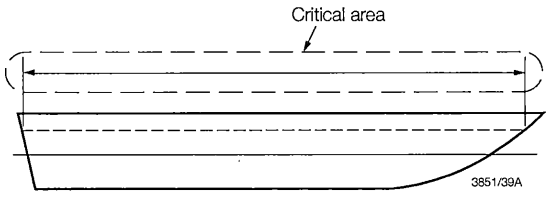
AREA: Deck structure

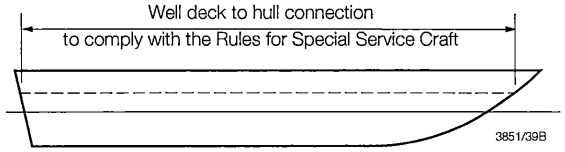
ITEM: Well deck, lower/sole deck to hull connection

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT









NOTES

Failure Mechanism	Excess loads due to berthing and slinging.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
5	COMPOSITE CONSTRUCTION	28

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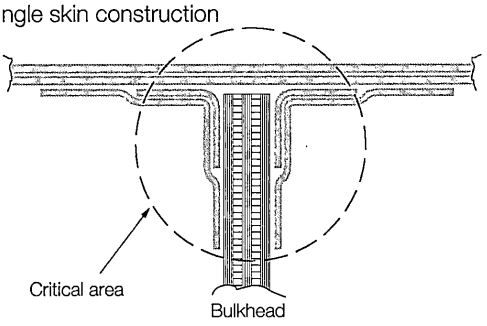
Detail Design Improvement for Composite Construction

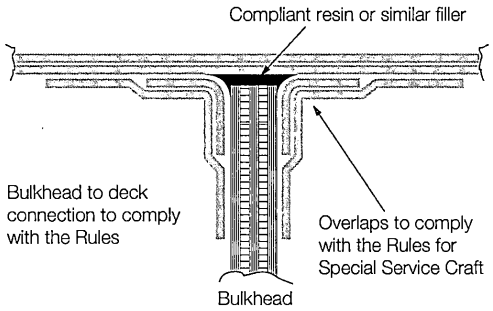
AREA: Deck

ITEM: Bulkhead to deck connection

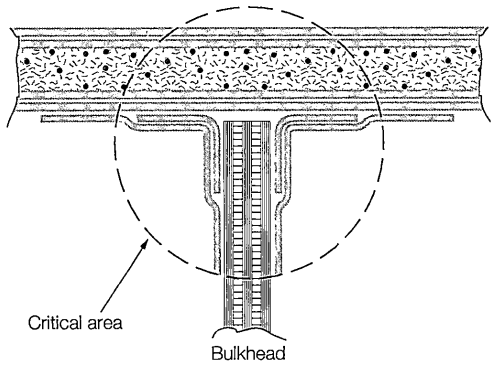
CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

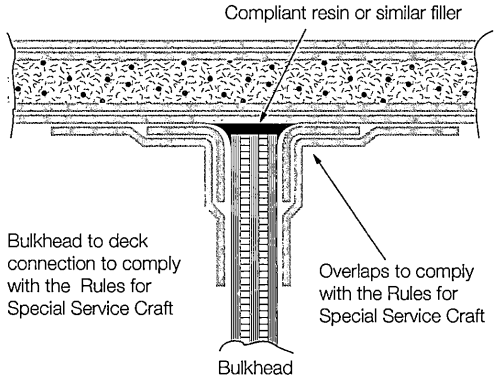
Single skin construction

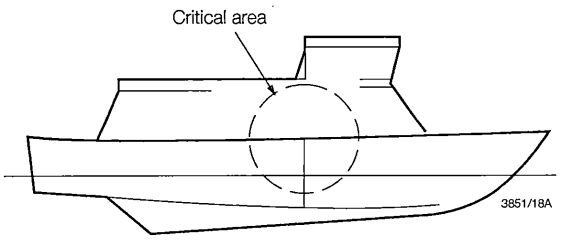


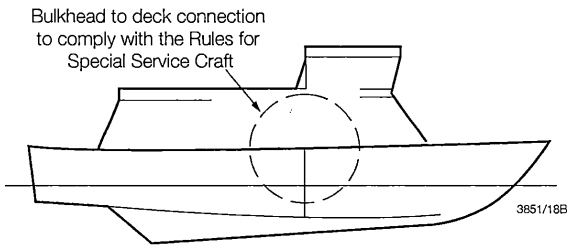


Sandwich construction









NOTES

Failure Mechanism	Excess loads due to berthing, slinging and impact.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft. Alignment and fit to be good, all gaps to be filled.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
5	COMPOSITE CONSTRUCTION	29

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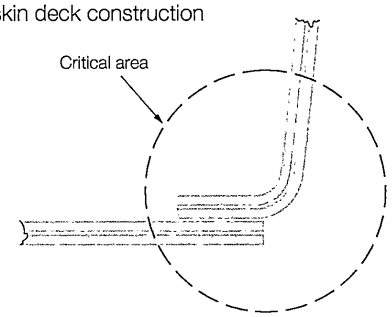
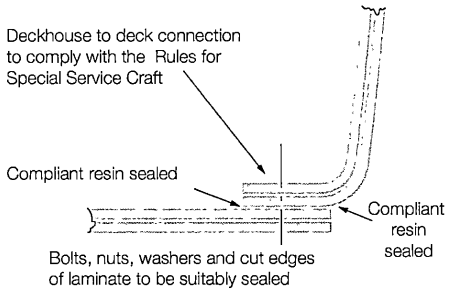
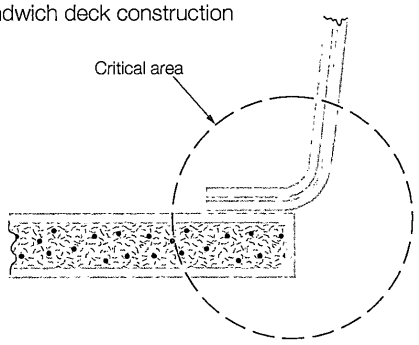
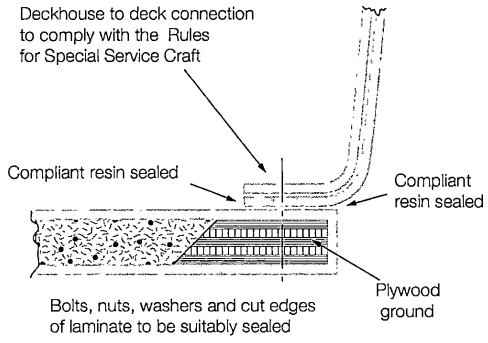
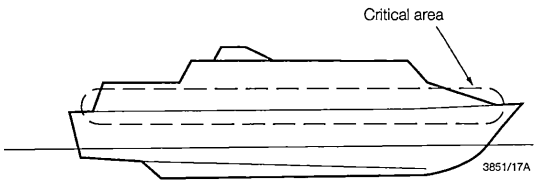
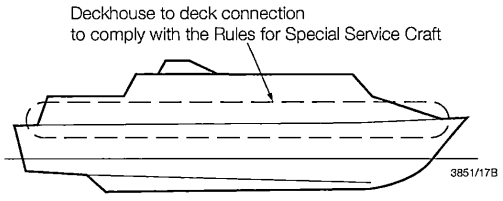
Detail Design Improvement for Composite Construction

AREA: Deck

ITEM: Deckhouse to deck connection

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT
Single skin deck construction  	
Sandwich deck construction  	
 	

NOTES

Failure Mechanism	Excess loads due to berthing, slinging, impact from green seas and other loads arising from heavy weather.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
5	COMPOSITE CONSTRUCTION	30

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Rules for Classification and Construction

I Ship Technology

3 Special Craft

1 High Speed Craft

Edition 2012

001805

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The following Rules come into force on 1 March 2012.

Alterations to the preceding Edition are marked by beams at the text margin.

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Premise

1. General

1.1

1.1.1 These Rules incorporate the text in full of the "International Code of Safety for High Speed Craft" ("HSC Code") adopted by the IMO Maritime Safety Committee, at its 73rd session, in December 2000, through Resolution MSC. 97(73) including the amendments adopted at its 79th session in December 2004, through Resolution MSC.175(79) and at its 82nd session in December 2006, through Resolution MSC.222(82). This text is printed in italics.

1.1.2 Classification requirements additional to the provisions of the HSC Code are printed in the Roman characters used for this item .2 and the relevant number is prefixed by the letter C.

In Section 10, which is subdivided into Parts, additional Classification requirements not directly related to a particular HSC Code item are numbered as follows: prefix C, Section number, letter indicating the Part concerned and an incremental figure starting from 1. These additional requirements are inserted at the end of the relevant part of the Section.

Where necessary, additional explanatory notes are given at the beginning of each Section.

1.1.3 Parts of the HSC Code not applicable for the purpose of Classification are identified by a vertical line placed in the margin of the text.

1.1.4 Equipment and arrangements dealt with in the parts of the Code mentioned in item 1.1.3, such as those concerning life-saving appliances and radiocommunications, which are not subject to control by GL, are intended to be covered by the relevant certification.

1.2 In those provisions of the HSC Code that are being used for Classification purposes the words "Administration" and "Code", wherever mentioned, are to be understood as equivalent to the words "GL" and "Rules", respectively.

The Rules for the Construction and Classification of ships are referred to below simply as "GL Rules".

2. Application

2.1 Craft for which Classification only is requested

These craft are to comply in full with the requirements of these Rules, except for those identified by a vertical line placed in the margin of the text (see P.1.1.3).

2.2 Craft for which both Classification and the IMO Certification are requested

These craft are to comply in full with the requirements of these Rules.

3. Class Notation

Craft complying with the Classification requirements of these Rules are assigned the Notation **HSC-CARGO, HSC-PASSENGER A or HSC-PASSENGER B.**

4. Compliance with other Rules

For any items not expressly stipulated or modified for Classification purposes by these Rules, the requirements of the GL Rules are to apply wherever relevant.

Classification of a craft with GL, or more generally any GL actions and decisions, do not absolve the interested parties from compliance with additional and/or more stringent requirements and provisions for their application, issued by the Administration of the State whose flag the craft is entitled to fly and/or of the State where the base port from which the craft is intended to operate is situated.

5. Novel or unusual features

Craft presenting novel or unusual arrangements for items such as systems, apparatuses and devices, described in these Rules, to which the requirements of these rules do not apply directly, either in whole or on part, may be classed on an individual basis, at the discretion of GL.

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Preamble

1. The international conventions ratified in respect of conventional ships and the regulations applied as a consequence of such conventions have largely been developed having in mind the manner *in which conventional ships are constructed and operated. Traditionally, ships have been built of steel and with the minimum of operational controls. The requirements for ships engaged on long international voyages are therefore framed in such away that, providing the ship is presented for survey and a Ship Safety Certificate is issued, the ship may go anywhere in the world without any operational restrictions being imposed. Providing the ship is not involved in a casualty, all that is needed is that it is made available to the Administration for the purpose of a satisfactory resurvey before the Ship Safety Certificate expires and the Certificate will be reissued.*

2. The traditional method of regulating ships should not be accepted as being the only possible way of providing an appropriate level of safety. Nor should it be assumed that another approach, using different criteria, could not be applied. Over a long period of time, numerous new designs of marine vehicles have been developed and hzave been in service. While these do not fully comply with the provisions of the international conventions relating to conventional ships built of steel, they have demonstrated an ability to operate at an equivalent level of safety when engaged on restricted voyages under restricted operational weather conditions and with approved maintenance and supervision schedules.

3. The High Speed Craft Code 1994(1994 HSC Code) was derived from the previous Code of Safety for Dynamically Supported Craft (DSC Code) adopted by IMO in 1977, recognizing that safety levels can be significantly enhanced by the infrastructure associated with regular service on a particular route, whereas the conventional ship safety philosophy relies on the ship being self-sustaining with all necessary emergency equipment being carried on board.

4. The safety philosophy of this Code is based on the management and reduction of risk as well as the traditional philosophy of passive protection in the event of an accident. Management of risk through accommodation arrangement, active safety systems, restricted operation, quality management and human factors engineering should be considered in evaluating safety equivalent to current conventions. Application of mathematical analysis should be encouraged to assess risk and determine the validity of safety measures.

5. The Code takes into account that a high-speed craft is of a light displacement compared with a conventional ship. This displacement aspect is the essential parameter to obtain fast and competitive sea transportation and consequently this Code allows for use of non-conventional shipbuilding materials, provided that a safety standard at least equivalent to conventional ships is achieved.

6. To clearly distinguish such craft, criteria based on speed and volumetric Froude number have been used to delineate those craft to which this Code applies from other, more conventional, craft.

7. The Code requirements also reflect the additional hazards which may be caused by the high speed compared with conventional ship transportation. Thus, in addition to the normal requirements (including life-saving appliances, evacuation facilities, etc.) provided in case of an accident occurring, further emphasis is placed on reducing the risk of hazardous situations arising. Some advantages result from the high-speed craft concept, i.e. the light displacement provides a large reserve buoyancy in relation to displacement, reducing the hazards addressed by the International Load Line Convention 1966. The consequences of other hazards, such as of collision at high speed, are balanced by more stringent navigational and operational requirements and specially developed accommodation provisions.

8. The above-mentioned safety concepts were originally reflected in the DSC Code and in the 1994 HSC Code. The development of novel types and sizes of craft has led to the development of pressures within the maritime industry for craft which are not dynamically supported cargo craft or passenger craft carrying larger numbers of passenger or operating further a field than permitted by that 1994 HSC Code to be certified according to those concepts. Additionally, improvements of maritime safety standards since 1994 were required to be reflected in the revisions of the Code to maintain safety equivalence with conventional ships.

9. Accordingly, two differing principles of protection and rescue were embodied in the Code.

10. The first of these recognizes the craft which were originally foreseen at the time of development of the DSC Code. Where rescue assistance is readily available and the total number of passengers is limited, a reduction in passive and active protection may be permitted. Such craft are called "assisted craft" and form the basis for "category A passenger craft" of this Code.

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11. *The second concept recognizes the further development of high-speed craft into larger craft. Where rescue assistance is not readily available or the number of passengers is unlimited, additional passive and active safety precautions are required. These additional requirements provide for an area of safe refuge on board, redundancy of vital systems, increased watertight and structural integrity and full fire-extinguishing capability. Such craft are called "unassisted craft" and form the basis for "cargo craft" and "category B passenger craft" of this Code.*

12. *These two concepts of the Code have been developed as a unified document on the basis that an equivalent level of safety to that normally expected on ships complying with the International Convention for the Safety of Life at Sea 1974 as amended is achieved. Where the application of new technology or design indicates an equivalent safety level to the strict application of the Code, the Administration is permitted to formally recognize such equivalence.*

13. *It is important that an Administration, in considering the suitability of a high-speed craft under this Code, should apply all sections of the Code because non-compliance with any part of the Code could result in an imbalance which would adversely affect the safety of the craft, passengers and crew. For a similar reason, modifications to existing craft, which may have an effect on safety, should be approved by the Administration.*

14. *In developing the Code, it has been considered desirable to ensure that high-speed craft do not impose unreasonable demands on existing users of the environment or conversely suffer unnecessarily through lack of reasonable accommodation by existing users. Whatever burden of compatibility there is, it should not necessarily be laid wholly on the high-speed craft.*

15. *Paragraph 1.15.1 of the 1994 HSC Code states that it should be reviewed by the Organization at intervals preferably not exceeding 4 years to consider revision of existing requirements to take account of new developments in design and technology. Experience gained with the application of the Code since it entered into force in 1996, has led to the recognition that it needed to be revised and updated. Subsequent work in Organization has resulted in the development of the present Code to ensure that safety is not compromised as a result of continuous introduction of state-of-the-art technology and innovative developments into the new and generally much larger and faster high-speed craft.*

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Section 1

General Comments and Requirements

1.1 General Comments

This Code shall be applied as a complete set of comprehensive requirements. It contains requirements for the design and construction of high-speed craft engaged on international voyages, the equipment which shall be provided and the conditions for their operation and maintenance. The basic aim of the Code is to set levels of safety which are equivalent to those of conventional ships required by the International *Convention for the Safety of Life at Sea, 1974, as amended, (SOLAS Convention) and the International Convention on Load Lines, 1966, (Load Line Convention) by the application of constructional and equipment standards in conjunction with strict operational controls.*[1]

1.2 General Requirements

1.2.1 The application of the provisions of this Code is subject to the following general requirements that:

.1 the Code will be applied in its entirety;

.2 the management of the company operating the craft exercises strict control over its operation and maintenance by a quality-management system[2]*;*

.3 the management ensures that only persons qualified to operate the specific type of craft used on the intended route are employed;

.4 the distances covered and the worst intended conditions in which high-speed craft operations are permitted will be restricted by the imposition of operational limits;

.5 the craft will at all times be in reasonable proximity to a place of refuge, having due regard to the provisions of 1.3.4;

.6 adequate communications facilities, weather forecasts and maintenance facilities are available within the area of craft operation;

.7 in the intended area of operation suitable rescue facilities will be readily available;

.8 areas of high fire risk, such as machinery spaces and special category spaces, are protected with fire-resistant materials and fire-extinguishing systems to ensure, as far as is practicable, containment and rapid extinguishing of fire;

.9 efficient facilities are provided for the rapid and safe evacuation of all persons into survival craft;

.10 all passengers and crew are provided with seats;

.11 no enclosed sleeping berths for passengers are provided.

C1.2.1.4 Restrictions for the operation of the craft will be specified in the Class Certificate.

1.2.2 On all craft, new installation of materials containing asbestos used for the structure, machinery, electrical installations and equipment of a craft to which this Code applies shall be prohibited except for:

.1 vanes used in rotary vane compressors and rotary vane vacuum pumps;

.2 watertight joints and linings used for the circulation of fluids when, at high temperature (in excess of 350 °C) or pressure (in excess of 7 x 10^6 Pa), there is a risk of fire, corrosion or toxicity; and

.3 supple and flexible thermal insulation assemblies used for temperatures above 1000 °C.

1.3 Application

1.3.1 This Code applies to high speed craft as specified in 1.3.4 engaged in international voyages the keels of which are laid or which are at a similar stage of construction on or after 1 July 2002.

C1.3.1 In addition to the craft specified in 1.3.1, these Rules also apply to high speed craft engaged in national voyages. Exemptions from some of the requirements of the Rules may be granted when particular circumstances (e.g. restricted services) warrant this, in the opinion of the GL Head Office.

1.3.2 For the purpose of this Code, the term "a similar stage of construction" means the stage at which:

---

[1] *Refer to MSC/Circ.652 on Application of the 1966 LL Convention to high-speed craft (subject to final consideration by SLF 43).*

[2] *Refer to the International Safety Management (ISM) Code adopted by the Organization by resolution A.741(18), as may be amended.*

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.1 construction identifiable with a specific craft begins; and

.2 assembly of that craft has commenced comprising at least 50 tonnes or three per cent of the estimated mass of all material used in the structure, including superstructure and deckhouse, whichever is less.

1.3.3 For the purpose of this Code :

.1 the expression "craft constructed" means craft the keels of which are laid or which are at a similar stage of construction; and

.2 a cargo craft, whenever built, which is converted to a passenger craft shall be treated as a passenger craft constructed on the date on which such a conversion commences.

1.3.4 This Code applies to:

.1 passenger craft which do not proceed in the course of their voyage more than four hours at 90 % of maximum speed from a place of refuge; and

.2 cargo craft of 500 gross tonnage and upwards which do not proceed in the course of their voyage more than 8 h at 90 % of maximum speed from a place of refuge when fully laden.

C1.3.4 In addition to the cargo craft specified in 1.3.4.2, these Rules also apply as far as appropriate to cargo craft of less than 500 tons gross tonnage.

1.3.5 This Code, unless expressly provided otherwise, does not apply to:

.1 craft of war and troopcraft;

.2 craft not propelled by mechanical means;

.3 wooden craft of primitive build;

.4 pleasure craft not engaged in trade; and

.5 fishing craft.

1.3.6 This Code does not apply to craft solely navigating the Great Lakes of North America and the River St. Lawrence as far east as a straight line drawn from Cap des Rosiers to West Point, Anticosti Island and, on the north side of Anticosti Island, the 63rd meridian.

1.3.7 The application of this Code shall be verified by the Administration and be acceptable to the Governments of the States to which the craft will be operating.

1.4 Definitions

For the purpose of this Code, unless expressly provided otherwise, the terms used therein have the meanings defined in the following paragraphs. Additional definitions are given in the general parts of the various Sections.

1.4.1 "Administration" means the Government of the State whose flag the craft is entitled to fly.

1.4.2 "Air-cushion vehicle (ACV)" is a craft such that the whole or a significant part of its weight can be supported, whether at rest or in motion, by a continuously generated cushion of air dependent for its effectiveness on the proximity of the surface over which the craft operates.

1.4.3 "Anniversary date" means the day and the month of each year which will correspond to the date of expiry of the relevant certificate.

1.4.4 "Assembly station" is an area where passengers can be gathered in the event of an emergency, given instructions and prepared to abandon the craft, if necessary. The passenger spaces may serve as assembly stations if all passengers can be instructed there and prepared to abandon the craft.

1.4.5 "Auxiliary machinery spaces" are spaces containing internal combustion engines of power output up to and including 110 kW driving generators, sprinkler, drencher or fire pumps, bilge pumps, etc., oil filling stations, switchboards of aggregate capacity exceeding 800 kW, similar spaces and trunks to such spaces.

1.4.6 "Auxiliary machinery spaces having little or no fire risk" are spaces such as refrigerating, stabilizing, ventilation and air conditioning machinery, switchboards of aggregate capacity 800 kW or less, similar spaces and trunks to such spaces.

1.4.7 "Base port" is a specific port identified in the route operational manual and provided with:

.1 appropriate facilities providing continuous radio communications with the craft at all times while in ports and at sea;

.2 means for obtaining a reliable weather forecast for the corresponding region and its due transmission to all craft in operation;

.3 for a category A craft, access to facilities provided with appropriate rescue and survival equipment; and

.4 access to craft maintenance services with appropriate equipment.

C1.4.7 It is the owner's responsibility to propose a base port to the Administration for approval.

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1.4.8 *"Base port State" means the State in which the base port is located.*

1.4.9 *"Breadth (B)" means breath of the broadest part of the moulded watertight envelope of the rigid hull, excluding appendages, at or below the design waterline in the displacement mode with no lift or propulsion machinery active.*

1.4.10 *"Cargo craft" is any high-speed craft other than passenger craft, and which is capable of maintaining the main functions and safety systems of unaffected spaces, after damage in any one compartment on board.*

1.4.11 *"Cargo spaces" are all spaces other than special category spaces and ro-ro spaces used for cargo and trunks to such spaces. For the purposes of Section 7, part D, "cargo spaces" include ro-ro spaces, special category spaces and open deck spaces.*

1.4.12 *"Category A craft" is any high-speed passenger craft:*

.1 *operating on a route where it has been demonstrated to the satisfaction of the flag and port States that there is a high probability that in the event of an evacuation at any point of the route, all passengers and crew can be rescued safely within the least of:*

- *the time to prevent persons in survival craft from exposure causing hypothermia in the worst intended conditions,*
- *the time appropriate with respect to environmental conditions and geographical features of the route, or*
- *4 hours; and*

.2 *carrying not more than 450 passengers.*

1.4.13 *"Category B craft" is any high-speed passenger craft other than a category A craft, with machinery and safety systems arranged such that, in the event of any essential machinery and safety systems in any one compartment being disabled, the craft retains the capability to navigate safely. The damage scenarios considered in Section 2 should not be inferred in this respect.*

C1.4.13 With reference to 1.4.13, the term "navigate safely" means that the craft can reach the port of refuge within the period of weather forecast validity.

1.4.14 *"Company" means the company as defined in chapter IX of the Convention.*

1.4.15 *"Continuously manned control station" is a control station which is continuously manned by a responsible member of the crew while the craft is in normal service.*

1.4.16 *"Control stations" are those spaces in which the craft's radio or navigating equipment (main displays and controls for equipment specified in 13.2 to 13.7) or the emergency source of power and emergency switchboard are located, or where the fire recording or fire control equipment is centralized, or where other functions essential to the safe operation of the craft such as propulsion control, public address, stabilization systems, etc., are located.*

1.4.17 *"Convention" means the International Convention for the Safety of Life at Sea, 1974, as amended.*

1.4.18 *"Crew accommodation" are those spaces allocated for the use of the crew, and include cabins, sick bays, offices, lavatories, lounges and similar spaces.*

1.4.19 *"Critical design conditions" means the limiting specified conditions, chosen for design purposes, which the craft shall keep in displacement mode. Such conditions shall be more severe than the "worst intended conditions" by a suitable margin to provide for adequate safety in the survival condition.*

1.4.20 *"Datum" means a watertight deck or equivalent structure of a non-watertight deck covered by a weathertight structure of adequate strength to maintain the weathertight integrity and fitted with weathertight closing appliances.*

1.4.21 *"Design waterline" means the waterline corresponding to the maximum operational weight of the craft with no lift or propulsion machinery active and is limited by the requirements of Sections 2 and 3.*

1.4.22 *"Displacement mode" means the regime, whether at rest or in motion, where the weight of the craft is fully or predominantly supported by hydrostatic forces.*

1.4.23 *"Failure Mode and Effect Analysis (FMEA)" is an examination, in accordance with annex 4, of the craft's system and equipment to determine whether any reasonably probable failure or improper operation can result in a hazardous or catastrophic effect.*

1.4.24 *"Fire Test Procedures Code (FTP Code)" means the International Code for Application of Fire Test Procedures, as defined in chapter II-2 of the Convention.*

1.4.25 *"Flap" means an element formed as integrated part of, or an extension of, a foil, used to adjust the hydrodynamic or aerodynamic lift of the foil.*

1.4.26 *"Flashpoint" means a flashpoint determined by a test using the closed-cup apparatus referenced in the International Maritime Dangerous Goods (IMDG) Code.*

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1.4.27 "Foil" means a profiled plate or three dimensional construction at which hydrodynamic lift is generated when the craft is under way.

1.4.28 "Fully submerged foil" means a foil having no lift components piercing the surface of the water in the foil-borne mode.

1.4.29 "Galleys" are those enclosed spaces containing cooking facilities with exposed heating surfaces, or which have any cooking or food heating appliances each having a power of more than 5 kW.

1.4.30 "High-speed craft" is a craft capable of maximum speed, in metres per second (m/s), equal to or exceeding:

$$3.7\nabla^{0.1667}$$

where:

∇ = *volume of displacement corresponding to the design waterline (m^3)*

excluding craft the hull of which is supported completely clear above the water surface in non-displacement mode by aerodynamic forces generated by ground effect.

1.4.31 "Hydrofoil craft" is a craft the hull of which is supported completely clear above the water surface in non-displacement mode by hydrodynamic forces generated on foils.

1.4.32 "IMDG Code" means the International Maritime Dangerous Goods (IMDG) Code as defined in chapter VII of the Convention.

1.4.33 "Length (L)" means the overall length of the underwater watertight envelope of the rigid hull, excluding appendages, at or below the design waterline in the displacement mode with no lift or propulsion machinery active.

1.4.34 "Lightweight" is the displacement of the craft in tonnes without cargo, fuel, lubricating oil, ballast water, fresh water and feedwater in tanks, consumable stores, passengers and crew and their effects.

1.4.35 "Life-Saving Appliances Code (LSA Code)" means the International Life-Saving Appliance Code as defined in chapter III of the Convention.

1.4.36 "Machinery spaces" are spaces containing internal combustion engines either used for main propulsion or having an aggregate total power output of more than 110 kW, generators, oil fuel units, major electrical machinery and similar spaces and trunks to such spaces.

1.4.37 "Maximum operational weight" means the overall weight up to which operation in the intended mode is permitted by the Administration.

1.4.38 "Maximum speed" is the speed achieved at the maximum continuous propulsion power for which the craft is certified at maximum operational weight and in smooth water.

1.4.39 "Non-displacement mode" means the normal operational regime of a craft when non-hydrostatic forces substantially or predominantly support the weight of the craft.

1.4.40 "Oil fuel unit" includes any equipment for the preparation of oil fuel and delivery of oil fuel, heated or not, to boilers and engines (including gas turbines) at a pressure of more than 0,18 N/mm^2.

1.4.41 "Open ro-ro spaces" are those ro-ro spaces:

.1 to which any passengers carried have access; and

.2 either:

.2.1 are open at both ends; or

.2.2 have an opening at one end and are provided with permanent openings distributed in the side plating or deckhead or from above, having a total area of at least 10 % of the total area of the space sides.

1.4.42 "Operating limitations" means the craft limitations in respect of handling, controllability and performance and the craft operational procedures within which the craft is to operate.

1.4.43 "Operating compartment" means the enclosed area from which the navigation and control of the craft is exercised.

1.4.44 "Operating station" means a confined area of the operating compartment equipped with necessary means for navigation, manoeuvring and communication, and from where the functions of navigating, manoeuvring, communication, commanding, conning and lookout are carried out.

1.4.45 "Organization" means the International Maritime Organization.

1.4.46 "Passenger" is every person other than:

.1 the master and members of the crew or other persons employed or engaged in any capacity on board a craft on the business of that craft; and

.2 a child under one year of age.

1.4.47 "Passenger craft" is a craft which carries more than twelve passengers.

1.4.48 "Place of refuge" is any naturally or artificially sheltered area which may be used as a shelter

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by a craft under conditions likely to endanger its safety.

1.4.49 *"Public spaces" are those spaces allocated for the passengers and include bars, refreshment kiosks, smoke rooms, main seating areas, lounges, dining rooms, recreation rooms, lobbies, lavatories and similar spaces, and may include sales shops.*

1.4.50 *"Refreshment kiosks" are those spaces which are not enclosed, serving refreshments and containing food warming equipment having a total power of 5 kW or less and with an exposed heating surface temperature not above 150 °C.*

1.4.51 *"Ro-ro craft" is a craft fitted with one or more ro-ro spaces.*

1.4.52 *"Ro-ro spaces" are spaces not normally subdivided in any way and normally extending to either a substantial length or the entire length of the craft in which motor vehicles with fuel in their tanks for their own propulsion and/or goods (packaged or in bulk, in or on rail or road cars, vehicles (including road or rail tankers), trailers, containers, pallets, demountable tanks or in or on similar stowage units or other receptacles) can be loaded and unloaded, normally in a horizontal direction.*

1.4.53 *"Service spaces" are those enclosed spaces used for pantries containing food warming equipment but no cooking facilities with exposed heating surfaces, lockers, sales shops, store-rooms and enclosed baggage rooms. Such spaces containing no cooking appliances may contain:*

.1 *coffee automats, toasters, dish washers, microwave ovens, water boilers and similar appliances, each of them with a maximum power of 5 kW; and*

.2 *electrically heated cooking plates and hot plates for keeping food warm, each of them with a maximum power of 2 kW and a surface temperature not above 150 °C.*

1.4.54 *"Significant wave height" is the average crest-to-trough height of the highest one third of the zero-upcrossing waves in a specified period.*

1.4.55 *"Special category spaces" are those enclosed ro-ro spaces to which passengers have access. Special category spaces may be accommodated on more than one deck provided that the total overall clear height for vehicles does not exceed 10 m.*

1.4.56 *"Surface-effect ship" (SES) is an air-cushion vehicle whose cushion is totally or partially retained by permanently immersed hard structures.*

1.4.57 *"Transitional mode" means the regime between displacement and non-displacement modes.*

1.4.58 *"Watertight" in relation to a structure means capable of preventing the passage of water through the structure in any direction under the head of water likely to occur in the intact or damaged condition.*

1.4.59 *"Weather deck" is a deck which is completely exposed to the weather from above and from at least two sides.*

1.4.60 *"Weathertight" means that water will not penetrate into the craft in any wind and wave conditions up to those specified as critical design conditions.*

1.4.61 *"Worst intended conditions" means the specified environmental conditions within which the intentional operation of the craft is provided for in the certification of the craft. This shall take into account parameters such as the worst conditions of wind force allowable, significant wave height (including unfavourable combinations of length and direction of waves), minimum air temperature, visibility and depth of water for safe operation and such other parameters as the Administration may require in considering the type of craft in the area of operation.*

C1.4.62 "Approved type" means the status conferred by GL on a particular and clearly identified material, item of equipment or process, shown by design assessment to meet all the stipulations of GL Rules for the specified application(s).

C1.4.63 "Small waterplane area twin hull" (SWATH) is a craft for which the weight is substantially supported by a submerged twin hull connected to the emerging part of the craft by struts with a small waterplane area.

1.5 Surveys

C1.5 In respect of Classification the survey requirements in accordance with the GL Rules Classification and Surveys (I-0-0) apply.

1.5.1 *Each craft shall be subject to the surveys specified below:*

.1 *an initial survey before the craft is put in service or before the Certificate is issued for the first time;*

.2 *a renewal survey at intervals specified by the Administration but not exceeding 5 years except where 1.8.5 or 1.8.10 is applicable;*

.3 *a periodical survey within three months before or after each anniversary date of the Certificate; and*

.4 *an additional survey as the occasion arises.*

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1.5.2 The surveys referred to in 1.5.1 shall be carried out as follows:

.1 the initial survey shall include:

.1.1 an appraisal of the assumptions made and limitations proposed in relation to loadings, environment, speed and maneuverability;

.1.2 an appraisal of the data supporting the safety of the design, obtained, as appropriate, from calculations, tests and trials;

.1.3 a failure mode and effect analysis as required by this Code;

.1.4 an investigation into the adequacy of the various manuals to be supplied with the craft; and

.1.5 a complete inspection of the structure, safety equipment, radio installations and other equipment, fittings, arrangements and materials to ensure that they comply with the requirements of the Code, are in satisfactory condition and are fit for the service for which the craft is intended;

.2 the renewal and periodical surveys shall include a complete inspection of the structure, including the outside of the craft's bottom and related items, safety equipment, radio installations and other equipment as referred to in 1.5.2.1 to ensure that they comply with the requirements of the Code, are in satisfactory condition and are fit for the service for which the craft is intended. The inspection of the craft's bottom shall be conducted with the craft out of the water under suitable conditions for close-up examination of any damaged or problem areas; and

.3 an additional survey, either general or partial according to the circumstances, shall be made after a repair resulting from investigations prescribed in 1.7.3, or wherever any important repairs or renewals are made. The survey shall be such as to ensure that the necessary repairs or renewals have been effectively made, that the material and work manship of such repairs or renewals are in all respects satisfactory, and that the craft complies in all respects with the requirements of the Code.

1.5.3 The periodical surveys referred to in 1.5.1.3 shall be endorsed on the High-Speed Craft Safety Certificate.

1.5.4 The inspection and survey of the craft, so far as regards the enforcement of the provisions of the Code, shall be carried out by officers of the Administration. The Administration may, however, entrust the inspections and surveys either to surveyors nominated for the purpose or to organizations recognized by it.

1.5.5 An Administration nominating surveyors or recognizing organizations to conduct inspections and surveys as set forth in 1.5.4 shall, as a minimum, empower any nominated surveyor or recognized organization to:

.1 require repairs to a craft; and

.2 carry out inspections and surveys if requested by the appropriate authorities of a port State.

The Administration shall notify the Organization of the specific responsibilities and conditions of the authority delegated to nominated surveyors or recognized organizations.

1.5.6 When an nominated surveyor or recognized organization determines that the condition of the craft or its equipment does not correspond substantially with the particulars of the Certificate or is such that the craft is not fit to operate without danger to the craft or persons on board, such surveyor or organization shall immediately ensure that corrective action is taken and shall, in due course, notify the Administration. If such corrective action is not taken the Certificate shall be withdrawn and the Administration shall be notified immediately; and, if the craft is in an area under the jurisdiction of another Government, the appropriate authorities of the port State shall be notified immediately.

When an officer of the Administration, a nominated surveyor or a recognized organization has notified the appropriate authorities of the port State, the Government of the port Sate concerned shall give such officer, surveyor or organization any necessary assistance to carry out their obligations under this section. When applicable, the Government of the port State concerned shall ensure that the craft shall not continue to operate until it can do so without danger to the craft or the persons on board.

1.5.7 In every case, the Administration shall fully guarantee the completeness and efficiency of the inspection and survey, and shall undertake to ensure the necessary arrangements to satisfy this obligation.

1.6 Approvals

The owner of a craft shall accept the obligation to supply sufficient information to enable the Administration to fully assess the features of the design. It is strongly recommended that the Company and the Administration and, where appropriate, the port State or States shall commence discussions at the earliest possible stage so that the Administration may fully evaluate the design in determining what additional or alternative requirements shall be applied to the craft, to achieve the required level of safety.

1.7 Maintenance of Conditions after Survey

1.7.1 The condition of the craft and its equipment shall be maintained to conform with the provisions of this Code to ensure that the craft in all respects will

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remain fit to operate without danger to the craft or the persons on board.

C1.7.1 With reference to 1.7.1, the above responsibility lies with the Owner of the craft (or his representative).

1.7.2 *After any survey of the craft corresponding to 1.5 has been completed, no change shall be made to structure, equipment, fittings, arrangements and materials covered by the survey, without the sanction of the Administration.*

1.7.3 *Whenever an accident occurs to a craft or a defect is discovered, either of which affects the safety of the craft or the efficiency or completeness of structure, equipment, fittings, arrangements and materials, the person in charge or owner of the craft shall report at the earliest opportunity to the Administration, the nominated surveyor or recognized organization responsible, who shall cause investigations to be initiated to determine whether a survey, as required by 1.5, is necessary. If the craft is in an area under the jurisdiction of another Government, the person in charge or the owner shall also report immediately to the appropriate authorities of the port State and the nominated surveyor or recognized organization shall ascertain that such a report has been made.*

C1.7.3 With reference to 1.7.2 and 1.7.3, it is the Owner's responsibility to inform GL of any modification, damage or repair affecting the class of the craft.

1.8 High-Speed Craft Safety Certificate

1.8.1 *A Certificate called a High-Speed Craft Safety Certificate is issued after completion of an initial or renewal survey to a craft which complies with the requirements of the Code. The Certificate shall be issued or endorsed either by the Administration or by any person or organization recognized by it. In every case, that Administration assumes full responsibility for the Certificate. On all craft, all Certificates issued under this Section, or certified copies thereof, shall be carried on the craft. Except where the flag State is a Party to the 1988 SOLAS Protocol, a copy of each of these Certificates shall be posted up in a prominent and accessible place in the craft.*

1.8.2 *A Contracting Government to the Convention may, at the request of the Administration, cause a craft to be surveyed and, if satisfied that the requirements of the Code are compiled with, shall issue or authorize the issue of a Certificate to the craft and, where appropriate, endorse or authorize the endorsement of a Certificate on the craft in accordance with the Code. Any Certificate so issued shall contain a statement to the effect that it has been issued at the request of the Government of the State the flag of which the craft is entitled to fly, and it shall have the same force and receive the same recognition as a Certificate issued under 1.8.1.*

1.8.3 *The Certificate shall be that of the model given in the annex 1 to the Code. If the language used is not English, French or Spanish, the text shall include a translation into one of these languages.*

1.8.4 *The High-Speed Craft Safety Certificate shall be issued for a period specified by the Administration which shall not exceed 5 years.*

1.8.5 *Notwithstanding the requirements of 1.8.4, when the renewal survey is completed within three months before the expiry date of the existing Certificate, the new Certificate shall be valid from the date of completion of the renewal survey to a date not exceeding 5 years from the date of expiry of the existing Certificate.*

1.8.6 *When the renewal survey is completed after the expiry date of the existing Certificate, the new Certificate shall be valid from the date of completion of the renewal survey to a date not exceeding 5 years from the date of expiry of the existing Certificate.*

1.8.7 *When the renewal survey is completed more than 3 months before the expiry date of the existing Certificate, the new Certificate shall be valid from the date of completion of the renewal survey to a date not exceeding 5 years from the date of completion of the renewal survey.*

1.8.8 *If a Certificate is issued for a period of less than 5 years, the Administration may extend the validity of the Certificate beyond the expiry date to the maximum period specified in 1.8.4, provided that the surveys when a Certificate is issued for a period of 5 years are carried out.*

1.8.9 *If a renewal survey has been completed and a new Certificate cannot be issued or placed on board the craft before the expiry date of the existing Certificate, the person or organization authorized by the Administration may endorse the existing Certificate and such a Certificate shall be accepted as valid for a further period which shall not exceed 5 months from the expiry date.*

1.8.10 *If a craft, at the time when a Certificate expires, is not in the place in which it is to be surveyed, the Administration may extend the period of validity of the Certificate but this extension shall be granted only for the purpose of allowing the craft to proceed to the place in which it is to be surveyed, and then only in cases where it appears proper and reasonable to do so. No Certificate shall be extended for a period longer than one month, and a craft to which an extension is granted shall not, on its arrival in the place in which it is to be surveyed, be entitled by virtue of such extension to leave that place without having a new Certificate. When the renewal survey is completed, the new Certificate shall be valid to a date not exceeding 5 years from the date of expiry of the existing Certificate before the extension was granted.*

1.8.11 *In special circumstances, as determined by the Administration, a new Certificate need not be dated from the date of expiry of the existing Certificate*

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as required by 1.8.6 or 1.8.10. In these circumstances, the new Certificate shall be valid to a date not exceeding 5 years from the date of completion of the renewal survey.

1.8.12 *If a periodical survey is completed before the period specified in 1.5 then:*

.1 *the anniversary date shown on the relevant Certificate shall be amended by endorsement to a date which shall not be more than 3 months later than the date on which the survey was completed;*

.2 *the subsequent periodical survey required by 1.5 shall be completed at the intervals prescribed by 1.5 using the new anniversary date; and*

.3 *the expiry date may remain unchanged provided one or more periodical surveys are carried out so that the maximum intervals between the surveys prescribed by 1.5.1.3 are not exceeded;*

1.8.13 *A Certificate issued under 1.8.1 or 1.8.2 shall cease to be valid in any of the following cases:*

.1 *if the relevant surveys are not completed with the periods specified in 1.5.1;*

.2 *if the Certificate is not endorsed in accordance with 1.5.3;*

.3 *upon transfer of the craft to the flag of another State. A new Certificate shall only be issued when the Government issuing the new Certificate is fully satisfied that the craft is in compliance with the requirements of 1.7.1 and 1.7.2. In the case of a transfer between Governments that are Contracting Governments to the Convention if requested within 3 months after the transfer has taken place, the Government of the State whose flag the craft was formerly entitled to fly shall, as soon as possible, transmit to the Administration a copy of the Certificate carried by the craft before the transfer and, if available, copies of the relevant survey reports.*

1.8.14 *The privileges of the Code may not be claimed in favour of any craft unless it holds a valid Certificate.*

1.9 Permit to Operate High-Speed Craft

1.9.1 *The craft shall not operate commercially unless a Permit to Operate High-Speed Craft is issued and valid in addition to the High-Speed Craft Safety Certificate.*

1.9.1.1 *On all craft, transit voyages may be undertaken without a valid Permit to Operate High-Speed Craft provided the craft is not operating commercially with passengers or cargo onboard. For the purpose of this provision, these transit voyages include delivery voyages, i.e., builder's port to base port, and voyages for repositioning purposes, i.e., change of base port and/or route. Such transit voyages in excess of the limits set out in this Code may be undertaken provided that:*

.1 *the craft has a valid High-Speed Craft Safety Certificate or similar before the start of such a voyage;*

.2 *the operator has developed a safety plan for the voyage including any temporary accommodation and all relevant matters listed in 18.1.3 to ensure that the craft is capable of safely completing the transit voyage;*

.3 *the master of the craft is provided with the materials and information necessary to operate the craft safely during the transit voyage; and*

.4 *the Administration is satisfied that arrangements have been made for the safe conduct of the voyage.*

1.9.2 *The Permit to Operate High-Speed Craft shall be issued by the Administration to certify compliance with 1.2.2 to 1.2.7 and stipulate conditions of the operation of the craft and drawn up on the basis of the information contained in the route operational manual specified in Section 18 of this Code.*

1.9.3 *Before issuing the Permit to Operate, the Administration shall consult with each port State to obtain details of any operational conditions associated with operation of the craft in that State. Any such conditions imposed shall be shown by the Administration on the Permit to Operate and included in the route operational manual.*

1.9.4 *A port State may inspect the craft and audit its documentation for the sole purpose of verifying its compliance with the matters certified by and conditions associated with the Permit to Operate. Where deficiencies are shown by such an audit, the Permit to Operate ceases to be valid until such deficiencies are corrected or otherwise resolved.*

1.9.5 *The provisions of 1.8 shall apply to the issue and the period of validity of the Permit to Operate High-Speed Craft.*

1.9.6 *The Permit to Operate High-Speed Craft shall be that of the model given in annex 2 to this Code. If the language used is not English, French or Spanish, the text shall include a translation into one of these languages.*

1.9.7 *In determining the worst intended conditions and the operational limitations on all craft for insertion in the Permit to Operate, the Administration shall give consideration to all the parameters listed in annex 12. The limitations assigned shall be those that enable compliance with all of these factors.*

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1.10 Control

The provisions of regulation I/19 of the Convention shall be applied to include the Permit to Operate High-Speed Craft in addition to the Certificate issued under 1.8.

1.11 Equivalents

1.11.1 Where this Code requires that a particular fitting, material, appliance or apparatus, or type thereof, shall be fitted or carried in a craft, or that any particular provision shall be made, the Administration may allow any other fitting, material, appliance or apparatus, or type thereof, to be fitted or carried, or any other provision to be made in the craft, if it is satisfied by trial thereof or otherwise that such fitting, material, appliance or apparatus, or type thereof, or provision, is at least as effective as that required by this Code.

1.11.2 Where compliance with any of the requirements of this Code would be impractical for the particular designs of the craft, the Administration may substitute those with alternative requirements provided that equivalent safety is achieved. The Administration which allows any such substitution shall communicate to the Organization Particulars of these substitutions and the reasons therefor, which the Organization shall circulate to its Member Governments for their information.

C1.11 For classification purposes equivalent arrangements may be approved on a case-by-case basis.

1.12 Information to be made available

1.12.1 The Administration shall ensure that the management of the company operating the craft has provided the craft with adequate information and guidance in the form of manuals to enable the craft to be operated and maintained safely. These manuals shall include a route operational manual, craft operating manual, maintenance manual and servicing schedule. Such information shall be updated as necessary.

1.12.2 The manuals shall contain at least the information specified in Section 18, and shall be in a language understood by the crew. Where this language is not English, a translation into English shall be provided of at least the route operational manual and the craft operating manual.

1.13 Further Developments

1.13.1 It is recognized that there is much ongoing research and development in the design of high-speed craft and that new types may emerge which have different geometry to that envisaged during the formulation of this Code. It is important that this Code does not restrict this progress and the development of new designs.

1.13.2 A design may be produced which cannot comply with the provisions of this Code. In such a case the Administration shall determine the extent to which the provisions of the Code are applicable to the design and, if necessary, develop additional or alternative requirements to provide an equivalent level of safety for the craft.

1.13.3 The foregoing shall be considered by the Administration when assessing the granting of equivalents under the Code.

1.14 Circulation of Safety Information

1.14.1 In the event that an Administration has cause to investigate an accident involving a craft to which this Code applies, that Administration shall provide a copy of the official report to the Organization, which will invite Member States to note the existence of the report and to obtain a copy.

1.14.2 In the event that operational experience reveals structural or equipment failures affecting the safety of a design, craft owners shall inform the Administration.

1.15 Review of the Code

1.15.1 The Code shall be reviewed by the Organization at intervals preferably not exceeding six years to consider revision of existing requirements to take account of new developments in design and technology.

1.15.2 Where a new development in design and technology has been found acceptable to an Administration, that Administration may submit particulars of such development to the Organization for consideration for incorporation into the Code during periodical review.

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Section 2

Buoyancy, Stability and Subdivision

Part A - General

C2.0 Documents to be submitted

C2.0.1 The following drawings and documents are to be submitted. To facilitate a smooth and efficient approval process they shall be submitted electronically via GLOBE [1]. In specific cases and following prior agreement with GL they can also be submitted in paper form in triplicate.

.1 Hull, plotted and numerically;

.2 Side contour, plotted and numerically;

.3 Coordinates of non-watertight and non-weathertight openings;

.4 Hydrostatic tables;

.5 Cross curve tables;

.6 Data of boundaries of all subcompartments and a plan in which these compartments are stated;

.7 Damage stability investigation, complete input and output data including initial loading conditions;

.8 Damage control plan;

.9 Inclining test report;

.10 Intact stability booklet.

C2.0.2 Further documentation may be required if deemed necessary by GL.

2.1 General

2.1.1 A craft shall be provided with:

.1 stability characteristics and stabilization systems adequate for safety when the craft is operated in the non-displacement mode and during the transitional mode;

.2 buoyancy and stability characteristics adequate for safety where the craft is operated in the displacement mode, both in the intact condition and the damaged condition; and

.3 stability characteristics in the non-displacement and transitional modes adequate to transfer the craft safely to displacement mode in case of any system malfunction.

2.1.2 Account shall be taken of the effect of icing in the stability calculations. An example of established practice for ice accretion allowances is given in annex 5 for the guidance of the Administration.

2.1.3 For the purpose of this and other Sections, unless expressly defined otherwise, the following definitions apply:

.1 "Downflooding point" means any opening, irrespective of size, that would permit passage of water through a water/weathertight structure (e.g., opening windows), but excludes any opening kept closed to an appropriate standard of water/weathertightness at all times other than when required for access or for operation of portable submersible bilge pumps in an emergency (e.g., non-opening windows of similar strength and weathertight integrity to the structure in which they are installed).

.2 "Elsewhere" when applied to sill and coaming heights in 2.2.7 and 2.2.8 is taken as applying to all weathertight and watertight closures located on or below the datum.

.3 "Fully submerged foil" means a foil having no lift components piercing the surface of the water in the foil-borne mode.

.4 "Monohull craft" means any craft which is not a multihull craft.

.5 "Multihull craft" means a craft which in any normally achievable operating trim or heel angle, has a rigid hull structure which penetrates the surface of the sea over more than one discrete area.

.6 "Permeability" of a space means the percentage of the volume of that space which can be occupied by water.

.7 "Skirt" means a downwardly extending, flexible structure used to contain or divide an air cushion.

2.1.4 Other means of demonstrating compliance with the requirements of any part of this Section may be accepted, provided that the method chosen can be shown to provide an equivalent level of safety. Such methods may include:

.1 mathematical simulation of dynamic behaviour;

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1 Detailed information about the secured GL system GLOBE can be found on GL's website www.gl-group.com/globe.

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.2 scale model testing; and

.3 full-scale trials.

2.1.5 The adequacy of mathematical simulations must first be demonstrated by correlation with full-scale or model tests for the appropriate type of craft. It may be appropriate to use mathematical simulations to help to identify the more critical scenarios for subsequent physical testing.[2]

2.1.6 Model or full-scale tests and/or calculations (as appropriate) shall also include consideration of the following known stability hazards to which high-speed craft are known to be liable, according to craft type:

.1 directional instability, which is often coupled to roll and pitch instabilities;

.2 broaching and bow diving in following seas at speeds near to wave speed, applicable to most types;

.3 bow diving of planing monohulls and catamarans due to dynamic loss of longitudinal stability in relatively calm seas;

.4 reduction in transverse stability with increasing speed of monohulls;

.5 porpoising of planing monohulls, being coupled pitch and heave oscillations, which can become violent;

.6 chine tripping, being a phenomenon of planing monohulls occurring when the immersion of a chine generates a strong capsizing moment;

.7 plough-in of air-cushion vehicles, either longitudinal or transverse, as a result of bow or side skirt tuck-under or sudden collapse of skirt geometry, which, in extreme cases, can result in capsize;

.8 pitch instability of SWATH (small waterplane area twin hull) craft due to the hydrodynamic moment developed as a result of the water flow over the submerged lower hulls;

.9 reduction in effective metacentric height (roll stiffness) of surface effect ship (SES) in high speed turns compared to that on a straight course, which can result in sudden increases in heel angle and/or coupled roll and pitch oscillations; and

.10 resonant rolling of SES in beam seas, which, in extreme cases, can result in capsize.

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[2] *Some mathematical simulation methods are not well suited to accurate modelling of extreme events. For safety level 3 or 4, it may be appropriate to use model testing as a precursor to, or instead of, full-scale testing*

2.1.7 Suitable calculations shall be carried out and/or tests conducted to demonstrate that, when operating within approved operational limitations, the craft will, after a disturbance causing roll, pitch, heave or heel due to turning or any combination thereof, return to the original attitude. Where calculations are employed, it shall first be shown that they correctly represent dynamic behaviour within the operational limitations of the craft.

C2.1.8 Arrangement of watertight bulkheads

.1 At least the following watertight bulkheads are to be fitted in all craft:

- one collision bulkhead,
- one afterpeak bulkhead,
- one bulkhead at each end of the machinery space.

.2 The distance [m] of the collision bulkhead from the forward perpendicular is to be between 0,05 L and 0,05 L + 3 m. The collision bulkhead is to be fitted at least in places used for providing the reserve of buoyancy used for proving compliance with the intact and damage stability requirements of the present HSC Rules.

.3 The collision bulkhead is to extend watertight up to the datum (bulkhead deck). Steps or recesses may be permitted provided C2.1.7.2 are observed.

.4 The remaining watertight bulkheads are, in general, to extend to the datum. Wherever practicable, they shall be situated in one frame plane, otherwise those portions of decks situated between parts of transverse bulkheads are to be watertight.

2.2 Intact Buoyancy and Watertight and Weathertight Integrity

2.2.1 Buoyant spaces

2.2.1.1 All craft shall have a sufficient reserve of buoyancy at the design waterline to meet the intact and damage stability requirements of this Section. The Administration may require a larger reserve of buoyancy to permit the craft to operate in any of its intended modes. This reserve of buoyancy shall be calculated by including only those compartments that are:

.1 watertight and situated below the datum, or

.2 watertight or weathertight and situated above the datum.

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In considering the stability after damage, flooding shall be assumed to occur until limited by watertight boundaries in the equilibrium condition, and weathertight boundaries in intermediate stages of flooding and within the range of positive righting lever required to satisfy the residual stability requirements. Where a buoyant space may be subjected to increased fluid pressure in the equilibrium position after damage, the boundaries and associated openings and penetrations of that space shall be designed and constructed to prevent the passage of fluid under that pressure.

Craft built in conformity with the requirements of organizations recognised by the Administration, in accordance with regulation XI/1 of the Convention may be considered to possess adequate strength and integrity.

2.2.1.2 *Arrangements shall be provided for checking the watertight or weathertight integrity of those compartments taken into account in 2.2.1.1, and the details incorporated in the Craft Operating Manual required by 18.2.1.*

2.2.2 Openings in watertight divisions

2.2.2.1 *The number of openings in watertight bulkheads shall be reduced to the minimum compatible with the design and proper working of the craft, and all such doors shall be closed prior to departure of the craft from the berth.*

2.2.2.2 *Doors in watertight bulkheads may be hinged or sliding. They shall be shown by suitable testing to be capable of maintaining the watertight integrity of the bulkhead. Such testing shall be carried out for both sides of the door and shall apply a pressure head 10 % greater than that determined from the minimum permissible height of a downflooding opening. Testing may be carried out either before or after the door is fitted into the craft but, where shore testing is adopted, satisfactory installation in the craft shall be verified by inspection and hose testing.*

2.2.2.3 *Type approval may be accepted in lieu of testing individual doors, provided the approval process includes pressure testing to a head equal to, or greater, than the required head (refer to 2.2.2.2).*

2.2.2.4 *All watertight doors shall be capable of being operated when the craft is inclined up to 15° and shall be fitted with means of indication in the operating compartment showing whether they are open or closed. All such doors shall be capable of being opened and closed locally from each side of the bulkhead.*

2.2.2.5 *Watertight doors shall remain closed when the craft is at sea, except that they may be opened for access. A notice shall be attached to each door to the effect that it is not to be left open.*

2.2.2.6 *Watertight doors shall be capable of being closed by remote control from the operating compartment in not less than 20 s and not more than 40s, and shall be provided with an audible alarm, distinct from other alarms in the area, which will sound for at least 5 s but no more than 10 s before the doors begin to move whenever the door is closed remotely by power, and continue sounding until the door is completely closed. The power, control and indicators shall be operable in the event of main power failure, as required by regulation II-1/15.7.3 of the Convention. In passenger areas and areas where the ambient noise exceeds 85 dB(A) the audible alarm shall be supplemented by an intermittent visual signal at the door. If the Administration is satisfied that such doors are essential for the safe work of the craft, hinged watertight doors having only local control may be permitted for areas to which crew only have access, provided they are fitted with remote indicators as required by 2.2.2.4.*

2.2.2.7 *Where pipes, scuppers, electric cables, etc. are carried through watertight divisions, the arrangements for creating a watertight penetration shall be of a type which has been prototype tested under hydrostatic pressure equal to or greater than that required to be withstood for the actual location in the craft in which they are to be installed. The test pressure shall be maintained for at least 30min and there must be no leakage through the penetration arrangement during this period.*

The test pressure head shall be 10 % greater than that determined from the minimum permissible height of a downflooding opening. Watertight bulkhead penetrations which are effected by continuous welding do not require prototype testing. Valves on scuppers from weathertight compartments, included in the stability calculations, shall have arrangements for remote closing from the operating station.

2.2.2.8 *Where a ventilation trunk forms part of a watertight boundary, the trunk shall be capable of withstanding the water pressure that may be present taking into account the maximum inclination angle allowable during all stages of flooding.*

C2.2.2.9 No doors, manholes, or access openings are generally permitted in the collision bulkhead below the datum. GL may authorize a single manhole in the collision bulkhead, in each hull for catamaran, if deemed necessary.

2.2.3 Inner bow doors

2.2.3.1 *Where ro-ro craft are fitted with bow loading openings, an inner bow door shall be fitted abaft such openings, to restrict the extent of flooding in the event of failure of the outer closure. This inner bow door, where fitted, shall be:*

.1 weathertight to the deck above, which deck shall itself be weathertight forward to the bow loading opening;

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.2 so arranged as to preclude the possibility of a bow loading door causing damage to it in the case of damage to, or detachment of, the bow loading door;

.3 forward of all positions on the vehicle deck in which vehicles are intended to be carried; and

.4 part of a boundary designed to prevent flooding into the remainder of the craft.

2.2.3.2 A craft may be exempted from the requirement for such an inner bow door where one of the following applies:

.1 the vehicle loading deck at the inner bow door position is above the design waterline by a height more than the significant wave height corresponding to the worst intended conditions;

.2 it can be demonstrated using model tests or mathematical simulations that when the craft is proceeding at a range of speeds up to the maximum attainable speed in the loaded condition at all headings in long crested seas of the greatest significant wave height corresponding to the worst intended conditions, either:

.2.1 the bow loading door is not reached by waves; or

.2.2 having been tested with the bow loading door open to determine the maximum steady state volume of water which accumulates, it can be shown by static analysis that, with the same volume of water on the vehicle deck(s) the residual stability requirements of 2.6.11 and 2.13 or 2.15 are satisfied. If the model tests or mathematical simulations are unable to show that the volume of water accumulated reaches a steady state, the craft shall be considered not to have satisfied the conditions of this exemption.

Where mathematical simulations are employed they shall already have been verified against full-scale or model testing;

.3 bow loading openings lead to open ro-ro spaces provided with guard-rails or having freeing ports complying with 2.2.3.2.4 ;

.4 the deck of the lowest ro-ro space above the design waterline is fitted on each side of the deck with freeing ports evenly distributed along the sides of the compartment. These shall either be proven to be acceptable using tests according to 2.2.3.2.2 above or comply with the following:

.4.1 $A \geq 0.3\,l$

where :

A = the total area of freeing ports on each side of the deck in m² ; and

l = the length of the compartment in m;

.4.2 the craft shall maintain a residual freeboard to the deck of the ro-ro space of at least 1 m in the worst condition;

.4.3 such freeing ports shall be located within the height of 0.6 m above the deck of the ro-ro space, and the lower edge of the ports shall be within 0.02 m above the deck of the ro-ro space; and

.4.4 such freeing ports shall be fitted with closing devices or flaps to prevent water entering the deck of the ro-ro space whilst allowing water which may accumulate on the deck of the ro-ro space to drain.

2.2.4 Other provisions for ro-ro craft

2.2.4.1 All accesses in the ro-ro space that lead to spaces below the deck shall have a lowest point which is not less than the height required from the tests conducted according to 2.2.3.2.2 or 3 m above the design waterline.

2.2.4.2 Where vehicle ramps are installed to give access to spaces below the deck of the ro-ro space, their openings shall be capable of being closed weathertight to prevent ingress of water below.

2.2.4.3 Accesses in the ro-ro space that lead to spaces below the ro-ro deck and having a lowest point which is less than the height required from the tests conducted according to 2.2.3.2.2 or 3 m above the design waterline may be permitted provided they are watertight and are closed before the craft leaves the berth on any voyage and remain closed until the craft is at its next berth.

2.2.4.4 The accesses referred to in 2.2.4.2 and 2.2.4.3 above shall be fitted with alarm indicators in the operating compartment.

2.2.4.5 Special category spaces and ro-ro spaces shall be patrolled or monitored by effective means, such as television surveillance, so that any movement of vehicles in adverse weather conditions and unauthorised access by passengers thereto can be detected whilst the craft is underway (refer to 7.8.3.1).

2.2.5 Indicators and surveillance

2.2.5.1 Indicators

Indicators shall be provided in the operating compartment for all shell doors, loading doors and other closing appliances which, if left open or not properly secured, could lead to major flooding in the intact and damage conditions. The indicator system shall be designed on the fail-safe principle and shall show by visual alarms if the door is not fully closed or if any of the securing arrangements are not in place and

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fully locked, and by audible alarms if such door or closing appliance becomes open or the securing arrangements become unsecured. The indicator panel in the operating compartment shall be equipped with a mode selection function 'harbour/sea voyage' so arranged that an audible alarm is given in the operating compartment if the craft leaves harbour with the bow doors, inner doors, stern ramp or any other side shell doors not closed or any closing device not in the correct position. The power supply for the indicator systems shall be independent of the power supply for operating and securing the doors.

2.2.5.2 Television surveillance

Television surveillance and a water leakage detection system shall be arranged to provide an indication to the operating compartment and to the engine control station of any leakage through inner and outer bow doors, stern doors or any other shell doors which could lead to major flooding.

2.2.6 Integrity of superstructure

2.2.6.1 Where entry of water into structures above the datum would significantly influence the stability and buoyancy of the craft, such structures shall be:

.1 of adequate strength to maintain the weathertight integrity and fitted with weathertight closing appliances; or

.2 provided with adequate drainage arrangements; or

.3 an equivalent combination of both measures.

2.2.6.2 Weathertight superstructures and deckhouses located above the datum shall in the outside boundaries have means of closing openings with sufficient strength such as to maintain weathertight integrity in all damage conditions where the space in question is not damaged. Furthermore, the means of closing shall be such as to maintain weathertight integrity in all operational conditions.

2.2.7 Doors, windows, etc., in boundaries of weathertight spaces

2.2.7.1 Doors, windows, etc., and any associated frames and mullions in weathertight superstructures and deckhouses shall be weathertight and shall not leak or fail at a uniformly applied pressure less than that at which adjacent structure would experience permanent set or fail. Conformity with the requirements of organizations recognized by the Administration in accordance with regulation XI/1 of the Convention may be considered to possess adequate strength.

2.2.7.2 For doors in weathertight superstructures, hose tests shall be carried out with a water pressure from the outside in accordance with specifications at least equivalent to those acceptable to the Organization [3].

2.2.7.3 The height above the deck of sills to doorways leading to exposed decks shall be as high above the deck as is reasonable and practicable, particularly those located in exposed positions. Such sill heights shall in general not be less than 100 mm for doors to weathertight spaces on decks above the datum, and 250 mm elsewhere. For craft of 30 m in length and under, sill heights may be reduced to the maximum which is consistent with the safe working of the craft.

2.2.7.4 Windows shall not be permitted in the boundaries of special category spaces or ro-ro spaces or below the datum. If required by restrictions in the Permit to Operate, forward facing windows, or windows which may be submerged at any stage of flooding shall be fitted with hinged or sliding storm shutters ready for immediate use.

2.2.7.5 Side scuttles to spaces below the datum shall be fitted with efficient hinged deadlights arranged inside so that they can be effectively closed and secured watertight.

2.2.7.6 No side scuttle shall be fitted in a position so that its sill is below a line drawn parallel to and one metre above the design waterline.

2.2.8 Hatchways and other openings

2.2.8.1 Hatchways closed by weathertight covers

The construction and the means for securing the weathertightness of cargo and other hatchways shall comply with the following:

.1 coaming heights shall in general not be less than 100 mm for hatches to weathertight spaces on decks above the datum, and 250 mm elsewhere. For craft of 30 m in length and under, coaming heights may be reduced to the maximum which is consistent with the safe working of the craft;

.2 the height of these coamings may be reduced, or the coamings omitted entirely, on condition that the Administration is satisfied that the safety of the ship is not thereby impaired in any sea conditions up to the worst intended conditions. Where coamings are provided, they shall be of substantial construction; and

.3 the arrangements for securing and maintaining weathertightness shall ensure that the tightness can be maintained in any sea conditions up to the worst intended conditions.

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3 Refer to ISO 6042 - Ships and Marine Technology – Weathertight single-leaf steel doors, or a similar standard.

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2.2.8.2 ***Machinery space openings***

2.2.8.2.1 Machinery space openings shall be properly framed and efficiently enclosed by casings of ample strength and, where the casings are not protected by other structures, their strength shall be specially considered. Access openings in such casings shall be fitted with weathertight doors.

2.2.8.2.2 Heights of sills and coaming shall, in general, not be less than 100 mm for openings to weathertight spaces on decks above the datum, and 380 mm elsewhere. For craft of 30 m in length and under, these heights may be reduced to the maximum which is consistent with the safe working of the craft.

2.2.8.2.3 Machinery space ventilator openings shall comply with the requirements of 2.2.8.4.2.

2.2.8.3 ***Miscellaneous openings in exposed decks***

2.2.8.3.1 Manholes and flush scuttles on the datum or within superstructures other than enclosed superstructures shall be closed by substantial covers capable of being made watertight. Unless secured by closely spaced bolts, the covers shall be permanently attached.

2.2.8.3.2 Service hatches to machinery, etc. may be arranged as flush hatches provided that the covers are secured by closely spaced bolts, are kept closed at sea, and are equipped with arrangements for portable guardrails.

2.2.8.3.3 Openings in exposed decks leading to spaces below the datum or enclosed superstructures other than hatchways, machinery space openings, manholes and flush scuttles shall be protected by an enclosed superstructure, or by a deckhouse or companionway of equivalent strength and weathertightness.

2.2.8.3.4 The height above the deck of sills to the doorways in companionways shall, in general, not be less than 100 mm for doors to weathertight spaces on decks above the datum, and 250 mm elsewhere. For craft of 30 m in length and under sill heights may be reduced to the maximum which is consistent with the safe working of the craft.

2.2.8.4 ***Ventilators***

2.2.8.4.1 Ventilators to spaces below the datum or decks of enclosed superstructures shall have substantially constructed coamings efficiently connected to the deck. Coaming heights shall in general not be less than 100 mm for ventilators to weathertight spaces on decks above the datum, and 380 mm elsewhere. For craft of 30 m in length and under, coaming heights may be reduced to the maximum which is consistent with the safe working of the craft.

2.2.8.4.2 Ventilators the coamings of which extend to more than one metre above the deck or which are fitted to decks above the datum need not be fitted with closing arrangements unless they face forward or are specifically required by the Administration.

2.2.8.4.3 Except as provided in 2.2.8.4.2, ventilator openings shall be provided with efficient weathertight closing appliances.

2.2.8.4.4 Ventilator openings shall face aft or athwartships wherever practicable.

2.2.9 ***Scuppers, inlets and discharges***

2.2.9.1 Discharges led through the shell either from spaces below the datum or from within superstructures and deckhouses fitted above the datum shall be fitted with efficient and accessible means for preventing water from passing inboard. Normally each separate discharge shall have one automatic non-return valve with a positive means of closing it from a position above the datum. Where, however, the vertical distance from the design waterline to the inboard end of the discharge pipe exceeds 0.01L, the discharge may have two automatic non-return valves without positive means of closing, provided that the inboard valve is always accessible for examination under service conditions. Where that vertical distance exceeds 0.02L, a single automatic non-return valve without positive means of closing may be accepted. The means for operating the positive action valve shall be readily accessible and provided with an indicator showing whether the valve is open or closed.

2.2.9.2 Valves on scuppers from weathertight compartments included in the stability calculations shall be operable from the operating compartment.

2.2.9.3 In manned machinery spaces, main and auxiliary sea inlets and discharges in connection with the operation of machinery may be controlled locally. Such controls shall be readily accessible and shall be provided with indicators showing whether the valves are open or closed. In unmanned machinery spaces, main and auxiliary sea inlet and discharge controls in connection with the operation of machinery shall either:

.1 be located at least 50 % of the significant wave height corresponding to the worst intended conditions above the deepest flooded waterline following damage specified in 2.6.6 to 2.6.10; or

.2 be operable from the operating compartment.

2.2.9.4 Scuppers leading from superstructures or deckhouses not fitted with weathertight doors shall be led overboard.

2.2.9.5 All shell fittings and the valves required by this Code shall be of a suitable ductile material. Valves of ordinary cast iron or similar material shall not be acceptable.

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2.2.10 Air pipes

2.2.10.1 Main storage tanks containing flammable liquids or tanks which can be pumped or filled from the sea shall have air pipes which do not terminate in enclosed spaces.

2.2.10.2 All air pipes extending to exposed decks shall have a height from the deck to the point where water may have access below of at least 300 mm where the deck is less than 0.05L above the design waterline, and 150 mm on all other decks.

2.2.10.3 Air pipes may discharge through the side of the superstructure provided that this is at a height of at least 0.02L above any waterline when the intact craft is heeled to an angle of 15° or 0.02L above the highest waterline at all stages of flooding as determined by the damaged stability calculations, whichever is higher.

2.2.10.4 All air pipes shall be equipped with weathertight closing devices that close automatically.

2.2.11 Freeing ports

2.2.11.1 Where bulwarks on weather decks form wells, ample provision shall be made for rapidly freeing the decks of water and for draining them. The minimum freeing port area (A) on each side of the craft for each well on the weather deck of the main hull(s) shall be:

.1 where the length of bulwark (l) in the well is 20 m or less:

$$A = 0.7 + 0.035\,l\ (m^2);\ \text{and}$$

.2 where l exceeds 20 m:

$$A = 0.07l\ (m^2),$$

and, in no case, l need be taken as greater than 0.7L.

If the bulwark is more than 1.2 m in average height, the required area shall be increased by 0.004 m^2 per metre of length of well for each 0.1 m difference in height. If the bulwark is less than 0.9 m in average height, the required area shall be decreased by 0.004 m^2 per metre of length of well for each 0.1 m difference in height.

2.2.11.2 Such freeing ports shall be located within the height of 0.6 m above the deck and the lower edge shall be within 0.02 m above the deck.

2.2.11.3 All such openings in the bulwarks shall be protected by rails or bars spaced approximately 230 mm apart. If shutters are fitted to freeing ports, ample clearance shall be provided to prevent jamming. Hinges shall have pins or bearings of non-corrodible material. If shutters are fitted with securing appliances, these appliances shall be of approved construction.

2.2.11.4 Craft, having superstructures which are open in front or both ends, shall comply with the provisions of 2.2.11.1.

2.2.11.5 In craft, having superstructures which are open at the aft end, the minimum freeing port area shall be:

$$A = 0.3b\ (m^2)$$

where:

b = the breadth of the craft at the exposed deck (m).

2.2.11.6 Ro-ro craft fitted with bow loading openings leading to open vehicle spaces shall comply with the provisions of 2.2.3.

2.3 Intact Stability in the Displacement Mode

2.3.1 Hydrofoil craft fitted with surface-piercing foils and/or fully submerged foils shall have sufficient stability under all permitted cases of loading to comply with the relevant provisions of annex 6 and specifically maintain a heel angle of less than 10° when subjected to the greater of the heeling moments in 1.1.2 and 1.1.4 of that annex.

2.3.2 Subject to 2.3.4, multihull craft other than hydrofoil craft shall meet the relevant requirements of annex 7 in all permitted cases of loading.

2.3.3 Subject to 2.3.4, monohull craft other than hydrofoil craft shall meet the relevant requirements of annex 8 in all permitted conditions of loading.

2.3.4 Where the characteristics of multihull craft are inappropriate for application of annex 7 or the characteristics of monohull craft are inappropriate for application of annex 8, the Administration may accept alternative criteria equivalent to those stipulated, as appropriate to the type of craft and area of operation. The requirements of annexes 7 and 8 may be applied as indicated in the table below.

Table 2.3.4 Application of annexes 7 and 8 to monohull and multihull craft

GM_T	Angle of maximum GZ	
	≤ 25°	> 25°
≤ 3 m	annex 7 or annex 8	annex 8
> 3 m	annex 7	annex 7 or annex 8

where:

GM_T = *transverse metacentric height in the loading condition corresponding to the design waterline, corrected for free surface effects (m)*

GZ = *righting lever*

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2.4 Intact Stability in the Non-Displacement Mode

2.4.1 The requirements of this section and of 2.12 shall be applied on the assumption that any stabilization systems fitted are fully operational.

2.4.2 The roll and pitch stability on the first and/or any other craft of a series shall be qualitatively assessed during operational safety trials as required by Sections 17 and 18 and annex 9. The results of such trials may indicate the need to impose operational limitations.

2.4.3 Where craft are fitted with surface-piercing structure or appendages, precautions shall be taken against dangerous attitudes or inclinations and loss of stability subsequent to a collision with a submerged or floating object.

2.4.4 In designs where periodic use of cushion deformation is employed as a means of assisting craft control, or periodic use of cushion air exhausting to atmosphere for purposes of craft manoeuvring, the effects upon cushion-borne stability shall be determined, and the limitations on the use by virtue of craft speed or attitude shall be established.

2.4.5 In the case of an air cushion vehicle fitted with flexible skirts, it shall be demonstrated that the skirts remain stable under operational conditions.

2.5 Intact Stability in the Transitional Mode

2.5.1 Under weather conditions up to the worst intended conditions, the time to pass from the displacement mode to the non-displacement mode and vice versa shall be minimised unless it is demonstrated that no substantial reduction of stability occurs during this transition.

2.5.2 Hydrofoil craft shall comply with the relevant provisions of annex 6.

2.6 Buoyancy and Stability in the Displacement Mode following Damage

2.6.1 The requirements of this Section apply to all permitted conditions of loading.

2.6.2 For the purpose of making damage stability calculations, the volume and surface permeabilities shall be, in general, as follows:

Spaces	*Permeability*
Appropriated to cargo or stores	*60*
Occupied by accommodation	*95*
Occupied by machinery	*85*
Intended for liquids	*0 or 95* [4]
Appropriated for cargo vehicles	*90*
Void spaces	*95*

2.6.3 Notwithstanding 2.6.2, permeability determined by direct calculation shall be used where a more onerous condition results, and may be used where a less onerous condition results from that provided according to 2.6.2.

2.6.4 The Administration may permit the use of low-density foam or other media to provide buoyancy in void spaces, provided that satisfactory evidence is provided that any such proposed medium is the most suitable alternative and is:

.1 of closed-cell form if foam, or otherwise impervious to water absorption;

.2 structurally stable under service conditions;

.3 chemically inert in relation to structural materials with which it is in contact or other substances with which the medium is likely to be in contact (reference is made to 7.4.3.7); and

.4 properly secured in place and easily removable for inspection of the void spaces.

2.6.5 The Administration may permit void bottom spaces to be fitted within the watertight envelope of the hull without the provision of a bilge system or air pipes provided that:

.1 the structure is capable of withstanding the pressure head after any of the damages required by this section;

.2 when carrying out a damage stability calculation in accordance with the requirements of this section, any void space adjacent to the damaged zone shall be included in the calculation and the criteria in 2.6, 2.13 and 2.15 complied with;

.3 the means by which water which has leaked into the void space is to be remove d shall be included in the craft operating manual required by Section 18; and

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[4] *whichever results in the more severe requirements*

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.4 *adequate ventilation is provided for inspection of the space under consideration as required by 2.2.1.2.*

.5 *void spaces filled with foam or modular buoyancy elements or any space without a venting system are considered to be void spaces for the purposes of this paragraph, provided such foam or elements fully comply with 2.6.4.*

2.6.6 *Any damage of a lesser extent than that postulated in 2.6.7 to 2.6.10, as applicable, which would result in a more severe condition shall also be investigated.*

2.6.7 Extent of side damage

The following side damage shall be assumed anywhere on the periphery of the craft:

.1 *the longitudinal extent of damage shall be 0.75 $\nabla^{1/3}$, or (3 m + 0.225 $\nabla^{1/3}$), or 11 m, whichever is the least;*

.2 *the transverse extent of penetration into the craft shall be 0.2 $\nabla^{1/3}$. However, where the craft is fitted with inflated skirts or with non-buoyant side structures, the transverse extent of penetration shall be at least 0.12 $\nabla^{1/3}$ into the main buoyancy hull or tank structure; and*

.3 *the vertical extent of damage shall be taken for the full vertical extent of the craft,*

where:

∇ = *volume of displacement corresponding to the design waterline (m^3).*

The damage described in this paragraph shall be assumed to have the shape of a parallelepiped. [5] *Applying this to figure 2.6.7 a, the inboard face at its mid-length shall be tangential to, or otherwise touching in a least 2 places, the surface corresponding to the specified transverse extent of penetration, as illustrated in figure 2.6.7 a.*

Side damage shall not transversely penetrate a greater distance than the extent of $0.2\nabla^{1/3}$ at the design waterline, except where a lesser extent is provided for in 2.6.7.2. Refer to figures 2.6.7b and c.

If considering a multihull, the periphery of the craft is considered to only be the surface of the shell encompassed by the outboard surface of the outermost hull at any given section.

2.6.8 Extent of bow and stern damage

2.6.8.1 *The following extents of damage are to be applied to bow and stern, as illustrated in figure 2.6.8:*

.1 *at the fore end, damage to the area defined as A_{bow} in 4.4.1, the aft limit of which being a transverse vertical plane, provided that this area need not extend further aft from the forward extremity of the craft's watertight envelope than the distance defined in 2.6.7.1; and*

.2 *at the aft end, damage to the area aft of a transverse vertical plane at a distance $0.2\nabla^{1/3}$ forward of the aft extremity of the watertight envelope of the hull.*

2.6.8.2 *The provisions of 2.6.6 in relation to damage of lesser extent remain applicable to such damage.*

2.6.9 *Extent of bottom damage in areas vulnerable to raking damage*

2.6.9.1 Application

.1 *Any part of the surface of the hull(s) is considered to be vulnerable to raking damage if:*

.1 *it is in contact with the water at 90 % of maximum speed in smooth water, and*

.2 *it also lies below two planes which are perpendicular to the craft centreline plane and at heights as shown in figure 2.6.8.1. For multihulls, individual hulls shall be considered separately.*

.2 *Raking damage shall be assumed to occur along any fore-and-aft line on the surface of the hull(s) between the keel and the upper limit defined in the figure below:*

.3 *Damage shall not be applied at the same time as that defined in 2.6.7 or 2.6.9.*

where:

T = maximum draught of the hull (each hull considered individually in the case of multihulls) to the design waterline, excluding any no buoyant structure, provided that structures such as single plate skegs or solid metal appendages shall be considered to be non-buoyant and thus exluded.

2.6.9.2 Extent

2.6.9.2.1 *Two different longitudinal extents shall be considered separately:*

.1 *55 % of the length L, measured from the most forward point of the underwater buoyant volume of each hull; and*

.2 *a percentage of the length L, applied anywhere in the length of the craft, equal to 35 % for craft where L = 50 m and over and equal to (L/2 + 10) % for craft where L is less than 50 m.*

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[5] *A parallelepiped is defined as "a solid contained by parallelograms" and a parallelogram is defined as "a four-sided rectilinear figure whose opposite sides are parallel".*

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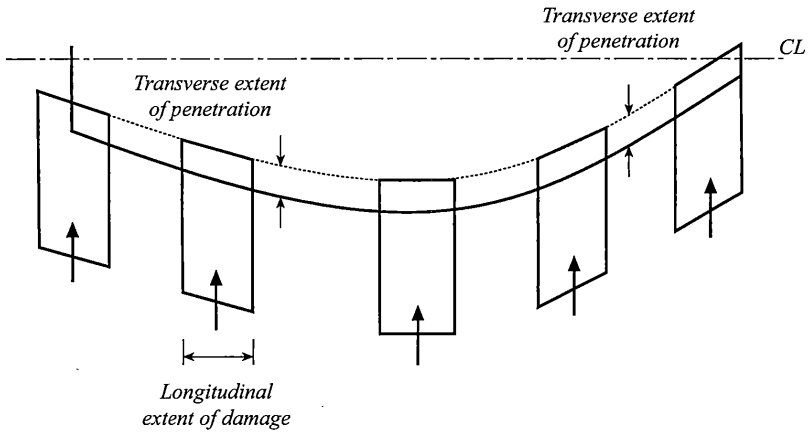

Figure 2.6.7 a

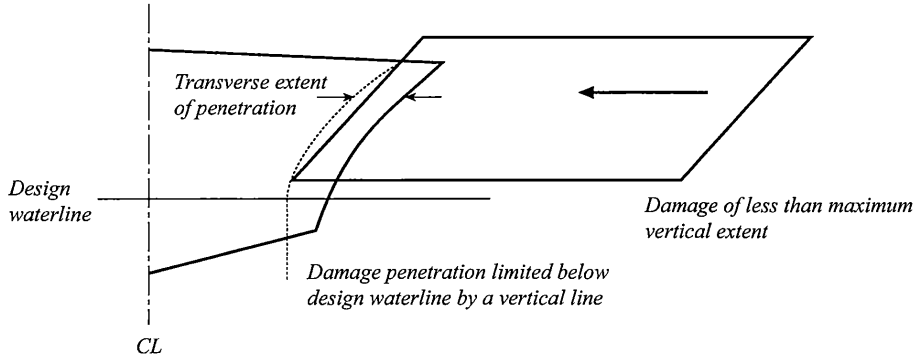

Figure 2.6.7 b

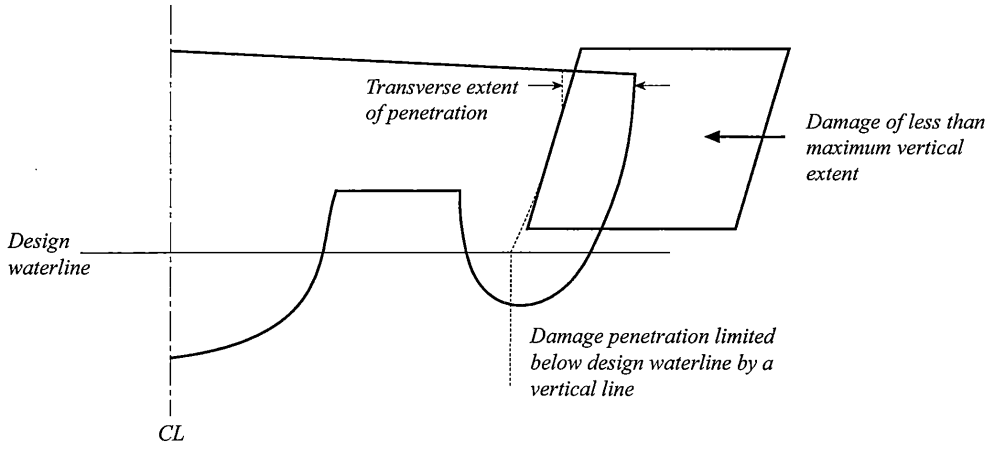

Figure 2.6.7 c

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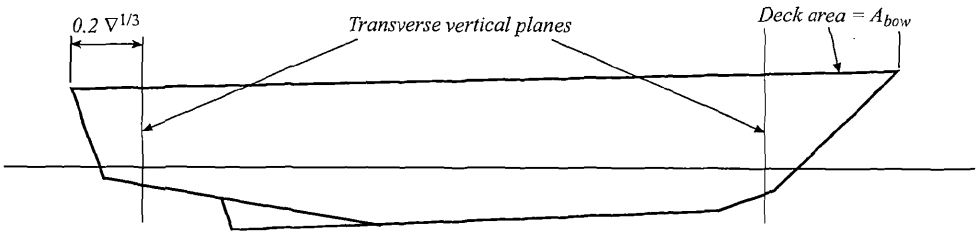

Figure 2.6.8

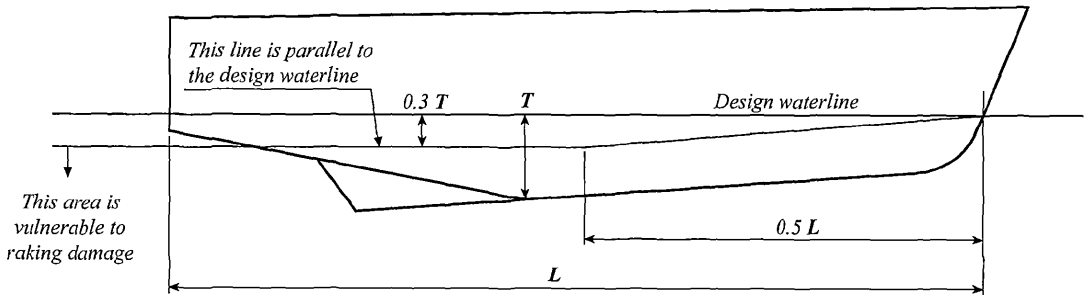

Figure 2.6.8.1

2.6.9.2.2 Except as provided below, the penetration normal to the shell shall be $0.04\nabla^{1/3}$ or

0.5 m, whichever is the lesser, in association with a girth along the shell equal to $0.1\nabla^{1/3}$, where ∇ is the volume of displacement corresponding to the design waterline (m^3). However this penetration or girth shall under no circumstances extend above the vertical extent of the vulnerable area as specified in 2.6.8.1.1.

2.6.9.2.3 The shape of damage shall be assumed to be rectangular in the transverse plane as illustrated in figure 2.6.9.2 below. Damage is to be assumed at a series of sections within the defined longitudinal extent in accordance with figure 2.6.9.2, the mid-point of the damaged girth being maintained at a constant distance from the centreline throughout that longitudinal extent.

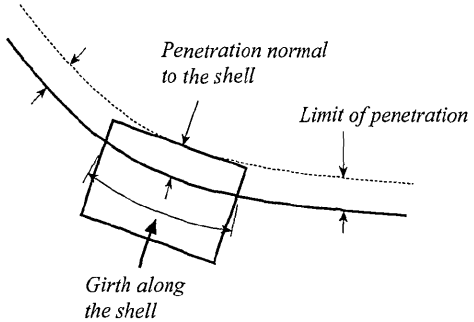

Figure 2.6.9.2

2.6.10 Extent of bottom damage in areas not vulnerable to raking damage

2.6.10.1 Application

This applies to all parts of the hull(s) below the design waterline which are not defined as vulnerable to raking damage in 2.6.8.1. Damage shall not be applied at the same time as that defined in 2.6.7 or 2.6.8.

2.6.10.2 Extent

The following extent of damage shall be assumed:

.1 the length of damage in the fore-and-aft direction shall be $0.75\nabla^{1/3}$, or $(3\text{ m} + 0.225\nabla^{1/3})$, or 11 m whichever is the least;

.2 the athwartships girth of damage shall be $0.2\nabla^{1/3}$; and

.3 the depth of penetration normal to the shell shall be $0.02\nabla^{1/3}$, where:

∇ = volume of displacement corresponding to the design waterline (m^3).

.4 the shape of damage shall be assumed to be rectangular in the plane of the shell of the craft, and rectangular in the transverse plane as illustrated in figure 2.6.9.2.

2.6.11 In applying 2.6.8 and 2.6.9 to multihull craft, an obstruction at or below the design waterline of up to 7 m width shall be considered in determining

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the number of hulls damaged at any one time. The requirement of 2.6.6 shall also be applied.

2.6.12 *Following any of the postulated damages detailed in 2.6.6 to 2.6.10, the craft in still water shall have sufficient buoyancy and positive stability to simultaneously ensure that:*

.1 *for all craft other than amphibious air-cushion vehicles, after flooding has ceased and a state of equilibrium has been reached, the final waterline is below the level of any opening through which further flooding could take place by at least 50 % of the significant wave height corresponding to the worst intended conditions;*

.2 *for amphibious air-cushio n vehicles, after flooding has ceased and a state of equilibrium has been reached, the final waterline is below the level of any opening through which further flooding could take place by at least 25 % of the significant wave height corresponding to the worst intended conditions;*

.3 *there is a positive freeboard from the damage waterline to survival craft embarkation positions;*

.4 *essential emergency equipment, emergency radios, power supplies and public address systems needed for organizing the evacuation remain accessible and operational;*

.5 *the residual stability of craft meets the appropriate criteria as laid out in annexes 7 and 8 according to table 2.3.4. Within the range of positive stability governed by the criteria of annexes 7 or 8, no unprotected opening shall be submerged.*

2.6.13 *Downflooding openings referred to in 2.6.11.1 and 2.6.11.2 shall include doors and hatches which are used for damage control or evacuation procedures, but may exclude those which are closed by means of weathertight doors and hatch covers and not used for damage control or evacuation procedures.*

2.7 Inclining and Stability Information

2.7.1 *Every craft, on completion of build, shall be inclined and the elements of its stability determined. When an accurate inclining is not practical, the lightweight displacement and centre of gravity shall be determined by a lightweight survey and accurate calculation.*

2.7.2 *On all craft, where an accurate inclining experiment is impractical owing to the height of the centre of gravity (VCG or KG) being less than one third of the transverse metacentric height (GM_T), the Administration may accept estimation of KG by detailed calculation in place of an inclining experiment. In such cases, a displacement check shall be undertaken to confirm the calculated lightship characteristics, including LCG, which may be accepted if the measured lightship displacement and LCG are respectively within 2 % and 1 % L relative to the estimate.*

2.7.3 *The master shall be supplied by the owner with reliable information relating to the stability of the craft in accordance with the following provisions of this paragraph. The information relating to stability shall , before issued to the master, be submitted to the Administration for approval, together with a copy thereof for their retention, and shall incorporate such additions and amendments as the Administration may in any particular case require.*

2.7.4 *Where any alterations are made to a craft so as significantly to affect the stability information supplied to the master, amended stability information shall be provided. If necessary the craft shall be re-inclined.*

2.7.5 *A report of each inclining or lightweight survey carried out in accordance with this Section and of the calculation therefrom of the lightweight condition particulars shall be submitted to the Administration for approval, together with a copy for their retention. The approved report shall be placed on board the craft by the owner in the custody of the master and shall incorporate such additions and amendments as the Administration may in any particular case require. The amended lightweight condition particulars so obtained from time to time shall be used by the master in substitution for such previously approved particulars when calculating the craft's stability.*

2.7.6 *Following any inclining or lightweight survey, the master shall be supplied with amended stability information if the Administration so requires. The information so supplied shall be submitted to the Administration for approval, together with a copy thereof for their retention, and shall incorporate such additions and amendments as the Administration may in any particular case require.*

2.7.7 *Stability information demonstrating compliance with this Section shall be furnished in the form of a stability information book which shall be kept on board the craft at all times in the custody of the master. The information shall include particulars appropriate to the craft and shall reflect the craft loading conditions and mode of operation. Any enclosed superstructures or deck-houses included in the cross curves of stability and the critical downflooding points and angles shall be identified. At the operating station there shall be plans showing clearly for each deck and hold the boundaries of the watertight compartments, the openings therein with their means of closure and position of any controls thereof. For amphibious air-cushion vehicles this may be achieved*

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by the use of draught gauges in conjunction with deck datum plates.

2.7.8 Every craft shall have scales of draughts marked clearly at the bow and stern. In the case where the draught marks are not located where they are easily readable, or operational constraints for a particular trade make it difficult to read the draught marks, then the craft shall also be fitted with a reliable draught-indicating system by which the bow and stern draughts can be determined.

2.7.9 The owner or builder, as appropr iate, shall ensure that the positions of the draught marks are accurately determined and that the marks are located on the hull in a permanent manner. Accuracy of the draught marks shall be demonstrated to the Administration prior to the inclining experiment.

2.8 Loading and Stability Assessment

On completion of loading of the craft and prior to its departure on a voyage, the master shall determine the trim and stability of the craft and also ascertain and record that the craft is in compliance with stability criteria of the relevant requirements. The Administration may accept the use of an electronic loading and stability computer or equivalent means for this purpose.

2.9 Marking and Recording of the Design Waterline

2.9.1 The design waterline shall be clearly and permanently marked on the crafts outer sides by the load line mark described below. This and the reference line described in 2.9.2.2 below shall be recorded in the High-Speed Craft Safety Certificate. For craft where this is not practical, e.g. amphibious air-cushion vehicles fitted with peripheral skirts, defined deck reference points shall be provided, from which the freeboard can be measured, and hence the draughts obtained.

2.9.2 Load line mark

2.9.2.1 The load line mark shall consist of a ring with an outside diameter of 300 mm and width of 25 mm which is intersected by a horizontal line of length 450 mm and having a breadth of 25 mm, the upper edge of which passes through the centre of the ring. The centre of the ring shall be placed at the longitudinal centre of flotation in the displacement mode and at a height corresponding to the design waterline.

2.9.2.2 To assist in verifying the position of the load line mark, a reference line shall be marked on the hull at the longitudinal centre of flotation by a horizontal bar having a length of 300 mm and a breadth of 25 mm and having the upper edge corresponding to the reference line.

2.9.2.3 Where practicable, the reference line should be related to the uppermost deck at side. Where it is not possible, the position of the reference line should be defined from the underside of keel at the longitudinal centre of flotation.

2.9.2.4 The mark of the Authority by whom the load lines are assigned may be indicated alongside the load line ring above the horizontal line which passes through the centre of the ring, or above and below it. This mark shall consist of not more than four initials to identify the Authority's name, each measuring approximately 115 mm in height, and 75 mm in width.

2.9.2.5 The ring, lines and letters shall be painted in white or yellow on a dark ground or in black on a light ground, and permanently marked. The marks shall be plainly visible.

2.9.3 Verification

The High-Speed Craft Safety Certificate shall not be delivered until the Administration has verified that the marks are correctly and permanently indicated on the sides of the craft.

Part B - Requirements for Passenger Craft

2.10 General

2.10.1 Where compliance with this Section requires consideration of the effects of passenger weight, the following information shall be used:

- *.1 The distribution of passengers is 4 persons per square metre.*
- *.2 Each passenger has a mass of 75 kg.*
- *.3 Vertical centre of gravity of seated passengers is 0.3 m above seat.*
- *.4 Vertical centre of gravity of standing passengers is 1.0 m above deck.*
- *.5 Passengers and luggage shall be considered to be in the space normally at their disposal.*
- *.6 Passengers shall be distributed on available deck areas towards one side of the craft on the decks where assembly stations are located and in such a way that they produce the most adverse heeling moment.*
- *.7 Passengers assumed to be occupying seats shall be taken as having a vertical centre of gravity corresponding to being seated, with all others standing.*
- *.8 On the decks where assembly stations are located, the number of passengers on each deck shall be that which generates the maximum heeling moment. Any remaining passengers shall be assumed to occupy decks adja-*

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cent to those on which the assembly stations are located, and positioned such that the combination of number on each deck and total heeling moment generate the maximum static heel angle.

.9 Passengers shall not be assumed to gain access to the weather deck nor be assumed to crowd abnormally towards either end of the craft unless this is a necessary part of the planned evacuation procedure.

.10 Where there are seats in areas occupied by passengers, one passenger per seat shall be assumed, passengers being assigned to the remaining free areas of the deck (including stairways, if appropriate) at the rate of four per square metre.

2.11 Intact Stability in the Displacement Mode

The craft shall have sufficient intact stability that, when in still water conditions, the inclination of the craft from the horizontal would not exceed 10° (under all permitted cases of loading and uncontrolled passenger movements as may occur).

2.12 Intact Stability in the Non-Displacement Mode

2.12.1 *The total heel angle in still water due to the effect of passenger movements or due to beam wind pressure as per 1.1.4 of annex 6 shall not to exceed 10°. Passenger movement need not be considered where passengers are required to be seated whenever the craft is operating in the non-displacement mode.*

2.12.2 *In all loading conditions, the outward heel due to turning shall not exceed 8° and the total heel due to beam wind pressure as per 1.14 of annex 6 and due to turning shall not exceed 12°.*

2.12.3 *Demonstrating the effect of the passenger heeling moment calculated as given by 2.10 above, or a defined beam wind pressure when at speed, shall be established by conducting a trial or model test with an equivalent heeling moment applied by test weights. Passenger movement may only be neglected on craft where the safety announcement (refer to 8.4.1 and 18.7) expressly requires passengers to remain seated throughout the voyage.*

2.13 Buoyancy and Stability in the Displacement Mode following Damage

2.13.1 *Following any of the postulated damages detailed in 2.6.6 to 2.6.10, in addition to satisfying the requirements of 2.6.11 and 2.6.12, the craft in still water shall have sufficient buoyancy and positive stability to simultaneously ensure that:*

.1 the angle of inclination of the craft from the horizontal does not normally exceed 10° in any direction. However, where this is clearly impractical, angles of inclination up to 15° immediately after damage but reducing to 10° within 15 min shall be permitted provided that efficient non-slip deck surfaces and suitable holding points, e.g., holes, bars, etc., are provided; and

.2 any flooding of passenger compartments or escape routes which might occur will not significantly impede the evacuation of passengers.

2.13.2 *In addition to the requirements in 2.13.1, Category B craft shall also satisfy the following criteria after sustaining raking damage of 100 % of length L, having the girth and penetration given in 2.6.8.2.2, to any part of the surface of the hull(s) defined in 2.6.8.1:*

.1 The angle of inclination of the craft from the horizontal shall not exceed 20° in the equilibrium condition;

.2 the range of positive righting lever shall be at least 15° in the equilibrium condition;

.3 the positive area under the righting lever curve shall be at least 0.015 m-rad in the equilibrium condition;

.4 the requirements of 2.6.11.3 and 2.13.1.2 are satisfied; and

.5 in intermediate stages of flooding, the maximum righting lever shall be at least 0.05 m and the range of positive righting lever shall be at least 7°

In complying with the above, the righting lever curve shall be terminated at the angle of downflooding, and only one free surface need be assumed.

2.14 Inclining and Stability Information

2.14.1 *At periodical intervals not exceeding 5 years, a lightweight survey shall be carried out on all passenger craft to verify any changes in lightweight displacement and longitudinal centre of gravity. The passenger craft shall be re-inclined whenever, in comparison with the approved stability information, a deviation from the lightweight displacement exceeding 2 %, or a deviation of the longitudinal centre of gravity exceeding 1 % of L is found or anticipated.*

2.14.2 *A report of each inclining or lightweight survey carried out in accordance with 2.7.1 and of the calculation therefrom of the lightweight condition particulars shall be submitted to the Administration for approval, together with a copy for their retention. The approved report shall be placed on board the craft by the owner in the custody of the master and shall incorporate such additions and amendments as*

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the Administration may in any particular case require. The amended lightweight condition particulars so obtained from time to time shall be used by the master in substitution for such previously approved particulars when calculating the craft's stability.

2.14.3 Following any inclining or lightweight survey, the master shall be supplied with amended stability information if the Administration so requires. The information so supplied shall be submitted to the Administration for approval, together with a copy thereof for their retention, and shall incorporate such additions and amendments as the Administration may in any particular case require.

Part C - Requirements for Cargo Craft

2.15 Buoyancy and Stability in the Displacement Mode following Damage

Following any of the postulated damages detailed in 2.6.6 to 2.6.10, in addition to satisfying the requirements of 2.6.11 and 2.6.12, the craft in still water shall have sufficient buoyancy and positive stability to simultaneously ensure that the angle of inclination of the craft from the horizontal does not normally exceed 15° in any direction. However, where this is clearly impractical, angles of inclination up to 20° immediately after damage but reducing to 15° within 15 minutes may be permitted provided that efficient non-slip deck surfaces and suitable holding points are provided.

2.16 Inclining

Where it is satisfied by lightweight survey, weighing or other demonstration that the lightweight of a craft is closely similar to that of another craft of the series to which 2.7.1 has been applied, the Administration may waive the requirement of 2.7.1 for craft to be inclined. In this regard, a craft which lies within the parameters of 2.14.1, when compared with a craft of the series which has been inclined, shall be regarded as being closely similar to that craft.

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Section 3

Structures

3.1 General

This Section covers those elements of hull and superstructure which provide longitudinal and other primary and local strength of the craft as a whole and also important components such as foils and skirts which are directly associated with the hull and superstructure.

3.2 Materials

Materials used for the hull and superstructure and the other features referred to in 3.1 shall be adequate for the intended use of the craft.

3.3 Structural Strength

The structure shall be capable of withstanding the static and dynamic loads which can act on the craft under all operating conditions in which the craft is permitted to operate, without such loading resulting in inadmissible deformation and loss of watertightness or interfering with the safe operation of the craft.

3.4 Cyclic Loads

Cyclic loads, including those from vibrations which can occur on the craft, shall not:

.1 impair the integrity of structure during the anticipated service life of the craft or the service life agreed with the Administration;

.2 hinder normal functioning of machinery and equipment; and

.3 impair the ability of the crew to carry out its duties.

Note

In scope of Classification, the structural strength against vibrations is not checked.

The vibration check shall be performed during the sea trials of the craft. Where deemed necessary, the Society may require vibration measurements to be carried out using suitable instruments; where appropriate, remedial measures may be required to adequately eliminate situations deemed unacceptable.

3.5 Design Criteria

The Administration shall be satisfied that the choice of design conditions, design loads and accepted safety factors corresponds to the intended operating conditions for which certification is sought.

3.6 Trials

If the Administration consider it necessary, it shall require full-scale trials to be undertaken in which loadings are determined. Cognisance shall be taken of the results where these indicate that loading assumptions of structural calculations have been inadequate.

C3.1 General

C3.1.1 Introductory comments

.1 This Section contains the requirements for structural scantlings of the craft to which these Rules apply, i.e. to craft for which $V \geq 7{,}16\ \Delta^{1/6}$. Craft for which $V/\sqrt{L} \geq 10$ shall be individually considered by GL (V in knots, Δ in tonnes, L in metre).

For what concerns multihull craft, this Section provides the requirements for scantlings of catamarans and trimarans. Other craft will be considered in each separate case by GL.

.2 The requirements for scantlings of hydrofoils and air-cushion vehicles are contained in Appendices C3A1 and C3A2. Unless otherwise specified, the requirements of this Section apply to such craft only as far as the provisions regarding limit operating conditions, materials and construction criteria are concerned.

.3 The scantlings indicated in the following paragraphs apply to craft constructed of steel, aluminium alloy or fibre reinforced plastic, as specified in C3.2.

C3.1.2 Direct calculations

C3.1.2.1 General

.1 GL may require direct calculations to be carried out, if deemed necessary.

Such calculations are to be carried out based on structural modelling, loading and checking criteria described below. Calculations based on other criteria

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may be accepted if deemed equivalent to those laid down by GL.

.2 In order to increase the flexibility in the structural design of ships GL also accepts direct calculations with computer programs. The aim of such analyses should be the proof of equivalence of a design with the rule requirements.

.3 Direct calculations may also be used in order to optimise a design; in this case only the final results are to be submitted for review.

C3.1.2.2 General programs

.1 The choice of computer programs according to "State of the Art" is free. The programs may be checked by GL through comparative calculations with predefined test examples. A generally valid approval for a computer program is, however, not given by GL.

.2 Direct calculations may be used in the following fields

- global strength
- longitudinal strength
- beams and grillages
- detailed strength

.3 For such calculation the computer model, the boundary condition and load cases are to be agreed upon with GL. The calculation documents are to be submitted including input and output. During the examination it may prove necessary that GL perform independent comparative calculations.

.4 GL is prepared to carry out the following calculations of this kind within the marine advisory services:

.4.1 Strength

Linear and/or non-linear strength calculations with the FE-method:

For an automated performance of these calculations, a number of effective pre- and post processing programmes is at disposal:

- calculation of seaway loads as per modified strip method or by 3 D-panel method
- calculation of resultant accelerations to ensure quasi-static equilibrium
- calculation of composite structures
- evaluation of deformations, stresses, buckling behaviour, ultimate strength and local stresses, assessment of fatigue strength

.4.2 Vibrations

Calculation of free vibrations with the FE-method as well as forced vibrations due to harmonic or shock excitation:

- global vibrations of hull, aft ship, deckhouse, etc.
- vibrations of major local components, such as rudders, radar masts, etc.
- local vibrations of plate fields, stiffeners and panels
- vibrations of simply or double-elastically mounted aggregates

A number of pre- and post processing programs is available here as well for effective analyses:

- calculation of engine excitation forces/moments
- calculation of propeller excitation forces (pressure fluctuations and shaft bearing reactions)
- calculation of hydrodynamic masses
- graphic evaluation of amplitude level as per ISO 6954 recommendations or as per any other standard
- noise predictions

C3.1.2.3 Specific programs related to Rules

GLRP (GL RULES and Programs) is available on CD-ROM. It includes the wording of GL-Rules and an elementary program for dimensioning the structural members of the hull.

C3.1.3 Units

.1 Unless otherwise specified, the following units are used in the Rules:

- thickness of plating [mm]
- section modulus of stiffeners [cm^3]
- shear area of stiffeners [cm^2]
- span and spacing of stiffeners [m]
- stresses [MPa]
- concentrated loads [kN]
- distributed loads [kN/m] or [kPa]

C3.1.4 Documents for Approval

The following documents are to be submitted. To facilitate a smooth and efficient approval process they shall be submitted electronically via GLOBE [1]. In specific cases and following prior agreement with GL they can also be submitted in paper form in triplicate.

.1 Midship section

The cross sectional plans (midship section, other typical sections) shall contain all necessary data on the scantlings of the longitudinal and transverse hull structure as well as details of anchor and mooring equipment.

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1 Detailed information about the secured GL system GLOBE can be found on GL's website www.gl-group.com/globe.

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.2 Longitudinal section

The plan of longitudinal sections shall contain all necessary details on the scantlings of the longitudinal hull structure and on the location of the watertight bulkheads and the deck supporting structures, the arrangement of superstructures and deck houses.

.3 Decks

Plans of the decks showing the scantlings of the deck structures, length and breadth of cargo hatches, openings above the engine and boiler room, and other deck openings. On each deck, deck load caused by cargo is to be defined as assumed in determining the scantlings of the decks and their supports.

.4 Shell

Drawings of shell expansion, containing full details on the location and size of the openings and drawings of the sea chests.

.5 Bulkheads

Drawings of the transverse, longitudinal and wash bulkheads and of all tank boundaries, with details on densities of liquids, heights of overflow pipes and set pressures of the pressure or vacuum relief valves (if any).

.6 Bottom structure

Drawings of single and double bottom showing the arrangement of the transverse and longitudinal girders as well as the water and oil tight subdivision of the double bottom.

.7 Engine and boiler seatings

Drawings of the engine and boiler seatings, the bottom structure under the seatings and of the transverse structures in the engine room, with details on fastening of the engine foundation plate to the seating, as well as type and output of engine.

.8 Appendages

Drawings of rudder, shaft brackets, stabilizers including supports, bearing materials and propeller details.

.9 Longitudinal strength

Maximum and minimum still water bending moments, shear forces and, if necessary, torsional moments. This includes the mass distribution for the envisaged loading conditions and the distribution of section moduli and moduli of inertia over the ship's length.

.10 Materials

The drawings mentioned in 1 – 8 and 13 shall contain details on the hull materials (e.g. hull structural steel grades, standards, material numbers). Where higher tensile steels or materials other than ordinary hull structural steels are used, drawings for possible repairs have to be placed on board.

.11 Weld joints

The drawings listed in 1 – 8 and 13 shall contain details on the welded joints e.g. weld shapes and dimensions and weld quality. For the relevant data for manufacturing and testing of welded joints see Rules for Welding.

.12 Lashing and stowage devices

Drawings containing details on stowage and lashing of cargo (e.g. containers, car decks). In the drawings the location of the connections and the appropriate substructures at the ship shall be shown in detail.

.13 Substructures

Drawings of substructures below steering gears, windlasses and chain stoppers as well as masts and boat davits, supporting structure of cargo masts, cranes, etc. together with details on loads to be transmitted into structural elements.

.14 Additional information for fibre reinforced plastic (FRP) craft

For FRP craft, the drawing and documents to be submitted for examination and listed in C3.1.4 are to contain the following additional information:

- arrangement of laminate for the various structural elements: thickness, definition of successive layers of reinforcement, areal weight of reinforcement layers, mass or volume fraction of reinforcement layers, directions of roving layers and unidirectional reinforcements, decreasing in thickness between layers
- direction of laminate in relation to craft structure
- structure of oil tanks or other liquid tanks which are integrated into the hull
- details of connection among various structural elements and details of attachment to the hull of supplementary reinforcing elements
- pillars

Suppliers' technical specifications with indication of types, trademarks and references of resins and gelcoats, reinforcements and core materials are to be supplied.

These specifications are to give the following information:

- resins: type (orthophthalic or isophthalic), specific gravity, Young's modulus, Poisson's ratio, breaking strength and elongation at break

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- reinforcements (mats, woven rovings, unidirectional reinforcements): quality (glass or other material, with specific gravity, breaking strength of the elementary fibre, Young's modulus and Poisson's ratio), mass per square metre, thickness and possibly weft-warp distribution
- core materials: type and quality; specific gravity; tensile, compressive and shear strength and elasticity moduli

C3.1.5 Definitions and symbols

The definitions of the following terms and symbols are applicable throughout this Section and its Appendices and are not, as a rule, repeated in the different paragraphs. Definitions applicable only to certain paragraphs are specified therein.

- "Moulded base line": The line parallel to the summer load waterline, crossing the upper side of keel plate or the top of skeg at the middle of length L.
- "Hull": The hull is the outer boundary of the enclosed spaces of the craft, except for the deckhouses, as defined below.
- "Chine": For hulls that do not have a clearly identified chine, the chine is the hull point at which the tangent to the hull is inclined 50° to the horizontal.
- "Bottom": The bottom is the part of the hull between the keel and the chines.
- "Main deck": The main deck is the uppermost complete deck of the hull. It may be stepped.
- "Side": The side is the part of the hull between the chine and the main deck.
- "Deckhouse": The deckhouse is a decked structure located above the main deck, with lateral walls inboard of the side of more than 4 per cent of the local breadth. Structure located on the main deck and whose walls are not in the same longitudinal plane as the under side shell may be regarded as a deckhouse.
- "Wet deck": For multihull craft, the wet deck is the bottom structure connecting the hulls which is defined as cross-deck.
- "Deadrise angle α_d": For hulls that do not have a clearly identified deadrise angle, α_d is the angle between the horizontal and a straight line joining the keel and the chine. For catamarans with non-symmetrical hulls (where inner and outer deadrise angles are different), α_d is the lesser angle.
- "Fore end": Hull region forward of 0,9 L from the aft perpendicular.
- "Aft end": Hull region abaft of 0,1 L from the aft perpendicular.
- "Midship area": Hull region between 0,3 L and 0,7 L from the aft perpendicular.

L = Rule length [m], equal to LWL which is the waterline measured with the craft at rest in calm water and, for SESs, in the off-cushion condition, for trimarans L will be defined in each separate case at the discretion of GL.

FP = forward perpendicular, i.e. the perpendicular at the intersection of the waterline at draught T and the foreside of the stem

AP = aft perpendicular, i.e. the perpendicular located at a distance L abaft of the forward perpendicular

B = the greatest moulded breadth [m], of the craft

B_W = the greatest moulded breadth [m], measured on the waterline at draught T; for catamarans, B_W is the breadth of each hull; for trimarans, B_W will be defined in each separate case at the discretion of GL.

D = depth [m], measured vertically in the transverse section at the middle of length L from the moulded base line of the hull(s) to the top of the deck beam at one side of the main deck (if the main deck is stepped, D will be defined in each separate case at the discretion of GL)

T = draught of the craft [m], measured vertically on the transverse section at the middle of length L, from the moulded base line of the hull(s) to the full load waterline, with the craft at rest in calm water and, for SESs, in the off-cushion condition

Δ = moulded displacement at draught T, in sea water (mass density = 1,025 t/m^3) [t]

C_B = total block coefficient, defined as follows:

$$C_B = \frac{\Delta}{1,025 \cdot L \cdot B_W \cdot T}$$

For catamarans, C_B is to be calculated for a single hull, assuming Δ equal to one half of the craft's displacement; for trimarans the calculation of C_B depends on the distribution of displacement of each hull. It will be defined in each separate case at the discretion of GL.

V = maximum service speed [kn]

g = acceleration of gravity, equal to 9,81 m/s^2

LCG = longitudinal centre of gravity of the craft.

C3.1.6 Rounding-Off Tolerances

Where in determining plate thicknesses in accordance with the provisions of this Section the figures differ from full or half mm, they may be rounded off to full or half millimeters up to 0,2 or 0,7; above 0,2 or 0,7 mm they are to be rounded up.

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If plate thicknesses are not rounded the calculated required thicknesses shall be shown in the drawings. The section moduli of profiles usual in the trade and including the effective width according to C3.7.4 may be 3 % less than the required values according to the following rules for dimensioning.

C.3.1.7 Workmanship

C3.1.7.1 General

.1 Requirements to be complied with by the manufacturer

.1.1 The manufacturing plant shall be provided with suitable equipment and facilities to enable proper handling of the materials, manufacturing processes, structural components, etc. GL reserve the right to inspect the plant accordingly or to restrict the scope of manufacture to the potential available at the plant.

.1.2 The manufacturing plant shall have at its disposal sufficiently qualified personnel. GL is to be advised of the names and areas of responsibility of all supervisory and control personnel. GL reserve the right to require proof of qualification.

.2 Quality control

.2.1 As far as required and expedient, the manufacturer's personnel has to examine all structural components both during manufacture and on completion, to ensure that they are complete, that the dimensions are correct and that workmanship is satisfactory and meets the standard of good shipbuilding practice.

.2.2 Upon inspection and corrections by the manufacturing plant, the structural components are to be shown to the GL Surveyor for inspection, in suitable sections, normally in unpainted condition and enabling proper access for inspection.

.2.3 The Surveyor may reject components that have not been adequately checked by the plant and may demand their re-submission upon successful completion of such checks and corrections by the plant.

C3.1.7.2 Structural details

.1 Details in manufacturing documents

.1.1 All significant details concerning quality and functional ability of the component concerned shall be entered in the manufacturing documents (workshop drawings, etc.). This includes not only scantlings but - where relevant - such items as surface conditions (e.g. finishing of flame cut edges and weld seams), and special methods of manufacture involved as well as inspection and acceptance requirements and where relevant permissible tolerances. So far as for this aim a standard shall be used (works or national standard, etc.) it shall be harmonized with GL. This standard shall be based on the IACS Recommendation 47 Shipbuilding and Repair Quality Standard for New Construction. For weld joint details, see Section C.3.2.4.1

.1.2 If, due to missing or insufficient details in the manufacturing documents, the quality or functional ability of the component cannot be guaranteed or is doubtful, GL may require appropriate improvements. This includes the provision of supplementary or additional parts (for example reinforcements) even if these were not required at the time of plan approval or if - as a result of insufficient detailing - such requirement was not obvious.

.2 Cut-outs, plate edges

.2.1 The free edges (cut surfaces) of cut-outs, hatch corners, etc. are to be properly prepared and are to be free from notches. As a general rule, cutting drag lines, etc. shall not be welded out, but are to be smoothly ground. All edges should be broken or in cases of highly stressed parts, should be rounded off.

.2.2 Free edges of flame or machine cut plates or flanges are not to be sharp cornered and are to be finished off as laid down in 2.2.1. This also applies to cutting drag lines, etc., in particular to the upper edge of shear strake and analogously to weld joints, changes in sectional areas or similar discontinuities.

.3 Cold forming

.3.1 For cold forming (bending, flanging, beading) of plates the minimum average bending radius shall not fall short of 3 t (t = plate thickness) and shall be at least 2 t. Regarding the welding of cold formed areas, see C3.6.1.2.6.

.3.2 In order to prevent cracking, flame cutting flash or sheering burrs shall be removed before cold forming. After cold forming all structural components and, in particular, the ends of bends (plate edges) are to be examined for cracks. Except in cases where edge cracks are negligible, all cracked components are to be rejected. Repair welding is not permissible.

.4 Assembly, alignment

.4.1 The use of excessive force is to be avoided during the assembly of individual structural components or during the erection of sections. As far as possible major distortions of individual structural components should be corrected before further assembly.

.4.2 Girders, beams, stiffeners, frames, etc. that are interrupted by bulkheads, decks, etc. shall be accurately aligned. In the case of critical components, control drillings are to be made where necessary, which are then to be welded up again on completion.

.4.3 After completion of welding, straightening and aligning shall be carried out in such a manner that the material properties will not be influenced

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significantly. In case of doubt, GL may require a procedure test or a working test to be carried out.

C3.1.8 Protection against corrosion

.1 Scantlings stipulated in C3.7 assume that the materials used are chosen and protected in such a way that the strength lost by corrosion is negligible.

.2 The Shipyard is to give GL a document specifying all the arrangements made to protect the material against corrosion at the construction stage: coating types, number and thickness of layers, surface preparation, application conditions, control after completion, anodic protection, etc. The GL Guidelines for Corrosion Protection and Coating Systems (VI-10-2) are to be observed.

.3 This document shall also include maintenance arrangements to be made in service to restore and maintain the efficiency of this protection, whatever the reasons of its weakening, whether incidental or not.

.4 All such maintenance operations are to be listed in a book shown to GL surveyor at each visit.

C3.2 Materials and Connections

C3.2.1 General requirements

All materials to be used for the structural members indicated in the Construction Rules are to be in accordance with the GL Rules II – Materials and Welding, Part 1 – Metallic Materials or Part 2 – Non-metallic Materials, as applicable. Materials the properties of which deviate from these Rule requirements may only be used upon special approval.

C3.2.2 Steel Structures

C3.2.2.1 Normal strength hull structural steel

.1 Normal strength hull structural steel is a hull structural steel with a minimum nominal upper yield point R_{eH} of 235 MPa and a tensile strength R_m of 400 – 520 MPa.

.2 The material factor k in the formulae of this Section is to be taken 1,0 for normal strength hull structural steel.

.3 Normal strength hull structural steel is grouped into the grades GL–A, GL–B, GL–D, GL–E, which differ from each other in their toughness properties.

.4 If for special structures the use of steels with yield properties less than 235 MPa has been accepted, the material factor k is to be determined by:

$k = 235/R_{eH}$

C3.2.2.2 Higher strength hull structural steels

.1 Higher strength hull structural steel is a hull structural steel, the yield and tensile properties of which exceed those of normal strength hull structural steel. According to the GL Rules II – Materials and Welding, Part 1 – Metallic Materials, for three groups of higher strength hull structural steels the nominal upper yield stress R_{eH} has been fixed at 315, 355 and 390 MPa respectively. Where higher strength hull structural steel is used, for scantling purposes the values in Table C3.2.1 are to be used for the material factor k.

Table C3.2.1 Material factor k

R_{eH} [MPa]	k
315	0,78
355	0,72
390	0,68

For higher strength hull structural steel with other nominal yield stresses up to 390 MPa, the material factor k may be determined by the following formula:

$k = (235/R_{eH})^{0,75}$

Note

Especially when higher strength hull structural steels are used, limitation of permissible stresses due to buckling and fatigue strength criteria may be required.

.2 Higher strength hull structural steel is grouped into the following grades, which differ from each other in their toughness properties:

GL–A 32/36/40

GL–D 32/36/40

GL–E 32/36/40

GL–F 32/36/40

.3 Where structural members are completely or partly made from higher strength hull structural steel, a suitable Notation will be entered into the ship's certificate.

.4 Regarding welding of higher strength hull structural steel, see Rules II – Materials and Welding, Part 3 – Welding.

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Table C3.2.1 Aluminium alloys for welded construction

Guaranteed mechanical characteristics [1]							
Aluminium alloy				Unwelded condition		Welded condition	
Alloy [2]	Products	Temper [2]	Thickness [mm]	$R_{p0,2}$ [MPa] [4]	R_m [MPa] [5]	$R_{p0,2}'$ [MPa] [4]	R_m' [MPa] [5]
5083	rolled	0 / H111 / H112	t ≤ 50	125	275	125	275
		H116		215	305		
		H32 / H321					
5083	extruded	0 / H111	t ≤ 50	110	270	110	270
		H112		125			
5086	rolled	0 / H111 / H112	t ≤ 50	100	240	100	240
		H116		195	270		
		H32 / H321		185			
5086	extruded	0 / H111 / H112	t ≤ 50	95	240	95	240
5383	rolled	0 / H111	t ≤ 40	145	290	145	290
		H116 / H321		220	305		
5383	extruded	0 / H111	t ≤ 50	145	209	145	290
		H112		190	310		
5059	rolled	0 / H111	t ≤ 50	160	330	155	300
		H116 / H321	t ≤ 20	270	370		
			20 < t ≤ 40	260	360		
5059	extruded	H112	t ≤ 50	200	330	155	300
5454	rolled	0 / H111	t ≤ 40	85	215	85	215
		H32		180	260		
5754	rolled	0 / H111 / H112	t ≤ 50	80	190	80	190
		H32	t ≤ 40	165	240		
6005A	extruded	T5 / T6	t ≤ 50	215	260	115	165
6060 [3]	extruded	T5	t ≤ 5	120	160	65	95
			5 < t ≤ 25	100	140		
6061	extruded	T5 / T6	t ≤ 50	240	260	115	165
6082	extruded	T5 / T6	t ≤ 50	260	310	115	170
6106	extruded	T6	t ≤ 10	200	250	65	130

[1] The guaranteed mechanical characteristics in this Table correspond to general standard values. For more information, refer to the minimum values guaranteed by the product supplier. Higher values may be accepted on the basis of welding tests including recurrent workmanship test at the shipyard only.

[2] Other grades or tempers may be considered, subject to the Society's agreement.

[3] 6060 alloy is not to be for structural members sustaining impact loads (e.g. bottom longitudinals). The use of alloy 6106 is recommended in that case.

[4] $R_{p0,2}$ and $R_{p0,2}'$ are the minimum guaranteed yield stresses at 0,2 % in unwelded and welded condition respectively.

[5] R_m and R_m' are the minimum guaranteed tensile strengths in unwelded and welded condition respectively.

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C3.2.2.3 Structural members which are stressed in direction of their thickness

In case of high local stresses in the thickness direction, e.g. due to shrinkage stresses in single bevel or double bevel T-joints with a large volume of weld metal, steels with guaranteed material properties in the thickness direction according to the Rules Steel and Iron Materials (II-1-2), Section 1, I. are to be used.

C3.2.2.4 Forged Steel and Cast Steel

Forged steel and cast steel for stem, stern frame, rudder post as well as other structural components, which are subject of this Rule, are to comply with the Rules II – Materials and Welding, Part 1 – Metallic Materials. The tensile strength of forged steel and of cast steel is not to be less than 400 MPa. In this respect beside strength properties also toughness requirements and weldability shall be observed.

C3.2.2.5 Austenitic Steels

Where austenitic steels are applied having a ratio $R_{p0,2}/R_m \leq 0,5$, after special approval the 1 % proof stress $R_{p1,0}$ may be used for scantling purposes instead of the 0,2 % proof stress $R_{p0,2}$.

C3.2.3 Aluminium alloy structures

C3.2.3.1 General

All aluminium materials to be used for the structural members indicated in the Construction Rules are to be in accordance with the Rules Non-Ferrous Metals (II-1-3), Section 1. Materials the properties of which deviate from these Rule requirements may only be used upon special approval.

The strength properties for some typical aluminium alloys are given in Table C3.2.1.

C3.2.3.2 Influence of welding on mechanical characteristics

.1 Welding heat input lowers locally the mechanical strength of aluminium alloys hardened by work hardening (series 5000 other than condition 0 or H111) or by heat treatment (series 6000).

.2 Consequently, where necessary, a drop in mechanical characteristics of welded structures is to be considered in the heat-affected zone, with respect to the mechanical characteristics of the parent material.

.3 The heat-affected zone may be taken to extend 25 mm on each side of the weld axis.

.4 Aluminium alloys of series 5000 in 0 condition (annealed) or in H111 condition (annealed flattened) are not subject to a drop in mechanical strength in the welded areas.

.5 Aluminium alloys of series 5000 other than condition 0 or H111 are subjected to a drop in mechanical strength in the welded areas. The mechanical characteristics to consider in welded condition are, normally, those of condition 0 or H111, except otherwise indicated in Table C3.2.1. Higher mechanical characteristics may be taken into account, provided they are duly justified.

.6 Aluminium alloys of series 6000 are subject to a drop in mechanical strength in the vicinity of the welded areas. The mechanical characteristics to be considered in welded condition are, normally, to be indicated by the supplier, if not indicated in Table C3.2.1.

C3.2.3.3 Material factor k for scantlings of structural members made of aluminium alloy

.1 The value of the material factor k to be introduced into formulae for checking scantlings of structural members, given in this Section and the various Appendices, is determined by the following equation:

$$k = \frac{100}{R_{p0,2}'}$$

$R_{p0,2}'$ = minimum guaranteed yield stress of the parent metal in welded condition [MPa], but not to be taken greater than 70 % of the minimum guaranteed tensile strength of the parent metal in welded condition R'_m [MPa] (see Table C3.2.1).

.2 For welded constructions in hardened aluminium alloys (series 5000 other than condition 0 or H111 and series 6000), greater characteristics than those in welded condition may be considered, provided that welded connections are located in areas where stress levels are acceptable for the alloy considered in annealed or welded condition.

.3 In case of welding of two different aluminium alloys, the material factor k to be considered for the scantlings of welds is to be the greater material factor of the aluminium alloys of the assembly.

C3.2.3.4 Riveted connections for aluminium alloy hulls

.1 Use of rivets for connecting structures is limited, in principle, only to members which do not contribute to the overall strength of the hull. Exceptions are to be supported by experimental evidence or good in-service performance.

.2 The conditions for riveted connection acceptability are to be individually stated in each particular case, depending on the type of member to be connected and the rivet material.

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.3 Whenever riveted connections are to be employed, a detailed plan, illustrating the process, as well as the dimensions and location of rivets and holes, together with the mechanical and metallurgical properties of the rivets, is to be submitted for approval.

.4 GL may, at its discretion, require tension, compression and shear tests to be carried out on specimens of riveted connections constructed under the same conditions as during actual hull construction, to be witnessed by a GL surveyor.

.5 GL reserves the right to accept the results of tests performed by recognized bodies or other Societies.

C3.2.4 General Welding Requirements

Preface

The content of C3.2.4 and C3.6 is to a large extent identical to that of the Rules Welding in the Various Fields of Application (II-3-3), Section 1, G. Because of the re-issues of II-3-3 referred to and this Chapter 1 at different times, some temporary divergences may arise and in such circumstances the more recent Rules shall take precedence.

C3.2.4.1 Information contained in manufacturing documents

.1 The shapes and dimensions of welds and, where proof by calculation is supplied, the requirements applicable to welded joints (the weld quality grade, detail category) are to be stated in drawings and other manufacturing documents (parts lists, welding and inspection schedules). In special cases, e.g. where special materials are concerned, the documents shall also state the welding method, the welding consumables used, heat input and control, the weld build-up and any post-weld treatment which may be required.

.2 Symbols and signs used to identify welded joints shall be explained if they depart from the symbols and definitions contained in the relevant standards (e.g. DIN standards). Where the weld preparation (together with approved methods of welding) conforms both to normal shipbuilding practice and to these Rules and recognized standards, where applicable, no special description is needed.

C3.2.4.2 Materials, weldability

.1 Only base materials of proven weldability may be used for welded structures. Any approval conditions of the steel or of the procedure qualification tests and the steelmaker's recommendations are to be observed.

.2 For normal strength hull structural steels grades A, B, D and E which have been tested by GL, weldability normally is considered to have been proven. The suitability of these base materials for high efficiency welding processes with high heat input shall be verified.

.3 Higher strength hull structural steels grade AH/DH/EH/FH which have been approved by GL in accordance with the relevant requirements of Rules for Materials and Welding normally have had their weldability examined and, provided their handling is in accordance with normal shipbuilding practice, may be considered to be proven. The suitability of these base materials for high efficiency welding processes with high heat input shall be verified.

.4 High strength (quenched and tempered) fine grain structural steels, low temperature steels, stainless and other (alloyed) structural steels require special approval by GL. Proof of weldability of the respective steel is to be presented in connection with the welding procedure and welding consumables.

.5 Cast steel and forged parts require testing by GL. For castings intended to be used for welded shipbuilding structures the maximum permissible values of the chemical composition according to the GL Rules Steel and Iron Materials (II-1-2), Section 4, B.4 and Table 4.1 have to be observed.

.6 Aluminium alloys require testing by GL. Proof of their weldability shall be presented in connection with the welding procedure and welding consumables.

.7 Welding consumables used are to be suitable for the parent metal to be welded and are to be approved by GL.

C3.2.4.3 Manufacture and testing

.1 The manufacture of welded structural components may only be carried out in workshops or plants that have been approved. The requirements that have to be observed in connection with the fabrication of welded joints are laid down in the Rules II – Materials and Welding, Part 3 – Welding.

.2 The weld quality grade of welded joints without proof by calculation (see C3.2.4.1) depends on the significance of the welded joint for the total structure and on its location in the structural element (location to the main stress direction) and on its stressing. For details concerning the type, scope and manner of testing, see Rules Welding in the Various Fields of Application (II-3-3), Section 1, I. Where proof of fatigue strength is required, in addition the requirements of C3.7.6 apply.

C3.2.4.4 Welding processes for aluminium alloys

In general, the welding of the hull structures is to be performed with the MIG (metal-arc inert gas) and

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TIG (tungsten-arc inert gas) processes using welding consumables recognized as suitable for the base material to be used. Welding processes and filler materials other than those above are to be individually considered by GL at the time of the approval of welding procedures.

C3.2.5 Corrosion protection – heterogeneous steel/aluminium alloy assembly

.1 Connections between aluminium alloy parts, and between aluminium alloy and steel parts, if any, are to be protected against corrosion by means of coatings applied by suitable procedures agreed by GL.

.2 In any case, any direct contact between steel and aluminium alloy is to be avoided (e.g. by means of zinc or cadmium plating of the steel parts and application of a suitable coating on the corresponding light alloy parts).

.3 Any heterogeneous jointing system is subject to GL's agreement.

.4 The use of transition joints made of aluminium/ steel-cladded plates or profiles is subject to GL's agreement.

.5 Transition joints are to be type-approved.

.6 Qualifications tests for welding procedures are to be carried out for each joint configuration.

.7 A welding booklet giving preparations and various welding parameters for each type of assembly is to be submitted for review.

C3.2.6 Fibre-reinforced plastic (FRP) structures

C3.2.6.1 Materials

.1 Constituent materials

Constituent materials contributing to the structural integrity shall be GL-approved. For a composite structure this will include fibre fabrics, laminating resin (matrix), structural adhesives and core materials.

In individual cases it may be acceptable to provide GL-approval equivalence by tests.

Production facilities where the vessel and/or major structural components are constructed need to obtain a GL Shop approval for composite components.

The general requirements for material and production are defined in GL Rules Fibre Reinforced Plastics and Bonding (II-2-1).

In addition to this it is strongly recommended to carry out pre-construction baseline testing.

.2 Baseline testing

This testing of materials is done on pre-fabricated samples, representing typical construction methods and lay-up intended for the particular project. Testing and evaluation should be finished before the vessel's construction starts.

With a variety of tests, cognition shall be attained about:

- Confirming design values, i.e. bending stiffness, bending capacity limited by skins, bending/shear capacity limited by core and/or core bonding. All these issues could be covered with long beam bending tests or shorter beam bending tests.
- Proper building performance.
- Compatibility of materials.

.3 As-built testing

In order to obtain confirmation about the quality of the finished product, representative test samples need to be taken from the hull and be tested. These test samples can be taken from cut-outs and the scope of testing is depending on the composite design of the vessel and its areas of importance (usually 3 or 4 point bend test on sandwich beams or compressive strength test for solid laminates).

C3.3 Design Acceleration

C3.3.1 Vertical acceleration at LCG

.1 The design vertical acceleration at LCG, a_{CG} (expressed in g), is defined by the designer and corresponds to the average of the 1 per cent highest accelerations in the most severe sea conditions expected, in addition to the gravity acceleration.

Generally, it is to be not less than:

$$a_{CG} = c_{HSC} \cdot c_{RW} \cdot \frac{V}{\sqrt{L}}$$

where c_{HSC} values are indicated in Table C3.3.1.

Table C3.3.1

Type of service	Passenger, Ferry, Cargo	Supply	Pilot	Rescue
c_{HSC}	0,24	0,36	0,50	0,60

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c_{RW} = service range coefficient
= 1,00 for unlimited service range
= 0,90 for restricted service area **RSA (200)**
= 0,75 for restricted service area **RSA (50)**
= 0,66 for restricted service area **RSA (20)**
= 0,60 for restricted service area **RSA (SW)**

Note

The provisions in Section 1, 1.3.4 apply irrespective of the above service range restrictions.

.2 For craft with type of service "Passenger, Ferry, Cargo" an acceleration greater than a_{CG} = 1,0 g may not be adopted for the purpose of defining limit operating conditions.

.3 The longitudinal distribution of vertical acceleration along the hull is given by:

$$a_v = k_v \cdot a_{CG}$$

k_v = longitudinal distribution factor, not to be less than (see Figure C3.3.1):

= 1 for $x \le LCG$

$$= 2 - \frac{1-\frac{x}{L}}{1-\frac{LCG}{L}} \text{ for } x > LCG$$

a_{CG} = design acceleration at LCG

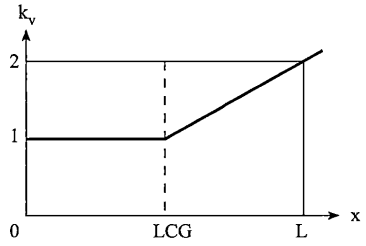

Fig. C3.3.1

.4 Variation of a_v in the transverse direction may generally be disregarded.

C3.3.2 Transverse acceleration

.1 Transverse acceleration is defined on the basis of results of model tests and full-scale measurements, considering their characteristic value as specified in C3.3.4.1.

.2 In the absence of such results, transverse acceleration [g] at the calculation point of the craft may be obtained from:

$$a_t = 2,5 \cdot \frac{H_s}{L} \cdot \left(1 + 5 \cdot \left(1 + \frac{V_x}{6\sqrt{L}}\right)^2 \cdot \frac{r}{L}\right)$$

H_s = permissible significant wave height at actual craft speed V_x (see C3.3.3),

r = distance of the point from:
- 0,5 D for monohull craft
- waterline at draught T, for twin-hull craft

C3.3.3 Assessment of limit operating conditions

C3.3.3.1 General

.1 "Limit operating conditions" in this paragraph are to be taken to mean sea states (characterized only by their significant wave heights) compatible with the structural design parameters of the craft, i.e. the sea states in which the craft may operate depending on its actual speed.

.2 Limit operating conditions are derived from the restrictions presented in C3.3.3.2, C3.3.3.3 and C3.3.3.4 below.

.3 Other specific design parameters influenced by sea state and speed could be also considered at the discretion of GL.

.4 It is the designer's responsibility to specify the format and the values of the limit operating conditions. Their format may be for example a relation between speed and significant wave height which ascertains actual loads less than the one used for structural design. They shall include the maximum allowed significant wave height H_{sm} consistent with the structural strength. H_{sm} is not to be greater than the value calculated according to C3.3.3.1.7 below.

.5 The limit operating conditions are defined, at the discretion of GL, on the basis of results of model tests and full-scale measurements or by numerical simulations.

.6 The limit operating conditions, taken as a basis for classification, are indicated in the Classification Certificate and are to be considered in defining the worst intended conditions and the critical design conditions in Section 1.

.7 It is assumed that, on the basis of weather forecast, the craft does not encounter, within the time interval required for the voyage, sea states with significant heights, in m, greater than the following:

$$H_{sm} = 5 \cdot \frac{a_{CG}}{V} \cdot \frac{L^{1,5}}{6 + 0,14 \cdot L}$$

where vertical acceleration a_{CG} is defined in C3.3.1, but need not to be taken less than 1,0 g.

.8 For craft with a particular shape or other characteristics, GL reserves the right to require model

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tests or full-scale measurements to verify results obtained by the above formula.

C3.3.3.2 Limitation imposed by vertical acceleration at LCG

.1 Bottom impact pressure, given in C3.5.3, and deck loads, given in C3.5.8, are explicitly or implicitly depending on the vertical acceleration at LCG. Therefore, the design values of these loads, taken as the basis for the classification, directly impose limitation on vertical acceleration level at LCG.

.2 It is the designer's responsibility to provide for a relation between the speed and the significant wave height that provides a maximum vertical acceleration less than the design value.

.3 The significant wave height is related to the craft's geometric and motion characteristics and to the vertical design acceleration a_{CG} by the following formula:

$$H_s = \frac{10{,}9 \cdot a_{CG} \cdot K_{cat} \cdot K_H}{K_F^2}$$

with $K_{cat} = 1 + \frac{B_{cl} - H_{sm}}{L} \geq 1{,}0$

= 1,0 for monohulls and trimarans

B_{cl} = distance between the center lines of the hulls of catamarans

$$K_F = \frac{3{,}23}{L} \cdot (2{,}43 \cdot \sqrt{L} + V_x)$$

$$K_H = K^{0{,}35} \sqrt{\left(\frac{1}{K^2} - 0{,}11\right)^2 + 1}$$

$$K = \frac{K_F}{K_T}$$

$$K_T = \sqrt{\frac{4{,}6 \cdot A_{wp}}{\Delta}} \cdot \sqrt{\frac{x_{CG}}{L}}$$

A_{wp} = area of water line

x_{CG} = distance [m] from aft perpendicular to LCG

.4 For craft, such as SESs, for which a speed reduction does not necessarily imply a reduction in acceleration, the speed is to be modified depending on the sea state according to criteria defined, at the discretion of GL, on the basis of motion characteristics of the craft.

.5 The reduction of vertical acceleration a_{CG} induced by stabilisation system if any is to be disregarded for the purpose of limit operating conditions imposed by bottom impact loads.

C3.3.3.3 Limitation imposed by wet deck impact loads for catamarans

.1 Wet deck impact pressure is given in C3.5.4.

.2 The formula in C3.5.4 may be used to define maximum speeds compatible with actual structure of wet deck, depending on sea states having a significant height H_s.

.3 The reduction of relative impact velocity V_{sl} induced by stabilisation system if any is to be disregarded for the purpose of limit operating conditions imposed by wet deck impact loads.

C3.3.3.4 Limitation imposed by global loads

.1 For monohulls, catamarans and trimarans, the longitudinal bending moment and shear forces as given in C3.4.1 and C3.4.2 are explicitly or implicitly depending on vertical acceleration along the ship. Therefore, the design values of these loads, taken as the basis for classification, directly impose limitation on vertical acceleration level at LCG. The requirements of C3.3.3.2 apply.

.2 For catamarans and trimarans, the transverse bending moment, the torsional bending moment and the vertical shear force as given in C3.4.2 are depending on vertical acceleration a_{CG}. Therefore, the requirements of C3.3.3.2 apply.

.3 For SWATH craft, the global loads as given in C3.4.3 are not depending on ship motions.

.4 For ships with length greater than 100m, the relation between vertical acceleration along the ship and global loads are to be ascertained on basis of results of model tests and/or full-scale measurements or by numerical simulations, as indicated in C3.3.3.2.

.5 The reduction of vertical acceleration along the ship induced by stabilisation system if any is to be disregarded for the purpose of limit operating conditions imposed by global loads.

C3.3.3.5 Hull monitoring

.1 GL may require a hull monitoring system to be fitted on board, allowing to monitor and display in real time the vertical acceleration and any other sensitive parameter with respect to the strength.

.2 The information is to be available at the wheelhouse and displayed in a clear format allowing to compare with design values.

.3 When a hull monitoring system is requested, its specification is to be submitted for review.

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C3.4 Overall Loads

C3.4.1 Monohulls

C3.4.1.1 General

.1 In general, the wave induced bending loads and shear forces according to C3.4.1.2 are accepted.

.2 For monohulls of unusual form and design and for ships with extreme bow flare, GL may require determination of vertical wave-induced bending moments and share forces as well as their distribution over the ship's length considering various mass distributions. Accepted calculation procedures are to be applied.

.3 Where deemed necessary, stresses due torsion and/or horizontal wave bending are to be considered in a global stress analysis.

Note

Upon request, such calculations will be performed by GL.

C3.4.1.2 Bending moment and shear force

.1 General

For the envisaged mass distributions for the defined loading condition values of vertical still water bending moment are to be calculated over the ship's length.

The values of the total longitudinal bending moments and shear force are given, in first approximation, by the formula in C3.4.1.2.3 and C3.4.1.2.4. The formula in C3.4.1.2.2 is to be applied when deemed necessary by GL on the basis of the motion characteristics of the ship.

For ships having L < 100 m, the total bending moments in hogging or in sagging condition respectively, are to be taken as the greatest of those given by the formulae in C3.4.1.2.2 and C3.4.1.2.3.

Hull girder loads determined by direct calculation according to C3.4.1.2.6 are accepted.

.2 Bending moment due to still water loads, wave induced loads and impact loads

$$M_{bIH} = M_{bIS} = 0,55 \cdot \Delta \cdot L \cdot (1 + a_{CG})$$

where a_{CG} is the vertical acceleration at the LCG, defined in C3.3.1.

.3 Bending moment due to still water loads and wave induced loads

$$M_{bIH} = M_{sH} + 0,21 \cdot C \cdot L^2 \cdot B \cdot C_B \cdot c_{RW}$$

$$M_{bIS} = M_{sS} + 0,12 \cdot C \cdot L^2 \cdot B \cdot (C_B + 0,7) \cdot c_{RW}$$

M_{sH} = still water hogging bending moment [kN·m]

M_{sS} = still water sagging bending moment [kN·m]

c_{RW} = see C3.3.1.1

$C = 6 + 0,02\ L$

For the purpose of this calculation, C_B may not be taken less than 0,6.

.4 Total shear force

$$T_{bI} = \frac{3,2 \cdot M_{bI}}{L}$$

M_{bI} = the greatest between M_{bIH} and M_{bIS}, calculated according to C3.4.1.2.2 and C3.4.1.2.3, as applicable.

.5 Longitudinal distribution of total bending moment

The longitudinal distribution of the total bending moments is given by:

$K_M \cdot M_{bIH}$ in hogging

$K_M \cdot M_{bIS}$ in sagging

K_M = longitudinal distribution factor as shown on Figure C3.4.1.

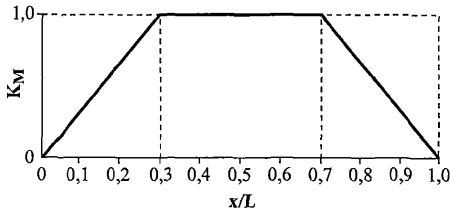

Fig. C3.4.1

.6 Direct calculation of hull girder design

As a basis for direct calculation of design values, loading conditions corresponding to the actual weight distribution are to be used.

In principle, the estimated representative mass distributions for the defined loading conditions will be the average of the mass distributions that result in the highest and the lowest stillwater vertical bending moment. This representative mass distribution leads to an average displacement and an average vertical stillwater bending moment.

Analysis of the craft in harmonic waves is to be executed by direct computational methods that evaluate response amplitude operators of wave-induced vertical shear forces and bending moments. Using an adequate nonlinear correction procedure that accounts for a realistic wave breaking criterion, the wave contour along the craft's side has to be determined for relevant harmonic waves of selected amplitudes and phase positions. Hydrodynamic pressures are to be extrapolated up to the wave contour.

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Hydrodynamic calculations are to be performed for speeds that correspond to the operational profile of the craft.

After completing the nonlinear correction procedure, the forces acting on the craft, including inertial forces, generally are not in balance. Equilibrium can be achieved by resolving the motion equations, resulting in nonlinearly corrected wave amplitude dependent response values of, e.g., bending moments. Repeating this procedure for different wave periods and wave headings yields nonlinearly corrected (pseudo) response amplitude operators that depend on wave height. Depending on the considered phase locations, two separate sets of transfer functions result, one set for the sagging condition and another set for the hogging condition.

Treating these nonlinearly corrected pseudo transfer functions like transfer functions of linear systems, stochastic methods are to be used to evaluate shear forces and bending moments. For stationary seaways, a $\cos^2$ distribution of wave energy about the principal direction of wave encounter direction is to be assumed. The seaways' main wave headings relative to the craft are to be considered as equally distributed. Wave heights used to obtain the wave amplitude dependent pseudo transfer functions are to be taken as equal to the significant wave height of the corresponding natural seaway.

Calculated long-term values of shear forces and bending moments are to be based on long-term wave statistics relevant for the craft's operating area.

For the sagging condition only, an additional shear force and bending moment caused by slamming loads in the craft's forebody area are to be determined as specified below. For the purpose of this calculation, the hull is considered longitudinally subdivided into a number of intervals. Generally, 20 intervals are to be considered.

For twin-hull craft, the calculation below applies to one of the hulls, i.e. the longitudinal distribution of weight forces g_i and the corresponding breadth B_i are to be defined for one hull.

The total impact force [kN] is:

$$F_{SL} = \sum q_{SLi} \cdot \Delta x_i$$

Δ_{xi} = length of interval [m]

q_{SLi} = additional load per unit length [kN/m]

for $x/L \geq 0,6$ see also Figure C3.4.2, given by:

$$q_{SLi} = p_0 \cdot B_i \cdot \sin\left(2 \cdot \pi \cdot \left(\frac{x_i}{L} - 0,6\right)\right)$$

x_i = distance [m] from the aft perpendicular

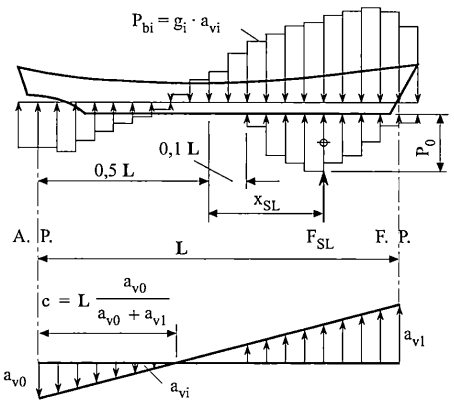

Fig. C3.4.2

B_i = craft breadth [m] at uppermost deck; (x_i and B_i to be measured at the centre of interval i),

p_0 = maximum hydrodynamic pressure [kPa] equal to:

$$= \frac{a_{v1} \cdot G \cdot (r_0^2 - x_W^2)}{f_{SL} \cdot \left(r_0^2 + 0,5 \cdot L \cdot (x_{SL} - x_W) - x_{SL} \cdot x_W\right)}$$

a_{v1} = vertical design acceleration at the forward perpendicular, as defined in C3.3,

G = weight force [kN] equal to:

$$= \sum g_i \cdot \Delta x_i$$

g_i = weight per unit length [kN/m] of interval i; for twin-hull craft, g_i is to be defined for one hull,

x_W = distance, in m, of LCG from the midship perpendicular:

$$= \frac{\sum (g_i \cdot \Delta x_i \cdot x_i)}{\sum (g_i \cdot \Delta x_i)} - 0,5 \cdot L$$

r_0 = radius of gyration [m] of weight distribution, equal to:

$$= \left(\frac{\sum g_i \cdot \Delta x_i \cdot (x_i - 0,5 \cdot L)^2}{\sum g_i \cdot \Delta x_i}\right)^{0,5}$$

normally $0,2\ L < r_0 < 0,25\ L$ (guidance value)

x_{SL} = distance [m] of centre of surface F_{SL} from the midship perpendicular, given by:

$$= \frac{1}{f_{SL}} \sum \Delta x_i \cdot x_i \cdot B_i \cdot \sin\left(2\pi \cdot \left(\frac{x_i}{L} - 0,6\right)\right) - 0,5 \cdot L$$

f_{SL} = surface [m^2] equal to:

$$= \sum \Delta x_i \cdot B_i \cdot \sin\left(2\pi \cdot \left(\frac{x_i}{L} - 0,6\right)\right)$$

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The resulting load distribution q_{si} [kN/m] for the calculation of the impact induced sagging bending moment and shear force is:

(a) For x/L < 0,6:

$q_{si} = q_{bi} = g_i \cdot a_{vi}$

a_{vi} = total dimensionless vertical acceleration at interval i, equal to:

$= a_h + a_p \cdot (x_i - 0,5 \cdot L)$

a_h = acceleration due to heaving motion, equal to:

$$= \frac{F_{SL}}{G} \cdot \left(\frac{r_0^2 - x_{SL} \cdot x_W}{r_0^2 - x_W^2} \right)$$

a_p = acceleration due to pitching motion [m^{-1}]:

$$= \frac{F_{SL}}{G} \cdot \left(\frac{x_{SL} - x_W}{r_0^2 - x_W^2} \right)$$

a_h and a_p are relative to g

(b) For x/L ≥0,6:

$q_{si} = q_{bi} - q_{SLi}$

The impact induced sagging bending moment and shear force are obtained by integration of the load distribution q_{si} along the hull. They are to be added to the respective values calculated according to C3.4.1.2.3 in order to obtain the total bending moment and shear force due to still water loads, wave induced loads and impact loads.

C3.4.2 Catamarans

C3.4.2.1 General

.1 The values of the longitudinal bending moment and shear force are given by the formulae in C3.4.1.2.

.2 For catamarans, the hull connecting structures are to be checked for load conditions specified in C3.4.2.2 and C3.4.2.3. These load conditions are to be considered as acting separately.

.3 Design moments and forces given in the following paragraphs are to be used unless other values are verified by model tests, full-scale measurements or any other information provided by the designer (see C3.3.4.1, Requirements for model tests).

.4 For craft with length L > 65 m or speed V > 45 knots, or for craft with structural arrangements that do not permit a realistic assessment of stress conditions based on simple models, the transverse loads are to be evaluated by means of direct calculations carried out in accordance with criteria specified in C3.6 or other criteria considered equivalent by GL.

C3.4.2.2 Longitudinal bending moment and shear force

.1 Refer to C3.4.1.2.

.2 In C3.4.1.2.6, the breadth B_i is defined as below:

B_i = maximum breadth of one hull at the considered longitudinal location x_i [m]

.3 When slamming of wet-deck is expected to occur (cf. C3.5.4), B_i is to be taken as:

B_i = the maximum breadth of one hull at the considered longitudinal location [m] without being greater than B/2, multiplied by the coefficient f_B, where:

$f_B = 2 \cdot (1 - B_W/B)$

C3.4.2.3 Transverse bending moment and shear force

The transverse bending moment M_{bt} [kNm] and shear force T_{bt} [kN] are given by:

$$M_{bt} = \frac{\Delta \cdot b \cdot a_{CG} \cdot g}{5}$$

$$T_{bt} = \frac{\Delta \cdot a_{CG} \cdot g}{4}$$

b = transverse distance [m] between the centres of the two hulls,

a_{CG} = vertical acceleration at LCG, defined in C3.3.1.

C3.4.2.4 Transverse torsional connecting moment

The catamaran transverse torsional connecting moment [kN · m] about a transverse axis is given by:

$$M_{tt} = 0,125 \cdot \Delta \cdot L \cdot a_{CG} \cdot g$$

where a_{CG} is the vertical acceleration at LCG, defined in C3.3.1, which need not to be taken greater than 1,0 g for this calculation.

C3.4.3 Small waterplane area twin-hull (SWATH) craft - Forces and moments acting on twin-hull connections

C3.4.3.1 Side beam force

.1 The design beam side force [kN] (see Figure C3.4.3) is given by:

$$F_Q = 12,5 \cdot T \cdot \Delta^{2/3} \cdot d \cdot L_S$$

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$$d = 1,55 - 0,75 \cdot \tanh\left(\frac{\Delta}{11000}\right)$$

$$L_S = 2,99 \cdot \tanh(\lambda) - 0,725$$

$$\lambda = \frac{0,137 \cdot A_{lat}}{T \cdot \Delta^{1/3}}$$

A_{lat} = lateral area [m^2] projected on a vertical plane, of one hull with that part of strut or struts below waterline at draught T.

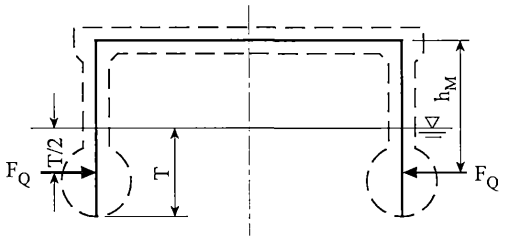

Fig. C3.4.3

.2 The lateral pressure [kN/m^2] acting on one hull is given by:

$$p_Q = \frac{F_Q}{A_{lat}}$$

The distribution of the lateral force F_Q can be taken as constant over the effective length $L_e = A_{lat} / T$ [m]. The constant lateral force per unit length [kN/m] is thus given by:

$$q_Q = \frac{F_Q}{L_e}$$

C3.4.3.2 Bending moment

.1 The corresponding design bending moment [kN · m] is given by:

$$M_Q = h_M \cdot F_Q$$

h_M = half the draught T plus the distance from the waterline at draught T to the midpoint of the wet deck structure (see Figure C3.4.4) [m]

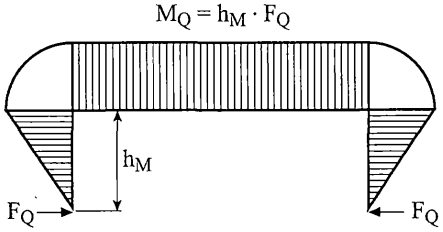

Fig. C3.4.4

C3.4.4 Trimarans

The transverse design bending moments and shear forces for trimarans, subdivided in two load cases, will be calculated with respect to the structural arrangement. In general, the design loads can be taken as symmetrical to the centre line of the vessel. The sum of deck loads, self weights and buoyancy forces can be evenly distributed in longitudinal direction. Concentrated masses, lifting forces of foils and pillar loads are considered at their effective positions.

.1 Upward load case: Following forces acting at their respective load centres are to be considered:

- maximum upward and outward lifting forces of foils and stabilizers jointed to the outer hulls according to GL rudder calculation (C3.10).
- Buoyancy force of the outer hull at 15° heeling angle and max displacement multiplied by 1,1.
- Tank loads and deck load outside the main (centre) hull not to be taken into account.

.2 Downward load case: Following design deck loads multiplied by (1+0,4 a_{CG}) are to be considered:

- Sheltered deck: p = 1,0 kPa
- Passenger deck: p = 2,5 kPa
- Car deck (1,0 t axle load): p = 2,0 kPa
- Car deck (3,5 t axle load): p = 4,0 kPa
- Truck deck: max. truck weights evenly distributed
- tank weights
- maximum downward and inward lifting forces of foils and stabilizers jointed to the outer hulls according to GL rudder calculation

Sum of static weights and tank loads up to the maximum displacement (half value for a symmetrical model) are to be taken into account in following order:

1. masses in fixed positions (tank loads, etc.)
2. distributed deck loads from upper to lower deck started from outside each with the intention to cover the worst possible transverse weight distribution (concerning the maximum transverse bending moment)

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C3.5 Local Loads and Design Criteria

C3.5.1 General

This Section provides data regarding design loads for determining the scantlings of the hull structural elements by means of the design formulae given in the following Sections or by means of direct calculations. The dynamic portions of the design loads are design values which can only be applied within the design concept of this Chapter.

C3.5.2 Load centre

.1 For plates:

- vertical stiffening system: 0,5 · stiffener spacing above the lower support of plate field, or lower edge of plate when the thickness changes within the plate field
- horizontal stiffening system: Midpoint of plate field

.2 For stiffeners and girders:

- centre of span

C3.5.3 Impact pressure on the bottom of hull

.1 In general, bottom slamming is expected on the whole bottom area. The slamming area may be limited if the conditions for a_{CG} and V_{Fr} according to Table C3.5.1 are met. V_{Fr} is defined as follows:

$$V_{Fr} = \frac{V}{L^{0,5}}$$

Aft of these slamming areas the impact pressure can be reduced to p_s over a length of 0,1 L

.2 The impact pressure [kPa] acting on the bottom of hull is not less than:

$$p_{sl} = 100 \cdot T \cdot K_1 \cdot K_2 \cdot K_3 \cdot a_{cg}$$

K_1 = longitudinal bottom impact pressure distribution factor (see Figure C3.5.1):

= 0,5 + x/L for x/L < 0,5:

= 1,0 for 0,5 ≤ x/L ≤ 0,8

= 3,0 - 2,5 · x/L for x/L > 0,8

where x is the distance [m] from the aft perpendicular to the load point

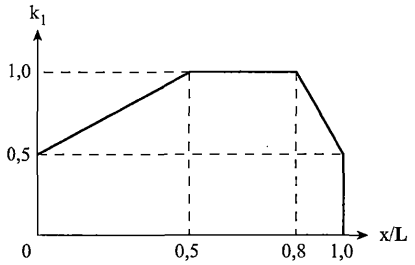

Fig. C3.5.1

K_2 = factor accounting for impact area:

$$= 0,455 - 0,35 \cdot \frac{u^{0,75} - 1,7}{u^{0,75} + 1,7}$$

≥ 0,50 for plating,

≥ 0,45 for stiffeners,

≥ 0,35 for girders and floors,

$$u = 100 \cdot \frac{s}{S_r}$$

S_r = reference area [m^2]

$$= 0,7 \cdot \frac{\Delta}{T}$$

Δ = displacement [t] (see C3.1.4). For catamaran, Δ in the above formula is to be taken as half of the craft displacement

where s is the area [m^2] supported by the element (plating, stiffener, floor or girder). For plating, the supported area is the spacing between the stiffeners multiplied by their span, without taking for the latter more than three times the spacing between the stiffeners

K_3 = factor accounting for shape and deadrise of the hull:

$$= \frac{70 - \alpha_d}{70 - \alpha_{dCG}}$$

where α_{dCG} is the deadrise angle [°] measured at LCG and α_d is the deadrise angle [°] between horizontal line and straight line joining the edges of respective area measured at the longitudinal position of the load point; values taken for α_d and α_{dCG} are to be between 10° and 30°

a_{CG} = design vertical acceleration at LCG, defined in C3.3.1.

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.3 Sea intakes and other openings

.1 Sea chests are to have scantlings as for bottom structure (see C3.7.7.3 and C3.7.8.2 condition (b)), taking a design pressure p_t, in kPa, equal to:

$$p_t = p_s + 0,5 \cdot p_{sl}$$

where p_s and p_{sl} are as defined in C3.5.5 and C3.5.3 respectively.

If a safety valve is installed p_t is not to be less than 100 p_v, where p_v is the blow out pressure at the safety valve in bar, but not less than 1 bar.

C3.5.4 Impact pressure on wet deck (including tunnel radius)

.1 In general, wet deck slamming is expected on the whole wet deck area. The slamming area may be limited if the conditions for a_{CG} and V_{Fr} according to Table C3.5.1 are met.

Table C3.5.1

a_{CG}	V_{Fr}	bottom	wet deck
$a_{CG} \le 1$	$V_{Fr} < 4,5$	fwd of 0,7 L	fwd of 0,8 L
	$4,5 \le V_{Fr} \le 5$	fwd of 0,5 L	fwd of 0,7 L
$1 < a_{CG} \le 1,5$	$V_{Fr} \le 5$	fwd of 0,5 L	fwd of 0,7 L

The impact pressure [kPa] acting on the wet deck is not less than:

$$p_{sl} = 3 \cdot K_2 \cdot K_3 \cdot K_{WD} \cdot V_X \cdot V_{sl} \cdot \left(1 - 0,85 \cdot \frac{H_A}{H_S}\right)$$

V_{sl} = relative impact velocity [m/s] equal to:

$$= \frac{4 \cdot H_S}{\sqrt{L}} + 1$$

H_S = significant wave height,

K_2 = factor accounting for impact area, as defined in C3.5.3.1 with maximum displacement of the craft

K_3 = factor accounting for shape and deadrise of wet deck, as defined in C3.5.3.2 where 10° is taken for α_{dCG},

K_{WD} = longitudinal wet deck impact pressure distribution factor (see Figure C3.5.2):

- for $x/L < 0,2$:

$$K_{WD} = 0,5 \cdot \left(1,0 - \frac{x}{L}\right)$$

- for $0,2 \le x/L \le 0,7$:

$$K_{WD} = 0,4$$

- for $0,7 < x/L < 0,8$:

$$K_{WD} = 6,0 \cdot \frac{x}{L} - 3,8$$

- for $x/L \ge 0,8$:

$$K_{WD} = 1,0$$

where x is the distance [m] from the aft perpendicular to the load point

V_X = ship's speed [kn]

H_A = air gap [m] equal to the distance between the waterline at draught T and the wet deck

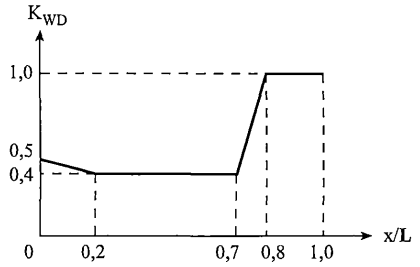

Fig. C3.5.2

C3.5.5 Sea pressures

C3.5.5.1 Sea pressure on bottom and side shell

.1 The sea pressure [kPa] considered as acting on the bottom and side shell is not less than p_{smin}, defined in Table C3.5.2, nor less than:

- for $z \le T$

$$p_s = 10 \cdot \left(T_0 + 0,75 \cdot S - \left(1 - 0,25 \cdot \frac{S}{T}\right) \cdot z\right)$$

- for $z > T$

$$p_s = 10 \cdot (T_0 + S - z)$$

T_0 = T, in general

= T + 0,09 y, for SWATH and outer hulls of trimaran

z = vertical distance [m] from the moulded base line to load point. z is to be taken positively upwards,

y = transverse distance [m] from the centre line to load point. y is to be taken positive,

S = as given [m] in Table C3.5.2 with C_B taken not greater than 0,5.

= T, for SWATH

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Table C3.5.2

	S	P_{min}
$x/L \geq 0,9$	$T \leq 0,36 \cdot a_{CG} \cdot \frac{\sqrt{L}}{C_B} \leq 3,5 \cdot T$	$20 \leq \frac{L+75}{5} \leq 35$
$x/L \leq 0,5$	$T \leq 0,60 \cdot a_{CG} \cdot \sqrt{L} \leq 2,5 \cdot T$	$10 \leq \frac{L+75}{10} \leq 20$

.2 Between midship area and fore end ($0,5 < x/L < 0,9$), p_S varies in a linear way as follows:

$$p_S = p_{SFP} - \left(2,25 - 2,5 \cdot \frac{x}{L}\right) \cdot (p_{SFP} - p_{SM})$$

where p_{SFP} is the sea pressure at fore end and p_{SM} in midship area.

C3.5.5.2 Stern doors and side shell doors

.1 The sea pressures on stern doors and side shell doors is to be taken according to C3.5.5.1 for scantlings of plating and secondary members.

.2 The design forces [kN] considered for the scantlings of primary members are to be not less than:

- external force: $F_e = A \cdot p_S$
- internal force: $F_i = F_o + 10 \cdot W$

A = area [m^2] of the door opening

W = mass of the door [t]

F_p = total packing force [kN]. Packing line pressure is normally not to be taken less than 5 N/mm,

F_o = the greater of F_c and $5 \cdot A$ [kN]

F_c = accidental force [kN] due to loose of cargo etc., to be uniformly distributed over the area A and not to be taken less than 300 kN. For small doors, such as bunker doors and pilot doors, the value of F_c may be appropriately reduced. However, the value of F_c may be taken as zero, provided an additional structure such as an inner ramp is fitted, which is capable of protecting the door from accidental forces due to loose cargoes,

p_S = sea pressure as defined in C3.5.5.1

.3 The design forces [kN] considered for the scantlings of securing or supporting devices of doors opening outwards are to be not less than:

- external force: $F_e = A \cdot p_S$
- internal force: $F_i = F_o + 10 \cdot W + F_p$

where the parameters are defined in C3.5.5.2.2.

.4 The design forces [kN] considered for the scantlings of securing or supporting devices of doors opening inwards are to be not less than:

- external force: $F_e = A \cdot p_S + F_p$
- internal force: $F_i = F_o + 10 \cdot W$

where the parameters are defined in C3.5.5.2.2.

C3.5.5.3 Bow doors

The arrangement of bow doors is to comply with the provisions of 2.2.3. Loads according to C3.5.5.2 are to be taken. If an inner bow door is required according to 2.2.3 a design load according to C3.5.5.4 is to be considered. The inner bow door is to be fitted within the limits for the collision bulkhead but not less than 1,2 m aft of the bow door.

C3.5.5.4 Sea pressures on front walls of the hull

.1 The pressure [kPa] considered as acting on front walls of the hull (in case of stepped main deck), not located at the fore end, is not less than:

$$p_{sf} = 6 \cdot \left(1 + \frac{x_1}{2 \cdot L \cdot (C_B + 0,1)}\right) \cdot (1 + 0,045 \cdot L - 0,38 \cdot z_1)$$

x_1 = distance [m] from front walls to the midship perpendicular (for front walls aft of the midship perpendicular, x_1 is equal to 0),

z_1 = distance [m] from load point to waterline at draught T.

p_{sF} is not less than the greater of:

$3 + (6,5 + 0,06 \cdot L)$

$3 + 2,4 \cdot a_{CG}$

.2 For front walls located at the fore end, the pressure p_{sF} will be individually considered by GL, but not less than 1,2 times the value according to C3.5.5.4.1.

C3.5.5.5 Sea pressures on deckhouses

.1 The pressure [kPa] considered as acting on walls of deckhouses is not less than:

$$p_{su} = K_{su} \cdot \left(1 + \frac{x_1}{2 \cdot L \cdot (C_B + 0,1)}\right) \cdot (1 + 0,045 \cdot L - 0,38 \cdot z_1)$$

K_{su} = coefficient

- for front walls of a deckhouse located directly on the main deck not at the fore end:

  $K_{su} = 6,0$

- for unprotected front walls of the second tier, not located at the fore end:

  $K_{su} = 5,0$

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– for sides of deckhouses, b being the breadth, in m, of the considered deckhouse:

$K_{su} = 1,5 + 3,5\ b/B$ (with $3 \leq K_{su} \leq 5$)

– for the other walls:

$K_{su} = 3,0$

x_1 = distance [m] from front walls or from wall elements to the midship perpendicular (for front walls or side walls aft of the midship perpendicular, x_1 is equal to 0),

z_1 = distance [m] from load point to waterline at draught T.

.2 The minimum values of p_{su} [kPa] to be considered are:

– for the front wall of the lower tier:

$p_{su} = 6,5 + 0,06 \cdot L$

– for the sides and aft walls of the lower tier:

$p_{su} = 4,0$

– for the other walls or sides:

$p_{su} = 3,0$

.3 For unprotected front walls located at the fore end, the pressure p_{su} will be considered by GL as given in C3.5.6.2.

C3.5.6 Bulkheads

C3.5.6.1 General

.1 This section applies to watertight and non-watertight bulkheads.

.2 Horizontal part of bulkheads are also to comply with the rules for deck beams.

.3 The special requirements for tanks in the hull are given in C3.5.7.

C3.5.6.1.1 Watertight subdivision

.1 Number and location of transverse bulkheads fitted in addition to those specified in C2.1.7 are to be so selected as to ensure sufficient transverse strength of the hull.

.2 For ships which require proof of survival capability in damaged conditions, the watertight subdivision will be determined by damage stability calculations.

C3.5.6.1.2 Collision bulkhead

.1 The collision bulkhead shall extend watertight up to the datum (bulkhead deck). Steps or recesses may be permitted provided Section 2, C2.1.8.2 is observed.

C3.5.6.1.3 Stern tube bulkhead

.1 If a stern tube bulkhead is provided, it shall, in general, be so arranged that the stern tube and the rudder trunk are enclosed in a watertight compartment. The stern tube bulkhead should extend to the datum or to a watertight platform situated above the design waterline.

.2 Where a complete stern tube bulkhead is not practicable, only watertight void spaces enclosing the stern tube entrances, providing the possibility for a second watertight sealing may be arranged. The same arrangement can be applied for the rudder trunk.

C3.5.6.1.4 Remaining watertight bulkheads

.1 The remaining watertight bulkheads are, in general, to extend to the datum. Wherever practicable, they shall be situated in one frame plane, otherwise those portions of decks situated between parts of transverse bulkheads are to be watertight.

C3.5.6.1.5 Openings in watertight bulkheads

.1 The requirements of Section 2, 2.2.2 are to be observed.

C3.5.6.2 Pressures on watertight bulkheads

The pressure [kPa] considered as acting on subdivision bulkheads is not less than:

$p_{sb} = 9,81 \cdot h_3$

h_3 = distance [m] from load point to a point 1 m above the bulkhead deck at the ship's side, for the collision bulkhead to a point 1 m above the upper edge of the collision bulkhead at ship's side.

C3.5.7 Tank structures

C3.5.7.1 General

This section applies to all kinds of tanks with the tank boundaries forming a direct part of the hull structure. In addition the requirements for detached tanks and the procedure of testing for tightness are given.

All tanks are to be suitably subdivided by bulkheads or swash bulkheads in order to avoid excessive liquid sloshing.

Hollow structural elements are not permitted in tanks for flammable liquids.

Oil is not be carried in a forepeak tank.

C3.5.7.2 Air, overflow and sounding pipes

Each tank is to be fitted with air pipes, overflow pipes and sounding pipes. The air pipes are to be led to above the exposed deck. The arrangement is to be such as to allow complete filling of the tanks. The height from the deck to the point where the water may have access is to be at least 760 mm on the datum and 450 mm on a superstructure deck.

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The sounding pipes are to be led to the bottom of the tanks.

C3.5.7.3 Separation of oil fuel tanks from tanks for other liquids

Fuel oil tanks are to be separated from tanks for lubricating oil, hydraulic oil, thermal oil, vegetable oil, feedwater, condensate water and potable water by cofferdams.

For steel and aluminium structures the arrangement of cofferdams between oil fuel and lubricating oil tanks may be dispensed with provided that:

- the common boundary is continuous, i.e. it does not abut at the adjacent tank boundaries, see Fig. C3.5.3

  Where the common boundary cannot be constructed continuously according to Fig. C3.5.3, the fillet welds on both sides of the common boundary are to be welded in two layers and the throat thickness is not to be less than $0,5 \cdot t$ (t = plate thickness).

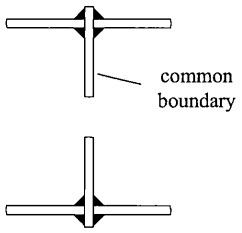

Fig. C3.5.3 Continuous common boundary replacing a cofferdam

- Stiffeners or pipes do not penetrate the common boundary.
- The corrosion allowance t_k for steel plates for the common boundary is not less than 1,0 mm.

C3.5.7.4 Potable Water Tanks

Potable water tanks shall be separated from tanks containing liquids other than potable water, ballast water, distillate or feed water.

In no case sanitary arrangement or corresponding piping are to be fitted directly above the potable water tanks.

Manholes arranged in the tank top are to have sills.

If pipes carrying liquids other than potable water are to be led through potable water tanks, they are to be fitted in a pipe tunnel.

Air and overflow pipes of potable water tanks are to be separated from pipes of other tanks.

C3.5.7.5 Swash Bulkheads

The total area of perforation shall not be less than 5 % and should not exceed 10 % of the total bulkhead area.

The plate thickness shall, in general, be equal to the minimum thickness. Strengthenings may be required for load bearing structural parts.

The free lower edge of a swash bulkhead is to be adequately stiffened.

The section modulus of the stiffeners and girders is to be calculated with p_{t1}, but disregarding p_V.

C3.5.7.6 Independent tanks

Detached tanks are to be adequately secured against forces due to the ship's motions.

Detached tanks in hold spaces are also to be provided with antifloatation devices. It is to be assumed that the hold spaces are flooded to the load water line. The stresses in the antifloatation devices caused by the floatation forces are not to exceed the material's yield stress.

Fittings and pipings on detached tanks are to be protected by battens, and gutter ways are to be fitted on the outside of tanks for draining any leakage oil.

C3.5.7.7 Pressures on tank structures

The design pressure [kPa] for service condition is:

$$p_{t1} = 9,81 \cdot h_1 \cdot \rho \cdot (1 + 0,4 \cdot a_v) + 100 \cdot p_v$$

h_1 = distance [m] from load point to tank top,

ρ = liquid density [t/m^3] (1,0 t/m^3 for water),

p_V = setting pressure [bar] of pressure relief valve, when fitted.

The maximum static design pressure [kPa] is:

$$p_{t2} = 9,81 \cdot h_2$$

h_2 = distance [m] from load point to top of overflow or to a point located 1,5 m above the tank top, whichever is greater.

For tanks equipped with pressure relief valves and/or for tanks intended to carry liquids of a density greater than 1,0 t/m^3, the head h_2 is at least to be measured to a level at the following distance h_p above tank top:

h_p = 2,5 ρ or

= 10 p_v, where $p_v > 0,25\ \rho$

Regarding the design pressure of fuel tanks and ballast tanks which are connected to an overflow system, the dynamic pressure increase due to the overflowing is to be taken into account in addition to the static pressure height up to the highest point of the overflow system.

C3.5.7.8 Testing for Tightness

.1 Testing of fuel oil, ballast, trimming, feed water, fresh water and anti-rolling tanks is to be effected by a combination of a leak test by means of air pressure and an operational test by means of water or

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the liquid for which the tank is intended to be used. The air pressure is not to exceed 0,2 bar gauge. The increased risk of accident while the tanks are subjected to the air pressure is to be observed.

.2 Where one tank boundary is formed by the ship's shell, the leak test is to be carried out before launching. For all other tanks leak testing may be carried out after launching. Erection welds as well as welds of assembly openings are to be coated [2] after the leak test is carried out. This applies also to manual weld connections of bulkheads with the other tanks boundaries and of collaring arrangements at intersections of tank boundaries and e.g. frames, beams, girders, pipes etc. If it is ensured that in adjacent tanks the same type of liquid is carried, e.g. in adjacent ballast tanks, the above mentioned weld connections may be coated [2] prior to the leak test.

All other welded connections in tank boundaries may be coated prior to the leak test if it is ensured by suitable means (e.g. by visual examination of the welded connections) that the connections are completely welded and the surfaces of the welds do not exhibit cracks or pores.

.3 Where the tanks are not subjected to the leak test as per 2. but are leak tested with water the bulkheads are, in general, to be tested from one side. The testing should be carried out prior to launching or in the dock. Subject to approval by GL, the test may also be carried out after launching. Water testing may be carried out after application of a coating [2], provided that during the visual inspection as per 2. above deficiencies are not noted. The test head shall correspond to a head of water of 2,5 m above the top of tank or to the top of overflow or air pipe, whichever is the greater.

.4 The operational test may be carried out when the ship is afloat or during the trial trip. For all tanks the proper functioning of filling and suction lines and of the valves as well as functioning and tightness of the vent, sounding and overflow pipes is to be tested.

C3.5.8 Deck loads

C3.5.8.1 General

.1 The pressure [kPa] considered as acting on decks is given by the formula:

$$p_d = p \cdot (1 + 0{,}4 \cdot a_v)$$

p = uniform pressure due to the load carried [kPa]. Minimum values are given in C3.5.8.2 to C3.5.8.6,

a_v = design vertical acceleration, defined in C3.3.

[2] Shopprimers are not regarded as a coating within the scope of these requirements.

.2 Where decks are intended to carry masses of significant magnitude, including vehicles, the concentrated loads transmitted to structures are given by the corresponding static loads multiplied by $(1 + 0{,}4 \cdot a_v)$.

C3.5.8.2 Weather decks and exposed areas

.1 For weather decks and exposed areas without deck cargo:

- if $z_d \leq 2$:

  $p = 6{,}0$ kPa

- if $2 < z_d < 3$:

  $p = (12 - 3\, z_d)$ kPa

- if $z_d \geq 3$:

  $p = 3{,}0$ kPa

where z_d is the vertical distance [m] from deck to waterline at draught T.

p can be reduced by 20 % for primary supporting members and pillars under decks located at least 4 m above the waterline at draught T, excluding embarkation areas.

.2 For weather decks and exposed areas with deck cargo:

- if $z_d \leq 2$:

  $p = (p_c + 3)$ kPa

- if $2 < z_d < 3$:

  $p = (p_c + 7 - 2\, z_d)$ kPa

- if $z_d \geq 3$:

  $p = (p_c + 1)$ kPa

z_d = distance defined in C3.5.8.2.1,

p_c = uniform pressure due to deck cargo load [kPa] to be defined by the designer, but taken as not less than 3,0 kPa.

C3.5.8.3 Enclosed cargo decks

.1 For enclosed cargo decks other than decks carrying vehicles:

$$p = p_c$$

with p_c as defined in C3.5.8.2.2.

For enclosed cargo decks carrying vehicles, the loads are defined in C3.5.8.7.

C3.5.8.4 Enclosed accommodation decks

.1 For enclosed accommodation decks not carrying goods:

$p = 3{,}0$ kPa

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p can be reduced by 20 per cent for primary supporting members and pillars under such decks.

.2 For enclosed accommodation decks carrying goods:

$$p = p_c$$

With p_c as defined in C3.5.8.2.2.

C3.5.8.5 Sheltered decks

.1 They are decks which are not accessible to the passengers and which are not subjected to the sea pressures. Crew can access such decks with care and taking account of the admissible load, which is to be clearly indicated.

The deck load [kPa] for shelter decks is:

$$p_d = 1,3\ (1 + 0,4\ a_v)$$

A lower value may be accepted, at the discretion of GL, provided that such a value as well as the way of access to the deck are clearly specified by and agreed upon with the Owner.

The minimum value to be considered for such areas forward of the bridge is

$$p_d = 3,0 \text{ kPa}$$

C3.5.8.6 Platforms of machinery spaces and mooring decks

.1 The minimum value to be considered for platforms of machinery spaces is

$$p = 8,0 \text{ kPa}$$

.2 The minimum value to be considered for platforms of mooring decks is

$$p = 6,0 \text{ kPa}$$

C3.5.8.7. Decks carrying vehicles

C3.5.8.7.1 General

.1 These Rules apply to movable as well as to removable car decks not forming part of the ship's structure.

.2 The following information should be included in the plans to be submitted for approval:

- scantlings of the car decks
- masses of the car decks
- number and masses of cars intended to be stowed on the decks
- wheel loads and distance of wheels
- connection of the car decks to the hull structure
- moving and lifting gear of the car decks

C3.5.8.7.2 Design loads

.1 For determining the deck scantlings, the following loads are to be used:

- uniformly distributed load resulting from the mass of the deck and maximum number of cars to be carried. This load is not to be taken less than 2,5 kPa multiplied by $(1 + 0,4\ a_v)$.
- wheel load P

Where all wheels of one axle are standing on a deck girder or a deck beam, the axle load is to be evenly distributed on all wheels.

Where not all of the wheels of one axle are standing on a deck girder or a deck beam, the following wheel loads are to be used:

P = 0,5 · axle load for 2 wheels per axle

= 0,3 · axle load for 4 wheels per axle

= 0,2 · axle load for 6 wheels per axle

.2 For determining the scantlings of the suspensions, the increased wheel load in case of four and six wheels per axle as per C3.5.8.7.2.1 need not be considered.

.3 For determining the primary structure of decks under racking effects, the following loads are to be used:

- uniformly distributed load resulting from the mass of the deck and maximum number of cars to be carried. This load is not to be taken less than 2,5 kPa.
- wheel load P.

C3.5.8.7.3 Permissible deflection

.1 The deflection of girders subjected to loads stipulated under C3.5.8.7.2 is not to exceed:

$$f = \frac{\ell}{200}$$ for steel and aluminium structures

ℓ = unsupported span of girder

.2 An adequate safety distance should be maintained between the girders of a loaded deck and the top of cars stowed on the deck below.

C3.5.8.7.4 Buckling

The buckling strength of girders is to be proved according to C3.7.5, if required.

C3.5.9 Handrails

Following design loads can be taken for handrails of

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- weather decks and exposed areas 750 N/m
- inner decks 750 N/m
- outer ramps 500 N/m
- Ro-Ro decks which are only accessible in harbour areas 200 N/m
- sheltered decks 200 N/m

If neither escape routes, life-raft accesses nor heli winch areas etc. are included, reduced requirements can be stipulated.

Following permissible bending stress [MPa] of the stanchions (loaded at upper end) is to be observed:

150/k for steel

70/k for aluminium alloys

The maximum permissible distance between the stanchions is 1,6 m.

C3.6 Welded Joints

Note

The content of C3.6 is to a large extent identical to that of the GL Rules for Welding in the Various Fields of Application (II-3-3), Section 1, G. Because of the re-issues of II-3-3 and these Rules at different times, some temporary divergences may arise and in such circumstances the more recent Rules shall take precedence. Special questions and problems will be solved in an actual case by using these Rules in addition to the following information.

These requirements and figures arise from welded joints of steel structures. For aluminium alloys deviations or further requirements may be taken into consideration.

C3.6.1 Design

C3.6.1.1 General design principles

.1 During the design stage welded joints are to be planned such as to be accessible during fabrication, to be located in the best possible position for welding and to permit the proper welding sequence to be followed.

.2 Both the welded joints and the sequence of welding involved are to be so planned as to enable residual welding stresses to be kept to a minimum in order that no excessive deformation occurs. Welded joints should not be over dimensioned, see also C3.6.3.3.3.

.3 When planning welded joints, it shall first be established that the type and grade of weld envisaged, such as full root weld penetration in the case of HV or DHV (K) weld seams, can in fact be perfectly executed under the conditions set by the limitations of the manufacturing process involved. If this is not the case, a simpler type of weld seam shall be selected and its possibly lower load bearing capacity taken into account when dimensioning the component.

.4 Highly stressed welded joints - which, therefore, are generally subject to examination - are to be so designed that the most suitable method of testing for faults can be used (radiography, ultrasonic, surface crack testing methods) in order that a reliable examination may be carried out.

.5 Special characteristics peculiar to the material, such as the lower strength values of rolled material in the thickness direction (see C3.6.2.5.1) or the softening of cold worked aluminium alloys as a result of welding, are factors which have to be taken into account when designing welded joints. Clad plates where the efficiency of the bond between the base and the clad material is proved may generally be treated as solid plates (up to medium plate thicknesses where mainly filled weld connections are used).

.6 In cases where different types of material are paired and operate in sea water or any other electrolytic medium, for example welded joints made between unalloyed carbon steels and stainless steels in the wear-resistant cladding in rudder nozzles or in the cladding of rudder shafts, the resulting differences in potential greatly increase the susceptibility to corrosion and shall therefore be given special attention. Where possible, such welds are to be positioned in locations less subject to the risk of corrosion (such as on the outside of tanks) or special protective countermeasures are to be taken (such as the provision of a protective coating or cathodic protection).

C3.6.1.2 Design details

.1 Stress flow, transitions

.1.1 All welded joints on primary supporting members shall be designed to provide as smooth a stress profile as possible with no major internal or external notches, no discontinuities in rigidity and no obstructions to strains, see C3.7.1.

.1.2 This applies in analogous manner to the welding of subordinate components on to primary supporting members whose exposed plate or flange edges should, as far as possible, be kept free from notch effects due to welded attachments.

.1.3 Butt joints in long or extensive continuous structures such as bilge keels, fenders, crane rails, slop coamings, etc. attached to primary structural members are therefore to be welded over their entire cross-section.

.1.4 Wherever possible, joints (especially site joints) in girders and sections shall not be located in

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areas of high bending stress. Joints at the knuckle of flanges are to be avoided.

.1.5 The transition between differing component dimensions shall be smooth and gradual. Where the depth of web of girders or sections differs, the flanges or bulbs are to be bevelled and the web slit and expanded or pressed together to equalize the depths of the members. The length of the transition should be at least equal twice the difference in depth.

.1.6 Where the plate thickness differs at joints perpendicularly to the direction of the main stress, differences in thickness greater than 3 mm shall be accommodated by bevelling the proud edge in the manner shown in Fig. C3.6.1 at a ratio of at least 1 : 3 or according to the notch category. Differences in thickness of 3 mm or less may be accommodated within the weld. For aluminium a ratio of 1 : 5 is recommended. Differences in thickness are not allowed.

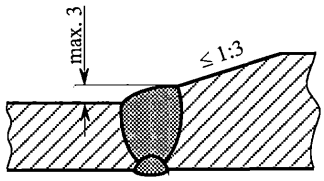

Fig. C3.6.1 Accommodation of differences of thickness

.1.7 For the welding on of plates or other relatively thin-walled elements, forgings and aluminium and steel castings should be appropriately tapered or provided with integrally cast or forged welding flanges in accordance with Fig. C3.6.2.

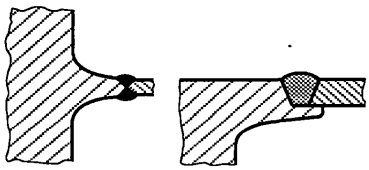

Fig. C3.6.2 Welding flanges on steel castings or forgings

.1.8 For the connection of shaft brackets to the boss and shell plating, see C3.6.1.4.3 and C3.9.1.

.2 Local clustering of welds, minimum spacing

.2.1 The local clustering of welds and short distances between welds are to be avoided. Adjacent butt welds should be separated from each other by a distance of at least

$$50 \text{ mm} + 4 \times \text{plate thickness}$$

Fillet welds should be separated from each other and from butt welds by a distance of at least

$$30 \text{ mm} + 2 \times \text{plate thickness}$$

The width of replaced or inserted plates (strips) should, however, be at least 300 mm or ten times the plate thickness, whichever is the greater.

.2.2 Reinforcing plates, welding flanges, mountings and similar components socket-welded into plating should be of the following minimum size:

$$D_{min} = 170 + 3\,(t - 10) \geq 170 \text{ mm}$$

D = diameter of round or length of side of angular weldments [mm]

t = plating thickness [mm]

The corner radii of angular socket weldments should be 5 t [mm] but at least 50 mm. Alternatively the "longitudinal seams" are to extend beyond the "transverse seams". Socket weldments are to be fully welded to the surrounding plating.

Regarding the increase of stress due to different thickness of plates see also C3.7.6.

.3 Welding cut-outs

.3.1 Welding cut-outs for the (later) execution of butt or fillet welds following the positioning of transverse members should be rounded (minimum radius 25 mm or twice the plate thickness, whichever is the greater) and should be shaped to provide a smooth transition on the adjoining surface as shown in Fig. C3.6.3 (especially necessary where the loading is mainly dynamic).

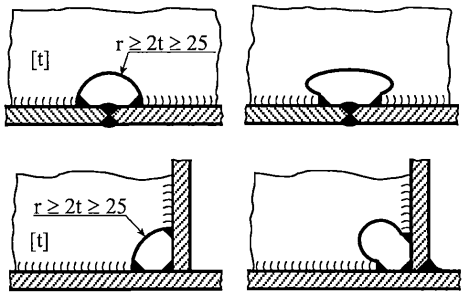

Fig. C3.6.3 Welding cut-outs

.3.2 Where the welds are completed prior to the positioning of the crossing members, no welding cut-outs are needed. Any weld reinforcements present are to be machined off prior to the location of the crossing members or these members are to have suitable cut-outs.

.4 Local reinforcements, doubling plates

.4.1 Where platings (including girder plates and tube walls) are subjected locally to increased stresses, thicker plates should be used wherever possible in preference to doubling plates. Bearing bushes, hubs etc. shall invariably take the form of thicker sections welded into the plating, see C3.6.2.2.2.

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.4.2 Where doublings cannot be avoided, the thickness of the doubling plates should not exceed twice the plating thickness. Doubling plates whose width is greater than approximately 30 times their thickness shall be plug welded to the underlying plating in accordance with C3.6.3.3.11 at intervals not exceeding 30 times the thickness of the doubling plate.

.4.3 Along their (longitudinal) edges, doubling plates shall be continuously fillet welded with a throat thickness "a" of 0,3 × the doubling plate thickness. At the ends of doubling plates, the throat thickness "a" at the end faces shall be increased to 0,5 × the doubling plate thickness but shall not exceed the plating thickness, see Fig. C3.6.4.

The welded transition at the end faces of the doubling plates to the plating should form with the latter an angle of 45° or less.

.4.4 Where proof of fatigue strength is required (see C3.7.6), the configuration of the end of the doubling plate shall conform to the selected detail category.

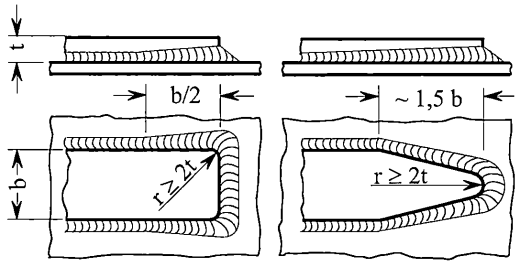

Fig. C3.6.4 Welding at the ends of doubling plates

.4.5 Doubling plates are not permitted in tanks for flammable liquids.

.5 Intersecting members, stress in the thickness direction

.5.1 Where, in the case of intersecting members, plates or other rolled products are stressed in the thickness direction by shrinking stresses due to the welding and/or applied loads, suitable measures shall be taken in the design and fabrication of the structures to prevent lamellar tearing (stratified fractures) due to the anisotropy of the rolled products.

.5.2 Such measures include the use of suitable weld shapes with a minimum weld volume and a welding sequence designed to reduce transverse shrinkage. Other measures are the distribution of the stresses over a larger area of the plate surface by using a build-up weld or the joining together of several "fibres" of members stressed in the thickness direction as exemplified by the deck stringer/sheer strake joint shown in Fig. C3.6.12.

.5.3 In case of very severe stresses in the thickness direction due, for example, to the aggregate effect of the shrinkage stresses of bulky single or double-bevel butt welds plus high applied loads, plates with guaranteed through thickness properties (extra high-purity material and guaranteed minimum reductions in area of tensile test specimens taken in thickness direction) [3] are to be used.

.6 Welding of cold formed sections, bending radii

.6.1 Wherever possible, welding should be avoided at the cold formed sections with more than 5 % permanent elongation [4] and in the adjacent areas of structural steels with a tendency towards strain ageing.

.6.2 Welding may be performed at the cold formed sections and adjacent areas of hull structural steels and comparable structural steels (e.g. those in quality groups S...J... and S...K... to DIN EN 10025) provided that the minimum bending radii are not less than those specified in Table C3.6.1.

Table C3.6.1 Minimum inner bending radius r

Plate thickness t	Minimum inner bending radius r
to 4 mm	1,0 × t
to 8 mm	1,5 × t
to 12 mm	2,0 × t
to 24 mm	3,0 × t
over 24 mm	5,0 × t

Note

The bending capacity of the material may necessitate a larger bending radius.

.6.3 For other steels and other materials, where applicable, the necessary minimum bending radius shall, in case of doubt, be established by test. Proof of adequate toughness after welding may be stipulated for steels with minimum nominal upper yield point of more than 355 N/mm² and plate thicknesses of 30 mm and above which have undergone cold forming resulting in 2 % or more permanent elongation.

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3 See Rules Steel and Iron Materials (II-1-2), Section 1 and also Supply Conditions 096 for Iron and Steel Products, "Plate, strip and universal steel with improved resistance to stress perpendicular to the product surface" issued by the German Iron and Steelmakers' Association.

4 Elongation ε in the outer tensile-stressed zone

$$\varepsilon = \frac{100}{1 + 2\,r/t} \quad [\%]$$

r = inner bending radius [mm]
t = plate thickness [mm]

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.7 Build-up welds on rudderstocks and pintles

.7.1 Wear resistance and/or corrosion resistant build-up welds on the bearing surfaces of rudderstocks, pintles etc. shall be applied to a thickened collar exceeding by at least 20 mm the diameter of the adjoining part of the shaft.

.7.2 Where a thickened collar is impossible for design reasons, the build-up weld may be applied to the smooth shaft provided that relief-turning in accordance with C3.6.1.2.7.3 is possible (leaving an adequate residual diameter).

.7.3 After welding, the transition areas between the welded and non-welded portions of the shaft shall be relief-turned with large radii, as shown in Fig. C3.6.5, to remove any base material whose structure close to the concave groove has been altered by the welding operation and in order to effect the physical separation of geometrical and metallurgical "notches".

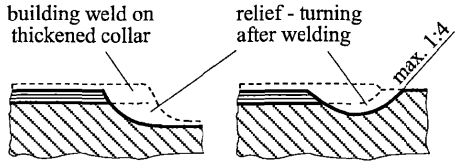

Fig. C3.6.5 Build-up welds applied to rudderstocks and pintles

C3.6.1.3 Weld shapes and dimensions

.1 Butt joints

.1.1 Depending on the plate thickness, the welding method and the welding position, butt joints shall be of the square, V or double-V shape conforming to the relevant standards (e.g. EN 22553/ISO 2533, ISO 9692 -1, -2, -3 or -4). Where other weld shapes are applied, these are to be specially described in the drawings. Weld shapes for special welding processes such as single-side or electrogas welding shall have been tested and approved in the context of a welding procedure test.

.1.2 As a matter of principle, the rear sides of butt joints shall be grooved and welded with at least one capping pass. Exceptions to this rule, as in the case of submerged-arc welding or the welding processes mentioned in C3.6.1.3.1.1, require to be tested and approved in connection with a welding procedure test. The effective weld thickness shall be deemed to be the plate thickness, or, where the plate thicknesses differ, the lesser plate thickness. Where proof of fatigue strength is required (see C3.7.6), the detail category depends on the execution (quality) of the weld.

.1.3 Where the aforementioned conditions cannot be met, e.g. where the welds are accessible from one side only, the joints shall be executed as lesser bevelled welds with an open root and an attached or an integrally machined or cast, permanent weld pool support (backing) as shown in Fig. C3.6.6.

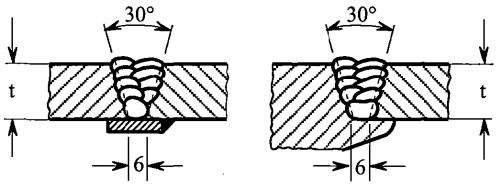

Fig. C3.6.6 Single-side welds with permanent weld pool supports (backings)

.1.4 The weld shapes illustrated in Fig. C3.6.7 shall be used for clad plates. These weld shapes shall be used in analogous manner for joining clad plates to (unalloyed and low alloyed) hull structural steels.

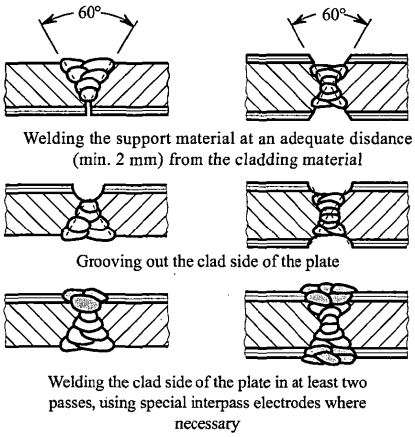

Fig. C3.6.7 Weld shapes for welding of clad plates

.2 Corner, T and double-T (cruciform) joints

.2.1 Corner, T and double-T (cruciform) joints with complete union of the abutting plates shall be made as single or double-bevel welds with a minimum root face and adequate air gap, as shown in Fig. C3.6.8, and with grooving of the root and capping from the opposite side.

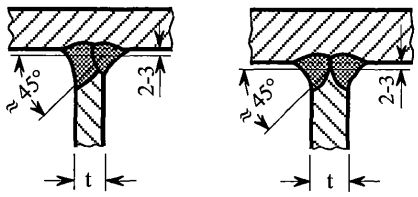

Fig. C3.6.8 Single and double-bevel welds with full root penetration

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The effective weld thickness shall be assumed as the thickness of the abutting plate. Where proof of fatigue strength is required (see C3.7.6), the detail category depends on the execution (quality) of the weld.

.2.2 Corner, T and double-T (cruciform) joints with a defined incomplete root penetration, as shown in Fig. C3.6.9, shall be made as single or double-bevel welds, as described in C3.6.1.3.2.1, with a back-up weld but without grooving of the root.

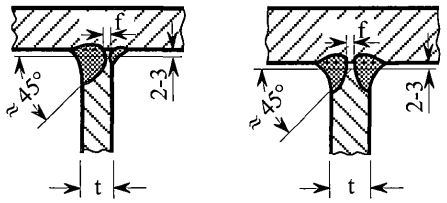

Fig. C3.6.9 Single and double-bevel welds with defined incomplete root penetration

The effective weld thickness may be assumed as the thickness of the abutting plate t, where f is the incomplete root penetration of 0,2 t with a maximum of 3 mm, which is to be balanced by equally sized double fillet welds on each side. Where proof of fatigue strength is required (see C3.7.6), these welds are to be assigned to type D1.

.2.3 Corner, T and double-T (cruciform) joints with both an unwelded root face c and a defined incomplete root penetration f shall be made in accordance with Fig. C3.6.10

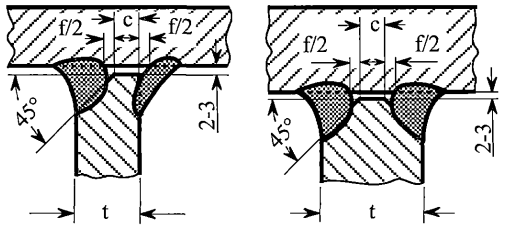

Fig. C3.6.10 Single and double-bevel welds with unwelded root face and defined in complete root penetration

The effective weld thickness shall be assumed as the thickness of the abutting plate t minus (c + f), where f is to be assigned a value of 0,2 t subject to a maximum of 3 mm. Where proof of fatigue strength is required (see C3.7.6), these welds are to be assigned to types D2 or D3.

.2.4 Corner, T and double-T (cruciform) joints which are accessible from one side only may be made in accordance with Fig. C3.6.11 in a manner analogous to the butt joints referred to in C3.6.1.3.1.3 using a weld pool support (backing), or as single-side, single bevel welds in a manner similar to those prescribed in C3.6.1.3.2.2.

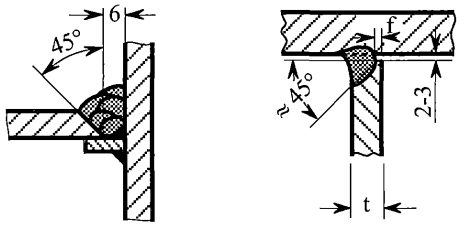

Fig. C3.6.11 Single-side welded T joints

The effective weld thickness shall be determined by analogy with C3.6.1.3.1.3 or C3.6.1.3.2.2, as appropriate. Wherever possible, these joints should not be used where proof of fatigue strength is required (see C.3.7.6).

.2.5 Where corner joints are flush, the weld shapes shall be as shown in Fig. C3.6.12 with bevelling of at least 30° of the vertically drawn plates to avoid the danger of lamellar tearing. A similar procedure is to be followed in the case of fitted T joints (uniting three plates) where the abutting plate is to be socketed between the aligned plates.

.2.6 Where, in the case of T joints, the direction of the main stress lies in the plane of the horizontal plates (e.g. the plating) shown in Fig. C3.6.13 and where the connection of the perpendicular (web) plates is of secondary importance, welds uniting three plates may be made in accordance with Fig. C3.6.13 (with the exception of those subjected mainly to dynamic loads). For the root passes of the three plate weld sufficient penetration shall be achieved. Sufficient penetration has to be verified in way of the welding procedure test.

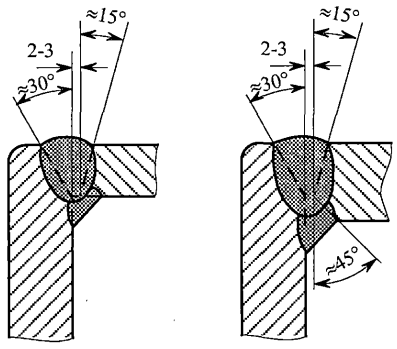

Fig. C3.6.12 Flush fitted corner joints

The effective thickness of the weld connecting the horizontal plates shall be determined in accordance with C3.6.1.3.2.2. The requisite "a" dimension is determined by the joint uniting the vertical (web) plates and shall, where necessary, be determined in accordance with Table C3.6.3 or by calculation as for fillet welds.

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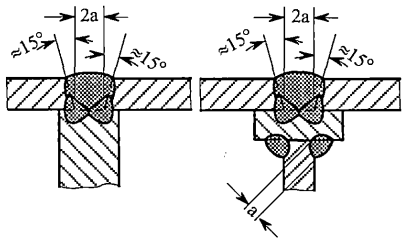

Fig. C3.6.13 Welding together three plates

.3 Fillet weld connections

.3.1 In principle fillet welds are to be of the double fillet weld type. Exceptions to this rule (as in the case of closed box girders and mainly shear stresses parallel to the weld) are subject to approval in each individual case. The throat thickness "a" of the weld (the height of the inscribed isosceles triangle) shall be determined in accordance with Table C3.6.3 or by calculation according to C3.6.2. The leg length of a fillet weld is to be not less than 1,4 times the throat thickness "a". For fillet welds at doubling plates, see C3.6.2.4.3 and for bracket joints, see C3.6.2.2.7.

.3.2 The relative fillet weld throat thicknesses specified in Table C3.6.3 relate to normal strength and higher strength hull structural steels and comparable structural steels. They may also be generally applied to high-strength structural steels and non-ferrous metals provided that the "tensile shear strength" of the weld metal used is at least equal to the tensile strength of the base material. Failing this, the "a" dimension shall be increased accordingly and the necessary increment shall be established during the welding procedure test (see Rules Welding in the Various Fields of Application (II-3-3), Section 1, F.). Alternatively proof by calculation taking account of the properties of the weld metal may be presented.

Note

In the case of higher-strength aluminium alloys, such an increment may be necessary for cruciform joints subject to tensile stresses, as experience shows that in the welding procedure tests the tensile-shear strength of fillet welds (made with matching filler metal) often fails to attain the tensile strength of the base material. See also Rules Welding in the Various Fields of Application (II-3-3), Section 1, F.

.3.3 The throat thickness of fillet welds shall not exceed 0,7 times the lesser thickness of the parts to be connected (generally the web thickness). The minimum throat thickness is defined by the expression:

$$a_{min} = \sqrt{\frac{t_1 + t_2}{3}} \quad [mm],$$

but not less than 2,5 mm

t_1 = lesser (e.g. the web) plate thickness [mm]

t_2 = greater (e.g. the flange) plate thickness [mm]

.3.4 It is desirable that the fillet weld section shall be flat faced with smooth transitions to the base material. Where proof of fatigue strength is required (see C3.7.6), machining of the weld (grinding to remove notches) may be required depending on the notch category. The weld should penetrate at least close to the theoretical root point.

.3.5 Where mechanical welding processes are used which ensure deeper penetration extending well beyond the theoretical root point and where such penetration is uniformly and dependably maintained under production conditions, approval may be given for this deeper penetration to be allowed for in determining the throat thickness. The effective dimension:

$$a_{deep} = a + \frac{2\, e_{min}}{3} \quad [mm]$$

shall be ascertained in accordance with Fig. C3.6.14 and by applying the term "e_{min}" to be established for each welding process by a welding procedure test. The throat thickness shall not be less than the minimum throat thickness related to the theoretical root point.

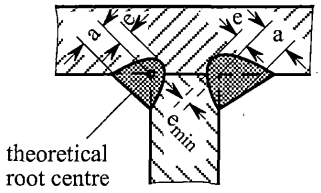

Fig. C3.6.14 Fillet welds with increased penetration

.3.6 When welding on top of shop primers which are particularly liable to cause porosity, an increase of the "a" dimension by up to 1 mm may be stipulated depending on the welding process used. This is specially applicable where minimum fillet weld throat thicknesses are employed. The size of the increase shall be decided on a case by case basis considering the nature and severity of the stressing following the test results of the shop primer in accordance with the Rules Welding in the Various Fields of Application (II-3-3), F. This applies in analogous manner to welding processes where provision has to be made for inadequate root penetration.

.3.7 Strengthened filled welds continuous on both sides are to be used in areas subjected to severe dynamic loads (e.g. for connecting the longitudinal and transverse girders of the engine base to top plates close to foundation bolts, see Table C3.6.3), unless single or double-bevel welds are stipulated in these

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locations. In these areas the "a" dimension shall equal 0,7 times the lesser thickness of the parts to be welded.

.3.8 Intermittent fillet welds in accordance with Table C3.6.3 may be located opposite one another (chain intermittent welds, possibly with scallops) or may be staggered, see Fig. C3.6.15. In case of small sections other types of scallops may be accepted.

In water and cargo tanks, in the bottom area of fuel oil tanks and of spaces where condensed or sprayed water may accumulate and in hollow components (e.g. rudders) threatened by corrosion, only continuous or intermittent fillet welds with scallops shall be used. This applies accordingly also to areas, structures or spaces exposed to extreme environmental conditions or which are exposed to corrosive cargo.

There shall be no scallops in areas where the plating is subjected to severe local stresses (e.g. in the bottom section of the fore ship) and continuous welds are to be preferred where the loading is mainly dynamic.

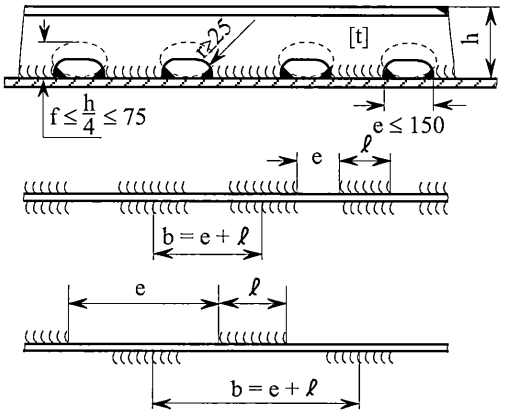

Fig. C3.6.15 Scallop, chain and staggered welds

.3.9 The throat thickness a_u of intermittent fillet welds is to be determined according to the selected pitch ratio b/ℓ by applying the formula:

$$a_u = 1{,}1 \cdot a \left(\frac{b}{\ell}\right) \text{ [mm]}$$

a = required fillet weld throat thickness [mm] for a continuous weld according to Table C3.6.3 or determined by calculation

b = pitch = $e + \ell$ [mm]

e = interval between the welds [mm]

ℓ = length of fillet weld [mm]

The pitch ratio b/ℓ should not exceed 5. The maximum unwelded length ($b - \ell$ with scallop and chain welds, or $b/2 - \ell$ with staggered welds) should not exceed 25 times the lesser thickness of the parts to be welded. The length of scallops should, however, not exceed 150 mm.

.3.10 Lap joints should be avoided wherever possible and are not to be used for heavily loaded components. In the case of components subject to low loads lap joints may be accepted provided that, wherever possible, they are orientated parallel to the direction of the main stress. The width of the lap shall be 1,5 t + 15 mm (t = thickness of the thinner plate). Except where another value is determined by calculation, the fillet weld throat thickness "a" shall equal 0,4 times the lesser plate thickness, subject to the requirement that it shall not be less than the minimum throat thickness required by C3.6.1.3.3.3. The fillet weld shall be continuous on both sides and shall meet at the ends.

.3.11 In the case of plug welding, the plugs should, wherever possible, take the form of elongated holes lying in the direction of the main stress. The distance between the holes and the length of the holes may be determined by analogy with the pitch "b" and the fillet weld length "ℓ" in the intermittent welds covered by C3.6.1.3.3.8. The fillet weld throat thickness "a_u" may be established in accordance with C3.6.1.3.3.9. The width of the holes shall be equal to at least twice the thickness of the plate and shall not be less than 15 mm. The ends of the holes shall be semi-circular. Plates or sections placed underneath should at least equal the perforated plate in thickness and should project on both sides to a distance of 1,5 × the plate thickness subject to a maximum of 20 mm. Wherever possible only the necessary fillet welds shall be welded, while the remaining void is packed with a suitable filler. Lug joint welding is not allowed.

C3.6.1.4 Welded joints of particular components

.1 Welds at the ends of girders and stiffeners

.1.1 As shown in Fig. C3.6.16, the web at the end of intermittently welded girders or stiffeners is to be continuously welded to the plating or the flange plate, as applicable, over a distance at least equal to the depth "h" of the girder or stiffener subject to a maximum of 300 mm. Regarding the strengthening of the welds at the ends, extending normally over 0,15 of the span, see Table C3.6.3.

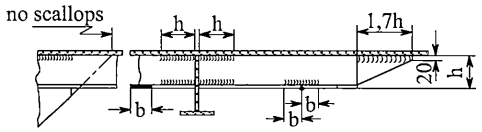

Fig. C3.6.16 Welds at the ends of girders and stiffeners

.1.2 The areas of bracket plates should be continuously welded over a distance at least equal to the

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length of the bracket plate. Scallops are to be located only beyond a line imagined as an extension of the free edge of the bracket plate.

.1.3 Wherever possible, the free ends of stiffeners shall abut against the transverse plating or the webs of sections and girders so as to avoid stress concentrations in the plating. Failing this, the ends of the stiffeners are to be sniped and continuously welded over a distance of at least 1,7 h subject to a maximum of 300 mm.

.1.4 Where butt joints occur in flange plates, the flange shall be continuously welded to the web on both sides of the joint over a distance at least equal to the width of the flange.

.2 Joints between section ends and plates

.2.1 Welded joints connecting section ends and plates may be made in the same plane or lapped.

Where no design calculations have been carried out or stipulated for the welded connections, the joints may be made analogously to those shown in Fig. C3.6.17.

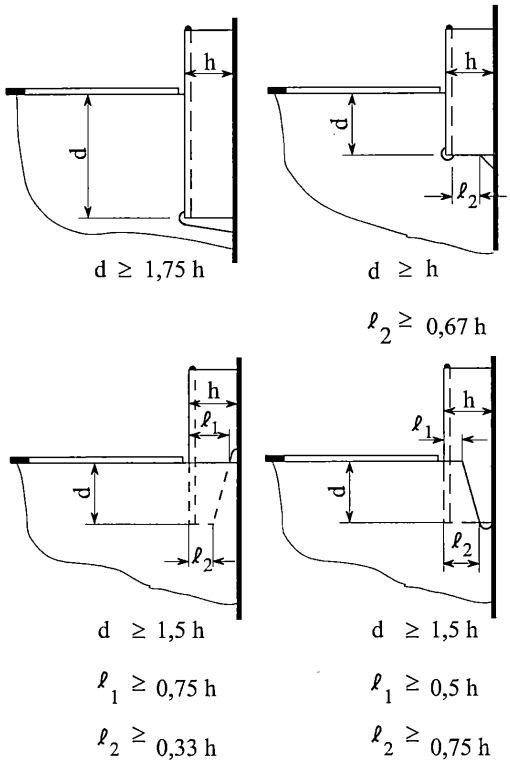


Fig. C3.6.17 Joints uniting section ends and plates

.2.2 Where the joint lies in the plane of the plate, it may conveniently take the form of a single-bevel butt weld with fillet. Where the joint between the plate and the section end overlaps, the fillet weld shall be continuous on both sides and shall meet at the ends. The necessary "a" dimension is to be calculated in accordance with C3.6.2.2.6. The fillet weld throat thickness is not to be less than the minimum specified in C3.6.1.3.3.3.

.3 Welded shaft bracket joints

.3.1 Unless cast in one piece or provided with integrally cast welding flanges analogous to those prescribed in C3.6.1.2.1.7 (see Fig. C3.6.18), strut barrel and struts are to be connected to each other and to the shell plating in the manner shown in Fig. C3.6.19.

.3.2 In the case of single-strut shaft brackets no welding is to be performed on the arm at or close to the position of constraint. Such components shall be provided with integrally forged or cast welding flanges.

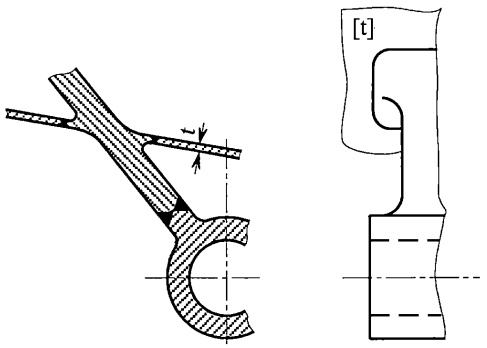
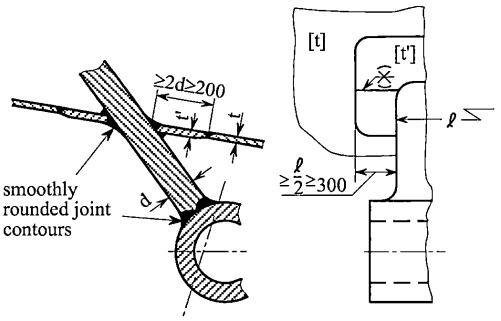


Fig. C3.6.18 Shaft bracket with integrally cast welding flanges



t = plating thickness in accordance with Section 6, F. in [mm]

$t' = \frac{d}{3} + 5$ [mm] where d < 50mm

$t' = 3\sqrt{d}$ [mm] where d ≥ 50mm

For shaft brackets of elliptically shaped cross section d may be substituted by 2/3 d in the above formulae.

Fig. C3.6.19 Shaft bracket without integrally cast welding flanges

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C3.6.2 Stress Analysis

C3.6.2.1 General analysis of fillet weld stresses

.1 Definition of stresses

For calculation purposes, the following stresses in a fillet weld are defined (see also Fig. C3.6.20):

$\sigma_\perp$ = normal stresses acting vertically to the direction of the weld seam

$\tau_\perp$ = shear stress acting vertically to the direction of the weld seam

$\tau_\parallel$ = Shear stress acting in the direction of the weld seam

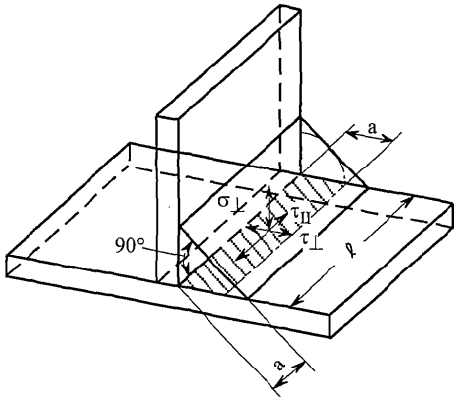

Fig. C3.6.20 Stresses in a fillet weld

Normal stresses acting in the direction of the weld seam need not be considered.

For calculation purposes the weld seam area is $a \cdot \ell$.

Due to equilibrium conditions the following applies to the flank area vertical to the shaded weld seam area: $\tau_\perp = \sigma_\perp$.

The equivalent stress is to be calculated by the following formula:

$$\sigma_v = \sqrt{\sigma_\perp^2 + \tau_\perp^2 + \tau_\parallel^2}$$

.2 Definitions

a = throat thickness [mm]

ℓ = length of fillet weld [mm]

P = single force [N]

M = bending moment at the position considered [Nm]

Q = shear force at the point considered [N]

S = first moment of the cross sectional area of the flange connected by the weld to the web in relation to the neutral beam axis [cm^3]

I = moment of inertia of the girder section [cm^4]

W = section modulus of the connected section [cm^2]

C3.6.2.2 Determination of stresses

.1 Fillet welds stressed by normal and shear forces

Flank and frontal welds are regarded as being equal for the purposes of stress analysis. In view of this, normal and shear stresses are calculated as follows:

$$\sigma = \tau = \frac{P}{\sum a \cdot \ell} \quad [N/mm^2]$$

Joint as shown in Fig. C3.6.21:

– Stresses in frontal fillet welds:

$$\tau_\perp = \frac{P_1}{2 \cdot a (\ell_1 + \ell_2)} \quad [N/mm^2]$$

$$\tau_\parallel = \frac{P_2}{2 \cdot a (\ell_1 + \ell_2)} \pm \frac{P_2 \cdot e}{2 \cdot a \cdot F_t} \quad [N/mm^2]$$

$$F_t = (\ell_1 + a)(\ell_2 + a) \quad [mm^2]$$

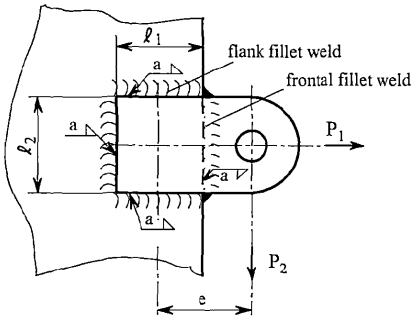

Fig. C3.6.21 Weld joint of an overlapped lifting eye

– Stresses in flank fillet welds:

$$\tau_\perp = \frac{P_2}{2 \cdot a (\ell_1 + \ell_2)} \quad [N/mm^2]$$

$$\tau_\parallel = \frac{P_1}{2 \cdot a (\ell_1 + \ell_2)} \pm \frac{P_2 \cdot e}{2 \cdot a \cdot F_t} \quad [N/mm^2]$$

ℓ_1, ℓ_2, e [mm]

– Equivalent stress for frontal and flank fillet welds:

$$\sigma_v = \sqrt{\tau_\perp^2 + \tau_\parallel^2}$$

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Joint as shown in Fig. C3.6.22:

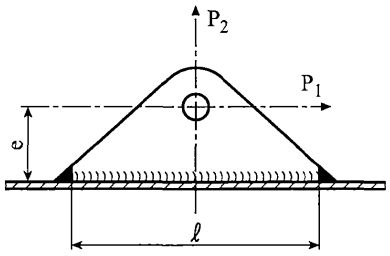

Fig. C3.6.22 Weld joint of a vertically mounted lifting eye

$$\tau_{\perp} = \frac{P_2}{2 \cdot \ell \cdot a} + \frac{3 \cdot P_1 \cdot e}{\ell^2 \cdot a} \quad [N/mm^2]$$

$$\tau_{\parallel} = \frac{P_1}{2 \cdot \ell \cdot a} \quad [N/mm^2]$$

Equivalent stress:

$$\sigma_v = \sqrt{\tau_{\perp}^2 + \tau_{\parallel}^2}$$

.2 Fillet weld joints stressed by bending moments and shear forces

The stresses at the fixing point of a girder are calculated as follows (in Fig. C3.6.23 a cantilever beam is given as an example):

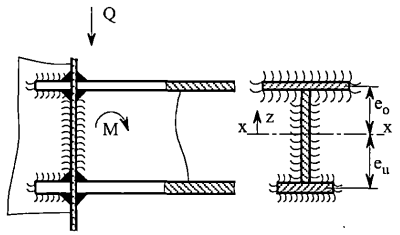

Fig. C3.6.23 Fixing point of a cantilever beam

– Normal stress due to bending moment:

$$\sigma_{\perp}(z) = \frac{M}{I_s} z \quad [N/mm^2]$$

$$\sigma_{\perp max} = \frac{M}{I_s} e_u \quad [N/mm^2], \text{ if } e_u > e_0$$

$$= \frac{M}{I_s} e_0 \quad [N/mm^2], \text{ if } e_u < e_0$$

– Shear stress due to shear force:

$$\tau_{\parallel}(z) = \frac{Q \cdot S_s(z)}{10 \cdot I_s \cdot \Sigma a} \quad [N/mm^2]$$

$$\tau_{\parallel max} = \frac{Q \cdot S_{s max}}{20 \cdot I_s \cdot a} \quad [N/mm^2]$$

I_s = moment of inertia of the welded joint related to the x-axis [cm^4]

$S_s(z)$ = the first moment of the connected weld section at the point under consideration [cm^3]

z = distance from the neutral axis [cm]

– Equivalent stress:

It has to be proved that neither $\sigma_{\perp max}$ in the region of the flange nor $\tau_{\parallel max}$ in the region of the neutral axis nor the equivalent stress $\sigma_v = \sqrt{\sigma_{\perp}^2 + \tau_{\parallel}^2}$ exceed the permitted limits given in C3.6.2.2.8 at any given point. The equivalent stress σ_v should always be calculated at the web-flange connection

.3 Fillet weld joints stressed by bending and torsional moments and shear forces

Regarding the normal and shear stresses resulting from bending, see C3.6.2.2.2. Torsional stresses resulting from the torsional moment M_T are to be calculated:

$$\tau_T = \frac{M_T \cdot 10^3}{2 \cdot a \cdot A_m} \quad [N/mm^2]$$

M_T = torsional moment [Nm]

A_m = sectional area [mm^2] enclosed by the weld seam

The equivalent stress composed of all three components (bending, shear and torsion) is calculated by means of the following formulae:

$$\sigma_v = \sqrt{\sigma_{\perp}^2 + \tau_{\parallel}^2 + \tau_T^2} \quad [N/mm^2],$$

where $\tau_{\parallel}$ and τ_T have not the same direction

$$\sigma_v = \sqrt{\sigma_{\perp}^2 + (\tau_{\parallel} + \tau_T)^2} \quad [N/mm^2],$$

where $\tau_{\parallel}$ and τ_T have the same direction

.4 Continuous fillet weld joints between web and flange of bending girders

The stresses are to be calculated in way of maximum shear forces. Stresses in the weld's longitudinal direction need not be considered.

In the case of continuous double fillet weld connections the shear stress is to be calculated as follows:

$$\tau_{\parallel} = \frac{Q \cdot S}{20 \cdot I \cdot a} \quad [N/mm^2]$$

The fillet weld thickness required is:

$$a_{req} = \frac{Q \cdot S}{20 \cdot I \cdot \tau_{zul}} \quad [mm]$$

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.5 Intermittent fillet weld joints between web and flange of bending girders

Shear stress:

$$\tau_{\parallel} = \frac{Q \cdot S \cdot \alpha}{20 \cdot I \cdot a}\left(\frac{b}{\ell}\right) \quad [N/mm^2]$$

b = pitch

α = 1,1 stress concentration factor which takes into account increases in shear stress at the ends of the fillet weld seam "ℓ"

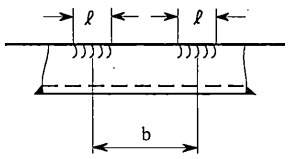

Fig. C3.6.24 Intermittent fillet weld joint

The fillet weld thickness required is:

$$a_{req} = \frac{Q \cdot S \cdot 1{,}1}{20 \cdot I \cdot \tau_{zul}}\left(\frac{b}{\ell}\right) \quad [mm]$$

.6 Fillet weld connections on overlapped profile joints

.6.1 Profiles joined by means of two flank fillet welds (see Fig. C3.6.25):

$$\tau_{\perp} = \frac{Q}{2 \cdot a \cdot d} \quad [N/mm^2]$$

$$\tau_{\parallel} = \frac{M \cdot 10^3}{2 \cdot a \cdot c \cdot d} \quad [N/mm^2]$$

The equivalent stress is:

$$\sigma_v = \sqrt{\tau_{\perp}^2 + \tau_{\parallel}^2}$$

c, d, ℓ_1, ℓ_2, r [mm] see Fig. C3.6.25

$$c = r + \frac{3\ell_1 - \ell_2}{4} \quad [mm]$$

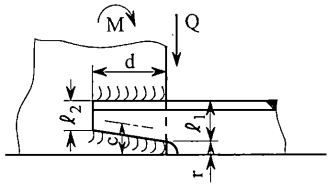

Fig. C3.6.25 Profile joined by means of two flank fillet joints

As the influence of the shear force can generally be neglected, the required fillet weld thickness may be determined by the following formula:

$$a_{req} = \frac{W \cdot 10^3}{1{,}5 \cdot c \cdot d} \quad [mm]$$

.6.2 Profiles joined by means of two flank and two frontal fillet welds (all round welding as shown in Fig. C3.6.26):

$$\tau_{\perp} = \frac{Q}{a\,(2d + \ell_1 + \ell_2)} \quad [N/mm^2]$$

$$\tau_{\parallel} = \frac{M \cdot 10^3}{a \cdot c\,(2d + \ell_1 + \ell_2)} \quad [N/mm^2]$$

The equivalent stress is:

$$\sigma_v = \sqrt{\tau_{\perp}^2 + \tau_{\parallel}^2}$$

$$a_{req} = \frac{W \cdot 10^3}{1{,}5 \cdot c \cdot d\left(1 + \frac{\ell_1 + \ell_2}{2d}\right)} \quad [mm]$$

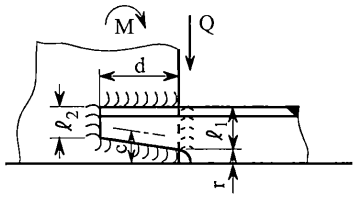

Fig. C3.6.26 Profile joined by means of two flank and two frontal fillet welds (all round welding)

.7 Bracket joints

Where profiles are joined to brackets as shown in Fig. C3.6.27, the average shear stress is:

$$\tau = \frac{3 \cdot M \cdot 10^3}{4 \cdot a \cdot d^2} + \frac{Q}{2 \cdot a \cdot d} \quad [N/mm^2]$$

d = length of overlap [mm]

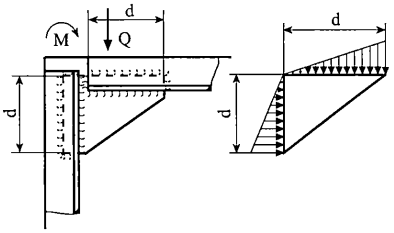

Fig. C3.6.27 Bracket joint with idealized stress distribution resulting from moment M and shear force Q

The required fillet weld thickness is to be calculated from the section modulus of the profile as follows:

$$a_{req} = \frac{1\,000 \cdot W}{d^2} \quad [mm]$$

(The shear force Q has been neglected.)

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.8 Permissible stresses

The permissible stresses for various materials under mainly static loading conditions are given in Table C3.6.2. The values listed for high strength steels, austenitic stainless steels and aluminium alloys are based on the assumption that the strength values of the weld metal used are at least as high as those of the parent metal. If this is not the case, the "a"-value calculated shall be increased accordingly (see also C3.6.1.3.2).

Table C3.6.2 Permissible stresses in fillet weld seams

Material		R_{eH} or $R_{p0,2}$ [N/mm²]	Permissible stresses [N/mm²] equivalent stress, shear stress σ_{vp}, τ_p
normal strength hull structural steel	GL–A/B/D/E	235	115
higher strength structural steel	GL–A/D/E/F 32	315	145
	GL–A/D/E/F 36	355	160
	GL–A/D/E/F 40	390	175
austenitic and austenitic-ferritic stainless steels	1.4306/304 L	180	110
	1.4404/316 L	190	
	1.4435/316 L	190	
	1.4438/317 L	195	
	1.4541/321	205	
	1.4571/316 Ti	215	
	1.4406/316 LN	280	130
	1.4429/316 LN	295	
	1.4439/317 LN	285	
	1.4462/318 LN	480	205
aluminium alloys	AlMg3/5754	80 [1]	36
	AlMg4,5Mn0,7/5083	125 [1]	56
	AlMgSi/6060	65 [2]	30
	AlSi1MgMn/6082	115 [2]	51

[1] Plates, soft condition
[2] Sections, cold hardened

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Table C3.6.3 Fillet weld connections

Structural parts to be connected	Basic thickness of fillet welds a/t_0 [1] for double continuous fillet welds [2]	Intermittent fillet welds permissible [3]
Bottom structures		
transverse and longitudinal girders to each other	0,35	×
– to shell and inner bottom	0,20	×
centre girder to flat keel and inner bottom	0,40	
transverse and longitudinal girders and stiffeners including shell plating in way of bottom strengthening forward	0,30	
machinery space		
transverse and longitudinal girders to each other	0,35	
– to shell and inner bottom	0,30	
inner bottom to shell	0,40	
sea chests, water side	0,50	
inside	0,30	
Machinery foundation		
longitudinal and transverse girders to each other and to the shell	0,40	
– to inner bottom and face plates	0,40	
– to top plates	0,50 [4]	
– in way of foundation bolts	0,70 [4]	
– to brackets and stiffeners	0,30	
longitudinal girders of thrust bearing to inner bottom	0,40	
Decks		
– to shell (general)	0,40	
deckstringer to sheerstrake	0,50	
Frames, stiffeners, beams etc.		
general	0,15	×
in peak tanks	0,30	×
bilge keel to shell	0,15	
Transverses, longitudinal and transverse girders		
general	0,15	×
within 0,15 of span from supports	0,25	
cantilevers	0,40	
pillars to decks	0,40	
Bulkheads, tank boundaries, walls of superstructures and deckhouses		
– to decks, shell and walls	0,40	
Hatch coamings		
– to deck	0,40	
– to longitudinal stiffeners	0,30	
Hatch covers		
general	0,15	× [5]
watertight or oiltight fillet welds	0,30	
Rudder		
plating to webs	0,25	×
Stem		
plating to webs	0,25	×

[1] t_0 = Thickness of the thinner plate.
[2] In way of large shear forces larger throat thicknesses may be required on the bases of calculations according to C3.6.2.
[3] For intermittent welding in spaces liable to corrosion C3.6.1.3.3.8 is to be observed.
[4] For plate thicknesses exceeding 15 mm single or double bevel butt joints with, full penetration or with defined incomplete root penetration according to Fig. C3.6.9 to be applied.
[5] excepting hatch covers above holds provided for ballast water.

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C3.7 Steel and Aluminium Alloy Craft

C3.7.1 Structural Details

C3.7.1.1 Longitudinal members

.1 All longitudinal members taken into account for calculating the midship section modulus are to extend over the required length within 0,4 L amidships and are to be tapered gradually to the required end scantlings.

.2 Abrupt discontinuities of strength of longitudinal members are to be avoided as far as practicable. Where longitudinal members having different scantlings are connected with each other, smooth transitions are to be provided.

.3 At the ends of longitudinal bulkheads or continuous longitudinal walls suitable scarping brackets are to be provided.

C3.7.1.2. Transverses and girders

.1 Where transverses and girders fitted in the same plane are connected to each other, major discontinuities of strength shall be avoided. The web depth of the smaller girder shall, in general, not be less than 60 % of the web depth of the greater one.

.2 The taper between face plates with different dimensions is to be gradual. In general the taper shall not exceed 1 : 3. At intersections the forces acting in the face plates are to be properly transmitted.

.3 For transmitting the acting forces the face plates and webs are to be supported at their knuckles.

.4 For preventing the face plates from tripping adequately spaced stiffeners or tripping brackets are to be provided. The spacing of these tripping elements shall not exceed 12 · bf

.5 The webs are to be stiffened to prevent buckling (see also C3.7.5).

.6 The location of lightening holes shall be such that the distance from hole edge to face plate is not less than 0,25 · web depth.

.7 In way of high shear stresses lightening holes in the webs are to be avoided as far as possible.

In the following requirements for the scantlings of hull structures (plating, stiffeners, primary supporting members) are given. The loads acting on such structures are to be calculated in accordance with the provisions of C3.5.

C3.7.2 Definitions and symbols

The definitions and symbols used are the following ones:

t = thickness [mm] of plating and deck panels,

Z = required section modulus [cm^3] of stiffeners and primary supporting members,

s = spacing of stiffeners [m] measured along the plating,

ℓ = overall span of stiffeners [m] i.e. the distance between the supporting elements at the ends of the stiffeners (see Figure C3.7.1),

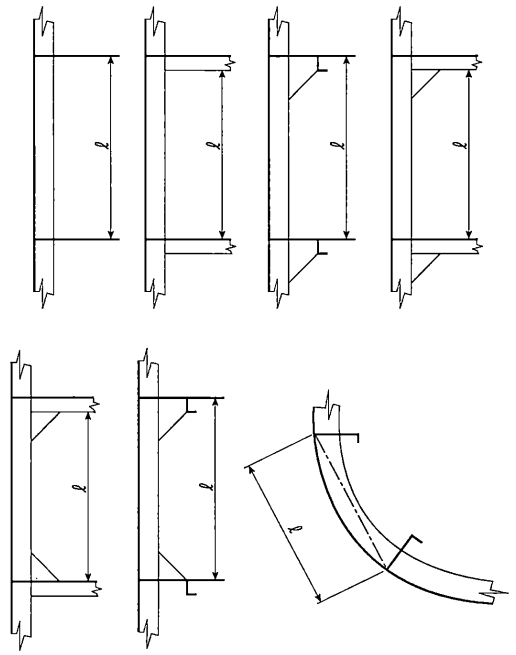

Fig. C3.7.1 Examples of spans of ordinary stiffeners

S = scantling span of primary supporting members [m], which can be reduced by one third of sum of bracket length, if any

b = actual spacing of primary supporting members

p = design pressure [kPa] calculated as defined in C3.5

σ_{am} = permissible normal stress [MPa]

τ_{am} = permissible shear stress [MPa]

k = material factor defined in C3.2

e = ratio between permissible and actual hull girder longitudinal bending stresses

= σ_p / σ_{bl}

σ_p = maximum permissible stress [MPa] as defined in C3.7.3.1

σ_{bl} = longitudinal bending stress [MPa] as defined in C3.7.3.1

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μ = defined as follows:

$$= \sqrt{1{,}1 - 0{,}5 \cdot \left(\frac{s}{\ell}\right)^2}$$

which needs not be taken greater than 1,0

C3.7.3 Overall strength

C3.7.3.1 Longitudinal strength

.1 In general, the scantlings resulting from local strength calculations in the following are such as to ensure adequate longitudinal strength of the hull girder for the craft with length less than or equal to 24 m.

.2 Specific longitudinal strength calculations are required for craft whose hull geometry suggests significant bending moments in still water with the craft at rest.

.3 Longitudinal stress [MPa] at height z above the base line contributing to the craft longitudinal strength is obtained from the following equation:

$$\sigma_{bl} = \left| \frac{M_{bl}}{I_y} \cdot (z - z_0) \cdot 10^{-3} \right|$$

M_{bl} = total bending moment [kNm] defined in C3.4.1 or C3.4.2,

z_0 = height of neutral axis above base line [m]

I_y = moment of inertia [m^4] related to the transverse axis

The values of stress σ_{bl} are not to exceed σ_p, with:

- steel structures:

  $\sigma_p = 150/k$ [MPa]

- aluminium alloy structures:

  $\sigma_p = 70/k$ [MPa]

.4 Moreover, the compressive values of σ are not to exceed the values of critical stresses for plates and stiffeners calculated according to C3.7.5 and C3.7.6.

C3.7.3.2 Transverse strength of catamaran

.1 The equivalent Von Mises stresses obtained for load conditions in C3.4.2.3 and C3.4.3.2 are not to exceed the following values:

- steel structures:

  $\sigma_p = 175/k$ [MPa]

- aluminium alloy structures:

  $\sigma_p = 75/k$ [MPa]

.2 The compressive values of normal stresses and the shear stresses are not to exceed the values of critical stresses for plates and stiffeners calculated according to C3.7.5 and C3.7.6.

.3 In general, the wet deck is to be constituted by continuous plating for its entire longitudinal and transverse extension. Alternative solutions may, however, be examined by GL on the basis of considerations pertaining to the height of the wet deck above the waterline and to the motion characteristics of the craft.

.4 In the special case of catamaran, when the structure connecting both hulls is formed by a deck with single plating stiffened by n reinforced beams, the normal and shear stresses in the beams for the load condition in C3.4.2.4 can be calculated as indicated in C3.7.3.3.

.5 For craft with L > 65 m or speed V > 45 knots, or for those craft whose structural arrangements do not permit a realistic assessment of stress conditions based on simple models, the transverse strength is to be checked by means of direct calculations carried out in accordance with the criteria specified in article C3.1.2.

C3.7.3.3 Transverse strength in the special case of catamaran craft when the structure connecting both hulls is formed by a deck with single plate stiffened by n reinforced beams over the deck

.1 Referring to Figure C3.7.2, G is the centre of the stiffnesses r_i of the n beams. Its position is defined by:

$$a = \frac{\sum r_i \cdot x_i}{\sum r_i}$$

a = abscissa [m] of the centre G with respect to an arbitrarily chosen origin 0,

r_i = stiffness [N/m] of the beam i:

$$= \frac{12 \cdot E_i \cdot I_i}{S_i^3} \cdot 10^6$$

E_i = Young's modulus [MPa] of the beam i

I_i = bending inertia [m^4] of the beam i

S_i = span [m] of the beam i between the inner faces of the hulls

x_i = abscissa, in m, of the beam i with respect to the origin 0

If F_i [N] is the force taken over by the beam i, the deflection y_i [m] of the hull in way of the beam i, is:

$$y_i = \frac{F_i \cdot S_i^3 \cdot 10^{-6}}{12 \cdot E_i \cdot I_i} = \frac{F_i}{r_i} = d_i \cdot \omega$$

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d_i = abscissa [m] of the beam i in relation to G:

= $x_i - a$

ω = rotation angle [rad] of one hull in relation to the other around a transverse axis passing through G

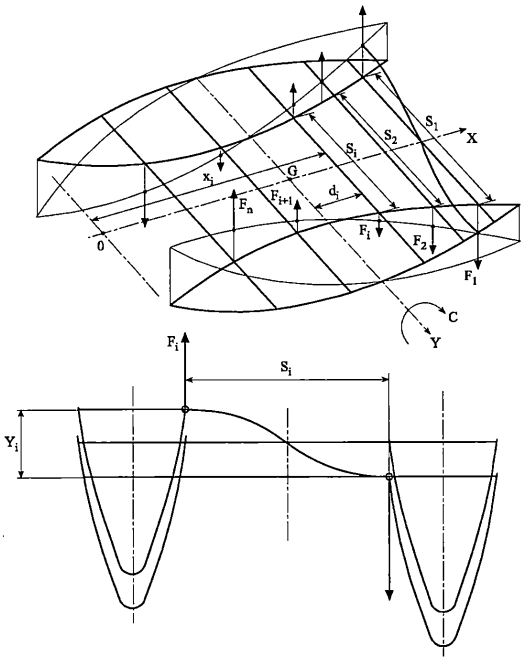

Fig.C3.7.2

.2 From the transverse torsional moment (cf. C3.4.2.4) $M_{tt} = F_i \cdot d_i \, 10^{-3}$, the formula for ω may be obtained:

$$\omega = \frac{M_{tt}}{\sum r_i \cdot d_i^2} \cdot 10^3$$

.3 As M_{tt} , r_i and d_i are known, ω is thus deduced, then the force F_i [N] the bending moment M_i [N·m] and the corresponding normal and shear stresses can be evaluated in each beam:

$$F_i = \omega \cdot r_i \cdot d_i$$

$$M_i = F_i \cdot S_i / 2$$

Note

Beams calculated by the above method are assumed to be fixed in each hull as beams in way of bulkheads inside hulls. For this hypothesis to be correct, the beams are to extend over the whole breadth of both hulls and their stiffness is to be kept the same over the overall span inside and outside the hulls.

C3.7.4 Effective width of plating

C3.7.4.1 Stiffeners

.1 Generally, the spacing of stiffeners (secondary members) may be taken as effective width of plating.

.2 The section modulus of ordinary stiffeners is to be calculated in association with an effective width of plating equal to the spacing of the stiffeners, without exceeding 20 per cent of the span.

C3.7.4.2 Girders

.1 The effective width of plating e_m of frames and girders may be determined according to Table 3.7.1 considering the type of loading.

Table C3.7.1 Effective width e_m of frames and girders

ℓ/e	0	1	2	3	4	5	6	7	8
e_{m1}/e	0	0,36	0,64	0,82	0,91	0,96	0,98	1,00	1,0
e_{m2}/e	0	0,20	0,37	0,52	0,65	0,75	0,84	0,89	0,9

e_{m1} is to be applied where girders are loaded by uniformly distributed loads or else by not less than 6 equally spaced single loads.

e_{m2} is to be applied where girders are loaded by 3 or less single loads.

Intermediate values may be obtained by direct interpolation.

ℓ = length between zero-points of bending moment curve, i.e. unsupported span in case of simply supported girders and 0,6 x unsupported span in case of constraint of both ends of girders

e = width of plating supported, measured from centre to centre of the adjacent unsupported fields

Special calculations may be required for determining the effective breadth of one-sided or non-symmetrical flanges.

.2 The effective cross sectional area of plates is not to be less than the cross sectional area of the face plate.

.3 The effective width of stiffeners and girders subjected to compressive stresses may be determined according to C3.7.5, but is in no case to be taken greater than the effective breadth determined by C3.7.4.2.1.

C3.7.4.3 Cantilevers

Where cantilevers are fitted at every frame, the effective width of plating may be taken as the frame spacing. Where cantilevers are fitted at a greater spacing the effective width of plating at the respective cross section may approximately be taken as the distance of the cross section from the point on which the load is acting, however, not greater than the spacing of the cantilevers.

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C3.7.5 Proof of buckling strength

The buckling strength is to be proved according to the GL Rules Hull Structures (I-1-1), Section 3, F.

C3.7.6 Fatigue

The fatigue strength is to be proved according to the GL Rules Hull Structures (I-1-1), Section 20.

C3.7.7 Plating

C3.7.7.1 Formula

.1 The thickness [mm] required for the purposes of resistance to design pressure, is given by the formula:

$$t = 22,4 \cdot \mu \cdot s \cdot \sqrt{\frac{p}{\sigma_{am}}}$$

Pressure p [kPa] and permissible stress σ_{am} [MPa] are defined in requirements stipulated in C3.7.7.3 to C3.7.7.8 for the various parts of the hull.

.2 Adequate provision is also to be made to limit corrosion. In general, a corrosion allowance of 0,5 mm has been considered in the following formulas. Steel plating of tanks, sea chests and chain lockers are to be increased by an additional 0,5 mm.

.3 In addition, the thicknesses of plating are to be not less than the minimum values given in Table C3.7.2, in general.

.4 Lesser thicknesses than given in Table C3.7.2 may be accepted provided that their adequacy in relation to strength against buckling and collapse is demonstrated to the satisfaction of GL.

Table C3.7.2

Element	Minimum thickness [mm]
Shell plating: – Bottom shell plating – Side shell plating and wet deck plating	 $1,35 \cdot L^{1/3} \geq 2,5$ $1,15 \cdot L^{1/3} \geq 2,5$
Deck plating	2,5
Bulkhead plating	2,5
Deckhouse side shell plating	2,5

C3.7.7.2 Keel

.1 The thickness of keel plating is to be not less than that required for adjacent bottom plating.

.2 This requirement may be waived in the case of special arrangements for dry-docking of craft of unusual hull design in the opinion of GL.

C3.7.7.3 Bottom shell and bilge plating

.1 The minimum required thickness is to satisfy the requirements of the formula in C3.7.7.1 under the following two conditions:

(a) p = impact pressure p_{sl} if occurring on the bottom as defined in C3.5.3;

$\sigma_{am} = 235/k$ [MPa] for steel structures

$= 95/k$ [MPa] for aluminium alloy structures

(b) p = sea pressure p_s as defined in C3.5.5;

$\sigma_{am} = 185/k$ [MPa] for steel structures

$= 85/k$ [MPa] for aluminium alloy structures

.2 The thickness of bilge plating is not, in any case, to be less than that of the bottom and side adjacent, whichever is greater.

.3 The thickness of plates connected to the stern frame, or in way of propeller shaft brackets, is to be at least 1,5 times the thickness of the adjacent plating.

.4 In craft fitted with a bow thruster, the thickness of the connection with the housing of such propeller is to be considered individually by GL.

.5 Sea intakes and other openings are to be well rounded at the corners and located, as far as practicable, well clear of sharp edges.

C3.7.7.4 Plating of side shell and front walls

.1 The minimum required thickness is given by the formula in C3.7.7.1, assuming:

p = sea pressure p_s as defined in C3.5.5, for side shell plating

= sea pressure p_{sf} as defined in C3.5.6, for front wall plating

$\sigma_{am} = 185/k$ [MPa] for steel structures

$= 85/k$ [MPa] for aluminium alloy structures

.2 The thickness of the sheerstrake is to be not less than that of the side or stringer plate.

3 At the ends of deckhouses, the thickness of the sheerstrake is to be suitably increased.

.4 Where side scuttles or windows or other openings are located on the sheerstrake, the thickness is to be increased to compensate for the openings.

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C3.7.7.5 Plating of wet deck and internal sides of catamaran

.1 The minimum required thickness for the wet deck plating is given by the formula in C3.7.7.1, assuming:

(a) p = impact pressure p_{sl} as defined in C3.5.4;

σ_{am} = 235/k [MPa] for steel structures
= 95/k [MPa] for aluminium alloy structures

(b) p = sea pressure p_s as defined in C3.5.5;

σ_{am} = 185/k [MPa] for steel structures
= 85/k [MPa] for aluminium alloy structures

.2 Moreover, the thickness of internal sides, may be intermediate between that of the bottom of hulls and the bottom of the wet deck. In any case, it is to be no less than that required in C3.7.7.4 for external sides.

C3.7.7.6 Deck plating

.1 The minimum required thickness is given by the formula in C3.7.7.1, assuming:

p = deck pressure p_d as defined in C3.5.8;

σ_{am} = 185/k [MPa] for steel structures
= 85/k [MPa] for aluminium alloy structures

The thickness of areas of watertight decks or flats forming steps in watertight bulkheads or the top or the bottom of a tank is also to comply with the provisions of C3.7.11 and C3.7.12.

.2 Thickness of decks for wheel loading

.2.1 The thickness of deck plating for wheel loading is to be determined by the following formula:

$t = c \cdot f_M (P \cdot k)^{0,5}$ [mm]

P = static load [kN] of one wheel or group of wheels on a plate panel s · b considering the acceleration factor $(1 + 0,4\ a_v)$, a_v defined in Section C3.3

f_M = 1,0 for steel
= 1,46 for aluminium

c = factor according to the following formulae:

for the aspect ratio b/s = 1:

for the range 0 < f/F < 0,3:

$$c = 1,87 - \sqrt{\frac{f}{F}\left(3,4 - 4,4\frac{f}{F}\right)}$$

for the range 0,3 ≤ f/F ≤ 1,0:

$$c = 1,20 - 0,40\ f/F$$

for the aspect ratio b/s ≥ 2,5:

for the range 0 < f/F < 0,3:

$$c = 2,0 - \sqrt{\frac{f}{F}\left(5,2 - 7,2\frac{f}{F}\right)}$$

for the range 0,3 ≤ f/F ≤ 1,0:

$$c = 1,20 - 0,517\ f/F$$

For intermediate values of b/s the factor c is to be obtained by direct interpolation.

f = print area of wheel or group of wheels

F = area of plate panel s · b according to Fig. C3.7.3

s = width of smaller side of plate panel (in general beam spacing)

b = width of larger side of plate panel

F need not be taken greater than 2,5 s^2

In case of narrowly spaced wheels these may be grouped together to one wheel print area.

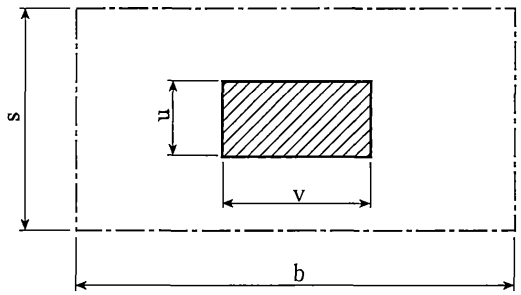

Fig. C3.7.3

.2.2 Where the wheel print area is not known, it may approximately be determined as follows:

$f = 100 \cdot P/p$ [cm^2]

p = specific wheel pressure according

.2.3 In deck beams and girders, the stress is not to exceed 165/k [MPa] for steel structures or 75/k [MPa] for aluminium structures respectively.

C3.7.7.8 Plating of deckhouse walls

.1 The minimum required thickness is given by the formula in C3.7.7.1, assuming:

p = sea pressure p_{su} as defined in C3.5.7;

σ_{am} = 185/k [MPa] for steel structures
= 85/k [MPa] for aluminium alloy structures

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.2 Openings (doors, windows) are to be well rounded at the corners.

.3 Where there is no access from inside deckhouses to 'tween-decks below or where one of the boundary walls concerned is in a particularly sheltered position, reduced scantlings compared with those above may be accepted, at the discretion of GL.

C3.7.8 Ordinary stiffeners

C3.7.8.1 General

.1 In the following the requirements are given to be complied with for ordinary stiffeners of the bottom, sides, decks and, for catamaran, the wet deck and internal sides.

.2 The section modulus Z [cm^3] and the shear area A_t [cm^2] required for the purpose of supporting the design pressure transmitted by the plating, are given by the following formulae:

$$Z = 1000 \cdot \frac{\ell^2 \cdot s \cdot p}{m \cdot \sigma_{am}}$$

$$A_t = 5 \cdot \frac{\ell \cdot s \cdot p}{\tau_{am}}$$

where m is a coefficient depending on the type of stiffener. The values of m are indicated in Table C3.7.4.

The pressure p [kPa] and allowable stresses σ_{am} and τ_{am} [MPa] are defined in C3.7.8.2 to C3.7.8.6 for the various regions of the hull.

Table C3.7.4 Coefficient m

Type of stiffener	m
Continuous stiffeners	12
Non-continuous stiffeners and without brackets at the end of span	8

.3 These formulae are valid for stiffeners whose web is perpendicular to the plating, or forms an angle to the plating of less than 15°.

In the case of stiffeners whose web forms an angle $\alpha > 15°$ to the perpendicular to the plating, the required modulus and shear area may be obtained from the same formulae, dividing the values of Z and A_t by cos (α).

.4 For steel stiffeners, the web thickness is to be not less than:

- 1/18 of the depth, for flat bars
- 1/50 of the depth, for other sections

and the thickness of the face plate is to be not less than 1/15 of its width.

.5 For aluminium alloy stiffeners, the web thickness is to be not less than:

- 1/15 of the depth, for flat bars
- 1/35 of the depth, for other sections

and the thickness of the face plate is to be not less than 1/20 of its width.

.6 In general, the resistant weld section A_w [cm^2] connecting the ordinary stiffeners to the web of primary members, is not to be less than:

$$A_w = \varphi \cdot p \cdot s \cdot \ell \cdot k \cdot 10^{-3}$$

φ = coefficient as indicated in Table C3.7.5

p = design pressure [kPa] acting on the secondary stiffeners, defined below for various hull regions

s = spacing of ordinary stiffeners [m]

ℓ = span of ordinary stiffeners [m]

k = greatest material factor of ordinary stiffener and primary member, defined in C3.2

Table C3.7.5 Coefficient φ

Case	Weld	Aluminium alloy	Steel
1	Parallel to the reaction exerted on primary member	200	100
2	Perpendicular to the reaction exerted on primary member	160	75

.7 For aluminium alloys, when calculating the resistant connecting weld section, the fillet weld length d_e [mm] is determined as follows (see cases 1 and 2 in Table C3.7.5):

case 1 : $d_e = l - 10$,

where l is the length of the weld [mm]

case 2 : for extruded T stiffeners, the lesser of:

$d_e = b - 10$ and $d_e = 4\ t$,

where b [mm] is the flange width of the ordinary stiffener and t [mm] is the web thickness of the primary member.

C3.7.8.2 Bottom and bilge stiffeners

.1 Both single and double bottoms are generally to be longitudinally framed.

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.2 The section modulus, shear area and welding section required for bottom and bilge stiffeners are given by the formulae in C3.7.8.1, assuming:

(a) p = impact pressure p_{sl} if occurring on the bottom as defined in C3.5.3;

For steel structures:

$\sigma_{am} = 150/k$ [MPa]

$\tau_{am} = 90/k$ [MPa]

For aluminium alloy structures:

$\sigma_{am} = 70/k$ [MPa]

$\tau_{am} = 45/k$ [MPa]

(b) p = sea pressure p_s as defined in C3.5.5;

For stiffeners contributing to the longitudinal strength:

– steel structures:

$\sigma_{am} = 150\ C_S/k$ [MPa]

$\tau_{am} = 90/k$ [MPa]

– aluminium alloy structures:

$\sigma_{am} = 70\ C_A/k$ [MPa]

$\tau_{am} = 45/k$ [MPa]

For stiffeners not contributing to the longitudinal strength:

– steel structures:

$\sigma_{am} = 150/k$ [MPa]

$\tau_{am} = 90/k$ [MPa]

– aluminium alloy structures:

$\sigma_{am} = 70/k$ [MPa]

$\tau_{am} = 45/k$ [MPa]

where C_S and C_A are given by Table C3.7.6.

.3 Bottom longitudinals are preferably continuous through the transverse elements. Where they are interrupted at a transverse watertight bulkhead, continuous brackets are to be positioned through the bulkhead so as to connect the ends of longitudinals.

C3.7.8.3 Side and front wall stiffeners

.1 The section modulus, shear area and welding section are given by the formulae in C3.7.8.1, assuming:

p = sea pressure p_s as defined in C3.5.5, for side stiffeners

= sea pressure p_{sf} as defined in C3.5.6, for front wall stiffeners

For side stiffeners contributing to the longitudinal strength:

– steel structures:

$\sigma_{am} = 150\ C_S/k$ [MPa]

$\tau_{am} = 90/k$ [MPa]

– aluminium alloy structures:

$\sigma_{am} = 70\ C_A/k$ [MPa]

$\tau_{am} = 45/k$ [MPa]

For side stiffeners not contributing to the longitudinal strength and front wall stiffeners:

– steel structures:

$\sigma_{am} = 150/k$ [MPa]

$\tau_{am} = 90/k$ [MPa]

– aluminium alloy structures:

$\sigma_{am} = 70/k$ [MPa]

$\tau_{am} = 45/k$ [MPa]

where C_S and C_A are given by Table C3.7.6.

C3.7.8.4 Stiffeners of wet deck and internal sides of catamaran

.1 The section modulus, shear area and welding section required for bottom stiffeners of the wet deck are given by the formulae in C3.7.8.1, assuming:

(a) p = impact pressure p_{sl} if occurring on the bottom as defined in C3.5.4;

For steel structures:

$\sigma_{am} = 180/k$ [MPa]

$\tau_{am} = 90/k$ [MPa]

For aluminium alloy structures:

$\sigma_{am} = 85/k$ [MPa]

$\tau_{am} = 45/k$ [MPa]

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(b) p = sea pressure p_s as defined in C3.5.5;

For stiffeners contributing to the longitudinal strength:

- steel structures:

  $\sigma_{am} = 150\ C_S/k$ [MPa]

  $\tau_{am} = 90/k$ [MPa]

- aluminium alloy structures:

  $\sigma_{am} = 70\ C_A/k$ [MPa]

  $\tau_{am} = 45/k$ [MPa]

For stiffeners not contributing to the longitudinal strength:

- steel structures:

  $\sigma_{am} = 150/k$ [MPa]

  $\tau_{am} = 90/k$ [MPa]

- aluminium alloy structures:

  $\sigma_{am} = 70/k$ [MPa]

  $\tau_{am} = 45/k$ [MPa]

where C_S and C_A are given by Table C3.7.6.

.2 Internal side stiffeners may have characteristics intermediate between those of the bottom of the hull and those of the bottom of the wet deck. In any case, such characteristics are not to be less than those required in C3.7.8.3 for external sides.

C3.7.8.5 Deck stiffeners

.1 The section modulus, shear area and welding section are given by the formulae in C3.7.8.1, assuming:

p = deck pressure p_d as defined in C3.5.8

For stiffeners contributing to the longitudinal strength:

- steel structures:

  $\sigma_{am} = 150\ C_S/k$ [MPa]

  $\tau_{am} = 90/k$ [MPa]

- aluminium alloy structures:

  $\sigma_{am} = 70\ C_A/k$ [MPa]

  $\tau_{am} = 45/k$ [MPa]

For side stiffeners not contributing to the longitudinal strength:

- steel structures:

  $\sigma_{am} = 150/k$ [MPa]

  $\tau_{am} = 90/k$ [MPa]

- aluminium alloy structures:

  $\sigma_{am} = 70/k$ [MPa]

  $\tau_{am} = 45/k$ [MPa]

where C_S and C_A are given by Table C3.7.6.

.2 Where longitudinals are interrupted in way of watertight bulkheads or reinforced transverse structures, the continuity of the structure is to be maintained by means of brackets penetrating the transverse element. GL may allow double brackets welded to the transverse element, provided that special provision is made for the alignment of longitudinals.

C3.7.8.6 Stiffeners of boundary walls of deckhouses

.1 The section modulus, shear area and welding section are given by the formulae in C3.7.8.1, assuming:

p = sea pressure p_{su} as defined in C3.5.7

- steel structures:

  $\sigma_{am} = 150/k$ [MPa]

  $\tau_{am} = 90/k$ [MPa]

- aluminium alloy structures:

  $\sigma_{am} = 70/k$ [MPa]

  $\tau_{am} = 45/k$ [MPa]

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Table C3.7.6 Coefficient C_S and C_A

L	x/L	Steel structures C_S [1]	Aluminium alloy structure C_A [1]
$L \le 24$ m	$0 \le x/L \le 1$	1	1
$L > 24$ m [2]	$0 \le x/L \le 1$	$1,4-\frac{1}{e}$	$1,3-\frac{1}{e}$
Alternative method for $24 \text{ m} < L \le 65$ m [3]	$x/L < 1$	1	1
	$0,1 < x/L \le 0,3$	$1+0,5\cdot\left(0,4-\frac{1}{e}\right)\cdot\left(10\cdot\frac{x}{L}-1\right)$	$1+0,5\cdot\left(0,3-\frac{1}{e}\right)\cdot\left(10\cdot\frac{x}{L}-1\right)$
	$0,3 < x/L < 0,7$	$1,4-\frac{1}{e}$	$1,3-\frac{1}{e}$
	$0,7 \le x/L \le 0,9$	$1-0,5\cdot\left(0,4-\frac{1}{e}\right)\cdot\left(10\cdot\frac{x}{L}-9\right)$	$1-0,5\cdot\left(0,3-\frac{1}{e}\right)\cdot\left(10\cdot\frac{x}{L}-9\right)$
	$0,9 < x/L \le 1$	1	1

[1] In these formulae, the values of C_S and C_A are to be taken less than or equal to 1.

[2] The ratio e is to be calculated at the location x, on basis of bending moments distribution defined in C3.4.1 and C3.4.2.

[3] The ratio e is to be calculated at the section comprised between $0,3 \cdot L$ and $0,7 \cdot L$ at which e takes the highest value.

.2 Any front or side wall vertical stiffeners of first tier deckhouses are to be connected, by means of brackets at the ends, to strengthening structures for decks or adjacent sides.

.3 In general, reinforced stiffeners are to be fitted on the edges of large openings in the plating. They are to be scarphed into the area outside of openings. The openings for doors are, in general, to be stiffened all the way round.

C3.7.9 Primary supporting members

C3.7.9.1 General

.1 In the following the requirements are given to be complied with for primary supporting members of the bottom, sides, decks and, for catamaran, the wet deck.

.2 The primary supporting members (floors, frames, beams) are to form continuous transverse frames. In general, the stiffened frame spacing [mm] is not to exceed:

$$1200 + 10 \cdot L$$

without being greater than 2 m.

Primary supporting members with spacing other than that defined above may be required for specific parts of the hull (e.g. machinery space, under pillars), as stipulated in the provisions below.

.3 The section modulus Z [cm^3] and shear area A_t [cm^2] required to support the design pressure transmitted by the ordinary stiffeners are given by the following formulae:

$$Z = 1000 \cdot \frac{S^2 \cdot b \cdot p}{m \cdot \sigma_{am}}$$

$$A_t = 5 \cdot \frac{S \cdot b \cdot p}{\tau_{am}}$$

m = coefficient which depends on support conditions at the ends of the girder span, generally assumed to be:

= 10, in general

= 8, if one end condition is to be regarded as simply supported, at least

= 12, if the bending stiffness of both supporting structures are considerably higher than for this girder

The pressure p [kPa] and allowable stresses σ_{am} and τ_{am} [MPa] are defined in C3.7.9.2 to C3.7.9.6 for various parts of the hull.

.4 The above formulae are applicable where reinforced structures are not of the grillage type. Otherwise, the scantlings of reinforced structures are to be stipulated by means of direct calculations performed on the basis of criteria agreed upon with GL.

.5 The section modulus of primary supporting members is to be calculated in association with an attached plating, according to criteria according to C3.7.4 to C3.7.6.

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.6 For steel stiffeners, the following geometric ratios are to be satisfied:

- The web thickness is to be not less than 1/80 of web depth.
- The face plate thickness is to be not less than 1/30 of face plate breadth (1/15 for face plates which are not symmetrical with respect to the web).

.7 For aluminium stiffeners, the following geometric ratios are to be satisfied, where the compressive stress is not known:

- The web thickness is to be not less than 1/35 of web depth.
- The face plate thickness is to be not less than 1/20 of face plate breadth (1/10 for face plates which are not symmetrical with respect to the web).

.8 Particular attention is to be paid to compressive buckling strength of associated plating of transverse primary members.

C3.7.9.2 Floors and girders of single bottom

.1 The section modulus and shear area are given by the formulae in C3.7.9.1 for the following two conditions:

(a) p= impact pressure p_{sl} if occurring on the bottom as defined in C3.5.3;

For steel structures:

$\sigma_{am} = 150/k$ [MPa]

$\tau_{am} = 90/k$ [MPa]

For aluminium alloy structures:

$\sigma_{am} = 70/k$ [MPa]

$\tau_{am} = 45/k$ [MPa]

(b) p = sea pressure p_S as defined in C3.5.5;

- steel floors:

  $\sigma_{am} = 150/k$ [MPa]

  $\tau_{am} = 90/k$ [MPa]

- aluminium alloy floors:

  $\sigma_{am} = 70/k$ [MPa]

  $\tau_{am} = 45/k$ [MPa]

- steel girders:

  $\sigma_{am} = 150\ C_S/k$ [MPa]

  $\tau_{am} = 90/k$ [MPa]

- aluminium alloy girders:

  $\sigma_{am} = 70\ C_A/k$ [MPa]

  $\tau_{am} = 45/k$ [MPa]

where C_S and C_A are given by Table C3.7.6.

.2 Floors are to be positioned in way of side and deck transverses. Intermediate floors may also be fitted provided that they are adequately connected at the ends.

.3 Manholes and other openings are not to be located at the ends of floor or girder spans, unless shear stress checks are carried out in such areas.

.4 Floors are to be fitted in machinery spaces, generally at every frame, and additional stiffeners are to be provided at bottom in way of machinery and pillars.

.5 In way of main machinery seatings, girders are to be positioned extending from the bottom to the foundation plate of main engines.

.6 A girder is, generally, to be fitted centreline for dry-docking. The height of such a girder is to be not less than that of floors amidships and the thickness less than the value t [mm] obtained from the formula:

$t = (0,05 \cdot L + 2) \cdot k^{0,5}$ for steel

$= (0,07 \cdot L + 2,5) \cdot k^{0,5}$ for aluminium alloys

In hulls with a longitudinally framed bottom and width B > 8 m, side girders are also to be positioned in such a way as to divide the floor span into approximately equal parts. In catamaran, B is to be taken as the width of a single-hull. The thickness of the web may be assumed to be equal to that of the centre girder less 1 mm, and the area of the face plate may be reduced to 60 % of that of the centre girder. Where side girders are intended to support floors, a structural check of their scantlings is to be carried out as deemed necessary by GL.

C3.7.9.3 Primary supporting members of sides and front walls

.1 The section modulus and shear area are given by the formulae in C3.7.9.1, assuming:

p = sea pressure p_{sf} as defined in C3.5.5, for primary members of side

= sea pressure p_{sf} as defined in C3.5.6, for primary members of front walls

- steel structures:

  $\sigma_{am} = 150/k - \sigma_a$ [MPa]

  $\tau_{am} = 90/k$ [MPa]

- aluminium alloy structures:

  $\sigma_{am} = 70/k - \sigma_a$ [MPa]

  $\tau_{am} = 45/k$ [MPa]

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σ_a being the stress induced by the normal force in side transverses due to deck loads transmitted by deck beams.

C3.7.9.4 Primary supporting members of the wet deck and internal sides of catamaran

.1 The required section modulus and shear area are given by the formulae in C3.7.9.1 for the following two conditions:

(a)

p = impact pressure p_{sl} as defined in C3.5.4:

– steel structures:

$\sigma_{am} = 180/k$ [MPa]

$\tau_{am} = 90/k$ [MPa]

– aluminium alloy structures:

$\sigma_{am} = 85/k$ [MPa]

$\tau_{am} = 45/k$ [MPa]

Additional intermediate frames are to be provided forward of 0,8L. The required section modulus and shear area is not to be less than 70 % of the required values according to the slamming pressure considering the main frame spacing.

(b)

p = sea pressure p_d as defined in C3.5.8

– steel structures:

$\sigma_{am} = 150/k$ [MPa]

$\tau_{am} = 90/k$ [MPa]

– aluminium alloy structures:

$\sigma_{am} = 70/k$ [MPa]

$\tau_{am} = 45/k$ [MPa]

C3.7.9.5 Primary supporting members of decks

.1 The required section modulus and shear area are given by the formulae in C3.7.9.1 for the following two conditions:

p = deck pressure p_d as defined in C3.5.8

– steel deck transverses:

$\sigma_{am} = 150/k$ [MPa]

$\tau_{am} = 90/k$ [MPa]

– aluminium alloy deck transverses:

$\sigma_{am} = 70/k$ [MPa]

$\tau_{am} = 45/k$ [MPa]

– steel deck girders:

$\sigma_{am} = 150\ C_S/k$ [MPa]

$\tau_{am} = 90/k$ [MPa]

– aluminium alloy deck girders:

$\sigma_{am} = 70\ C_A/k$ [MPa]

$\tau_{am} = 45/k$ [MPa]

where C_S and C_A are given by Table C3.7.6.

.2 When there are concentrated loads of significant magnitude (e.g. transmitted by pillars or other primary members or due to the carriage of vehicles), deck girders are to be adequately strengthened.

C3.7.9.6 Primary supporting members of deckhouse boundary walls

.1 The section modulus and shear area are given by the formulae in C3.7.9.1, assuming:

p = sea pressure p_{su} as defined in C3.5.7

– steel structures:

$\sigma_{am} = 150/k$ [MPa]

$\tau_{am} = 90/k$ [MPa]

– aluminium alloy structures:

$\sigma_{am} = 70/k$ [MPa]

$\tau_{am} = 45/k$ [MPa]

C3.7.10 Pillars

.1 General

.1.1 Structural members at heads and heels of pillars as well as substructures are to be constructed according to the forces they are subjected to.

Where pillars are affected by tension loads doublings are not permitted.

.1.2 Pillars in tanks are to be checked for tension. Tubular pillars are not permitted in tanks for flammable liquids.

.1.3 For structural elements of the pillars' transverse section, sufficient buckling strength according to C3.7.5 has to be verified. The wall thickness of tubular pillars which may be expected to be damaged during loading and unloading operations is not to be less than:

$t_w = 4,5 + 0,015\ d_a$ [mm] for $d_a \leq 300$ mm

$= 0,03\ d_a$ [mm] for $d_a > 300$ mm

.1.4 Pillars also loaded by bending moments have to be specially considered.

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.2 Scantlings

The sectional area of pillars is not to be less than:

$$A_{s\,req} = 10 \cdot \frac{P_s}{\sigma_p} \quad [cm^2]$$

σp = permissible compressive stress [MPa]

$$= \frac{\kappa}{S'} \cdot R_{eH}$$

S' = safety factor

= 2,00 in general

= 1,66 in accommodation area, for steel pillar, only

κ = reduction factor

$$= \frac{1}{\phi + \sqrt{\phi^2 - \lambda_s^2}}$$

$$\phi = 0,5 \left[1 + n_p \left(\lambda_s - \lambda_0\right) + \lambda_s^2\right]$$

for steel:

λ_0 = 0,2

n_p = 0,34 for tubular and rectangular pillars

= 0,49 for open sections

for aluminium without heat treatment (i.e. 5000 series):

λ_0 = 0,0

n_p = 0,32

for aluminium with heat treatment (i.e. 6000 series):

λ_0 = 0,1

n_p = 0,20

λ_s = degree of slenderness of the pillar

$$= \frac{\ell_s}{i_s \cdot \pi} \sqrt{\frac{R_{eH}}{E}} \geq \lambda_0$$

l_s = length of the pillar [cm]

R_{eH} = nominal yield point or $R_{p0,2}$ for aluminium alloy [MPa]

E = Young's modulus [MPa]

i_s = minimum radius of gyration [cm] of the pillar cross section

$$= \sqrt{\frac{I}{A}}$$

= 0,25 d_s for solid pillars of circular cross section

= 0,25 $(d_a^2 + d_i^2)^{0,5}$ for tubular pillars

I_s = minimum moment of inertia [cm^4] of the pillar cross section

A = sectional area of the pillar [cm^2]

d_s = pillar diameter [cm]

d_a = outside diameter of pillar [cm]

d_i = inside diameter of pillar [cm]

C3.7.11 Bulkhead Structures

.1 Proof of buckling strength of longitudinal and transverse bulkhead structures is to be carried out according to C3.7.5. For longitudinal bulkheads the global design stresses and the stresses due to local loads are to be considered.

C3.7.11.1 Plating

.1 The thickness of the bulkhead plating [mm] is not to be less than:

$$t = 22,4 \cdot f_m \cdot \mu \cdot s \cdot \sqrt{\frac{p_{sb}}{\sigma_{am}}}$$

f_m = coefficient depending on the material

= 0,75 for steel structures

= 0,70 for aluminium alloy structures

p_{sb} = design pressure [kPa] as defined in C3.5.6

σ_{am} = 235/k [MPa] for steel structures

= 95/k [MPa] for aluminium alloy structures

.2 The stern tube bulkhead is to be provided with a strengthened plate in way of the stern tube.

.3 In areas where concentrated loads due to ship manoeuvres at terminals may be expected, the buckling strength of bulkhead plate fields directly attached to the side shell, is to be examined.

C3.7.11.2 Stiffeners and girders

.1 The required scantlings of stiffeners and girders are determined according to strength calculations, by applying the following permissible stress values :

– for steel structures:

σ_{am} = 200/k [MPa]

τ_{am} = 120/k [MPa]

σ_{vM} = 220/k [MPa]

– for aluminium alloy structures:

σ_{am} = 90/k [MPa]

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τ_{am} = 55/k [MPa]

σ_{vM} = 95/k [MPa]

.2 The buckling strength of the webs is to be checked according to C3.7.5

.3 Bulkhead stiffeners cut in way of watertight doors are to be supported by carlings or stiffeners.

.4 In areas with cut-outs secondary bending of the plate strips beneath the cut-out shall be taken into account for girders.

C3.7.11.3 Corrugated Bulkheads

.1 The plate thickness of corrugated bulkheads is not to be less than required according to C3.7.11.1

For the spacing s [m] the greater one of the values b or c according to C3.7.11.3.3 is to be taken.

.2 The section modulus of a corrugated bulkhead element is to be determined according to C3.7.11.2.

.3 The actual section modulus [cm^3] of a corrugated bulkhead element is to be assessed according to the following formula:

$$W_c = d \cdot t \cdot (3 \cdot b + c) / 6000$$

where the symbols are as shown in Figure C3.7.6 and are expressed in mm. In no case is the angle φ to be less than 45°.

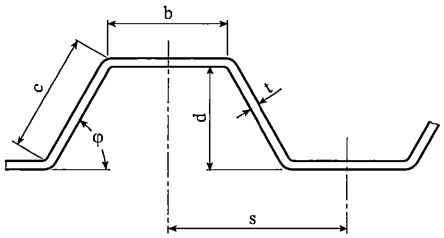

Fig. C3.7.6

C3.7.12 Tank Structures

.1 General

If the boundaries of tanks are formed by integrated structural elements of the ship, their dimensioning has to follow the definitions in the sections for the relevant parts. The requirements of this section have to be observed additionally.

For independent tanks the minimum thickness is 2,5 mm in general.

.2 Plating

The plate thickness, in mm, is not to be less than:

$$t = 22,4 \cdot f_m \cdot \mu \cdot s \cdot \sqrt{\frac{p_t}{\sigma_{am}}} + t_k$$

f_m = coefficient depending on the material
= 0,80 for steel structures
= 0,75 for aluminium alloy structures

p_t = design pressure [kPa] as taken the maximum value of p_{t1} and p_{t2}, as defined in C3.5.7.7

σ_{am} = 185/k [MPa] for steel structures

σ_{am} = 85/k [MPa] for aluminium alloy structures

The corrosion allowance t_k for steel plates is not less than 0,5 mm, for aluminium plates t_k = 0 mm.

.3 Stiffeners and girders

The required scantlings of stiffeners and girders are determined according to strength calculations, by applying the following permissible stress values :

– if subjected to load p_{t1}:

steel structures

σ_{am} = 150/k [MPa]

τ_{am} = 90/k [MPa]

σ_{vM} = 180/k [MPa]

aluminium alloy structures:

σ_{am} = 70/k [MPa]

τ_{am} = 45/k [MPa]

σ_{vM} = 85/k [MPa]

– if subjected to load p_{t2}:

steel structures

σ_{am} = 180/k [MPa]

τ_{am} = 115/k [MPa]

σ_{vM} = 200/k [MPa]

aluminium alloy structures:

σ_{am} = 80/k [MPa]

τ_{am} = 50/k [MPa]

σ_{vM} = 90/k [MPa]

The buckling strength of the webs is to be checked according to C3.7.5

C3.7.13 Bow, Shell Side and Stern Doors

C3.7.13.1 Plating

.1 The required thickness, in mm, is given by the following formula:

$$t = 22,4 \cdot \mu \cdot s \cdot \sqrt{\frac{p_s}{\sigma_{am}}}$$

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p_s = design pressure [kPa] as defined in C3.5.5.2.1,

σ_{am} = 185/k [MPa] for steel structures

= 85/k [MPa] for aluminium alloy structures

C3.7.13.2 Ordinary stiffeners

.1 The section modulus, shear area and welding section required for ordinary stiffeners are given by the formulae in C3.7.8.1, assuming:

p = design pressure p_s as defined in C3.5.5.2.1,

m = coefficient depending on the type of stiffener and support conditions at the ends of the stiffener span, to be taken according to Table C3.7.4,

– steel structures:

σ_{am}= 150/k [MPa]

τ_{am}= 90/k [MPa]

– aluminium alloy structures:

σ_{am}= 70/k [MPa]

τ_{am}= 45/k [MPa]

C3.7.13.3 Primary members, securing and supporting devices

.1 The scantlings of the primary members, securing and supporting devices of side shell doors and stern doors are to be determined to withstand the design loads defined in C3.5.5.2.2 and C3.5.5.2.3, using the following permissible stresses, where k is the material factor defined in C3.2.2 for steel (not to be taken less than 0,72) or in C3.2.3.3 for aluminium alloys:

σ_{am} = bending stress

= 120/k [MPa] for steel structures

= 55/k [MPa] for aluminium alloy structures

τ_{am} = shear stress

= 80/k [MPa] for steel structures

= 35/k [MPa] for aluminium alloy structures

σ_{vM} = 150/k [MPa] for steel structures

= 70/k [MPa] for aluminium alloy structures

C3.8 Fibre-reinforced Plastic Craft

C3.8.1 General

The subsequent requirements are applicable under the following conditions, which are subject to update/amendment:

– Loads and design pressures are of "maximum service loads" character, as defined in relevant GL Rules. Possible reductions on particularly "rare loading" scenarios such as pressure loading on watertight bulkheads have not been implemented and yet should be handled case by case.

– The following methodology typically applies to orthogonal structured components with a clear hierarchy of structural members. Where this condition is not fulfilled, more comprehensive investigations will have to apply, e.g. grillage analysis.

– The orthogonal structured components are assumed to have constant structural and material properties along their length, respectively. If this is not the case, the locations of highest bending moment and shear force can vary from the general assumptions within this section and thus need to be treated specifically (e.g. stiffener or girder with varying height or laminate).

C3.8.2 Elasto-mechanical properties of laminated structures

C3.8.2.1 Nomenclature:

ψ = mass content of reinforcing material in a laminate

φ = volume content of reinforcement material in a laminate

E_{11} = Young's modulus of a single ply with unidirectional fibres, parallel to fibres

E_{22} = Young's modulus of a single ply with unidirectional fibres, perpendicular to fibres

ν_{12}, ν_{21} = Poisson's ratios of a single ply

G_{12} = shear modulus of a single ply

ρ_f = specific gravity of fibre material

ρ_m = specific gravity of matrix material

E_{fL} = Young's modulus of fibre in fibre direction

E_{fT} = Young's modulus of fibre transverse to fibre direction

E_m = Young's modulus of matrix

ν_{f12} = Poisson's ratio of fibre

ν_m = Poisson's ratio of resin

G_m = shear modulus of the matrix

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G_f = shear modulus of the fibre

E_x = Young's modulus of a ply, multiply or laminate in x-direction of global laminate co-ordinate system

E_y = Young's modulus of a ply, multiply or laminate in y-direction of global laminate co-ordinate system

G_{xy} = shear modulus of a ply, multiply or laminate in xy-direction of global laminate co-ordinate system

Θ = angle of inclination/transformation from local ply coordinate system (1, 2 coordinates) to global laminate coordinate system (x, y coordinates), see Fig. 3.8.1

laminate = is a general expression for a structural unity, a composition of structural fibres, laid down in a polymer matrix. A laminate may contain a sandwich core or other constituents for achieving certain mechanical purposes.

layer types:

ply = In the definition of these Rules, a ply is one laminated layer containing fibre reinforcements aligned in one direction only (unidirectional) or one layer of isotropic or quasi-isotropic material (CSM)

multiply = A multiply is consisting of a limited number of plies of different alignments (e.g. laminated fabrics, such as bi-axial, tri-axial, quad-axial, in woven or stiched arrangement, or as pre-preg).

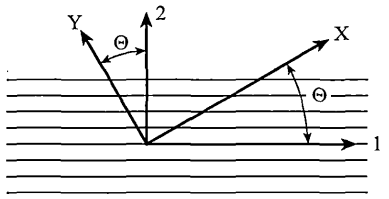

Fig. C3.8.1 Local single ply and global laminate coordinate systems

C3.8.2.2 Basic single ply analysis

.1 Fibre content by volume

The fibre volume fraction of a laminate is determined by the formula:

$$\varphi = \frac{\psi}{\psi + (1-\psi)\cdot\frac{\rho_f}{\rho_m}}$$

The thickness $t_{i,ply}$ of a single ply is then derived as:

$$t_{i,ply} = m_{fi}\cdot\left(\frac{1}{\rho_f} + \frac{1-\psi_i}{\psi_i\cdot\rho_m}\right)$$

m_{fi} = single ply areal weight of fibre reinforcements

ψ_i = fibre mass fraction of single ply

.2 Basic ply stiffness properties

A single unidirectional laminated ply consists of long fibres, oriented in one direction, embedded in a polymeric matrix. Typical fibre materials are E-glass, aramid or carbon. Representative material properties of fibre and matrix materials can be found in Table C3.8.1.

Table C3.8.1 Constituent materials properties

			Fibres				Matrices	
			E-Glass	Aramid	HS Carbon	HM Carbon	Polyester	Epoxy
Specific gravity		[g/cm³]	2,54	1,44	1,74	1,81	1,2	1,2
Young's Modulus	parallel to fibres	[MPa]	73000	124000	230000	392000	3000	3600
	perpendicular to fibres	[MPa]	73000	6900	28000	15000		
Shear Modulus		[MPa]	30000	2800	50000	28600	1140	1330
Poisson's ratio		–	0,18	0,36	0,23	0,20	0,316	0,35

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The following values are derived for plies containing unidirectional fibres. From those, the properties of multiaxially aligned laminated plies may be derived, see C3.8.2.1.3 and C3.8.2.1.4. Chopped strand mats are considered separately in C3.8.2.1.5.

a) Longitudinal Young's modulus:

$$E_{11} = \varphi \cdot E_{fL} + (1-\varphi) \cdot E_m$$

b) Transverse Young's modulus:

$$E_{22} = \frac{E_m}{1-\nu_m^2} \cdot \frac{1+0.85 \cdot \varphi^2}{(1-\varphi)^{1.25} + \varphi \cdot \frac{E_m}{E_{fT} \cdot (1-\nu_m^2)}}$$

c) Poisson's ratios:

$$\nu_{12} = \varphi \cdot \nu_{f12} + (1-\varphi) \cdot \nu_m$$

$$\nu_{21} = \nu_{12} \cdot \frac{E_{22}}{E_{11}}$$

d) Shear modulus:

$$G_{12} = G_m \cdot \frac{1+0.8 \cdot \varphi^{0.8}}{(1-\varphi)^{1.25} + \frac{G_m}{G_{f12}} \cdot \varphi}$$

$$G_m = \frac{E_m}{2 \cdot (1+\nu_m)}$$

.3 Stiffness properties of chopped strand mat

The Young's modulus of a chopped strand mat (CSM) laminate can be calculated as:

$$E_{CSM} = \frac{3}{8} \cdot E_{11} + \frac{5}{8} \cdot E_{22}$$

$$G_{CSM} = \frac{E_{CSM}}{2 \cdot (1+\nu_{CSM})}$$

with E_{11} and E_{22} determined like for a basic single unidirectional layer with fibre volume content appropriate for CSM.

C3.8.2.3 Single ply stiffness

The representative stiffness values for a single ply that is part of a multiply fabric or a laminate is derived in three steps. Firstly the stiffness matrix Q is computed for each ply from its engineering constants in the local coordinate system (ref. C3.8.2.3.1). In a second step, the stiffness matrix Q is transformed to the global coordinate system, resulting in the transformed stiffness matrix Q´ (ref. C3.8.2.3.2). From this, the engineering constants of each ply in the global laminate coordinate system are determined in a third step (see C3.8.2.4).

.1 Stiffness matrix of single ply in local coordinate system

The components of the stiffness matrix are determined for an orthotropic ply, which is part of a non-woven or woven fabric and are calculated as follows:

$$Q11 = \frac{E_{11}}{(1-\nu_{12} \cdot \nu_{21})}$$

$$Q12 = \frac{\nu_{21} \cdot E_{11}}{(1-\nu_{12} \cdot \nu_{21})}$$

$$Q22 = \frac{E_{22}}{(1-\nu_{12} \cdot \nu_{21})}$$

$$Q33 = G_{12} \cdot a$$

$$Q21 = Q12$$

Q = Stiffness matrix of orthotropic layer in local ply coordinate system

a = 1.0 for a non-woven fabric

= 1.2 for satin (1×8 or 1×6) weave style fabrics

= 1.5 for twill (2×2, 3×1, 4×4) weave style fabrics

= 2.0 for plain (1×1) weave style fabrics

Stiffness matrix components Q for chopped strand mat (CSM) are to be derived using the above equations, too, where:

$E11 = E22 = E_{CSM}$

$\nu_{12} = \nu_{21} = 0{,}28$

$G12 = G_{CSM}$

.2 Angle transformation for single unidirectional ply stiffnesses to global coordinate system

The following formulae are used to transform elasto-mechanical properties found in C3.8.2.3.1 for a unidirectional laminated ply in the local 1, 2 coordinate system to the global x, y coordinate system by an in-plane polar transformation of angle "Θ".

$$Q11' = Q11 \cdot \cos^4\Theta + 2 \cdot (Q12 + 2 \cdot Q33) \cdot \sin^2\Theta \cdot \cos^2\Theta + Q22 \cdot \sin^4\Theta$$

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$$Q22' = Q11 \cdot \sin^4\Theta + 2 \cdot (Q12 + 2 \cdot Q33) \cdot \sin^2\Theta \cdot \cos^2\Theta + Q22 \cdot \cos^4\Theta$$

$$Q23' = Q32' = (Q22 - Q12 - 2 \cdot Q33) \cdot \cos^3\Theta \cdot \sin\Theta - (Q11 - Q12 - 2 \cdot Q33)\ \cos\Theta \cdot \sin^3\Theta$$

$$Q13' = Q31' = (Q22 - Q12 - 2 \cdot Q33) \cdot \cos\Theta \cdot \sin^3\Theta - (Q11 - Q12 - 2 \cdot Q33)\ \cos^3\Theta \cdot \sin\Theta$$

$$Q12' = (Q11 + Q22 - 4 \cdot Q33) \cdot \sin^2\Theta \cdot \cos^2\Theta + Q12 \cdot (\sin^4\Theta + \cos^4\Theta)$$

$$Q33' = (Q11 + Q22 - 2 \cdot Q12 - 2 \cdot Q33) \cdot \sin^2\Theta \cdot \cos^2\Theta + Q33 \cdot (\sin^4\Theta + \cos^4\Theta)$$

$$Q21' = Q12'$$

Θ = Angle of transformation

Q' = Transformed stiffness matrix of orthotropic layer in global coordinate system

C3.8.2.4 Stiffness properties of a single or multiply layer

The multiply is a layer, which is treated as laminate with a distinct number of plies (e.g. woven, stitched or pre-pregged; bi-axial, tri-axial or quad-axial arrangement) and is considered to be one layer of fabric used to build up a laminate

The stiffness properties of this single or multiply layer will be determined by Classical Laminate Theory with the exception that coupling effects causing out-of plane deformations are restrained.

Thus, the bending extension coupling effects of the single or multiply will be neglected here by forcing the coupling matrix "B" to be zero. This simulates the multiply to be symmetrical.

Following the classical laminate theory the ABD_L matrix is the stiffness matrix of the multiply (Index "L" for "layer") and will lead to the engineering constants of the multiply.

The individual matrices are calculated as follows:

Extension matrix A_L:

$$A11_L = \sum_{i=1}^{n} Q11'_i \cdot t_i$$

$$A12_L = A21 = \sum_{i=1}^{n} Q12'_i \cdot t_i$$

$$A13_L = A31 = \sum_{i=1}^{n} Q13'_i \cdot t_i$$

$$A22_L = \sum_{i=1}^{n} Q22'_i \cdot t_i$$

$$A23_L = A32 = \sum_{i=1}^{n} Q23'_i \cdot t_i$$

$$A33_L = \sum_{i=1}^{n} Q33'_i \cdot t_i$$

Bending extension matrix B_L:

All forced to be zero:

$$B11_L = B12_L = B13_L = B21_L = B22_L = B23_L = B31_L = B32_L = B33_L = 0$$

Bending matrix D:

$$D11_L = \frac{1}{3} \sum_{i=1}^{n} Q11'_i \cdot \left(z_i^3 - z_{i-1}^3\right)$$

$$D12_L = D21 = \frac{1}{3} \sum_{i=1}^{n} Q12'_i \cdot \left(z_i^3 - z_{i-1}^3\right)$$

$$D13_L = D31 = \frac{1}{3} \sum_{i=1}^{n} Q13'_i \cdot \left(z_i^3 - z_{i-1}^3\right)$$

$$D22_L = \frac{1}{3} \sum_{i=1}^{n} Q22'_i \cdot \left(z_i^3 - z_{i-1}^3\right)$$

$$D23_L = D32 = \frac{1}{3} \sum_{i=1}^{n} Q23'_i \cdot \left(z_i^3 - z_{i-1}^3\right)$$

$$D33_L = \frac{1}{3} \sum_{i=1}^{n} Q33'_i \cdot \left(z_i^3 - z_{i-1}^3\right)$$

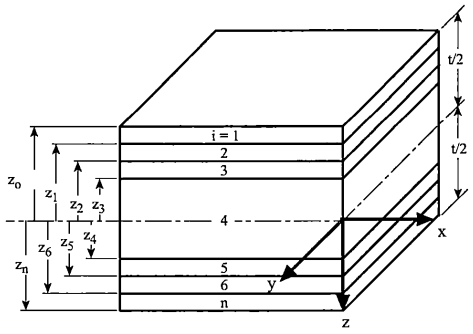

Fig. C3.8.2 Ply definitions

Resulting in the ABD_L matrix:

$$\begin{bmatrix} A11_L & A12_L & A13_L & 0 & 0 & 0 \\ A21_L & A22_L & A23_L & 0 & 0 & 0 \\ A31_L & A32_L & A33_L & 0 & 0 & 0 \\ 0 & 0 & 0 & D11_L & D12_L & D13_L \\ 0 & 0 & 0 & D21_L & D22_L & D23_L \\ 0 & 0 & 0 & D31_L & D32_L & D33_L \end{bmatrix} = \begin{bmatrix} A & B \\ B & D \end{bmatrix}_L$$

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and the inverse ABD_L matrix

$$\begin{bmatrix} a11_L & a12_L & a13_L & 0 & 0 & 0 \\ a21_L & a22_L & a23_L & 0 & 0 & 0 \\ a31_L & a32_L & a33_L & 0 & 0 & 0 \\ 0 & 0 & 0 & d11_L & d12_L & d13_L \\ 0 & 0 & 0 & d21_L & d22_L & d23_L \\ 0 & 0 & 0 & d31_L & d32_L & d33_L \end{bmatrix} = \begin{bmatrix} a & b \\ b & d \end{bmatrix}_L = \begin{bmatrix} A & B \\ B & D \end{bmatrix}_L^{-1}$$

The engineering constants for the multiply layer are:

$$E_x = \frac{1}{t \cdot a11_L};$$

$$E_y = \frac{1}{t \cdot a22_L};$$

$$G_{xy} = \frac{1}{t \cdot a33_L};$$

$$\upsilon_{xy} = -\frac{a12_L}{a11_L}$$

The following layer stiffness values will be used for buckling analysis in C3.8.6.2:

$$Q11'_L = \frac{A11_L}{t_L}$$

$$Q12'_L = \frac{A12_L}{t_L}$$

$$Q22'_L = \frac{A22_L}{t_L}$$

$$Q33'_L = \frac{A33_L}{t_L}$$

$$Q21'_L = Q'12_L$$

t_L = thickness of single or multiply layer

C3.8.2.5 Laminate stiffness

.1 Single skin laminates

A single skin laminate is consisting of a total of n laminated layers, where the index i stands for a particular layer i of this compound. The following is also valid for determining the properties of sandwich skins each:

a) The mean laminate engineering constants and the thickness of a laminate are:

$$E_{x,laminate} = \frac{\sum E_{xi} \cdot t_i}{\sum t_i}; \quad E_{y,laminate} = \frac{\sum E_{yi} \cdot t_i}{\sum t_i}$$

$$G_{xy,laminate} = \frac{\sum G_{xyi} \cdot t_i}{\sum t_i}; \quad t_{laminate} = \sum t_i$$

$E_{xi,yi}$; $G_{xy,i}$ = engineering constants of layer

t_i = thickness of layer i

These mean values should only be used for in-plane assessments or for very homogeneous layups:

b) Neutral axis z of an unsymmetrical laminate, measured vs. a reference axis:

$$z = \frac{\sum E_i \cdot t_i \cdot z_i}{\sum E_i \cdot t_i}$$

E_i = Young´s modulus layer in relevant direction

z_i = distance of layer centroid from reference axis

Note that the neutral axes of a laminate can be dissimilar in different directions.

c) Flexural stiffness EI of a single skin laminate per unit width:

$$EI = \sum E_i \cdot \left(\frac{t_i^3}{12} + t_i \cdot e_i^2\right)$$

e_i = distance of layer centriod from neutral axis of laminate

Note that the flexural stiffness of a laminate can be dissimilar in different directions.

d) The in-plane shear stiffness GA_u of a single skin laminate per unit width:

$$GA_u = \sum G_i \cdot t_i$$

If the shear stiffness per unit width is not applicable but the shear stiffness of a whole plate, the relevant plate width needs to be accounted for additionally.

$$GA = \sum G_i \cdot t_i \cdot w$$

w = plate width

.2 Sandwich laminates

In the sense of this methodology, "sandwich" is considered to be an effective structural arrangement of materials with significantly different stiffness characteristics, where however the sandwich core shall have a sufficient amount of shear stiffness to allow for simplifications made in elemental beam theory.

Thus, the flexural and in-plane shear stiffness of a sandwich laminate is calculated like for single skin laminates, taking into account the core as an elementary layer with its particular thickness and modulus.

C3.8.2.6 Beam analysis

Beams are structural elements that are mainly subjected to bending moments and also to shear forces when loaded laterally. In general, the associated plating contributes to stiffness and strength. Stiffeners, frames and girders can be considered as beams in this sense.

The following assumptions imply that the beams perform "plane bending", i.e. that the neutral axis of the beam with associated plating is parallel to the

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axis about which the assembly bends; the beam assembly is symmetrical about the axis which is perpendicular to the plating.

.1 Effective width of plating

The following approach provides an indication about the effective width of plating. This is based on the assumption that the associated plating has near-quasi-isotropic in-plane properties. It may be adopted for reasonably balanced in-plane stiffness laminates.

The effective width of plating w_{eff} is taken as being dependant on the ratio L_1/w solely. The width of plating to account for when determining the beams stiffness can be taken from Fig. C3.8.3 as a fraction of w.

L_1 is the length between zero bending moments of a beam between supports and is determined as follows:

L_1 = unsupported span for beams with hinged end supports

= 0,4 – times the unsupported span for beam with ends fixed

w = width of plating supported, measured from centre to centre of the adjacent unsupported fields

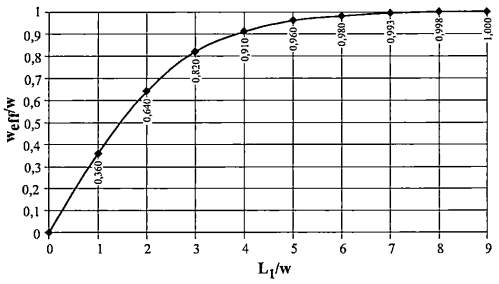

Fig. C3.8.3 Effective width of plating

Additionally the beams foot width "w_f" can be added to w_{eff}, see Fig. C3.8.4.

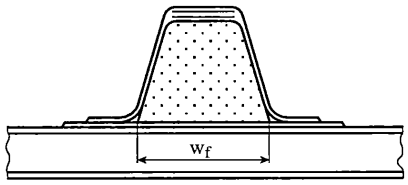

Fig. C3.8.4 Typical top hat stiffener

The calculated effective width shall not be taken greater than the load width.

.2 Flexural stiffness

$$EI = \sum E_i \cdot (I_i + S_i \cdot e_i^2)$$

E_i = tensile modulus of element

I_i = specific moment of inertia of element

e_i = distance of element's centroid from neutral axis of assembly

S_i = cross sectional area of element

.3 Shear stiffness

For determining the shear stiffness of a beam assembly, usually only the shear webs are accounted for.

$$GA = \sum G_i \cdot t_i \cdot h_i$$

t_i = web thickness

h_i = height of web measured perpendicular to associated plating

G = in-plane shear modulus of element

C3.8.3 Laterally loaded plates

C3.8.3.1 Applicability

In the following the structural design requirements for laterally loaded shells and plates are given. Lateral loading is usually caused by static or dynamic sea or water pressure (slamming) of hull shells, decks, superstructure, watertight bulkheads, tank walls etc.

The methodology presented in the following is covering flat or slightly curved panels of generally square or rectangular geometry with different boundary conditions. Other geometries (e.g. triangular or trapezoid styled) require an equivalent approach.

Plates considered here are generally laminated as single skin or sandwich panels.

It is recommended that elasto-mechanical properties of inner and outer sandwich skin do not differ significantly. This is to avoid secondary effects, such as superimposed twist or bending in plates.

The following approaches are featuring the ideas and the background of the "plate theory". Membrane effects occurring due to curved shells are treated with a linear reduction coefficient. Further contribution, like calculated using other methods or FEA, will generally not be accepted.

The objective is to determine plate stresses and strains from bending moments and shear forces caused by lateral pressure. The problem of an all-side supported panel will effectively be reduced to a unit beam strip, by using appropriate coefficients. The evaluation of stresses/strains is focussing on the spot where the maximum bending stress/strain occurs and a spot where the maximum through-thickness shear stress/strain occurs. Further to that, a correction is incorporated to allow the use of orthotropic material and plate properties and the application to sandwich construction.

If not explicitly mentioned, unit consistent variables are to be used.

C3.8.3.2 Parameters

Laminated plates are to be characterised by the following parameters:

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.1 Structural parameters

EI_x = panel bending stiffness in panels global x-direction (about panels global y-direction

EI_y = panel bending stiffness in panels global y-direction (about panels global x-direction

t_c = thickness of sandwich core

z_i = distance from a certain location of the neutral axis in bending

These values are calculated in C3.8.2.2 or C3.8.2.3.

.2 Geometrical parameters

s_x = unsupported span in global x-direction

s_y = unsupported span in global y-direction

Boundary conditions: all edges fixed or all edges simply supported

.3 Load details and design pressures

Lateral design pressures acc. to relevant GL Rules and Guidelines.

.4 Geometric aspect ratio ar_g

$$ar_g = \frac{s_x}{s_y}$$

.5 Effective aspect ratio

For orthotropic panel properties with EI_x not equal EI_y, the geometrical aspect ratio ar_g needs to be corrected:

$$ar_{corr} = ar_g \cdot \sqrt[4]{\frac{EI_y}{EI_x}}$$

For the purpose of further calculations, the corrected aspect ratio ar_{corr} has to be related to the span of the panel that is considered to be effective to take up the major bending and shear loads (see C3.8.3.1) and will be called "effective span s_{eff}":

If ar_{corr} is > 1, then $ar_{eff} = ar_{corr}$.

Thus, the panel effective span s_{eff} (direction of main load take-up) runs in y-direction.

If ar_{corr} is < 1, then $ar_{eff} = 1/ar_{corr}$

Thus, the panel effective span s_{eff} (direction of main load take-up) runs in x-direction.

.6 Edge support boundary conditions and corrections

Generally, panels which are continuous over their supporting structure can be assumed providing a fixed edge boundary condition, whereas panels e.g. butting against a sandwich panel will be considered with edge condition "simply supported". Similar considerations should be carried out for great variations in neighboring panel sizes.

In specific cases, hull chines or other sudden changes in geometry may be considered being a boundary as well. Should a chine be considered presenting one edge of a panel, the angle of the chine ω shall be close to 90° to allow for such assumption, see Fig. C3.8.5. Should the angle be greater than 90°, the panel span taken for panel calculations needs to be increased virtually, using the characteristic correction factors described below.

The panel span which is delimited by a chine has to be multiplied by the correction factor c_s:

$s_{x/y}$ = corrected panel span

= $c_s \cdot s_c$

c_s = correction factor

s_c = panel span

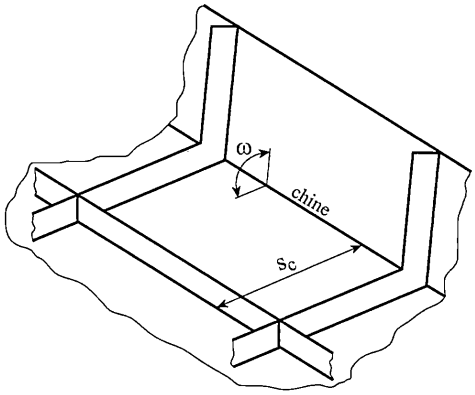

Fig. C3.8.5 Panel span

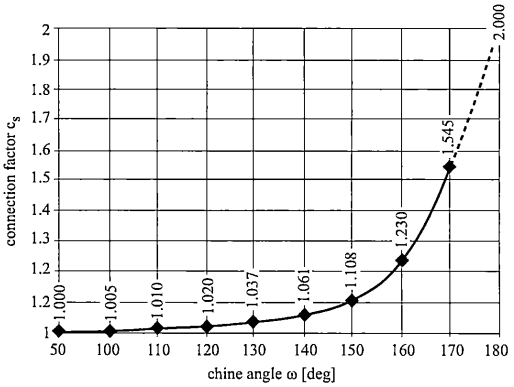

Fig. C3.8.6 Panel span correction factor c_s dependant on chine angle

This correction is particularly applicable for equidistant spacings of panels, i.e. for panels on both sides of vessel's chined centreline without the existence of a centreline girder, e.g.where the panels are delimited by off-centre longitudinals. For determination of c_s see Fig. C3.8.6

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.7 Plate curvature

Curvature will only be considered if the plate is curved in the direction of the effective span s_{eff}, see Fig. C3.8.7.

Curvature correction coefficient:

$$r_c = 1{,}15 - 5 \cdot \frac{h}{s_{eff}}$$

for $0{,}03 < \frac{h}{s} < 0{,}1$

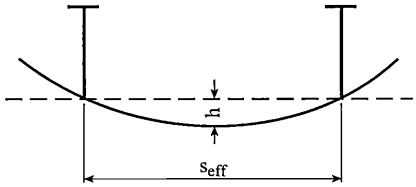

Fig. C3.8.7 Plate curvature

C3.8.3.3 Maximum bending moment, shear force and lateral deflection of panel

As mentioned in C3.8.3.1, the calculation is being reduced to the assessment of a panel strip of one unit width (e.g. 1 mm).

.1 Maximum bending moment

$$M_{b-max} = \frac{\beta \cdot P_d \cdot s_{eff}^2}{6} \cdot r_c$$

β = see Table C3.8.2

P_d = lateral design pressure on associated plating acc. to C3.8.1

s_{eff} = effective panel span

r_c = curvature correction coefficient

.2 Maximum reaction shear force

$$F_{Q-max} = \gamma \cdot P_d \cdot s_{eff}$$

γ = see Table C3.8.2

P_d = lateral design pressure on associated plating acc. to C3.8.1

s_{eff} = effective panel span

.3 Maximum lateral deflection

$$z_{max} = \frac{\alpha \cdot P_d \cdot s_{eff}^4}{12 \cdot EI_{eff}}$$

α = see Table C3.8.2

P_d = lateral design pressure on associated plating acc. to C3.8.1

s_{eff} = effective panel span

EI_{eff} = plate bending stiffness relevant for the direction of the effective panel span

For allowable deflections see C3.8.8.

Table C3.8.2 Values β, α, γ

For all edges simply supported										
ar_{eff}	1	1,2	1,4	1,6	1,8	2	3	4	5	∞
β	0,2874	0,3762	0,453	0,5172	0,5688	0,6102	0,7134	0,741	0,7476	0,75
α	0,0444	0,0616	0,077	0,0906	0,1017	0,111	0,1335	0,14	0,1417	0,1421
γ	0,42	0,455	0,478	0,491	0,499	0,503	0,505	0,502	0,501	0,5
For all edges fixed										
ar_{eff}	1	1,2	1,4	1,6	1,8	2	∞			
β	0,3078	0,3834	0,4356	0,468	0,4872	0,4974	0,5			
α	0,0138	0,0188	0,0226	0,0251	0,0267	0,0277	0,0284			
γ	0,42	0,455	0,478	0,491	0,499	0,503	0,5			

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C3.8.3.4 Determination of laminate strains and stresses

.1 Laminate strains

The structural performance of a laterally loaded plate is characterised by the occurring strains in the laminate using the following approach.

Resulting strains at a distance of z_i from the plate's neutral axis:

$$\varepsilon_i = \frac{M_{b-max} \cdot z_i}{EI_{eff}}$$

The maximum strains through bending moments usually emerge at the outer surfaces of a composite. Hence, for evaluating the maximum strains, use the maximum distances from the neutral axis at each side of the plate.

The calculated strains may not exceed the allowables defined in C3.8.8. Apart from the pure bending strains, stability issues such as skin wrinkling need to be considered, relate to C3.8.6.

.2 Determination of core shear stresses in sandwich laminates

Whereas with solid coreless laminates, the through-thickness interlaminar stress is rarely a design criterion, it is so for most of the lower density/strength cores of a typical sandwich. The core has to transmit the through-thickness shear forces. A certain contribution by the skins is assumed.

Core shear stress is calculated as being:

$$\tau_c = \frac{F_{q-max}}{t_c + \frac{t_{s1}}{2} + \frac{t_{s2}}{2}}$$

$F_{q\text{-}max}$ = see C3.8.3.3.2

t_c = core thickness

t_{s1}, t_{s2} = skin thickness of skins

The calculated stresses may not exceed the allowables defined in C3.8.8.

C3.8.4 Laterally loaded beams

C3.8.4.1 Applicability

The following approach can be used for laterally loaded beams, stiffeners, frames and girders, with or without associated plating attached. These structural members are usually part of an orthogonal structural system of a vessel. In well found cases, curvature effects may be taken into account in a similar way as shown for panels, see Fig. C3.8.8.

Typically, the beams consist of a web designed to carry the shear force and two flanges to carry the bending load, both generated by lateral pressure.

The web may be attached vertically or inclined to the attached shell (only the structural height times the thickness as effective shear area is to be considered). One flange is usually presented by a certain amount of attached plating (see effective width) and possible additional pads beneath the web. The other flange is presented by the "capping" of the beam.

Beams should be designed in a way that the transfer of loads is fibre dominant. In general this will require shear webs to consist of +/-45° layers of laminate, whereas the flanges consist of a certain number of 0° plies. However, it shall be taken into account that shear loads are transferred from the web into the flange.

The following approaches are featuring the partly simplified "Classical Laminate Theory" and the simple "Beam Theory".

The objective is to determine beam stresses and strains from bending moments and shear forces caused by lateral pressure on the associated plating. The computational model is presented by a simple beam with appropriate support conditions.

In case the scantlings are constant over the full length of the beam, it is sufficient to evaluate stresses and strains, respectively, through

- bending moment and shear force at the end of the beam for a support condition "ends fixed"
- bending moment at the centre of the beam and shear effects at the end of the beam for a support condition "ends simply supported"

Laminated beams may have a great variety of section shapes. Generally it is recommended to use symmetrical or near-symmetrical section shapes, as unsymmetrical shapes are subjected to superimposed secondary effects such as transverse bending or a twisting of the beam (flange). This makes a more refined analysis necessary than offered below.

Note

Due to the resulting transverse bending moment occurring in the flange, L-section beams with common width to height ratio show up to 2-times the calculated strains/stresses compared to calculated using the below approach. Measures shall be taken to reduce the strains by increasing the flange scantlings, or mounting tripping brackets along the beam.

If not explicitly mentioned, use consistent unit variables.

Laminated beams including their associated plating are to be characterised by the following parameters:

C3.8.4.2 Parameters

.1 Structural parameters

The following parameters have been determined in C3.8.2.6:

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EI = beam bending stiffness including associated plating

GA = shear stiffness of webs

z_i = distance from a certain location within the beam to the neutral axis in bending

w_{eff} = effective width of plating

.2 Geometrical parameters

l = unsupported length of the beam

w = load width

Boundary condition (all edges fixed or all edges simply supported)

.3 Load details

For panel design pressures see C3.8.1

.4 Beam curvature correction

Curvature correction coefficient:

$$r_{cb} = 1{,}15 - 5 \cdot \frac{h}{\ell}$$

for $0{,}03 < \frac{h}{\ell} < 0{,}1$

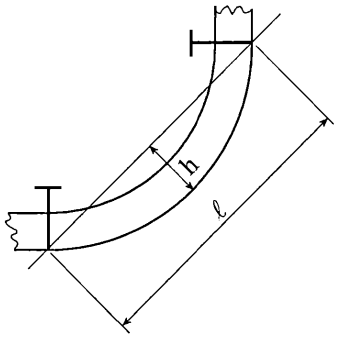

Fig. C3.8.8 Beam curvature definitions

C3.8.4.3 Maximum bending moment, shear force and lateral deflection of beam

.1 Maximum bending moment

$$M_{b-max} = \frac{P_d \cdot w \cdot l^2 \cdot r_{cb}}{c_b}$$

P_d = lateral design pressure on associated plating acc. to C3.8.1

w = load width

l = length of beam between supports

r_{cb} = beam curvature reduction factor see 3.8.4.2.4

c_b = boundary condition coefficient

= 12 for fixed end supports

= 8 for simply supported

.2 Maximum reaction shear force

The maximum shear force typically occurs at the boundaries:

$$F_{q-max} = \frac{P_d \cdot l \cdot w}{2}$$

P_d = see C3.8.1

l = see C3.8.4.3.1

w = see C3.8.4.3.1

.3 Maximum lateral deflection

The maximum lateral deflection of a beam is typically observed half way along the beam, considering that both ends have similar end support conditions and the beam has constant structural section and material properties along its length:

$$z_{max} = \frac{P_d \cdot w \cdot l^4 \cdot c_d}{384 \cdot EI}$$

P_d = see C3.8.1

l = see C3.8.4.3.1

w = see C3.8.4.3.1

c_d = boundary condition coefficient

= 1 for fixed end supports

= 5 for simply supported

For allowable deflections see C3.8.8.

C3.8.4.4 Beam construction notes

.1 In general, the bonding laminate (if not integral with the shear web) of a shear web needs to have the same shear stiffness/strength as the web. The lap of the bonding has to be large enough to transmit in-plane shear forces. It is important to place the bonding tapes using the specified fibre orientations throughout, see Fig. C3.8.9.

This is not only applicable to the bond between the beam and the associated plate but also to the bond between the beam and the next higher hierarchical member in structure, which it is supported by.

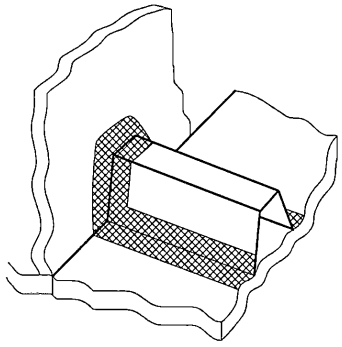

Fig. C3.8.9 Bonding of a beam to adjacent structure

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.2 The requirement for a sufficient amount of shear buckling stiffness of web laminates may lead to the inclusion of stabilising measures for webs (e.g. sandwich web or foam filled). If webs are of single skin style, the web height may not exceed 30-times the web thickness to prevent shear buckling.

.3 In special cases it may be required to replace the core of the associated plate with a higher strength/stiffness shear tie.

.4 Web laminates necessary to carry the shear loads should in general continue across the capping laminate and be interspersed with the capping laminate.

C3.8.5 Determination of laminate strains and stresses

C3.8.5.1 General

The structural performance of a laterally loaded beam is characterised by the occurring strains in the laminate. The maximum bending strains usually emerge at the most external areas of the composite. The most critical shear loading can usually be found in the shear webs.

C3.8.5.2 Strains and stresses

.1 In-plane uniaxial strains

Resulting bending strains at a distance of e_i from the beam's neutral axis:

$$\varepsilon_i = \frac{M_{b-max} \cdot e_i}{EI}$$

For evaluating the maximum strains, the maximum distances e_i from the neutral axis at each side of the beam are to be used. Due to special configurations, materials or geometries it might be necessary to calculate the strains at other characteristic locations along the beam.

The calculated strains may not exceed the allowables defined in C3.8.8.

.2 In-plane shear strains in webs

$$\gamma_s = \frac{F_{q-max}}{GA}$$

The calculated strains shall not exceed the allowables defined in C3.8.8.

C3.8.6 Stability considerations

Sandwich structures need to undergo special stability evaluations to prove that pertinent buckling in different forms will not occur. For marine structures typically the most critical buckling modes are the global buckling of a panel and face wrinkling of the skins. To cope for the latter, analytical approaches are offered in the following. Buckling modes like shear crimping and face dimpling are less likely to occur but need to be evaluated in addition should facings or cores be of uncommon type or configuration.

C3.8.6.1 Skin wrinkling of sandwich skins

Skin wrinkling of sandwich skins may be critical especially in cases where a sandwich panel is subjected to loadings so that at least one skin is in compression. Depending on the stiffness of the laminate in the relevant direction and on the supporting properties of the core, the following approach is used to assess strains above which skin wrinkling is expected:

Critical wrinkling strain for sandwich with "solid, isotropic" cores like foam:

$$\varepsilon_{sw-crit} = k_1 \cdot \frac{(E_{bf} \cdot E_c \cdot G_c)^{1/3}}{E_f}$$

Critical wrinkling strain for sandwich cored with honeycomb:

$$\varepsilon_{sw-crit} = k_2 \cdot \frac{(E_{bf} \cdot E_c \cdot t_f / t_c)^{1/2}}{E_f}$$

E_{bf} = skin laminate flexural modulus relevant to direction of compression. Thus, care shall be taken for laminate stacks of only few layers of alternating fibre direction. For skins made of many layers providing balanced through thickness elastic properties, a mean compressive young's modulus may be adopted instead

E_f = skin laminate tensile (compressive) modulus

E_c = core's Young's modulus in compression

G_c = core's shear modulus

t_f = thickness of skin

t_c = thickness of core

k_1 = 0,5

k_2 = 0,6

C3.8.6.2 Buckling of orthotropic plates under uniaxial membrane loads

.1 Considerations and limitations

The buckling of sandwich panels needs to be considered for global in-plane compression and in-plane shear.

The following methodology is based on simplified classical laminate theory, i.e. only valid for laminate plates (sandwich or single skin) which are well balanced through thickness. Only sandwich laminates with skin in-plane tensile stiffness (E · t) difference of no more than 20 % in each direction x or y may be considered this way:

$$0.8 \le \frac{E_{x-os} \cdot t_{os}}{E_{x-is} \cdot t_{is}} \le 1.2$$

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and:

$$0.8 \le \frac{E_{y-os} \cdot t_{os}}{E_y \cdot t_{is}} \le 1.2$$

where "os" and "is" are indices for "outer skin" and "inner skin".

Also, all edges need to be supported. There is no implementation for the possibility to calculate plates with one free edge.

This condition presumes that there will be no or only minor coupling between in-plane and out-of-plane effects.

.2 Critical buckling strain

For arbitrary boundary conditions the critical membrane strain of an orthotropic plate that leads to buckling is:

$$\varepsilon_{B-crit} = \frac{1}{E_{a-mean} \cdot t_{tot}} \cdot k_x \cdot \left(\frac{\pi}{b}\right)^2 \cdot \sqrt{D11 \cdot D22}$$

$E_{a\text{-}mean}$ = mean Young's modulus in load direction (a) of full laminate (incl. core)

t_{tot} = total thickness of full laminate (incl. core)

b = plate width perpendicular to load direction

a = plate width parallel to load direction

k_x = buckling coefficient:

$= h(\bar{\alpha}) + q \cdot \beta$

q = boundary condition adjustment factor

= 2 for unloaded edges simply supported

= 2,36 for unloaded edges clamped

$h(\bar{\alpha})$ = see Fig. C3.8.10

$\bar{\alpha}$ = modified aspect ratio:

$= \frac{a}{b} \cdot \sqrt[4]{\frac{D22}{D11}}$

β = "Seydel" orthotropic parameter:

$= \frac{D12 + 2 \cdot D33}{\sqrt{D11 \cdot D22}}$

Coefficients from the laminate's bending matrix D:

$$D11 = \sum_{i=1}^{n} Q11'_{Li} \cdot \frac{1}{3}(z_i^3 - z_{i-1}^3)$$

$$D12 = \sum_{i=1}^{n} Q12'_{Li} \cdot \frac{1}{3}(z_i^3 - z_{i-1}^3)$$

$$D22 = \sum_{i=1}^{n} Q22'_{Li} \cdot \frac{1}{3}(z_i^3 - z_{i-1}^3)$$

$$D33 = \sum_{i=1}^{n} Q33'_{Li} \cdot \frac{1}{3}(z_i^3 - z_{i-1}^3)$$

Index "i" stands for each particular layer of a total of "n" layers of a laminate

$Q11'_L$, $Q12'_L$, $Q22'_L$ and $Q33'_L$ are coefficients determined in C3.8.2.4

z_i are distances from ply surfaces to the laminate midplane as depicted in Fig. C3.8.2

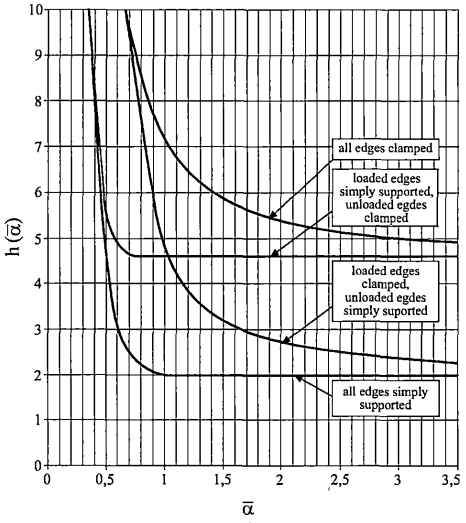

Fig. C3.8.10: Simplified $h(\bar{\alpha})$ curves

C3.8.6.3 Buckling of orthotropic plates under in-plane shear loads

The general provisions C3.8.6.2.1 apply.

.1 Critical buckling strain

For an all-sided simply supported orthotropic plate, the critical in-plane shear strain that leads to buckling is:

$$\gamma_{B-crit} = \frac{1}{G_{a-mean} \cdot t_{tot}} \cdot k_S \cdot \left(\frac{\pi}{w}\right)^2 \cdot \sqrt[4]{D_a \cdot D_b^3}$$

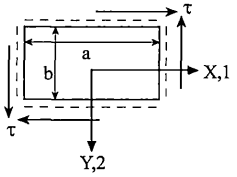

Fig. C3.8.11: Nomenclature

$G_{a\text{-}mean}$ = mean in-plane shear modulus of full laminate

t_{tot} = total thickness of full laminate

w = plate width a or b, see below

k_S = buckling coefficient, as per Fig. C3.8.12

β = Seydel orthotropic parameter

$= \frac{D12 + 2 \cdot D33}{\sqrt{D11 \cdot D22}}$

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α = modified inverse aspect ratio

$$= \frac{1}{\alpha} = \frac{b}{a}\sqrt[4]{\frac{D11}{D22}}$$

If $\alpha \leq 1$, then

w = b

D_a = D11

D_b = D22

If $\alpha > 1$, then

$\alpha = \overline{\alpha}$

w = a

D_a = D22

D_b = D11

b = plate width in X,1 direction

a = plate width in Y,2 direction

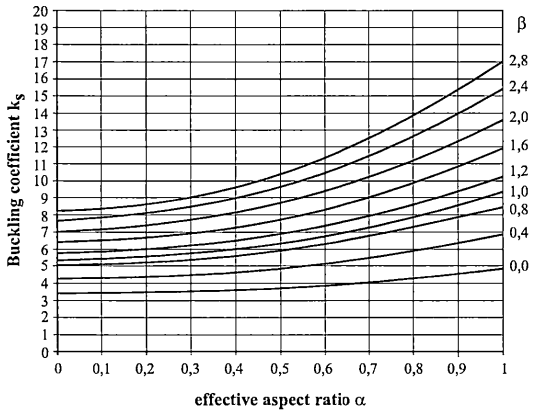

Fig. C3.8.12 Buckling coefficient k_s

C3.8.7 Further considerations

C3.8.7.1 Through-thickness effects

In general it is preferred to have a fibre-dominant load absorption in a composite structure, but in some cases it will be unavoidable that through thickness effects occur. Those structural details will be treated individually and case by case.

C3.8.7.2 Minimum shell thickness

No particular algorithm has been implemented to determine a minimum shell or skin thickness for hull laminates. As global strength and stiffness criteria have been set, a remaining issue is that of a shell laminate being prone to local forces or impact when docking, dry docking or from collision with floating or submerged debris. This subject will be handled individually.

C3.8.8 Allowable strains, safety factors and maximum deflections

For fibre reinforced composite components, the "maximum strain criteria" is mainly used to assess the structural integrity. This criterion may solely be used in association with the provisions described and defined so far.

This criterion is providing an appropriate limit for fibre reinforced composites under the condition that the composite shows a fibre-dominant load transfer.

These limits provide a sufficient margin over inter-laminar micro cracking and fibre failure in all in-plane directions.

For adhesive bonds, the structural evaluation of sandwich cores and evaluation of stability criteria, safety factors are serving to achieve sufficient integrity. Further to that, a deflection criterion has to be fulfilled:

- Maximum strain for carbon laminates in axial tension/compression is to be the smaller value of:
  - 0,25 % (typical for standard modulus, intermediate modulus or high strength carbon fibre) or
  - Ultimate compressive strain/3

    GL reserves the right to inquire test certificates for tests on ultimate compressive strain, using ASTM D-695. Tests need to be carried out at accredited, independant laboratories.
- Maximum allowable strain of 0,35 % for E-Glass laminates in axial tension/compression
- Maximum allowable in-plane shear strain for carbon laminates is to be smaller value of
  - 0,45 % (typical for standard modulus, intermediate modulus or high strength carbon fibres) or
  - Ultimate compressive strain · 0,6
- Maximum allowable in-plane shear strain for E-Glass laminates of 0,7 %
- Safety factor of 2,5 vs. core shear failure (linear shear stress distribution over the core and each half of the skins). Basis are the GL approved values or the "msmv" (manufacturer specified minimum values) values for structural cores.
- Appropriate safety of skin/core bond
- Factor of 2,5 vs. panel buckling and 2,0 for skin wrinkling on the strains determined according to C3.8.6.
- Factor of 2,5 vs. shear strength in an adhesive bond using adhesives approved by GL.
- Maximum permissible lateral deflections under lateral load:
  - 1,5 % of effective panel span for single skin laminate panels
  - 1,0 % of effective panel span for sandwich panels
  - 0,5 % of unsupported span of a stiffener or girder

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– 0,3 % of unsupported span of engine foundation

C3.8.9 Construction and design details

C3.8.9.1 Consequences of elasticity

Unlike metals, fibre reinforced composites used for marine applications exhibit almost linear elastic behaviour to failure. This is as long as the structural response is fibre-dominated, which is preferred over a matrix dominant behaviour. Respecting this, composites show little or no yielding until failure. This aspect requires particular attention. Especially in structural details with occurring stress concentrations, consideration shall already be given in static strength analysis. In cases in which these concentrations are compensated appropriately, fatigue will not be as critical. This is valid for in-plane loads with fibre dominated load absorption. However, through-thickness loading (especially shear and tension) can not always be avoided and yet needs to be handled in an appropriately conservative way. "Intercracking" or delamination caused by overloading, impact or deficient structural design is considered to be the cause for subsequent failure of components and thus can be deemed as cause for fatigue with composites.

C3.8.9.2 Recommendations

The following recommendations do not claim to be all-inclusive and are subject to up-date/change/amendment:

– In general, the basic laminate stacking sequence shall be homogeneous; preferably symmetrical and balanced, if not particular attention has to be paid to possible arising secondary effects.

– A laminate should consist of plies aligned in at least 4 distinct directions (e.g. 0°, +/-45°, 90°), with not less than 10 % in each direction. Ply angles should be aligned appropriately for major load direction(s). Exemptions are the following components/items:

  – mainly in-plane shear loaded webs of girders, stiffeners, frames

  – local tape reinforcements

– Grouping of plies with the same fibre direction should be avoided, but total thickness of these plies may not exceed 1,5 mm (typically for carbon laminates).

– Not all parts are suitable for composites. Complex 3-dimensional stress states may make suitable isotropic materials a preferred choice (e.g. local fittings).

– Inaccessibility of composite components needs to be considered in design in terms of inspectability during production, in-service and after damage.

C3.8.9.3 Details

All structural details are subject to examination by GL. In general the following provisions shall be observed.

1. The occurrence of peeling effects, such as abrupt stiffness changes is to be minimized. Secondary bonding is always to be backfilled with suitably coved filler bed.

2. For mechanical fastenings, a domination of fibre orientation in one direction of more than 40 % is not advisable.

3. Core chamfers of sandwich laminates should not be steeper than 1:3 thickness/taper ratio.

4. Exposed fibres and sandwich cores shall be sealed or clashed with laminate.

C3.9 Hull Appendages

C3.9.1 Shaft brackets

.1 The strut axes should intersect in the axis of the propeller shaft as far as practicable. The angle between two struts shall be in range from 50° to 120° which differs from the angle included between propeller blades. Where 3- or 5-bladed propellers are fitted, an approximately 90° angle is recommended. Where 4-bladed propellers are fitted, the angle should be approximately 70° or 110°. The axes of the arms should intersect in the axis of the propeller shaft. Exceptions to this will be considered by GL on a case-by-case basis.

The struts are to be extended through the shell plating and are to be attached in an efficient manner to the frames and plate floors respectively. The construction in way of the shell is to be carried out with special care. For strengthening of the shell in way of struts and shaft bossings, see C3.7.7.3.3.

In case of welded connection, the struts are to have a weld flange or a thickened part or are to be connected with the shell plating in another suitable manner. The requirements of C3.6.1.4.3 are to be observed.

.2 In general, the scantlings of solid struts can be determined as outlined below depending on shaft diameter d:

– strut thickness	0,44 d
– cross-sectional area	0,44 d^2 in propeller bracket
– length of boss	2,5 d_a
– wall thickness of boss	0,25 d

d_a = as-built diameter

$d = 95 (P_w \cdot C_w / n)^{(1/3)}$

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C_w = 560/(160+R_m)

R_m = tensile strength of the strut material

P_w = single engine output in kW

n = shaft revolutions per minute

Based on further details other scantling calculations can be accepted as agreed by GL.

.3 Propeller brackets and shaft bossings of welded construction are to have the same strength as solid ones according to 2. The thickness of plating shall not be less than 0,1 d.

.4 The shaft brackets are to be checked of cracks during each drydocking.

.5 For one strut propeller brackets a strength, vibration and fatigue analysis is to be carried out.

C3.9.2 Waterjets

.1 The supporting structures of waterjets are to be able to withstand the loads thereby generated in the following conditions:

- maximum ahead thrust
- maximum thrust at maximum lateral inclination
- maximum reversed thrust (going astern)

Information on the above loads is to be given by the waterjet manufacturer and supported by documents.

.2 For each waterjet, following loading cases are to be investigated:

LDC 1 : internal hydrodynamic pressure ph in the built-in nozzle

LDC 2 : horizontal longitudinal force F_{x1} in normal service (ahead)

LDC 3 : horizontal transverse force F_y and associated moment M_z during steering operation

LDC 4 : horizontal longitudinal force F_{x2}, vertical force F_z and overturning moment M_y in crash-stop situation

.3 The actual location of the thrust bearing is to be adequately considered (either located aft of the stem in the stator bowl or inside the waterjet compartment)

.4 The scantlings are to be checked by direct calculations.

.5 Table C3.9.1 indicates the loading cases to be considered for the various components of the waterjet system. Other loading cases could be considered for specific or new design.

.6 The stress criteria for static analysis may be taken as the following one, in MPa:

- bending stress:

$$\sigma_{am} = \frac{150}{k \cdot f'_m}$$

- shear stress:

$$\tau_{am} = \frac{90}{k \cdot f'_m}$$

- Von Mises equivalent bending stress:

$$\sigma_{eq,am} = \frac{190}{k \cdot f'_m}$$

k = material factor defined in C3.2

f'_m = coefficient depending on the material

= 1,00 for steel structures

= 2,15 for aluminium alloy structures

Table C3.9.1

Component	LDC1	LDC2	LDC3	LDC4
Built-in nozzle: - plating - bending behaviour	X [1]	X [2]		X [3]
Ship stern		X [2]	X	X [4]
Bolting on stern			X [5]	X [5]

[1] to be checked under lateral pressure and against fatigue behaviour

[2] buckling to be checked (100 % of F_x transferred by built-in nozzle in case of thrust bearing aft of the stern)

[3] ratio of M_y directly sustained by the built-in nozzle to be estimated on basis of relative stiffnesses

[4] ratio of M_y directly sustained by the transom structure to be estimated on basis of relative stiffnesses

[5] bolting calculation taking account of the actual pre-tension in bolts

.7 The stress criteria for fatigue analysis are to be specified by the designer.

.8 The shell thickness in way of nozzles as well as the shell thickness of the tunnel are to be individually considered. In general, such thicknesses are to be not less than 1,5 times the thickness of the adjacent bottom plating.

.9 General principles to be followed for such structures subject to cyclic loadings are listed hereafter:

- continuous welding
- shear connections between stiffeners and transverse frames
- soft toe brackets
- no sniped ends
- no termination on plate fields

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- no scallops in critical areas
- no start and stop of welding in corners or at ends of stiffeners and brackets
- possibly grinding of toes of critical welds

Note

As a guidance, the following criteria may be considered:

The bending natural frequency of plates and strength members of the hull in the area of waterjets should not be less than 2,3 times the blade frequency for structures below the design waterline and between transom and aft engine room bulkhead. Structural components (such as the casing of waterjet and accessory parts and the immersed shell area) which may transfer pressure fluctuations into the ship structure have to fulfill the requirements of the waterjet manufacturer. Especially with regard the grids installed in the inlet duct, the hydrodynamic design should assure an unproblematic operation with respect to cavitation phenomenon.

This checking is left to the manufacturers (see paragraph 3.4)

C3.10 Rudder

C3.10.1 General

.1 Rudder stock, cone coupling, rudder bearings and the rudder body of spade rudders are dealt with in the following. For rudders supported by sole piece and semi-spade rudders and other types of couplings the GL Rules Hull Structures (I-1-1), Section 14 are to be observed.

.2 The steering gear compartment shall be readily accessible and, as far as practicable, separated from the machinery space.

Note

Concerning the use of non-magnetisable material in the wheel house in way of a magnetic compass, the requirements of the national Administration concerned are to be observed.

C3.10.2 Structural details

.1 Effective means are to be provided for supporting the weight of the rudder body without excessive bearing pressure, e.g. by a rudder carrier attached to the upper part of the rudder stock. The hull structure in way of the rudder carrier is to be suitably strengthened.

.2 Suitable arrangements are to be provided to prevent the rudder from lifting.

Connections of rudder blade structure with solid parts in forged or cast steel, which are used as rudder stock housing, are to be suitably designed to avoid any excessive stress concentration at these areas.

.3 The rudder stock is to be carried through the hull either enclosed in a watertight trunk, or glands are to be fitted above the deepest load waterline, to prevent water from entering the steering gear compartment and the lubricant from being washed away from the rudder carrier. If the top of the rudder trunk is below the deepest waterline two separate stuffing boxes are to be provided.

Note

The following measures are recommended in the GL Technical Publication, Paper No. 05-1 "Recommendations for Preventive Measures to Avoid or Minimize Rudder Cavitation", regarding:

Profile selection:

- *Use the appropriate profile shape and thickness.*
- *Use profiles with a sufficiently small absolute value of pressure coefficient for moderate angles of attack (below 5°). The pressure distribution around the profile should be possibly smooth. The maximum thickness of such profiles is usually located at more than 35 % behind the leading edge.*
- *Use a large profile nose radius for rudders operating in propeller slips.*
- *Computational Fluid Dynamic (CFD) analysis for rudder considering the propeller and ship wake can be used.*

Rudder sole cavitation:

Round out the leading edge curve at rudder sole.

Propeller hub cavitation:

Fit a nacelle (body of revolution) to the rudder at the level of the propeller hub. This nacelle functions as an extension of the propeller hub.

Cavitation at surface irregularities:

- *Grind and polish all welds.*
- *Avoid changes of profile shape. Often rudders are built with local thickenings (bubbles) and dents to ease fitting of the rudder shaft. Maximum changes in profile shape should be kept to less than two percent of profile thickness.*

Gap cavitation:

- *Round out all edges of the part around the gap.*
- *Gap size should be as small as possible.*
- *Place gaps outside of the propeller slipstream.*

C3.10.3 Materials

.1 For materials for rudder stock, pintles, coupling bolts etc. see Rules II – Materials and Welding, Part 1 – Metallic Materials.

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.2 In general materials having a minimum nominal upper yield point R_{eH} of less than 200 MPa and a minimum tensile strength of less than 400 MPa or more than 900 MPa shall not be used for rudder stocks, pintles, keys and bolts.

The requirements of this Section are based on a material's minimum nominal upper yield point R_{eH} of 235 MPa. If material is used having a R_{eH} differing from 235 MPa, the material factor k_r is to be determined as follows:

$$k_r = \left(\frac{235}{R_{eH}}\right)^{0,75} \quad \text{for } R_{eH} > 235 \quad [N/mm^2]$$

$$= \frac{235}{R_{eH}} \quad \text{for } R_{eH} \le 235 \quad [N/mm^2]$$

R_{eH} = minimum nominal upper yield point of material used [MPa]

R_{eH} is not to be taken greater than $0,7 \cdot R_m$ or 450 MPa, whichever is less. R_m = tensile strength of the material used.

.3 Before significant reductions in rudder stock diameter due to the application of steels with R_{eH} exceeding 235 MPa are accepted, GL may require the evaluation of the elastic rudder stock deflections. Large deflections should be avoided in order to avoid excessive edge pressures in way of bearings.

.4 The permissible stresses given in C3.10.8 are applicable for normal strength hull structural steel. When higher tensile steels are used, higher values may be used which will be fixed in each individual case.

C3.10.4 Definitions

C_R = rudder force [N]

Q_R = rudder torque [Nm]

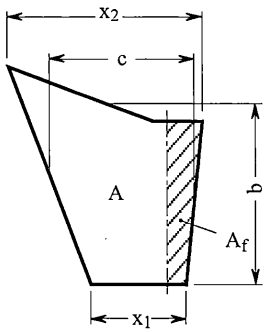
A = total movable area of the rudder [m^2], measured at the mid-plane of the rudder

A_t = A + area of a rudder horn, if any [m^2]

A_f = portion of rudder area located ahead of the rudder stock axis [m^2]

b = mean height of rudder area [m]

c = mean breadth of rudder area [m], see Fig. C3.10.1



$$c = \frac{x_1 + x_2}{2} \qquad b = \frac{A}{c}$$

C3.10.1 Rudder area geometry

Λ = aspect ratio of rudder area A_t

$$= \frac{b^2}{A_t}$$

v_a = astern speed of ship [kn]; if the astern speed v_a is less than $0,4 \cdot v_0$ or 6 kn, whichever is less, determination of rudder force and torque for astern condition is not required. For greater astern speeds special evaluation of rudder force and torque as a function of the rudder angle may be required. If no limitations for the rudder angle at astern condition is stipulated, the factor κ_2 is not to be taken less than given in Table C3.10.1 for astern condition.

C3.10.5 Rudder Force and Torque

.1 The rudder force is to be determined according to the following formula:

$$C_R = 132 \cdot A \cdot V_0^2 \cdot k_1 \cdot k_2 \cdot k_3$$

$$V_0 = \min [V, 2/3 \cdot (V + 2 \cdot L^{0,5})]$$

$= v_a$ for astern condition

k_1 = coefficient, depending on the aspect ratio Λ

$= (\Lambda + 2)/3$, where Λ need not be taken greater than 2

k_2 = coefficient, depending on the type of the rudder and the rudder profile according to Table C3.10.1

k_3 = coefficient, depending on the location of the rudder

= 0,8 for rudders outside the propeller jet

= 1,0 elsewhere, including also rudders within the propeller jet

= 1,15 for rudders aft of the propeller nozzle

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Table C3.10.1 Coefficient k_2

Profile / type of rudder	κ_2 ahead	κ_2 astern
NACA-00 series Göttingen profiles	1,1	1,4
flat side profiles	1,1	1,4
mixed profiles (e. g. HSVA)	1,21	1,4
hollow profiles	1,35	1,4
high lift rudders	1,7	to be specially considered; if not known: 1,7

.2 The rudder torque is to be determined by the following formula:

$$Q_R = C_R \cdot r \quad [Nm]$$

$r = c\,(\alpha - k_b)$ [m]

α = 0,33 for ahead condition

= 0,66 for astern condition (general)

k_b = balance factor as follows:

$$= \frac{A_f}{A}$$

= 0,08 for unbalanced rudders

$r_{min} = 0{,}1 \cdot c$ [m] for ahead condition

.3 Effects of the provided type of rudder/profile on choice and operation of the steering gear are to be observed.

C3.10.6 Scantlings of the Rudder Stock

C3.10.6.1 Rudder stock diameter

.1 The diameter of the rudder stock for transmitting the rudder torque is not to be less than:

$$D_t = 4{,}2 \sqrt[3]{Q_R \cdot k_r} \quad [mm]$$

Q_R = see C3.10.5.1.2

The related torsional stress is:

$$\tau_t = \frac{68}{k_r} \quad [N/mm^2]$$

k_r = see C3.10.3.2

.2 The steering gear is to be determined for the rudder torque Q_R as required in C3.10.5.1.2 and under consideration of the frictional losses at the rudder bearings.

.3 In case of mechanical steering gear the diameter of the rudder stock in its upper part which is only intended for transmission of the torsional moment from the auxiliary steering gear may be 0,9 D_t. The length of the edge of the quadrangle for the auxiliary tiller shall not be less than 0,77 D_t and the height not less than 0,8 D_t.

.4 The rudder stock is to be secured against axial sliding. The degree of the permissible axial clearance depends on the construction of the steering engine and on the bearing.

C3.10.6.2 Strengthening of rudder stock

.1 If the rudder is so arranged that additional bending stresses occur in the rudder stock, the stock diameter has to be suitably increased. The increased diameter is, where applicable, decisive for the scantlings of the coupling.

For the increased rudder stock diameter the equivalent stress of bending and torsion is not to exceed the following value:

$$\sigma_v = \sqrt{\sigma_b^2 + 3\tau^2} \le \frac{118}{k_r} \quad [N/mm^2]$$

Bending stress:

$$\sigma_b = \frac{10{,}2 \cdot M_b}{D_1^3} \quad [N/mm^2]$$

M_b = bending moment at the neck bearing [Nm]

Torsional stress:

$$\tau = \frac{5{,}1 \cdot Q_R}{D_1^3} \quad [N/mm^2]$$

D_1 = increased rudder stock diameter [cm]

The increased rudder stock diameter may be determined by the following formula:

$$D_1 = 0{,}1 \cdot D_t \sqrt[6]{1 + \frac{4}{3}\left(\frac{M_b}{Q_R}\right)^2}$$

Q_R = see C3.10.5.1.2

D_t = see C3.10.6.1.1

Note

Where a double-piston steering gear is fitted, additional bending moments may be transmitted from the steering gear into the rudder stock. These additional bending moments are to be taken into account for determining the rudder stock diameter.

C3.10.6.3 Analysis

.1 General

The evaluation of bending moments, shear forces and support forces for the system rudder - rudder stock may be carried out for some basic rudder type as shown in Fig. C3.10.1 as outlined in .2 to .3.

.2 Data for the analysis

$\ell_{10} - \ell_{30}$ = lengths of the individual girders of the system [m]

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Load on rudder body (general):

$$p_R = \frac{C_R}{\ell_{10} \cdot 10^3} \quad [kN/m]$$

C_R, see C3.10.5.1.1

.3 Moments and forces to be evaluated

.3.1 The bending moment M_R and the shear force Q_1 in the rudder body, the bending moment M_b in the neck bearing and the support forces B_2, B_3 are to be evaluated.

The so evaluated moments and forces are to be used for the stress analyses required by C3.10.6.2 and C3.10.8.1.

.3.2 The moments and forces may be determined by the following formulae:

$$M_b = C_R \left(\ell_{20} + \frac{\ell_{10} \, (2\, x_1 + x_2)}{3 \, (x_1 + x_2)} \right) \quad [Nm]$$

$$B_3 = \frac{M_b}{\ell_{30}} \quad [N]$$

$$B_2 = C_R + B_3 \quad [N]$$

C3.10.7 Rudder Couplings

C3.10.7.1 General

.1 The couplings are to be designed in such a way as to enable them to transmit the full torque of the rudder stock.

.2 For spade rudders only cone couplings are permitted, in general.

C3.10.7.2 Cone couplings

C3.10.7.2.1 Cone couplings with key

.1 Cone couplings shall have a taper c on diameter of 1 : 8 - 1 : 12. $c = (d_0 - d_u)/\ell$ according to Fig. C3.10.3.

The cone shapes should fit very exact. The nut is to be carefully secured, e.g. by a securing plate as shown in Fig. C3.10.3.

.2 The coupling length ℓ shall, in general, not be less than $1{,}5 \cdot d_0$.

.3 For couplings between stock and rudder a key is to be provided, the shear area of which is not to be less than:

$$a_s = \frac{16 \cdot Q_F}{d_k \cdot R_{eH1}} \quad [cm^2]$$

Q_F = design yield moment of rudder stock [Nm] according to C3.10.9

d_k = diameter of the conical part of the rudder stock [mm] at the key

R_{eH1} = minimum nominal upper yield point of the key material [MPa]

.4 The effective surface area of the key (without rounded edges) between key and rudder stock or cone coupling is not to be less than:

$$a_k = \frac{5 \cdot Q_F}{d_k \cdot R_{eH2}} \quad [cm^2]$$

R_{eH2} = minimum nominal upper yield point of the key, stock or coupling material [MPa], whichever is less.

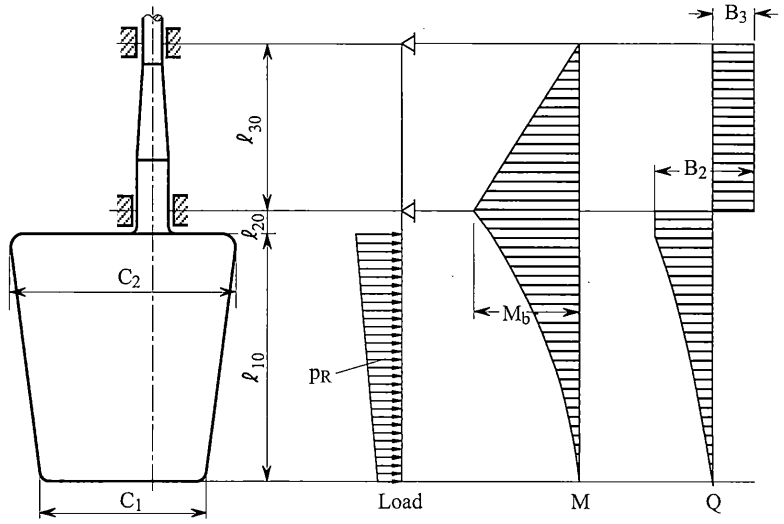

Fig. C3.10.2 Spade rudder

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.5 The dimensions of the slugging nut are to be as follows, see Fig. C3.10.3:

- height:

$$h_n = 0{,}6 \cdot d_g$$

- outer diameter (the greater value to be taken):

$$d_n = 1{,}2 \cdot d_u \quad \text{or} \quad d_n = 1{,}5 \cdot d_g$$

- external thread diameter:

$$d_g = 0{,}65 \cdot d_0$$

.6 It is to be proved that 50 % of the design yield moment will be solely transmitted by friction in the cone couplings. This can be done by calculating the required push-up pressure and push-up length according to C3.10.7.3 for a torsional moment Q'F = 0,5 · QF.

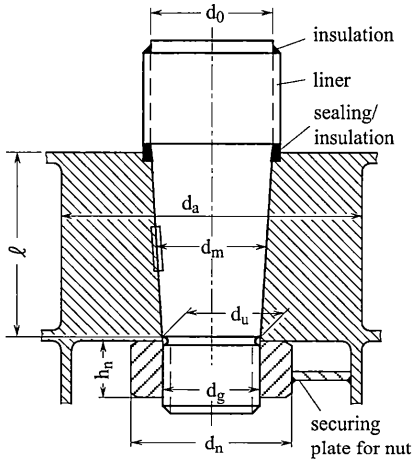

Fig. C3.10.3 Cone coupling with key and securing plate

C3.10.7.3 Cone couplings with special arrangements for mounting and dismounting the couplings

.1 Where the stock diameter exceeds 200 mm the press fit is recommended to be effected by a hydraulic pressure connection. In such cases the cone shall be more slender, c ≈ 1 : 12 to ≈ 1 : 20.

.2 In case of hydraulic pressure connections the nut is to be effectively secured against the rudder stock or the pintle. A securing plate for securing the nut against the rudder body is not to be provided, see Fig. C3.10.4.

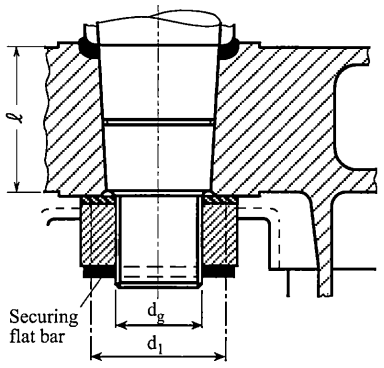

Fig. C3.10.4 Cone coupling without key and with securing flat bar

Note

A securing flat bar will be regarded as an effective securing device of the nut, if its shear area is not less than:

$$A_s = \frac{P_s \cdot \sqrt{3}}{R_{eH}} \quad [mm^2]$$

P_s = *shear force as follows*

$$= \frac{P_e}{2} \cdot \mu_1 \left(\frac{d_1}{d_g} - 0{,}6 \right) \quad [N]$$

P_e = *push-up force according to C3.10.7.3.3.2 [N]*

μ_1 = *frictional coefficient between nut and rudder body, normally* $\mu_1 = 0{,}3$

d_1 = *mean diameter of the frictional area between nut and rudder body, see C3.10.4*

d_g = *thread diameter of the nut*

R_{eH} = *yield point [MPa] of the securing flat bar material*

.3 For the safe transmission of the torsional moment by the coupling between rudder stock and rudder body the push-up length and the push-up pressure are to be determined by the following formulae.

.3.1 Push-up pressure

The push-up pressure is not to be less than the greater of the two following values:

$$p_{req1} = \frac{2 \cdot Q_F \cdot 10^3}{d_m^2 \cdot \ell \cdot \pi \cdot \mu_0} \quad [MPa]$$

$$p_{req2} = \frac{6 \cdot M_b \cdot 10^3}{\ell^2 \cdot d_m} \quad [MPa]$$

Q_F = design yield moment of rudder stock according to C3.10.9 [Nm]

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d_m = mean cone diameter [mm]

ℓ = cone length [mm]

μ_0 = 0,15 (frictional coefficient)

M_b = bending moment in the cone coupling (e.g. in case of spade rudders) [Nm]

It has to be proved that the push-up pressure does not exceed the permissible surface pressure in the cone. The permissible surface pressure is to be determined by the following formula:

$$p_{perm} = \frac{0,8 \cdot R_{eH} \left(1 - \alpha^2\right)}{\sqrt{3 + \alpha^4}}$$

R_{eH} = yield point [MPa] of the material of the gudgeon

$\alpha = \frac{d_m}{d_a}$ (see Fig. C3.10.3)

The outer diameter of the gudgeon shall not be less than:

$$d_a = 1,5 \cdot d_m \quad [mm]$$

.3.2 Push-up length

The push-up length is not to be less than:

$$\Delta\ell_1 = \frac{p_{req} \cdot d_m}{E\left(\frac{1 - \alpha^2}{2}\right)c} + \frac{0,8 \cdot R_{tm}}{c} \quad [mm]$$

R_{tm} = mean roughness [mm]

$\approx$ 0,01 mm

c = taper on diameter according to C3.10.7.3.1

E = Young's modulus ($2,06 \cdot 10^5$ MPa)

The push-up length is, however, not to be taken greater than:

$$\Delta\ell_2 = \frac{1,6 \cdot R_{eH} \cdot d_m}{\sqrt{3 + \alpha^4}\ E \cdot c} + \frac{0,8 \cdot R_{tm}}{c} \quad [mm]$$

Note

In case of hydraulic pressure connections the required push-up force P_e for the cone may be determined by the following formula:

$$P_e = p_{req} \cdot d_m \cdot \pi \cdot \ell\left(\frac{c}{2} + 0,02\right) \quad [N]$$

The value 0,02 is a reference for the friction coefficient using oil pressure. It varies and depends on the mechanical treatment and roughness of the details to be fixed.

Where due to the fitting procedure a partial push-up effect caused by the rudder weight is given, this may be taken into account when fixing the required push-up length, subject to approval by GL.

C3.10.8 Rudder Body, Rudder Bearings

C3.10.8.1 Strength of rudder body

.1 The rudder body is to be stiffened by horizontal and vertical webs in such a manner that the rudder body will be effective as a beam. The rudder shall be additionally stiffened at the aft edge.

.2 The strength of the rudder body is to be proved by direct calculation according to C3.10.6.3

.3 For rudder bodies without cut-outs the permissible stress are limited to:

bending stress due to M_R:

$$\sigma_b = 110 \text{ MPa}$$

shear stress due to Q_1:

$$\tau = 50 \text{ MPa}$$

equivalent stress due to bending and shear:

$$\sigma_v = \sqrt{\sigma_b^2 + 3\tau^2} = 120 \text{ MPa}$$

M_R, Q_1 see C3.10.6.3.3.

In case of openings in the rudder plating for access to cone coupling the permissible stresses according to 1.4 apply. Smaller permissible stress values may be required if the corner radii are less than $0,15 \cdot h_o$, where h_o = height of opening.

.4 In rudder bodies with cut-outs the following stress values are not to be exceeded:

bending stress due to M_R:

$$\sigma_b = 90 \text{ MPa}$$

shear stress due to Q_1:

$$\tau = 50 \text{ MPa}$$

torsional stress due to M_t:

$$\tau_t = 50 \text{ MPa}$$

The distance ℓ between the vertical webs shall not exceed $1,2 \cdot h$.

The radii in the rudder plating are not to be less than 4 – 5 times the plate thickness, but in no case less than 50 mm.

C3.10.8.2 Rudder plating

.1 The thickness of the rudder plating is to be determined according to the following formula:

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$$t = 1,74 \cdot a \sqrt{p_R \cdot k} + t_k \quad [mm]$$

t_k = 2 mm for steel,

= 0 mm for aluminium

$$p_R = 10 \cdot T + \frac{C_R}{10^3 \cdot A} \quad [kPa]$$

a = the smaller unsupported width of a plate panel [m]

The thickness shall, however, not be less than the thickness t_{min} of hull bottom plating.

Regarding dimensions and welding GL Rules Hull Structures (I-1-1), Section 19, B.4.4.1 have to be observed in addition.

.2 For connecting the side plating of the rudder to the webs tenon welding is not to be used. Where application of fillet welding is not practicable, the side plating is to be connected by means of slot welding to flat bars which are welded to the webs (on one side of the rudder only).

.3 The thickness of the webs is not to be less than 70 % of the thickness of the rudder plating according to .1. Webs exposed to seawater shall be dimensioned according to .1.

C3.10.8.3 Transmitting of the rudder torque

.1 For transmitting the rudder torque, the rudder plating according to C3.10.8.2.1 is to be increased by 25 % in way of the coupling. A sufficient number of vertical webs is to be fitted in way of the coupling.

.2 If the torque is transmitted by a prolonged shaft extended into the rudder, the latter shall have the diameter D_t or D_1, whichever is greater, at the upper 10 % of the intersection length. Downwards it may be tapered to 0,6 D_t, in spade rudders to 0,4 times the strengthened diameter, if sufficient support is provided for.

C3.10.8.4 Rudder bearings

.1 In way of bearings liners and bushes are to be fitted. Their minimum thickness is

t_{min} = 8 mm for metallic materials and synthetic material

= 22 mm for lignum material

Where in case of small ships bushes are not fitted, the rudder stock is to be suitably increased in diameter in way of bearings enabling the stock to be re-machined later.

.2 An adequate lubrication is to be provided.

.3 The projected bearing surface A_b (bearing height × external diameter of liner) is not to be less than

$$A_b = \frac{B}{q} \quad [mm^2]$$

B = support force [N]

q = permissible surface pressure acc. to Table C3.10.2

Table C3.10.2 Permissible surface pressure q

Bearing material	q [N/mm²]
lignum vitae	2,5
white metal, oil lubricated	4,5
synthetic material [1]	5,5
steel [2], bronze and hot-pressed bronze-graphite materials	7,0

1 Synthetic materials to be of approved type. Surface pressures exceeding 5,5 N/mm² may be accepted in accordance with bearing manufacturer's specification and tests, but in no case more than 10 N/mm².

2 Stainless and wear resistant steel in an approved combination with stock liner. Higher surface pressures than 7 N/mm² may be accepted if verified by tests.

.5 Stainless and wear resistant steels, bronze and hot-pressed bronze-graphit materials have a considerable difference in potential to non-alloyed steel. Respective preventive measures are required.

.6 The bearing height shall be equal to the bearing diameter, however, is not to exceed 1,2 times the bearing diameter. Where the bearing depth is less than the bearing diameter, higher specific surface pressures may be allowed.

C3.10.8.5 Guidance values for bearing clearances

.1 For metallic bearing material the bearing clearance shall generally not be less than:

$$\frac{d_b}{1000} + 1,0 \quad [mm]$$

d_b = inner diameter of bush

.2 If non-metallic bearing material is applied, the bearing clearance is to be specially determined considering the material's swelling and thermal expansion properties.

.3 The clearance is not to be taken less than 1,5 mm on diameter. In case of self lubricating bushes going down below this value can be agreed to on the basis of the manufacturer's specification.

C3.10.9 Design Yield Moment of Rudder Stock

The design yield moment of the rudder stock is to be determined by the following formula:

$$Q_F = 0,02664 \frac{D_t^3}{k_r} \quad [Nm]$$

D_t = stock diameter [mm] according to C3.10.6.1

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Where the actual diameter D_{ta} is greater than the calculated diameter D_t, the diameter D_{ta} is to be used. However, D_{ta} need not be taken greater than $1{,}145 \cdot D_t$.

C3.10.10 Stopper, Locking Device

.1 Stopper

The motions of quadrants or tillers are to be limited on either side by stoppers. Except where the steering gear is provided with its own rudder stopping devices, the stoppers and their foundations connected to the ship's hull are to be of strong construction so that the yield point of the applied materials is not exceeded at the design yield moment of the rudder stock.

.2 Locking device

Each steering gear is to be provided with a locking device in order to keep the rudder fixed at any position. This device as well as the foundation in the ship's hull are to be of strong construction so that the yield point of the applied materials is not exceeded at the design yield moment of the rudder stock as specified in C3.10.9.

Where the ship's speed exceeds 12 kn, the design yield moment need only be calculated for a stock diameter based on a speed $v_0 = 12$ kn.

C3.11 Stabilizers

C3.11.1 General

Two different situations are to be considered for the purpose of Section 3, depending on the main function of the stabilisation system.

- In general, the stabilisation system (foils, trim tabs or interceptors) is only a motion reduction or a ride control system. The hydrodynamic effects of fin stabilizers on the rolling or pitching behaviour of the ship are not part of the classification procedure. The classification however includes the integration of the system into the hull structure.
- The second situation is that the stabilisation system is associated with the safe operation of the craft as described in 16.1.1. In that case, the system has to comply to the present Rules.

C3.11.2 Classification process

.1 The complete bearing system and the drive unit directly mounted at the fin stock are to be situated within an own watertight compartment of moderate size at the ship's side or bottom. For installation purposes, inspection and maintenance watertight closable openings (with safeguards that they can be opened only during docking) have to be provided in suitable number and size.

For retractable fins a recess of sufficient size to harbour the complete fin has to be provided in addition at the ship's shell.

.2 At the penetration of the fin stock and at the slot of retractable fins, the shell has to be strengthened in a sufficient way.

.3 The watertight boundaries of the fin recess, if applicable, and of the drive compartment have to be dimensioned according to bottom and side shell requirements. Special attention has to be given to the transmission of the fin support forces from the stock bearings into the ship's structure. The local reinforcements and the overall transmission of the forces by girders, web frames, etc. have to be defined by direct calculations considering fatigue strength and have to be included in the hull drawings submitted.

.4 If the fin body extends over the maximum breadth of the ship, the location of non-retractable fins should be marked on the shell.

.5 Possible interferences between hydraulic installation and the safety of the craft are of concern, only. The applicable regulations depend on the location of the hydraulic power pack. The working principles are not checked. However, the hydraulic system documentation is to be submitted.

.6 For the second situation the structure of the stabilisation devices, hydraulic system used for activation of stabilisation system and associated electrical devices has additionally comply to the present rule.

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Appendix C3A1

Special Requirements for Scantlings of Hydrofoil Hull Structures

C3A1.1 Foreword

.1 The requirements of this Appendix apply to hydrofoils, i.e. craft which can sail both at high speed, with the hull emerging from the water surface, supported by the hydrodynamic lift of a system of connected underwater foil planes (foils), and as conventional floating craft during manoeuvring operations or in emergency conditions.

.2 Where not expressly specified, the symbols used here are those already defined in this Section.

.3 This Appendix generally covers hydrofoils with a length $L \leq 35$ m and fitted with two foils, a bow and an after foil, and a screw propeller, having a maximum sailing speed on foils of 40 knots, and intended for the carriage of passengers and, if applicable, of cargo.

.4 Hydrofoils with characteristics other than those above, or which are not designed in accordance with these Rules, are to be individually considered.

C3A1.2 General

.1 The hull is to be designed with the aim of achieving safe navigation of the hydrofoil, both when emerging on foils and when floating under the different displacement, trim and stability conditions, in still water and in sea waves, which are expected in service.

The designer is to establish, by calculations and, if necessary, tank tests on models, hull shapes, weights and their distribution, the position, shape and type of foils and the thrust of the propulsion system in order to ensure suitable structural strength of the hull and safe transverse and longitudinal stability of the hydrofoil, with particular reference to transient conditions of lifting from water, alighting on water and turning.

.2 Hydrofoils covered by this Appendix generally have hard chine hulls as well as bottoms presenting a significant deadrise, bow foil within 1/3 L of the bow and after foil within 1/3 L of the stern.

Foils may be of the partially submerged Vee (narrow or wide) self-stabilizing type, or of the completely submerged, horizontal non-self-stabilizing type fitted with automatic stabilizing devices; foils may be of the fixed or lifting type.

.3 In the case of hydrofoils with general characteristics substantially different from those above or having special arrangements, GL reserves the right to require appropriate additional calculations as well as tank tests on models, followed, if necessary, by exhaustive sea trials before entry into service.

C3A1.3 Definitions and Symbols

L = Rule length, in m (see C3.1),

L_a = longitudinal distance, in m, between mid bow foil and mid after foil, measured parallel to L,

L_{ft} = overall length, in m,

B = moulded breadth, in m (see C3.1),

B_a = greatest foil breadth, in m,

D = depth, in m (see C3.1),

D_a = greatest depth, in m, measured vertically from the lower side of the more deeply submerged foil to the corresponding top of the deck beam, at the side of the main deck,

T = draught, in m (see C3.1),

T_a = greatest draught, in m, of the more deeply submerged foil, measured vertically with craft at rest,

T'_a = greatest draught, in m, of the more deeply submerged foil, measured vertically with full load craft on sailing trim on foils,

f_m = coefficient depending on the material:

- 1,00 for steel structures
- 1,45 for aluminium alloy structures

f'_m = coefficient depending on the material:

- 1,00 for steel structures
- 2,15 for aluminium alloy structures

k = material factor defined in Section 3, C3.2

C3A1.4 Documents to be submitted

.1 In addition to the plans and information listed in C3.0, the following calculations, specifications and plans (in triplicate) are to be submitted to GL for approval, together with the following information:

(a) outer shell expansion, including stiffeners in way of foils, rudder, stern tubes and propeller shaft brackets;

(b) structure of foils and relevant hull connection stiffeners as well as quality of materials employed, with specification of intended heat treatments and non-destructive tests;

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(c) calculations and diagrams relevant to the longitudinal strength of the hull;

(d) calculation of foil structure strength, including the specification of the loading conditions considered and restraints assumed.

.2 Any other documents, calculations and plans deemed useful by GL for the purpose of classification are also to be submitted.

C3A1.5 Longitudinal Strength

C3A1.5.1 General

.1 The longitudinal strength of the hull is to be calculated for at least the two conditions specified below, adopting the more severe of the resulting scantlings.

(a) Floating hydrofoil

Hydrofoil floating in still water,

(b) Emerging hydrofoil on foils

(1) Emerging hydrofoil supported by its foils and considered on its sailing trim in still water without any additional motion, taking account, in the acting forces diagram, of the vertical components (lift) of hydrodynamic forces on the foils,

(2) Hydrofoil in the conditions specified in (1) but in sea waves, taking account of pitching, rolling and heaving motions, and of consequent acceleration and forces of inertia.

.2 The calculation of the hull cross-section modulus is to include the shells and associated stiffeners which, due to their longitudinal continuity, effectively contribute to longitudinal strength.

.3 As regards the acceleration values and wave characteristics to be assumed in the calculations, they are to include the severest sea conditions expected for the hydrofoil in service, according to the provisions in C3.3.

C3A1.5.2 Allowable stresses Rule values of midship section modulus / Section modulus calculation

.1 The maximum allowable bending stresses σ at deck and bottom and shear stress τ at sides are generally not to exceed the values given in Table C3A1.1.

Table C3A1.1 Maximum allowable stresses

Hydrofoil under conditions specified in:	σ at bottom [N/mm^2]	σ at deck [N/mm^2]	τ at sides [N/mm^2]
C3A1.5.1.1 (a) C3A1.5.1.1 (b)(1)	45 / (k·f_m)	45 / (k·f_m)	40 / (k·f_m)
C3A1.5.1.1 (b)(2)	85 / (k·f_m)	85 / (k·f_m)	70 / (k·f_m)

In general, maximum σ stresses occur at about 0,5 L_a, and maximum τ stresses in way of the bow foil.

.2 Attention is to be paid to scantling distribution for structures contributing to the longitudinal strength of the different hull zones, so as to avoid structural discontinuities, which would give rise to peaks in the diagrams of moments of inertia and of section moduli, with consequent abrupt variations in stresses. The structures constituting the hull are also to comply with the requirements for local hull strength, set out below.

.3 For hydrofoils with length $L \leq 35$m, the Rule midship section moduli at bottom Z_b and at deck Z_d, in cm^3, are given by the formula:

$$Z_b = Z_d = (6{,}3 \cdot L_a\, 60) \cdot 10^3$$

.4 The section modulus is, in any case, to be such as to comply with the allowable stresses given in Table C3A1.1.

.5 The section moduli of the cross-sections W_b at bottom and W_d at deck are conventionally obtained by dividing the moment of inertia of the cross-section under consideration by the vertical distance between the horizontal neutral axis and the base line, and by the distance between this axis and the top of the deck beam, at the side, of the strength deck, respectively.

.6 To calculate the moment of inertia of the above cross-sections, the net cross-section of continuous elements contributing to longitudinal strength, and therefore reduced for openings, manholes and other holes which are not completely compensated, is to be taken into account; in the case of riveted structures, in contrast, rivet holes in shells and bars are not required to be deducted from the strength cross-section.

C3A1.6 Local Strength

C3A1.6.1 General

.1 Hull structure dimensions are to comply with the relevant requirements of this Section considering the craft as floating, and neglecting dynamic effects due to accelerations, impact and wave loads.

.2 The structural arrangements to be adopted in these craft are specified below, together with minimum scantlings to be satisfied in any case.

.3 The scantlings of the outer shell, decks and relevant stiffeners contributing to local hull strength are to comply with the requirements of this Appendix. They are to be increased, if necessary, depending on the longitudinal strength as required in C3A1.5.

.4 The spacing of secondary stiffeners is, in general, not to exceed 300 mm, at least in way of foils, the machinery space and forward of the bow foil.

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.5 Primary transverse frames, consisting of floors, side transverses and deck transverses, are to be fitted both where the structure of ordinary stiffeners is of the transverse type and where it is of the longitudinal type.

In the first case, the frames give support to bottom girders, side stringers and deck girders, which in turn, support the ordinary shell stiffeners, i.e., floors, webs and beams, respectively; in the second case they support the longitudinals directly.

Structures different from the above are to be individually considered in each case.

C3A1.6.2 Bottom shell plating

.1 The thickness t_b, in mm, of the bottom shell, in the area from the bow foil to the stern, is in no case to be less than:

$$3 \cdot f_m \cdot \sqrt{k}$$

.2 The thickness t_k of the keel strake is to be, in general, at least equal to 1,2 times the thickness adopted for the bottom and in no case less than 4 mm.

.3 The bottom thickness t_{bf} in the area forward of the bow foil is to be at least 1,2 t_b, provided that the takeoff speed of the hydrofoil is not greater than approximately 20 knots and the maximum sailing speed on foils is not greater than approximately 40 knots. For greater speeds, the thickness t_{bf} is to be individually considered in each case, depending on the results of calculations and, if necessary, experiments to be performed by the designer, to assess the hydrodynamic force on the shell due to water in the takeoff stage and the wave action on the shell in the sailing condition on foils at maximum service speed.

.4 Takeoff speed is intended as the minimum speed necessary to lift the hull on foils in still water.

.5 In way of foils, the bottom thickness is to be increased appropriately and in no case is it to be less than, in mm:

$$5 \cdot f_m \cdot \sqrt{k}$$

C3A1.6.3 Side shell plating

.1 The thickness t_s, in mm, of the side shell is to be not less than:

$$3 \cdot f_m \cdot \sqrt{k}$$

.2 The thickness t_s, in mm, from 0,1 L aft the bow foil to 0,1 L forward of such foil is to be not less than:

$$5 \cdot f_m \cdot \sqrt{k}$$

.3 The thickness t_{sh} of the sheerstrake, for the whole hull length, is to be at least equal to that of the corresponding side.

.4 Where, on the sheerstrake, side ports or side scuttles or other large openings are fitted, the thickness is to be increased such as to compensate these openings.

.5 The thickness t_{sh} is also to be increased in way of end bulkheads of any castles, or, in any case, in way of steps in the strength deck.

.6 In way of foils, the side thickness is to be suitably increased and is, in no case, to be less than, in mm:

$$5 \cdot f_m \cdot \sqrt{k}$$

C3A1.6.4 Deck and flat plating

.1 The thickness t_d, in mm, of the deck plating is to be not less than:

$$3 \cdot f_m \cdot \sqrt{k}$$

.2 The thickness t_{st} of the stringer plate of the strength deck is to be at least equal to that adopted for the sheerstrake or for the remaining deck plating, whichever is greater.

.3 The thickness, in mm, of decks below the strength deck, generally consisting of flats, is to be not less than:

- if the 'tween deck is intended for accommodation or similar:

  $$2 \cdot f_m \cdot \sqrt{k}$$

- if the deck forms a tank bottom or tank top:

  $$2,5 \cdot f_m \cdot \sqrt{k}$$

C3A1.6.5 Bottom structure

.1 For the bottom, longitudinal framing extending through the whole length is generally required, except for extreme stern and extreme bow areas, where the framing is generally transverse.

.2 In way of the bow foil and after foil, ordinary floors of suitable scantlings, to be individually considered in each case, are to be fitted. In way of the fore foil, the floor spacing is generally to be one half the frame spacing.

.3 In the machinery space, at least two girders on each side are to be fitted, at least one of which is to be fitted in way of one of the engine seating girders.

.4 In the area forward of the bow foil, at least one girder on each side is to be fitted. The height, in general, is to be at least equal to that of the bottom

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transverses, and preferably located in the same plane as a deck girder, if fitted. The girder thickness is to be not less than, in mm:

$$3 \cdot f_m \cdot \sqrt{k}$$

.5 At the bow foil and after foil, the number and scantlings of the floors are to be individually considered in each case, depending on the type of structure proposed. In any case, two floors belonging to complete transverse rings (side and deck transverses) are to be fitted, and located one forward and the other aft of the hull penetrations of the bow foil bearing arm.

Intermediate floors in this area are to be positioned, between those usually fitted at each frame spacing, and all such bottom transverses are to have a section modulus of at least 1,25 times that required for the area aft of the engine room.

.6 In the area forward of the bow foil, the floors are generally to have a section modulus of at least 1,8 times that required for the area aft of the engine room and a spacing not greater than four web spacings. In the usual case of bottoms presenting forward a deadrise angle greater than approximately 25°, the floors are to have a horizontal upper edge and a height of at least $0,2 \cdot D$ in the centreline.

.7 In the case the takeoff and sailing speed of the hydrofoil are greater than those specified in C3A1.6.2.3, the scantlings of the forward floors are to be individually considered in each case.

C3A1.6.6 Side structure

.1 This structure may be of the transverse type, i.e. consisting of ordinary webs, supported by stringers (or flats) and side transverses belonging to the primary transverse rings, or, for hydrofoils with length L greater than approximately 20 m, of the longitudinal type, i.e. consisting of longitudinals supported by side transverses belonging to these rings.

.2 Continuity of the longitudinals is to be ensured, considering their contribution to the longitudinal strength of the hull.

.3 Side transverses are to be fitted for the purpose of supporting the longitudinals, and side stringers (or flats), to be individually considered in each case, are to be fitted in way of and forward of the machinery space.

.4 In way of foils, scantlings are to be individually considered in each case.

.5 The section modulus of the side transverses forward of the bow foil is to be individually considered in each case: in any event, two side transverses are to be fitted in way of the floors located forward and aft of the hull penetrations of the bow foil bearing arm, for which in general:

$$h / S \geq 0,25$$

where h is the web height and S is the conventional span of the side transverse.

.6 In way of the bow and after foils and in the case of side transverses supporting deck bracket-transverses, the provisions of C3A1.6.5.5 to C3A1.6.5.7 apply.

.7 In the area forward of the bow foil, the side transverses are preferably to have an h/S ratio of at least 0,2. As regards the case of high hydrofoil speeds, the provisions of C3A1.6.5.5 to C3A1.6.5.7 are to be complied with.

C3A1.6.7 Deck structure

.1 Strength deck stiffeners may be of the transverse type where constituted by beams supported by girders which are in turn supported by deck transverses belonging to the primary transverse rings, which may or may not be associated with pillars; such stiffeners are of the longitudinal type where they consist of longitudinals supported by the deck transverses. The latter structure is recommended where L > 20 m.

.2 Stiffeners of decks below the strength deck and stiffeners of flats intended for passenger accommodation or forming the top of the machinery space are to have a section modulus not less than, in cm^3:

$$4 \cdot f_m \cdot \sqrt{k}$$

.3 Where the deck or flat forms the top of a tank for liquids, the provisions of C3.7 or C3.8 are to be complied with.

.4 The scantlings of stiffeners fitted on account of special structural requirements, for example in way of foils, are to be individually considered in each case.

.5 Deck transverses are to be fitted in way of side transverses, so as to constitute members of complete transverse rings.

.6 They may instead be of the bracket type in the general case of hydrofoils for which L is less than approximately 15 m, and fitted with long deck openings; in such case, deck transverses, continuous from side to side, are to be fitted at least immediately aft and forward of the machinery space and forward of the bow foil. An intermediate flat, between bottom and deck, is to be fitted at least in the area aft of the machinery space.

.7 The scantlings of deck transverses in way of foils and the scantlings of panting deck transverses fitted in the fore peak, at approximately mid-depth between bottom and deck, are to be individually considered in each case.

.8 Owing to their span (roughly 0,3 to 0,5 m), deck transverses of the bracket type are generally composed of wide brackets connected to the web frame and the side stringer of the deck opening. The

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scantlings of such deck transverses are to be individually considered in each case.

C3A1.6.8 Watertight bulkheads

.1 For the hydrofoils considered in this Appendix, four watertight subdivision bulkheads are generally required to be fitted as follows:

- watertight collision bulkhead, located not less than 0,05 · L from the forward perpendicular and, in general, not more than 0,08 · L from the same perpendicular,
- fore and after watertight bulkhead of the machinery space,
- after watertight bulkhead, located, in general, about 0,05 · L from the aft perpendicular, but in no case more than 0,08 · L from the same perpendicular.

.2 In the case of hydrofoils intended for the carriage of passengers, the watertight subdivision bulkheads are also to satisfy the relevant requirements of Section 2.

C3A1.7 Foils

C3A1.7.1 General

.1 The type, shape and location of foils is to be determined by the designer based upon the general design provisions specified in C3A1.2, taking account of the fact that the essential function of foils is to support the hull, emerging at a sufficient height above the water surface so as to allow sailing even in waves, while ensuring the stability of the hydrofoil at the same time.

After determining these characteristics, the strength calculations for foils and relevant hull supporting connections are to be performed.

.2 In the case of hydrofoils with foil types other than those considered below, GL reserves the right, after examining the calculations, to require special checks and tests, as specified in C3A1.2.

.3 The foil profile and shape are to comply with the provisions of the present article and, even when sailing in waves, to avoid cavitation phenomena dangerous for the stability of the hydrofoil.

.4 Calculation of the forces acting on the hydrofoil may be performed by considering the craft in sailing condition on foils in still water.

.5 The following acting forces are assumed:

- hydrofoil weight, at least in the two conditions of full load and without passengers
- hydrodynamic resistance of the bow foil and after foil and associated lift
- thrust of propellers

.6 For the equilibrium, the algebraic sum of the acting forces and relevant moments with respect to the hydrofoil's centre of gravity is obviously to be equal to zero.

.7 In addition, the hydrofoil is to be considered during its turning manoeuvres. This means that water thrust on the rudder, whose action gives rise to variations in the hydrodynamic resistance and in the lift distribution on foils, as well as the forces generated by balancing flaps, are to be added to the forces above.

.8 Moreover, taking into account the most severe dynamic conditions expected for the hydrofoil in service, the above forces and, in addition, forces of inertia generated by rolling, pitching and heaving, including those during takeoff from the water and alighting on the water, are to be considered in the designer's calculations.

The characteristics of such motions, i.e. oscillation amplitude and period, and the consequent acceleration from which the forces of inertia originate, are to be considered individually by GL in each case, based upon the experience already gained, if the hydrofoil under consideration is similar to previous ones which have given good results in service, or, otherwise, upon the results of exhaustive tank tests on models, as well as sea trials on the hydrofoil itself, before entry into service.

C3A1.7.2 Foil strength calculations

.1 In the case of V-type or W-type foils, each is usually connected, by quasi-vertical or vertical arms, to a horizontal member, fitted transversely with respect to the hull, and supported by special hull structures.

The foils and arms may therefore in such cases be considered, overall, as a system consisting of beams and joints supported by the hull structures.

.2 The forces acting on the foils consist of hydrodynamic resistance and lift, as well as the reactions of the structures mentioned above which balance such forces.

.3 Strength calculations are therefore to take account of the nature of the restraints from the hull on the reticular system and acting forces, in the loading conditions specified above, as well as of the mechanical properties of the materials employed, which are generally high-strength welding steels.

.4 In particular, diagrams of bending moments and axial and shear forces acting on the foils are to be plotted and the stresses deriving from them are to be calculated.

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C3A1.7.3 Foil construction

.1 The foil joints are generally constituted of forged or cast steel, or are obtained from plate, while the beams are to be made of fabricated plating, and connections are to be welded.

.2 Since, due to the shape and dimensions of the foil profile, the foils themselves are not internally accessible, and therefore back-welding of all welded joints is not possible, the constructional plan is to specify special types of edge preparation, welding sequence and performance, to ensure the absence of defects and minimise internal stresses due to shrinkage at welds.

In particular, the number of slot-welded joints on plating is to be minimised.

.3 Materials are to be tested by GL, and electrodes and welding processes are to be recognised as suitable in accordance with the Rules.

.4 Butt-joints are to be subjected to radiographic examination and, if inaccessible from one side, to magnetic particle or dye-penetrant examination.

.5 Depending on the quality of the material adopted and on welding processes, GL reserves the right to require thermal stress-relieving in the furnace after welding.

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Appendix C3A2

Requirements for Scantlings of Air-cushion Vehicle Hull Structures

C3A2.1 Foreword

The requirements of this Appendix apply to "flexible skirt hovercraft", i.e. air-cushion vehicles with a downwardly-extending flexible structure used to contain or divide the air-cushion. This type of air-cushion vehicle is amphibious.

Unless otherwise specified, the symbols used here are those already defined in C3.1.

C3A2.2 General

C3A2.2.1 Definitions and symbols

W_{max} = maximum operational weight: the weight up to which operation in the intended mode is permitted [kg]

W_{min} = minimum operational weight: is the minimum overall weight at which the craft is permitted to operate under normal conditions [kg]

The W_{min} is the sum of the weights of:

- basic weight: weight of the craft with its basic equipment, including a declared quantity of oil and unusable fuel, without any passengers and payload [kg]
- weight of a minimum crew to ensure a save manoeuvring and navigation of the craft [kg]

L = maximum length of the rigid structure [m]

LCG = longitudinal centre of gravity, measured from stern [m]

Section = longitudinal fragmentation of craft into parts of equal length

Station = centre of one section

C3A2.3 Documents to be submitted

C3A2.3.1 Documents submitted for approval

In addition to the information stipulated in **C3.0**, the following information and drawings are requested:

- general arrangement drawing showing the general structural layout, intended use of different spaces and tanks, and location of propelling, lifting and operating installations.
- structural members of the hull shown in side view, plan view and cross sections, which includes hull, deck, superstructures, bulkheads, frames, floors, bottom plating, side plating, etc.
- hull to deck joint drawing
- fuel tanks, holding tanks (material, dimensions, connections, pressure head, fastening details)
- bonding of structural components to the hull and to each other (for example laminate angles or welding (procedure, throat thickness))
- engine foundation
- structural design of the propelling mountings and integration of propelling foundation to the hull structure with designation of maximum occurring thrust/lifting loads in all relevant directions
- skirt and its structural integration and the occurring loads at its mounting parts
- seating, foundations, supporting brackets and air pipes of lifting plant
- landing, ground supporting and mooring arrangements, if any, including handling equipment
- hoisting and handling equipment, if any, used on board
- longitudinal weight distribution for following loading cases:
  - minimum operational weight
  - maximum operational weight
- a design performance curve showing the speed in kn vs. the significant wave height in m has to be provided for minimum operational weight and maximum operational weight.

This is not an exhaustive list; other drawings and information may be required.

C3A2.3.2 Justification of scantlings

.1 Scantlings are to be justified by calculation notes indicating relevant loads, calculation methods and computation results.

.2 When computer calculations are carried out, the software is to be indicated, and indications are to be communicated with regard to structure description, boundary conditions and the way loads are introduced.

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.3 Justifications can be based on recognised experimental results: recorded for similar structures and corrected, if required, to allow for minor variations of certain parameters, the effects of which have been suitably evaluated.

In that case, tested structures, test conditions, methods and results, as well as variations in the parameters and their effects on the structure in question, are to be clearly defined.

C3A2.4 Overall Loads

The overall loads addressed in this section are considered to subject global structural characteristics of the vessel, i.e. global sections.

C3A2.4.1 Loads due to water impact while flying

.1 General

This section addresses load scenarios in which air-cushion vehicles are subjected to wave impacts while operating in the flying mode.

Impact by waves is causing a global response of the vessel. The resulting inertia effects are acting on the hull's global structure and are causing a global longitudinal bending and global shear loading, varying over the craft's length.

The amount of this inertia load is depending on following parameters:

- Loading case
- Speed of air cushion vehicle
- Corresponding wave
- Location of wave impact

and has to be determined for the most severe combination which can arise within the design environmental conditions and the craft limitations for which certification is sought.

The results of these calculations are to be submitted to GL.

.2 Principle of procedure

The craft will be divided into equally spaced longitudinal sections. Weights, accelerations and the corresponding inertia loads will be calculated for each section station to result in a global force balance.

These individual forces of each section are resulting in a characteristic bending moment and shear force distribution.

For this procedure a detailed weight distribution has to be provided to determine:

- Masses per section
- Craft's centre of gravity, LCG
- Craft's gyration radius

.3 Determination of weight distribution, LCG and radius of gyration

The following defines the mass moment of inertia characteristics:

The overall weight of each weight scenario has to be distributed over the longitudinal stations likewise the existing mass distribution.

$$W = \sum_{i=1}^{m} M_i$$

W = overall weight [kg]

m = total number of sections

M_i = mass of section i [kg]

Determination of longitudinal centre of gravity:

$$LCG = \frac{\sum_{i=1}^{m} (M_i \cdot x_i)}{\sum_{i=1}^{m} M_i}$$

x_i = x – location of station i [m]

Determination of mass moment of inertia J [kg · m^2]:

$$J = \sum_{i=1}^{m} \left(M_i \cdot x'^2_i \right)$$

x'_i = $LCG - x_i$ [m]

Determination of radius of gyration k [m]:

$$k = \sqrt{\frac{J}{W}}$$

As described in C3A2.4.1.1, the wave's impact leads to inertia loads, acting on the whole structure of the craft. The loads consist mainly of two components, which are the overall vertical acceleration and the angular acceleration. Both depend amongst others on the location of the impact. Does the wave impact the craft at its LCG, the crafts reaction will result in vertical acceleration only, whereas an impact off the LCG will result in an overall vertical acceleration and angular acceleration. Both types of acceleration will be determined separately and will be superimposed afterwards.

.4 Vertical acceleration

The overall vertical acceleration is depending on the maximum speed of the craft, the craft's overall weight, the vertical speed of impact and location of impact. It can be expressed by the formula:

$$n_W = \frac{K_x \cdot V_v \cdot V}{W^{1/3} \cdot \left(1 + r_G^2\right)^{2/3}}$$

n_W = impact load of the craft at position x_i of spot of the impact [g]

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n_{Wmin} = 0,5

K_x = coefficient depending on position x_i of spot of the impact, determined according to Fig. C3A2.1

V_v = relative vertical speed of impact [m/s]

V = the maximum speed of air-cushion vehicle [m/s]. It correlates to a significant wave height H. The relation between V and H is to be provided by the designer as the design performance curve.

r_G = ratio of distance measured parallel to the hull reference axis from spot of impact to LCG, to the radius of gyration:

$$r_G = \frac{x'_i}{k}$$

Determination of relative vertical speed of impact V_v [m]:

$$V_v = 0{,}6 + H \cdot \sqrt{\frac{\pi \cdot g}{2 \cdot A}}$$

H = wave height [m]

A = wave length [m]

Values of A and H are defined in C3A2.4.2

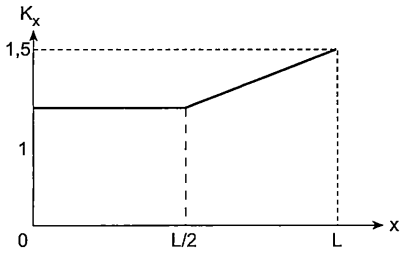

Fig. C3A2.1 Coefficient K_x

.5 Angular acceleration

The angular acceleration results from a wave impact at the rigid bottom of the air -cushion vehicle at a longitudinal location, which differs from the location of the craft's LCG. The impact induces a rotation about the LCG and yields to a linear distribution of tangential acceleration.

Equation of overall angular acceleration, n_a:

$$n_a = \frac{T}{J} = \frac{n_{W\,i} \cdot W \cdot x_{i,\,impact}}{J}$$

n_a = overall angular acceleration [rad/s^2], applies for all stations

T = applied torque [N· m]

n_{Wi} = impact load at station of wave impact [g] (see C3A2.4.1.4)

$x_{i,\,impact}$ = distance of station of wave impact to LCG [m]

.6 Superimposing of accelerations

The superimposing of both, the vertical (see C3A2.4.1.4) and the tangential acceleration gives the occurring (vertical) acceleration for each station.

Equation of superimposed vertical acceleration at the rearmost station, $n_{v,\,aft}$:

$$n_{v,\,aft} = n_{w,i} - n_a \cdot x_{aft}$$

$n_{v,\,aft}$ = vertical acceleration at rearmost station [g]

x_{aft} = distance of the rearmost station to LCG [m]

Equation of superimposed vertical acceleration at the foremost station, $n_{v,\,fore}$:

$$n_{v,\,fore} = n_{w,\,i} + n_a \cdot x_{fore}$$

$n_{v,\,fore}$ = acceleration at foremost station [g]

x_{fore} = distance of the foremost station to LCG [mm]

$n_{v,\,i}$ = acceleration at station i [g]

Linear interpolation between the rearmost and foremost acceleration gives the individual acceleration n_{vi} of each station.

.7 Forces acting on each section

As described in C3A2.4.1, the bending moment and shear force distribution will be derived by the summation of vertical forces acting on each station.

This force is the product of the section mass and the stations acceleration (derived in C3A2.4.1.5) In addition to that, if applicable for the specific station, the direct load of the wave impact also has to be added to the respective section load.

The forces acting on each section are finally described in following equation:

$$F_i = M_i \cdot n_{v,\,i} \cdot g + F_{i,\,wave}$$

The amount of the total wave impact force is equal to the sum of all station forces. It is recommended to distribute the direct wave load onto two adjacent stations, and apply it depending on the location of impact at the bow, stern or LCG.

$$F_{i,\,wave} = \sum_{i=1}^{m} \left(M_i \cdot g \cdot n_{v\,i} \right)$$

Note

Hence the wave impact load $F_{i,\,wave}$ is acting in the opposite direction to the section mass, it is negative.

M_i = mass of section i [kg]

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n_{vi} = acceleration for station i [rad/s^2]

g = acceleration due to gravity [9,81 m/s^2]

To analyse the most critical load case, it is required to investigate wave impacts at bow, stern and LCG.

Note

Steady state 1g is not included and is assumed to be supported by cushion with negligible effect on global loads.

C3A2.4.2 Air-cushion vehicle afloat

The wave considered for scantling calculations of flexible skirt craft afloat is a sinusoidal wave of height H and length A [m] and confirming the following equations:

- for A ≤41,50 m:

  H = A / 10

- for A > 41,50 m:

$$H = 6,51 - 0,57 \cdot \left(\frac{300 - A^{3/2}}{100} \right)$$

The value H is defined by the designer on the basis of the limit operating conditions indicated in the Enclosure of the Class Certificate and on the midship section drawing (see C3.3.1 and C3.3.4).

The worst conditions are generally encountered when A is approximately equal to:

- L for head wave,
- B for beam wave.

C3A2.5 Local Loads

C3A2.5.1 Water impact loads

The rigid structure can be subjected to direct wave impact under the following circumstances:

- Craft in flying situation under worst intended conditions
- Plough-in of cushion system
- Craft afloat, at rest or not

The local and distributed pressures have to be determined for the maximum loads which can arise from the most severe combination of loading scenarios, speed of air cushion vehicle and corresponding relative vertical velocity.

.1 Local pressure

The local pressure due to water impact is considered to be the peak slamming load. It will be applied to evaluate scantlings of secondary stiffeners and shell elements on a frame space. It can be expressed by the formula:

$$P_{loc} = 1,2 \cdot K'_x \cdot V_V \cdot V \quad [kN/m^2]$$

K'_x = coefficient depending on position x of spot of the impact and determined according to Fig. C3A2.2

V_V and V = values defined in C3A2.4.1.4 above.

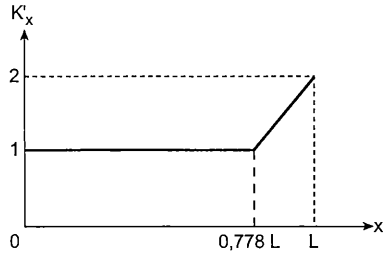

Fig. C3A2.2 Coefficient K'_x

.2 Distributed bottom pressure

The average pressure is 44% of the local pressure. It will be applied to evaluate scantlings of main frames and is given by the formula:

$$P_{distr} = 0,53 \cdot K'_x \cdot V_V \cdot V \quad [kN/m^2]$$

.3 Increased pressures in bow section

Hence the bow area of the craft is exposed to slamming loads, pressures in this area will be determined regardless of the values provided by the design performance curve. A high velocity in combination with a high wave height yields to the increased local and distributed pressure:

$$P_{loc,\,bow} = 1,2 \cdot K'_x \cdot V_V \cdot V_{bow}$$

$$P_{distr,\,bow} = 0,53 \cdot K'_x \cdot V_V \cdot V_{bow}$$

The bow area is defined as: $\frac{x}{L} \geq 0,8$

$$V_{bow} = V_{max} \cdot 0,8$$

$$H_{bow} = H(0,8 \cdot V_{max}) \cdot 3$$

Note

V_{max} and H to be taken from design performance curve V_V, see C3A2.4.1.4

C3A2.5.2 Loads arising from propelling and steering installation

These loads are applied to the structure through the connections of foundations, seating, gantries, etc. supporting the propelling engine, the lifting installation, their auxiliaries as well as steering gear such as rudders and skegs.

For propelling and lifting plants, loads are calculated on the basis of the most critical situations to be ex-

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pected (e.g. breakdowns, sudden changes in engine speed, reverse propeller pitch).

For steering arrangements, loads are either contractual loads (power rudders) or loads actually encountered. The latter can be deduced from calculations or tests. The basic contractual loads applied by the pilot on the controls are as follows:

- 0,46 kN on a control stick or control wheel ahead or reverse gear
- 0,28 kN on a control stick - laterally
- 0,185 kN on a control wheel - tangential action
- 0,60 kN on pedals or levers

See also C3A2.7.8.

C3A2.5.3 Deck loads

.1 General

.1 The pressure [kN/m^2] considered as acting on deck is given by the formula:

$p_d = p\ (1+n_{vi})$

p = uniform pressure due to the load carried [kN/m^2]. Minimum values are given in C3.5.8.2 to C3.5.8.6

n_{vi} = design vertical acceleration, see C3A2.4.1.5

.2 Where decks are intended to carry masses of significant magnitude, including vehicles, the concentrated loads transmitted to structures are given by the corresponding static loads multiplied by $(1 + n_{vi})$

.2 Decks loads in particular

For determination of :

- weather decks and exposed areas
- sheltered decks
- enclosed accommodation decks
- enclosed cargo decks
- platforms in machinery spaces
- decks carrying vehicles
- pressures on tank structures
- pressures on subdivision bulkheads

see: C3.5.8.2 to C3.5.8.10

.3 Sea pressures on deckhouses

For determination see C3.5.7

C3A2.5.4 Landing load

.1 This refers to amphibious air-cushion vehicles normally parking on land.

.2 The worst landing case is defined by the following parameters:

- Maximum lifting height
- Highest possible descending speed
- Worst mass, trim, heeling and horizontal speed conditions (e.g. asymmetrical landing supports, gusts of wind)

.3 This case determines local forces applied to landing-gear connecting points.

It can also determine certain general forces, in particular for torsion resulting from asymmetrical landing supports.

C3A2.5.5 Hoisting Load

.1 This case affects the scantlings of hoisting points and their connections to the structure (distribution of concentrated forces).

.2 It also has to be checked that this case does not generate general bending or torsion forces (asymmetrical hoisting) leading to stresses that exceed allowable values.

.3 The maximum authorized mass for hoisting is to be determined by the designer and indicated in the maintenance manual.

C3A2.5.6 Anchoring – Mooring – Towage

.1 These situations determine the concentrated forces applied to points of ground or quay anchoring and mooring, together with towage.

.2 The maximum authorized forces to be applied at the preceding points are equal to the respective breaking loads of anchor, mooring and towing cable lines.

C3A2.6 Load Factors

C3A2.6.1 Acceleration under service conditions

.1 For the calculation of local forces, including those resulting from liquid loads, acceleration can be

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at least any of the values between the following limits:

- from 0,7 g upwards to 0,8 g downwards in addition with gravity
- from 0,5 g afterwards to 1,0 g forwards
- from 0,5 g on one side to 0,5 g on the other side

.2 The preceding values apply to air-cushion vehicles for "open sea" or "restricted open sea" service.

.3 Reductions may be allowed for craft for "moderate environment" or "smooth sea" service (see C3.3.1).

C3A2.6.2 Acceleration in event of collision

See C4.3

C3A2.7 Allowable Stresses

All Loads defined in C3A2.4 and C3A2.5 are maximum design loads. These loads are maximum loads anticipated in the conditions for which the certification is sought.

Requirements for the scantlings of hull structures (plating, stiffeners, primary supporting members) and corresponding limiting values for materials are defined for

- steel and aluminium alloy structures in C3.7
- for reinforced fibre structures in C3.8

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Section 4

Accommodation and Escape Measures

C4.0 Documents to be submitted

The following plans and documents are to be submitted. To facilitate a smooth and efficient approval process they shall be submitted electronically via GLOBE [1]. In specific cases and following prior agreement with GL they can also be submitted in paper form in triplicate.

.1 Windows, arrangements and details.

.2 Plan showing the arrangement of means of communication.

.3 Calculation of the collision load and relevant arrangement of the accommodation spaces (containing the indication of seat characteristics, arrangement and installation, the characteristics of the safety belts).

.4 Plans showing the means of escape and the means of access to the various craft spaces.

.5 Evacuation procedure and evacuation time calculation.

Further documentation may be required if deemed necessary by GL.

4.1 General

4.1.1 *Public spaces and crew accommodation shall be designed and arranged so as to protect the occupants from unfavourable environmental conditions and to minimize the risk of injury to occupants during normal and emergency conditions.*

4.1.2 *Spaces accessible to passengers shall not contain controls, electrical equipment, high-temperature parts and pipelines, rotating assemblies or other items, from which injury to passengers could result, unless such items are adequately shielded, isolated, or otherwise protected.*

4.1.3 *Public spaces shall not contain operating controls unless the operating controls are so protected and located that their operation by a crew member shall not be impeded by passengers during normal and emergency conditions.*

4.1.4 *Windows in passenger and crew accommodation shall be of adequate strength and suitable for the worst intended conditions specified in the Permit to Operate and be made of material which will not break into dangerous fragments if fractured.*

4.1.5 *The public spaces, crew accommodation and the equipment therein shall be designed so that each person making proper use of these facilities will not suffer injury during craft's normal and emergency start, stop and manoeuvring in normal cruise and in failure or maloperation conditions.*

4.2 Public Address and Information System

4.2.1 *A general emergency alarm system shall be provided. The alarm shall be audible throughout all the public spaces, corridors and stairways, crew accommodation and normal crew working spaces and open decks, and the sound pressure level shall be at least 10 dB(A) above ambient noise levels under way in normal cruise operation. The alarm shall continue to function after it has been triggered until it is normally turned off or is temporarily interrupted by a message on the public address system.*

4.2.2 *There shall be a public address system covering all areas where passengers and crew have access, escape routes, and places of embarkation into survival craft. The system shall be such that flooding or fire in any compartment does not render other parts of the system inoperable. The public address system and its performance standards shall be approved by the Administration having regard to the recommendations developed by the Organization [2].*

4.2.3 *All passenger craft shall be equipped with illuminated or luminous notices or video information system(s) visible to all sitting passengers, in order to notify them of safety measures.*

4.2.4 *The master shall, by means of the public address system and the visual information system, be able to request passengers "please be seated" when found to be appropriate to safeguard passengers and always when the safety level 1 according to table 1 of annex 3 is exceeded.*

4.3 Design Acceleration Levels

4.3.1 *For passenger craft, superimposed vertical accelerations above 1.0 g at longitudinal centre of gravity shall be avoided unless special precautions are taken with respect to passenger safety.*

4.3.2 *Passenger craft shall be designed for the collision design acceleration g_{coll} with respect to the*

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1 Detailed information about the secured GL system GLOBE can be found on GL's website www.gl-group.com/globe.

2 *Refer to the Recommendations on performance standards for public address systems on passenger ships, including cabling (MSC/Circ.808) and the Code on Alarms and Indicators, 1995 (resolution A.830(18)).*

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safety in, and escape from, the public spaces, crew accommodation and escape routes, including in way of life-saving appliances and emergency source of power. The size and type of craft together with speed, displacement and building material shall be taken into consideration when the collision load is determined. The collision design condition shall be based on head-on impact at a defined collision speed.

4.3.3 *Mounting of large masses such as main engines, auxiliary engines, lift fans, transmissions and electrical equipment shall be proved by calculation to withstand, without fracturing, the design acceleration given in table 4.3.3.*

Table 4.3.3 - Design acceleration as multiples of g

Types of craft / Direction	All HSC except amphibious ACVs	Amphibious ACVs
Forward direction	g_{coll}	6
After direction	2 or g_{coll} if less	3
Transverse direction	2 or g_{coll} if less	3
Vertical direction	2 or g_{coll} if less	3

where:

g_{coll} *= the collision design acceleration expressed as a multiple of the acceleration due to gravity (9.806 m/s²)*

4.3.4 *Collision design acceleration g_{coll} (for craft other than amphibious ACVs where g_{coll} = 6) shall be calculated as follows:*

$g_{coll} = 1{,}2\left(\frac{P}{g \times \Delta}\right)$, *but not to be taken greater than 12*

where the load P shall be taken as the lesser of P1 and P2, where:

$$P_1 = 460(M \cdot C_L)^{2/3}(E \cdot C_H)^{1/2}$$

$$P_2 = 9000 \cdot M \cdot C_L(C_H D)^{1/2}$$

where the hull material factor M shall be taken as:

M = 1,3 for high tensile steel

M = 1,0 for aluminium alloy

M = 0,95 for mild steel

M = 0,8 for fibre-reinforced plastics,

where the length factor C_L of the craft is:

$$C_L = \frac{(165+L)}{245}\left(\frac{L}{85}\right)^{0.4}$$

where the height factor C_H= (80 – L)/45 but not greater than 0,75 or less than 0,3,

where the kinetic energy of the craft at speed V_{imp} is:

$$E = 0{,}5\Delta\, V_{imp}^2$$

where the main particulars of the craft are:

L = *craft length as defined in Section 1 [m]*

D = *depth of the craft from the underside of keel to the top of the effective hull girder [m]*

Δ = *craft displacement, being the mean of the lightweight and maximum operational weight [t]*

V_{imp} = *estimated impact speed [m/s] = 60 % of maximum speed as defined in Section 1*

g = *acceleration due to gravity = 9.806 m/s².*

For hydrofoils, the collision design acceleration, g_{coll} shall be taken as the greater of either the g_{coll} as calculated above or:

$$g_{coll} = F/(g \cdot \Delta)$$

where:

F = *failure load of bow foil assembly applied at the operational waterline [kn].*

C4.3.4 For sandwich structures, the hull material factor M is taken equal to 0,8.

4.3.5 *As an alternative to the requirements of 4.3.4, the collision design acceleration g_{coll} may be determined by carrying out a collision load analysis of the craft on a vertical rock having a maximum height of 2 m above the waterline and using the same assumption for displacement and impact speed V_{imp} as described in 4.3.4. This evaluation may be carried out as part of the safety analysis. If the collision design accelerations are determined by both 4.3.6 and the collision load analysis, the lower resulting value may be used as the collision design acceleration.*

4.3.6 *Compliance with the provisions of 4.1.5 and 4.3.1 shall be shown for the actual type of craft, as described in annex 9.*

4.3.7 *Limiting sea states for operation of the craft shall be given in normal operation condition and in the worst intended conditions, at 90 % of maximum speed and at reduced speed as necessary.*

4.4 Accommodation Design

4.4.1 *The public spaces, control stations and crew accommodation of high-speed craft shall be located and designed to protect passengers and crew in the design collision condition. In this respect, these spaces shall not be located forward of a transverse plane (see figure 4.4.1) such that:*

A_{bow} = *0,0035 A m f V, but never less than 0,04 A,*

where:

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A_{bow} = *the plan projected area of craft energy absorbing structure forward of the transverse plane (m^2)*

A = *total plan projected area of craft [m^2]*

m = *material factor* $= \frac{0,95}{M}$

M = *appropriate hull material factor as given in 4.3.4*

Where materials are mixed, the material factor shall be taken as a weighted mean, weighted according to the mass of material in the area defined by A_{bow}.

f = *framing factor as follows:*

- *longitudinal deck and shell stiffening = 0,8*
- *mixed longitudinal and transverse = 0,9*
- *transverse deck and shell stiffening = 1,0*

V = *90 % of maximum speed [m/s].*

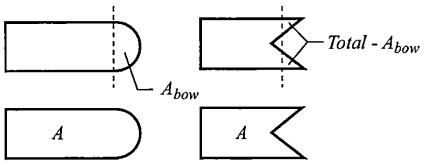

Figure 4.4.1 : Plan view of two different craft styles

4.4.2 *The public spaces and crew accommodation shall be designed based on the guidelines given in table 4.4.2 or by other methods which have been proven to give equal protective qualities.*

4.4.3 *Equipment and baggage in public spaces and in the operator's compartment shall be positioned and secured so that they remain in the stowed position when exposed to the collision design acceleration according to 4.3.4, 4.3.5 and table 4.3.3.*

4.4.4 *Seats, life-saving appliances and items of substantial mass and their supporting structure shall not deform or dislodge under any loads up to those specified in 4.3.4, 4.3.5 and table 4.3.3 in any manner that would impede subsequent rapid evacuation of passengers.*

4.4.5 *There shall be adequate handholds on both sides of any passage to enable passengers to steady themselves while moving about. The armrests and backrests of seats in public spaces may serve as handholds.*

Table 4.4.2 – Overview general design guidelines [3]

Design level 1: g_{coll} less than 3	
1	*Seat/seat belts*
1.1	*Low or high seatback*
1.2	*No restrictions on seating direction*
1.3	*Sofas allowed*
1.4	*No seat belts requirement*
2	*Tables in general allowed*
3	*Padding of projecting objects*
4	*Kiosks, bars, etc., no special restrictions*
5	*Baggage, no special requirements*
6	*Large masses, restrainment and positioning*
Design level 2: g_{coll} = 3 to 12	
1	*Seat/seat belts*
1.1	*Seatbacks with protective deformation and padding*
1.2	*Forward or backward seating direction*
1.3	*No sofas allowed as seat*
1.4	*Lap belt in seats when no protective structure forward unless satisfactorily tested without belts in that orientation and arrangement*
2	*Tables with protective feature allowed. Dynamic testing*
3	*Padding of protective objects*
4	*Kiosks, bars, etc., on aft side of bulkheads, or other specially approved arrangements*
5	*Baggage placed with protection forward*
6	*Large masses, restrainment and positioning*

[3] *Other arrangements may be employed if an equivalent level of safety is achieved*

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4.5 Seating Construction

4.5.1 *A seat shall be provided for each passenger and crew member for which the craft is certified to carry. Such seats shall be arranged in enclosed spaces.*

4.5.2 *Seats fitted in addition to those required under 4.5.1 and which are not permitted to be used in hazardous navigational situations or potentially dangerous weather or sea conditions need not comply with 4.5 or 4.6. Such seats shall be secured according to 4.4.4 and clearly identified as not being able to be used in hazardous situations.*

4.5.3 *The installation of seats shall be such as to allow adequate access to any part of the accommodation space. In particular, they shall not obstruct access to, or use of, any essential emergency equipment or means of escape.*

4.5.4 *Seats and their attachments, and the structure in the proximity of the seats, shall be of a form and design, and so arranged, such as to minimize the possibility of injury and to avoid trapping of the passengers after the assumed damage in the collision design condition according to 4.4.1. Dangerous projections and hard edges shall be eliminated or padded.*

4.5.5 *Seats, seat belts, seat arrangements and adjacent parts such as tables shall be designed for the actual collision design acceleration as specified in 4.3.4.*

4.5.6 *All seats, their supports and their deck attachments shall have good energy-absorbing characteristics and shall meet the requirements of annex 10.*

4.6 Safety Belts

4.6.1 *One-hand-release safety belts of three-point type or with shoulder harness shall be provided for all seats from which the craft may be operated for all craft with the g_{coll} acceleration from the collision design acceleration exceeding 3, as prescribed in 4.3.4.*

4.6.2 *Safety belts shall be provided on passenger seats and crew seats, if necessary, to obtain the protective performance measures described in annex 10.*

4.7 Exits and Means of Escape

4.7.1 *In order to ensure immediate assistance from the crew in an emergency situation, the crew accommodation, including any cabins, shall be located with due regard to easy, safe and quick access to the public spaces from inside the craft. For the same reason, easy, safe and quick access from the operating compartment to the public spaces shall be provided.*

4.7.2 *The design of the craft shall be such that all occupants may safely evacuate the craft into survival craft under all emergency conditions, by day or by night. The positions of all exits which may be used in an emergency, and of all life-saving appliances, the practicability of the evacuation procedure, and the evacuation time to evacuate all passengers and crew shall be demonstrated.*

4.7.3 *Public spaces, evacuation routes, exits, lifejacket stowage, survival craft stowage, and the embarkation stations shall be clearly and permanently marked and illuminated as required in Section 12.*

4.7.4 *Each enclosed public space and similar permanently enclosed space allocated to passengers or crew shall be provided with at least two exits as widely separated as practical. All exits shall clearly indicate the directions to the evacuation station and safe areas. On category A craft and cargo craft, at least one exit shall give access to the evacuation station serving the persons in the enclosed space considered, and all other exits shall give access to a position on the open deck from which access to an evacuation station is provided. On category B craft, exits shall provide access to the alternative safe area required by 7.11.1; external routes may be accepted providing that the requirements of 4.7.3 and 4.7.11 are complied with.*

4.7.5 *Subdivision of public spaces to provide refuge in case of fire may be required in compliance with 7.4.4.1 and 7.11.1.*

4.7.6 *Exit doors shall be capable of being readily operated from inside and outside the craft in daylight and in darkness. The means of operation shall be obvious, rapid and of adequate strength. Doors along escape routes should, wherever appropriate, open in the direction of escape flow from the space served.*

4.7.7 *The closing, latching and locking arrangements for exits shall be such that it is readily apparent to the appropriate crew member when the doors are closed and in a safe operational condition, either in direct view or by an indicator. The design of external doors shall be such as to minimize the possibility of jamming by ice or debris.*

4.7.8 *The craft shall have a sufficient number of exits which are suitable to facilitate the quick and unimpeded escape of persons wearing approved lifejackets in emergency conditions, such as collision damage or fire.*

4.7.9 *Sufficient space for a crew member shall be provided adjacent to exits for ensuring the rapid evacuation of passengers.*

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4.7.10 All exits, together with their means of opening, shall be adequately marked for the guidance of passengers. Clear markings, including the location of the fire control plan, shall be provided for the guidance of rescue personnel outside the craft.

4.7.11 Footholds, ladders, etc., provided to give access from the inside to exits shall be of rigid construction and permanently fixed in position. Permanent handholds shall be provided whenever necessary to assist persons using exits, and shall be suitable for conditions when the craft has developed any possible angles of list or trim.

4.7.12 At least two unobstructed evacuation paths shall be available for the use of each person. Evacuation paths shall be disposed such that adequate evacuation facilities will be available in the event of any likely damage or emergency conditions, and evacuation paths shall have adequate lighting supplied from the main and emergency sources of power. Doors providing escape from a space shall, where possible, be situated at opposite ends of the space. Where the doors providing escape from a space are situated in the same end of the space, the distance between those doors shall be greater than the maximum length of the space.

4.7.13 The width of corridors, doorways and stairways which form part of the evacuation paths shall be not less than 900 mm for passenger craft and 700 mm for cargo craft. This width may be reduced to 600 mm for corridors, doorways and stairways serving spaces where persons are not normally employed. There shall be no protrusions in evacuation paths which could cause injury, ensnare clothing, damage lifejackets or restrict evacuation of disabled persons. Requirements of this paragraph do not apply to aisles (fore-aft passageways separating seating areas) or to spaces between adjacent rows of seats. However, the width of aisles and the seat pitch shall be such as to allow the craft to comply with the provisions of 4.8.

4.7.14 Special category spaces used for stowage of motor vehicles shall be provided with walkways having a width of at least 600 mm leading to a safe means of escape

4.7.15 Adequate notices shall be provided to direct passengers to exits.

4.7.16 Provision shall be made on board for embarkation stations to be properly equipped for evacuation of passengers into life-saving appliances. Such provision shall include handholds, anti-skid treatment of the embarkation deck, and adequate space which is clear of cleats, bollards and similar fittings.

4.7.17 Main propulsion machinery spaces and ro-ro spaces shall be provided with two means of escape leading to a position outside the spaces from which a safe route to the evacuation stations is available. One means of escape from the main propulsion machinery spaces shall avoid direct access to any ro-ro space. Main propulsion machinery spaces having a length of less than 5 m and not being routinely entered or continuously manned, may be provided with a single means of escape. At least one means of escape from a machinery space shall consist of either a ladder leading to a door or hatch (not being a horizontal flush-hatch) or a door located in the lower part of that space and giving access to an adjacent compartment from which a safe means of escape is provided.

4.7.18 Spaces that are only entered occasionally by crew members may have only one means of escape provided that it is independent of watertight doors.

4.8 *Evacuation* Time

4.8.1 The provisions for evacuation shall be designed such that the craft can be evacuated under controlled conditions in a time of one third of the structural fire protection time (SFP) provided in 7.4.2 for areas of major fire hazard areas after subtracting a period of 7 min for initial detection and extinguishing action.

$$Evacuation\,time = \frac{(SFT - 7)}{3}\ (min)$$

where:

SFP = structural fire protection time (min)

In determining the evacuation time, all means of escape are to be considered serviceable and they need not be dimensioned to take into account any additional number of persons that might be diverted from other means of escape if one or more of those other means of escape are lost or rendered unserviceable.

4.8.2 An evacuation procedure, including an evacuation analysis carried out taking into account the guidelines developed by the Organization [4] shall be developed for the information of the Administration in connection with the approval of fire insulation plans and for assisting the owners and builders in planning the evacuation demonstration required in 4.8.3. The evacuation procedures shall include:

.1 the emergency announcement made by the master;

.2 contact with base port;

.3 the donning of lifejackets;

.4 manning of survival craft and emergency stations;

.5 the shutting down of machinery and oil fuel supply lines;

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[4] *Refer to the Guidelines to be developed by the Organization.*

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.6 the order to evacuate;

.7 the deployment of survival craft and marine escape systems and rescue boats;

.8 the bowsing in of survival craft;

.9 the supervision of passengers;

.10 the orderly evacuation of passengers under supervision;

.11 crew checking that all passengers have left the craft;

.12 the evacuation of crew;

.13 releasing the survival craft from the craft; and

.14 the marshalling of survival craft by the rescue boat, where provided.

4.8.3 *Achievement of the required evacuation time (as ascertained in accordance with 4.8.1) shall be verified by a practical demonstration conducted under controlled conditions in the presence of the Administration, and shall be fully documented and verified for passenger craft by the Administration.*

4.8.4 *Evacuation demonstrations shall be carried out with due concern for the problems of mass movement or panic acceleration likely to arise in an emergency situation when rapid evacuation is necessary. The evacuation demonstrations shall be dry shod with the survival craft initially in their stowed positions and be conducted as follows:*

.1 The evacuation time on a category A craft shall be the time elapsed from the moment the first abandon craft announcement is given, with any passengers distributed in a normal voyage configuration, until the last person has embarked in a survival craft, and shall include the time for passengers and crew to don lifejackets.

.2 The evacuation time on a category B craft and cargo craft shall be the time elapsed from the moment the order to abandon the craft is given until the last person has embarked in a survival craft. Passengers and crew may be wearing lifejackets and prepared for evacuation, and they may be distributed among assembly stations.

.3 For all craft the evacuation time shall include the time necessary to launch, inflate and secure the survival craft alongside ready for embarkation.

4.8.5 *The evacuation time shall be verified by an evacuation demonstration which shall be performed using the survival craft and exits on one side, for which the evacuation analysis indicates the greatest evacuation time, with the passengers and crew allocated to them.*

4.8.6 *On craft where a half trial is impracticable, the Administration may consider a partial evacuation trial using a route which the evacuation analysis shows to be the most critical.*

4.8.7 *The demonstration shall be carried out in controlled conditions in the following manner in compliance with the evacuation plan.*

.1 The demonstration shall commence with the craft afloat in harbour, in reasonably calm conditions, with all machinery and equipment operating in the normal seagoing condition.

.2 All exits and doors inside the craft shall be in the same position as they are under normal seagoing condition.

.3 Safety belts, if required, shall be fastened.

.4 The evacuation routes for all passengers and crew shall be such that no person need enter the water during the evacuation.

4.8.8 *For passenger craft, a representative composition of persons with normal health, height and weight shall be used in the demonstration, and shall consist of different sexes and ages so far as it is practicable and reasonable.*

4.8.9 *The persons, other than the crew selected for the demonstration, shall not have been specially drilled for such a demonstration.*

4.8.10 *Where the Administration is satisfied that the evacuation time determined in accordance with 4.8.1 to 4.8.9 can thereby be accurately estimated, the Administration may accept an evacuation demonstration in which persons are not required to descend through MES or equivalent means of evacuation, provided the time required to embark into the survival craft can be determined using:*

.1 data obtained from the type-approval tests of the equipment, increased by a factor based on the guidelines developed by the Organization [5]; or

.2 time extrapolated from trials using a limited number of participants.

4.8.11 *An emergency evacuation demonstration shall be carried out for all new designs of high-speed craft and for other craft where evacuation arrangements differ substantially from those previously tested.*

4.8.12 *The specific evacuation procedure followed during the craft's initial demonstration on which*

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5 Refer to the Guidelines for a simplified evacuation analysis of high-speed passenger craft (MSC/Circ.1166), in particular paragraph 3.5.1 thereof.

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certification is based shall be included in the craft operating manual together with the other evacuation procedures contained in 4.8.2. During the demonstration, video recordings shall be made, both inside and outside the craft, which shall form an integral part of the training manual required by 18.2.

4.9 Baggage, Stores, Shops and Cargo Compartments

4.9.1 *Provision shall be made to prevent shifting of baggage, stores and cargo compartment contents, having due regard to occupied compartments and accelerations likely to arise. If safeguarding by positioning is not practicable, adequate means of restraint for baggage, stores and cargo shall be provided. Shelves and overhead shelves for storage of carry-on baggage in public spaces shall be provided with adequate means to prevent the luggage from falling out in any conditions that may occur.*

4.9.2 *Controls, electric equipment, high-temperature parts, pipelines or other items, the damage or failure of which could affect the safe operation of the craft or which may require access by crew members during a voyage, shall not be located in baggage, store and cargo compartments unless such items are adequately protected so that they cannot be damaged or, where applicable, operated inadvertently by loading, by unloading or by movement of the contents of the compartment.*

4.9.3 *Loading limits, if necessary, shall be durably marked in those compartments.*

4.9.4 *Having regard to the purpose of the craft, the closures of the exterior openings of the luggage and cargo compartments as well as special-category spaces shall be appropriately weathertight.*

4.10 Noise Levels

4.10.1 *The noise level in public spaces and crew accommodation shall be kept as low as possible to enable the public address system to be heard, and shall not in general exceed 75 dB(A).*

4.10.2 *The maximum noise level in the operating compartment shall not in general exceed 65 dB(A) to facilitate communication within the compartment and external radiocommunications.*

4.11 Protection of the Crew and Passengers

4.11.1 *Efficient guard rails or bulwarks shall be fitted on all exposed parts of decks to which crew or passengers have access. Alternative arrangements such as safety harnesses and jack-stays may be accepted if they provide an equivalent level of safety. The height of the bulwarks or guard rails shall be at least 1 m from the deck, provided that where this height would interfere with the normal operation of the craft, a lesser height may be approved.*

4.11.2 *The opening below the lowest course of the guard rails shall not exceed 230 mm. The other courses shall be not more than 380 mm apart. In the case of craft with rounded gunwales the guard rail supports shall be placed on the flat of the deck.*

4.11.3 *Satisfactory means (in the form of guard rails, life lines, gangways or underdeck passages, etc.) shall be provided for the protection of the crew in getting to and from their quarters, the machinery space and all other parts used in the necessary work of the craft.*

4.11.4 *Deck cargo carried on any craft shall be so stowed that any opening which is in way of the cargo and which gives access to and from the crew's quarters, the machinery space and all other parts used in the necessary work of the craft, can be properly closed and secured against the admission of water. Effective protection for the crew in the form of guard rails or life lines shall be provided above the deck cargo if there is no convenient passage on or below the deck of the craft.*

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Section 5

Direction Control Systems

C5.0 Documents to be submitted

C5.0.1 The following drawings and documents are to be submitted. To facilitate a smooth and efficient approval process they shall be submitted electronically via GLOBE [1]. In specific cases and following prior agreement with GL they can also be submitted in paper form in triplicate.

.1 Assembly and general drawings of all directional control systems;

.2 Diagrams of hydraulic and electric equipment;

.3 Detail drawings of all load-transmitting components.

C5.0.2 The drawings and other documents must contain all data necessary for verifying scantlings and power calculations as well as material specifications.

C5.0.3 Further documentation may be required if deemed necessary by GL.

5.1 General

5.1.1 Craft shall be provided with means for directional control of adequate strength and suitable design to enable the craft's heading and direction of travel to be effectively controlled to the maximum extent possible in the prevailing conditions and craft speed without undue physical effort at all speeds and in all conditions for which the craft is to be certificated. The performance shall be verified in accordance with annex 9.

5.1.2 Directional control may be achieved by means of air or water rudders, foils, flaps, steerable propellers or jets, yaw control ports or side thrusters, differential propulsive thrust, variable geometry of the craft or its lift-system components or by a combination of these devices.

C5.1.2 Any other arrangement will be given special consideration.

5.1.3 For the purpose of this Section, a directional control system includes any steering device or devices, any mechanical linkages and all power or manual devices, controls and actuating systems.

5.1.4 Attention is drawn to the possibility of interaction between directional control systems and stabilisation systems. Where such interaction occurs or where dual-purpose components are fitted, the requirements of 12.5 and Sections 16 and 17 are also to be complied with, as applicable.

C5.1.5 Steering devices are to be installed so as to be accessible at all times and to be able to be maintained without difficulty.

C5.1.6 Steering devices are to be mounted on substantial seatings in order to transmit the force sufficiently to the hull structure.

C5.1.7 Important load-transmitting components and components subjected to internal pressure are to be made of steel or other approved ductile material.

At the discretion of GL, grey cast iron may be used for certain components with low stress level.

C5.1.8 The pipes of hydraulic systems are to be made of seamless or longitudinally welded steel tubes.
At the discretion of GL, copper may be used.

C5.1.9 Approved high-pressure hose assemblies may be used for short pipe connections.

C5.1.10 Testing of materials

The materials of important load-transmitting components, including pressurized pipes and casings, are to be tested in the presence of the Surveyor in accordance with GL's Rules for Materials.

5.2 Reliability

5.2.1 The probability of total failure of all directional control systems shall be extremely remote when the craft is operating normally, i.e., excluding emergency situations such as grounding, collision or a major fire.

C5.2.1 Guidance to probability levels is given in Annex 3.

5.2.2 A design incorporating a power drive or an actuation system employing powered components for normal directional control shall provide a secondary means of actuating the device unless an alternative system is provided.

C5.2.2 The actuation system is to be operated by power:

– for passenger craft category B

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[1] Detailed information about the secured GL system GLOBE can be found on GL's website www.gl-group.com/globe.

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– in any case where the maximum effective torque to be applied to the directional control device exceeds 25 kNm

5.2.3 The secondary means of actuating the directional control device may be manually driven when the Administration is satisfied that this is adequate, bearing in mind the craft's size and design and any limitations of speed or other parameters that may be necessary.

C5.2.3.1 The secondary means of actuating the device is to be power-operated if the effective torque to be applied to the directional control device by the secondary means exceeds 40 kNm.

C5.2.3.2 A secondary means of actuating the device need not be installed in a craft equipped with two rudders and/or similar devices, or with two approved means for steering, provided that each system is capable of steering the craft with the other system out of operation.

5.2.4 The directional control systems shall be constructed so that a single failure in one drive or system, as appropriate, will not render any other one inoperable or unable to bring the craft to a safe situation. The Administration may allow a short period of time to permit the connection of a secondary control device when the design of the craft is such that such delay will not, in their opinion, hazard the craft.

5.2.5 A failure mode and effect analysis shall include the directional control system.

5.2.6 If necessary to bring the craft to a safe condition, power drives for directional control devices, including those required to direct thrust forward or astern, shall become operative automatically, and respond correctly, within 5 s of power or other failure. Back-up electrical systems may be required for the starting-up time of an auxiliary diesel according to 12.2 or an emergency diesel generator according to 12.3.6.

5.2.7 Directional control devices involving variable geometry of the craft or its lift system components shall, so far as is practicable, be so constructed that any failure of the drive linkage or actuating system will not significantly hazard the craft.

C5.2.8 The average rate of turning of the main actuation system in general is to be not less than 2.3 degrees per second. It may be reduced with the consent of the Society, if hazard to the stability of the craft can occur.

C5.2.9 The average rate of turning of the secondary actuation system is to be not less than 0,5 degrees per second.

C5.2.10 Steering devices are to be provided with suitable mechanical stopping arrangements at the maximum design steering device angle.

C5.2.11 Power-operated directional control systems are to be provided with power cut-off arrangements which stop the steering device before the mechanical stoppers are reached. These arrangements are to be synchronized with the steering device itself and not with the control system.

C5.2.12 Steering devices are to be able to be locked in any required position for maintenance purposes.

C5.2.13 Power-operated directional control systems are to be provided with an overload protection device. This device is to be secured to prevent later adjustment by unauthorized persons. Means are to be provided for checking the setting while in service.

C5.2.14 The pipes of hydraulically operated control systems are to be installed in such a way as to ensure maximum protection while remaining readily accessible. They are to be installed at a sufficient distance from the craft shell.

C5.2.15 Hydraulic power supply and piping for steering is not to be used for other purposes. At the discretion of GL, exemptions may be permitted for water jets, azimuth thrusters and similar units.

C5.2.16 In the event of loss of hydraulic oil, it is to be possible to isolate the damaged system in such a way that the second control system remains fully serviceable.

C5.2.17 Tanks forming part of a hydraulic control system are to be fitted with oil level indicators.

C5.2.18 A low-level alarm is to be provided at the craft's operating position.

C5.2.19 Filters for cleaning the fluid are to be located in the piping system.

C5.2.20 In power-operated hydraulic main steering control systems, an additional permanently installed storage tank is to be provided with the capacity to refill at least one of the control systems, including the service tank.

5.3 Demonstrations

5.3.1 The limits of safe use of any of the control system devices, shall be based on demonstrations and a verification process in accordance with annex 9.

5.3.2 Demonstration in accordance with annex 9 shall determine any adverse effects upon safe operation of the craft in the event of an uncontrollable total deflection of any one control device. Any limitation on the operation of the craft as may be necessary to ensure that the redundancy or safeguards in the systems provide equivalent safety shall be included in the craft operating manual.

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C5.3.3 Each power unit is to be subjected to a type test in the manufacturer's workshop according to a programme accepted by GL. During the test, no overheating, excessive vibration or other irregularities are to occur. After the test the power unit is to be dismantled and inspected.

C5.3.4 Pressure vessels including cylinders and pipes are to be subjected to a pressure test. The test pressure is to be 1,5 times the maximum working pressure. Tightness tests are to be conducted on components for which this is appropriate.

C5.3.5 Sea trials have to be carried out in conformity with the GL Rules for Machinery Installations (I-1-2), Section 14. (See also the GL Guidelines for Sea Trials of Motor Vessels (VI-11-3)). Notwithstanding from the before mentioned Rules and Guidelines, the average turning rates have to be in compliance witch C5.2.8 and C5.2.9.

5.4 Control Position

5.4.1 All directional control systems shall normally be operated from the craft's operating station.

5.4.2 If directional control systems can also be operated from other positions, then two-way communication shall be arranged between the operating station and these other positions.

5.4.3 Adequate indications shall be provided at the operating station and these other positions to provide the person controlling the craft with verification of the correct response of the directional control device to this demand, and also to indicate any abnormal responses or malfunction. The indications of steering response or rudder angle indicator shall be independent of the system for directional control. The logic of such feedback and indications shall be consistent with the other alarms and indications so that in an emergency operators are unlikely to be confused.

C5.4.4 Adequate indication which other operating position is in service is to be provided at the operating station.

C5.4.5 Controls are to be independent of one another, and so designed that the control system device cannot move unintentionally.

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Section 6

Anchoring, Towing and Berthing

6.1 General

6.1.1 *A primary assumption made in this Section is that high-speed craft will only need an anchor for emergency purposes.*

6.1.2 *The arrangements for anchoring, towing and berthing and the local craft structure, the design of the anchor, towing and berthing arrangements and the local craft structure shall be such that risks to persons carrying out anchoring, towing or berthing procedures are kept to a minimum.*

6.1.3 *All anchoring equipment, towing bitts, mooring bollards, fairleads, cleats and eyebolts shall be so constructed and attached to the hull that, in use up to design loads, the watertight integrity of the craft will not be impaired. Design loads and any directional limitations assumed shall be listed in the craft operating manual.*

6.1.4 *Under any operating load up to the breaking strength of the anchor cable or mooring lines, the loads on the bitts, bollards, etc., shall not result in damage to the hull structure that will impair its watertight integrity. A strength margin of at least 20 % above the resultant load based on the minimum specified breaking strength of the relevant cable or warp shall be required.*

C6.1.5 The SWL for the intended use for each shipboard fitting is to be noted in the towing and mooring arrangements plan available on board for the guidance of the Master.

6.2 Anchoring

6.2.1 *High-speed craft shall be provided with at least one anchor with its associated cable or cable and warp and means of recovery. Every craft shall be provided with adequate and safe means for releasing the anchor and its cable and warp.*

C6.2.1 The equipment of anchors, chain cables, wires and ropes is to be determined from Table C6.5.1 in accordance with the equipment numeral EN.

Ships built under survey of GL and which are to have the mark ✠ stated in their Certificate and in the Register Book shall be equipped with anchors and chain cables complying with the Rules for Materials and having been tested on approved machines in the presence of a Surveyor.

For small craft with a length $L \leq 25$ m, some partial exemption from the Rules may be accepted especially for what concerns anchor operation; in particular, where proper and safe anchor operation is assured, hand operated machinery and/or absence of hawse pipe may be accepted.

For such ships engaged in a regular service, the second anchor and its relevant chain cable may be hold readily available in one of the home ports.

Note

The anchoring equipment required by this Section is intended of temporary mooring of a vessel within a harbour or sheltered area when the vessel is awaiting berth, tide, etc.

The equipment is, therefore, not designed to hold a ship off fully exposed coasts in rough weather or to stop a craft which is moving or drifting. In this condition the loads on the anchoring equipment increase to such a degree that its components may be damaged or lost owing to the high energy forces generated, particularly in large craft.

For crafts where frequent anchoring in open sea is expected, the owner's and shipyard's attention is drawn to the fact that anchoring equipment shall be provided in excess of the requirements of these Rules.

The anchoring equipment required by this Section is designed to hold a ship in good holding ground in conditions such as to avoid dragging of the anchor. In poor holding ground the holding power of the anchors will be significantly reduced.

The equipment numeral formula for anchoring equipment required under this Section is based on an assumed current speed of 2,5 m/sec, wind speed of 25 m/sec and a scope of chain cable between 6 and 10, the scope being the ratio between length of chain paid out and water depth.

It is assumed that under normal circumstances a ship will use only one bow anchor and chain cable at a time.

6.2.2 *Good engineering practice shall be followed in the design of any enclosed space containing the anchor-recovery equipment to ensure that persons using the equipment are not put at risk. Particular care shall be taken with the means of access to such spaces, the walkways, the illumination and protection from the cable and the recovery machinery.*

6.2.3 *Adequate arrangements shall be provided for two-way voice communication between the operating compartment and persons engaged in dropping, weighing or releasing the anchor.*

6.2.4 *The anchoring arrangements shall be such that any surfaces against which the cable may chafe*

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(for example, hawse pipes and hull obstructions) are designed to prevent the cable from being damaged and fouled. Adequate arrangements shall be provided to secure the anchor under all operational conditions.

6.2.5 The craft shall be protected so as to minimize the possibility of the anchor and cable damaging the structure during normal operation.

6.3 Towing

6.3.1 Adequate arrangements shall be provided to enable the craft to be towed in the worst intended conditions. Where towage is to be from more than one point, a suitable bridle shall be provided.

6.3.2 The towing arrangements shall be such that any surface against which the towing cable may chafe (for example, fairleads) is of sufficient radius to prevent the cable being damaged when under load.

6.3.3 The maximum permissible speed at which the craft may be towed shall be included in the operating manual.

6.4 Berthing

6.4.1 Where necessary, suitable fairleads, bitts and mooring ropes shall be provided.

6.4.2 Adequate storage space for mooring lines shall be provided such that they are readily available and secured against the high relative wind speeds and accelerations which may be experienced.

C6.5 Equipment

C6.5.1 Documents to be submitted

A detailed drawing showing all the elements necessary for the evaluation of the equipment number of the craft is to be submitted together with the calculations of the EN number.

The anchoring equipment to be fitted on the concerned craft is to be specified.

C6.5.2 Equipment number

.1 Monohull craft

The equipment number is to be calculated as follows:

$$EN = \Delta^{2/3} + 2 \cdot \left[a \cdot B + \sum_i \left(b_i \cdot h_i \cdot \sin \Theta_i \right) \right] + 0{,}1 \cdot A$$

Δ = maximum displacement [t]

a = distance [m] from summer load waterline amidships to the upper deck at side

h_i = height [m] on the centreline of each tier of deck houses having an actual breadth bi greater than B/4, where B is the breadth [m] as defined in C3.1.4 of Section 3

Θ_i = angle of inclination aft of each front bulkhead, as shown on Figure C6.5.1

A = area [m^2] in profile view of the hull, superstructures and houses, having a breadth greater than B/4, above the summer load waterline within the length **L** of the craft defined in C3.1.4.

In the measurement of h_i, sheer and trim are to be ignored.

If a deckhouse having a breadth greater than B/4 is located above of a deck house equal to or less than B/4 in breadth, the wider house is to be considered and the narrow house may be ignored.

Only the parts of windscreens or bulwarks more than 1,5 m in height above the deck are to be included when determining hi and A.

.2 Multihull craft

The equipment number is to be calculated as follows:

$$EN = K_m \cdot \Delta^{2/3} + 2 \cdot \left[a \cdot B + \sum_i \left(b_i \cdot h_i \cdot \sin \Theta_i \right) - S_t \right] + 0{,}1 \cdot A$$

where:

- for craft with N identical hulls: $K_m = N^{1/3}$

i.e.:

  - for catamarans: $K_m = 1{,}26$
  - for trimarans: $K_m = 1{,}44$
  - for quadrimarans: $K_m = 1{,}59$

- for craft with one mid hull and 2 · n non-identical lateral hulls (N = 2 · n + 1):

$$K_m = \frac{\left(B_0 \cdot T_0 \right)^{2/3} + 2 \cdot \sum_{i=1}^{n} \left(B_i \cdot T_i \right)^{2/3}}{\left(B_0 \cdot T_0 + 2 \cdot \sum_{i=1}^{n} B_i \cdot T_i \right)}$$

(N odd)

- for craft with non-identical hulls, but of an even number (N = 2 · n):

$$K_m = 2^{1/3} \cdot \frac{\sum_{i=1}^{n} \left(B_i \cdot T_i \right)^{2/3}}{\left(\sum_{i=1}^{n} B_i \cdot T_i \right)^{2/3}}$$

(N even)

S_t = transverse area, amidships, of the tunnel(s) existing between the hulls and the waterline

B_0, T_0 = breadth and draught [m] of the mid full hull (if any), measured amidship (see Figure C6.5.2)

B_i, T_i = breadth and draught [m] of the lateral hulls, measured amidship (see Figure C6.5.2)

N = total number of craft hulls

n = number of lateral hulls on one side of the longitudinal symmetry plane of the craft

Δ = total displacement of the craft [t]

Other symbols are defined in C6.5.2.1.

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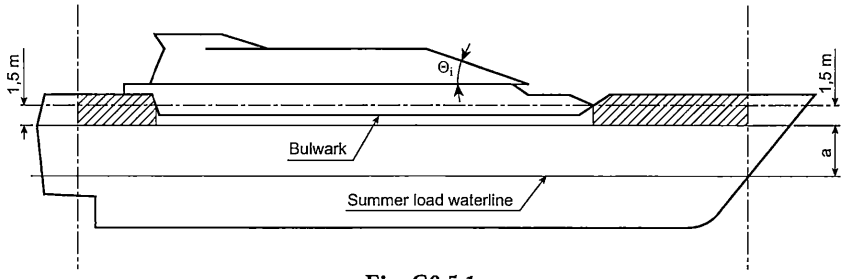


Fig. C6.5.1

C6.5.3 Anchors

.1 For craft with an equipment number greater than 600, two anchors and two relevant chain cables are required. When two bow anchors are fitted, the mass of each anchor, the diameter and the length of each chain cable are to comply with the requirements of Table C6.5.1.

The bow anchors are to be connected to their chain cables and positioned on board ready for use. It is to be ensured that each anchor can be stowed in the hawse and hawse pipe in such a way that it remains firmly secured in seagoing conditions. Details have to be coordinated with the owner.

Chafing lips of suitable form with ample lay-up and radius adequate for the size of the chain cable are to be provided at the shell and deck. The shell plating at the hawse pipes is to be reinforced as necessary.

.2 Anchors shall be of an approved design. Normally "high holding power anchors" (HHP) or "very high holding power anchors" (VHHP) are to be used. Possible use of ordinary anchors will be specially considered by GL.

.3 For HHP anchors, the mass of the anchor shall comply with the values in Table C6.5.1. The actual mass of each anchor may vary within (+7, -3) per cent of the required individual mass provided that the total mass of all bower anchors is not less than the sum of the required individual masses.

.4 The mass of a VHHP anchor is to be not less than 2/3 of the required mass as per Table C6.5.1.

.5 A HHP or VHHP anchor is to be suitable for use on board without any prior adjustment or special placement on the sea bed.

For approval as a HHP or VHHP anchor satisfactory tests are to be made on various types of bottom and the anchor is to have a holding power at least, twice or four times, respectively, that of an ordinary stockless anchor ("Admiralty Standard Stockless") of the same mass. The mass of anchors to be tested should be representative of the full range of sizes intended to be manufactured. The tests are to be carried out on at least two sizes of anchors in association with the chain cables appropriate to the weight. The anchors to be tested and the standard stockless anchors should be of approx. the same mass.

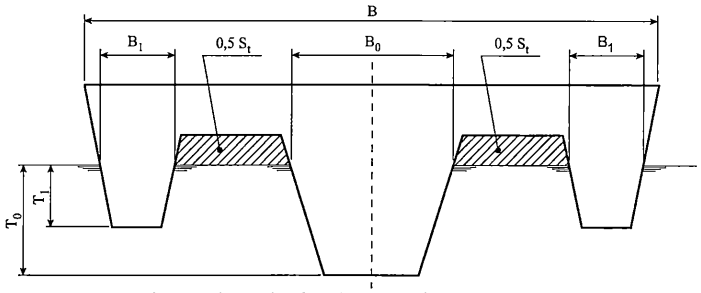
The chain length used in the tests should be approx. 6 to 10 times the depth of water.

The tests are normally to be carried out from a tug, however, alternative shore based tests (e.g. with suitable winches) may be accepted.

Three tests are to be carried out for each anchor and type of bottom. The pull shall be measured by means of a dynamometer or recorded by a recording instrument. Measurements of pull based on rpm/bollard pull curve of the tug may be accepted.

Testing by comparison with a previously approved HHP anchor may be accepted as a basis for approval. The maximum mass of an anchor thus approved may be 10 times the mass of the largest size of anchor tested.

The dimensioning of the chain cable and of the windlass is to be based on the undiminished anchor mass according to the Tables.



In the example: N = 3 and n = 1. In cases where N is even : $B_0 = T_0 = 0$

Fig. C6.5.2

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C6.5.4 Chain cables

.1 The diameters for stud link chain cables given in the Tables apply to chain cables made of chain cable materials specified in the Rules II – Materials and Welding, Part 1 – Metallic Materials, for the following grades:

– Grade K2 (special quality)

– Grade K3 (extra special quality)

Normally grade K2 or K3 stud link chain cables are to be used with HHP anchors. In case of VHHP anchors, grade K3 chain cables are to be used.

Proposal for use of grade K1 chain cables connected to ordinary anchors will be specially considered by GL.

.2 The total length of chain given in Table C6.5.1 is to be divided in approximately equal parts between the required number of bower anchors

.3 The breaking load, in kN, of the chain cable diameters shown between parentheses in Table C6.5.1 may be derived from the following formulae:

– for grade K2 chain cables:
$BL = 13{,}73 \cdot d^2 \cdot (44 - 0{,}08 \cdot d) \cdot 10^{-3}$

– for grade K3 chain cables:
$BL = 19{,}61 \cdot d^2 \cdot (44 - 0{,}08 \cdot d) \cdot 10^{-3}$

where d is, in mm, the chain cable diameter taken from Table C6.5.1 corresponding respectively to grade K2 and grade K3 chain cables.

.4 For craft with an equipment number $EN \leq 205$, studless short link chain cables may be used, provided that:

(a) steel grade of the studless chain cable meets the requirement of C6.5.4.1

(b) equivalence in strength is to be based on proof load (not on breaking load)

(c) the studless chain cable meets the requirements of GL.

The proof loads PL and breaking loads BL, in kN, required for the studless link chain cables are given by the following formulae, where d, in mm, is the required diameter of grade K2 and grade K3 stud chain cables taken from Table C6.5.1:

– grade K2:
$PL_2 = 9{,}807 \cdot d^2 \cdot (44 - 0{,}08 \cdot d) \cdot 10^{-3}$
$BL_2 = 2 \cdot PL_2$

– grade K3:
$PL_3 = 13{,}73 \cdot d^2 \cdot (44 - 0{,}08 \cdot d) \cdot 10^{-3}$
$BL_3 = 2 \cdot PL_3$

.5 For connection of the anchor with the chain cable approved Kenter-type anchor shackles may be chosen in lieu of the common Dee-shackles. A forerunner with swivel is to be fitted between anchor and chain cable. In lieu of a forerunner with swivel an approved swivel shackle may be used. However, swivel shackles are not to be connected to the anchor shank unless specially approved. A sufficient number of suitable spare shackles are to be kept on board to facilitate fitting of the spare anchor at any time. On owner's request the swivel shackle may be dispensed with.

.6 The attachment of the inboard ends of the chain cables to the ship's structure is to be provided with means suitable to permit, in case of emergency, an easy slipping of the chain cables to sea operable from an accessible position outside the chain locker.

The inboard ends of the chain cables are to be secured to the structures by a fastening able to withstand a force neither less than 15 % nor more than 30 % of the rated breaking load of the chain cable.

C6.5.5 Steel wire ropes for anchors

.1 Steel wire ropes may be used as an alternative to stud link chain cables required in Table C6.5.1 provided that the following requirements are complied with.

.2 The length L_{swr} in m, of the steel wire rope is to be not less than:

– when $EN \leq 130$:
$L_{swr} = L_{ch}$

– when $130 < EN \leq 500$:
$L_{swr} = L_{ch} \cdot (EN + 850) / 900$

– when $EN > 500$:
$L_{swr} = 1{,}5 \cdot L_{ch}$

where L_{ch} is the required length of stud link chain cable as per Table C6.5.1.

.3 The effective breaking load of the steel wire rope is to be not less than the required breaking load of the chain cable it replaces.

.4 Between anchor and steel wire rope a shot of 12,5 m in length or of the distance between stowed anchor and windlass shall be provided. The smaller length of this chain part is to be taken.

C6.5.6 Synthetic fibre ropes for anchors

.1 Synthetic fibre ropes may be used as an alternative to stud link chain cables required in Table C6.5.1 when $EN \leq 130$, provided that the following requirements are complied with.

.2 Fibre ropes are to be made of polyamide or other equivalent synthetic fibres, excluding polypropylene.

.3 The length L_{sfr}, in m, of the synthetic fibre rope is to be not less than:

– when $EN \leq 60$:
$L_{sfr} = L_{ch}$

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– when $60 < EN \leq 130$
$L_{sfr} = L_{ch} \cdot (EN + 80)/140$

where L_{ch} is the required length of stud link chain cable as per Table C6.5.1.

.4 The effective breaking load P_s, in kN, of the synthetic fibre rope is to be not less than the following value:

$P_s = 2{,}2 \cdot BL^{8/9}$

where BL, in kN, is the required breaking load of stud link chain cable as per Table C6.5.1.

.5 Between anchor and synthetic fibre rope a short length of chain cable shall be provided.

C6.5.7 Windlass

.1 The windlass is to be power driven and suitable for the size of chain cable, and is to have the characteristics stated below.

.2 The windlass is to be fitted in a suitable position in order to ensure an easy lead of the chain cable to and through the hawse pipe; the deck, at the windlass, is to be suitably reinforced.

.3 The windlass is to be able to supply, for at least 30 minutes, a continuous duty pull P_C, in N, corresponding to the grade of the chain cables, given by the following formulae:

– for grade K2 chain cables:
$P_C = 42{,}5 \cdot d^2$

– for grade K3 chain cables:
$P_C = 47{,}5 \cdot d^2$

where d is the stud link chain cable diameter of the intended steel grade, in mm.

.4 The windlass unit prime mover is to provide the necessary temporary overload capacity for breaking out the anchor.

The temporary overload capacity or "short term pull" is to be not less than 1,5 times the continuous duty pull PC for at least two minutes.

The speed in this overload period may be lower than the nominal speed specified in C6.5.9.5.

.5 The nominal speed of the chain cable when hoisting the anchor and cable may be a mean speed only and is to be not less than 0,15 m/s.

The speed is to be measured over two shots of chain cable during the entire trip; the test is to commence with 3 shots (82,5 m) of chain fully submerged, or with the longest practicable submerged chain length where the chain length does not allow 3 shots to be paid out.

.6 The windlass is to be provided with a brake having sufficient capacity to stop chain cable and anchor when paying out, even in the event of failure of the power supply.

.7 Windlass and brake not combined with a chain stopper have to be designed to withstand a pull of 80 % of the breaking load of the chain cable without any permanent deformation of the stressed parts and without brake slip.

Windlass and brake combined with a chain stopper have to be designed to withstand a pull of 45 % of the breaking load of the chain cable.

.8 The windlass, its frame and the brake are to be efficiently anchored to the deck. Corresponding drawings including joining details are to be submitted for approval.

C6.5.8 Chain stopper

.1 A chain stopper is normally to be fitted between the windlass and the hawse pipe in order to relieve the windlass of the pull of the chain cable when the ship is at anchor.

.2 A chain stopper is to be capable of withstanding a pull of 80 % of the breaking load of the chain cable; the deck at the chain stopper is to be suitably reinforced.

However, fitting of a chain stopper is not compulsory.

.3 Chain tensioners or lashing devices supporting the weight of the anchor when housed in the anchor pocket are not to be considered as chain stoppers.

.4 Where the windlass is at a distance from the hawse pipe and no chain stopper is fitted, suitable arrangements are to be provided to lead the chain cable to the
windlass.

C6.5.9 Chain locker

.1 The chain locker is to be of capacity and depth adequate to stow all chain cable equipment and provide an easy direct lead to the windlass.

.2 Where two anchor lines are fitted, the port and starboard chain cables are to be separated by a steel bulkhead in the locker.

.3 The minimum required stowage capacity without mud box for each bow anchor chain is as follows:

$S = 1{,}1\ d^2\ \ell / 200\ 000\ [m^3]$

d = chain diameter [mm] according to Table C6.5.1

ℓ = total length of stud link chain cable according to Table C6.5.1

The shape of the base areas shall as far as possible be quadratic with a maximum edge length of 33 d. As an alternative, circular base areas may be selected, the diameter of which shall not exceed 30 – 35 d.

Above the stowage of each chain locker a free depth of at least

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h = 750 [mm] for L = 25 m

h = 1500 [mm] for L ≥ 50 m

is to be additionally provided. For intermediate lengths L linear interpolation is to be applied for the depth h.

.4 The chain locker boundaries and their access openings are to be watertight to prevent flooding of adjacent spaces, where essential installations or equipment are arranged, in order to not affect the proper operation of the ship after accidental flooding of the chain locker.

C6.5.10 Special requirements to minimize the ingress of water

.1 Spurling pipes and cable lockers are to be watertight up to the weather deck.

.2 Where means of access is provided, it is to be closed by a substantial cover and secured by closely spaced bolts.

.3 Spurling pipes through which anchor cables are led are to be provided with permanently attached closing appliances to minimize water ingress.

.4 Adequate drainage facilities of the chain locker are to be provided.

.5 Where the chain locker boundaries are also tank boundaries their scantlings of stiffeners and plating are to be determined as for tanks in accordance with C3.7.12.

Where this is not the case the plate thickness and the section modulus are to be determined according to C3.7.12. The distance from the load centre to the top of the chain locker pipe is to be taken for calculating the load.

C6.5.11 Allowable stresses

The allowable stresses for the windlass, chain stopper and the corresponding substructures etc. are not to exceed

Normal:	85 %
Shear:	55 %
Von Mises:	95 %

of the specific minimum yield point R_{eH} or $R_{p0,2}$ of the used material, respectively.

C6.5.12 Anchoring sea trials

.1 The anchoring sea trials are to be carried out on board in the presence of a Society surveyor.

.2 The test is to demonstrate that the windlass complies with the requirements given in C6.5.9.5.

(See also GL Rules Machinery Installations (I-1-2), Section 14 and Guidelines for Sea Trials of Motor Vessels (VI-11-3)).

.3 The brake is to be tested during lowering operations.

C6.6 Shipboard fittings for towing

C6.6.1 Arrangement and strength

Shipboard fittings for towing are to be located on longitudinals, beams and/or girders, which are part of the deck construction so as to facilitate efficient distribution of the towing load. Other arrangements may be accepted provided the strength is confirmed adequate for the intended service.

The strength of shipboard fittings used for ordinary towing operations (not emergency towing) at bow, sides and stern and their supporting hull structures are to be determined on the basis of 1.1.1 and 1.1.2.

.1 Load considerations

Unless greater safe working load (SWL) of shipboard fittings is specified by the applicant, the minimum design load to be used is the following value of (1) or (2), whichever is applicable:

(1) for normal towing operations (e.g. harbour / manoeuvring), 1.25 times the intended maximum towing load (e.g. static bollard pull) as indicated on the towing and mooring arrangements plan.

(2) for other towing service (e.g. escort), the nominal breaking strength of the tow line according to Table C6.4.1.

Note

Side projected area including maximum stacks of deck cargoes is to be taken into account for selection of towing lines.

(3) The design load is to be applied through the tow line according to the arrangement shown on the towing and mooring arrangements plan, see Fig.C6.4.1.

(4) When a specific SWL is applied for a shipboard fitting at the request of the applicant, by which the design load will be greater than the above minimum values, the strength of the fitting is to be designed using this specific design load.

.2 Allowable stresses

Normal stress: 100% of the specified minimum yield point of the material

Shearing stress: 60% of the specified minimum yield point of the material

C6.6.2 Safe working load (SWL)

1) The SWL used for normal towing operations (e.g. harbour / manoeuvring) is not to exceed 80% of the design load per 1.1.1(1) and the SWL used for other towing operations (e.g. escort) is not to exceed the design load per 1.1.1(2). For fittings used for both normal and other towing operations, the greater of the design loads of 1.1.1(1) and 1.1.1(2) is to be used.

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2) The SWL of each shipboard fitting is to be marked (by weld bead or equivalent) on the deck fittings used for towing.

3) The above requirements on SWL apply for a single post basis (no more than one turn of one cable).

4) The towing and mooring arrangements plan mentioned in H. is to define the method of use of towing lines.

C6.7 Mooring Equipment

C6.7.1 Ropes

1 The following requirements and the Tables C6.7.1 and C6.5.1 for tow lines and mooring ropes are recommendations only, a compliance with which is not a condition of Class.

.2 For tow lines and mooring lines, steel wire ropes as well as fibre ropes made of natural or synthetic fibres or wire ropes consisting of steel wire and fibre cores may be used. The breaking loads [1] specified in Table C6.7.1 are valid for wire ropes and ropes of natural fibre (manila) only. Where ropes of synthetic fibre are used, the breaking load is to be increased above the table values. The extent of increase depends on the material quality.

The required diameters of synthetic fibre ropes used in lieu of steel wire ropes may be taken from Table C6.7.1.

Table C6.7.1 Wire/fibre ropes diameter

Steel wire ropes [1]	Synthetic wire ropes	Fibre ropes		
	polyamide [2]	polyamide	polyester	polypropylene
diam. [mm]	diam. [mm]	diam. [mm]	diam. [mm]	diam. [mm]
12	30	30	30	30
13	30	32	32	32
14	32	36	36	36
16	32	40	40	40
18	36	44	44	44
20	40	48	48	48
22	44	48	48	52
24	48	52	52	56
26	56	60	60	64
28	60	64	64	72
32	68	72	72	80
36	72	80	80	88
40	72	88	88	96

[1] according to DIN 3068 or similar.

[2] Regular laid ropes of refined polyamide monofilaments and filament fibres.

[1] The term "breaking load" used throughout this section means the "nominal breaking load".

.3 Wire ropes shall be of the following type:

- 6 × 24 wires with 7 fibre cores for breaking loads of up to 500 kN
  type: Standard
- 6 × 36 wires with 1 fibre core for breaking loads of more than 500 kN
  type: Standard

Where wire ropes are stored on mooring winch drums, steel cored wire ropes may be used e.g.:

- 6 × 19 wires with 1 steel core
  type: Seale
- 6 × 36 wires with 1 steel core
  type: Warrington-Seale

.4 Regardless of the breaking load, recommended in C6.5.1, the diameter of fibre ropes should not be less than 20 mm.

.5 The length of the individual mooring ropes may be up to 7 per cent less than that given in the table provided that the total length of all the wires and ropes is not less than the sum of the required individual lengths.

Where mooring winches on large ships are located on one side of the ship, the lengths of mooring ropes should be increased accordingly.

C6.7.2 Shipboard fittings (mooring bollards and bitts, fairleads, stand rollers, chocks)

The selection of shipboard fittings is to be made by the shipyard in accordance with an industry standard (e.g. ISO 3913 Shipbuilding Welded Steel Bollards) accepted by GL. When the shipboard fitting is not selected from an accepted industry standard, the design load used to assess its strength and its attachment to the ship is to be in accordance with C6.7.3.

.1 Arrangement

Shipboard fittings for mooring are to be located on longitudinals, beams and/or girders, which are part of the deck construction so as to facilitate efficient distribution of the mooring load. Other arrangements may be accepted provided the strength is confirmed adequate for the service.

.2 Safe working load (SWL)

1) The SWL is not to exceed 80% of the design load per C6.7.3.1.

2) The SWL of each shipboard fitting is to be marked (by weld bead or equivalent) on the deck fittings used for mooring.

3) The above requirements on SWL apply for a single post basis (no more than one turn of one cable).

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4) The towing and mooring arrangements plan mentioned in C6.1.5 is to define the method of use of mooring lines.

C6.7.3 Supporting hull structure for mooring equipment

Arrangement of the reinforced members (carling) beneath shipboard fittings is to consider any variation of direction (horizontally and vertically) of the mooring forces (which is to be not less than the design load as per .1) acting through the arrangement of connection to the shipboard fittings.

.1 Load considerations

1) Unless greater safe working load (SWL) of shipboard fittings is specified by the applicant, the design load applied to shipboard fittings and supporting hull structures is to be 1,25 times the breaking strength of the mooring line according to Table C6.7.1.

2) The design load applied to supporting hull structures for winches, etc. is to be 1,25 times the intended maximum brake holding load and, for capstans, 1,25 times the maximum hauling-in force.

3) The design load is to be applied through the mooring line according to the arrangement shown on the towing and mooring arrangements plan, see Fig. C6.7.1.

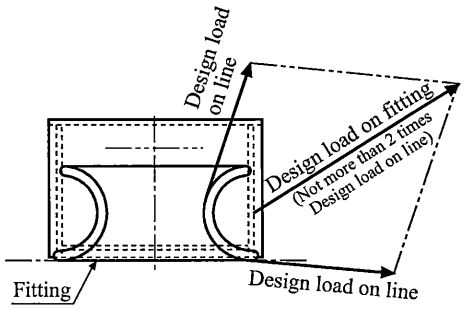

Fig. C6.7.1 Application of design loads

4) When a specific SWL is applied for a shipboard fitting at the request of the applicant, by which the design load will be greater than the above minimum values, the strength of the fitting is to be designed using this specific design load.

5) The acting point of the mooring force on shipboard fittings is to be taken at the attachment point of a mooring line or at a change in its direction.

.2 Allowable stresses

Normal stress: 100 % of the specified minimum yield point of the material

Shearing stress: 60 % of the specified minimum yield point of the material

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Table C6.5.1 Equipment

No. for Reg.	Equipment Number EN		HHP bow anchor		Stud link chain cable for bow anchor			Recommended ropes				
	A < EN ≤ B		Mass of each anchor	Number of anchors	Total length	Diameter [1]		Towline		Mooring ropes		
						grade K2 steel	grade K3 steel	Length [2]	Break. Load	Number	Length [3]	Break. Load
	A	B	[kg]		[m]	[mm]	[mm]	[m]	[kN]		[m]	[kN]
51	19	22	16	1	65	(6)	(5,5)	180	100	3	80	35
52	22	25	20	1	70	(6,5)	(6)	180	100	3	80	35
53	25	30	24	1	70	(7)	(6,5)	180	100	3	80	35
54	30	35	28	1	75	(7,5)	(7)	180	100	3	80	35
55	35	40	32	1	75	(8)	(7,5)	180	100	3	80	35
56	40	45	40	1	80	(8,5)	(7,5)	180	100	3	80	35
57	45	50	48	1	82,5	(9)	(8)	180	100	3	80	35
58	50	60	60	1	82,5	(10)	(8,5)	180	100	3	80	35
59	60	70	67	1	82,5	11	(9,5)	180	100	3	80	35
60	70	80	75	1	110	11	(10)	180	100	3	100	40
61	80	90	90	1	110	12,5	11	180	100	3	100	40
62	90	100	105	1	110	12,5	11	180	100	3	110	40
63	100	110	120	1	110	14	12,5	180	100	3	110	40
64	110	120	135	1	110	14	12,5	180	100	3	110	45
65	120	130	150	1	110	14	12,5	180	100	3	110	45
66	130	140	180	1	110	16	14	190	100	3	120	50
67	140	150	195	1	137,5	16	14	180	100	3	120	50
68	150	175	225	1	137,5	17,5	16	180	100	3	120	55
69	175	205	270	1	137,5	17,5	16	180	110	3	120	60
70	205	240	315	1	137,5	19	17,5	180	130	4	120	65
71	240	280	360	1	137,5	20,5	19	180	150	4	120	70
72	280	320	430	1	165	22	20,5	180	175	4	140	80
73	320	360	495	1	165	24	22	180	200	4	140	85
74	360	400	525	1	165	26	22	180	225	4	140	95
75	400	450	585	1	165	26	24	180	250	4	140	100
76	450	500	675	1	192,5	28	26	190	275	4	140	110
77	500	550	765	1	192,5	30	26	190	305	4	160	120
78	550	600	855	1	192,5	32	28	190	340	4	160	130
79	600	660	900	2	385	32	30	190	370	4	160	145
80	660	720	970	2	385	34	30	190	405	4	160	160
81	720	780	1080	2	440	36	32	190	440	4	170	170
82	780	840	1125	2	440	36	32	190	480	4	170	185
83	840	910	1195	2	440	38	34	190	520	4	170	200
84	910	980	1305	2	440	40	36	200	560	4	170	215
85	980	1060	1440	2	440	42	36	200	600	4	180	230
86	1060	1140	1575	2	440	42	38	200	645	4	180	250
87	1140	1220	1710	2	467,5	44	38	200	690	4	180	270
88	1220	1300	1845	2	467,5	46	40	200	740	4	180	285

[1] Values of chain cable diameters shown in brackets are given only to allow determination of the corresponding studless chain cable.

[2] Length of towline needs not to be taken greater than 5 L

[3] Length of mooring ropes needs not to be taken greater than 2 L

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Section 7

Fire Safety

C7.0 Documents to be submitted

C7.0.1 The following drawings and documents are to be submitted. To facilitate a smooth and efficient approval process they shall be submitted electronically via GLOBE [1] . In specific cases and following prior agreement with GL they can also be submitted in paper form in triplicate.

.1 Plan showing the arrangements of the fire subdivision, including doors and other closing means of openings in fire resisting divisions.

.2 Schematic plan concerning the natural and mechanical ventilation, with indication of location of dampers and identification numbers of the fans serving each craft section.

.3 Plan showing automatic fire detection systems and manually operated call points, including fire alarm systems.

.4 Plan relating to the water fire-fighting system (pumps, piping, etc.).

.5 Plan relating to the arrangement of fixed fire extinguishing systems.

.6 Constructional plans relevant to pressure vessels or bottles serving fixed fire extinguishing systems mentioned under .5.

.7 Plans of pumping and drainage means for the water delivered by fixed water-spraying fire extinguishing systems.

.8 Plan relating to all other fire-fighting installations, either fixed or portable.

C7.0.2 Further documentation may be required, if deemed necessary by GL.

7.1 General Requirements

7.1.1 The following basic principles underlie the provisions in this Section and are embodied therein as appropriate, having regard to the category of craft and the potential fire hazard involved:

.1 maintenance of the main functions and safety systems of the craft, including propulsion and control, fire-detection, alarms and extinguishing capability of unaffected spaces, after fire in any one compartment on board;

.2 division of the public spaces for category B craft, in such a way that the occupants of any compartment can escape to an alternative safe area or compartment in case of fire;

.3 subdivision of the craft by fire-resisting boundaries;

.4 restricted use of combustible materials and materials generating smoke and toxic gases in a fire;

.5 detection, containment and extinction of any fire in the space of origin;

.6 protection of means of escape and access for fire fighting; and

.7 immediate availability of fire-extinguishing appliances.

7.1.2 The requirements in this Section are based in the following conditions:

.1 Where a fire is detected, the crew immediately puts into action the fire-fighting procedures, informs the base port of the accident and prepares for the escape of passengers to alternative safe area or compartment, or, if necessary, for the evacuation of passengers.

.2 The use of fuel with a flashpoint below 43 °C is not recommended. However, fuel with a lower flashpoint, but not lower than 35 °C, may be used in gas turbines only subject to compliance with the provisions specified in 7.5.1 to 7.5.6.

.3 The repair and maintenance of the craft is carried out in accordance with the requirements given in Sections 18 and 19 of this Code.

.4 Enclosed spaces having reduced lighting, such as cinemas, discotheques, and similar spaces are not permitted.

.5 Passenger access to special category spaces and open ro-ro spaces is prohibited during the voyage except when accompanied by a crew member responsible for fire safety. Only authorised crew members shall be permitted to enter cargo spaces at sea.

C7.1.3 The following products are to be of approved type:

- Fire-restricting materials,
- Fire-resisting divisions (decks, bulkheads, doors),
- Penetrations of fire-resisting divisions for pipes, cables, ducts,

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1 Detailed information about the secured GL system GLOBE can be found on GL's website www.gl-group.com/globe.

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- Surface materials,
- Primary deck covering,
- Upholstery furniture,
- Bedding components,
- Curtains,
- Non-combustible materials,
- Oil pipes (other than steel or copper and copper alloys),
- Flexible pipes,
- Portable and mobile fire extinguishers,
- Nozzles for water spray systems or sprinkler systems,
- Fire-detection systems,
- Fire hoses and nozzles,
- Vapour detection systems,
- Non-sparking fans.

7.2 Definitions

7.2.1 "Fire-resisting divisions" are those divisions formed by bulkheads and decks which comply with the following:

.1 They shall be constructed of non-combustible or fire-restricting materials which by insulation or inherent fire-resisting properties satisfy the requirements of 7.2.1.2 to 7.2.1.6.

.1 They shall be suitably stiffened.

.2 They shall be so constructed as to be capable of preventing the passage of smoke and flame up to the end of the appropriate fire protection time.

.3 Where required they shall maintain load-carrying capabilities up to the end of the appropriate fire protection time.

.4 They shall have thermal properties such that the average temperature on the unexposed side will not rise more than 140 °C above the original temperature, nor will the temperature, at any one point, including any joint, rise more than 180 °C above the original temperature during the appropriate fire protection time.

.5 A test of a prototype bulkhead or deck in accordance with the Fire Test Procedures Code shall be required to ensure that it meets the above requirements.

C7.2.1 With reference to 7.2.1.6 test procedures for fire-resisting divisions of high speed craft adopted by the Organization by IMO Resolution MSC 45 (65) are to be applied.

7.2.2 "Fire-restricting materials" are those materials which have properties complying with the Fire Test Procedures Code.

7.2.3 "Non-combustible material" is a material which neither burns nor gives off flammable vapours in sufficient quantity for self-ignition when heated to approximately 750 °C, this being determined in accordance with the Fire Test Procedures Code.

7.2.4 "A standard fire test" is one in which specimens of the relevant bulkheads, decks or other constructions are exposed in a test furnace by a specified test method in accordance with the Fire Test Procedures Code.

7.2.5 Where the words "steel or other equivalent material" occur, "equivalent material" means any non-combustible material which, by itself or due to insulation provided, has structural and integrity properties equivalent to steel at the end of the applicable exposure to the standard fire test (e.g., aluminium alloy with appropriate insulation).

7.2.6 "Low flame-spread" means that the surface thus described will adequately restrict the spread of flame, this being determined in accordance with the Fire Test Procedures Code.

7.2.7 "Smoke-tight" or "capable of preventing the passage of smoke" means that a division made of non-combustible or fire-restricting materials is capable of preventing the passage of smoke.

7.3 Classification of Space Use

7.3.1 For the purposes of classification of space use in accordance with fire hazard risks, the following grouping shall apply:

.1 "Areas of major fire hazard", referred to in Tables 7.4-1 and 7.4-2 by A, include the following spaces:

- *machinery spaces*
- *ro-ro spaces*
- *spaces containing dangerous goods*
- *special category spaces*
- *store-rooms containing flammable liquids*
- *galleys*
- *sales shops having a deck area of 50 m² or greater and containing flammable liquids for sale*
- *trunks in direct communication with the above spaces.*

.2 "Areas of moderate fire hazard", referred to in Tables 7.4-1 and 7.4-2 by B, include the following spaces:

- *auxiliary machinery spaces, as defined in 1.4.5*
- *bond stores containing packaged beverages with alcohol content not exceeding 24 % by volume*
- *crew accommodation containing sleeping berths*

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- *service spaces*
- *sales shops having a deck area of less than 50 m² containing a limited amount of flammable liquids for sale and where no dedicated store is provided separately*
- *sales shops having a deck area of 50 m² or greater not containing flammable liquids*
- *trunks in direct communication with the above spaces.*

.3 *"Areas of minor fire hazard", referred to in Tables 7.4-1 and 7.4-2 by C, include the following spaces:*

- *auxiliary machinery spaces, as defined in 1.4.6*
- *cargo spaces.*
- *fuel tank compartments*
- *public spaces*
- *tanks, voids and areas of little or no fire risk*
- *refreshment kiosks*
- *sales shops other than those specified in 7.3.1.1 and 7.3.1.2*
- *corridors in passenger areas and stairway enclosures*
- *crew accommodation other than that mentioned in 7.3.1.2*
- *trunks in direct communication with the above spaces.*

.4 *"Control stations", referred to in Tables 7.4-1 and 7.4-2 by D, as defined in 1.4.16*

.5 *"Evacuation Stations and external escape routes", referred to in Tables 7.4-1 and 7.4-2 by E, include the following areas:*

- *external stairs an open decks used for escape routes*
- *assembly stations, internal and external*
- *open deck spaces and enclosed promenades forming lifeboat and liferaft embarkation and lowering stations*
- *the craft's side to the waterline in the lightest seagoing condition, superstructure and deckhouse sides situated below and adjacent to the liferaft's and evacuation slide's embarkation areas.*

.6 *"Open Spaces" referred to in Tables 7.4-1 and 7.4-2 by F, include the following areas:*

- *open spaces locations other than evacuation stations and external escape routes and control stations.*

7.3.2 *In relation to the classification of spaces in 7.3.1, the following additional criteria shall be applied:*

.1 *if a space is divided by partial bulkheads into two (or more) smaller areas such that they form enclosed spaces, then the enclosed spaces shall be surrounded by bulkheads and decks in accordance with tables 7.4-1 and 7.4-2, as applicable. However, if the separating bulkheads of such spaces are at least 30 % open, then the spaces may be considered as the same space.*

.2 *Cabinets having a deck area of less than 2 m² may be accepted as part of the space they serve, provided they have open ventilation to the space and do not contain any material or equipment that could be a fire risk.*

.3 *Where a space has the special characteristics of two or more space groupings, the structural fire protection time of the divisions shall be the highest for the space groupings concerned. For example, the structural fire protection time of the divisions of emergency generator rooms shall be of the highest value for the space when the space is considered as being a control station (D) and a machinery space (A).*

7.3.3 *In approving structural fire protection details, the Administration shall have regard to the risk of heat transmission at intersections and terminal points of required thermal barriers.*

7.3.4 *To prevent heat transmission at intersections and terminal points, the insulation of the deck or bulkhead shall be carried past the intersection or terminal point for a distance of at least 450 mm in the case of steel or aluminium structures (refer to figures 7.3.4a and 7.3.4b).*

7.3.5 *If a space is divided by a deck or bulkhead and the fire insulation required for each space is different, the insulation with the higher structural fire protection time shall continue on the deck or bulkhead with the insulation of the lesser structural fire protection time for a distance of at least 450 mm beyond the boundary between the spaces.*

7.3.6 *Where the lower part of the fire insulation has to be cut for drainage, the construction shall be in accordance with the structural details shown in figure 7.3.6.*

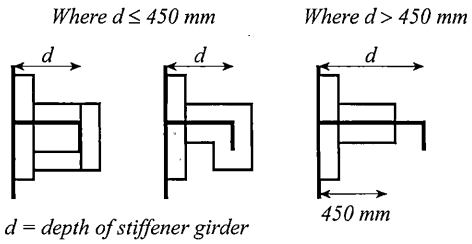

Figure 7.3.4a

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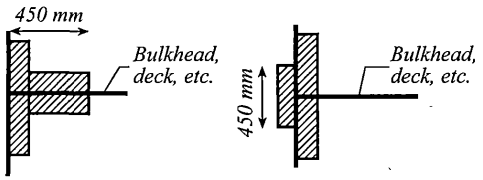

Figure 7.3.4b

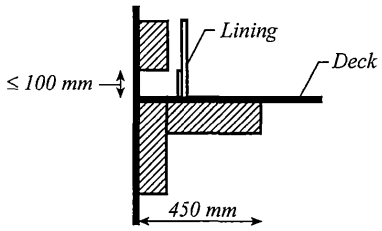

Figure 7.3.6

7.4 Structural Fire Protection

7.4.1 Main structure

7.4.1.1 The requirements below apply to all craft irrespective of construction material. The structural fire protection times for separating bulkheads and decks shall be in accordance with tables 7.4-1 and 7.4.-2, and the structural fire protection times are all based on providing protection for a period of 60 min as referred to in 4.8.1. If any other lesser structural fire protection time is determined for category A craft and cargo craft by 4.8.1, then the times given below in 7.4.2.2 and 7.4.2.3 may be amended pro rata. In no case shall the structural fire protection time be less than 30 min.

C7.4.1.1 Fire insulation may be omitted on upper side of decks provided that a fixed water spraying system delivering not less than 5 l/min/m^2 is installed.

7.4.1.2 In using Tables 7.4-1 and 7.4-2, it shall be noted that the title of each category is intended to be typical rather than restricted. For determining the appropriate fire integrity standards to be applied to boundaries between adjacent spaces, where there is doubt as to their classification for the purpose of this Section, they shall be treated as spaces within the relevant category having the most stringent boundary requirement.

7.4.1.3 The hull, superstructure, structural bulkheads, decks, deckhouses and pillars shall be constructed of approved non-combustible materials having adequate structural properties. The use of other fire-restricting materials may be permitted provided the requirements of this Section are complied with and the materials are in compliance with the Fire Test Procedures Code.

7.4.1.4 Paragraph 7.4.1.3 does not apply to appendages such as air propellers, air ducts to propellers, transmission shafts, rudders and other control surfaces, struts, spars, flexible skirts, etc., which do not comprise part of the main structure of the craft.

Table 7.4-1 Structural fire protection times for separating bulkheads and decks of passenger craft

	A	*B*	*C*	*D*	*E*	*F*
A Areas of major fire hazard	60 (1,2) / 60 (1,2)	30 / 60 (1)	(3) / 60 (1,8)	(3,4) / 60 (1)	(3) / 60 (1)	— / 60 (1,7,9)
B Areas of moderate fire hazard		30 (2) / 30 (2)	(3) / 30 (8)	(3,4) / 60	(3) / 30	— / (3)
C Areas of minor fire hazard			(3) / (3)	(3,4) / 30 (8,10)	(3) / (3)	— / (3)
D Control stations				(3,4) / (3,4)	(3) / (3,4)	— / (3)
E Evacuation stations and escape routes					(3) / (3)	— / (3)
F Open spaces						— / —

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Table 7.4-2 Structural fire protection times for separating bulkheads and decks of cargo craft

	A	B	C	D	E	F
A Areas of major fire hazard	60 (1,2) / 60 (1,2)	30 / 60 (1)	(3) / 60 (1,8)	(3,4) / 60 (1)	(3) / 60 (1)	— / 60 (1,7,9)
B Areas of moderate fire hazard		(2,6) / (2,6)	(3) / (6)	(3,4) / 60	(3) / (6)	— / (3)
C Areas of minor fire hazard			(3) / (3)	(3,4) / 30 (8)	(3) / (3)	— / (3)
D Control stations				(3,4) / (3,4)	(3) / (3,4)	— / (3)
E Evacuation stations and escape routes					(3) / (3)	— / (3)
F Open spaces						— / —

Notes:

The figures on either side of the diagonal line represent the required structural fire protection time for the protection system on the relevant side of the division. When steel construction is used and two different structural fire protection times are required for a division in the table, only the greater one need be applied.

1. *The upper side of decks within spaces protected by fixed fire-extinguishing systems need not be insulated.*
2. *Where adjacent spaces are in the same alphabetical category and a note 2 appears, a bulkhead or deck between such spaces need not be fitted if deemed unnecessary by the Administration. For example, a bulkhead need not be required between two store-rooms. A bulkhead, is however, required between a machinery space and a special category space even through both spaces are in the same category.*
3. *No structural fire protection requirements; however, a smoke-tight division made of non-combustible or fire restricting material is required.*
4. *Control stations which are also auxiliary machinery spaces shall be provided with 30 min structural fire protection.*
5. *There are no special requirements for material or integrity of boundaries where only a dash appears in the tables.*
6. *The fire protection time is 0 min and the time for prevention of passage of smoke and flame is 30 min as determined by the first 30 min of the standard fire test.*
7. *Fire resisting divisions need not comply with 7.2.1.5.*
8. *When steel construction is used, fire resisting divisions adjacent to void spaces need not comply with 7.2.1.5.*
9. *The fire protection time may be reduced to 0 min for those parts of open ro-ro spaces which are not essential parts of the craft's main load bearing structure, where passengers have no access to them and the crew need not have access to them during any emergency.*
10. *On category A craft, this value may be reduced to 0 min where the craft is provided with only a single public space (excluding lavatories) protected by a sprinkler system and adjacent to the operating compartment.*

7.4.2 Fire-resisting divisions

7.4.2.1 *Areas of major and moderate fire hazard shall be enclosed by fire-resisting divisions comply-*

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ing with the requirements of 7.2.1 except where the omission of any such division would not affect the safety of the craft. These requirements need not apply to those parts of the structure in contact with water at least 300 mm below the craft's waterline in the light-weight condition in displacement mode, but due regard shall be given to the effect of temperature of hull in contact with water and heat transfer from any uninsulated structure in contact with water to insulated structure above the water.

7.4.2.2 *Fire-resisting bulkheads and decks shall be constructed to resist exposure to the standard fire test for a period of 30 min for areas of moderate fire hazard and 60 minutes for areas of major fire hazard except as provided in 7.4.1.1.*

7.4.2.3 *Main load-carrying structures within areas of major fire hazard and areas of moderate fire hazard and structures supporting control stations shall be arranged to distribute load such that there will be no collapse of the construction of the hull and superstructure when it is exposed to fire for the appropriate fire protection time. The load-carrying structure shall also comply with the requirements of 7.4.2.4 and 7.4.2.5.*

7.4.2.4 *If the structures specified in 7.4.2.3 are made of aluminium alloy their installation shall be such that the temperature of the core does not rise more than 200°C above the ambient temperature in accordance with the times in 7.4.1.1 and 7.4.2.2.*

7.4.2.5 *If the structures specified in 7.4.2.3 are made of combustible material, their insulation shall be such that their temperatures will not rise to a level where deterioration of the construction will occur during the exposure to the standard fire test in accordance with the Fire Test Procedures Code to such an extent that the load-carrying capability, in accordance with the times in 7.4.1.1 and 7.4.2.3, will be impaired.*

7.4.2.6 *The construction of all doors, and door frames in fire-resisting divisions, with the means of securing them when closed, shall provide resistance to fire as well as to the passage of smoke and flame equivalent to that of the bulkheads in which they are situated. Watertight doors of steel need not be insulated. Also, where a fire-resisting division is penetrated by pipes, ducts, electrical cables etc., arrangements shall be made to ensure that the fire-resisting integrity of the division is not impaired, and necessary testing shall be carried out in accordance with the Fire Test Procedures Code. Where machinery shafts penetrate fire-resisting watertight divisions, arrangements shall be made to ensure that the required watertight and fire-resisting integrity of the division is not impaired.*

7.4.2.7 *Ventilation openings may be accepted in entrance doors to public toilets, provided they are positioned in the lower portion of the door and fitted with closable grilles made of non-combustible or fire-restricting material and operable from outside the space.*

7.4.3 Restricted use of combustible materials

7.4.3.1 *All separating divisions, ceilings or linings if not a fire resisting division, shall be of non-combustible or fire restricting materials. Draught stops shall be of non-combustible or fire-restricting material.*

7.4.3.2 *Where insulation is installed in areas in which it could come into contact with any flammable fluids or their vapours, its surface shall be impermeable to such flammable fluids of vapours. The fire insulation in such spaces may be covered by metal sheets (not perforated) or by vapour proof glass cloth sealed at joints.*

7.4.3.3 *Furniture and furnishings in public spaces and crew accommodation shall comply with the following standards [2]:*

- ***.1*** *all case furniture e.g., desks, wardrobes, dressing tables, bureaux and dressers is constructed entirely of approved non-combustible or fire-restricting materials, except that a combustible veneer with a calorific value not exceeding 45 MJ/m^2 may be used on the exposed surface of such articles;*
- ***.2*** *all other furniture such as chairs, sofas and tables, is constructed with frames of non-combustible or fire-restricting materials;*
- ***.3*** *all draperies, curtains and other suspended textile materials have qualities of resistance to the propagation of flame, this being determined in accordance with the Fire Test Procedures Code;*
- ***.4*** *all upholstered furniture has qualities of resistance to the ignition and propagation of flame, this being determined in accordance with the Fire Test Procedures Code;*
- ***.5*** *all bedding components have qualities of resistance to the ignition and propagation of flame, this being determined in accordance with the Fire Test Procedures Code; and*

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2 *Fire test procedures referenced in the FTP Code (resolution MSC.61(67), as amended, and MSC/Circ.916, 964, 1004, 1008, 1036 and 1120 should be applied to items and materials covered by this paragraph as follows:*

- *.1 case furniture (FTP Code, annex 1, parts 1 and 10);*
- *.2 frames of all other furniture (FTP Code, annex 1, parts 1 and 10);*
- *.3 draperies, textiles and other suspended textile materials (FTP Code, annex 1, part 7);*
- *.4 upholstered furniture, e.g. passenger seating (FTP Code, annex 1, part 8);*
- *.5 bedding components (FTP Code, annex 1, part 9); and*
- *.6 deck finish materials (FTP Code, annex 1, parts 2 and 6).*

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.6 all deck finish materials comply with the Fire Test Procedures Code.

C7.4.3.3 Requirement 7.4.3.3.1 is applicable to furniture such as desks, wardrobes, dressing tables, bureaux and dressers.

7.4.3.4 *Subject to 7.4.3.5 the following surfaces shall, as a minimum standard, be constructed of materials having low flame-spread characteristics:*

.1 exposed surfaces in corridors and stairway enclosures, and of bulkheads (including windows), wall and ceiling linings in all public spaces, crew accommodation, service spaces, control stations and internal assembly and evacuation stations;

.2 surfaces in concealed or inaccessible spaces in corridors and stairway enclosures, public spaces, crew accommodation, service spaces, control stations and internal assembly and evacuation stations.

7.4.3.5 *Paragraph 7.4.3.4 does not apply to partitions, windows and sidescuttles made of glass which are deemed to be non-combustible and to comply with the requirements for low-flame spread surfaces or to items and materials referred to in 7.4.3.3 [3].*

7.4.3.6 *Any thermal and acoustic insulation shall be of non-combustible or of fire-restricting material. Vapour barriers and adhesives used in conjunction with insulation, as well as insulation of pipe fittings for cold service systems need not be non-combustible or fire-restricting, but they shall be kept to the minimum quantity practicable and their exposed surfaces shall have low flame spread characteristics.*

7.4.3.7 *Exposed surfaces in corridors and stairway enclosures, and of bulkheads (including windows), wall and ceiling linings, in all public spaces, crew accommodation, service spaces, control stations and internal assembly and evacuation stations shall be constructed of materials which, when exposed to fire, are not capable of producing excessive quantities of smoke or toxic products, this being determined in accordance with the Fire Test Procedures Code.*

7.4.3.8 *Void compartments, where low-density combustible materials are used to provide buoyancy, shall be protected from adjacent fire hazard areas by fire-resisting divisions, in accordance with tables 7.4-1 and 7.4-2. Also, the space and closures to it shall be gastight but it shall be ventilated to atmosphere.*

7.4.3.9 *In compartments where smoking is allowed, suitable non-combustible ash containers shall be provided. In compartments where smoking is not allowed, adequate notices shall be displayed.*

7.4.3.10 *The exhaust gas pipes shall be arranged so that the risk of fire is kept to a minimum. To this effect, the exhaust system shall be insulated and all compartments and structures which are contiguous with the exhaust system, or those which may be affected by increased temperatures caused by waste gases in normal operation or in an emergency, shall be constructed of non-combustible material or be shielded and insulated with non-combustible material to protect from high temperatures.*

7.4.3.11 *The design and arrangement of the exhaust manifolds or pipes shall be such as to ensure the safe discharge of exhaust gases.*

7.4.4 Arrangement

7.4.4.1 *Internal stairways connecting only two decks need only be enclosed at one deck by means of divisions and self-closing doors having the structural fire protection time as required by tables 7.4-1 and 7.4-2 for divisions separating those areas which each stairway serves.*

7.4.4.2 *Open stairways may be fitted in public spaces consisting of only two decks, provided the stairways lie wholly within such public spaces and the following conditions are met:*

.1 all levels are used for the same purpose;

.2 the area of the opening between the lower and upper parts of the space is at least 10 % of the deck area between the upper and lower parts of the space;

.3 the design is such that persons within the space should be generally aware, or could easily be made aware of, a developing fire or other hazardous situation located within that space;

.4 sufficient means of escape are provided from both levels of the space directly leading to an adjacent safe area or compartment; and

.5 the whole space is served by one section of the sprinkler system.

7.4.4.3 *Lift trunks shall be so fitted as to prevent the passage of smoke and flame from one deck to another and shall be provided with means of closing so as to permit the control of draught and smoke.*

7.4.4.4 *In public spaces, crew accommodation, service spaces, control stations, corridors and stairways, air spaces enclosed behind ceilings, panelling or linings shall be suitably divided by close-fitting draught stops not more than 14 m apart. Draught stops are not required in public spaces of category A craft having only one public space and on other craft in spaces with open ceilings (perforated ceilings) where the opening is 40 % or more and the ceiling is*

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3 Refer to 7.9.3.4 and the FTP Code, annex 2, paragraphs 1 and 5.1.

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arranged in such a way that a fire behind the ceiling can be easily seen and extinguished.

7.5 Fuel and Other Flammable Fluid Tanks and Systems

7.5.1 Tanks containing fuel and other flammable fluids shall be separated from passenger, crew, and baggage compartments by vapour-proof enclosures or cofferdams which are suitably ventilated and drained.

7.5.2 Fuel oil tanks shall not be located in, be formed by any part of the structural boundary of, areas of major fire hazard. However, flammable fluids of a flashpoint not less than 60 °C may be located within such areas provided the tanks are made of steel or other equivalent material. The use of aluminium in lubricating oil sump tanks for engines, or in lubricating oil filter housings fitted integral with the engines, is accepted.

C7.5.2 Integral or independent fuel tanks made of aluminium alloys, GRP or equivalent may be located within major fire hazard areas when they are insulated for 60 minutes fire integrity. The same insulation standard is required for bulkheads or decks separating oil fuel tanks from major fire hazard areas.

7.5.3 Every fuel oil pipe which, if damaged, would allow oil to escape from a storage, settling or daily service tank shall be fitted with a cock or valve directly on the tank capable of being closed from a position outside the space concerned in the event of a fire occurring in the space in which such tanks are situated.

7.5.4 Pipes, valves and couplings conveying flammable fluids shall be of steel or such alternative material satisfactory to a standard [4], in respect of strength and fire integrity having regard to the service pressure and the spaces in which they are installed. Wherever practicable, the use of flexible pipes shall be avoided.

7.5.5 Pipes, valves and couplings conveying flammable fluids shall be arranged as far from hot surfaces or air intakes of engine installations, electrical appliances and other potential sources of ignition as is practicable and be located or shielded so that the likelihood of fluid leakage coming into contact with such sources of ignition is kept to a minimum.

7.5.6 Fuel with a flash point below 35 °C shall not be used. In every craft in which fuel with a flashpoint below 43 °C is used, the arrangements for the storage, distribution and utilization of the fuel shall be such that, having regard to the hazard of fire and explosion which the use of such fuel may entail, the safety of the craft and of persons on board is preserved. The arrangements shall comply, in addition to the requirements of 7.5.1 to 7.5.5, with the following provisions:

.1 tanks for the storage of such fuel shall be located outside any machinery space and at a distance of not less than 760 mm inboard from the shell side and bottom plating, and from decks and bulkheads;

.2 arrangements shall be made to prevent overpressure in any fuel tank or in any part of the oil fuel system, including the filling pipes. Any relief valves and air or overflow pipes shall discharge to a position which, in the opinion of the Administration, is safe;

.3 the spaces in which fuel tanks are located shall be mechanically ventilated, using exhaust fans providing not less than six air changes per hour. The fans shall be such as to avoid the possibility of ignition of flammable gas-air mixtures. Suitable wire mesh guards shall be fitted over inlet and outlet ventilation openings. The outlets for such exhausts shall be discharged to a position which, in the opinion of the Administration is 'No Smoking' signs shall be posted at the entrance to such spaces;

.4 earthed electrical distribution systems shall not be used, with the exception of earthed intrinsically safe circuits;

.5 suitable certified safe type [5] electrical equipment be used in all spaces where fuel leakage could occur, including the ventilation system. Only electrical equipment and fittings essential for operational purposes shall be fitted in such spaces;

.6 a fixed vapour-detection system shall be installed in each space through which fuel lines pass, with alarms provided at the continuously manned control station;

.7 every fuel tanks shall, where necessary, be provided with "savealls" or gutters which would catch any fuel which may leak from such tank;

.8 safe and efficient means of ascertaining the amount of fuel contained in any tank shall be provided. Sounding pipes shall not terminate in any space where the risk of ignition of spillage from the sounding pipe might arise. In particular, they shall not terminate in passenger or crew spaces. The use of cylindrical

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[4] Refer to the Guidelines for the application of plastic pipes on ships, adopted by the Organization by resolution A.753(18).

[5] Refer to Recommendations published by the International Electrotechnical Commision and, in particular, publication 60092 – Electrical Installations in Ships.

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gauge glasses is prohibited, except for cargo craft where the use of oil-level gauges with flat glasses and self-closing valves between the gauges and fuel tanks may be permitted by the Administration. Other means of ascertaining the amount of fuel contained in any tank may be permitted if such means do not require penetration below the top of the tank, and providing their failure or overfilling of the tank will not permit the release of fuel;

.9 during bunkering operations, no passenger shall be on board the craft or in the vicinity of the bunkering station, and adequate 'No Smoking' and 'No Naked Lights' signs shall be posted. Vessel-to-shore fuel connections shall be of closed type and suitably grounded during bunkering operations;

.10 the provision of fire detection and extinguishing systems in spaces where non-integral fuel tanks are located shall be in accordance with paragraphs 7.7.1 to 7.7.3; and

.11 refuelling of the craft shall be done at the approved refuelling facilities, detailed in the route operational manual, at which the following fire appliances are provided:

.11.1 a suitable foam applicator system consisting of monitors and foam-making branch pipes capable of delivering foam solution at a rate of not less than 50 l/m for not less than 10 min;

.11.2 dry powder extinguishers of total capacity not less than 50 kg; and

.11.3 carbon dioxide extinguishers of total capacity not less than 16 kg.

C7.5.6 With reference to 7.5.6.3, fans are to be of a non-sparking type in accordance with GL's Rules.

7.6 Ventilation

7.6.1 *The main inlets and outlets of all ventilation systems shall be capable of being closed from outside the spaces being ventilated. The controls shall be easily accessible as well as prominently and permanently marked and shall indicate whether the shut-off is open or closed. In addition, such openings to areas of major fire hazard shall be capable of being closed from a continuously manned control station.*

7.6.2 *All ventilation fans shall be capable of being stopped from outside the spaces which they serve, and from outside the spaces in which they are installed. Ventilation fans serving areas of major fire hazard shall be capable of being operated from a continuously manned control station. The means provided for stopping the power ventilation to the machinery space shall be separated from the means provided for stopping ventilation of other spaces.*

7.6.3 *Areas of major fire hazard and spaces serving as assembly stations shall have independent ventilation systems and ventilation ducts. Ventilation ducts for areas of major fire hazard shall not pass through other spaces, unless they are contained within a trunk or in an extended machinery space or casing insulated in accordance with tables 7.4-1 and 7.4-2; ventilation ducts of other spaces shall not pass through areas of major fire hazard. Ventilation outlets from areas of major fire hazard shall not terminate within a distance of 1 m from any control station, evacuation station or external escape route. In addition, exhaust ducts from galley ranges shall be fitted with:*

.1 a grease trap readily removable for cleaning unless an alternative approved grease removal system is fitted;

.2 a fire damper located in the lower end of the duct (the junction between the duct and the galley range hood) which is automatically and remotely operated, and in addition a remotely operated fire damper located in the upper end of the duct;

.3 a fixed means for extinguishing a fire within the duct;

.4 remote control arrangements for shutting off the exhaust fans and supply fans, for operating the fire dampers mentioned in .2 and for operating the fire-extinguishing system, which shall be placed in a position close to the entrance to the galley. Where a multi-branch system is installed, a remote means located with the above controls shall be provided to close all branches exhausting through the same main duct before an extinguishing medium is released into the system; and

.5 suitably located hatches for ins pection and cleaning. At minimum, one hatch shall be provided close to the exhaust fan and others located in areas of high grease accumulation such as the lower end of the duct as referred to in 7.6.3.2.

7.6.4 *Where a ventilation duct passes through a fire-resisting division, a fail safe automatic closing fire damper shall be fitted adjacent to the division. The duct between the division and the damper shall be of steel or other equivalent material and insulated to the same standard as required for the fire resisting division. The fire damper may be omitted where ducts pass through spaces surrounded by fire-resisting divisions without serving those spaces providing that the duct has the same structural fire protection time as the divisions it penetrates. Where a ventilation duct passes through a smoke-tight division, a smoke damper shall be fitted at the penetration unless the duct which passes through the space does not serve*

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that space. Fire and smoke dampers shall be arranged so as to be readily accessible. Where placed behind ceilings or linings, they shall be provided with an inspection door marked to identify the damper. Such identification shall also be placed on any required remote controls.

7.6.5 Where ventilation systems penetrate decks, the arrangements shall be such that the effectiveness of the deck in resisting fire is not thereby impaired and precautions shall be taken to reduce the likelihood of smoke and hot gases passing from one between-deck space to another through the system.

7.6.6 All dampers fitted on fire-resisting or smoke-tight divisions shall also be capable of being manually closed from each side of the division in which they are fitted, except for those dampers fitted on ducts serving spaces not normally manned such as stores and toilets that may be manually operated only from outside the served spaces. Manual closing may be achieved by mechanical means of release or by remote operation of the fire or smoke damper by means of a fail-safe electrical switch or pneumatic release (i.e. spring-loaded, etc.). All dampers shall also be capable of being remotely closed from the continuously manned control station.

7.6.7 Ducts shall be made of non-combustible or fire restricting material. Short ducts, however, may be of combustible materials subject to the following conditions:

.1 their cross-section does not exceed 0,02 m² ;

.2 their length does not exceed 2 m;

.3 they may only be used at the terminal end of the ventilation system;

.4 they shall not be situated less than 600 mm from an opening in a fire-resisting or fire-restricting division; and

.5 their surfaces have low flame spread characteristics.

7.7 Fire Detection and Extinguishing Systems

7.7.1 Fire detection systems

Areas of major and moderate fire hazard and other enclosed spaces not regularly occupied within public spaces and crew accommodation, such as toilets, stairway enclosures, corridors and escape routes shall be provided with an approved automatic smoke detection system and manually operated call points complying with the requirements of 7.7.1.1 and 7.7.1.3 to indicate at the control station the location of outbreak of a fire in all normal operating conditions of the installations. Control stations not normally occupied (e.g., emergency generator rooms) need not be provided with manually operated call points. Detectors operated by heat instead of smoke may be installed in galleys. Main propulsion machinery room(s) shall in addition have detectors sensing other than smoke and be supervised by TV cameras monitored from the operating compartment. Manually operated call points shall be installed throughout the public spaces, crew accommodation, corridors and stairway enclosures, service spaces and where necessary control stations. One manually operated call point shall be located at each exit from these spaces and from areas of major fire hazard.

7.7.1.1 General requirements

.1 Any required fixed fire-detection and fire alarm system with manually operated call points shall be capable of immediate operation at all times.

.2 Power supplies and electric circuits necessary for the operation of the system shall be monitored for loss of power or fault conditions as appropriate. Occurrence of a fault condition shall initiate a visual and audible fault signal at the control panel which shall be distinct from a fire signal.

.3 There shall be not less than two sources of power supply for the electrical equipment used in the operation of the fixed fire-detection and fire alarm system, one of which shall be an emergency source. The supply shall be provided by separate feeders reserved solely for that purpose. Such feeders shall run to an automatic change-over switch situated in or adjacent to the control panel for the fire-detection system.

.4 Detectors and manually operated call points shall be grouped into sections, each of which shall comprise a group of fire detectors and manually operated call points as displayed at the indicating unit(s) required by this paragraph. The activation of any detector or manually operated call point shall initiate a visual and audible fire signal at the control panel and indicating units. If the signals have not received attention within two minutes an audible alarm shall be automatically sounded throughout the crew accommodation and service spaces, control stations and machinery spaces. There shall be no time delay for the audible alarms in crew accommodation areas when all the control stations are unattended. The alarm sounder system need not be an integral part of the detection system.

.5 The control panel shall be located in the operating compartment or in the main fire control station.

.6 Indicating units shall, as a minimum, denote the section in which a detector or manually operated call point has operated. At least one unit shall be so located that it is easily acces-

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sible to responsible members of the crew at all times, when at sea or in port, except when the craft is out of service. One indicating unit shall be located in the operating compartment if the control panel is located in the space other than the operating compartment.

.7 *Clear information shall be displayed on or adjacent to each indicating unit about the spaces covered and the location of the sections.*

.8 *Where the fire-detection system does not include means of remotely identifying each detector individually, no section covering more than one deck within public spaces, crew accommodation, corridors, service spaces and control stations shall normally be permitted except a section which covers an enclosed stairway. In order to avoid delay in identifying the source of fire, the number of enclosed spaces included in each section shall be limited as determined by the Administration. In no case shall more than 50 enclosed spaces be permitted in any section. If the detection system is fitted with remotely and individually identifiable fire detectors, the sections may cover several decks and serve any number of enclosed spaces.*

.9 *In passenger craft, if there is no fire-detection system capable of remotely and individually identifying each detector, a section of detectors shall not serve spaces on both sides of the craft nor on more than one deck and neither shall it be situated in more than one zone according to 7.11.1. Notwithstanding the preceding requirements of this paragraph, the Administration may accept that the same section of detectors can serve spaces on more than one deck if such spaces are located in the fore or aft end of the craft or they are so arranged that they constitute common spaces on different decks (e.g., fan rooms, galleys, public spaces, etc.).*

.10 *A section of fire detectors which covers a control station, a service space, a public space, crew accommodation, corridor or stairway enclosure shall not include a machinery space of major fire hazard. In the case of a fire detection system with remotely and individually identifiable fire detectors, this requirement is met if no machinery spaces of a major fire hazard are included in a loop (electrical circuit linking detectors of various sections in a sequence and connected (input and output) to the indicating unit(s)) covering accommodation spaces, service spaces and control stations.*

.11 *Detectors shall be operated by heat, smoke or other products of combustion, flame, or any combination of these factors. Detectors operated by other factors indicative of incipient fires may be considered by the Administration provided that they are no less sensitive than such detectors. Flame detectors shall only be used in addition to smoke or heat detectors.*

.12 *Suitable instructions and component spares for testing and maintenance shall be provided.*

.13 *The function of the detection system shall be periodically tested by means of equipment producing hot air at the appropriate temperature, or smoke or aerosol particles having the appropriate range of density or particle size, or other phenomena associated with incipient fires to which the detector is esigned to respond. All detectors shall be of a type such that they can be tested for correct operation and restored to normal surveillance without the renewal of any component.*

.14 *The fire-detection system shall not be used for any other purpose, except that the control panel may be used to activate one or more of the following:*

- **.1** *paging system;*
- **.2** *fan stops;*
- **.3** *closure of fire doors;*
- **.4** *closure of fire and smoke dampers; and*
- **.5** *sprinkler system.*

.15 *Fire detection systems in which all fire detectors are individually identifiable (i.e. having zone address identification capability) shall be so arranged that:*

- **.1** *a loop cannot be damaged at more than one point by a fire and no loop shall pass through a space twice. When this is not practical (e.g., for large public spaces), the part of the loop which by necessity passes through the space for a second time shall be installed at the maximum possible distance from the other parts of the loop;*
- **.2** *means are provided to ensure that any fault (e.g., power break; short circuit; earth) occurring in the loop shall not render the whole loop ineffective;*
- **.3** *all arrangements are made to enable the initial configuration of the system to be restored in the event of failure (electrical, electronic, informatic); and*
- **.4** *the first initiated fire alarm shall not prevent any other detector to initiate further fire alarms.*

.16 *The fire detection system in vehicle deck spaces, excluding manual call points, may be*

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switched off with a timer during loading/unloading of vehicles.

7.7.1.2 Installation requirements

.1 *In addition to 7.7.1, manually operated call points shall be readily accessible in the corridors of each deck such that no part of the corridor is more than 20 m from a manually operated call point.*

.2 *Where a fixed fire-detection and fire alarm system is required for the protection of spaces other than stairways, corridors and escape routes, at least one detector complying with 7.7.1.1.11 shall be installed in each such space.*

.3 *Detectors shall be located for optimum performance. Positions near beams and ventilation ducts or other positions where patterns of air flow could adversely affect performance and positions where impact or physical damage is likely shall be avoided. Detectors which are located in the overhead shall be a minimum distance of 0,5 m away from bulkheads, except in corridors, lockers and stairways.*

.4 *The maximum spacing of detectors shall be in accordance with the table below:*

Type of detector	*Maximum floor area per detector*	*Maximum distance apart between centres*	*Maximum distance away from bulkheads*
Heat	*37 m^2*	*9 m*	*4,5 m*
Smoke	*74 m^2*	*11 m*	*5,5 m*

The Administration may require or permit other spacings based upon test data which demonstrate the characteristics of the detectors.

.5 *Electrical wiring which forms parts of the system shall be so arranged as to avoid machinery spaces of major fire hazard, and other enclosed spaces of major fire hazard except, where it is necessary, to provide for fire detection or fire alarm in such spaces or to connect to the appropriate power supply.*

7.7.1.3 Design requirements

.1 *The system and equipment shall be suitably designed to withstand supply voltage variation and transients, ambient temperature changes, vibration, humidity, shock, impact and corrosion normally encountered in ships.*

.2 *Smoke detectors shall be certified to operate before the smoke density exceeds 12,5 % obscuration per metre, but not until the smoke density exceeds 2 % obscuration per metre. Smoke detectors to be installed in other spaces shall operate within sensitivity limits to the satisfaction of the Administration having regard to the avoidance of detector insensitivity or over-sensitivity.*

.3 *Heat detectors shall be certified to operate before the temperature exceeds 78 °C but not until the temperature exceeds 54 °C, when the temperature is raised to those limits at a rate less than 1 °C per minute. At higher rates of temperature rise, the heat detector shall operate within temperature limits having regard to the avoidance to detector insensitivity or oversensitivity.*

.4 *At the discretion of the Administration, the permissible temperature of operation of heat detectors may be increased to 30 °C above the maximum deckhead temperature in drying rooms and similar spaces of a normal high ambient temperature.*

.5 *Flame detectors corresponding to 7.7.1.1.11 shall have a sensitivity sufficient to determine flame against an illuminated space background and a false signal identification system.*

7.7.2 Fire detection for periodically unattended machinery spaces

A fixed fire-detection and fire alarm system for periodically unattended machinery spaces shall comply with the following requirements:

.1 *The fire-detection system shall be so designed and the detectors so positioned as to detect rapidly the onset of fire in any part of those spaces and under any normal conditions of operation of the machinery and variations of ventilation as required by the possible range of ambient temperatures. Except in spaces of restricted height and where their use is specially appropriate, detection systems using only thermal detectors shall not be permitted. The detection system shall initiate audible and visual alarms distinct in both respects from the alarms of any other system not indicating fire, in sufficient places to ensure that the alarms are heard and observed on the navigating bridge and by a responsible engineer officer. When the operating compartment is unmanned the alarm shall sound in a place where a responsible member of the crew is on duty.*

.2 *After installation, the system shall be tested under varying conditions of engine operation and ventilation.*

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7.7.3 Fixed fire-extinguishing systems

7.7.3.1 Areas of major fire hazard shall be protected by an approved fixed fire-extinguishing system operable from the operating compartment and, where provided, from a control position which is adequate for the fire hazard that may exist. The system shall comply with 7.7.3.2 and 7.7.3.3 or with alternative arrangements approved by the Administration taking into account the recommendations and guidelines developed by the Organization [6] and be capable of local manual control and remote control from the continuously manned control stations.

7.7.3.2 Additional fixed fire-extinguishing systems not required by the Code, but fitted to the craft are to meet the design requirements of this Code, except for the second discharge required for fixed gas fire-extinguishing systems.

7.7.3.3 General requirements

.1 In all craft where gas is used as the extinguishing medium, the quantity of gas shall be sufficient to provide two independent discharges. The second discharge into the space shall only be activated manually from a position outside the space being protected. Where the space has a local fire-suppression system installed, based on the guidelines developed by the Organization [7], to protect fuel oil, lubricating oil and hydraulic oil located near exhaust manifolds, turbo chargers or similar heated surfaces on main and auxiliary internal combustion engines, a second discharge need not be required.

.2 The use of a fire-extinguishing medium which, in the opinion of the Administration, either by itself or under expected conditions of use will adversely affect the earth's ozone layer and/or gives off toxic gases in such quantities as to endanger persons shall not be permitted.

.3 The necessary pipes for conveying fire-extinguishing medium into protected spaces shall be provided with control valves so marked as to indicate clearly the spaces to which the pipes are led. Non-return valves shall be installed in discharge lines between cylinders and manifolds. Pipelines may pass through accommodation spaces, provided they are of substantial thickness and their tightness is verified with a pressure test, after their installation, at a pressure head not less than 5 N/mm^2. In addition, pipelines passing through accommodation areas shall only be joined by welding and shall not be fitted with drains or other openings within such spaces. Pipelines shall not pass through refrigerated spaces. Suitable provision shall be made to prevent inadvertent admission of the medium to any space.

.4 The piping for the distribution of fire-extinguishing medium shall be arranged and discharge nozzles so positioned that a uniform distribution of medium is obtained.

.5 Means shall be provided to close all openings which may admit air to, or allow gas to escape from, a protected space. Openings that may admit air to, or allow gas to escape from, a protected space shall be capable of being closed from outside the protected space.

.6 Where the volume of free air contained in air receivers in any space is such that, if released in such space in the event of fire, such release of air within that space would seriously affect the efficiency of the fixed fire-extinguishing system, the Administration shall require the provision of an additional quantity of fire-extinguishing medium corresponding to the gross volume of the machinery space being increased by the volume of air receivers converted to free air volume. Alternatively, a discharge pipe connected to a safety valve may be fitted to each air receiver, provided it leads directly to the open air.

.7 Means shall be provided for automatically giving audible warning of the release of fire-extinguishing medium into any space in which personnel normally work or which personnel can be expected to enter (e.g., ro-ro spaces) and where their access is facilitated by doors or hatches or to which they have access. The alarm shall automatically operate (e.g., by opening of the release cabinet door) for a suitable period before the medium is released, but not less than 20 s. Visible alarm shall be arranged in addition to the audible alarm [8].

.8 The means of control of any fixed gas fire-extinguishing system shall be readily accessible and simple to operate and shall be grouped together in as few locations as possible at positions not likely to be cut off by a fire in a protected space. At each location there shall be clear instructions relating to the operation of the system, having regard to the safety of personnel.

.9 Automatic release of fire-extinguishing medium shall not be permitted.

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6 Refer to MSC/Circ.1165 – Revised Guidelines for the Approval of Equivalent water-based fire-extinguishing systems for Machinery Spaces and Cargo Pump-Rooms and to MSC/Circ.848 – Revised Guidelines for the approval of equivalent fixed gas fire-extinguishing systems, as referred to in SOLAS 74, for machinery spaces and cargo pump-rooms.

7 Refer to MSC.1/Circ.1387 – Revised Guidelines for the Approval of fixed water-based local Application fire-fighting systems for Use in Category A Machinery Spaces (MSC/Circ.913).

8 Refer to the Code on Alarms and Indicators, 1995 (resolution A.830(19)).

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.10 Where the quantity of extinguishing medium is required to protect more than one space, the quantity of medium available need not be more than the largest quantity required for any one space so protected. Spaces are considered as separated where divisions comply with tables 7.4-1 and 7.4-2, as appropriate, or the divisions are gastight and of steel or equivalent materials.

.11 Pressure containers required for the storage of fire-extinguishing medium shall be located outside protected spaces in accordance with 7.7.3.2.14. Pressure containers may be located inside the space to be protected if in the event of accidental release persons will not be endangered.

.12 Means shall be provided for the crew to safely check the quantity of medium in the containers without moving the containers completely from their fixing position.

.13 Containers for the storage of fire-extinguishing medium and associated pressure components shall be designed having regard to their locations and maximum ambient temperatures expected in service.

.14 When the fire-extinguishing medium is stored outside a protected space, it shall be stored in a room which shall be situated in a safe and readily accessible location. For the purpose of the application of tables 7.4-1 and 7.4-2, such storage rooms shall be treated as control stations. For the storage rooms for fire-extinguishing media of fixed gas fire-extinguishing systems, the following apply:

.1 the storage room shall not be used for any other purposes;

.2 if the storage space is located below deck, it shall be located no more than one deck below the open deck and shall be directly accessible by a stairway or ladder from the open deck;

.3 spaces shall be effectively ventilated. Spaces which are located below deck or spaces where access from the open deck is not provided, shall be fitted with a mechanical ventilation system designed to take exhaust air from the bottom of the space and shall be sized to provide at least 6 air changes per hour; and

.4 access doors shall open outwards, and bulkheads and decks including doors and other means of closing any opening therein, which form the boundaries between such rooms and adjacent enclosed spaces shall be gastight.

.15 Spare parts for the system shall be stored on board or at a base port.

.16 If the release of a fire extinguishing medium produces significant over or under pressurisation in the protected space, means shall be provided to limit the induced pressures to acceptable limits to avoid structural damage.

C7.7.3.2

(a) With reference to 7.7.3.2.10, see also the requirements of 7.7.3.2.1.

(b) With reference to C7.7.3.2.13, the GL Rules apply.

(c) With reference to 7.7.3.2.14, storage rooms are to be provided with a mechanical ventilation system, capable of effecting at least 6 air changes per hour; if such rooms have a direct door access to open deck, natural ventilation may be sufficient.

7.7.3.4 Carbon dioxide systems

.1 For cargo spaces, the quantity of carbon dioxide available shall, unless otherwise provided, be sufficient to give a minimum volume of free gas equal to 30 % of the gross volume of the largest cargo space so protected in the craft.

.2 For machinery spaces, the quantity of carbon dioxide carried shall be sufficient to give a minimum volume of free gas equal to the larger of the following volumes, either:

.2.1 40 % of the gross volume of the largest machinery space so protected, the volume to exclude that part of the casing above the level at which the horizontal area of the casing is 40 % or less of the horizontal area of the space concerned taken midway between the tank top and the lowest part of the casing; or

.2.2 35 % of the gross volume of the largest machinery space protected, including the casing; respectively for cargo craft of less than 2000 gross tonnage; provided also that if two or more machinery spaces are not entirely separate they shall be considered as forming one space.

.3 For the purpose of this paragraph the volume of free carbon dioxide shall be calculated at 0,56 m^3/kg.

.4 For machinery spaces, the fixed piping system shall be such that 85 % of the gas can be discharged into the space within 2 min.

.5 Two separate controls shall be provided for releasing carbon dioxide into a protected space and to ensure the activation of the alarm. One control shall be used to discharge the gas from its storage containers. A second

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control shall be used for opening the valve of the piping which conveys the gas into the protected spaces.

.6 The two controls shall be located inside a release box clearly identified for the particular space. If the box containing the controls is to be locked, a key to the box shall be in a break-glass type enclosure conspicuously located adjacent to the box.

7.7.4 Portable fire extinguishers [9]

Control stations, public spaces, crew accommodation, corridors and service spaces shall be provided with portable fire extinguishers of approved type and design. At least five portable extinguishers shall be provided, and so positioned, as to be readily available for immediate use. In addition, at least one extinguisher suitable for machinery space fires shall be positioned outside each machinery space entrance.

Each portable fire extinguisher shall:

.1 not exceed 23 kg in total mass;

.2 have a capacity of at least 5 kg if of powder or carbon dioxide type;

.3 have a capacity of at least 9 l if of foam type;

.4 be examined annually;

.5 be provided with a sign indicating the date when was last examined;

.6 be hydraulic-pressure tested (cylinders and propellant bottles) every 10 years;

.7 not be placed in accommodation spaces if of carbon dioxide type;

.8 if located in control stations and other spaces containing electrical or electronic equipment or appliances necessary for the safety of the craft, be provided with extinguishing media which are neither electrically conductive nor harmful to the equipment and appliances;

.9 be ready for use and located in easily visible places such that it can be reached quickly and easily at any time in the event of a fire;

.10 be located such that its serviceability is not impaired by the weather, vibration or other external factors; and

.11 be provided with a device to identify whether it has been used.

C7.7.4 In the vicinity of the main switchboard and of any electrical panel of 20 kW or more, at least one portable carbon dioxide fire extinguisher or equivalent are to be provided.

7.7.5 Fire pumps, fire mains, hydrants and hoses

Fire pumps, and appropriate associated equipment, or alternative effective fire-extinguishing systems shall be fitted as follows:

.1 At least two pumps powered by independent sources of power shall be arranged. Each pump shall have at least two-thirds the capacity of a bilge pump as determined by 10.3.5 and 10.3.6 but not less than 25 m^3/h. Each fire pump shall be able to deliver sufficient quantity and pressure of water to simultaneously operate the hydrants as required by .4.

.2 The arrangement of the pumps shall be such that in the event of a fire in any one compartment, all the fire pumps will not be put out of action.

.3 Isolating valves to separate the section of the fire main within the machinery space containing the main fire pump or pumps from the rest of the fire main shall be fitted in an easily accessible and tenable position outside the machinery spaces. The fire main shall be so arranged that when the isolating valves are shut all the hydrants on the craft, except those in the machinery space referred to above, can be supplied with water by a fire pump not located in this machinery space through pipes which do not enter this space. The fire main shall be capable of being drained and shall be fitted with valves arranged so that fire main branches can be isolated when the main is used for purposes other than fire-fighting. The spindles of manually operated valves shall be easily accessible and all valves shall be clearly marked.

.4 Hydrants shall be so arranged so that any location on the craft can be reached by the water jets from two fire hoses from two different hydrants, one of the jets being from within the space can be reached by two water jets from two different hydrants, each jet being supplied from a single length of hose. One hydrant shall be located in the vicinity of and outside each entrance to a machinery space.

.5 Each fire hose shall be of non-perishable material. Fire hoses shall have a length of:

.1 at least 10 m;

.2 or more than 15 m in machinery spaces; and

.3 or more than 20 m for other spaces and open decks.

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9 *Refer to the Improved guidelines for marine portable fire extinguishers (resolution A.951(23)), and Fire protection equipment – Portable fire extinguishers – Performance and construction (ISO 7165:1999).*

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.6 Each fire hose shall be provided with a nozzle of an approved dual purpose type (i.e. spray/jet type) incorporating a shutoff.

C7.7.5 With reference to 7.7.5.1, the sufficient quantity of water is to be delivered with a discharge pressure at the nozzles of at least:

- 0,3 N/mm^2 for cargo craft and passenger craft of less than 4000 tons GT,
- 0,4 N/mm^2 for passenger craft of 4000 tons GT and above.

With reference to 7.7.5.5, the maximum length is to be 20 m.

7.7.6 Protection of deep-fat cooking equipment

Where deep-fat cooking equipment is installed, all such installations shall be fitted with:

.1 an automatic or manual fixed extinguishing system tested to an appropriate standard acceptable to the Organization [10];

.2 a primary and back up thermostat with an alarm to alert the operator in the event of failure of either thermostat;

.3 arrangements for automatically shutting off the electrical power to the deep-fat cooking equipment upon activation of the extinguishing system;

.4 an alarm for indicating operation of the extinguishing system in the galley where the equipment is installed; and

.5 controls for manual operation of the extinguishing system which are clearly labelled for ready use by the crew.

7.8 Protection of Special Category Spaces and Ro-Ro Spaces

7.8.1 Structural protection

7.8.1.1 *Subject to 7.8.1.2 boundaries of special category spaces shall be insulated in accordance with tables 7.4-1 and 7.4-2.*

7.8.1.2 *The vehicle deck of a special category space or a ro-ro space, including an open ro-ro space, need only be insulated on the underside if required. Vehicle decks located totally within ro-ro spaces may be accepted without structural fire protection, provided these decks are not part of, or do not provide support to, the craft's main load-carrying structure and provided satisfactory measures are taken to ensure that the safety of the craft, including fire-fighting abilities, integrity of fire resisting divisions and means of evacuation, is not affected by a partial or total collapse of these internal decks.*

7.8.1.3 *Indicators shall be provided on the navigating bridge which shall indicate when any door leading to or from the special category space or ro-ro space is closed.*

7.8.1.4 *Fire doors in boundaries of special category spaces leading to spaces below the vehicle deck shall be arranged with coamings of a height of at least 100 mm.*

7.8.2 Fixed fire-extinguishing system

7.8.2.1 *Each special category space and ro-ro space shall be fitted with an approved fixed pressure water-spraying system [11] for manual operation which shall protect all parts of any deck and vehicle platform in such space, provided that the Administration may permit the use of any other fixed fire-extinguishing system that has been shown by full-scale test in conditions simulating a flowing petrol fire in the space to be not less effective in controlling fires likely to occur in such a space.*

7.8.2.2 *The pumps of the system shall be capable of maintaining:*

.1 half the total required application rate with any one pump unit out of function, for category A craft; and

.2 the total required application rate with any one pump unit out of function, for category B craft.

7.8.2.3 *Fixed fire-extinguishing systems shall fulfil the following requirements:*

.1 the valve manifold shall be provided with a pressure gauge, and each of the valves shall be marked to identify the protected areas;

.2 instructions for maintenance and operation of the installation shall be set up in the room where the valves are located; and

.3 the piping system shall be provided with a sufficient number of drainage valves.

7.8.3 Patrols and detection

7.8.3.1 *A continuous fire patrol shall be maintained in special category spaces and ro-ro spaces unless a fixed fire detection and fire alarm system, complying with the requirements of 7.7.1, and a television surveillance system are provided. The fixed fire detection system shall be capable of rapidly detecting the*

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10 Refer to ISO 15371 – Ships and marine technology – Fire-extinguishing systems for protection of galley deep-fat cooking equipment – Fire tests.

11 Refer to Recommendation on fixed fire-extinguishing systems for special category spaces (resolution A.123(V)).

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onset of fire. The spacing and location of detectors shall be tested taking into account the effects of ventilation and other relevant factors.

7.8.3.2 *Manually operated call points shall be provided as necessary throughout the special category spaces and ro-ro spaces and one shall be placed close to each exit from such spaces. Manually operated call points shall be spaced so that no part of the space shall be more than 20 m from a manually operated call point.*

7.8.4 Fire-extinguishing equipment

7.8.4.1 *There shall be provided in each special category space and ro-ro space:*

.1 *at least three water fog applicators, which shall consist of a metal L-shaped pipe, the long limb being approximately 2 m in length and capable of being fitted to a fire hose, and the short limb being approximately 250 mm in length and fitted with a fixed water fog nozzle or capable of being fitted with a water spray nozzle;*

.2 *one portable foam applicator unit consisting of an air foam nozzle of an inductor type capable of being connected to the fire main by a fire hose, together with a portable tank containing 20 l of foam-making liquid and one spare tank. The nozzle shall be capable of producing effective foam suitable for extinguishing an oil fire of at leas 1,5 m^3/min. At least two portable foam applicator units shall be available in the craft for use in such space; and*

.3 *portable fire extinguishers of approved type and design shall be located so that no point in the space is more than approximately 15 m walking distance from an extinguisher, provided that at least one portable extinguisher is located at each access to such space. In addition to complying with 7.7.4, fire extinguishers shall be suitable for A and B class fires and have a capacity of 12 kg dry powder or equivalent.*

7.8.5 Ventilation system

7.8.5.1 *There shall be provided an effective power ventilation system [12] for the special category spaces and ro-ro spaces sufficient to give at least 10 air changes per hour while navigating and 20 air changes per hour at the quayside during vehicle loading and unloading operations. The system for such spaces shall be entirely separated from other ventilation systems and shall be operating at all times when vehicles are in such spaces. Ventilation ducts serving special category spaces and ro-ro spaces capable of being effectively sealed shall be separated for each such space. The system shall be capable of being controlled from a position outside such spaces.*

7.8.5.2 *The ventilation shall be such as to prevent air stratification and the formation of air pockets.*

7.8.5.3 *Means shall be provided to indicate in the operating compartment any loss or reduction of the required ventilating capacity.*

7.8.5.4 *Arrangements shall be provided to permit a rapid shutdown and effective closure of the ventilation system in case of fire, taking into account the weather and sea conditions.*

7.8.5.5 *Ventilation ducts, including dampers, shall be made of steel or other equivalent material. Ducts lying inside the served space may be made of non-combustible or fire-restricting material.*

7.8.6 Scuppers, bilge pumping and drainage

7.8.6.1 *In view of the serious loss of stability which could arise due to large quantities of water accumulating on the deck or decks consequent to the operation of the fixed pressure water-spraying system, pumping and drainage arrangements shall be such as to prevent such accumulation. Scuppers fitted for this purpose shall be arranged so as to ensure that such water is rapidly discharged directly overboard. Alternatively, pumping and drainage facility shall be provided additional to the requirements of Section 10. When it is required to maintain watertight or weathertight integrity, as appropriate, the scuppers shall be arranged so that they can be operated from outside the space protected.*

C7.8.6.1 Unless justificatory calculations are submitted, scuppers at least 150 mm in diameter are to be fitted every 9 m on both sides.

7.8.6.2 *In respect of scuppers and drainage pumps fitted in accordance with 7.8.6.1:*

.1 *the amount of water for which drainage is provided shall take into account the capacity of both the water spraying system pumps and required number of fire hose nozzles;*

.2 *the drainage system shall have a capacity of not less than 125 % of the capacity specified in .1 above; and*

.3 *bilge wells shall be of sufficient holding capacity and shall be arranged at the side shell of the ship at a distance from each other of not more than 40 m in each watertight compartment.*

7.8.7 Precautions against ignition of flammable vapours or liquids

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[12] *Refer to the Design guidelines and operational recommendations for ventilation systems in ro-ro cargo spaces (MSC/Circ.729).*

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7.8.7.1 *On any deck or platform, if fitted, on which vehicles are carried and on which explosive vapours might be expected to accumulate, except platforms with openings of sufficient size permitting penetration of petrol gases downwards, equipment which may constitute a source of ignition of flammable vapours and, in particular, electrical equipment and wiring, shall be installed at least 450 mm above the deck or platform. Electrical equipment installed more than 450 mm above the deck or platform shall be of a type enclosed and protected by an enclosure having an ingress protection based on an international standard acceptable to the Organization [13]. However, if the installation electrical equipment and wiring less than 450 mm above the deck or platform is necessary for the safe operation of the craft, such electrical equipment and wiring may be installed provided that the equipment is certified "safe type" based on an international standard acceptable to the Organization. [14]*

7.8.7.2 *If installed in an exhaust ventilation duct, electrical equipment shall be certified "safe type".[15] The equipment and wiring, if fitted, shall be suitable for use based on standards acceptable to the Organization [16] and the outlet from any exhaust duct shall be sited in a safe position, having regard to other possible sources of ignition.*

7.8.7.3 *If pumping and drainage arrangements are provided, it shall be ensured that:*

.1 *water contaminated with petrol or other flammable substances is not drained to machinery spaces or other spaces where sources of ignition may be present; and*

.2 *electrical equipment fitted in tanks or other components of the drainage system shall be of a type suitable for use in explosive petrol/air mixtures.*

7.8.8 Open ro-ro spaces

7.8.8.1 *Open ro-ro spaces shall comply with the requirements set out in 7.8.1.1, 7.8.2, 7.8.3, 7.8.4 and 7.8.6.*

7.8.8.2 *For those parts of a ro-ro space which are completely open from above, the requirements set out in 7.8.2, 7.8.3.1 and 7.8.6 need not be complied with. However, a continuous fire patrol or a television surveillance system shall be maintained.*

7.9 Miscellaneous

7.9.1 *There shall be permanently exhibited, for the guidance of the master and officers of the craft, fire control plans showing clearly for each deck the following positions: the control stations, the sections of the craft which are enclosed by fire-resisting divisions together with particulars of the fire alarms, fire detection systems, the sprinkler installations, the fixed and portable fire-extinguishing appliances, the means of access to the various compartments and decks in the craft, the ventilating system (including particulars of the master fan controls, the positions of dampers and identification numbers of the ventilating fans serving each section of the craft), the location of the international shore connection, if fitted, and the position of all means of control referred to in 7.5.3, 7.6.2, 7.7.1 and 7.7.3.1. The text of such plans [17] shall be in the official language of the flag state. However, if the language is neither English nor French, a translation into one of those languages shall be included.*

7.9.2 *A duplicate set of fire control plans or a booklet containing such plans shall be permanently stored in a prominently marked weathertight enclosure outside the deckhouse for the assistance of shore-side fire-fighting personnel.*

7.9.3 Openings in fire resisting divisions

7.9.3.1 *Except for any hatches between cargo, special category, ro-ro, store, and baggage spaces and between such spaces and the weather decks, all openings shall be provided with permanently attached means of closing which shall be at least as effective for resisting fires as the divisions in which they are fitted.*

7.9.3.2 *It shall be possible for each door to be opened and closed from each side of the bulkhead by one person only.*

7.9.3.3 *Fire doors bounding areas of major fire hazard and stairway enclosures shall satisfy the following requirements:*

.1 *The doors shall be self-closing and be capable of closing with an angle of inclination of up to 3.5° opposing closure. The approximate time of closure for hinged fire doors shall be no more than 40 s and no less than 10 s from the beginning of their movement with the craft in the upright position. The approximate uniform rate of closure for sliding fire doors shall be*

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13 *Refer to publication IEC 60529 – Degrees of protection provided by enclosures (IP Code), in particular, refer to the standards for an ingress protection of at least IP 55 or refer to the publication IEC 60079 series – Electrical apparatus for explosive gas atmospheres, in particular, refer to the standards for protection by an apparatus for use in zone 2 areas.*

14 *Refer to the publication IEC 60079 series – Electrical apparatus for explosive gas atmospheres (in particular, refer to the standards for equipment and wiring to be suitable for use in zone 1 areas).*

15 *Refer to publication IEC 60092.*

16 *Refer to zone 1 areas as defined in the publication IEC 60079 series.*

17 *Refer to Graphical symbols for fire control plans, adopted by the Organization by resolution A.654(16) and Graphical symbols for shipboard fire control plans adopted by the Organization by resolution A.952(23).*

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of no more than 0,2 m/s and no less than 0,1 m/s with the craft in the upright position.

.2 *Remote released sliding or power-operated doors shall be equipped with an alarm that sounds at least 5 s but no more than 10 s after the door is released from the continuously manned control station and before the door begins to move and continue sounding until the door is completely closed. Doors designed to reopen upon contacting an object in their paths shall re-open no more than 1 m from the point of contact.*

.3 *All doors shall be capable of remote release from a continuously manned central control station, either simultaneously or in groups, and shall be capable of release also individually from a position at both sides of the door. Indication shall be provided at the fire door indicator panel in the continuously manned control station whether each of the remote released doors is closed. The release mechanism shall be so designed that the door will automatically close in the event of disruption of the control system or main source of electrical power. Release switches shall have an on-off function to prevent automatic resetting of the system. Hold-back hooks not subject to continuously manned control station release shall be prohibited.*

.4 *A door closed remotely from the continuously manned control station shall be capable of being re-opened at both sides of the door by local control. After such local opening, the door shall automatically close again.*

.5 *Local power accumulators for power-operated doors shall be provided in the immediate vicinity of the doors to enable the doors to be operated after disruption of the control system or main source of electric power at least ten times (fully opened and closed) using the local controls.*

.6 *Disruption at one door of the control system or main source of electric power shall not impair the safe functioning of the other doors.*

.7 *Double-leaf doors equipped with a latch necessary to their fire integrity shall have a latch that is automatically activated by the operation of the doors when released by the system.*

.8 *Doors giving direct access to special category spaces which are power-operated and automatically closed need not be equipped with alarms and remote-release mechanisms required in .2 and .3.*

.9 *The components of the local control system shall be accessible for maintenance and adjusting.*

.10 *Power-operated doors shall be provided with a control system of an approved type which shall be able to operate in case of fire, this being determined in accordance with the Fire Test Procedures Code. This system shall satisfy the following requirements:*

.1 *the control system shall be able to operate at a temperature of at least 200 °C for at least 60 min, served by the power supply;*

.2 *the power supply for all other doors not subject to fire shall not impaired; and*

.3 *at temperatures exceeding 200 °C the control system shall be automatically isolated from the power supply and shall be capable of keeping the door closed up to at least 945 °C.*

7.9.3.4 *The requirements for integrity of fire-resisting divisions of the outer boundaries facing open spaces [18] of a craft shall not apply to glass partitions, windows and side scuttles. Similarly, the requirements for integrity of fire-resisting divisions facing open spaces shall not apply to exterior doors in superstructures and deck houses.*

7.9.3.5 *Doors in smoke-tight divisions shall be self-closing. Doors which are normally kept open shall close automatically or by remote control from a continuously manned control station.*

7.10 Firefighter's Outfits

7.10.1 *All craft other than category A passenger craft shall carry at least two firefighter's outfits complying with the requirements of 7.10.3.*

7.10.1.1 *In addition, there shall be provided in category B passenger craft for every 80 m, or part thereof, of the aggregate of the length of all passenger spaces and service spaces on the deck which carries such spaces or, if there is more than one such deck, on the deck which has the largest aggregate of such length, two firefighter's outfits and two sets of personal equipment, each comprising the items stipulated in 7.10.3.1.1 to 7.10.3.1.3.*

7.10.1.2 *In category B passenger craft, for each pair of breathing apparatuses there shall be provided one water fog applicator complying with the requirements of 7.8.4.1, which shall be stored adjacent to such apparatus.*

7.10.1.3 *The Administration may require additional sets of personal equipment and breathing apparatus, having due regard to the size and type of the craft.*

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[18] *Refer to the definition in 7.3.1.6*

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7.10.2 The firefighter's outfits and sets of personal equipment shall be stored in permanently and clearly marked locations arranged so as to be easily accessible and ready for use and, where more than one firefighter's outfit or more than one set of personal equipment is carried, they shall be stored in widely separated positions.

7.10.3 A firefighter's outfit shall consist of:

.1 Personal equipment comprising:

.1.1 protective clothing [19] of material to protect the skin from the heat radiating from the fire and from burns and scalding by steam or gases. The outer surface shall be water-resistant;

.1.2 boots of rubber or other electrically non-conductive material;

.1.3 a rigid helmet providing effective protection against impact;

.1.4 an electric safety lamp (hand lantern) of an approved explosion-proof type certified to a standard acceptable to the Organization [20] with a minimum burning period of 3 h; and

.1.5 high-voltage insulation.

.2 a self-contained compressed-air-operated breathing apparatus of an approved type, the volume of air contained in the cylinders of which shall be at least 1200 l, or other self-contained breathing apparatus, which shall be capable of functioning for at least 30 min. Two spare charges suitable for use with the apparatus shall be provided for each required apparatus.

.3 For each breathing apparatus a fireproof lifeline of approximately 30 m in length and sufficient strength shall be provided capable of being attached by means of a snaphook to the harness of the apparatus or to a separate belt in order to prevent the breathing apparatus becoming detached when the lifeline is operated. The lifeline shall be subjected to a test by static load of 3,5 kN for 5 min.

7.11 Arrangement

7.11.1 For category B craft, the public spaces shall be divided into zones according to the following:

.1 The craft shall be divided into at least two zones. The mean length of each zone shall not exceed 40 m.

.2 For the occupants of each zone there shall be an alternative safe area to which it is possible to escape in case of fire. The alternative safe area shall be separated from other passenger zones by smoke-tight divisions of non-combustible materials or fire-restricting materials extending from deck to deck. The alternative safe area can be another passenger zone. Alternative safe areas shall be dimensioned on the basis of one person per seat and 0,35 m^2 per person of the net remaining area, based on the maximum number of persons they are called to accommodate in an emergency.

.3 The alternative safe area shall, as far as practicable, be located adjacent to the passenger zone it is intended to serve. There shall be at least two exits from each passenger zone, located as far away from each other as possible, leading to the alternative safe area. Escape routes shall be provided to enable all passengers and crew to be safely evacuated from the alternative safe area within the structural fire protection time for areas of major fire hazard.

7.11.2 Category A craft need not be divided into zones.

7.11.3 Control stations, stowage positions of life-saving appliances, escape routes and places of embarkation into survival craft shall not, as far as practicable, be located adjacent to any areas of major or moderate fire hazard.

7.12 Ventilation

Each safe zone in the public spaces shall be served by a ventilation system independent of the ventilation system of any other zone. The ventilation fans of each zone in the public spaces shall also be capable of being independently controlled from a continuously manned control station.

7.13 Fixed Sprinkler System

7.13.1 Public spaces and service spaces, crew accommodation areas where sleeping berths are provided, storage rooms other than those containing flammable liquids, and similar spaces shall be protected by a fixed sprinkler system based on the standards developed by the Organization [21]. A stairway open at one deck shall be considered part of the space to which it is open and consequently shall be protected by any sprinkler system provided for that

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19 Refer to Protective clothing – Protection against heat and fire – Evaluation of materials and material assemblies when exposed to source of radiant heat (ISO 6942:2002).

20 Refer to Electrical apparatus for explosive gas atmospheres (IEC publication 60079).

21 Refer to the Standards for fixed sprinkler systems for high speed craft, adopted by the Organization by resolution MSC.44(65), as may be amended, and the associated interpretations of MSC/Circ.912.

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space. Manually operated sprinkler systems shall be divided into sections of appropriate size and the valves for each section, start of sprinkler pump(s) and alarms shall be capable of being operated from two spaces separated as widely as possible, one of which shall be a continuously manned control station. In category B craft, no section of the system shall serve more than one of the zones required in 7.11.

7.13.2 Plans of the system shall be displayed at each operating station. Suitable arrangements shall be made for the drainage of water discharged when the system is activated.

7.13.3 Category A craft need not comply with the requirements of 7.13.1 and 7.13.2 providing that:

- smoking is not permitted;
- sales shops, galleys, service spaces, ro-ro spaces and cargo spaces are not fitted;
- the maximum number of passengers carried does not exceed 200; and
- the voyage duration at 90 % of maximum speed from departure port to destination when fully laden does not exceed 2 h.

Part C - Requirements for Cargo Craft

7.14 Control Stations

Control stations, life-saving appliances stowage positions, escape routes and places of embarkation into survival craft shall be located adjacent to crew accommodation areas.

7.15 Cargo Spaces

Cargo spaces, except open deck areas or refrigerated holds, shall be provided with an approved automatic smoke-detection system complying with 7.7.1 to indicate at the control station the location of outbreak of a fire in all normal operating conditions of the installations and shall be protected by an approved fixed quick-acting fire-extinguishing system complying with 7.7.3.2 operable from the control station.

7.16 Fixed Sprinkler System

7.16.1 Crew accommodation where sleeping berths are provided, having a total deck area greater than 50 m^2 (including corridors serving such accommodation), shall be protected by a fixed sprinkler system based on the standards developed by the Organization [21].

7.16.2 Plans of the system shall be displayed at each operating station. Suitable arrangements shall be made for the drainage of water discharged when the system is activated.

Part D – Requirements for Craft and Cargo Spaces intended for the Carriage of Dangerous Goods [22]

7.17 General

7.17.1 In addition to complying with the requirements of 7.15 for cargo craft and with the requirements of 7.8 for both passenger and cargo craft as appropriate, craft types and cargo spaces referred to in 7.17.2 intended for the carriage of dangerous goods shall comply with the requirements of this paragraph, as appropriate, except when carrying dangerous goods in limited quantities [23] and excepted quantities [24], unless such requirements have already been met by compliance with the requirements elsewhere in this Section. The types of craft and modes of carriage of dangerous goods are referred to in 7.17.2 and in table 7.17-1, where the numbers appearing in 7.17.2 are referred to in the top line.

Craft constructed on or after 1 July 2002 but before 1 January 2011, with cargo spaces intended for the carriage of packaged dangerous goods, shall comply with 7.13.3, except when carrying dangerous goods specified as classes 6.2 and 7 and dangerous goods in limited quantities [23] and excepted quantities [24] in accordance with tables 7.17-1 and 7.17-3, not later than the date of the first renewal survey on or after 1 January 2011.

Cargo craft of less than 500 gross tonnage constructed on or after 1 July 2002 shall comply with this paragraph, but the Administration of the State whose flag the craft is entitled to fly may, in consultation with the port State, reduce the requirements and such reduced requirements shall be recorded in the document of compliance referred to in 7.17.4.

7.17.2 Application of Tables 7.17-1 and 7.17-2

The following craft types and cargo spaces shall govern the application of tables 7.17-1 and 7.17-2:

.1 craft and cargo spaces not specifically designed for the carriage of freight containers but intended for the carriage of dangerous goods in packaged form including goods in freight containers and portable tanks;

.2 purpose-built container craft and cargo spaces intended for the carriage of dangerous goods in freight containers and portable tanks. In this regard, a purpose-built container space is a cargo space fitted with cell guides for stowage and securing containers;

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22 Refer to the International Maritime Dangerous Goods Code (IMDG Code), adopted by the Organization by resolution A.716(17), as amended, and the International Maritime Solid Bulk Cargoes Code, adopted by resolution MSC.268(85), as amended.

23 Refer to chapter 3.4 of the IMDG Code.

24 Refer to chapter 3.5 of the IMOG Code.

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Table 7.17-1 Application of the requirements of 7.17.3 to different modes of carriage of dangerous goods in craft and cargo spaces

Sub-section 7.17.2 / *Sub-section 7.17.3*		*7.17.2.1*	*7.17.2.2*	*7.17.2.3*		*7.17.2.4*
	Weather decks .1 to .4 inclusive	*Not specifically designed*	*Container cargo spaces*	*Ro-ro spaces*	*Open ro-ro spaces*	*Solid dangerous goods in bulk (includes cargoes of group B of the International Maritime Solid Bulk Cargoes Code, , except for cargoes denoted Materials Hazardous in Bulk)*
7.17.3.1.1	×	×	×	×	×	*For application of requirements of Part D to different classes of dangerous goods, see Table 7.17-2*
7.17.3.1.2	×	×	×	×	×	
7.17.3.1.3	–	×	×	×	×	
7.17.3.1.4	–	×	×	×	×	
7.17.3.2	–	×	×	×	×	
7.17.3.3	–	×	×	×	–	
7.17.3.4.1	–	×	× [1]	×	×	
7.17.3.4.2	–	×	× [1]	×	×	
7.17.3.5	–	×	×	×	–	
7.17.3.6.1	×	×	×	×	×	
7.17.3.6.2	×	×	×	×	×	
7.17.3.7	×	×	–	–	×	
7.17.3.8.1	–	×	×	×	–	
7.17.3.8.2	–	–	–	× [2]	×	
7.17.3.9	–	–	–	×	×	
7.17.3.10	×	–	–	×	×	

[1] *For classes 4 and 5.1 solids not applicable to closed freight containers. For classes 2, 3, 6.1 and 8 when carried in closed freight containers the ventilation rate may be reduced to not less than two air changes per hour. For classes 4 and 5.1 liquids when carried in closed freight containers, the ventilation rate may be reduced to not than two air changes per hour. For the purpose of this requirement a portable tank is a closed freight container.*

[2] *Applies only to ro-ro spaces, not capable of being sealed.*

× *Wherever "×" appears in the table it means that this requirement is applicable to all classes of dangerous goods as given in the appropiate line of Table 7.17-3, except as indicated by the notes.*

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Table 7.17-2 Application of the requirements of 7.17.3 to different classes of dangerous goods for craft and cargo spaces carrying solid dangerous goods in bulk

Class / Sub-section	4.1	4.2	4.3 [3]	5.1	6.1	8	9
7.17.3.1.1	×	×	–	×	–	–	×
7.17.3.1.2	×	×	–	×	–	–	×
7.17.3.2	×	× [4]	×	× [5]	–	–	× [5]
7.17.3.4.1	–	× [4]	×	–	–	–	–
7.17.3.4.2	× [6]	× [4,7]	× [7]	× [4,6]	–	–	× [4,6]
7.17.3.4.4	×	×	×	×	×	×	×
7.17.3.6	×	×	×	×	×	×	×

3 The hazards of substances in this Class which may be carried in bulk are such that special consideration must be given by the Administration to the construction and equipment of the craft involved in addition to meeting the requirements enumerated in this table.

4 Only applicable to seedcake containing residues of solvent extractions, to ammonium nitrate and to ammonium nitrate fertilizers.

5 Only applicable to ammonium nitrate fertilizers. However, a degree of protection in accordance with standards contained in the "International Electrotechnical Commision, publication 79 – Electrical Apparatus for Explosive Gas Atmosphere", is sufficient.

6 Only suitable wire mesh guards are required.

7 For seedcake containing residues of solvent extraction and cargoes of IMSBC Code Class 4.3, two separate fans shall be permanently fitted unless portable type fans have been adapted for being securely fitted (e.g., fixed) prior to loading and during the voyage. The ventilation system shall comply with the provisions of 7.17.3.4.1 and 7.17.3.4.2. Ventilation shall be such that any escaping gases cannot reach public spaces or crew accommodation on or under deck.

.3 craft and ro-ro spaces, including special category spaces, intended for the carriage of dangerous goods; and

.4 craft and cargo spaces intended for the carriage of solid dangerous goods in bulk.

7.17.3 Requirements

Unless otherwise specified the following requirements shall govern the application of tables 7.17-1, 7.17-2 and 7.17-3 to both "on deck" and "under deck" stowage of dangerous goods. The numbers of the following sub-sections are indicated in the first column of the above-mentioned tables. For the purpose of this section, "on deck" shall be taken to mean spaces on the weather deck.

7.17.3.1 Water supplies

***7.17.3.1.1** Arrangements shall be made to ensure immediate availability of a supply of water from the fire main at the required pressure either by permanent pressurization or by suitably placed remote starting arrangements for the fire pumps.*

C7.17.3.1.1 Immediate supply of water from the fire main shall be provided by remote starting arrangement for all main fire pumps from the navigation bridge or by permanent pressurization of the fire main and by automatic start-up of the main fire pumps.

***7.17.3.1.2** The quantity of water delivered shall be capable of simultaneously supplying the arrangements required by 7.17.3.1.3 for the largest designated cargo space and the four nozzles of a size and at a pressure as specified in 7.7.5, capable of being trained on any part of the cargo space when empty. This requirement shall be met by the total capacity of the main fire pump(s) not including the capacity of the emergency fire pump, if fitted. This amount of water may be applied by equivalent means to the satisfaction of the Administration.*

***7.17.3.1.3** Means shall be provided of effectively cooling the designated under deck cargo space with water at not less than 5 l/min/m^2 of the horizontal area of cargo spaces, either by a fixed arrangement of spraying nozzles, or flooding the space with water. Hoses may be used for this purpose in small cargo spaces and in small areas of larger cargo-spaces at the discretion of the Administration. In any event the drainage and pumping arrangements shall meet the requirements of 7.8.6 and be such as to prevent the build-up of free surfaces. If this is not possible the adverse effect upon*

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stability of the added weight and free surface of water shall be taken into account.

7.17.3.1.4 *Provision to flood a designated under deck cargo space with suitable specified media may be substituted for the requirements in 7.17.3.1.3 above. Substitution by a high expansion foam system complying with regulation II-2/40.4.1.1.2 of the Convention is also acceptable.*

7.17.3.1.5 *The requirements of 7.17.3.1.1 to 7.17.3.1.4 may be fulfilled by a water spray system approved by the Administration based on the standards developed by the Organization [25], provided that the amount of water required for fire-fighting purposes in the largest cargo space allows simultaneous use of the water spray system plus four jets of water from hose nozzles in accordance with 7.17.3.1.2.*

7.17.3.1.6 *Craft carrying dangerous goods shall be provided with three fire hoses and nozzles complying with 7.7.5.6 in addition to those required by 7.7.5.5.*

7.17.3.2 Sources of ignition

Electrical equipment and wiring shall not be fitted in enclosed cargo spaces or vehicle decks, unless it is essential for operational purposes. However, if electrical equipment is fitted in such spaces, it shall be of a certified safe type [26] for use in the dangerous environments to which it may be exposed unless it is possible to completely isolate the electrical system (by removal of links in the system, other than fuses). Cable penetrations of the decks and bulkheads shall be sealed against the passage of gas or vapour. Through runs of cables and cables within the cargo spaces shall be protected against damage from impact. Any other equipment which may constitute a source of ignition of flammable vapour shall not be permitted.

C7.17.3.2 For the design and explosion protection of the electrical equipment and classification of the dangerous areas, see GL Rules for Electrical Installations (I-1-3), Section 17.

7.17.3.3 Detection system

Enclosed cargo spaces shall be provided with an approved automatic smoke detection system complying with 7.7.1 or with a detection system which, in the opinion of the Administration gives equivalent protection.

7.17.3.4 Ventilation

7.17.3.4.1 *Adequate power ventilation shall be provided in enclosed spaces. The arrangement shall be such as to provide for at least six air changes per hour in the cargo space based on an empty space and for removal of vapours from the upper or lower parts of the space, as appropriate.*

7.17.3.4.2 *The fans shall be such as to avoid the possibility of ignition of flammable gas air mixtures. Exhaust fans shall be of non-sparking type. Suitable wire mesh guards having a mesh size not exceeding 13 mm x 13 mm shall be fitted over inlet and outlet ventilation openings to prevent foreign objects from entering into the casing.*

7.17.3.4.3 *If adjacent spaces are not separated from cargo spaces by gastight bulkheads or decks, ventilation requirements shall apply to the adjacent spaces as for the cargo space itself.*

7.17.3.4.4 *Natural ventilation shall be provided in enclosed spaces intended for the carriage of solid dangerous goods in bulk, where there is no provision for mechanical ventilation.*

7.17.3.4.5 *For open-top container craft, power ventilation is required only for the lower part of the cargo hold for which purpose-built ducting is required. The ventilation rate shall be at least two air changes per hour based on the empty hold volume below the weather deck.*

C7.17.3.4 The ducting is to be arranged for removal of gases and vapours from the upper and lower part of the cargo hold. This requirement is considered to be met if the ducting is arranged such that approximately 1/3 of the air volume is removed from the upper part and 2/3 from the lower part. The position of air inlets and air outlets shall be such as to prevent short circuiting of the air. Interconnection of the hold atmosphere with other is not permitted.

7.17.3.5 Bilge pumping

Where it is intended to carry flammable or toxic liquids in enclosed spaces, the bilge pumping system shall be designed to ensure against inadvertent pumping of such liquids through machinery space piping or pumps. Where large quantities of such liquids are carried, consideration shall be given to the provision of additional means of draining those spaces as follows:

.1 *if the bilge drainage system for cargo spaces is additional to the system served by pumps in the machinery space, the capacity of the system shall be not less than 10 m^3/h per cargo space served. If the additional system is a common system, the capacity need not exceed 25 m^3/h. The additional bilge system need not be arranged with redundancy. Whenever flammable or toxic liquids are carried, the bilge line into the machinery*

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[25] *Refer to paragraphs 9.2, 9.3 and 9.4 of the Interim guidelines for open-top containerships (MSC/Circ.608/Rev.1).*

[26] *Refer to IEC publication 92-506 Electrical Installations in Ships Part 506: Special features-Ships carrying specific dangerous goods and materials hazardous only in bulk and IEC 79 – Electrical apparatus for explosive gas atmospheres.*

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space shall be isolated either by fitting a blank flange or by a closed lockable valve;

.2 if bilge drainage of cargo spaces is arranged by gravity drainage, the drainage shall be either lead directly overboard or to a closed drain tank located outside the machinery spaces. The tank shall be provided with vent pipe to a safe location on the open deck;

.3 enclosed spaces outside machinery spaces containing bilge pumps serving cargo spaces intended for carriage of flammable or toxic liquids shall be fitted with separate mechanical ventilation giving at least six air changes per hour. Electrical equipment in the space shall be of certified safe type.[27] If the space has access from another enclosed space, the door shall be selfclosing; and

.4 drainage from a cargo space into bilge wells in a lower space is only permitted if that space satisfies the same requirements as the cargo space above.

7.17.3.6 Personnel protection

7.17.3.6.1 *Four sets of full protective clothing resistant to chemical attack shall be provided in addition to the firefighter's outfits required by 7.10 and shall be selected taking into account the hazards associated with the chemicals being transported and the standards developed by the Organization according to the class and physical state. The protective clothing shall cover all skin, so that no part of the body is unprotected.*

7.17.3.6.2 *At least two self-contained breathing apparatuses additional to those required by 7.10 shall be provided. In addition to the requirements of 7.10.3.2.2, two spare charges suitable for use with the breathing apparatus shall be provided for each required apparatus.*

7.17.3.7 Portable fire extinguishers

Portable fire extinguishers with a total capacity of at least 12 kg of dry powder or equivalent shall be provided for the cargo spaces. These extinguishers shall be in addition to any portable fire extinguishers required elsewhere in this Section.

7.17.3.8 Fixed fire extinguishing system

7.17.3.8.1 *Cargo spaces, except for open decks, shall be provided with an approved fixed fire extinguishing system complying with the provisions of 7.7.3 or with a fire extinguishing system which, in the opinion of the Administration, gives equivalent protection for the cargo carried [28].*

7.17.3.8.2 *Each open ro-ro space having a deck above it and each ro-ro space not capable of being sealed shall be fitted with an approved fixed pressure water-spraying system for manual operation which shall protect all parts of any deck and vehicle platform in such space, except that the Administration may permit the use of any other fixed fire-extinguishing system that has been shown by full-scale test to be no less effective. In any event the drainage and pumping arrangements shall meet the requirements of 7.8.6, have valves operable from outside the space at a position in the vicinity of the extinguishing system controls and shall be such as to prevent the build-up of free surfaces. If this is not possible the adverse effect upon stability of the added weight and free surface of water shall be taken into account to the extent deemed necessary by the Administration in its approval of the stability information.*

7.17.3.9 Separation between ro-ro spaces and open ro-ro spaces

A separation shall be provided between a ro-ro space and an adjacent open ro-ro space. The separation shall be such as to minimize the passage of dangerous vapours and liquids between such spaces. Alternatively, such separation need not be provided if both spaces fully comply with the requirements for ro-ro spaces in Part D.

7.17.3.10 Separation between ro-ro spaces and weather decks

A separation shall be provided between a ro-ro space and the adjacent weather deck. The separation shall be such as to minimize the passage of dangerous vapours and liquids between such spaces. Alternatively, a separation need not be provided if the ro-ro space fully complies with the requirements for ro-ro spaces in Part D. However, a separation is still required when dangerous goods carried shall be loaded on the weather deck only.

7.17.4 Document of compliance

The Administration shall provide the craft with an appropriate document as evidence of compliance of construction and equipment with the requirements of this Part D.

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[27] *Refer to publication IEC 60092-506: Special features – Ships carrying dangerous goods and materials hazardous only in bulk.*

[28] *For cargoes for which a fixed gas fire extinguishing system is ineffective, refer to the List of cargoes in table 2 of MSC.1/Circ.1395.*

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Table 7.17-3 Application of the requirements of Sub-section 7.17.3 to different classes of dangerous goods except solid dangerous goods in bulk

Section \ Class	1.1 to 1.6 [9]	1.4S	2.1	2.2	2.3 flammable [17]	2.3 non-flammable	3 FP [12] < 23 °C	3 FP [12] ≥ 23 °C to ≤ 60 °C	4.1	4.2	4.3 liquids [18]	4.3 solids	5.1 [10]	5.2 [13]	6.1 liquids FP [12] < 23 °C	6.1 liquids FP [12] ≥ 23 °C to ≤ 60 °C	6.1 liquids	6.1 solids	8 liquids FP [12] < 23 °C	8 liquids FP [12] ≥ 23 °C to ≤ 60 °C	8 liquids	8 solids	9
7.17.3.1.1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
7.17.3.1.2	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
7.17.3.1.3	X																						
7.17.3.1.4	X																						
7.17.3.2	X		X		X		X				X[15]				X				X				X[14]
7.17.3.3	X	X	X	X		X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	
7.17.3.4.1			X			X	X		X[8]	X[8]	X	X	X[8]		X	X		X[8]	X	X			X[8]
7.17.3.4.2			X				X								X				X				X[14]
7.17.3.5							X								X	X	X		X	X[16]	X[16]		
7.17.3.6			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X[11]
7.17.3.7							X	X	X	X	X	X	X		X	X			X	X			
7.17.3.8	X[9]	X	X	X	X	X	X	X	X	X	X	X	X[10]	X	X	X	X	X	X	X	X	X	X
7.17.3.9	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
7.17.3.10	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

8 *When "mechanically-ventilated spaces" are required by the IMDG Code.*

9 *Stow 3 m horizontally away from the machinery space boundaries in all cases.*

10 *Refer to the IMDG Code.*

11 *As appropriate for the goods to be carried.*

12 *FP means flashpoint.*

13 *Under the provisions of the IMDG Code, stowage of class 5.2 dangerous goods under deck or in enclosed ro-ro spaces is prohibited.*

14 *Only applicable to dangerous goods evolving flammable vapour listed in the IMDG Code.*

15 *Only applicable to dangerous goods having a flashpoint less than 23 °C listed in the IMDG Code.*

16 *Only applicable to dangerous goods having a subsidiary risk class 6.1.*

17 *Under the provisions of the IMDG Code, stowage of class 2.3 having subsidiary risk class 2.1 under deck or in enclosed ro-ro spaces is prohibited.*

18 *Under the provisions of the IMDG Code, stowage of class 4.3 liquids having a flashpoint less than 23 °C under deck or in enclosed ro-ro spaces is prohibited.*

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Section 8

Life-Saving Appliances and Arrangements

8.1 General and Definitions

8.1.1 *Life-saving appliances and arrangements shall enable abandonment of the craft in accordance with the requirements of 4.7 and 4.8.*

8.1.2 *Except where otherwise provided in this Code, the life-saving appliances and arrangements required by this Section shall meet the detailed specifications set out in chapter III of the Convention and the LSA Code and be approved by the Administration.*

8.1.3 *Before giving approval to life-saving appliances and arrangements, the Administration shall ensure that such life-saving appliances and arrangements:*

.1 *are tested to confirm that they comply with the requirements of this Section, in accordance with the recommendations of the Organization [1] ; or*

.2 *have successfully undergone, to the satisfaction of the Administration, tests which are substantially equivalent to those specified in those recommendations.*

8.1.4 *Before giving approval to novel life-saving appliances or arrangements, the Administration shall ensure that such appliances or arrangements:*

.1 *provide safety standards at least equivalent to the requirements of this Section and have been evaluated and tested in accordance with the recommendations of the Organization [2] ; or*

.2 *have successfully undergone, to the satisfaction of the Administration, evaluation and tests which are substantially equivalent to those recommendations.*

8.1.5 *Before accepting life-saving appliances and arrangements that have not been previously approved by the Administration, the Administration shall be satisfied that life-saving appliances and arrangements comply with the requirements of this Section.*

8.1.6 *Except where otherwise provided in this Code, life-saving appliances required by this Section for which detailed specifications are not included in the LSA Code shall be to the satisfaction of the Administration.*

8.1.7 *The Administration shall require life-saving appliances to be subjected to such production tests as are necessary to ensure that the life-saving appliances are manufactured to the same standard as the approved prototype.*

8.1.8 *Procedures adopted by the Administration for approval shall also include the conditions whereby approval would continue or would be withdrawn.*

8.1.9 *The Administration shall determine the period of acceptability of life-saving appliances which are subject to deterioration with age. Such life-saving appliances shall be marked with a means for determining their age or the date by which they shall be replaced.*

8.1.10 *For the purposes of this Section, unless expressly provided otherwise:*

.1 *Detection is the determination of the location of survivors or survival craft.*

.2 *Embarkation ladder is the ladder provided at survival craft embarkation stations to permit safe access to survival craft after launching.*

.3 *Embarkation station is the place from which a survival craft is boarded. An embarkation station may also serve as an assembly station, provided there is sufficient room, and the assembly station activities can safely take place there.*

.4 *Float-free launching is that method of launching a survival craft whereby the craft is automatically released from a sinking craft and is ready for use.*

.5 *Free-fall launching is that method of launching a survival craft whereby the craft with its complement of persons and equipment on board is released and allowed to fall into the sea without any restraining apparatus.*

.6 *Immersion suit" is a protective suit which reduces the body heat-loss of a person wearing it in cold water.*

.7 *Inflatable appliance is an appliance which depends upon non-rigid, gas-filled chambers*

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[1] *Refer to the Revised Recommendation on Testing of Life-Saving Appliances, adopted by the Organization by resolution MSC.81(70).*

[2] *Refer to the Code of Practice fort he Evaluation, Testing and Acceptance of Prototype Novel Life-Saving Appliances and Arrangements, adopted by the Organization by resolution A.520(13).*

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for buoyancy and which is normally kept uninflated until ready for use.

.8 *Inflated appliance is an appliance which depends upon non-rigid, gas-filled chambers for buoyancy and which is normally kept inflated and ready for use at all times.*

.9 *Launching appliance or arrangement is a means of transferring a survival craft or rescue boat from its stowed position safely to the water.*

.10 *Marine evacuation system (MES) is an appliance designed to rapidly transfer a large number of persons from an embarkation station by means of a passage to a floating platform for subsequent embarkation into associated survival craft or directly into associated survival craft.*

.11 *Novel life-saving appliance or arrangement is a life-saving appliance or arrangement which embodies new features not fully covered by the provisions of this Section but which provides an equal or higher standard of safety.*

.12 *Rescue boat is a boat designed to assist and rescue persons in distress and to marshal survival craft.*

.13 *Retrieval is the safe recovery of survivors.*

.14 *Retro-reflective material is a material which reflects in the opposite direction a beam of light directed on it.*

.15 *Survival craft is a craft capable of sustaining the lives of persons in distress from the time of abandoning the craft.*

.16 *Thermal protective aid is a bag or suit of waterproof material with low thermal conductance.*

8.2 Communications

8.2.1 *Craft shall be provided with the following radio life-saving appliances:*

.1 *at least three two-way VHF radiotelephone apparatus shall be provided on every passenger high-speed craft and on every cargo high-speed craft of 500 gross tonnage and upwards. Such apparatus shall conform to performance standards not inferior to those adopted by the Organization [3] ;*

.2 *at least one search and rescue locating device shall be carried on each side of every passenger high-speed craft and every cargo high-speed craft of 500 gross tonnage and upwards. Such search and rescue locating device shall conform to the applicable performance standards not inferior to those adopted by the Organization [4]. The search and rescue locating device shall be stowed in such locations that they can be rapidly placed in any one of the liferafts. Alternatively, one search and rescue locating device shall be stowed in each survival craft.*

8.2.2 *Craft shall be provided with the following onboard communications and alarm systems:*

.1 *an emergency means comprising either fixed or portable equipment or both for two-way communications between emergency control stations, assembly and embarkation stations and strategic positions on board;*

.2 *a general emergency alarm system complying with the requirements of paragraph 7.2.1 of the LSA Code to be used for summoning passengers and crew to assembly stations and to initiate the actions included in the muster list. The system shall be supplemented by a public address system complying with the requirements of paragraph 7.2.2 of the LSA Code, or by other suitable means of communication. The systems shall be operable from the operating compartment.*

8.2.3 Signalling equipment

8.2.3.1 *All craft shall be provided wit h a portable daylight signalling lamp which is available for use in the operating compartment at all times and which is not dependent on the craft's main source of electrical power.*

8.2.3.2 *Craft shall be provided with not less than 12 rocket parachute flares, complying with the requirements of paragraph 3.1 of the LSA Code, stowed in or near the operating compartment.*

8.3 Personal Life-saving Appliances

8.3.1 *Where passengers or crew have access to exposed decks under normal operating conditions, at least one lifebuoy on each side of the craft capable of quick release from the control compartment and from a position at or near where it is stowed, shall be provided with a self-igniting light and a self-activating smoke signal. The positioning and securing arrangements of the self-activating smoke signal shall be such that it cannot be released or activated solely by the accelerations produced by collisions or groundings.*

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[3] *Refer to the Recommendation on Performance Standards for Survival Craft Portable Two-Way VHF Radiotelephone Apparatus, adopted by the Organization by resolution A.809(19).*

[4] *Refer to the Recommendation on performance standards for survival craft radar transponders for use in search and rescue operations, adopted by the Organization by resolution MSC.247(83) (A.802(19), as amended) and the Recommendation on performance standards for survival craft AIS search and rescue transmitter (AIS SART), adopted by the Organization by resolution MSC.246(83).*

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8.3.2 At least one lifebuoy shall be provided adjacent to each normal exit from the craft and on each open deck to which passengers and crew have access, subject to a minimum of two being installed.

8.3.3 Lifebuoys fitted adjacent to each normal exit from the craft shall be fitted with buoyant lines of at least 30 m in length.

8.3.4 Not less than half the total number of lifebuoys shall be fitted with self-igniting lights. However, the lifebuoys provided with self-igniting lights shall not include those provided with lines in accordance with 8.3.3.

8.3.5 A lifejacket complying with the requirements of paragraph 2.2.1 or 2.2.2 of the LSA Code be provided for every person on board the craft and, in addition:

.1 a number of lifejackets suitable for children equal to at least 10 % of the number of passengers on board shall be provided or such greater number as may be required to provide a lifejacket for each child;

.2 every passenger craft shall carry lifejackets for not less than 5 % of the total number of persons on board. These lifejackets shall be stowed in conspicuous places on deck or at assembly stations;

.3 a sufficient number of lifejackets shall be carried for persons on watch and for use at remotely located survival craft and rescue boat stations; and

.4 all lifejackets shall be fitted with a light, which complies with the requirements of paragraph 2.2.3 of the LSA Code.

8.3.6 Lifejackets shall be so placed as to be readily accessible and their positions shall be clearly indicated.

8.3.7 An immersion suit, of an appropriate size, complying with the requirements of paragraph 2.3 of the LSA Code shall be provided for every person assigned to crew the rescue boat.

8.3.8 An immersion suit or anti-exposure suit shall be provided for each member of the crew assigned, in the muster list, to duties in an MES party for embarking passengers into survival craft. These immersion suits or anti-exposure suits need not be required if the craft is constantly engaged on voyages in warm climates where, in the opinion of the Administration, such suits are unnecessary.

8.4 Muster List, Emergency Instructions and Manuals

8.4.1 Clear instructions to be followed in the event of an emergency shall be provided for each person on board .[5]

8.4.2 Muster lists complying with the requirements of regulation III/37 of the Convention shall be exhibited in conspicuous places throughout the craft including the control compartment, engine-room and crew accommodation spaces.

8.4.3 Illustrations and instructions in appropriate languages shall be posted in public spaces and be conspicuously displayed at assembly stations, at other passenger spaces and near each seat to inform passengers of:

.1 their assembly station;

.2 the essential actions they must take in an emergency;

.3 the method of donning lifejackets.

8.4.4 Every passenger craft shall have passenger assembly stations:

.1 in the vicinity of, and which provide ready access for all the passengers to, the embarkation stations unless in the same location; and

.2 which have ample room for the marshalling and instruction of passengers.

8.4.5 A training manual complying with the requirements of 18.2.3 shall be provided in each crew messroom and recreation room

8.5 Operating Instructions

8.5.1 Poster or signs shall be provided on or in the vicinity of survival craft and their launching controls and shall:

.1 illustrate the purpose of controls and the procedures for operating the appliance and give relevant instructions and warnings:

.2 be easily seen under emergency lighting conditions;

.3 use symbols in accordance with the recommendations of the Organization [6] *.*

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[5] *Refer to the Guidelines for passenger safety instructions on roro passenger ships (MSC/Circ.681).*

[6] *Refer to Symbols related to Life-Saving Appliances and Arrangements, adopted by the Organization by resolution A.760(18), as amended by resolution MSC.82(70).*

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8.6 Survival Craft Stowage

8.6.1 *Survival craft shall be securely stowed outside and as close as possible to the passenger accommodation and embarkation stations. The stowage shall be such that each survival craft can be safely launched in a simple manner and remain secured to the craft during and subsequent to the launching procedure. The length of the securing lines and the arrangements of the bowsing lines shall be such as to maintain the survival craft suitably positioned for embarkation. The Administrations may permit the use of adjustable securing and/or bowsing lines at exits where more than one survival craft is used. The securing arrangements for all securing and bowsing lines shall be of sufficient strength to hold the survival craft in position during the evacuation process.*

8.6.2 *Survival craft shall be so stowed as to permit release from their securing arrangements at or near to their stowage position on the craft and from a position at or near to the operating compartment.*

8.6.3 *So far as is practicable, survival craft shall be distributed in such a manner that there is an equal capacity on both sides of the craft.*

8.6.4 *The launching procedure for inflatable liferafts shall, where practicable, initiate inflation. Where it is not practicable to provide automatic inflation of liferafts (for example, when the liferafts are associated with an MES), the arrangement shall be such that the craft can be evacuated within the time specified in 4.8.1.*

8.6.5 *Survival craft shall be capable of being launched and then boarded from the designated embarkation stations in all operational conditions and also in all conditions of flooding after receiving damage to the extent prescribed in Section 2.*

8.6.6 *Survival craft launching stations shall be in such positions as to ensure safe launching having particular regard to clearance from the propeller or waterjet and steeply overhanging portions of the hull.*

8.6.7 *During preparation and launching, the survival craft and the area of water into which it is to be launched shall be adequately illuminated by the lighting supplied from the main and emergency sources of electrical power required by Section 12.*

8.6.8 *Means shall be available to prevent any discharge of water on to survival craft when launched.*

8.6.9 *Each survival craft shall be stowed:*

.1 *so that neither the survival craft nor its stowage arrangements will interfere with the operation of any other survival craft or rescue boat at any other launching station;*

.2 *in a state of continuous readiness;*

.3 *fully equipped; and*

.4 *as far as practicable, in a secure and sheltered position and protected from damage by fire and explosion.*

8.6.10 *Every liferaft shall be stowed with its painter permanently attached to the craft and with a float free arrangement complying with the requirements of paragraph 4.1.6 of the LSA Code so that, as far as practicable, the liferaft floats free and, if inflatable, inflates automatically should the high speed craft sink.*

8.6.11 *Rescue boats shall be stowed:*

.1 *in a state of continuous readiness for launching in not more than 5 min;*

.2 *in a position suitable for launching and recovery; and*

.3 *so that neither the rescue boat nor its stowage arrangements will interfere with the operation of survival craft at any other launching station.*

8.6.12 *Rescue boats and survival craft shall be secured and fastened to the deck so that they at least withstand the loads likely to arise due to a defined horizontal collision load for the actual craft and the vertical design load at the stowage position.*

8.7 Survival Craft and Rescue Boat Embarkation and Recovery Arrangements

8.7.1 *Embarkation stations shall be readily accessible from accommodation and work areas. If the designated assembly stations are other than the passenger spaces, the assembly stations shall be readily accessible from the passenger spaces, and the embarkation stations shall be readily accessible from the assembly stations.*

8.7.2 *Evacuation routes, exits and embarkation points shall comply with the requirements of 4.7.*

8.7.3 *Alleyways, stairways and exits giving access to the assembly and embarkation stations shall be adequately illuminated by lighting supplied from the main and emergency source of electrical power required by Section 12.*

8.7.4 *Where davit-launched survival craft are not fitted, MES or equivalent means of evacuation shall be provided in order to avoid persons entering the water to board survival craft. Such MES or equivalent means of evacuation shall be so designed as to enable persons to board survival craft in all operational conditions and also in all conditions of flooding after receiving damage to the extent prescribed in Section 2.*

8.7.5 *Subject to survival craft and rescue boat embarkation arrangements being effective within the environmental conditions in which the craft is permit-*

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ted to operate and in all undamaged and prescribed damage conditions of trim and heel, where the freeboard between the intended embarkation position and the waterline is not more than 1.5 m, the Administration may accept a system where persons board lifecrafts directly.

8.7.6 *Where an MES is provided for embarkation into survival craft on a category B craft, an alternative means of evacuating passengers and crew into survival craft on the same side of the craft in conditions up to and including the worst intended conditions is to be provided for use if the MES is lost or rendered unserviceable in the event of damage of longitudinal extent specified in 2.6.7.1.*

8.7.7 *Rescue boat embarkation arrangements shall be such that the rescue boat can be boarded and launched directly from the stowed position and recovered rapidly when loaded with its full complement of persons and equipment.*

8.7.8 *Launching systems for rescue boats on category B craft may be based on power supply from the craft's power supply under the following conditions:*

.1 *the davit or crane shall be supplied with power from 2 sources in each independent engine room;*

.2 *the davit or crane shall comply with the required launching, lowering and hoisting speeds when using only one power source; and*

.3 *the davit or crane is not required to be activated from a position within the rescue boat.*

8.7.9 *On multihull craft with a small HL1 angle of heel and trim, the design angles in paragraph 6.1 of the LSA Code may be changed from 20° /10° to the maximum angles calculated in accordance with annex 7, including heeling lever HL2, HTL, HL3 or HL4.*

8.7.10 *Rescue boat davits or cranes may be designed for launching and recovering the boat with 3 persons only on the condition that an additional boarding arrangement is available on each side complying with 8.7.5.*

8.7.11 *A safety knife shall be provided at each MES embarkation station.*

8.8 Line-throwing Appliance

A line-throwing appliance complying with the requirements of paragraph 7.1 of the LSA Code shall be provided.

8.9 Operational Readiness, Maintenance and Inspections

8.9.1 *Operational readiness Before the craft leaves port and at all times during the voyage, all life-saving appliances shall be in working order and ready for immediate use.*

8.9.2 Maintenance

.1 *Instructions for on-board maintenance of life-saving appliances complying with the requirements of regulation III/36 of the Convention shall be provided and maintenance shall be carried out accordingly.*

.2 *The Administration may accept, in lieu of the instructions required by .1, a shipboard planned maintenance programme which includes the requirements of regulation III/36 of the Convention.*

8.9.3 Maintenance of falls

8.9.3.1 *Falls used in launching shall be turned end for end at intervals of not more than 30 months and be renewed when necessary due to deterioration of the falls or at intervals of not more than five years, whichever is the earlier.*

8.9.3.2 *The Administration may accept in lieu of "end for ending" required in paragraph 8.9.3.1, periodic inspection of the falls and their renewal whenever necessary due to deterioration or at intervals of not more than four years, whichever is the earlier.*

8.9.4 *Spares and repair equipment Spares and repair equipment shall be provided for life-saving appliances and their components which are subject to excessive wear or consumption and need to be replaced regularly.*

8.9.5 *Weekly inspection The following tests and inspections shall be carried out weekly:*

.1 *all survival craft, rescue boats and launching appliances shall be visually inspected to ensure that they are ready for use;*

.2 *all engines in rescue boats shall be run ahead and astern for a total period of not less than 3 min provided the ambient temperature is above the minimum temperature required for starting and running the engine. During this period of time, it should be demonstrated that the gearbox and gearbox train are engaging satisfactorily. If the special characteristics of an outboard motor fitted to a rescue boat would not allow it to be run other than with its propeller submerged for a period of 3 min, it should be run for such period as prescribed in the manufacturer's handbook.; and*

.3 *the general emergency alarm system shall be tested.*

8.9.6 *Monthly inspections Inspection of the life-saving appliances, including survival craft equipment shall be carried out monthly using the checklist required by regulation III/36.1 of the Convention to*

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ensure that they are complete and in good order. A report of the inspection shall be entered in the log-book.

8.9.7 *Servicing of inflatable liferafts, inflatable lifejackets, marine evacuation systems and inflated rescue boats*

8.9.7.1 *Every inflatable liferaft, inflatable lifejacket and MES shall be serviced:*

.1 *at intervals not exceeding 12 months, provided where in any case this is impracticable, the Administration may extend this period by one month;*

.2 *at an approved servicing station which is competent to service them, maintains proper servicing facilities and uses only properly trained personnel [7].*

8.9.8 *Rotational deployment of marine evacuation systems In addition to or in conjunction with the servicing intervals of marine evacuation systems required by paragraph 8.9.7.1, each marine evacuation system shall be deployed from the craft on a rotational basis at intervals to be agreed by the Administration provided that each system is to be deployed at least once every six years.*

8.9.9 *An Administration which approves new and novel inflatable liferaft arrangements pursuant to 8.1 may allow for extended service intervals under the following conditions:*

8.9.9.1 *The new and novel liferaft arrangement shall maintain the same standard, as required by testing procedure, throughout the extended service intervals.*

8.9.9.2 *The liferaft system shall be checked on board by certified personnel according to paragraph 8.9.7.1.*

8.9.9.3 *Service at intervals not exceeding five years shall be carried out in accordance with recommendations of the Organization*

8.9.10 *All repairs and maintenance of inflated rescue boats shall be carried out in accordance with the manufacturers instructions. Emergency repairs may be carried out on board the craft, however, permanent repairs shall be effected at an approved servicing station.*

8.9.11 *An Administration which permits extension of liferaft service intervals in accordance with paragraph 8.9.9 shall notify the Organization of such action in accordance with regulation I/5(b) of the Convention.*

[7] *Refer to the Recommendation on Conditions for the Approval of Servicing Stations for Inflatable Liferafts, adopted by the Organization by resolution A.761(18), as amended by resolution MSC.55(66).*

8.9.12 *Periodic servicing of hydrostatic release units Hydrostatic release units shall be serviced:*

.1 *at intervals not exceeding 12 months, provided where in any case this is impracticable, the Administration may extend this period by one month;*

.2 *at a servicing station which is competent to service them, maintains proper servicing facilities and uses only properly trained personnel.*

8.9.13 *Marking of stowage locations Containers, brackets, racks and other similar stowage locations for life-saving equipment, shall be marked with symbols in accordance with the recommendations of the Organization, indicating the devices stowed in that location for that purpose. If more than one device is stowed in that location, the number of devices shall also be indicated.*

8.9.14 *Periodic servicing of launching appliances.*

8.9.14.1 *Launching appliances:*

.1 *shall be serviced at recommended intervals in accordance with instructions for on-board maintenance as required by regulation III/36 of the Convention;*

.2 *shall be subject to a thorough examination at the annual surveys required by paragraph 1.5.1.3;*

.3 *shall upon completion of the examination in .2 be subjected to a dynamic test of the winch brake at maximum lowering speed. The load to be applied shall be the mass of the survival craft or rescue boat without persons on board, except that, at intervals not exceeding five years, the test shall be carried out with a proof load equal to 1.1 times the weight of the survival craft or rescue boat and its full complement of persons and equipment.*

8.10 Survival Craft and Rescue Boats

8.10.1 *All craft shall carry:*

.1 *survival craft with sufficient capacity as will accommodate not less than 100 % of the total number of persons the craft is certified to carry, subject to a minimum of two such survival craft being carried;*

.2 *in addition, survival craft with sufficient aggregate capacity to accommodate not less than 10% of the total number of persons the craft is certified to carry;*

.3 *sufficient survival craft to accommodate the total number of persons the craft is certified to carry even, in the event that all the survival craft to one side of the craft centerline and within the longitudinal extent of damage de-*

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fined in 2.6.7.1 are considered lost or rendered unserviceable;

.4 *at least one rescue boat for retrieving persons from the water, but not less than one such boat on each side when the craft is certified to carry more than 450 passengers;*

.5 *craft of less than 30 m in length may be exempted from carrying a rescue boat, provided the craft meets all of the following requirements:*

.5.1 *the craft is arranged to allow a helpless person to be recovered from the water;*

.5.2 *recovery of the helpless person can be observed from the navigating bridge; and*

.5.3 *the craft is sufficiently manoeuvrable to close in and recover persons in the worst intended conditions.*

.6 *notwithstanding the provisions of .4 and .5 above, craft shall carry sufficient rescue boats to ensure that, in providing for abandonment by the total number of persons the craft is certified to carry:*

.6.1 *not more than nine of the liferafts provided in accordance with 8.10.1.1 are marshalled by each rescue boat; or*

.6.2 *if the Administration is satisfied that the rescue boats are capable of towing a pair of such liferafts simultaneously, not more than 12 of the liferafts provided in accordance with 8.10.1.1 are marshalled by each rescue boat; and*

.6.3 *the craft can be evacuated within the time specified in 4.8.*

8.10.2 *Where the Administration considers it appropriate, in view of the sheltered nature of the voyages and the suitable climatic conditions of the intended area of operations, the Administration may permit the use of open reversible inflatable liferafts complying with annex 11 on category A craft as an alternative to liferafts complying with paragraph 4.2 or 4.3 of the LSA Code.*

8.11 Helicopter Pick-up Areas

Craft operating on voyages having a duration of 2 h or more between each port of call shall be provided with a helicopter pick-up area approved by the Administration having regard to the recommendations adopted by the Organization [8].

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[8] *Refer to the Merchant ship search and rescue manual (MERSAR), adopted by the Organization by resolution A.229(VII), as amended.*

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Section 9

Machinery

Part A - General

9.1 General

9.1.1 *The machinery, associated piping systems and fittings relating to main machinery and auxiliary power units shall be of a design and construction adequate for the service for which they are intended and shall be so installed and protected as to reduce to a minimum any danger to persons on board, due regard being paid to moving parts, hot surfaces and other hazards. The design shall have regard to materials used in construction, the purpose for which the equipment is intended, the working conditions to which it will be subjected and the environmental conditions on board.*

9.1.2 *All surfaces with temperatures exceeding 220 °C where impingement of flammable liquids may occur as a result of a system failure shall be insulated. The insulation shall be impervious to flammable liquids and vapours.*

9.1.3 *Special consideration shall be given to the reliability of single essential propulsion components and a separate source of propulsion power sufficient to give the craft a navigable speed, especially in the case of unconventional arrangements, may be required.*

9.1.4 *Means shall be provided whereby normal operation of propulsion machinery can be sustained or restored even though one of the essential auxiliaries becomes inoperative. Special consideration shall be given to the malfunctioning of:*

.1 a generating set which serves as a main source of electrical power;

.2 the fuel oil supply systems for engines;

.3 the sources of lubricating oil pressure;

.4 the sources of water pressure;

.5 an air compressor and receiver for starting or control purposes;

.6 the hydraulic, pneumatic or electrical means for control in main propulsion machinery, including controllable-pitch propellers.

However, having regard to overall safety considerations, a partial reduction in propulsion capability from normal operation may be accepted.

9.1.5 *Means shall be provided to ensure that the machinery can be brought into operation from the dead craft condition without external aid.*

9.1.6 *All parts of machinery, hydraulic, pneumatic and other systems and their associated fittings which are under internal pressure shall be subjected to appropriate tests including a pressure test before being put into service for the first time.*

9.1.7 *Provision shall be made to facilitate cleaning, inspection and maintenance of main propulsion and auxiliary machinery including boilers and pressure vessels.*

9.1.8 *The reliability of machinery installed in the craft shall be adequate for its intended purpose.*

9.1.9 *The Administration may accept machinery which does not show detailed compliance with the Code where it has been used satisfactorily in a similar application, provided that it is satisfied:*

.1 that the design, construction, testing, installation and prescribed maintenance are together adequate for its use in a marine environment; and

.2 that an equivalent level of safety will be achieved.

9.1.10 *A failure mode and effect analysis shall include machinery systems and their associated controls.*

9.1.11 *Such information as is necessary to ensure that machinery can be installed correctly regarding such factors as operating conditions and limitations shall be made available by the manufacturers.*

9.1.12 *Main propulsion machinery and all auxiliary machinery essential to the propulsion and the safety of the craft shall, as fitted in the craft, be designed to operate when the craft is upright and when inclined at any angle of list up to and including 15° either way under static conditions and 22.5° under dynamic conditions (rolling) either way and simultaneously inclined by dynamically (pitching) 7.5° by bow or stern. The Administration may permit deviation from these angles, taking into consideration the type, size and service conditions of the craft.*

9.1.13 *All boilers, and pressure vessels and associated piping systems shall be of a design and construction adequate for the purpose intended and shall be so installed and protected as to minimise danger to persons on board. In particular, attention shall be paid to*

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the materials used in the construction and the working pressures and temperatures at which the item will operate and the need to provide an adequate margin of safety over the stresses normally produced in service. Every boiler, pressure vessel and associated piping systems shall be fitted with adequate means to prevent over-pressures in service and be subjected to a hydraulic test before being put into service, and where appropriate at subsequent specified intervals, to a pressure suitably in excess of the working pressure.

C9.1.13 Pressure vessels and steam and hot water generators are to be designed, constructed, equipped and tested according to GL Rules.

For the installation of oil-fired steam and hot-water generators automatic oil, steam or air atomizing burners or rotary cup burners complying with GL Rules are to be provided.

9.1.14 *Arrangements shall be provided to ensure that, in the event of failure in any liquid cooling system, it is rapidly detected and alarmed (visual and audible) and means instituted to minimise the effects of such failures on machinery serviced by the system.*

C9.1.15 Classification

C9.1.15.1 Designs which deviate from the Rules may be approved provided that such designs have been examined by GL for suitability and have been recognized as equivalent.

C9.1.15.2 Machinery installations which have been developed on novel principles and/or which have not yet been sufficiently tested in shipboard service require GL's special approval.

Such machinery may be designated by a suffix attached to the character of classification and be subjected to intensified survey, if sufficiently reliable proof cannot be provided of its suitability and equivalence.

C9.1.15.3 In addition to the Rules, GL reserves the right to impose further requirements in respect of all types of machinery, where this is unavoidable due to new findings or operational experience, or GL may permit deviations from the Rules where these are specially warranted.

C9.1.15.4 National rules or regulations outside GL Rules remain unaffected.

C9.1.16 Ambient conditions

The selection, layout and arrangement of all shipboard machinery, equipment and appliances is to be such as to ensure faultless continuous operation under the ambient conditions specified in Tables C9.1 and C9.2.

C9.1.17 Design and construction of machinery installation

C9.1.17.1 General

Main propulsion and manoeuvring equipment must provide full control of speed and direction of the craft. Every important, automatically or remote controlled system must have alternative arrangements for operation.

C9.1.17.2 Materials, welding and tests

.1 All materials and components subject to the Rules are to be manufactured and tested in accordance with GL Rules.

.2 The fabrication of welded components, approval of companies and testing of welders are subject to GL Rules.

.3 Machinery and its components are subject to constructional and material tests, pressure and leakage tests and trials. All the tests prescribed in the following sections are to be conducted under the supervision of GL.

Table C9.1 Inclinations (see note)

Installations, Components	Angle of inclinations [°] [2]			
	Athwartship		Fore-and-aft	
	static	dynamic	static	Dynamic
Main and auxiliary machinery	15	22,5	5	7,5
Ship safety equipment, e.g. emergency power installations, emergency fire pumps and their drives	22,5	22,5	10	10
Switchgear, electrical and electronic appliances [1] and remote-control systems				

[1] Up to an angle of inclination of 45° no undesired switching operations or functional changes may occur.

[2] Athwartships and fore-and-aft inclinations may occur simultaneously.

Note: GL may be consider deviations from these angles, talking into consideration the type, size and service condition of the craft.

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Table C9.2 Environmental conditions for machinery and electrical installations (see Note)

Seawater temperature +32 °C	
Ambient air temperature -25 °C to -45 °C, relative humidity (1 bar / 45 °C) 60 %	
Enclosed machinery spaces	Temperature range 0 °C to 55 °C. Relative humidity 100 %. Ability to withstand oil vapour and salt-laden air
Air-conditioned control rooms	Temperature range 0 °C to 40 °C. Relative humidity 80 %
Open deck	Temperature range -25 °C to +45 °C. Ability to withstand temporary flooding with seawater and salt-laden spray
Note: GL may approve other conditions for craft operating only in special agreed geographical areas.	

.4 In the case of parts produced in series, other methods of testing may be agreed with GL instead of the tests prescribed, provided that the former are recognized as equivalent by GL.

.5 GL reserves the right, where necessary, to increase the scope of the tests and also to subject to testing those parts which are not expressly required to be tested according to the Rules.

.6 After installation on board of propulsion and auxiliary machinery, operational functioning of the machinery including the associated auxiliary equipment is to be verified. All safety equipment is to be tested, unless adequate testing has already been performed at the manufacturer's works in the presence of GL Representative.

.7 In addition, the entire machinery installation is to be tested during sea trials as far as possible under intended service conditions.

C9.1.18 Shipboard trials (dock and sea trials)

C9.1.18.1 Dock and sea trials are to be carried out to the satisfaction of the GL Surveyor

Sea trials are to be performed in compliance with the Guidelines for Sea Trials of Motor Vessels (VI-11-3), unless stipulated otherwise in these Rules.

C9.1.18.2 Sea trials with propulsion engines driving fixed pitch propellers:

.1 Sea trials with internal combustion engines driving fixed pitch propellers are to be performed in conformity with the GL Rules Machinery Installations (I-1-2), Section 2, E.5 (See also Guidelines for Sea Trials of Motor Vessels (VI-11-3)).

.2 Sea trials with gas turbines driving fixed pitch propellers have to be carried out at rated turbine speed n_0 for at least 2 hours. Other tests such as starting tests, minimum on load speed, astern trial and final testing of monitoring and safety system have to be carried out in conformity with the GL Rules Machinery Installations (I-1-2), Section 2, E.5 (See also Guidelines for Sea Trials of Motor Vessels (VI-11-3)).

C9.1.18.3 Sea trials with propulsion engines driving controllable pitch propellers, reversing gears or water jets:

.1 Sea trials with internal combustion engines driving controllable pitch propeller, reversing gears or water jets are to be performed in conformity with the GL Rules Machinery Installations (I-1-2), Section 2, E.5 (See also Guidelines for Sea Trials of Motor Vessels (VI-11-3)). Manoeuvring trials are to be conducted with various propeller pitches. Where provision is made for combinator operation, the combinator curves are to be plotted and verified by measurements.

.2 Sea trials with gas turbines driving controllable pitch propellers, reversing gears or water jets have to be carried out at 100 % power at turbine speed n_0 for at least 2 hours. Other tests such as starting tests, minimum on load speed, astern trial and final testing of monitoring and safety system have to be carried out in conformity with the GL Rules Machinery Installations (I-1-2), Section 2, E.5 (See also Guidelines for Sea Trials of Motor Vessels (VI-11-3)). Manoeuvring trials are to be conducted with various propeller pitches. Where provision is made for combinator operation, the combinator curves are to be plotted and verified by measurements.

C9.1.18.4 Sea trials for main engines driving generators for propulsion:

Sea trials for main engines driving generators for propulsion are to be performed in conformity with the GL Rules Machinery Installations (I-1-2), Section 2, E.5 (See also Guidelines for Sea Trials of Motor Vessels (VI-11-3)).

C9.1.18.5 Sea trials for engines driving auxiliaries and electrical generators:

Sea trials for engines driving auxiliaries and electrical generators are to be performed in conformity with the GL Rules Machinery Installations (I-1-2), Section 2, E.5. (See also Guidelines for Sea Trials of Motor Vessels (VI-11-3)).

C9.1.18.6 Stopping test from full ahead is to be carried out. Time and distance are to be noted.

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9.2 Engine (general)

9.2.1 The engines shall be fitted with adequate safety monitoring and control devices in respect of speed, temperature, pressure and other operational functions. Control of the machinery shall be from the craft's operating compartment. Category B craft and cargo craft shall be provided with additional machinery controls in or close to the machinery space. The machinery installation shall be suitable for operation as in an unmanned machinery space [1], including automatic fire detection system, bilge alarm system, remote machinery instrumentation and alarm system. Where the space is continuously manned, this requirement may be varied in accordance with the requirements of the Administration.

9.2.2 The engines shall be protected against overspeed, loss of lubricating oil pressure, loss of cooling medium, high temperature, malfunction of moving parts and overload. Safety devices shall not cause complete engine shutdown without prior warning, except in cases where there is a risk of complete breakdown or explosion. Such safety devices shall be capable of being tested.

9.2.3 At least two independent means of stopping the engines quickly from the operating compartment under any operating conditions shall be available. Duplication of the actuator fitted to the engine shall not be required.

9.2.4 The major components of the engine shall have adequate strength to withstand the thermal and dynamic conditions of normal operation. The engine shall not be damaged by a limited operation at a speed or at temperatures exceeding the normal values but within the range of the protective devices.

9.2.5 The design of the engine shall be such as to minimise the risk of fire or explosion and to enable compliance with the fire precaution requirements of Section 7.

9.2.6 Provision shall be made to drain all excess fuel and oil to a safe position so as to avoid a fire hazard.

9.2.7 Provision shall be made to ensure that, whenever practical, the failure of systems driven by the engine shall not unduly affect the integrity of the major components.

9.2.8 The ventilation arrangements in the machinery spaces shall be adequate under all envisaged operating conditions. Where appropriate, arrangements shall ensure that enclosed engine compartments are forcibly ventilated to the atmosphere before the engine can be started.

9.2.9 Any engines shall be so installed as to avoid excessive vibration within the craft.

9.3 Gas Turbines

C9.3.0.1 Documents to be submitted

For every gas turbine installation, the drawings and documents required in GL's Rules are to be submitted for approval by the turbine manufacturer. To facilitate a smooth and efficient approval process they shall be submitted electronically via GLOBE[2]. In specific cases and following prior agreement with GL they can also be submitted in paper form in triplicate.

C9.3.0.2 The materials of shafts, turbine and compressor wheels, guide vanes and blades, turbine and compressor casings, combustion chambers and heat exchangers are to be tested in accordance with test specifications laid down by the gas turbine manufacturer and recognized by GL as part of the approval procedure.

9.3.1 Gas turbines shall be designed to operate in the marine environment and shall be free from surge or dangerous instability throughout its operating range up to the maximum steady speed approved for use. The turbine installation shall be arranged to ensure that the turbine cannot be continuously operated within any speed range where excessive vibration, stalling, or surging may be encountered.

9.3.2 The gas turbines shall be designed and installed such that any reasonably probable shedding of compressor or turbine blades will not endanger the craft, other machinery, occupants of the craft or any other persons.

9.3.3 Requirements of 9.2.6 shall apply to gas turbines in respect of fuel which might reach the interior of the jet pipe or exhaust system after a false start or after stopping.

9.3.4 Turbines shall be safeguarded as far as practicable against the possibility of damage by ingestion of contaminants from the operating environment. Information regarding the recommended maximum concentration of contamination shall be made available. Provision shall be made for preventing the accumulation of salt deposits on the compressors and turbines and, if necessary, for preventing the air intake from icing.

9.3.5 In the event of a failure of a shaft or weak link, the broken end shall not hazard the occupants of the craft, either directly or by damaging the craft or its systems. Where necessary, guards may be fitted to achieve compliance with these requirements.

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[1] *Refer to part E of chapter II-I of the Convention.*

[2] Detailed information about the secured GL system GLOBE can be found on GL's website www.gl-group.com/globe.

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9.3.6 Each engine shall be provided with an emergency overspeed shutdown device connected, where possible, directly to each rotor shaft.

C9.3.6 Startup is to take place automatically, in a fixed sequence.

9.3.7 Where an acoustic enclosure is fitted which completely surrounds the gas generator and the high pressure oil pipes, a fire detection and extinguishing system shall be provided for the acoustic enclosure.

9.3.8 Details of the manufacturers' proposed automatic safety devices to guard against hazardous conditions arising in the event of malfunction in the turbine installation shall be provided together with the failure mode and effect analysis.

9.3.9 The manufacturers shall demonstrate the soundness of the casings. Intercoolers and heat exchangers shall be hydraulically tested on each side separately.

C9.3.10 The following minimum monitoring equipment is to be provided:

.1 Air pressure and temperature at compressor inlet,

.2 Gas pressure and temperature at gas generator outlet,

.3 Lubricating oil pressure and temperature,

.4 Gas generator and power turbine speeds.

C9.3.11 Gas turbine and compressor rotors are to be dynamically balanced when in the condition ready for assembly and are to undergo an overspeed test.

C9.3.12 Sea trials have to be carried out according to C9.1.18.

9.4 Diesel Engines for Main Propulsion and Essential Auxiliaries

C9.4.0.1 Documents to be submitted

For each diesel engine type, the drawings and documents required in the GL Rules are to be submitted for approval by the engine manufacturer. To facilitate a smooth and efficient approval process they shall be submitted electronically via GLOBE [2]. In specific cases and following prior agreement with GL they can also be submitted in paper form in triplicate.

C9.4.0.1.1 Auxiliary engines intended as prime movers for harbour generator sets with less than 50 kW are not subject to approval.

C9.4.0.2 Definitions

C9.4.0.2.1 For the purposes of these Rules, diesel engines are reciprocating internal combustion engines.

C9.4.0.2.2 Diesel engines are to be designed such that their rated power when running at rated speed can be delivered as continuous power.
The continuous power for which the engine is to be designed is defined as in ISO 3046/1.

C9.4.0.2.3 Subject to the approval of GL for propulsion plants where overload is used/required frequently, the diesel engines may be designed for a continuous power (fuel stop power) which cannot be exceeded.

C9.4.0.2.4 Diesel engines for installation on board of high speed craft must have been type-tested by GL. For this purpose, a type-approval test in accordance with GL's Rules for diesel engines is to be performed.

9.4.1 Any main diesel propulsion system shall have satisfactory torsional vibration and other vibrational characteristics verified by individual and combined torsional and other vibration analyses for the system and its components from power unit through to propulsor.

C9.4.1 The speed ranges where excessive vibrations may be encountered are to be marked in red on the tachometer, where practicable, and an instruction plate indicating that the engine is not to be continuously operated within these speed ranges is to be fitted near each control station.

9.4.2 All external high-pressure fuel delivery lines between the high-pressure fuel pumps and fuel nozzles shall be protected with a jacketed tubing system capable of containing fuel from a high-pressure line failure. The jacketed tubing system shall include a means for collection of leakages and arrangements shall be provided for an alarm to be given of a fuel line failure.

9.4.3 Engines of a cylinder diameter of 200 mm or a crankcase volume of 0.6 m^3 and above shall be provided with crankcase explosion relief valves of an approved type with sufficient relief area. The relief valves shall be arranged with means to ensure that discharge from them is directed so as to minimise the possibility of injury to personnel.

C9.4.3 Where crankcase venting systems are provided, their clear opening is to be as small as possible.

The vent pipes of two or more engines are not to be combined.

9.4.4 The lubrication system and arrangements shall be efficient at all running speeds, due consideration being given to the need to maintain suction and avoid the spillage of oil in all conditions of list and trim and degree of motion of the craft.

9.4.5 Arrangements shall be provided to ensure that visual and audible alarms are activated in the

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event of either lubricating oil pressure or lubricating oil level falling below a safe level, considering the rate of circulation of oil in the engine. Such events shall also cause automatic reduction of engine speed to a safe level, but automatic shutdown shall only be activated by conditions leading to a complete breakdown, fire or explosion.

9.4.6 Where diesel engines are arranged to be started, reversed or controlled by compressed air, the arrangement of the air compressor, air receiver and air starting system shall be such as to minimise the risk of fire or explosion.

C9.4.7 Tests and trials

Material tests for main components of diesel engines, pressure tests and shop trials have to be conducted according the GL Rules Machinery Installations (I-1-2).

Sea Trials have to be carried out according to C9.1.18.

C9.4.8 Filters

C9.4.8.1 Lubricating oil filters

Lubricating oil lines are to be fitted with lubricating oil filters of suitable size and fineness, located in the main oil flow on the delivery side of the pumps.

Steps are to be taken to ensure that main flow filters can be cleaned without interrupting operation and filtration.

C9.4.8.2 Fuel filters

The supply lines of the fuel-injection pumps are to be fitted with switch-over duplex filters.

C9.4.8.3 Filters for emergency engines

For emergency diesel generators and emergency diesel fireextinguishing pump sets, simplex filters for fuel oil and lubricating oil are acceptable.

C9.4.8.4 Filter arrangements

Fuel and lubricating oil filters which are to be mounted directly on the engine are not to be located above rotating parts or in the immediate proximity of hot components.

Where this arrangement is not feasible, rotating parts and hot components are to be sufficiently shielded.

Drip pans of suitable size are to be mounted under fuel filters. The same applies to lubricating oil filters if oil can escape during dismantling of the filter.

C9.4.9 Starting equipment

C9.4.9.1 The starting equipment is to enable engines to be started up from the shut-down condition using the starting equipment available in the machinery space.

C9.4.9.2 Details of the starting equipment as well as the number of starts are to be in compliance with the GL Rules for Machinery Installations (I-1-2), Section 2, H. (See also Guidelines for Sea Trials of Motor Vessels (VI-11-3)).

C9.4.9.3 Starting air compressors are to be approved according to GL's Rules.

C9.4.10 Control equipment

C9.4.10.1 Main engines

Engine control position

An engine control position is to be provided from which the propulsion plant (including reversing gear or controllable pitch propeller) can be operated and monitored.

As a minimum requirement, the engine control position is to be equipped with the following indicators, which are to be clearly and logically arranged:

.1 Speed.

.2 Lubricating oil pressure at engine inlet.

.3 Fuel pressure at engine inlet.

.4 Cylinder cooling water pressure.

.5 Starting air pressure.

.6 Charging air pressure.

.7 Control air pressure at engine inlet.

Indicators are to be provided directly on the engine for the following readings:

.8 Lubricating oil temperature.

.9 Coolant temperature.

.10 Exhaust gas temperature, wherever the dimensions permit, at each cylinder outlet and at the turbocharger inlet/outlet.

In case of geared transmissions or controllable-pitch propellers, the scope of the control equipment mentioned above is to be extended accordingly.

C9.4.10.2 Auxiliary engines

As a minimum requirement, the following indicating instrumentsare to be mounted in a logical manner on the engine:

.1 Tachometer.

.2 Pressure gauge for lubricating oil pressure.

.3 Pressure gauge for fuel pressure.

.4 Pressure gauge for cooling water pressure.

.5 Thermometer for cooling water.

9.5 Transmissions

C9.5.0.1 The design and arrangement of transmission components such as shaftings, couplings, clutches

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and gears in propulsion, manoeuvring and lifting devices are subject to approval and certification.

C9.5.0.2 Documentation and strength calculations on the basis of GL's Rules are to be submitted. Alternatively, recognized calculation procedures may be accepted.

C9.5.0.3 Steel shaft lines

.1 Materials are to comply with GL's Rules.

.2 Shaft dimensions are to comply with GL's Rules standard calculations.

.3 Alternatively, for shafts protected from seawater (no direct contact between steel and seawater):

- a fatigue strength calculation e.g. according to DIN 743 or similar may be accepted. This calculation is to be based on the loads (torque, bending moment, thrust etc.) acting on the shaft at MCR conditions.
- in addition to a fatigue strength calculation, a static load calculation is required. At no location of the shaft is the von Mises (equivalent) stress to exceed the yield point of the shaft material for the torque at MCR multiplied by the safety factor S, where $S \geq 3$.

.4 In any case for thin walled hollow shafts, a safety factor S against buckling is required in reference to the torque at MCR, where $S \geq 3$.

.5 All relevant load and material data have to be submitted.

C9.5.0.4 Composites shaft lines

.1 Materials are to comply with GL's Rules.

.2 Mathematical analysis of the relevant types of failure (static, fatigue, buckling and vibrations) according to classical laminate theory for a simple geometry or FEM for a complex analysis is required.

.3 The material components and manufacturing process has to be specified and an experimental strength analysis (tests on samples and prototypes in presence of GL representative) is to be provided. The required safety factors and the validity of experimental strength analysis for the full scale component have to be agreed with GL.

.4 If fire protection requirements are relevant for the composites shafting, specific arrangements are to be provided at the satisfaction of GL.

9.5.1 *The transmission shall be of adequate strength and stiffness to enable it to withstand the most adverse combination of the loads expected in service without exceeding acceptable stress levels for the material concerned.*

9.5.2 *The design of shafting, bearings and mounts shall be such that hazardous whirling and excessive vibration could not occur at any speed up to 105% of the shaft speed attained at the designed overspeed trip setting of the prime mover.*

C9.5.2.1 Torsional vibrations

Calculations for torsional vibration behaviour are to be submitted to GL in due time. Calculations must include the equivalent mass-elastic system, natural frequencies and corresponding vibration modes, as well as the forced response for gears, couplings, shaftings. Calculations are to be checked in accordance with GL Rules.

Torsional vibration measurements may be required by GL. Such measurements will be necessary to detect dynamic torques, especially for plants working under unclearly defined conditions. As far as such measurements aim to provide special knowledge concerning load and response characteristics, adequate measuring techniques are to be applied, by agreement with GL.

C9.5.2.2 Stability of the system

The closed loop system including governor and plant must be stable under all conditions. This may be checked during sea trials for normal and misfiring conditions, clutch-in procedures, parallel connecting of units, loading of generators, etc.

In special cases, stability calculations may be required by GL.

C9.5.2.3 Whirling vibrations

Calculations of natural frequencies for whirling may be required by GL. This will regularly be the case for thin, long shaftings supported by few bearings. The calculations may be required in a simplified form (natural frequencies), or as complete forced vibrations using methods or programmes approved by GL.

C9.5.2.4 Lateral vibrations

Vibration calculations for resiliently mounted reciprocating main engines are to be submitted to GL for approval. Calculations may be carried out in a simplified form, i.e. natural frequencies for the six degrees of freedom and corresponding modes, provided that no resonances excited by major engine orders are within the operational speed range.

9.5.3 *The strength and fabrication of the transmission shall be such that the probability of hazardous fatigue failure under the action of the repeated loads of variable magnitude expected in service is extremely remote throughout its operational life. Compliance shall be demonstrated by suitably conducted tests, and by designing for sufficiently low stress levels, combined with the use of fatigue resistant materials and suitable detail design. Torsional vibration or oscillation likely to cause failure may be acceptable if it occurs at transmission speeds which would not be used in normal craft operation, and it is recorded in the craft operating manual as a limitation.*

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9.5.4 Where a clutch is fitted in the transmission, normal engagement of the clutch shall not cause excessive stresses in the transmission or driven items. Inadvertent operation of any clutch shall not produce dangerously high stresses in the transmission or driven item.

9.5.5 Provision shall be made such that a failure in any part of the transmission, or of a driven component, will not cause damage which might hazard the craft or its occupants.

9.5.6 Where failure of lubricating fluid supply or loss of lubricating fluid pressure could lead to hazardous conditions, provision shall be made to enable such failure to be indicated to the operating crew in adequate time to enable them as far as practicable to take the appropriate action before the hazardous condition arises.

9.6 Propulsion and Lift Devices

C9.6.0.1 The design and arrangement of propulsion and lift devices are subject to approval and certification.

C9.6.0.2 Documentation and strength calculations on the basis of GL's Rules are to be submitted. Alternatively, recognized calculation procedures may be accepted.

C9.6.0.3 The scantlings of propellers intended for hydrofoils classed as HSC category A is to be such that the strength of the blade, at the relevant verification sections, is not less than 4 with respect to the ultimate tensile strength of the propeller blade material. The designer is to be present GL, together with the propeller drawings, a detailed hydrodynamic load and stress analysis at the relevant verification sections.

9.6.1 The requirements of this section are based on the premise that:

.1 Propulsion arrangements and lift arrangements may be provided by separate devices, or be integrated into a single propulsion and lift device. Propulsion devices may be air, or water propellers or water jets and the requirements apply to all types of craft.

.2 Propulsion devices are those which directly provide the propulsive thrust and include machinery items and any associated ducts, vanes, scoops and nozzles, the primary function of which is to contribute to the propulsive thrust.

.3 The lift devices, for the purposes of this section, are those items of machinery which directly raise the pressure of the air and move it for the primary purpose of providing lifting force for an air-cushion vehicle.

9.6.2 The propulsion and lift devices shall be of adequate strength and stiffness. The design data, calculations and trials, where necessary, shall establish the ability of the device to withstand the loads which can arise during the operations for which the craft is to be certificated, so that the possibility of catastrophic failure is extremely remote.

9.6.3 The design of propulsion and lift devices shall pay due regard to the effects of allowable corrosion, electrolytic action between different metals, erosion or cavitation which may result from operation in environments in which they are subjected to spray, debris, salt, sand, icing, etc.

9.6.4 The design data and testing of propulsion and lift devices shall pay due regard, as appropriate, to any pressure which could be developed as a result of a duct blockage, to steady and cyclic loadings, to loadings due to external forces and to the use of the devices in manoeuvring and reversing and to the axial location of rotating parts.

9.6.5 Appropriate arrangements shall be made to ensure that:

.1 ingestion of debris or foreign matter is minimised;

.2 the possibility of injury to personnel from shafting or rotating parts is minimised; and

.3 where necessary, inspection and removal of debris can be carried out safely in service.

C9.6.6 For stabilisation means:

.1 The different situations are described in C3.11.

.2 In case of situation 1, only power activated items such as foils, trims and tabs are assessed. The following parts are reviewed:

- hydraulic system used for activation of stabilisation system,
- associated electrical devices.

.3 In case of situation 2, only possible interference between hydraulic/electrical installations and the safety of the craft are to be checked. The hydraulic/electrical systems documentation is to be submitted for that purpose. The applicable regulations depend on the location of the hydraulic power pack. The working principles are not checked.

Part B - Requirements for Passenger Craft

9.7 Independent Means of Propulsion for Category B Craft

Category B craft shall be provided with at least two independent means of propulsion so that the failure of one engine or its support systems would not cause the failure of the other engine or engine systems and

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with additional machinery controls in or close to the machinery space.

9.8 Means for Return to a Port of Refuge for Category B Craft

Category B craft shall be capable of maintaining the essential machinery and control so that, in the event of a fire or other casualties in any one compartment on board, the craft can return to a port of refuge under its own power.

Part C - Requirements for Cargo Craft

9.9 Essential Machinery and Control

Cargo craft shall be capable of maintaining the essential machinery and control in the event of a fire or other casualties in any one compartment on board. The craft need not be able to return to a place of refuge under its own power.

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Section 10

Auxiliary Systems

Part A General

C10.0 Documents to be submitted

C10.0.1 Diagrammatical plans for piping systems and arrangements, including all the details necessary for approval as listed below, are to be submitted. To facilitate a smooth and efficient approval process they shall be submitted electronically via GLOBE [1]. In specific cases and following prior agreement with GL they can also be submitted in paper form in triplicate.

.1 Tank arrangement for fuel and other flammable fluids

.2 Fuel systems (bunkering, transfer and service)

.3 Lubricating oil systems

.4 Cooling water systems (seawater and fresh water)

.5 Compressed air systems (starting air, control air, working air)

.6 Exhaust gas systems

.7 Bilge pumping and drainage systems

.8 Oily bilge water and oil residue systems

.9 Ballast and antiheeling systems

.10 Steam heating, feed water and condensate systems

.11 Air, overflow and sounding pipes

.12 Sanitary systems

.13 Fittings on side and bottom

.14 Arrangement of remote controlled valves

.15 Hydraulic systems for hatch covers, shell closing appliances, watertight doors and hoists.

C10.0.2 The diagrammatical plans or accompanying lists are to include the following particulars:

.1 Outside diameters and wall thicknesses of pipes

.2 Materials for pipes, valves and fittings

.3 Type and capacity of pumps

.4 Type of flexible hoses and expansion elements

.5 Maximum working pressures

.6 Temperature ranges

.7 Equipment list.

C10.0.3 Machinery arrangement plan showing the layout of machinery components such as engines, fans, heat exchangers, generators, switchboards, pumps, purifiers, excluding pipes, valves and accessories.

C10.0.4 Further documentation may be required if deemed necessary by GL.

10.1 General

10.1.1 *Fluid systems shall be constructed and arranged so as to assure a safe and adequate flow of fluid at a prescribed flow rate and pressure under all conditions of craft operation. The probability of a failure or a leakage in any one fluid system, causing damage to the electrical system, a fire or an explosion hazard shall be extremely remote. Attention shall be directed to the avoidance of impingement of flammable liquid on hot surfaces in the event of leakage or fracture of the pipe.*

10.1.2 *The maximum allowable working pressure in any part of the fluid system shall not be greater than the design pressure, having regard to the allowable stresses in the materials. Where the maximum allowable working pressure of a system component, such as a valve or a fitting, is less than that computed for the pipe or tubing, the system pressure shall be limited to the lowest of the component maximum allowable working pressures. Every system which may be exposed to pressures higher than the system's maximum allowable working pressure shall be safeguarded by appropriate relief devices.*

10.1.3 *Tanks and piping shall be pressure-tested to a pressure that will assure a safety margin in excess of the working pressure of the item. The test on any storage tank or reservoir shall take into account any possible static head in the overflow condition and the dynamic forces arising from craft motions.*

10.1.4 *Materials used in piping systems shall be compatible with the fluid conveyed and selected giving due regard to the risk of fire. Non-metallic piping material may be permitted in certain systems provided the integrity of the hull and watertight decks and bulkheads is maintained [2].*

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1 Detailed information about the secured GL system GLOBE can be found on GL's website www.gl-group.com/globe.

2 *Refer to the Guidelines for the Application of Plastic Pipes on Ships, adopted by the Organization by resolution.*

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C10.1.5 Definitions

C10.1.5.1 Maximum allowable working pressure PB

This is the maximum allowable working pressure for components and piping systems with regard to the materials used, requirements, working temperatures and undisturbed operation.

C10.1.5.2 Nominal pressure PN

This is the term applied to a selected pressure/temperature ratio used for the standardization of structural components. In general, the numerical value of the nominal pressure for a standardized component made of the material specified in the standard will correspond to the maximum allowable working pressure PB at 20 °C.

C10.1.5.3 Test pressure PP

This is the pressure to which components and piping systems are subjected for testing purposes.

C10.1.5.4 Design pressure PR

This is the maximum allowable working pressure PB for which components and piping systems are designed with regard to their mechanical characteristics. In general, the design pressure is the maximum allowable working pressure at which the safety equipment will intervene (e.g. activation of safety valves, opening of return lines of pumps, operating of overpressure safety arrangements, opening of relief valves) or at which the pumps will operate against closed valves.

C10.1.6 Materials

For the testing of pipes, selection of joints, welding and heat treatment, pipes are divided into three classes, as indicated in Tables C10.1 and C10.2.

Details of approved materials are given in Table C10.3.

GL's Rules for Materials are also to be observed.

C10.1.6.1 Steel pipes, valves and fittings

Pipes belonging to Classes I and II are to be either of seamless drawn material, or produced by a welding procedure approved by GL. In general, carbon and carbonmanganese steel pipes, valves and fittings are not to be used for temperatures above 400 °C.

Table C10.1 Classification of pipes into pipe classes

Medium/type of pipeline	Design pressure PR [bar] Design temperature t [°C]		
Pipe class	**I**	**II**	**III**
Toxic media	all		
Corrosive media Inflammable media with service temperature above the flash point Inflammable media with a flash point of 60 °C or less	all	[1]	–
Steam	PR > 16 or t > 300	PR ≤ 16 and t ≤ 300	PR ≤ 7 and t ≤170
Air, gas Non-flammable hydraulic fluid Boiler feedwater, condensate Seawater and fresh water for cooling Brine in refrigerating plant	PR > 40 or t > 300	PR ≤ 40 and t ≤ 300	PR ≤ 16 and t ≤ 200
Liquid fuels, lubricating oil, flammable hydraulic fluid	PR > 16 or t > 150	PR ≤ 16 and t ≤ 150	PR ≤ 7 and t ≤ 60
Refrigerants	–	all	–
Open-ended pipelines (without shutoff), e.g. drains, venting pipes, overflow lines and boiler blowdown lines	–	–	all

1 Classification in Pipe Class II is possible if special safety arrangements are available and structural safety precautions are arranged.

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Table C10.2 Approved materials and types of material Certificates

Type of component	Approved materials	Design temperature	Pipe class	Nominal diameter DN	Type of Certificate [2]		
					A	B	C
Pipes [1], Pipe elbows, Fittings	Steel, Copper, Copper alloys, Aluminium Aluminium alloys Plastics	–	I + II	> 50	×	–	–
				≤ 50	–	×	–
			III	All	–	–	×
Valves [1], Flanges,	Steel, Cast steel, Nodular cast iron	> 300 °C	I, II	DN > 100	×	–	–
				DN ≤ 100	–	×	–
	Copper, Copper alloys	> 225 °C					
	Steel, Cast steel, Nodular cast iron	≤ 300 °C	I, II	PB × DN > 2500 or DN > 250	×	–	–
				PB × DN ≤ 2500 or DN ≤ 250	–	×	–
	Steel, Cast steel, Nodular cast iron, Grey cast iron	–	III	All	–	–	×
	Copper, Copper alloys	≤ 225 °C	I, II	PB × DN > 1500	×	–	–
	Aluminium, Aluminium alloys	≤ 200 °C		PB × DN ≤ 1500	–	×	–
	Plastics	Acc. to Type Approval Certificate	III	All	–	–	×
Semi-finished products, Screws and other components	According to Table C10.3	–	I, II	–	–	×	–
			III	–	–	–	×

1 Casings of valves and pipes fitted on ship's side and bottom and bodies of valves fitted on collision bulkhead are to be included in pipe class II

2 Test Certificates acc. to GL Rules II – 1 – 1, Section 1, H. with the following abbreviations:
A: GL Material Certificate, B: Manufacturer Inspection Certificate, C: Manufacturer Test Report

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C10.1.6.2 Pipes, valves and fittings of aluminium and aluminium alloy

Aluminium and aluminium alloys are to comply with GL's Rules for Materials and may be used for temperatures up to 200 °C.

- Pipes made of aluminium may be used for the following services:
- Fresh cooling water systems
- Bilge systems outside areas of major fire hazard, as defined in 7.3.1
- Air and sounding pipes; for air and sounding pipes of tanks containing flammable liquids outside of major fire hazard areas, as defined in 7.3.1
- Pipes containing flammable liquids outside areas of major fire hazards, as defined in 7.3.1
- Pipes for non-essential services.

Seawater cooling pipes and ballast pipes and other seawater pipes made of aluminium alloys, may be accepted at the discretion of GL.

C10.1.6.3 Pipes, valves and fittings of non-metallic materials

Pipes, connecting pieces, valves and fittings made of plastic materials may be used at the discretion of the Society.

Note: Plastic pipes and the application are to comply with IMO Resolution A 753(18).

Plastic pipes are to be permanently marked with the following particulars:

- Manufacturer's marking
- Standard specification number
- Outside diameter and wall thickness
- Year of manufacture.

Valves and connecting pieces made of plastic shall, as a minimum requirement, be marked with the manufacturer's marking and the nominal diameter.

C10.1.6.4 Pipes, valves and fittings of copper and copper alloys

Pipes of copper and copper alloys are to be of seamless drawn material, or produced by a method approved by GL. Copper pipes for Classes I and II are to be seamless.

In general, copper and copper alloy pipelines are not to be used for media having temperatures above the following limits:

- Copper and aluminium brass: 200 °C
- Copper nickel alloys: 300 °C
- High-temperature bronze: 260 °C.

C10.1.6.5 Pipes, valves and fittings of nodular ferritic cast iron

Pipes, valves and fittings of nodular ferritic cast iron according to GL's Rules may be used for bilge and ballast pipes within double-bottom tanks, and tanks for other purposes approved by GL. In special cases (applications corresponding in principle to Classes II and III) and at GL's discretion, valves and fittings made of ferritic nodular cast iron may be accepted for temperatures up to 350 °C.

C10.1.6.6 Pipes, valves and fittings of lamella graphite cast iron (grey cast iron)

Pipes, valves and fittings of grey cast iron may be used for Class III systems.

The use of grey cast iron is not permitted:

- for media at temperatures above 220 °C and for pipelines subject to water hammering, severe stresses or vibration
- for valves and pipes fitted on craft sides, and for valves fitted on the collision bulkhead
- for valves on fuel and oil tanks which are subject to static head.

C10.1.7 Testing

C10.1.7.1 Testing of materials

Pipes, bends, fittings, valve bodies and flanges for piping systems belonging to Classes I and II are subject to tests in accordance with GL's Rules for Materials under GL's supervision.

C10.1.7.2 Testing prior to installation on board

.1 All Class I and II piping as well as all piping for compressed air and flammable liquids with a design pressure PR greater than 0,35 MPa are, after completion of manufacture but before insulation and coating, to be subjected to a hydraulic pressure test in the presence of a Surveyor at a pressure of 1,5·PR.

When technical reasons do not allow complete hydraulic pressure tests on all pre-fabricated pipe sections before assembly on board, proposals are to be submitted for approval to GL.

.2 When hydraulic pressure tests of piping are carried out on board, they may be conducted in conjunction with the tests required under C10.1.7.3.

.3 Pressure testing of pipes with nominal diameters less than 15 mm may be omitted, at GL's discretion, pending the application.

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Table C10.3 Approved materials

Material or application		Pipe class		
		I	II	III
Steels	Pipes	Pipes for general applications: – above 300 °C: high-temperature steel pipes – below -10 °C: pipes made of steel with high low-temperature toughness, stainless steel pipes for chemicals	Pipes for general applications	Steel not subject to any special quality specification, weldability in accordance with Rules for Welding
	Forgings, Plates, Fanges	Steel suitable for the corresponding loading and process conditions, for temperatures > 300 °C, high temperature steels, for temperatures below –10 °C, steel with high low-temperature toughness		
	Bolts, Nuts	Bolts for general machinery constructions: – above 30 °C: high-temperature steels – below -10 °C: steel with high low-temper- ature toughness	Bolts for general machinery construction	
Castings (valves, fittings, pipes)	Cast steel	Cast steel for general applica-tions: – above 30 °C: high-temperature cast steel – below -10 °C: cast steel with high low-temperature toughness – for aggressive media: stainless castings	Cast steel for general applications	
	Nodular cast iron	Only ferritic grades, elongation A_5 at least 15 %		
	Cast iron with lamellar graphite	–	–	At least GG-20 up to 200 °C, Grey cast iron is not permitted in values and fittings on ship's side, collision bulkhead and fuel and oil tanks
Non-ferrous metals (valves, fittings, pipes)	Copper, Copper alloys	–	For seawater and alkaline water, only corrosion resistant copper and copper alloys	
	Aluminium, Aluminium alloys	–	Upon special approval of GL	See C10.1.6.2
Non-metallic materials	Non-metallic	–	–	See C10.1.6.3

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C10.1.7.3 Testing after installation on board

.1 After assembly on board, all piping covered by these Rules is to be subjected to a tightness test in presence of a Surveyor.

In general, all pipe systems are to be tested for leakage under operational conditions. If necessary, alternative tests to hydraulic pressure tests may be applied.

.2 Heating coils in tanks and piping for flammable liquids are to be tested at a pressure of 1,5 PR, but in no case at less than 0,4 MPa.

C10.1.7.4 Testing of valves

Valves are to be subjected to a hydraulic pressure and tightness test in the manufacturer's works, in presence of a Surveyor:

- Valves of pipe Classes I and II to 1,5 PR
- Valves and connections in the ship's side to not less than 0,5 MPa.

C10.1.8 Minimum wall thickness

C10.1.8.1 Minimum pipe thicknesses are stated in Table C10.4 to Table C10.10. These minimum thicknesses may be increased if considered necessary, following stress analysis.

Slight differences in diameters and wall thicknesses based on recognized standards may be accepted.

Provided that pipes are effectively protected against corrosion, the wall thicknesses of group M steel pipes may, at the discretion of GL, be reduced by up to 1 mm. The amount of the reduction is to be in relation to the wall thickness.

Protective coatings (e.g. hot-dip galvanizing) may be recognized as effective corrosion protection provided that its preservation during installation is guaranteed.

Table C10.4 Choice of minimum wall thickness for steel pipes

<table>
<tr><th rowspan="2">Piping system</th><th colspan="11">Location</th></tr>
<tr><th>Machinery spaces</th><th>Cofferdam / void spaces</th><th>Cargo holds</th><th>Ballast water tanks</th><th>Fuel and changeover tanks</th><th>Fresh cooling water tanks</th><th>Lubricating oil tanks</th><th>Hydraulic oil tanks</th><th>Drinking water tanks</th><th>Living quarters</th><th>Weather deck</th></tr>
<tr><td>Bilge lines</td><td rowspan="3">M</td><td rowspan="7">M</td><td rowspan="3">M</td><td>---</td><td rowspan="3">---</td><td rowspan="6">X</td><td rowspan="3">X</td><td rowspan="6">X</td><td>M</td><td>---</td></tr>
<tr><td>Ballast lines</td><td>X</td><td rowspan="6">N</td></tr>
<tr><td>Seawater lines</td><td>M</td></tr>
<tr><td>Fuel lines</td><td rowspan="5">N</td><td>---</td><td>N</td><td rowspan="4">X</td><td rowspan="3">X</td><td rowspan="2">X</td></tr>
<tr><td>Lubricating lines</td><td rowspan="2">---</td><td rowspan="4">X</td><td rowspan="4">X</td><td>N</td><td rowspan="3">N</td></tr>
<tr><td>Hydraulic lines</td><td>---</td></tr>
<tr><td>Drinking water lines</td><td rowspan="2">M</td><td rowspan="2">X</td><td rowspan="2">X</td><td rowspan="2">N</td><td rowspan="2">N</td></tr>
<tr><td>Fresh cooling water lines</td><td>N</td><td>X</td></tr>
</table>

M, N Refer to Table C10.10
x Pipelines are not to be installed.
(-) Pipelines may be installed by special agreement with GL.

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Table C10.5 Choice of minimum wall thickness for air, overflow, sounding and sanitary pipes made of steel

Piping system or position of open pipe outlets	Location								
	Tanks with same media	Tanks with disparate media	Drain lines and scupper pipes			Air, sounding and overflow pipes		Cargo holds	Machinery spaces
			below freeboard deck or datum		above freeboard deck	above open deck	below open deck		
			without shut-off on ship's side	with shut-off on ship's side					
Air, overflow and sounding pipes	M	C	–	–	–	C	M	M	M
Scupper pipes from open deck	A	B	B	A	A	–	–	B	A
Discharge and scupper pipe leading directly overboard					–				
Discharge of pumps of sanitary systems			–		A				
A, B, C : Refer to Table C10.10 M : Refer to Table C10.6									

Table C10.6 Minimum wall thickness of steel pipes

Group N						Group M			
d_a [1] [mm]	s [mm]	d_a [1] [mm]	s [mm]	d_a [1] [mm]	s [mm]	d_a [1] [mm]	s [mm]	d_a [1] [mm]	s [mm]
from 10,2	1,6	from 114,3	3,2	from 406,4	6,3	from 21,3	3,2	from 219,1	5,9
from 43,5	1,8	from 133,0	3,6	from 660,0	7,1	from 38,0	3,6	from 244,5	6,3
from 20,0	2,0	from 152,4	4,0	from 762,0	8,0	from 51,0	4,0	from 660,4	7,1
from 48,3	2,3	from 177,8	4,5	from 864,0	8,8	from 76,1	4,5	from 762,0	8,0
from 70,0	2,6	from 244,5	5,0	from 914,0	10,0	from 117,8	5,0	from 863,6	8,8
from 88,9	2,9	from 323,9	5,6			from 193,7	5,4	from 914,4	10,0
[1] d_a = outside diameter									

Table C10.7 Minimum wall thickness for austenitic steel pipes

Pipe outside diameter d_a [mm]	Minimum wall thickness s [mm]
up to 17,2	1,0
up to 48,3	1,6
up to 88,9	2,0
up to 168,3	2,3
up to 219,1	2,6
up to 273,0	2,9
up to 406,0	3,6
over 406,0	4,0

Table C10.8 Minimum wall thickness for copper and copper alloy pipes

Pipe outside diameter d_a [mm]	Minimum wall thickness s [mm]	
	Copper	Copper alloy
8 – 10	1,0	0,8
12 – 20	1,2	1,0
25 – 44,5	1,5	1,2
50 – 76,1	2,0	1,5
88,9 – 108	2,5	2,0
133 – 159	3,0	2,5
193,7 – 267	3,5	3,0
273 – 457,2	4,0	3,5
(470) –	4,0	3,5
508 –	4,5	4,0

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Table C10.9 Minimum wall thickness for aluminium and aluminium alloy pipes

Pipe outside diameter [mm]	Minimum wall thickness s [mm]
< 10	1,5
12 – 38	2,0
43 – 57	2,5
76 – 89	3,0
108 – 133	4,0
159 – 194	4,5
219 – 273	5,0
> 273	5,5

Note: For Seawater pipes the wall thickness is not to be less than 5,0 mm.

Table C10.10 Minimum wall thickness for copper and copper alloy pipes

Pipe outside diameter [mm]	Minimum wall thickness s [mm]		
	A	B [1]	C
38 – 82,5	4,5	7,1	6,3
88,9 –	4,5	8,0	6,3
101,6 – 114,3	4,5	8,0	7,1
127 – 139,7	4,5	8,8	8,0
152,4 –	4,5	10,0	8,8
159 – 177,8	5,0	10,0	8,8
193,7 –	5,4	12,5	8,8
219,1 –	5,9	12,5	8,8
244,5 – 457,2	6,3	12,5	8,8

[1] The pipe thickness may not be greater than the thickness of the shell plates.

C10.1.9 Pipe connections

C10.1.9.1 The following pipe connections may be used for steel pipes:

- Fully penetrating butt welds with/without provision to improve the quality of the root
- Socket welds with suitable fillet weld thickness
- Screw connection of a type approved by GL
- Steel flanges of a recognized standard.

Screwed socket connections or similar are permitted only for subordinate systems for pipes below DN 65.

C10.1.9.2 Flanges made of non-ferrous metals may be used in accordance with recognized standards and within the limits laid down in approvals.

C10.1.9.3 Non-metallic pipes are to be connected by approved methods (e.g. welding, glueing or cementing) or by approved detachable connections.

C10.1.9.4 Type-approved pipe couplings may be used in the following systems:

- Bilge and ballast lines
- Sea water lines
- Fresh and seawater cooling lines
- Firefighting and deckwash lines
- Vent, fill and sounding pipes
- Drinking water lines
- Sanitary discharge lines.

Use of pipe couplings is not permitted in:

- Bilge lines inside ballast and fuel tanks
- Ballast lines inside cargo holds and fuel tanks
- Pipes containing flammable liquids within major fire hazard areas as defined in 7.3.1, cargo holds and ballast tanks.

C10.1.10 Layout, marking and installation

C10.1.10.1 Piping systems are to be identified according to their purpose. Valves are to be permanently marked.

C10.1.10.2 Pipe penetrations through bulkheads and tank walls are to be water- and oil-tight. Bolts penetrating bulkheads are not permitted. Holes for set screws are not to be drilled in tank walls.

C10.1.10.3 The installation of pipes for water or oil behind or above electric switchboards is to be avoided. If this is impracticable, pipes and valves are to be well shielded and/or located as far as possible from the switchboard.

C10.1.10.4 Piping systems are to be so arranged that they may be completely emptied, drained and vented. Piping systems in which accumulation of liquids during operation could cause damage are to be equipped with special draining devices.

C10.1.10.5 Pipelines laid through coated tanks are to be either effectively protected against corrosion or made of a material with low susceptibility to corrosion. The protection against corrosion of the tanks as well as that of the pipes are to be compatible to each other.

C10.1.10.6 Water pipes, air and sounding pipes passing through freezing chambers are to be avoided as far as practicable.

C10.1.10.7 Piping systems are to be adequately supported, to prevent detrimental vibrations occurring in the system.

C10.1.11 Valves

C10.1.11.1 Shutoff devices
Shutoff devices are to comply with a recognized standard. Valves with screwed-on covers are to be

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secured, to prevent inadvertent loosening of the cover.

Hand-operated shutoff devices are to be closed by turning in a clockwise direction.

Valves are to be clearly marked to show whether they are open or closed.

C10.1.11.2 Craft side valves

.1 Craft side valves are to be easily accessible and capable of being operated from above the floor.

Where, subject to C10.1.6.2 and C10.1.6.3, sea water pipes made of aluminium alloys or non-metallic materials are accepted by GL, craft's side valves inside machinery spaces and other spaces with major fire hazard are to be provided with means of remote closure from outside the space.

.2 Valves are to be of a flanged type and made of metallic ductile material.

.3 The minimum wall thickness of pipe branches connected to the craft's hull below the datum shall be as follows:

- for steel pipes: in accordance with Table C10.10, Group B
- for aluminium pipes: at least equal to that of the shell plating, but need not to exceed 8 mm.

C10.1.11.3 Remote-controlled valves

.1 General

For remote-controlled valves, failure of power supply is not to cause:

- opening of closed valves
- closing of open valves on fuel tanks and in cooling water systems for propulsion and power generating machinery.

Remote-controlled valves are to be equipped with an emergency operating arrangement. They are to be accessible for maintenance and repair work.

.2 Power units

Power units for remote-controlled valves are to be equipped with at least two independent power supply units.

For the closing of valves which are not closed by spring action, power units are to be fitted with pressure accumulators.

Pneumatically operated valves may be supplied by air from the general compressed air system.

.3 Control station

At the control station, means are to be provided to show whether the valves are open or closed.

For visual indication of the closed position of valves, limitposition indicators approved by GL are to be provided.

The control position is to be located in a space which is normally attended, e.g. operating compartment.

.4 Bilge piping

Valves and control lines for bilge systems are to be located as far as possible from the bottom and side shell of the craft.

.5 Fuel pipes

Valves mounted directly at fuel tanks above the double bottom are to be capable of being closed from outside the compartment in which they are installed (e.g. from craft's operating compartment or other suitable locations).

C10.1.12 Hose assemblies and compensators of non-metallic materials

C10.1.12.1 Requirements

Hose assemblies and compensators of non-metallic material are to be type-approved and tested according to GL's Rules.

Hose assemblies and compensators including their couplings are to be suitable for media, pressures and temperatures.

Selection of hose assemblies and compensators is to be based on the maximum allowable working pressure of the system concerned. 0,5 MPa is to be considered as the minimum working pressure.

C10.1.12.2 Installation

Hose assemblies are not to be longer than necessary for the application.

The minimum bending radius is not to be less than the radius specified by the manufacturer.

Hose assemblies and compensators are to be accessible.

Hoses used in fresh water systems with working pressures $\leq$ 0,5 MPa, or in charging air and scavenging air ducts, may be fastened with double clips. Hoses which are installed directly near hot surfaces are to be provided with additional heat-resistant sheathing.

C10.1.13 Pumps

C10.1.13.1 General

Construction, materials and tests of pumps are to comply with the Society Rules.

C10.1.13.2 Relief valves

Positive displacement pumps are to be fitted with relief valves which cannot be adjusted to the closed position. They are to discharge into the suction side of the pump.

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C10.1.13.3 Tests

The pumps listed below are subject to tests carried out at the manufacturer's works, under GL supervision:

- Fire pumps and emergency fire pumps
- Bilge pumps
- Seawater cooling pumps
- Fresh water cooling pumps
- Fuel transfer pumps
- Fuel service pumps
- Fuel injection valve cooling pumps
- Lubricating oil pumps
- Ballast pumps
- Boiler feedwater pumps
- Boiler water circulating pumps
- Other pumps considered necessary for performance ofessential functions.

10.2 Arrangement of Oil Fuel, Lubricating Oil and Other Flammable Oil

10.2.1 The provisions of 7.1.2.2 apply to the use of oil as fuel.

C10.2.1 The requirements stipulated in 7.5 are to be complied with.

10.2.2 Oil fuel, lubricating oil and other flammable oil lines shall be screened or otherwise suitably protected to avoid, as far as practicable, oil spray or oil leakages onto hot surfaces, into machinery air intakes or other sources of ignition. The number of joints in such piping systems shall be kept to a minimum. Flexible pipes carrying flammable liquids shall be of an approved type. [3]

C10.2.2(a) As far as practicable, flammable liquid lines are not to be arranged in the vicinity of boilers, turbines or equipment with surface temperatures greater than 220 °C, nor above electrical equipment.

C10.2.2(b) Pumps are to be provided with shutoff valves.

C10.2.2(c) Filling pipes for tanks containing flammable liquids are to terminate on open deck and be arranged so that leakages are collected by suitable coamings.

Fuel-oil filling connections are, as far as practicable, to be arranged on both sides of the craft.

[3] *Refer to the Guidelines to Minimize Leakages from Flammable Liquid Systems for Improving Reliability and Reducing Risk of Fire (MSC/Circ.647).*

10.2.3 Fuel oil, lubricating oils and other flammable oils shall not be carried forward of public spaces and crew accommodation.

C10.2.3

C10.2.3.1 All tanks not forming part of the craft structure are to be fastened securely and arranged so that they can be readily inspected.

Free-standing fuel tanks are to be installed so as to allow free circulation of air around the tanks.

Fuel tanks for emergency diesel generators are to be located inside the emergency generator room.

C10.2.3.2 Appliances, mountings and fittings not forming part of the fuel tank equipment may be fitted to tank walls only by means of intermediate supports. Only components forming part of the tank equipment may be fitted to freestanding tanks.

For valves and pipe connections, the tank walls are to beprovided with strengthening flanges. Bolt holes are not to be drilled in tank surfaces.

Instead of strengthening flanges, short, thick pipe flange connections may be welded to the tank surfaces.

10.2.4 Oil fuel arrangements

In a craft in which oil fuel is used, the arrangements for the storage, distribution and utilisation of the oil fuel shall be such as to ensure the safety of the craft and persons on board and shall at least comply with the following provisions.

10.2.4.1 As far as practicable, all parts of the oil fuel system containing heated oil under pressure exceeding 0.18 N/mm² shall not be placed in a concealed position such that defects and leakage cannot readily be observed. The machinery spaces in way of such parts of the oil fuel system shall be adequately illuminated.

C10.2.4.1 Fuel lines are not to pass through tanks containing feedwater, drinking water or lubricating oil.

10.2.4.2 The ventilation of machinery spaces shall be sufficient under all normal conditions to prevent accumulation of oil vapour.

C10.2.4.2 The provisions of Art. 10.6 and Art. 10.7 are to be complied with.

10.2.4.3 Location of fuel tanks shall be in accordance with 7.5.2.

C10.2.4.3 Fuel tanks are to be separated by voids/cofferdams from tanks containing lubricating, hydraulic, thermal or edible oil and drinking water.

Fuel service tanks inside machinery spaces are to be made of steel.

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10.2.4.4 No oil fuel tank shall be situated where spillage or leakage therefrom can constitute a hazard by falling on heated surfaces. Reference is made to the fire safety requirements in 7.5.

10.2.4.5 Oil fuel pipes shall be fitted with cocks or valves in accordance with 7.5.3.

C10.2.4.5(a) The controls of such valves are to be located outside the space in which the tanks are arranged, as far as possible combined in one location, preferably the craft's operating compartment.

C10.2.4.5(b) Valves subject to static head are to be made of ductile material.

C10.2.4.5(c) Remote-controlled shutoff valves may be dispensed with for tanks with a capacity of less than 50 litres.

10.2.4.6 Every fuel tank shall, where necessary, be provided with savealls or gutters to catch any fuel which may leak from such tanks.

C10.2.4.6 Tanks located above the double bottom are to be fitted with self-closing drains.

10.2.4.7 Safe and efficient means of ascertaining the amount of oil fuel contained in any oil fuel tank shall be provided.

10.2.4.7.1 Where sounding pipes are used, they shall not terminate in any space where the risk of ignition of spillage from the sounding pipe might arise. In particular, they shall not terminate in public spaces, crew accommodation or machinery spaces. Terminations shall be provided with a suitable means of closure and provision to prevent spillage during refuelling operations.

10.2.4.7.2 Other oil-level gauges may be used in place of sounding pipes. Such means are subject to the following conditions:

.1 In passenger craft, such means shall not require penetration below the top of the tank and their failure or overfilling of the tanks will not permit release of fuel.

.2 The use of cylindrical gauge glasses shall be prohibited. In cargo craft, the Administration may permit the use of oil-level gauges with flat glasses and self-closing valves between the gauges and fuel tanks. Such other means shall be acceptable to the Administration and shall be maintained in the proper condition to ensure their continued accurate functioning in service.

C10.2.4.7.3 Level-indicating devices which are not type approved by GL may be accepted if sounding pipes are provided in addition. Sight glasses and oil gauges fitted directly on the tank wall, and cylindrical glass gauges, are not permitted.

C10.2.4.7.4 Sounding pipes are to terminate outside main fire hazard areas and as far as possible above the open deck. However, where this is not possible, the following requirements are to be met:

- Oil-level gauges are to be provided in addition to sounding pipes.
- Sounding pipes are either to terminate in locations remote from ignition hazards or to be fitted with effective screens to prevent spillages coming into contact with a source of ignition.
- Sounding pipes are to be fitted with self-closing shutoff devices and self-closing testing devices.

10.2.4.8 Provision shall be made to prevent overpressure in any oil tank or in any part of the fuel system, including bunkering pipes and any filling pipes served by on-board pumps. Any relief valves and air or overflow pipes shall discharge to a safe position where there is no risk of fire and explosion from the emergence of oils and vapours, shall not lead into crew spaces, passenger spaces, special category spaces, ro-ro spaces (other than open ro-ro spaces), machinery spaces or similar spaces. For fuel of flashpoint less than 43 °C such valves and pipes shall terminate with flame arresters in accordance with the standards developed by the Organization [4].

C10.2.4.8 Lines of relief/safety valves and overflow-lines are to discharge into leakage, drain or overflow tanks.

10.2.4.9 Oil fuel pipes and their valves and fittings shall be of steel or other approved material, except that restricted use of flexible pipes shall be permissible in positions where the Administration is satisfied that they are necessary. Such flexible pipes and end attachments shall be approved fire-resisting materials of adequate strength and shall be constructed to the satisfaction of the Administration.

10.2.5 Lubricating oil arrangements

The arrangements for the storage, distribution and utilisation of oil used in pressure lubrication systems shall be such as to ensure the safety of the craft and persons on board. The arrangements made in machinery spaces and, whenever practicable, in auxiliary machinery spaces shall at least comply with the provisions of 10.2.4.1 and 10.2.4.4 to 10.2.4.8 except that:

.1 this does not preclude the use of sight-flow glasses in lubricating systems provided they are shown by test to have a suitable degree of fire resistance; and

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[4] *Refer to the Revised Standards for the Design, Testing and Locating of Devices to Prevent the Passage into Cargo Tanks in Tankers (MSC/Circ.677).*

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.2 sounding pipes may be permitted in machinery spaces if fitted with appropriate means of closure; and

.3 lubricating oil storage tanks with a capacity of less than 500 l may be permitted without remote operated valves as required in 10.2.4.5.

C10.2.5(a) Flexible pipes are permissible in positions where GL is satisfied that they are necessary. Such flexible pipes and end attachments in pressure lubricating systems located in machinery spaces and auxiliary machinery spaces as defined in Section 7 are to be of approved fire-resistant material of adequate strength and constructed to the satisfaction of GL.

C10.2.5(b) Lubricating oil systems are to be constructed to ensure reliable lubrication over the whole range of speed and during run-down of the engines, and are to ensure adequate heat transfer.

C10.2.5(c) Independent standby pumps are to be provided for propulsion engines. For craft with more than one main engine, each provided with an independent lubricating oil system, standby pumps are not required.

Engines and gears fitted with attached pumps are to be provided with an independent auxiliary lubricating pump if lubrication before starting is necessary.

C10.2.5(d) Equipment for suitable treatment of lubricating oil (e.g. purifiers, automatic back-flushing filters, filters, free-jet centrifuges) are to be provided.

.1 Lubricating oil filters are to be fitted in pump pressure lines.
Uninterrupted supply of filtered oil has to be ensured under maintenance conditions of filter equipment. Mesh size and filter capacity are to be in accordance with the engine manufacturer's requirements.

.2 Main filters are to be provided with differential pressure monitoring.
Back-flushing cycles of automatic filters are also to be monitored.

.3 Engines for emergency power supply or emergency fire pumps may be provided with simplex filters.

10.2.6 *The arrangements for storage, distribution and utilisation of other flammable oil employed under pressure in power transmission systems, control and activating systems and heating systems shall be such as to ensure the safety of the craft and persons on board. In locations where means of ignition are present, such arrangements shall at least comply with the provisions of 10.2.4.4 and 10.2.4.7 and with the provisions of 10.2.4.8 and 10.2.4.9 in respect of strength and construction.*

C10.2.6 The provisions of 10.2.4.6, 10.2.5.2 and 10.2.5.3 are to be complied with where applicable, as well as the provisions of 10.2.4.9 in respect of the approval of the fire-resistant materials of flexible pipes.

10.2.7 Arrangement within machinery spaces

In addition to the requirements of 10.2.1 to 10.2.6, the oil fuel and lubricating oil systems shall comply with the following:

.1 Where daily service fuel tanks are filled automatically or by remote control, means shall be provided to prevent overflow spillages.

C10.2.7.1 Service tanks are to be fitted with high- and low-level alarms.

.2 Other equipment which treats flammable liquids automatically, such as oil fuel purifiers, which, whenever practicable, should shall be installed in a special space reserved for purifiers and their heaters, shall have arrangements to prevent overflow spillages.

C10.2.7.2 Purifiers for cleaning fuel and lubricating oil are to be in accordance with GL's Rules.

.3 Where daily service oil fuel tanks or settling tanks are fitted with heating arrangements, a high-temperature alarm shall be provided if the flashpoint of the oil can be reached due to failure of the thermostatic control.

C10.2.7.3 Tanks which require preheating are to be fitted with temperature-indicating devices and, where necessary, thermal insulation.

Heating coils are to be provided with shutoff valves at tank inlet and outlet. Heating coils are also to be fitted at the tank outlet with an upstream device to test the condensate. Heating coil connections in tanks are to be welded.

Heating coils are to be supported in such a way as not to be subjected to non-allowable stresses due to vibration, particularly at their points of clamping.

Further requirements concerning heating systems (e.g. boiler, piping layout) are to be taken into consideration.

10.3 Bilge Pumping and Drainage Systems

10.3.1 *Arrangements shall be made for draining any watertight compartment other than the compartments intended for permanent storage of liquid. Where, in relation to particular compartments, drainage is not considered necessary, drainage arrangements may be omitted, but it shall be demonstrated that the safety of the craft will not be impaired.*

C10.3.1(a) Bilge suctions are to be suitably arranged and fitted with mud boxes.

C10.3.1(b) Every machinery space is normally to be provided with at least two bilge suctions, one at each

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side. Additional suctions may be required for craft having long machinery spaces.

C10.3.1(c) Bilge suctions are to be arranged so as not to impede the cleaning of bilges and bilge wells.

10.3.2 Bilge pumping arrangements shall be provided to allow every watertight compartment other than those intended for permanent storage of liquid to be drained. The capacity or position of any such compartment shall be such that flooding thereof could not affect the safety of the craft.

10.3.3 The bilge pumping system shall be capable of operation under all possible values of list and trim after the craft has sustained the postulated damage in 2.6.6 to 2.6.10. The bilge pumping system shall be so designed as to prevent water flowing from one compartment to another. The necessary valves for controlling the bilge suctions shall be capable of being operated from above the datum. All distribution boxes and manually operated valves in connection with the bilge pumping arrangements shall be in positions which are accessible under ordinary circumstances. The spindles of manually operated valves shall be easily accessible and all valves shall be clearly marked.

C10.3.3(a) Valves in pipe connections between bilge and seawater or ballast water systems, as well as between bilge connections of different compartments, are to be arranged so that even in the event of faulty operation or intermediate positions of the valves, seawater is safely prevented from penetrating through the bilge system.

C10.3.3(b) To prevent penetration of ballast and seawater into the ship through the bilge system, two means of reverse-flow protection are to be fitted in the bilge connections, one of which is to be a screw-down non-return valve. One such means of protection is to be fitted in each branch line.

For emergency and direct suctions, one screw-down nonreturn valve is sufficient.

C10.3.3(c) A combination of a non-return valve with positive closing device and shutoff valve may be recognized as equivalent to a screw-down non-return valve, at the discretion of GL.

C10.3.3(d) Discharges below the datum are to be provided with shutoff valves located at the shell.

10.3.4 The power operated self-priming bilge pumps may be used for other duties such as fire fighting or general service but not for pumping fuel or other flammable liquids.

C10.3.4(a) In the event of pump failure, one pump for fire fighting and one pump for bilge pumping are to remain available.

C10.3.4(b) Bilge ejectors are acceptable for bilge pumping arrangements if an independent supply of driving water is provided.

10.3.5 Each power bilge pump shall be capable of pumping water through the required bilge pipe at a speed of not less than 2 m/s.

10.3.6 The diameter (d) of the bilge main shall be calculated according to the following formula, except that the actual internal diameter of the bilge main may be rounded off to the nearest size of a recognized standard:

$$d = 25 + 1.68(L(B+D))^{0.5}$$

where :

d is the internal diameter of the bilge main [mm];

L is the length of the craft [m] as defined in Section 1;

B is, for monohull craft, the breadth of the craft [m] as defined in Section 1 and, for multi-hull craft, the breadth of a hull at or below the design waterline [m]; and

D is the moulded depth of the craft to the datum [m].

10.3.7 Internal diameters of suction branches shall meet the requirements of the Administration but shall not be less than 25 mm. Suction branches shall be fitted with effective strainers.

C10.3.7 The diameter is given by the formula:

$$d_B = 25 + 2{,}15\ (L_B \cdot (B_1 + d))^{0,5}$$

where:

d_B = internal diameter [mm] of the branch pipes

L_B = length [m] of the watertight compartment

B_1 = average breadth [m] of the compartment at or below the design waterline.

10.3.8 An emergency bilge suction shall be provided for each machinery space containing a propulsion prime mover. This suction shall be led to the largest available power pump other than a bilge pump, propulsion or oil pump. Emergency bilge suctions shall be provided for craft with common bilge pumping systems according to 10.3.6 and for craft with individual bilge pumps according to 10.3.13.

C10.3.8(a) Emergency bilge suctions are to be arranged in an accessible position, at a suitable distance from the double bottom ceiling or the craft bottom. The position is to allow the free flow of bilge water.

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The diameter is to be equal to the diameter of the suction line of the pump.

C10.3.8(b) Emergency bilge valves and the suction valves of the relevant pumps are to be capable of being operated from above the floor.

10.3.9 The spindles of the sea inlet valves shall extend well above the machinery space floor plates.

C10.3.9 The provisions of C10.1.11.2 are to be complied with.

10.3.10 All bilge suction piping up to the connection to the pumps shall be independent of other piping.

10.3.11 Spaces situated above the water level in the worst anticipated damage conditions may be drained directly overboard through scuppers fitted with non-return valves.

10.3.12 Any unattended space for which bilge pumping arrangements are required shall be provided with a bilge alarm.

C10.3.12 Each machinery space is normally to be provided with at least two bilge alarms.

10.3.13 For craft with individual bilge pumps, the total capacity Q of the bilge pumps for each hull shall not be less than 2.4 times the capacity of the pump defined in 10.3.5 and 10.3.6.

10.3.14 In bilge pumping arrangements where a bilge main is not provided, then, with the exception of the spaces forward of public spaces and crew accommodation, at least one fixed submersible pump shall be provided for each space. In addition, at least one portable pump shall be provided supplied from the emergency supply, if electric, for use on individual spaces. The capacity of each submersible pump Qn shall not be less than:

$Qn = Q/(N-1)$ *tonnes/h with a minimum of 8 tonnes/h*

where :

N = *number of submersible pumps*

Q = *total capacity as defined in 10.3.13.*

10.3.15 Nonreturn valves shall be fitted in the following components:

.1 bilge valve distribution manifolds;

.2 bilge suction hose connections where fitted directly to the pump or to the main bilge suction pipe; and

.3 direct bilge suction pipes and bilge pump connections to main bilge suction pipe.

C10.3.15 For reverse-flow protections, see C10.3.3.2 and C10.3.3.3.

C10.3.16 Arrangements for oily bilge water and oil residues

Each craft is to be provided with at least:

- a collecting tank for oily bilge water, fuel and oil residues
- equipment for discharge of oil residues to reception facilities.

Note

MARPOL 73/78 as amended and national requirements are to be observed.

10.4 Ballast Systems

10.4.1 Water ballast shall not in general be carried in tanks intended for oil fuel. In craft in which it is not practicable to avoid putting water in oil fuel tanks, oily-water separating equipment shall be fitted, or other alternative means such as discharge to shore facilities shall be provided for disposing of the oily-water ballast. The provisions of this paragraph are without prejudice to the provisions of the International Convention for the Prevention of Pollution from Ships in force.

10.4.2 Where a fuel-transfer system is used for ballast purposes, the system shall be isolated from any water ballast system and meet the requirements for fuel systems and the International Convention for the Prevention of Pollution from Ships in force.

C10.4.3 Piping layout

Where pipes are led through the collision bulkhead, a shutoff valve, made of ductile metallic material, is to be fitted directly at the collision bulkhead.

The valve is to be capable of being closed by remote control from the operating compartment.

10.5 Cooling Systems

The cooling arrangements provided shall be adequate to maintain all lubricating and hydraulic fluid temperatures within the manufacturers' recommended limits during all operations for which the craft is to be certificated.

C10.5.1 General

Cooling water circuits are to be provided with temperature controls in accordance with the requirements of Section 11. Control devices whose failure may impair the functional reliability of the system are to be equipped for manual operation.

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C10.5.2 Cooling water pumps

C10.5.2.1 Main and standby cooling water pumps are to be provided for propulsion systems with one main engine, or systems with more than one engine using a common cooling water system.

For propulsion plants with more than one engine, and for auxiliary engines provided with individual cooling circuits, standby pumps may be dispensed with

C10.5.2.2 Standby cooling water pumps shall be driven independently.

C10.5.3 Heat exchangers, coolers

C10.5.3.1 For common cooling systems, the number and capacity of heat exchangers and coolers is to be considered by GL.

C10.5.3.2 Heat exchangers and coolers are to be provided with:

- shutoff valves at inlet and outlet
- vents and drains.

C10.5.4 Keel coolers

Keel coolers are to be fitted with pressure gauges at the fresh water inlet and outlet.

C10.5.5 Seawater cooling systems

C10.5.5.1 At least two sea inlets are to be provided. Wherever possible, sea chests are to be provided and positioned as low as possible on either side of the craft.

On multi-hull craft or craft with independent engine rooms, one sea chest or sea inlet for each hull or engine room is considered sufficient.

C10.5.5.2 Each sea chest is to be provided with an effective vent and a connection to flush the sea chest gratings. The flushing media may not exceed the construction pressure of the sea chest.

C10.5.5.3 The suction lines of seawater pumps are to be fitted with strainers.

Strainers are to be arranged so that they can be cleaned while the pumps are in operation.

For multiple-engine installations, single strainers are considered sufficient.

C10.5.6 Sea valves

The provisions of C10.1.11.2 are to be complied with.

Discharge pipes for seawater cooling systems are to be fitted with a shutoff valve at the shell. If discharges are located above the datum, shutoff valves may be dispensed with.

C10.5.7 Fresh water cooling systems

C10.5.7.1 Where heat exchangers for fuel or lubricating oil are incorporated in cylinder cooling water circuits of propulsion engines, the entire cooling water circuit is to be monitored for fuel and oil contamination.

C10.5.7.2 Expansion tanks are to be fitted with filling connections, aeration/de-aeration devices, water level indicators and drains.

C10.5.7.3 Means are to be provided for preheating as required.

10.6 Engine Air Intake Systems

Arrangements shall provide sufficient air to the engine and shall give adequate protection against damage, as distinct from deterioration, due to ingress of foreign matter.

C10.6.1 The provisions of 7.6 of Section 7 and of Art. 10.7, if relevant, are to be complied with.

10.7 Ventilation Systems

Machinery spaces shall be adequately ventilated so as to ensure that when machinery therein is operating at full power in all weather conditions, including heavy weather, an adequate supply of air is maintained to the spaces for the safety and comfort of personnel and the operation of the machinery. Auxiliary machinery spaces shall be adequately ventilated appropriate for the purpose of those spaces. The ventilation arrangements shall be adequate to ensure that the safe operation of the craft is not put at risk.

C10.7.1 The provisions of 7.6 of Section 7 are to be complied with.

C10.7.2 Each independent machinery space is to be provided with its own ventilation system.

In general, ventilation systems for machinery spaces are to be independent of each other.

C10.7.3 The height of the coamings from the inlet and outlet openings is to comply with 2.2.8.4 of Section 2.

If water traps are to be provided, air velocity is to be taken into account.

C10.7.4 The air is to be conducted in such a way as to avoid local accumulations of heat wherever possible (e.g. by means of a secondary system of selective ventilation or by under-floor ducting of exhaust air).

C10.7.5 The air supply is not to be directed immediately towards hot machine parts, turbine components, measuring instruments or switchboards. Electrical machinery and installations (e.g. switch cabinets) are to be protected, so that water particles penetrating into air ducts will not cause damage. Risks of this

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kind are to be minimized by appropriate arrangement of ducts and air outlets.

C10.7.6 The capacity and arrangement of ventilation systems/ducts is to ensure that accumulation of oil vapour is avoided and a slight overpressure in the machinery space during normal operation is guaranteed.

Provision is to be made to remove CO_2, in case of flooding of the machinery space.

C10.7.7 Ventilation capacity is to be based on the heat radiation of equipment installed in the space.

10.8 Exhaust Systems

10.8.1 All engine exhaust systems shall be adequate to assure the correct functioning of the machinery and that safe operation of the craft is not put at risk.

C10.8.1 Exhaust pipes are to be installed separately from each other, taking structural fire protection into account.

Account is to be taken of thermal expansion when laying out and suspending lines.

Exhaust lines and silencers are to be provided with suitable drains of adequate size.

10.8.2 Exhaust systems shall be so arranged as to minimise the intake of exhaust gases into manned spaces, air-conditioning systems, and engine intakes. Exhaust systems shall not discharge into air-cushion intakes.

10.8.3 Pipes through which exhaust gases are discharged through the hull in the vicinity of the waterline shall be fitted with erosion-/corrosion-resistant shut-off flaps or other devices on the shell or pipe end and acceptable arrangements made to prevent water flooding the space or entering the engine exhaust manifold.

C10.8.3(a) Shutoff flaps may be omitted if the overflow point of the exhaust pipe is located above the most unfavourable damage water line.

Shutoff devices are to be fitted with means for remote controlled closing above the datum, preferably from the operating compartment. The closed position is to be indicated.

C10.8.3(b) The use of flexible hoses in wet exhaust systems may be accepted at the discretion of the Society, if the hoses are suitable for this purpose (media, pressure and temperature).

C10.8.3(c) Materials used in exhaust systems are to be resistant to sea water corrosion and exhaust products.

10.8.4 Gas turbine engine exhausts shall be arranged so that hot exhaust gases are directed away from areas to which personnel have access, either on board the craft or in the vicinity of the craft when berthed.

C10.8.5 Insulation
Exhaust lines, silencers and exhaust gas boilers are to be insulated properly.

Insulating materials are to be incombustible.

Exhaust lines inside engine rooms are to be provided with metal sheathing or other approved type of hard sheathing.

C10.A.1 Compressed Air Systems

C10.A.1.1 Starting equipment
Starting equipment (e.g. air compressors and air receivers) are to comply with Art. 9.3 of Section 9 for gas turbines and Art. 9.4 of Section 9 for diesel engines.

C10.A.1.2 Compressed air lines

Pressure lines connected to air compressors are to be fitted with non-return valves at the compressor outlets.

Oil and water separators are to be provided.

The starting air line to each engine is to be fitted with a nonreturn device and drain.

A safety valve is to be fitted behind each pressure-reducing valve.

The compressed air supply for blowing through sea chests may not exceed the design pressure of the sea chest (see C10.5.5.2).

C10.A.1.3 Control air system

Control air systems for essential consumers are to be provided with the necessary means of air treatment.

C10.A.2 Steam Heating, Feedwater and Condensate Systems

C10.A.2.1 General

For steam and hot water generators as well as for oil-fired burners, the provision of 9.1.13 of Section 9 are to be complied with.

Pipes, pumps and valves belonging to these systems are also subject to the following requirements.

C10.A.2.2 Steam lines

Steam lines are to be installed and supported so that expected stresses due to thermal expansion, external loads and shifting of the supporting structure under both normal and interrupted service conditions will be safely compensated. Sufficiently rigid positions are to be arranged as fixed points for the steam piping systems. Steam lines are to be provided with sufficient expansion arrangements.

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Steam lines are to be installed so that water pockets will be avoided. Means are to be provided for reliable drainage of the piping system.

Steam lines are to be effectively insulated to prevent heat losses. Pipe penetrations through bulkheads and decks are to be insulated to prevent heat conduction. At points where there is a possibility of contact, the surface temperature of the insulated steam lines may not exceed 60 °C. Wherever necessary, additional protection arrangements against unintended contact are to be provided.

C10.A.2.3 Feedwater lines

Feedwater lines are to be fitted with shutoff valves and check valves at the boiler inlet. Where shutoff and check valves are not directly connected in series, the intermediate pipe is to be fitted with a drain.

Feedwater pumps are to be fitted with shutoff valves on the suction side and screw-down non-return valves on the delivery side. The pipes are to be arranged so that each pump can supply each feedwater line.

Provision of only one feedwater line for auxiliary and exhaust gas boilers is sufficient if the preheaters and automatic regulating devices are fitted with bypass lines.

Continuous-flow boilers need not be fitted with these valves, provided that the heating of the boiler is automatically switched off if the feedwater supply fails, and that the feedwater pump supplies only one boiler.

Feedwater lines may not pass through tanks which do not contain feedwater.

C10.A.2.4 Capacity of feedwater pumps

Provision of only one feedwater pump is sufficient if the boiler is not intended for essential services.

Where two feedwater pumps are provided, the capacity of each is to be equivalent to at least 1,25 times the maximum permitted output of all the connected steam producers.

Where more than two feedwater pumps are installed, the capacity of all other feedwater pumps, in the event of failure of the pump with the largest capacity, is to comply with the requirements above.

For continuous-flow boilers, the capacity of the feedwater pumps is to be at least 1,0 times the maximum steam output.

Special conditions may be accepted for the capacity of the feedwater pumps, for plants incorporating a combination of oil-fired and exhaust-gas boilers or other arrangements.

C10.A.2.5 Boiler water circulating systems

The provision of only one circulating pump for each boiler is sufficient in the following cases:

- boilers are heated only by gases whose temperature does not exceed 400 °C, or
- a common standby circulating pump is provided, which can be connected to any boiler,
- the burners of oil- or gas-fired auxiliary boilers are arranged so that they are automatically shut off if the circulating pump fails and the heat stored in the boiler does not cause any unacceptable evaporation of the available water in the boiler,
- the boiler is not intended for essential services.

C10.A.2.6 Condensate recirculation

The condensate of all heating systems used to heat oil (e.g. fuel, lubricating, cargo oil) is to be led to condensate observation tanks. These tanks are to be fitted with vents to the open deck.

C10.A.3 Air, Overflow and Sounding Pipes

C10.A.3.1 General

The minimum wall thickness for steel pipes is to be in accordance with Table C10.5, Table C10.6 and Table C10.10.

The minimum wall thickness for pipes in material other than steel shall be at least:

- in accordance with Tables C10.7, C10.8 or C10.9 below the open deck
- increased by at least 50 % above the open deck.

All compartments and tanks arranged with filling and/or drainage equipment are to be fitted with air pipes and sounding devices.

C10.A.3.2 Air and overflow pipes

Voids, cofferdams and tanks are to be fitted with air pipes. The arrangement is to allow total filling of tanks under normal trim conditions.

Air pipes located on open deck are to be fitted with automatic air pipe heads approved by GL at a height not lower than 760 mm above deck.

Note: Refer to International Convention on Load Lines, 1966 Reg. 20 (LLC66) as amended.

Air pipes of tanks which contain fuel oil are to terminate on open deck to save locations with no risk of ignition (see also 10.2.4.8).

Air pipes of tanks which contain liquids other than fuel oil may terminate inside closed spaces. Means are to be provided for safe drainage in the event of overflow.

Air pipes of integral tanks located at the shell side are to terminate above the datum.

Air and overflow pipes are to be arranged in such a way that they are self-draining under normal conditions.

Where air and overflow pipes of several tanks are connected to a common line, the common line and connections are to be arranged so that, if a leakage occurs in one tank due to hull damage or listing of the ship, fuel or water cannot flow into another tank.

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The minimum inner diameter of air/overflow pipes is not to be less than 40 mm.

The clear cross-sectional area of air/overflow pipes is to be at least 1,25 times the cross-sectional area of the filling pipes. However, pump capacity and pressure head are to be considered in sizing air and overflow pipes.

C10.A.3.3 Sounding pipes

Sounding pipes are to be provided for tanks, cofferdams and void spaces and bilge wells in spaces which are not accessible at all times. As far as possible, sounding pipes are to be laid straight and are to extend as near as possible to the bottom of the tank close to the pump suction.

Sounding pipes may not be used as filling pipes.

Where tanks are fitted with remote level indicators approved by GL, provision of sounding pipes may be dispensed with.

Sounding pipes which terminate below the datum are to be fitted with self-closing shutoff devices. Such sounding pipes are permissible only in spaces which are accessible at all times. All other sounding pipes are to be extended to the open deck. Sounding pipe openings are always to be accessible and fitted with watertight closing devices.

Sounding pipes for tanks which contain flammable liquids are to extend to the open deck, or comply with the requirements of Art. 7.5 of Section 7 and 10.2.4.7.

Sounding pipes are to have a nominal inside diameter of at least 32 mm.

C10.A.4 Drinking Water Systems

Note

Any national rules are to be observed.

Drinking water systems are to comply with GL's Rules.

C10.A.5 Sanitary Systems

C10.A.5.1 General arrangement

Sanitary discharge pipes are to be arranged so that, in the event of damage, undamaged compartments cannot be flooded by damaged discharge lines, even if the craft inclines temporarily.

Where discharge lines from several watertight compartments are connected to one tank, the compartments are to be separated from each other by gate or ball valves at the watertight bulkheads. Valves shall be capable of being closed by remote control from the craft operating compartment or another space above the datum. An indicator for the closed position is to be provided among the controls.

The minimum wall thicknesses of sanitary discharge pipes are to be determined in accordance with Table C10.5 and Table C10.10. Penetrations of pipes of smaller thickness, pipes of special types and plastic pipes through bulkheads or decks of type A fire integrity require Society approval.

Overboard discharges are to be fitted with means of preventing ingress of water from the sea. The Load Line Convention (LLC) as amended is to be applied analogously.

C10.A.5.2 Sewage tanks and sewage treatment systems

Sewage tanks are to be fitted with air pipes leading to the open deck above the datum.

Sewage tanks are to be fitted with a filling connection, a connection for flushing the tank and a level alarm. Existing overflows to the bilge or openings for adding of chemicals are considered as internal openings.

The discharge lines of sewage tanks below the datum are to be fitted with a non-return valve and a gate valve. The gate valve is to be fitted directly at the craft's shell.

A single screw-down non-return valve may be used instead of the gate and non-return valves.

The second means of reverse-flow protection may be a pipe loop with an overflow height which remains above the water level in the worst anticipated damage condition. The pipe loop is to be fitted with an automatic ventilation device located 45° below the crest of the loop.

Ballast and bilge pumps may not be used for emptying sewage tanks.

C10.A.6 Hydraulic Systems for Hatch Covers, Shell Closing Appliances, Watertight Doors and Hoists

C10.A.6.1 General

Cylinders are preferably to be made of steel, cast steel or nodular cast iron (with a predominantly ferritic matrix).

For cylinders, where $PB \cdot \Delta_i > 2000$, materials are to be tested in accordance with GL's Rules (D_i being the inside diameter [mm]).

Testing of materials by GL may be dispensed with in the case of cylinders for secondary applications, provided that evidence in the form of a works test certificate (e.g. to EN 10 204 - 2.3) is supplied.

For testing the materials of hydraulic accumulators, see Section 9.

C10.A.6.2 Hydraulic operating equipment for hatch covers

C10.A.6.2.1 Design and construction

Hydraulic operating equipment for hatch covers may be served either by a common power station for all

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hatch covers or by several power stations individually assigned to a single hatch cover. Where a common power station is used, at least two pump units are to be fitted. Where the systems are supplied individually, changeover valves or fittings are required so that operation can be maintained if one pump unit fails.

Movement of hatch covers may not be initiated by starting of the pumps. Special control stations are to be provided to control the opening and closing of hatch covers. Controls are to be so designed that, as soon as they are released, movement of the hatch covers stops immediately.

Hatches are normally to be visible from control stations. If, in exceptional cases, this is impossible, opening and closing of the hatches are to be signalled by an audible alarm. In addition, the control stations are then to be equipped with indicators to monitor movements of the hatch covers.

At control stations, the controls governing opening and closing operations are to be appropriately marked.

Suitable equipment is to be fitted in, or immediately adjacent to, each power unit (cylinder or similar) used to operate hatch covers, to enable the hatches to be closed slowly in the event of a power failure (e.g. due to a pipe rupture).

Hatch covers are to be fitted with devices which prevent them from moving into their end positions at excessive speed. Such devices are not to cause the power unit to be switched off.

C10.A.6.2.2 Pipes

Pipe dimensions are to be calculated according to GL's Rules.

Piping systems are to be fitted with filters to clean the hydraulic fluid.

Equipment is to be provided to enable the hydraulic systems to be vented.

The accumulator space of the hydraulic accumulator is to have permanent access to the relief valve of the connected system. The gas chamber of the accumulator may be filled only with inert gases. Gas and operating media are to be separated by accumulator bags, diaphragms or similar devices.

Connection between the hydraulic systems used for hatch cover operation and other hydraulic systems is permitted only at the discretion of GL.

Tanks forming part of the hydraulic system are to be fitted with oil-level indicators.

C10.A.6.2.3 Emergency operation

Devices shall be fitted that are independent of the main system and which enable hatch covers to be opened and closed in the event of failure of the main system. Such devices may, for example, take the form of loose rings enabling hatch covers to be moved by cargo winches, warping winches etc.

C10.A.6.3 Hydraulically operated closing appliances in the craft's shell

C10.A.6.3.1 Scope

The following requirements apply to the power equipment of hydraulically operated closing appliances in the craft's shell, such as shell and landing doors which are not normally operated while at sea.

C10.A.6.3.2 Design and construction

The movement of doors and other closing devices in the shell may not be initiated by starting of the pumps at the power station.

Local control, inaccessible to unauthorized persons, is to be provided for every closing appliance in the craft's shell. As soon as the controls (push-buttons, levers or similar) are released, movement of the appliance is to be stopped immediately.

Closing appliances in the craft's shell are normally to be visible from control stations. If the movement cannot be observed, audible alarms are to be fitted. In addition, control stations are to be equipped with indicators enabling the movement to be monitored.

Closing appliances in the craft's shell are to be fitted with devices which prevent them from moving into their end positions at excessive speed. Such devices are not to cause the power unit to be switched off.

As far as necessary, mechanical means are to be provided to lock closing appliances in the open position.

Every power unit driving horizontally hinged or vertically operated closing appliances is to be fitted with throttle valves or similar devices, to prevent sudden dropping of the closing appliance.

Driving power shall be shared between at least two mutually independent pump units.

For pipes see C10.A.6.2.2.

C10.A.6.4 Hydraulic operating systems for watertight doors

Requirements concerning these items are given in Section 2.

C10.A.6.5 Hoists

C10.A.6.5.1 Scope

For the purposes of these requirements, hoists include hydraulically operated appliances such as wheelhouse hoists, lifts and similar equipment.

C10.A.6.5.2 Design and construction

Hoists may be operated either by a combined power station or by individual power stations.

In the case of a combined power supply, with hydraulic drive pipes connected to other hydraulic systems, a second pump unit is to be fitted.

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The movement of hoists is not to be initiated merely by starting the pumps. The movement is to be controlled from special operating stations. Controls are to be so arranged that, as soon as they are released, the movement of the hoist stops immediately.

Local controls, inaccessible to unauthorized persons, are to be fitted. The movement of hoists is normally to be visible from the operating stations. If the movement cannot be observed, audible and/or visual warning devices are to be fitted. In addition, operating stations are to be equipped with indicators to monitor the movement of the hoist.

Devices are to be fitted which prevent the hoist from reaching its end position at excessive speed. Such devices are not to cause the power unit to be switched off. As far as necessary, mechanical means are to be provided to lock the hoist in its end positions.

Suitable equipment is to be fitted in, or immediately adjacent to, each power unit used to operate hoists to enable them to be lowered slowly if the power unit fails or a pipe ruptures.

For pipes see C10.A.6.2.2.

C10.A.6.6 Tests at the manufacturer's works

C10.A.6.6.1 Testing of power units

Power units are to undergo testing on a test bed. Factory test certificates for this testing are to be submitted at final inspection of the hydraulic system.

C10.A.6.6.2 Pressure and tightness tests

Pressure components are to undergo a pressure test at test pressure PP = 1,5 · PR.

For the definitions of the PP and PR see C10.1.5.3 and C10.1.5.4. However, for maximum working pressures above 20 MPa, the test pressure need not exceed PR + 10 MPa.

For pressure testing of pipes, their valves and fittings, see C10.1.7.

Tightness tests are to be performed on components for which this is appropriate.

C10.A.6.6.3 Function tests

Watertight doors are to be subjected to a functional test with an adverse list of 15°.

C10.A.6.6.4 Shipboard trials

After installation, the equipment is to undergo an operational test.

Operational testing of watertight doors is to include the emergency operating system and measurement of closing times.

Part B - Requirements for Passenger Craft

10.9 Bilge Pumping and Drainage Systems

10.9.1 *For Category B craft at least three and for Category A craft at least two power bilge pumps shall be fitted connected to the bilge main, one of which may be driven by the propulsion machinery. Alternatively, the arrangement may be in accordance with the requirements of 10.3.14.*

10.9.2 *The arrangements shall be such that at least one power bilge pump shall be available for use in all flooding conditions which the craft is required to withstand as follows:*

.1 *one of the required bilge pumps shall be an emergency pump of a reliable submersible type having an emergency source of power; or*

.2 *the bilge pumps and their sources of power shall be so distributed throughout the length of the craft that at least one pump in an undamaged compartment will be available.*

C10.9.2 The "emergency source" is to be located above the datum.

10.9.3 *On multihull craft, each hull shall be provided with at least two bilge pumps.*

10.9.4 *Distribution boxes, cocks and valves in connection with the bilge pumping system shall be so arranged that, in the event of flooding, one of the bilge pumps may be operative in any compartment. In addition, damage to a pump or its pipe connecting to the bilge main shall not put the bilge system out of action. When, in addition to the main bilge pumping system, an emergency bilge pumping system is provided, it shall be independent of the main system and so arranged that a pump is capable of operating in any compartment under flooding conditions as specified in 10.3.3. In that case only the valves necessary for the operation of the emergency system need be capable of being operated from above the datum.*

10.9.5 *All cocks and valves referred to in 10.9.4 which can be operated from above the datum shall have their controls at their place of operation clearly marked and shall be provided with means to indicate whether they are open or closed.*

C10.9.5 The control station for remote-controlled valves shall be located in the operating compartment as far as possible.

C10.B.1 Operating Systems for Watertight Doors

Requirements concerning these items are given in Section 2.

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Part C - Requirements for Cargo Craft

10.10 Bilge Pumping Systems

10.10.1 *At least two power pumps connected to the main bilge system shall be provided, one of which may be driven by the propulsion machinery. If the Administration is satisfied that the safety of the craft is not impaired, bilge pumping arrangements may be dispensed with in particular compartments. Alternatively, the arrangement may be in accordance with the requirements of 10.3.14.*

10.10.2 *On multihull craft each hull shall be provided with at least two power pumps, unless a bilge pump in one hull is capable of pumping bilge in the other hull. At least one pump in each hull shall be an independent power pump.*

C10.C.1 Hydraulic Operating Systems for Watertight Doors

Requirements concerning these items are given in Section 2.

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Section 11

Remote Control, Alarm and Safety Systems

C11.0 Documents to be submitted

C11.0.1 The following drawings and documents are to be submitted. To facilitate a smooth and efficient approval process they shall be submitted electronically via GLOBE [1]. In specific cases and following prior agreement with GL they can also be submitted in paper form in triplicate.

.1 Layout diagrams showing the location of individual components, input and output devices, control cabinets and interconnection lines between the components;

.2 Wiring and piping diagrams including details of their material and connecting units;

.3 Plans and specification showing the working principles of the system with comprehensive description;

.4 List of instruments stating name of manufacturers, types, working ranges, set points and application with regard to their environmental conditions;

.5 Plans of control and monitoring panels with details on their instrumentation and control devices;

.6 List of operating values of machinery and limits for alarm and safety action threshold;

.7 Diagrams of electric and non-electric power supply;

.8 System analysis of programmable electronic systems including hardware configuration, algorithms and - on special request -. data structure and storage allocations;

FMEA documentation as required in Annex 4 where manual intervention for averting of a danger is not possible;

.9 Testing programmes of the equipment in the manufacturer's works and on dock and sea trial.

C11.0.2 Further documentation may be required if deemed necessary by GL.

11.1 Definitions

11.1.1 "Remote control systems" comprise all equipment necessary to operate units from a control position where the operator cannot directly observe the effect of his actions.

11.1.2 "Back-up control systems" comprise all equipment necessary to maintain control of essential functions required for the craft's safe operation when the main control systems have failed or malfunctioned.

11.2 General

11.2.1 Failure of any remote or automatic control systems shall initiate an audible and visual alarm and shall not prevent normal manual control.

11.2.2 Manoeuvring and emergency controls shall permit the operating crew to perform the duties for which they are responsible in correct manner without difficulty, fatigue or excessive concentration

C11.2.2 The operation of the remote control from the craft's operation station is to be so designed and constructed that it does under normal conditions not require the operator's particular attention of the details of the machinery.

The remote control systems consisting of steel cable links or equivalent are to be submitted to GL for special consideration.

The equipment, to which this Section applies, shall be of state of the art design and construction and shall have proved their reliability in marine service. If evidence on the required reliability cannot be given by relevant documentation, the equipment has to be subjected to an approval according to the Rules of GL.

11.2.3 Where control of propulsion or manoeuvring is provided at stations adjacent to but outside the operating compartment, the transfer of control shall only be effected from the station which takes charge of control. Two-way voice communication shall be provided between all stations from which control functions may be exercised and between each such station and the look-out position. Failure of the operating control system or of transfer of control shall bring the craft to low speed without hazarding passengers or the craft

C11.2.3 Under normal conditions, the transfer of the control function between such control positions may only be effected if the respective control devices are in the same position or if equivalent means are provided for smooth transfer of command without significant change in the craft's speed and direction of thrust.

11.2.4 For category B and cargo craft, remote control systems for propulsion machinery and directional control shall be equipped with back-up systems controllable from the operating compartment. For cargo craft, instead of a back-up system described above, a

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1 Detailed information about the secured GL system GLOBE can be found on GL's website www.gl-group.com/globe.

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back-up system controllable from an engine control space such as an engine control room outside the operating compartment, is acceptable.

C11.2.4 If provided so, the communication of machinery propulsion orders shall be effected by a telegraph system or equivalent means, which imply an optical indication at the such control positions of the machinery orders received from the craft's operating station.

C11.2.5 Under all sailing conditions (including manoeuvring), the propulsion machinery, including propellers, jets, flaps or other means which affect the speed and direction of thrust of all category high speed craft, is to be controllable from the craft's operating station.

C11.2.6 In principle the remote control is to be performed by a single control device for each independent propulsion unit with automatic performance of all associated services including, where necessary, means of preventing overload and prolonged running in critical speed ranges of the propulsion unit.

In cases where multiple propulsion units are designed to operate simultaneously, the command on their controls shall be designed for the possibility of being connected in one control device, in order to select individual or common control of the units, as necessary for the appropriate mode of operation.

Movement of the control device shall take place in the same direction as the desired motion of the ship.

C11.2.7 Each control position is to be provided with means to indicate which of them is in control.
At any control position, from which control of craft's manoeuvring is exercised, the operating effects caused by control inputs to the propulsion unit shall continuously be indicated.

C11.2.8 After restoration of normal conditions following an automatic shut-down, the machinery shall not start inadvertently before the control device has been reset to stop. Following an automatic slow-down - if provided – the propulsion of the craft shall not accelerate inadvertently before the control device has been reset to the actual step of speed, to which the power of the propulsion had been decreased.

Alternatively, other arrangements may be provided for the operator to consciously admit starting or acceleration of propulsion machinery.

Remote starting of a propulsion unit is to be automatically inhibited if conditions exist which may hazard the machinery, e.g. turning gear engaged, clutch engaged, shut-down activated, etc.

C11.2.9 The power for the control system is to be supplied from the same source which supplies the essential services for the propulsion units. As an alternative, the power for the control system may be supplied from other sources of power with backing-up facilities, which are sufficient for at least 15 minutes operation of the control system, in case of failure in its normal supply.

In case of category B craft, the control system of each propulsion unit shall have its individual source of power.

11.3 Emergency Controls

11.3.1 In all craft, the station or stations in the operating compartment from which control of craft manoeuvring and/or of its main machinery is exercised shall be provided, within easy reach of the crew member at that station, with controls for use in an emergency to:

.1 activate fixed fire-extinguishing systems;

.2 close ventilation openings and stop ventilating machinery supplying spaces covered by fixed fire-extinguishing systems, if not incorporated in .1;

.3 shut off fuel supplies to machinery in main and auxiliary machinery spaces;.

.4 disconnect all electrical power sources from the normal power distribution system (the operating control shall be guarded to reduce the risk of inadvertent or careless operation); and

.5 stop main engine(s) and auxiliary machinery.

C11.3.1 Unless it is considered impracticable, a single failure of the emergency controls shall not have an inadvertent effect on the system which it serves. In case of such a failure, an alarm shall be given in the craft's operating compartment.

The stopping device for main engine(s) is to be independent from the remote control system at the craft's operating station.

11.3.2 Where control of propulsion and manoeuvring is provided at stations outside the operating compartment, such stations shall have direct communication with the operating compartment which shall be a continuously manned control station.

11.3.3 In addition, for category B craft control of propulsion and manoeuvring as well as emergency functions referred to in 11.3.1 shall be provided at one or more stations outside the operating compartment. Such stations shall have direct communication with the operating compartment which shall be a continuously manned control station.

11.4 Alarm System

11.4.1 Alarm systems shall be provided which announce at the craft's control position, by visual and audible means, malfunctions or unsafe conditions. Alarms shall be maintained until they are accepted and the visual indications of individual alarms shall remain until the fault has been corrected, when the alarm shall automatically reset to the normal operating condition. If an alarm has been accepted and a

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second fault occurs before the first is rectified, the audible and visual alarms shall operate again. Alarm systems shall incorporate a test facility.

***11.4.1.1** Emergency alarms giving indication of conditions requiring immediate action shall be distinctive and in full view of crew members in the operating compartment, and shall be provided for the following:*

.1 activation of a fire-detection system;

.2 total loss of normal electrical supply;

.3 overspeed of main engines;

.4 thermal runaway of any permanently installed nickel-cadmium battery.

C11.4.1.1 In addition to the alarms requested under 11.4.1.1, the following alarms, giving indication that is distinctive and in full view of crew members in the operating compartment, are to be provided:

.1 fire (alarm to summon the crew);

.2 general emergency alarm (alarm to summon crew and passengers to muster stations);

.3 fire-extinguishing medium imminent release;

.4 watertight doors imminent closing, compartment flooding.

***11.4.1.2** Alarms with a visual display distinct from that of alarms referred to in 11.4.1.1 shall indicate conditions requiring action to prevent degradation to an unsafe condition. These shall be provided for at least the following:*

.1 exceeding the limiting value of any craft, machinery or system parameter other than engine overspeed;

.2 failure of normal power supply to powered directional or trim control devices;

.3 operation of any automatic bilge pump;

.4 detection of bilge water in each watertight compartment below the design waterline;

.5 failure of compass system;

.6 low level of a fuel tank contents;

.7 fuel oil tank overflow;

.8 extinction of side, masthead or stern navigation lights;

.9 low level of contents of any fluid reservoir the contents of which are essential for normal craft operation;

.10 failure of any connected electrical power source;

.11 failure of any ventilation fan installed for ventilating spaces in which inflammable vapours may accumulate; and

.12 diesel engine fuel line failure as required by 9.4.2.

C11.4.1.2 With reference to 11.4.1.2.1 in particular, the machinery is to be monitored in the scope as listed in Table C11.4.1.2.1 to Table C11.4.1.2.6.

***11.4.1.3** All warnings required by 11.4.1.1 and 11.4.1.2 shall be provided at all stations at which control functions may be exercised.*

***11.4.2** The alarm system shall meet appropriate constructional and operational requirements for required alarms.* [2]

***11.4.3** Equipment monitoring the passenger, cargo and machinery spaces for fire and flooding shall, so far as is practicable, form an integrated sub-centre incorporating monitoring and activation control for all emergency situations. This sub-centre may require feedback instrumentation to indicate that actions initiated have been fully implemented.*

Table 11.4.1.2.1 Propulsion diesel engines

Parameter	Alarm level	Remark
Lubricating oil pressure	low	
Lubricating oil temperature inlet	high	
Differential pressure across lubricating oil filter	high	
Pressure or flow of cooling water	low	
Temperature of cooling water outlet	high	
Level in cooling water expansion tank	low	
Deviation of each cylinder from average of exhaust gas temperature, or Exhaust gas temperature of each cylinder	high low + high	if cylinder power above 130 kW
Exhaust gas temperature after turbocharger	high	if cylinder not monitored individually and if cylinder power below 130 kW
Pressure of fuel oil to engine	low	if supplied by electrical pumps
Temperature of fuel oil to engine	low + high	if heated
Pressure of control air	low	
Pressure of starting air	low	
Safety system	failure	

[2] *Refer to the Code on Alarms and Indicators, 1995, adopted by the Organization by resolution A.830(19).*

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C11.4.4 On category B craft, alarm systems including their power supply have to be separate for each independent propulsion unit and its essential auxiliaries.

11.5 Safety System

Where arrangements are fitted for overriding any automatic shutdown system for the main propulsion machinery in accordance with 9.2.2, they shall be such as to preclude inadvertent operation. When a shutdown system is activated, an audible and visual alarm shall be given at the control station and means shall be provided to override the automatic shutdown except in cases where there is a risk of complete breakdown or explosion.

C11.5.1 In case of need, the bridge operator may have a possibility to cancel the safety devices which could have caused the propelling machinery to stop (except for the overspeed one). Control of this device is to be such as to preclude inadvertent operation; the indication "safety devices off" shall be clearly visible.

C11.5.2 After restoration of normal conditions following a shut-down, resetting of the safety system shall be possible at the craft's operating station and at other positions from which the control can be exercised.

C11.5.3 Safety systems are to be designed as far as practicable to be independent of the alarm and control system and their power supply, such that a failure or malfunction in these systems will not prevent the safety system from operating.

Safety systems including their power supply shall be separate for each propulsion unit.

C11.5.4 Electrical circuits of safety systems for propulsion machinery and essential systems, which in case of their failure have sudden effect on the availability of the propulsion and directional control of the craft, shall be such that a single failure in the system does not result, as far as practicable, in a loss of propulsion and directional control. The electrical circuits of safety systems for other machinery, which have no sudden effect on the availability of the propulsion and steering, may be designed as suitable for their purpose with the most effective protection of the machinery.

C11.5.5 The power for the safety system shall be supplied from the main source of electrical power. Provisions are to be made for supplying power uninterrupted to the safety system for at least 15 minutes following a failure of the ship's main source of electrical power. The electric and pneumatic supplies are to be monitored.

C11.6 Stand-by systems

C11.6.1 Where stand-by units are required, they shall start up automatically:

- on failure of operational units
- to preserve stored energy resources (e.g. compressed air)
- on operational demand, if auxiliary machinery are operated in staggered service.

Table C11.4.1.2.2 Propulsion gas turbines

Parameter	Alarm level	Remark
Lubricating oil pressure	low	
Lubricating oil temperature	high	
Differential pressure across lubricating oil filter	high	
Bearing temperature	high	
Exhaust gas temperature outlet	high	
Vibrations	high	
Axial displacement	high	
Combustion/ignition	failure	
Hydraulic service oil pressure	low	
Safety system	failure	

C11.6.2 The threshold for activation of the stand-by system shall be such that normal operation is restored before the safety system is activated.

C11.6.3 The changeover to a stand-by unit due to a fault is to be signalled visually and audibly. However, an alarm is not to be tripped in the case of machinery installations with auxiliary machines driven mechanically from the propulsion plant where the stand-by machines start up automatically in the lower speed range.

C11.6.4 Sets which have suffered a malfunction and have shut down automatically may only be provided for restart after manual reset independent of the alarm acknowledgement.

Table C11.4.1.2.3 Transmission, shaft gears

Parameter	Alarm level	Remark
Lubricating oil pressure to gears	low	
Lubricating oil temperature of gears with sliding bears	high	
Servo oil pressure of gears and transmissions	low	
Thrust bearing temperature	high	
Stern tube temperature	high	

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Table C11.4.1.2.4 Main diesel generator sets

Parameter	Alarm level	Remark
Lubricating oil pressure	low	
Pressure or flow of cooling water	low	
Temperature of cooling water outlet	high	
Starting power capacity	low	
Voltage	low	
Frequency	low	
Overspeed	tripped	
Safety system	Failure	

Table C11.4.1.2.5 Auxiliary boilers

Parameter	Alarm level	Remark
Water level	low	
Stream pressure	low + high	
Flame failure	shut down	
Safety system	failure	

Table 11.4.1.2.6 Miscellaneous

Parameter	Alarm level	Remark
Remote control of propulsion	failure	
Safety system of each machinery	tripped	
Override of safety system	activated	
Power of alarm system	failure	
Electrical non-essential consumers	tripped	
Insulation resistance	low	
Emergency controls	failure	
Fire alarm system	failure	
Stand-by function of auxiliaries	start	
Machinery space bilge level	high	2 sensors at least for each machinery space
Fuel oil service tank temperature	high	if heated above flash-point
Purifier	failure	

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Section 12

Electrical Installations

Part A – General

C12.0 Documents to be submitted

C12.0.1 The following drawings and documents are to be submitted. To facilitate a smooth and efficient approval process they shall be submitted electronically via GLOBE [1]. In specific cases and following prior agreement with GL they can also be submitted in paper form in triplicate.

.1 Arrangement of essential electric equipment

.2 Single line general electric diagram of the installation (including emergency installation)

.3 Diagram of power supplies or converters

.4 Electrical load analysis

.5 Calculation of short-circuit currents for each installation in which the sum of rated power of the energy sources which may be connected contemporaneously to the network is greater than 500 kVA (kW), and in each installation where selective protective devices are foreseen

.6 List of circuits including, for each supply and distribution circuit, data concerning the nominal current, the cable type, length and cross-section, nominal and setting values of the protective and control devices

.7 Single line and functional diagram of the main switchboard

.8 Single line and functional diagram of the emergency switchboard

.9 Diagram of the most important section boards

.10 Diagram of the supply, monitoring and control systems of the steering gear

.11 Diagram of the supply, monitoring and control systems of the propulsion plant

.12 Diagram of the general alarm system

.13 Diagram of the navigation-light switchboard

.14 Electrical diagram of the gas fire extinguishing system

.15 Electrical diagram of the sprinkler fire extinguishing system

.16 Electrical diagram of the firedoor control and monitoring

.17 Diagram of the emergency stop systems

.18 Diagram of the public address system or other inter-communication systems.

C12.0.2 In addition to the documentation requested above, the following is also required:

.1 For passenger craft:

(a) Single line diagram of the main cable runs showing cables for duplicated equipment and the location of the main distribution and emergency switchboards

(b) Diagrams of switchboards for control, indication and alarm of watertight doors.

.2 For passenger and cargo craft with spaces intended for the carriage of motor vehicles with fuel in their tanks and/or spaces intended for the carriage of dangerous goods:

(a) Plan of dangerous spaces giving details of types of cables and safety characteristics of the equipment installed therein

(b) Diagrams of control and monitoring systems for doors, closed-circuit television or monitoring systems for flooding on passenger craft with ro-ro spaces or special category spaces

(c) Diagrams of supplementary emergency lighting systems for the craft in the previous item (b).

Further documentation may be required, if deemed necessary by GL.

12.1 General

12.1.1 Electrical installations [2] shall be such that:

.1 all electrical auxiliary services necessary for maintaining the craft in normal operation and habitable conditions will be ensured without recourse to the emergency source of electrical power;

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1 Detailed information about the secured GL system GLOBE can be found on GL's website www.gl-group.com/globe.

2 *Refer to the recommendations published by the International Electrotechnical Commission and, in particular, Publication 60092 - Electrical Installations in Ships.*

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.2 electrical services essential for safety will be ensured under various emergency conditions; and

.3 the safety of passengers, crew and craft from electrical hazards will be ensured.

The FMEA shall include the electrical system, taking into account the effects of electrical failure on the systems being supplied. In cases where faults can occur without being detected during routine checks on the installations, the analysis shall take into account the possibility of faults occurring simultaneously or consecutively.

12.1.2 *The electrical system shall be designed and installed so that the probability of the craft being at risk of failure of a service is extremely remote.*

12.1.3 *Where loss of particular essential service would cause serious risk to the craft, the service shall be fed by at least two independent circuits fed in such a way that no single failure in the electrical supply or distribution systems would affect both supplies.*

12.1.4 *The securing arrangements for heavy items, i.e. accumulator batteries, shall, as far as practicable, prevent excessive movement during the accelerations due to grounding or collision.*

12.1.5 *Precautions shall be taken to minimise risk of supplies to essential and emergency services being interrupted by the inadvertent or accidental opening of switches or circuit-breakers.*

C12.1.6 Ambient conditions for electrical equipment see Section 9, C9.1.16

12.2 Main Source of Electrical Power

12.2.1 *A main source of electrical power of sufficient capacity to supply all those services mentioned in 12.1.1 shall be provided. The main source of electrical power shall consist of at least two generating sets.*

C12.2.1 Electrical propulsion

For electrically propelled craft with two or more constant-voltage propulsion generating sets, the craft's service electric power may be derived from this source and additional service generators need not be fitted, provided that effective propulsion be maintained with one propulsion generator out of service.

12.2.2 *The capacity of these generating sets shall be such that, in the event of any one generating set being stopped or failing, it will still be possible to supply those services necessary to provide the normal operational conditions of propulsion and safety. Minimum comfortable conditions of habitability shall also be ensured which include at least adequate services for cooking, heating, domestic refrigeration, mechanical ventilation, and sanitary and fresh water.*

C12.2.2 Shaft-driven generators

One of the required generators may be a generator driven by a main propulsion unit (shaft generator) intended to operate at constant speed, (e.g. a system where craft speed and direction are controlled only by varying propeller pitch).

Shaft generator installations which do not comply with this criterion may be fitted as additional source(s) of power provided that:

.1 On loss of power from the shaft generator(s), a stand-by generating set starts up automatically

.2 The capacity of the stand-by set is adequate for the loads necessary for craft propulsion and safety

.3 These services are restored as quickly as practicable

12.2.3 *The arrangements of the craft's main source of electrical power shall be such that the services referred to in 12.1.1.1 can be maintained regardless of the speed and direction of the propulsion machinery or shafting.*

C12.2.3

(a) In addition to the normal operational conditions of propulsion and safety as per 12.2.2, steering conditions are also to be provided.

(b) Those services necessary to provide normal operational conditions of propulsion, steering and safety do not include services such as:

(1) Thrusters not forming part of the main propulsion system

(2) Windlass

(3) Moorings

(4) Cargo handling gear

(5) Cargo pumps

(6) Air conditioning.

12.2.4 *In addition, the generating sets shall be such as to ensure that, with any one generator or its primary source of power out of operation, the remaining generating set shall be capable of providing the electrical services necessary to start the main propulsion plant from dead craft condition. The emergency source of electrical power may be used for the purpose of starting from a dead craft condition if its capability either alone or combined with that of any other source of electrical power is sufficient to provide at the same time those services required to be provided by 12.7.3.1 to 12.7.3.3 or 12.7.4.1 to 12.7.4.4 or 12.8.2.1 to 12.8.2.4.1, as appropriate.*

12.2.5 *Where transformers constitute an essential part of the electrical supply system required by this section, the system shall be so arranged as to ensure the same continuity of supply as is stated in 12.2.*

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C12.2.5 This requirement also applies to static converters or charging units.

The following requirement also applies to these transformers.

The number, capacity and arrangement of power transformers supplying auxiliary electrical systems are to be such that, with any one transformer not in operation, the remaining transformer(s) is (are) sufficient to ensure the safe operation of those services necessary to provide normal operational conditions of propulsion and safety. Minimum comfortable conditions of habitability are also to be ensured, including at least adequate services for cooking, heating, domestic refrigeration, mechanical ventilation, sanitary and fresh water.

Each transformer required is to be located as a separate unit, with a separate enclosure or equivalent arrangement, and is to be served by separate circuits on the primary and secondary sides. Each primary circuit is to be provided with switchgear and protective devices in each phase.

Each of the secondary circuits is to be provided with a multipole isolating switch.

See the examples given in Figure C12.2.5.1.

Transformers supplying a bow thruster are excluded.

12.2.6 *A main electric lighting system which shall provide illumination throughout those parts of the craft normally accessible to and used by passengers and crew shall be supplied from the main source of electrical power.*

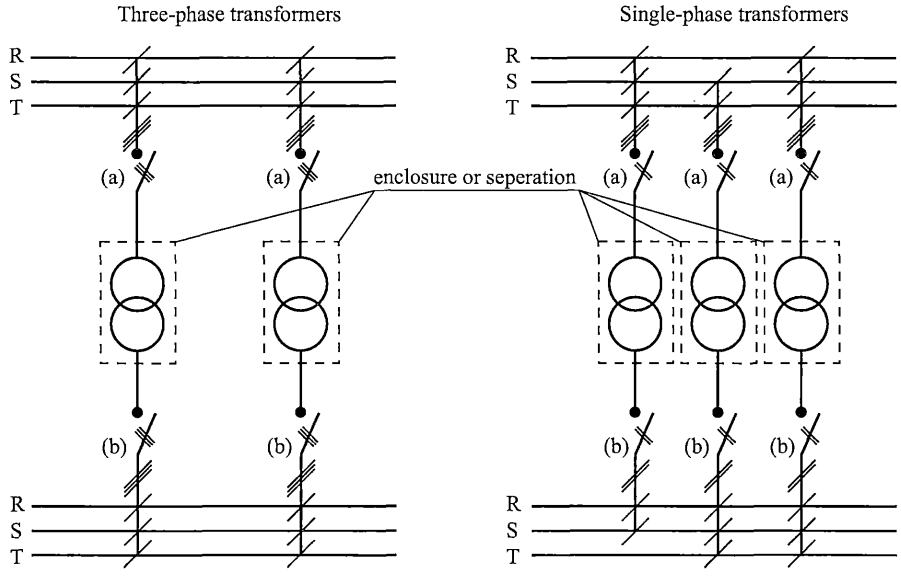
12.2.7 *The arrangement of the main electric lighting system shall be such that a fire or other casualty in spaces containing the emergency source of electrical power, associated transforming equipment, if any, the emergency switchboard and the emergency lighting switchboard will not render inoperative the main electric lighting systems required by 12.2.6.*

12.2.8 *The main switchboard shall be so placed relative to one main generating station that, as far as practicable, the integrity of the normal electrical supply may be affected only by a fire or other casualty in one space. An environmental enclosure for the main switchboard, such as may be provided by the machinery control room situated within the main boundaries of the space, shall not be considered as separating the switchboards from the generators.*

C12.2.8 By "main generating station" is understood one or more generating set(s).

For the purpose of classification, GL adds the following interpretation of the above requirement:

"The main switchboard and generating sets are, in general, to be located in the same main fire zone (if any) or in the same machinery compartment. However, the main switchboard may be installed inside a machinery control room, provided that such a room be contained within the main boundaries of the engine room".



(a) = switchgear and protective devices (b) = multiple isolation switch

Fig. C12.2.5.1

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12.2.9 The main busbars shall be subdivided into at least two parts which shall be connected by a circuit-breaker or other approved means. So far as is practicable, the connection of generating sets and any other duplicated equipment shall be equally divided between the parts. For category B craft, each part of the main busbars with its associated generators shall be arranged in separate compartments.

12.3 Emergency Source of Electrical Power

12.3.1 A self-contained emergency source of electrical power shall be provided.

12.3.2 The emergency source of electrical power, associated transforming equipment, if any, transitional source of emergency electrical power, emergency switchboard and emergency lighting switchboard shall be located above the waterline in the final condition of damage as referred to in Section 2, operable in that condition and readily accessible.

12.3.3 The location of the emergency source of electrical power and associated transforming equipment, if any, the transitional source of emergency power, the emergency switchboard and the emergency electrical lighting switchboards in relation to the main source of electrical power, associated transforming equipment, if any, and the main switchboard shall be such as to ensure that a fire or other casualty in spaces containing the main source of electrical power, associated transforming equipment, if any, and the main switchboard or in any machinery space will not interfere with the supply, control, and distribution of emergency electrical power. As far as practicable, the space containing the emergency source of electrical power, associated transforming equipment, if any, the transitional source of emergency electrical power and the emergency switchboard shall not be contiguous to the boundaries of the main machinery spaces or those spaces containing the main source of electrical power, associated transforming equipment, if any, or the main switchboard.

12.3.4 Provided that suitable measures are taken for safeguarding independent emergency operation under all circumstances, the emergency generator, if provided, may be used exceptionally, and for short periods, to supply non-emergency circuits.

C12.3.4 "Exceptionally" is understood to cover conditions such as:

(1) blackout,

(2) dead ship situation,

(3) routine use for testing.

12.3.5 Distribution systems shall be so arranged that the feeders from the main and emergency sources are separated both vertically and horizontally as widely as practicable.

12.3.6 The emergency source of electrical power may be either a generator or an accumulator battery, which shall comply with the following:

.1 Where the emergency source of electrical power is a generator, it shall be:

.1.1 driven by a suitable prime mover with an independent supply of fuel having a flashpoint which meets the requirements of 7.1.2.2;

.1.2 started automatically upon failure of the electrical supply from the main source of electrical power and shall be automatically connected to the emergency switchboard. Those services referred to in 12.7.5 or 12.8.3 shall then be transferred to the emergency generating set. The automatic starting system and the characteristic of the prime mover shall be such as to permit the emergency generator to carry its full rated load as quickly as is safe and practicable, subject to a maximum of 45 seconds; and

.1.3 provided with a transitional source of emergency electrical power according to 12.7.5 or 12.8.3.

.2 Where the emergency source of electrical power is an accumulator battery, it shall be capable of:

.2.1 carrying the emergency electrical load without recharging while maintaining the voltage of the battery throughout the discharge period within 12 % above or below its nominal voltage;

.2.2 automatically connecting to the emergency switchboard in the event of failure of the main source of electrical power; and

.2.3 immediately supplying at least those services specified in 12.7.5 or 12.8.3.

C12.3.6 With reference to 12.3.6.1.2, for the purpose of classification, the time for generator start-up and loading is not to exceed 15 s.

12.3.7 The emergency switchboard shall be installed as near as is practicable to the emergency source of electrical power.

12.3.8 Where the emergency source of electrical power is a generator, the emergency switchboard shall be located in the same space unless the operation of the emergency switchboard would thereby be impaired.

12.3.9 No accumulator battery fitted in accordance with this section shall be installed in the same space as the emergency switchboard. An indicator shall be mounted in a suitable space at the craft's operating compartment to indicate when the batteries constitut-

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ing either the emergency source of electrical power or the transitional source of emergency electrical power referred to in 12.3.6.1.3 are being discharged.

12.3.10 *The emergency switchboard shall be supplied during normal operation from the main switchboard by an interconnector feeder which shall be adequately protected at the main switchboard against overload and short circuit and which shall be disconnected automatically at the emergency switchboard upon failure of the main source of electrical power. Where the system is arranged for feedback operation, the interconnector feeder shall also be protected at the emergency switchboard at least against short circuit. Failure of the emergency switchboard, when being used in other than an emergency, shall not put at risk the operation of the craft.*

12.3.11 *In order to ensure ready availability of the emergency source of electrical power, arrangements shall be made, where necessary, to disconnect automatically non-emergency circuits from the emergency switchboard to ensure that power shall be available to the emergency circuits.*

12.3.12 *The emergency generator and its prime mover and any emergency accumulator battery shall be so designed and arranged as to ensure that they will function at full rated power when the craft is upright and when the craft has a list or trimming accordance with 9.1.12 including any damage cases considered in Section 2, or is in any combination of angles within those limits.*

12.3.13 *Where accumulator batteries are installed to supply emergency services, provisions shall be made to charge them in situ from a reliable on-board supply. Charging facilities shall be so designed to permit the supply of services, regardless of whether battery is on charge or not. Means shall be provided to minimise the risk of overcharging or overheating the batteries. Means for efficient air ventilation shall be provided.*

12.4 Starting Arrangements for Emergency Generating Sets

12.4.1 *Emergency generating sets shall be capable of being readily started in their cold condition at a temperature of 0 °C. If this is impracticable, or if lower temperatures are likely to be encountered, provisions shall be made for heating arrangements to ensure ready starting of the generating sets.*

12.4.2 *Each emergency generating set shall be equipped with starting devices with a stored energy capability of at least three consecutive starts. The source of stored energy shall be protected to preclude critical depletion by the automatic starting system, unless a second independent means of starting is provided. A second source of energy shall be provided for an additional three starts within 30 min, unless manual starting can be demonstrated to be effective.*

12.4.3 *The stored energy shall be maintained at all times, as follows:*

.1 electrical and hydraulic starting systems shall be maintained from the emergency switchboard;

.2 compressed air starting systems may be maintained by the main or auxiliary compressed air receivers through a suitable nonreturn valve or by an emergency air compressor which, if electrically driven, is supplied from the emergency switchboard;

.3 all of these starting, charging and energy-storing devices shall be located in the emergency generator space. These devices shall not be used for any purpose other than the operation of the emergency generating set. This does not preclude the supply to the air receiver of the emergency generating set from the main or auxiliary compresses air system through the non return valve fitted in the emergency generator space.

12.5 Steering and Stabilization

12.5.1 *Where steering and/or stabilization of a craft is essentially dependent on one device as with a single rudder or pylon, which is itself dependent on the continuous availability of electric power, it shall be served by at least two independent circuits, one of which shall be fed either from the emergency source of electric power or from an independent power source located in such a position as to be unaffected by fire or flooding affecting the main source of power. Failure of either supply shall not cause any risk to the craft or passengers during switching to the alterative supply and such switching arrangements shall meet the requirements in 5.2.5. These circuits shall be provided with short-circuit protection and an overload alarm.*

12.5.2 *Protection against excess current may be provided, in which case it shall be for not less than twice the full load current of the motor or circuit so protected and shall be arranged to accept the appropriate starting current with a reasonable margin. Where three-phase supply is used an alarm shall be provided in a readily observed position in the craft's operating compartment that will indicate failure of any one of the phases.*

12.5.3 *Where such systems are not essentially dependent on the continuous availability of electric power but at least one alternative system, not dependent on the electric supply, is installed, then the electrically powered or controlled system may be fed by a single circuit protected in accordance with 12.5.2.*

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12.5.4 The requirements of Sections 5 and 16 for power supply of the directional control system and stabilising system of the craft shall be met.

12.6 Precautions Against Shock, Fire and Other Hazards of Electrical Origin

12.6.1 Exposed metal parts of electrical machines or equipment which are not intended to be live but which are liable under fault conditions to become live shall be earthed unless the machines or equipment are:

.1 supplied at a voltage not exceeding 50V direct current or 50V, root-mean-square between conductors; auto-transformers shall not be used for the purpose of achieving this voltage; or

.2 supplied at a voltage not exceeding 250V by safety isolating transformers supplying only one consuming device; or

.3 constructed in accordance with the principle of double insulation.

12.6.1.2 The Administration may require additional precautions for portable electrical equipment for use in confined or exceptionally damp spaces where particular risks due to conductivity may exist.

12.6.1.3 All electrical apparatus shall be constructed and so installed as not to cause injury when handled or touched in the normal manner.

12.6.2 Main and emergency switchboards shall be so arranged as to give easy access, as may be needed, to apparatus and equipment, without danger to personnel. The sides and the rear and, where necessary, the front of switchboards shall be suitably guarded. Exposed live parts having voltages to earth exceeding a voltage to be specified by the Administration shall not be installed on the front of such switchboards. Where necessary, nonconducting mats or gratings shall be provided at the front and rear of the switchboard.

C12.6.2 The voltage, mentioned in 12.6.2, specified by GL is 50 V.

12.6.3 When a distribution system, whether primary or secondary, for power, heating or lighting, with no connection to earth is used, a device capable of continuously monitoring the insulation level to earth and of giving an audible or visual indication of abnormally low insulation values shall be provided. For limited secondary distribution systems the Administration may accept a device for manual checking of the insulation level.

C12.6.3 For the purpose of classification, the indication of abnormally low insulation value is required to be both audible and visual.

12.6.4 Cables and wiring

12.6.4.1 Except as permitted by the Administration in exceptional circumstances, all metal sheaths and armour of cables shall be electrically continuous and shall be earthed.

C12.6.4.1 With reference to 12.6.4.1, exemptions are not in principle permitted for the purpose of classification.

12.6.4.2 All electric cables and wiring external to equipment shall be at least of a flame-retardant type and shall be so installed as not to impair their original flame-retarding properties. Where necessary for particular applications, the Administration may permit the use of special types of cables such as radio-frequency cables, which do not comply with the foregoing.

C12.6.4.2 Cables, cores and wires are normally to be of a type approved by GL, on the basis of IEC standards, 92.3. series. Use of other cables is subject to special consideration by tGLand to appropriate and satisfactory testing.

Where cables are bunched, provisions are to be made to limit fire propagation. This may comprise by either of the following methods:

- use of cables successfully tested according to IEC Report 332.3, or to an equivalent testing procedure,
- fitting of suitable fire-stop screens,
- use of an appropriate protective coating.

In areas attended by passengers and in service areas, only halogen-free cables shall be used for permanent installations.

Electric cables having low emission of smoke and toxic gases according to national or international standards (e.g. IEC 754-1, IEC 1034-1, IEC 1034-2) may be accepted.

Exceptions for individual cables for special purposes have to be agreed with GL.

In all other areas of the craft, the use of halogen-free cable is recommended.

12.6.4.3 Cables and wiring serving essential or emergency power, lighting, internal communications or signals shall, as far as practicable, be routed clear of machinery spaces and their casings and other areas of high fire risk. Where practicable, all such cables shall be run in such a manner as to preclude their being rendered unserviceable by heating of the bulkheads that may be caused by a fire in an adjacent space.

C12.6.4.3 For fire-resistant cables, the scope of installation is as follows:

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.1 Cables for services required to be operable under fire conditions, including those for their power supplies, are to be of a fire resistant type, complying with IEC 60331 where they pass through high fire risk areas, fire zones or decks, other than those which they serve.

.2 Systems that are self monitoring, fail safe or duplicated with cable runs as widely separated as is practicable may be exempted provided their functionality can be maintained.

Note

In case of cables for services required to be operable under fire conditions, the fire resistant cables are to extend from the control monitoring panel to the nearest local distribution panel serving the relevant deck/area.

In case of power supply cables used for services required to be operable under fire conditions, the fire resistant cables are to extend from their distribution point within the space containing the emergency source of electrical power to the nearest local distribution panel serving the relevant deck/area.

.3 Emergency services required to be operable under fire conditions include:

- Fire and general alarm system,
- Fire extinguishing systems and fire extinguisher medium alarms,
- Fire detection system,
- Control and power systems to power operated fire doors and status indication for all fire doors,
- Control and power systems to power operated watertight doors and their status indication,
- Emergency lighting,
- Public address system

.4 The cables shall be arranged in such a way as to minimise the loss of operational availability as a result of a limited fire in any area.

.5 The cables shall be installed as straight as possible and with strict observance of special installation requirements, e.g. permitted bending radii.

12.6.4.4 *Where cables which are installed in hazardous areas introduce the risk of fire or explosion in the event of an electrical fault in such areas, special precautions against such risks shall be taken to the satisfaction of the Administration.*

C12.6.4.4 "Special precautions" as per 12.6.4.4, stipulated by GL include the following provisions:

.1 Where there are risks of corrosion, an impervious non metal sheath is to be applied on top of the armouring;

.2 Cables installed on deck or gangways are to be protected against mechanical damage;

.3 Cables of intrinsically safety circuits are to be separated from the others.

12.6.4.5 *Cables and wiring shall be installed and supported in such manner as to avoid chafing or other damage.*

12.6.4.6 *Terminations and joints in all conductors shall be so made as to retain the original electrical, mechanical, flame-retarding and, where necessary, fire-resisting properties of the cable.*

12.6.5.1 *Each separate circuit shall be protected against short circuit and against overload, except as permitted in 12.5 or where the Administration may exceptionally otherwise permit.*

12.6.5.2 *The rating or appropriate setting of the overload protective device for each circuit shall be permanently indicated at the location of the protective device.*

12.6.6 *Lighting fittings shall be so arranged as to prevent temperature rises which could damage the cables and wiring, and to prevent surrounding material from becoming excessively hot.*

12.6.7 *All lighting and power circuits terminating in a bunker or cargo space shall be provided with a multiple -pole switch outside the space for disconnecting such circuits.*

12.6.8.1 *Accumulator batteries shall be suitably housed, and compartments used primarily for their accommodation shall be properly constructed and efficiently ventilated.*

12.6.8.2 *Electrical or other equipment which may constitute a source of ignition of flammable vapours shall not be permitted in these compartments except as permitted in 12.6.9.*

12.6.8.4 *Accumulator batteries shall not be located in crew accommodation.*

12.6.9 *No electrical equipment shall be installed in any space where flammable mixtures are liable to collect, including those in compartments assigned principally to accumulator batteries, in paint lockers, acetylene stores or similar spaces, unless the Administration is satisfied that such equipment is:*

.1 *essential for operational purposes;*

.2 *of a type which will not ignite the mixture concerned;*

.3 *appropriate to the space concerned; and .4 appropriately certified for safe usage in the dusts, vapours or gases likely to be encountered.*

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C12.6.9 The requirements of 12.6.9 apply to accumulator batteries with total power exceeding 2 kW.

12.6.10 The following additional requirements from .1 to .7 shall be met, and requirements from .8 to .13 shall be met also for non-metallic craft:

.1 The electrical distribution voltages throughout the craft may be either direct current or alternating current and shall not exceed:

.1.1 500 V for cooking, heating and other permanently connected equipment; and

.1.2 250 V for lighting, internal communications and receptacle outlets. The Administration may accept higher voltages for propulsion purposes.

.2 For electrical power distribution, two-wire or three-wire systems shall be used. Four-wire systems with neutral solidly earthed but without hull return may also be used. Where applicable, the requirements for 7.5.6.4 or 7.5.6.5 shall also be met.

.3 Effective means shall be provided so that voltage may be cut off from each and every circuit and sub-circuit and from all apparatus as may be necessary to prevent danger.

.4 Electrical equipment shall be so designed that the possibility of accidentally touching live parts, rotating or moving parts as well as heated surfaces which might cause burns or initiate fire is minimized.

.5 Electrical equipment shall be adequately secured. The probability of fire or dangerous consequences arising from damage to electrical equipment shall be reduced to an acceptable minimum.

.6 The rating or appropriate setting of the overload protective device for each circuit shall be permanently indicated at the location of the protection device.

.7 Where it is impracticable to provide electrical protective devices for certain cables supplied from batteries, e.g., within battery compartments and in engine starting circuits, unprotected cable runs shall be kept as short as possible and special precautions shall be taken to minimize risk of faults, e.g., use of single-core cables with additional sleeve over the insulation of each core, with shrouded terminals.

.8 In order to minimize the risk of fire, structural damage, electrical shock and radio interference due to lightning strike or electrostatic discharge, all metal parts of the craft shall be bonded together, in so far as possible in consideration of galvanic corrosion between dissimilar metals, to form a continuous electrical system, suitable for the earth return of electrical equipment and to connect the craft to the water when water-borne. The bonding of isolated components inside the structure is not generally necessary, except in fuel tanks.

.9 Each pressure refuelling point shall be provided with a means of bonding the fuelling equipment to the craft.

.10 Metallic pipes capable of generating electrostatic discharges, due to the flow of liquids and gases, shall be bonded so as to be electrically continuous throughout their length and shall be adequately earthed.

.11 Primary conductors provided for lightning discharge currents shall have a minimum cross- section of 70 mm² in copper or equivalent surge-carrying capacity in aluminium.

.12 Secondary conductors provided for the equalisation of static discharges, bonding of equipment, etc., but not for carrying lightning discharges shall have a minimum cross section of 5 mm² copper of equivalent surge current carrying capacity in aluminium.

.13 The electrical resistance between bonded objects and the basic structure shall not exceed 0.02 Ohm except where is can be demonstrated that a higher resistance will not cause a hazard. The bonding path shall have sufficient cross-sectional area to carry the maximum current likely to be imposed on it without excessive voltage drop.

C12.6.10

(a) With reference to 12.6.10.6, see also 12.6.5.2.

(b) With reference to 12.6.10.11, stainless steel is also acceptable.

Part B - Requirements for Passenger Craft

12.7 General

12.7.1 Separation and duplication of electrical supply shall be provided for duplicated consumers of essential services. During normal operation the systems may be connected to the same power-bus, but facilities for easy separation shall be provided. Each system shall be able to supply all equipment necessary to maintain the control of propulsion, steering, stabilization, navigation, lighting and ventilation, and allow starting of the largest essential electric motor at any load. Automatic load-dependent disconnection of non-essential consumers may be allowed.

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12.7.2 Emergency source of electrical power

Where the main source of electrical power is located in two or more compartments which are not contiguous, each of which has its own self-contained systems, including power distribution and control systems, completely independent of each other and such that a fire or other casualty in any one of the spaces will not affect the power distribution from the others, or to the services required by 12.7.3 or 12.7.4, the requirement of 12.3.1, 12.3.2 and 12.3.4 may be considered satisfied without an additional emergency source of electrical power, provided that:

.1 there is at least one generating set, meeting the requirements of 12.3.12 and of sufficient capacity to meet the requirements of 12.7.3 or 12.7.4 in each of at least two non-contiguous spaces;

.2 the arrangements required by .1 in each such space are equivalent to those required by 12.3.6.1, 12.3.7 to 12.3.11 and 12.4 so that a source of electrical power is available at all times to the services required by 12.7.3 or 12.7.4; and

.3 the generator sets referred to in .1 and their self-contained systems are installed such that one of them remains operable after damage or flooding in any one compartment.

12.7.3 For category A craft, the emergency source of power shall be capable of supplying simultaneously the following services:

.1 for a period of 5 h emergency lighting:

.1.1 at the stowage, preparation, launching and deployed positions of survival craft and equipment for embarkation into those craft;

.1.2 at all escape routes, such as alleyways, stairways, exits from accommodation and service spaces, embarkation points, etc;

.1.3 in the public spaces;

.1.4 in the machinery spaces and main emergency generating spaces, including their control positions;

.1.5 in control stations;

.1.6 at the stowage positions for firemen's outfits; and

.1.7 at the steering gear;

.2 for a period of 5 h;

.2.1 main navigation lights, except for "not under command" lights;

.2.2 electrical internal communication equipment for announcements for passengers and crew required during evacuation;

.2.3 fire-detection and general alarm system and manual fire alarms; and

.2.4 remote control devices of fire-extinguishing systems, if electrical;

.3 for a period of 4 h of intermittent operation:

.3.1 the daylight signalling lamps, if they have no independent supply from their own accumulator battery; and

.3.2 the craft's whistle, if electrically driven;

.4 for a period of 5 h;

.4.1 craft radio facilities and other loads as set out in 14.13.2; and

.4.2 essential electrically powered instruments and controls for propulsion machinery, if alternate sources of power are not available for such devices;

.5 for a period of 12 h, the "not under command" lights; and

.6 for a period of 10 min:

.6.1 power drives for directional control devices, including those required to direct thrust forward and astern, unless there is a manual alternative acceptable to the Administration as complying with 5.2.3.

C12.7.3 With reference to 12.7.3.4, in addition to the services specified in 12.7.3.4.1 and 12.7.3.4.2, the emergency source of power is to be capable of supplying:

- One of the fire pumps required by 7.7.8.1.
- Sprinkler pump and drencher pump, if fitted.
- Emergency bilge pump and all equipment essential for the operation of electrically controlled bilge valves, as required by Section 10.

12.7.4 For category B craft, the electrical power available shall be sufficient to supply all those services that are essential for safety in an emergency, due regard being paid to such services as may have to be operated simultaneously. The emergency source of electrical power shall be capable, having regard to starting currents and the transitory nature of certain loads, of supplying simultaneously at least the following services for the periods specified hereinafter, if they depend upon an electrical source for their operation.

.1 for a period of 12 h, emergency lighting:

.1.1 at the stowage, preparation, launching and deployed positions of survival craft and equipment for embarkation into those craft;

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.1.2 *at all escape routes, such as alleyways, stairways, exits from accommodation and service spaces, embarkation points, etc;*

.1.3 *in the passenger compartments;*

.1.4 *in the machinery spaces and main emergency generating spaces including their control positions;*

.1.5 *in control stations;*

.1.6 *at the stowage positions for firemen's outfits; and*

.1.7 *at the steering gear;*

.2 *for a period of 12 h;*

.2.1 *the navigation lights, and other lights required by International Regulations for Preventing Collisions at Sea in force;*

.2.2 *electrical internal communication equipment for announcements for passengers and crew required during evacuation;*

.2.3 *fire-detection and general alarm system and manual fire alarms; and*

.2.4 *remote control devices of fire-extinguishing systems, if electrical;*

.3 *for a period of 4 h on intermittent operation:*

.3.1 *the daylight signalling lamps, if they have no independent supply from their own accumulator battery; and*

.3.2 *the craft's whistle, if electrically driven;*

.4 *for a period of 12 h;*

.4.1 *the navigational equipment as required by Section 13. Where such provision is unreasonable or impracticable, the Administration may waive this requirement for craft of less than 5,000 gross tonnage;*

.4.2 *essential electrically powered instruments and controls for propulsion machinery, if alternate sources of power are not available for such devices;*

.4.3 *one of the fire pumps required by 7.7.5.1;*

.4.4 *the sprinkler pump and drencher pump, if fitted;*

.4.5 *the emergency bilge pump and all the equipment essential for the operation of electrically powered remote controlled bilge valves as required by Section 10; and*

.4.6 *craft radio facilities and other loads as set out in 14.13.2;*

.5 *for a period of 30 min, any watertight doors, required by Section 2 to be power-operated, together with their indicators and warning signals;*

.6 *for a period of 10 min, power drives for directional control devices including those required to direct thrust forward and astern, unless there is a manual alternative acceptable to the Administration as complying with 5.2.3.*

12.7.5 *Transitional source of emergency electrical power The transitional source of emergency electrical power required by paragraph 12.3.6.1.3 may consist of an accumulator battery suitably located for use in an emergency which shall operate without recharging while maintaining the voltage of the battery throughout the discharge period within 12 % above or below its nominal voltage and be of sufficient capacity and so arranged as to supply automatically in the event of failure of either the main or emergency source of electrical power at least the following services, if they depend upon an electrical source for their operation:*

.1 *for a period of 30 min, the load specified in 12.7.3.1, .2 and .3, or in 12.7.4.1, .2 and .3; and*

.2 *with respect to the watertight doors:*

.2.1 *power to operate the watertight doors, but not necessarily simultaneously, unless an independent temporary source of stored energy is provided. The power source shall have sufficient capacity to operate each door at least three times, i.e. closed-open-closed, against an adverse list of 15 °and*

.2.2 *power to the control, indication and alarm circuits for the watertight doors for half an hour.*

12.7.6 *The requirements of 12.7.5 may be considered satisfied without the installation of a transitional source of emergency electrical power if each of the services required by that paragraph have independent supplies, for the period specified, from accumulator batteries suitably located for use in an emergency. The supply of emergency power to the instruments and controls of the propulsion and direction systems shall be uninterruptible.*

12.7.7 *In category A craft having limited public spaces, emergency lighting fittings of the type described in 12.7.9.1 as meeting the requirements of 12.7.3.1 and 12.7.5.1 may be accepted, provided that an adequate standard of safety is attained.*

12.7.8 *Provisions shall be made for the periodic testing of the complete emergency system, including the emergency consumers required by 12.7.3 or 12.7.4 and 12.7.5, and shall include the testing of automatic starting arrangements.*

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12.7.9 In addition to the emergency lighting required by paragraph 12.7.3.1, 12.7.4.1 and 12.7.5.1 on every craft with ro-ro spaces:

.1 all passenger public spaces and alleyways shall be provided with supplementary electric lighting that can operate for at least three h when all other sources of electric power have failed and under any condition of heel. The illumination provided shall be such that the approach to the means of escape can be readily seen. The source of power for the supplementary lighting shall consist of accumulator batteries located within the lighting units that are continuously charged, where practicable, from the emergency switchboard. Alternatively, any other means of lighting, which is at least as effective, may be accepted by the Administration.

The supplementary lighting shall be such that any failure of the lamp will be immediately apparent. Any accumulator battery provided shall be replaced at intervals having regard to the specified service life in the ambient condition that it is subject to in service; and

.2 a portable rechargeable battery-operated lamp shall be provided in every crew space alleyway, recreational space and every working space which is normally occupied unless supplementary emergency lighting, as required by .1, is provided.

12.7.10 Distribution systems shall be so arranged that fire in any main vertical zone will not interfere with services essential for safety in any other such zone. This requirement will be met if main and emergency feeders passing through any such zone are separated both vertically and horizontally as widely as is practicable.

Part C - Requirements for Cargo Craft

12.8 General

12.8.1 Separation and duplication of electrical supply shall be provided for duplicated consumers of essential services. During normal operation these consumers may be connected to the same power-bus directly or via distribution boards or group starters, but shall be separated by removable links or other approved means. Each power-bus shall be able to supply all equipment necessary to maintain the control of propulsion, steering, stabilization, navigation, lighting and ventilation, and allow starting of the largest essential electric motor at any load. However, having regard to 12.1.2, partial reduction in the capability from normal operation may be accepted. Non-duplicated consumers of essential services connected to the emergency switchboard directly or via distribution boards may be accepted. Automatic load-dependent disconnection of non-essential consumers may be allowed.

12.8.2 Emergency source of electrical power

12.8.2.1 Where the main source of electrical power is located in two or more compartments which are not contiguous, each of which has its own self-contained systems, including power distribution and control systems, completely independent of each other and such that a fire or other casualty in any one of the spaces will not affect the power distribution from the others, or to the services required by 12.8.2.2, the requirements of 12.3.1, 12.3.2 and 12.3.4 may be considered satisfied without an additional emergency source of electrical power, provided that:

.1 there is at least one generating set, meeting the requirements of 12.3.12 and each of sufficient capacity to meet the requirements of 12.8.2.2, in each of at least two non-contiguous spaces;

.2 the arrangements required by .1 in each such space are equivalent to those required by 12.3.6.1, 12.3.7 to 12.3.11 and 12.4 so that a source of electrical power is available at all times to the services required by 12.8.2; and

.3 the generator sets are referred to in .1 and their self-contained systems are installed in accordance with 12.3.2.

12.8.2.2 The electrical power available shall be sufficient to supply all those services that are essential for safety in an emergency, due regard being paid to such services as may have to be operated simultaneously. The emergency source of electrical power shall be capable, having regard to starting currents and the transitory nature of certain loads, of supplying simultaneously at least the following services for the periods specified hereinafter, if they depend upon an electrical source for their operation:

.1 for a period of 12 h, emergency lighting;

.1.1 at the stowage positions of life-saving appliances;

.1.2 at all escape routes, such as alleyways, stairways, exits from accommodation and service spaces, embarkation points, etc.;

.1.3 in public spaces, if any;

.1.4 in the machinery spaces and main emergency generating spaces including their control positions;

.1.5 in control stations;

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.1.6 at the stowage positions for fire-fighter's outfits; and

.1.7 at the steering gear;

.2 for a period of 12 h;

.2.1 the navigation lights, and other lights required by the International Regulations for Preventing Collisions at Sea in force;

.2.2 electrical internal communication equipment for announcements during evacuation;

.2.3 fire-detection and general alarm system and manual fire alarms; and

.2.4 remote control devices of fire-extinguishing systems, if electrical;

.3 for a period of 4 h of intermittent operation;

.3.1 the daylight signalling lamps, if they have no independent supply from their own accumulator battery; and

.3.2 the craft's whistle, if electrically driven;

.4 for a period of 12 h;

.4.1 the navigational equipment as required by Section 13. Where such provision is unreasonable or impracticable, the Administration may waive this requirement for craft of less than 5,000 gross tonnage;

.4.2 essential electrically powered instruments and controls for propulsion machinery, if alternate sources of power are not available for such devices;

.4.3 one of the fire pumps required by 7.7.5.1;

.4.4 the sprinkler pump and drencher pump, if fitted;

.4.5 the emergency bilge pump and all the equipment essential for the operation of electrically powered remote controlled bilge valves as required by Section 10; and

.4.6 craft radio facilities and other loads as set out in 14.13.2.

.5 for a period of 10 min, power drives for directional control devices, including those required to direct thrust forward and astern, unless there is a manual alternative acceptable to the Administration as complying with 5.2.3.

***12.8.2.3** Provision shall be made for the periodic testing of the complete emergency system, including the emergency consumers required by 12.8.2.2 and shall include the testing of automatic starting arrangements.*

***12.8.2.4** Where the emergency source of electrical power is a generator, a transitional source of emergency power shall be provided according to paragraph 12.8.3, unless the automatic starting system and the characteristics of the prime mover are such as to permit the emergency generator to carry its full rated load as quickly as is safe and practicable, subject to a maximum of 45 s.*

C12.8.2.4 For the purpose of classification, the time forgenerator start-up and loading is not to exceed 15s.

***12.8.3** Transitional source of emergency electrical power The transitional source of emergency electrical power required by paragraph 12.8.2.4 may consist of an accumulator battery suitably located for use in an emergency which shall operate without recharging while maintaining the voltage of the battery throughout the discharge period within 12% above or below its nominal voltage and be of sufficient capacity and so arranged as to supply automatically, in the event of failure of either the main or emergency source of electrical power, at least the following services, if they depend upon an electrical source for their operation:*

.1 for a period of 30 min, the load specified in 12.8.2.2.1, .2 and .3; and

.2 with respect to watertight doors:

.2.1 power to operate the watertight doors, but not necessarily simultaneously, unless an independent temporary source of stored energy is provided. The power source shall have sufficient capacity to operate each door at least three times, i.e. closed-open-closed, against an adverse list of 15° and

.2.2 power to the control, indication and alarm circuits for the watertight doors for half an hour.

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Section 13

Shipborne Navigational System and Equipment and Voyage Date Recorders

13.1 General

13.1.1 This Section covers items of equipment which relate to the navigation of the craft as distinct from the safe functioning of the craft. The following paragraphs set out the minimum requirements.

13.1.2 The equipment and its installation shall be to the satisfaction of the Administration. The Administration shall determine to what extent the provisions of this Section do not apply to craft below 150 gross tonnage.

13.1.3 The information provided by navigation systems and equipment shall be so displayed that the probability of misreading is reduced to a minimum. navigational systems and equipment shall be capable of giving readings to an optimum accuracy.

13.2 Compasses

13.2.1 Craft shall be provided with a magnetic compass which is capable of operating without electrical supply, and which may be used for steering purposes. This compass shall be mounted in a suitable binnacle containing the required correcting devices and shall be suitable for the speed and motion characteristics of the craft.

13.2.2 The compass card or repeater shall be capable of being easily read from the position at which the craft is normally controlled.

13.2.3 Each magnetic compass shall be properly adjusted and its table or curve of residual deviations shall be available at all times.

13.2.4 Care shall be taken in siting a magnetic compass or magnetic sensing element so that magnetic interference is eliminated or minimized as far as is practicable.

13.2.5 Passenger craft certified to carry 100 passengers or less shall, in addition to the compass required by 13.2.1, be provided with a properly adjusted transmitting heading device, suitable for the speed and motion characteristics and area of operation of the craft, capable of transmitting a true heading reference to other equipment.

13.2.6 Passenger craft certified to carry more than 100 passengers and cargo craft shall, in addition to the compass required in 13.2.1, be provided with a gyro-compass which shall be suitable for the speed and motion characteristics and area of operation of the craft.

13.3 Speed and Distance Measurement

13.3.1 Craft shall be provided with a device capable of indicating speed and distance.

13.3.2 Speed- and distance-measuring devices on craft fitted with an automatic radar plotting aid (ARPA) or automatic tracking aid (ATA) shall be capable of measuring speed and distance through the water.

13.4 Echo-sounding Device

Non-amphibious craft shall be provided with an echo-sounding device which will give an indication of depth of water to a sufficient degree of accuracy for use when the craft is in the displacement mode.

13.5 Radar Installations

13.5.1 Craft shall be provided with at least one azimuth-stabilized radar operating on 9 GHz.

13.5.2 Craft of 500 gross tonnage and upwards or craft certified to carry more than 450 passengers shall also be provided with a 3 GHz radar or where considered appropriate by the Administration a second 9 GHz radar, or other means to determine and display the range and bearing of other surface craft, obstructions, buoys, shorelines and navigational marks to assist in navigation and in collision avoidance, which are functionally independent of those referred to in paragraph 13.5.1.

13.5.3 At least one radar shall be provided with facilities for an ARPA or ATA suitable for the motion and speed of the craft.

13.5.4 Adequate communication facilities shall be provided between the radar observer and the person in immediate charge of the craft.

13.5.5 Each radar installation provided shall be suitable for the intended craft speed, motion characteristics and commonly encountered environmental conditions.

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13.5.6 Each radar installation shall be mounted so as to be as free as practicable from vibration

13.6 Electronic Positioning Systems

Craft shall be provided with a receiver for a global navigation satellite system or a terrestrial radio navigation system, or other means, suitable for use at all times throughout the intended voyage to establish and update the craft's position by automatic means.

13.7 Rate-of-turn Indicator and Rudder Angle Indicator

13.7.1 Craft of 500 gross tonnage or upwards shall be provided with a rate-of-turn indicator. A rate-of-turn indicator shall be provided in craft of less than 500 gross tonnage if the test according to annex 9 shows that the turn rate can exceed safety level 1.

13.7.2 Craft shall be provided with an indicator showing the rudder angle. In craft without a rudder, the indicator shall show the direction of steering thrust.

13.8 Navigational Charts and Nautical Publications

13.8.1 Craft shall be provided with nautical charts and nautical publications to plan and display the ship's route for the intended voyage and to plot and monitor positions throughout the voyage; an electronic chart display and information system (ECDIS) may be accepted as meeting the chart carriage requirements of this paragraph.

13.8.2 High-speed craft shall be fitted with an ECDIS as follows:

.1 craft constructed on or after 1 July 2008;

.2 craft constructed before 1 July 2008, not later than 1 July 2010.

13.8.3 Back-up arrangements shall be provided to meet the functional requirements of 13.8.1, if this function is partly or fully fulfilled by electronic means.

13.9 Searchlight and Daylight Signalling Lamp

13.9.1 Craft shall be provided with at least one adequate searchlight, which shall be controllable from the operating station.

13.9.2 One portable daylight signalling lamp shall be provided and maintained ready for use in the operating compartment at all times.

13.10 Night Vision Equipment

When operational conditions justify the provision of night vision equipment, such equipment shall be provided.

13.11 Steering Arrangement and Propulsion Indicator(s)

13.11.1 The steering arrangement shall be so designed that the craft turns in the same direction as that of the wheel, tiller, joystick or control lever.

13.11.2 Craft shall be provided with means to show the mode of the propulsion system(s).

13.11.3 Craft with emergency steering positions shall be provided with arrangements for supplying visual compass readings to the emergency steering position.

13.12 Automatic Steering Aid (automatic pilot)

13.12.1 Craft shall be provided with an automatic steering aid (automatic pilot).

13.12.2 Provision shall be made to change from the automatic to manual mode by a manual override.

13.13 Radar Reflector

If practicable, craft of 150 gross tonnage or below shall be provided with a radar reflector, or other means, to assist detection by ship navigating by radar at both 9 and 3 GHz.

13.14 Sound Reception System

When the craft's bridge is totally enclosed and unless the Administration determines otherwise, craft shall be provided with a sound reception system, or other means, to enable the officer in charge of the navigational watch to hear sound signals and determine their direction.

13.15 Automatic Identification System

13.15.1 Craft shall be provided with an automatic identification system (AIS) 13.15.2 Aid shall:

.1 provide automatically to appropriately equipped shore stations, other vessels and aircraft information, including the craft's identity, type, position, course, speed, navigational status and other safety-related information;

.2 receive automatically such information from similarly fitted ships;

.3 monitor and track ships; and

.4 exchange data with shore-based facilities.

13.15.2 The requirements of paragraph 13.15.3 shall not be applied to cases where international agreements, rules or standards provide for the protection of navigational information.

13.15.3 AIS shall be operated taking into account the guidelines adopted by the Organization.

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13.16 Voyage Data Recorder

13.16.1 To assist in casualty investigations, passenger craft irrespective of size and cargo craft of 3,000 gross tonnage and upwards shall be provided with a voyage data recorder (VDR).

13.16.2 The voyage data recorder system, including, all sensors, shall be subjected to an annual performance test. The test shall be conducted by an approved testing or servicing facility to verify the accuracy, duration and recoverability of the recorded data. In addition, tests and inspections shall be conducted to determine the serviceability of all protective enclosures and devices fitted to aid location. A copy of the certificate of compliance issued by the testing facilities stating the data of compliance and the applicable performance standards, shall be retained on board the craft.

13.17 Approval of Systems and Equipment, and Performance Standards

13.17.1 All equipment to which this Section applies shall be of a type approved by the Administration. Such equipment shall conform to performance standards not inferior to those adopted by the Organization.

13.17.2 The Administration shall require that the manufacturers have a quality control system audited by a competent authority to ensure continuous compliance with the type approval conditions. Alternatively, the Administration may use final product verification procedures where the compliance with the type approval certificate is verified by a competent authority before the product is installed on board craft.

13.17.3 Before giving approval to systems or equipment embodying new features not covered by this Section, the Administration shall ensure that such features support functions at least as effective as those required by this Section.

13.17.4 When equipment for which performance standards have been developed by the Organization, is carried on craft in addition to those items of equipment required by this Section, such additional equipment shall be subject to approval and shall as far as practicable comply with performance standards not inferior to those adopted by the Organization. [1]

C13.18 Electric Power Supply-distribution Panels

C13.18.1 Local distribution panels are to be provided for all items of electrically operated navigational equipment. These panels are to be supplied by two exclusive circuits, one fed from the main source of electrical power and one fed from an emergency source of electrical power.

Each item of navigational equipment is to be connected individually to its distribution panel.

C13.18.2 Power supplies to distribution panels are to be provided with automatic changeover facilities. Failure of the main power supply to the distribution panels is to set off an audible and visual alarm.

C13.18.3 Following loss of power (black-out), necessary arrangements are to be made to enable all primary functions to be reinstated within 30 seconds.

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[1] *Recommendation on performance standards for magnetic compasses(resolution A.382(X));*

Recommendation on performance standards for marine transmitting magnetic heading devices (TMHDs) (resolution MSC.86(70), annex 2);

Recommendation on performance standards for Gyro-compasses for high-speed craft (resolution A.821(19));

Recommendation on performance standards for devices to indicatespeed and distance (resolution A.824(19), as amended by resolution MSC.96(72));

Recommendation on performance standards for echo-sounding equipment (resolution A.224(VII) as amended by MSC.74(69), annex 2);

Recommendation on performance standards for navigational radar equipment for high-speed craft (resolution A.820(19));

Recommendation on performance standards for "Auto Tracking"(resolution MSC.64(67), annex 4, appendix 1);

Recommendation on performance standards for shipborne Decca navigator receivers (resolution A.816(19));

Recommendation on performance standards for shipborne Loran-C and Chayka receivers (resolution A.818(19));

Recommendation on performance standards for shipborne global positioning system receiver equipment (resolution A.819(19));

Recommendation on performance standards for shipborne GLONASS receiver equipment (resolution MSC.53(66));

Recommendation on performance standards for shipborne DGPS and DGLONASS maritime radio beacon receiver equipment (resolution MSC.64(67), annex 2);

Recommendation on performance standards for combined GPS/GLONASS receiver equipment (resolution MSC.74(69), annex 1);

Performance standards for rate-of-turn indicators (resolution A.526(13));

Recommendation on performance standards for night vision equipmentfor high-speed craft (resolution MSC.94(72));

Recommendation on performance standards for daylight signalling lamps (resolution MSC.95(72)); and

Recommendation on performance standards for automatic steering aids(automatic pilots) for high-speed craft (resolution A.822(19)).

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Section 14

Radiocommunications

14.1 Application

14.1.1 Unless expressly provided otherwise, this Section applies to all craft specified in 1.3.1 and 1.3.2.

14.1.2 This Section does not apply to craft to which this Code would otherwise apply while such craft are being navigated within the Great Lakes of North America and their connecting and tributary waters as far east as the lower exit of the St. Lambert Lock at Montreal in the Province of Quebec, Canada [1].

14.1.3 No provision in this Section shall prevent the use by any craft, survival craft or person in distress of any means at their disposal to attract attention, make known their position and obtain help.

14.2 Terms and Definitions

14.2.1 For the purpose of this Section, the following terms shall have the meanings defined below:

.1 Bridge-to-bridge communications means safety communications between craft and ships from the position from which the craft is normally navigated.

.2 Continuous watch means that the radio watch concerned shall not be interrupted other than for brief intervals when the craft's receiving capability is impaired or blocked by its own communications or when the facilities are under periodical maintenance or checks.

.3 Digital selective calling (DSC) means a technique using digital codes which enables a radio station to establish contact with, and transfer information to, another station or group of stations, and complying with the relevant recommendations of the International Telecommunication Union Radiocommunication Sector (ITU-R).

.4 Direct-printing telegraphy means automated telegraphy techniques which comply with the relevant recommendations of the International Telecommunication Union Radiocommunication Sector (ITU-R).

.5 General radiocommunications means operational and public correspondence traffic other than distress, urgency and safety messages, conducted by radio.

.6 Global Maritime Distress and Safety System (GMDSS) Identities means maritime mobile services identity, the craft's call sign, Inmarsat identities and serial number identity which may be transmitted by the craft's equipment and used to identify the craft.

.7 Inmarsat means the Organization established by the Convention on the International Maritime Satellite Organization (Inmarsat) adopted on 3 September 1976.

.8 International NAVTEX service means the coordinated broadcast and automatic reception on 518 kHz of maritime safety information by means of narrow-band direct-printing telegraphy using the English language. [2]

.9 Locating means the finding of the ships, craft, aircraft, units or persons in distress.

.10 Maritime safety information means navigational and meteorological warnings, meteorological forecasts and other urgent safety-related messages broadcast to ships and craft.

.11 Polar orbiting satellite service means a service which is based on polar orbiting satellites which receive and relay distress alerts from satellite EPIRBs and which provides their position.

.12 Radio Regulations mean the Radio Regulations annexed to, or regarded as being annexed to, the most recent International Telecommunication Convention which is in force at any time.

.13 Sea area A1 means an area within the radiotelephone coverage of at least one VHF coast station in which continuous DSC alerting is available, as may be defined by a Contracting Government to the Convention. [3]

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[1] Such craft are subject to special requirements relative to radio for safety purposes, as contained in the relevant agreement between Canada and the United States.

[2] Refer to the NAVTEX Manual approved by the Organization.

[3] Refer to resolution A.801(19) concerning provision of radio services for the global maritime distress and safety system (GMDSS), adopted by the Organization.

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.14 Sea area A2 means an area, excluding sea area A1, within the radiotelephone coverage of at least one MF coast station in which continuous DSC alerting is available, as may be defined by a Contracting Government to the Convention.[3]

.15 Sea area A3 means an area, excluding sea areas A1 and A2, within the coverage of an Inmarsat geostationary satellite in which continuous alerting is available.

.16 Sea area A4 means an area outside sea areas A1, A2 and A3.

14.2.2 *All other terms and abbreviations which are used in this Section and which are defined in the Radio Regulations and in the International Convention on Maritime Search and Rescue (SAR), 1979, as it may be amended, shall have the meanings as defined in those Regulations and the SAR Convention.*

14.3 Exemptions

14.3.1 *It is considered highly desirable not to deviate from the requirements of this Section; nevertheless the Administration, in conjunction with the base port State, may grant partial or conditional exemptions to individual craft from the requirements of 14.7 to 14.11 provided:*

.1 such craft comply with the functional requirements of 14.5; and

.2 the Administration has taken into account the effect such exemptions may have upon the general efficiency of the service for the safety of all ships and craft.

14.3.1.3 *An exemption may be granted under 14.3.1 only:*

.1 if the conditions affecting safety are such as to render the full application of 14.7 to 14.11 unreasonable or unnecessary; or

.2 in exceptional circumstances, for a single voyage outside the sea area or sea areas for which the craft is equipped.

14.3.2 *Each Administration shall submit to the Organization, as soon as possible after the first of January in each year, a report showing all exemptions granted under 14.3.1 and 14.3.2 during the previous calendar year and giving the reasons for granting such exemptions.*

14.4 Global Maritime Distress and Safety System Identities

14.4.1 *This section applies to all craft on all voyages.*

14.4.2 *Each Administration undertakes to ensure that suitable arrangements are made for registering Global Maritime Distress and Safety System (GMDSS) Identities and for making information on these identities available to Rescue Co-ordination Centres on a 24-hour basis. Where appropriate, international organizations maintaining a registry of these identities shall be notified by the Administration of these assignments.*

14.5 Functional Requirements

14.5.1 *Every craft, while at sea, shall be capable:*

.1 except as provided in 14.8.1.1 and 14.10.1.4.3, of transmitting ship-to-shore distress alerts by at least two separate and independent means, each using a different radiocommunication service;

.2 of receiving shore-to-ship distress alerts;

.3 of transmitting and receiving ship-to-ship distress alerts;

.4 of transmitting and receiving search and rescue co-ordinating communications;

.5 of transmitting and receiving on-scene communications;

.6 of transmitting and, as required by 13.5, receiving signals for locating [4]*;*

.7 of transmitting and receiving [5] *maritime safety information;*

.8 of transmitting and receiving general radiocommunications to and from shore-based radio systems or networks subject to 14.15.8; and

.9 of transmitting and receiving bridge-to-bridge communications.

14.6 Radio Installations

14.6.1 *Every craft shall be provided with radio installations capable of complying with the functional requirements prescribed by 14.5 throughout its intended voyage and, unless exempted under 14.3, complying with the requirements of 14.7 and, as appropriate for the sea area or areas through which it will pass during its intended voyage, the requirements of either 14.8, 14.9, 14.10 or 14.11.*

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[4] *Refer to resolution A.614(15) on carriage of radar operating in the frequency band 9,300 - 9, 500 MHz, adopted by the Organization.*

[5] *It should be noted that craft may have a need for reception of certain maritime safety information while in port.*

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14.6.2 Every radio installation shall:

.1 be so located that no harmful interference of mechanical, electrical or other origin affects its proper use, and so as to ensure electromagnetic compatibility and avoidance of harmful interaction with other equipment and systems;

.2 be so located as to ensure the greatest possible degree of safety and operational availability;

.3 be protected against harmful effects of water, extremes of temperature and other adverse environmental conditions;

.4 be provided with reliable, permanently arranged electrical lighting, independent of the main sources of electrical power, for the adequate illumination of the radio controls for operating the radio installation; and

.5 be clearly marked with the call sign, the ship station identity and other codes as applicable for the use of the radio installation.

14.6.3 Control of the VHF radiotelephone channels, required for navigational safety, shall be immediately available on the navigating bridge convenient to the conning position, and, where necessary, facilities shall be available to permit radiocommunications from the wings of the navigating bridge. Portable VHF equipment may be used to meet the latter provision.

14.6.4 In passenger craft, a distress panel shall be installed at the conning position. This panel shall contain either one single button which, when pressed, initiates a distress alert using all radiocommunication installations required on board for that purpose or one button for each individual installation. The panel shall clearly and visually indicate whenever any button or buttons have been pressed. Means shall be provided to prevent inadvertent activation of the button or buttons. If the satellite EPIRB is used as the secondary means of distress alerting and is not remotely activated, it shall be acceptable to have an additional EPIRB installed in the wheelhouse near the conning position.

14.6.5 In passenger craft, information on the craft's position shall be continuously and automatically provided to all relevant radiocommunication equipment to be included in the initial distress alert when the button or buttons on the distress panel is pressed.

14.6.6 In passenger craft, a distress alert panel shall be installed at the conning position. The distress alarm panel shall provide visual and aural indication of any distress alert or alerts received onboard and shall also indicate through which radiocommunication service the distress alerts have been received.

14.7 Radio Equipment: General

14.7.1 Every craft shall be provided with:

.1 a VHF radio installation capable of transmitting and receiving:

.1.1 DSC on the frequency 156.525 MHz (channel 70). It shall be possible to initiate the transmission of distress alerts on channel 70 from the position from which the craft is normally navigated; and

.1.2 radiotelephony on the frequencies 156.300 MHz (channel 6), 156.650 MHz (channel 13) and 156.800 MHz (channel 16);

.2 a radio installation capable of maintaining a continuous DSC watch on VHF channel 70 which may be separate from, or combined with, that required by 14.7.1.1.1;

.3 a radar transponder capable of operating in the 9 GHz band, which:

.3.1 shall be so stowed that it can be easily utilized; and

.3.2 may be one of those required by 8.2.1.2 for a survival craft;

.4 a receiver capable of receiving International NAVTEX service broadcasts if the craft is engaged on voyages in any area in which an International NAVTEX service is provided;

.5 a radio facility for reception of maritime safety information by the Inmarsat enhanced group calling system [6] if the craft is engaged on voyages in any area of Inmarsat coverage but in which an International NAVTEX service is not provided. However, craft engaged exclusively on voyages in areas where a HF direct printing telegraphy maritime safety information service is provided and fitted with equipment capable of receiving such service may be exempt from this requirements. [7]

.6 subject to the provisions of 14.8.3, a satellite emergency position indicating radio beacon (satellite EPIRB) [8] which shall be:

.6.1 capable of transmitting a distress alert either through the polar orbiting satellite service op-

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6 Refer to resolution A.701(17) concerning carriage of Inmarsat enhanced group call SafetyNET receivers under the GMDSS, adopted by the Organization.

7 Refer to the Recommendation on Promulgation of Maritime Safety Information, adopted by the Organization by resolution A.705(17).

8 Refer to resolution A.616(15) concerning search and rescue homing capability, adopted by the Organization.

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erating in the 406 MHz band or, if the craft is engaged only on voyages within Inmarsat coverage, through the Inmarsat geostationary satellite service operating in the 1.6 GHz band;

.6.2 installed in an easily accessible position;

.6.3 ready to be manually released and capable of being carried by one person into a survival craft;

.6.4 capable of floating free if the craft sinks and of being automatically activated when afloat; and

.6.5 capable of being activated manually.

14.7.2 Every passenger craft shall be provided with means for two-way on-scene radiocommunications for search and rescue purposes using the aeronautical frequencies 121.5 MHz and 123.1 MHz from the position from which the craft is normally navigated.

14.8 Radio Equipment: Sea Area A1

14.8.1 In addition to meeting the requirements of 14.7, every craft engaged on voyages exclusively in sea area A1 shall be provided with a radio installation capable of initiating the transmission of ship-to-shore distress alerts from the position from which the craft is normally navigated, operating either:

.1 on VHF using DSC; this requirement may be fulfilled by the EPIRB prescribed by 14.8.3, either by installing the EPIRB close to, or by remote activation from, the position from which the craft is normally navigated; or

.2 through the polar orbiting satellite service on 406 MHz; this requirement may be fulfilled by the satellite EPIRB, required by 14.7.1.6, either by installing the satellite EPIRB close to, or by remote activation from, the position from which the craft is normally navigated; or

.3 if the craft is on voyages within coverage of MF coast stations equipped with DSC on MF using DSC; or

.4 on HF using DSC; or

.5 through the Inmarsat geostationary satellite service; this requirement may be fulfilled by:

.5.1 an Inmarsat ship earth station [9] ; or

.5.2 the satellite EPIRB, required by 14.7.1.6, either by installing the satellite EPIRB close to, or by remote activation from, the position from which the craft is normally navigated.

14.8.2 The VHF radio installation, required by 14.71.1, shall also be capable of transmitting and receiving general radiocommunications using radiotelephony.

14.8.3 Craft engaged on voyages exclusively in sea area A1 may carry, in lieu of the satellite EPIRB required by 14.7.1.6, an EPIRB which shall be:

.1 capable of transmitting a distress alert using DSC on VHF channel 70 and providing for locating by means of a radar transponder operating in the 9 GHz band;

.2 installed in an easily accessible position;

.3 ready to be manually released and capable of being carried by one person into a survival craft;

.4 capable of floating free if the craft sinks and of being automatically activated when afloat; and

.5 capable of being activated manually.

14.9 Radio Equipment: Sea Areas A1 and A2

14.9.1 In addition to meeting the requirements of 14.7, every craft engaged on voyages beyond sea area A1, but remaining within sea area A2, shall be provided with:

.1 an MF radio installation capable of transmitting and receiving, for distress and safety purposes, on the frequencies:

.1.1 2,187.5 kHz using DSC; and

.1.2 2,182 kHz using radiotelephony;

.2 a radio installation capable of maintaining a continuous DSC watch on the frequency 2,187.5 kHz which may be separate from, or combined with, that required by 14.9.1.1.1; and

.3 means of initiating the transmission of ship-to-shore distress alerts by a radio service other than MF, operating either:

.3.1 through the polar orbiting satellite service on 406 MHz; this requirement may be fulfilled by the satellite EPIRB, required by 14.7.1.6, either by installing the satellite EPIRB close to, or by remote activation from, the position from which the craft is normally navigated; or

.3.2 on HF using DSC; or

.3.3 through the Inmarsat geostationary satellite service; this requirement may be fulfilled by:

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9 This requirement can be met by Inmarsat ship earth stations capable of two-way communications, such as Inmarsat-A and -B (resolution A.808(19)) or Inmarsat-C (resolution A.807(19) and MSC.68(68), annex 4) ship earth stations. Unless otherwise specified, this footnote applies to all requirements for an Inmarsat ship earth station prescribed by this chapter.

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.3.3.1 the equipment specified in 14.9.3.2; or

.3.3.2 the satellite EPIRB, required by 14.7.1.6, either by installing the satellite EPIRB close to, or by remote activation from, the position from which the craft is normally navigated.

14.9.2 *It shall be possible to initiate transmission of distress alerts by the radio installations specified in 14.9.1.1 and 14.9.1.3 from the position from which the craft is normally navigated.*

14.9.3 *The craft shall, in addition, be capable of transmitting and receiving general radiocommunications using radiotelephony or direct-printing telegraphy by either:*

.1 a radio installation operating on working frequencies in the bands between 1,605 kHz and 4,000 kHz or between 4,000 kHz and 27,500 kHz; this requirement may be fulfilled by the addition of this capability in the equipment required by 14.9.1.1; or

.2 an Inmarsat ship earth station.

14.10 Radio Equipment: Sea Areas A1, A2 and A3

14.10.1 *In addition to meeting the requirements of 14.7, every craft engaged on voyages beyond sea areas A1 and A2, but remaining within sea area A3, shall, if it does not comply with the requirements of 14.10.2, be provided with:*

.1 an Inmarsat ship earth station capable of:

.1.1 transmitting and receiving distress and safety communications using direct-printing telegraphy;

.1.2 initiating and receiving distress priority calls;

.1.3 maintaining watch for shore-to-ship distress alerts, including those directed to specifically defined geographical areas; and

.1.4 transmitting and receiving general radiocommunications, using either radiotelephony or direct-printing telegraphy;

.2 an MF radio installation capable of transmitting and receiving, for distress and safety purposes, on the frequencies:

.2.1 2,187.5 kHz using DSC; and

.2.2 2,182 kHz using radiotelephony;

.3 a radio installation capable of maintaining a continuous DSC watch on the frequency 2,187.5 kHz which may be separate from, or combined with, that required by 14.10.1.2.1; and

.4 means of initiating the transmission of ship-to-shore distress alerts by a radio service operating either:

.4.1 through the polar orbiting service on 406 MHz; this requirement may be fulfilled by the satellite EPIRB, required by 14.7.1.6, either by installing the satellite EPIRB close to, or by remote activation from, the position from which the craft is normally navigated; or

.4.2 on HF using DSC; or

.4.3 through the Inmarsat geostationary satellite service, by an additional ship earth station or by the satellite EPIRB required by 14.7.1.6, either by installing the satellite EPIRB close to, or by remote activation from, the position from which the craft is normally navigated.

14.10.2 *In addition to meeting the requirements of 14.7, every craft engaged on voyages beyond sea areas A1 and A2, but remaining within sea area A3, shall, if it does not comply with the requirements of 14.10.1, be provided with:*

.1 an MF/HF radio installation capable of transmitting and receiving, for distress and safety purposes, on all distress and safety frequencies in the bands between 1,605 kHz and 4,000 kHz and between 4,000 kHz and 27,500 kHz:

.1.1 using DSC;

.1.2 using radiotelephony; and

.1.3 using direct-printing telegraphy;

.2 equipment capable of maintaining a DSC watch on 2,187.5 kHz, 8,414.5 kHz and on at least one of the distress and safety DSC frequencies 4,207.5 kHz, 6,312 kHz, 12,577 kHz or 1 6,804.5 kHz at any time, it shall be possible to select any of these DSC distress and safety frequencies. This equipment may be separate from, or combined with, the equipment required by 14.10.2.1;

.3 means of initiating the transmission of ship-to-shore distress alerts by a radiocommunication service other than HF operating either:

.3.1 through the polar orbiting satellite service on 406 MHz; this requirement may be fulfilled by the satellite EPIRB required by 14.7.1.6, either by installing the satellite EPIRB close to, or by remote activation from, the position from which the craft is normally navigated; or

.3.2 through the Inmarsat geostationary satellite service, this requirement may be fulfilled by:

.3.2.1 an Inmarsat ship earth station; or

.3.2.2 the satellite EPIRB, required by 14.7.1.6, either by installing the satellite EPIRB close to,

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or by remote activation from, the position from which the craft is normally navigated; and

.4 in addition, the craft shall be capable of transmitting and receiving general radiocommunications using radiotelephony or direct-printing telegraphy by an MF/HF radio installation operating on working frequencies in the bands between 1,605 kHz and 4,000 kHz and between 4,000 kHz and 27,500 kHz. This requirement may be fulfilled by the addition of this capability in the equipment required by 14.10.2.1.

***14.10.3** It shall be possible to initiate transmission of distress alerts by the radio installations specified in 14.10.1.1, 14.10.1.2, 14.10.1.4, 14.10.2.1 and 14.10.2.3 from the position from which the craft is normally navigated.*

14.11 Radio Equipment: Sea Areas A1, A2, A3 and A4

In addition to meeting the requirements of 14.7, craft engaged on voyages in all sea areas shall be provided with the radio installations and equipment required by 14.10.2, except that the equipment required by 14.10.2.3.2 shall not be accepted as an alternative to that required by 14.10.2.3.1, which shall always be provided. In addition, craft engaged on voyages in all sea areas shall comply with the requirements of 14.10.3.

14.12 Watches

***14.12.1** Every craft, while at sea, shall maintain a continuous watch:*

.1 on VHF DSC channel 70, if the craft, in accordance with the requirements of 14.7.1.2, is fitted with a VHF radio installation;

.2 on the distress and safety DSC frequency 2,187.5 kHz, if the craft, in accordance with the requirements of 14.9.1.2 or 14.10.1.3, is fitted with an MF radio installation;

.3 on the distress and safety DSC frequencies 2,187.5 kHz and 8,414.5 kHz and also on at least one of the distress and safety DSC frequencies 4,207.5 kHz, 6,312 kHz, 12,577 kHz or 16,804.5 kHz, appropriate to the time of day and the geographical position of the craft, if the craft, in accordance with the requirements of 14.10.2.2 or 14.11.1, is fitted with an MF/HF radio installation. This watch may be kept by means of a scanning receiver; and

.4 for satellite shore-to-ship distress alerts, if the craft, in accordance with the requirements of 14.10.1.1, is fitted with an Inmarsat ship earth station.

***14.12.2** Every craft, while at sea, shall maintain a radio watch for broadcasts of maritime safety information on the appropriate frequency or frequencies on which such information is broadcast for the area in which the craft is navigating.*

***14.12.3** Until 1 February 2005, every craft, while at sea shall continue to maintain, when practicable, a continuous listening watch on VHF channel 16. This watch shall be kept at the position from which the craft is normally navigated.*

14.13 Sources of Energy

***14.13.1** There shall be available at all times, while the craft is at sea, a supply of electrical energy sufficient to operate the radio installations and to charge any batteries used as part of a reserve source of energy for the radio installations.*

***14.13.2** Reserve and emergency sources of energy shall be provided on every craft to supply radio installations, for the purpose of conducting distress and safety radiocommunications, in the event of failure of the craft's main and emergency sources of electrical power. The reserve source of energy shall be capable of simultaneously operating the VHF radio installation required by 14.7.1.1 and, as appropriate for the sea area or sea areas for which the craft is equipped, either the MF radio installation required by 14.9.1.1, the MF/HF radio installation required by 14.10.2.1 or 14.11.1 or the Inmarsat ship earth station required by 14.10.1.1 and any of the additional loads mentioned in 14.13.5 and 14.13.8 for a period of at least 1 h.*

***14.13.3** The reserve source of energy shall be independent of the propelling power of the craft and the craft's electrical system.*

***14.13.4** Where, in addition to the VHF radio installation, two or more of the other radio installations referred to in 14.13.2 can be connected to the reserve source or sources of energy, they shall be capable of simultaneously supplying, for the period specified in 14.13.2, the VHF radio installation and:*

.1 all other radio installations which can be connected to the reserve source of energy at the same time; or

.2 whichever of the radio installations will consume the most power, if only one of the other radio installations can be connected to the reserve source of energy at the same time as the VHF radio installation.

***14.13.5** The reserve source of energy may be used to supply the electrical lighting required by 14.6.2.4.*

***14.13.6** Where a reserve source of energy consists of a rechargeable accumulator battery or batteries:*

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.1 *a means of automatically charging such batteries shall be provided which shall be capable of recharging them to minimum capacity requirements within 10 h; and*

.2 *the capacity of the battery or batteries shall be checked, using an appropriate method [10], at intervals not exceeding 12 months, when the craft is not at sea.*

14.13.7 *The siting and installation of accumulator batteries which provide a reserve source of energy shall be such as to ensure:*

.1 *the highest degree of service;*

.2 *a reasonable lifetime;*

.3 *reasonable safety;*

.4 *that the battery temperatures remain within the manufacturer's specifications whether under charge or idle; and*

.5 *that when fully charged, the batteries will provide at least the minimum required hours of operation under all weather conditions.*

14.13.8 *If an uninterrupted input of information from the craft's navigational or other equipment to a radio installation required by this Section is needed to ensure its proper performance, including the navigation receiver referred to in 14.18, means shall be provided to ensure the continuous supply of such information in the event of failure of the craft's main or emergency source of electrical power.*

14.14 Performance Standards

14.14.1 *All equipment to which this Section applies shall be of a type approved by the Administration. Such equipment shall conform to appropriate performance standards not inferior to those adopted by the Organization [11].*

14.15 Maintenance Requirements

14.15.1 *Equipment shall be so designed that the main units can be replaced readily without elaborate recalibration or readjustment.*

14.15.2 *Where applicable, equipment shall be so constructed and installed that it is readily accessible for inspection and on-board maintenance purposes.*

14.15.3 *Adequate information shall be provided to enable the equipment to be properly operated and*

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10 One method of checking the capacity of an accumulator battery is to fully discharge and recharge the battery, using normal operating current and period (e.g. 10 h). Assessment of the charge condition can be made at any time, but it should be done without significant discharge of the battery when the craft is at sea.

11 Refer to the following resolutions adopted by the Assembly of the Organization:

Resolution A.525(13): Performance Standards for Narrow-Band Direct-Printing Telegraph Equipment for the Reception of Navigational and Meteorological Warnings and Urgent Information to Ships.

Resolution A.694(17): General Requirements for Shipborne Radio Equipment Forming Part of the Global Maritime Distress and Safety System (GMDSS) and for Electronic Navigational Aids.

Resolution A.808(19): Performance Standards for Ship Earth Stations Capable of Two-Way Communications, and resolution A.570(14), Type Approval of Ship Earth Stations.

Resolutions A.803(19) and MSC.68(68), annex 1: Performance Standards for Shipborne VHF Radio installations Capable of Voice Communication and Digital Selective Calling.

Resolutions A.804(19) and MSC.68(68), annex 2: Performance Standards for Shipborne MF Radio Installations Capable of Voice Communication and Digital Selective Calling.

Resolutions A.806(19) and MSC.68(68), annex 3: Performance Standards for Shipborne MF/HF Radio Installations Capable of Voice Communication, Narrow-Band Direct Printing and Digital Selective Calling.

Resolutions A.810(19) and MSC.56(66): Performance Standards for Float-Free Satellite Emergency Position-Indicating Radio Beacons (EPIRBs) Operating on 406 MHz (see also Assembly resolution A.696(17): Type Approval of Satellite Emergency Position-Indicating Radio Beacons (EPIRBs) Operating in the COSPAS-SARSAT System).

Resolution A.802(19): Performance Standards for Survival Craft Radar Transponders for Use in Search and Rescue Operations.

Resolution A.805(19): Performance Standards for Float-Free VHF Emergency Position-Indicating Radio Beacons.

Resolutions A. 807(19) and MSC.68(68), annex 4: Performance Standards for Inmarsat Standard-C Ship Earth Stations Capable of Transmitting and Receiving Direct-Printing Communications, and resolution A.570(14), Type Approval of Ship Earth Stations.

Resolution A.664(16): Performance Standards for Enhanced Group Call Equipment.

Resolution A.812(19): Performance Standards for Float-Free Satellite Emergency Position-indicating Radio Beacons Operating Through the Ceostationary Inmarsat Satellite System on 1.6 GHz.

Resolution A.662(16): Performance Standards for Float-Free Release and Activation Arrangements for Emergency Radio Equipment.

Resolution A.699(17): System Performance Standard for the Promulgation and Co-ordination of Maritime Safety Information Using High-Frequency Narrow-Band Direct Printing.

Resolution A.700(17): Performance Standards for Narrow-Band Direct-Printing Telegraph Equipment for the Reception of Navigational and Meteorological Warnings and Urgent Information to Ships (MSI) by HF.

Resolution MSC.80(70): Recommendation on Performance Standards for on-scene (Aeronautical) Portable Two-Way VHF Radiotelephone Apparatus.

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maintained, taking into account the recommendations of the Organization. [12]

14.15.4 *Adequate tools and spares shall be provided to enable equipment to be maintained.*

14.15.5 *The Administration shall ensure that radio equipment required by this Section is maintained to provide the availability of the functional requirements specified in 14.5 and to meet the recommended performance standards of such equipment.*

14.15.6 *On craft engaged on voyages in sea areas A1 and A2, the availability shall be ensured by using such methods as duplication of equipment, shore-based maintenance or at-sea electronic maintenance capability, or a combination of these, as may be approved by the Administration.*

14.15.7 *On craft engaged on voyages in sea areas A3 and A4, the availability shall be ensured by using a combination of at least two methods, such as duplication of equipment, shore-based maintenance or at-sea electronic maintenance capability, as may be approved by the Administration, taking into account the recommendations of the Organization.* [13]

14.15.8 *However, for craft operating solely between ports where adequate facilities for shore-based maintenance of the radio installations are available and provided no journey between two such ports exceeds six hours, then the Administration may exempt such craft from the requirement to use at least two maintenance methods. For such craft at least one maintenance method shall be used.*

14.15.9 *While all reasonable steps shall be taken to maintain the equipment in efficient working order to ensure compliance with all the functional requirements specified in 14.5, malfunction of the equipment for providing the general radiocommunications, required by 14.8, shall not be considered as making a craft unseaworthy or as a reason for delaying the craft in ports where repair facilities are not readily available, provided the craft is capable of performing all distress and safety functions.*

14.15.10 *Satellite EPIRBs on all craft shall be:*

.1 *annually tested for all aspects of operational efficiency, with special emphasis on checking the emission on operational frequencies, coding and registration, at intervals as specified below:*

.1.1 *on passenger craft, within 3 months before the expiry date of the High-Speed Craft Safety Certificate; and*

.1.2 *on cargo craft, within 3 months before the expiry date, or 3 months before or after the anniversary date, of the High-Speed Craft Safety Certificate;*

The test may be conducted on board the craft or at an approved testing station; and

.2 *subject to maintenance at intervals not exceeding five years, to be performed at an approved shore-based maintenance facility.*

14.16 Radio Personnel

14.16.1 *Every craft shall carry personnel qualified for distress and safety radiocommunication purposes to the satisfaction of the Administration. The personnel shall be holders of certificates specified in the Radio Regulations as appropriate, any one of whom shall be designated to have primary responsibility for radiocommunications during distress incidents.*

14.16.2 *In passenger craft, at least one person qualified in accordance with sub-paragraph .1 shall be assigned to perform only radiocommunication duties during distress incidents.*

14.17 Radio Records

A record shall be kept, to the satisfaction of the Administration and as required by the Radio Regulations, of all incidents connected with the radiocommunication service which appear to be of importance to safety of life at sea.

14.18 Position-updating

All two-way communication equipment carried on board craft to which this Section applies which is capable of automatically including the craft's position in the distress alert shall be automatically provided with this information from an internal or external navigation receiver, if either is installed. If such a receiver is not installed, the craft's position and the time that position was correct shall be manually updated at intervals not exceeding four hours, while the craft is underway, so that it is always ready for transmission by the equipment.

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[12] *Refer to the Recommendation on General Requirements for Shipborne Radio Equipment Forming Part of the Global Maritime Distress and Safety System (GMDSS) and for Electronic Navigational Aids, adopted by the Organization by resolution A.694(17).*

[13] *Administrations should take account of the Radio Maintenance Guidelines for the Global Maritime Distress and Safety System (GMDSS) related to Sea Areas A3 and A4, adopted by the Organization by resolution A.702(17).*

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Section 15

Operating Compartment Layout

15.1 Definitions

15.1.1 Operating area is the operating compartment and those parts of the craft on both sides of, and close to, the operating compartment which extend to the craft's side.

15.1.2 Workstation is a position at which one or several tasks constituting a particular activity are carried out.

15.1.3 Docking workstation is a place equipped with necessary means for docking the craft.

15.1.4 Primary controls are all control equipment necessary for the safe operation of the craft when it is under way, including those required in an emergency situation.

15.2 General

The design and layout of the compartment from which the crew operate the craft shall be such as to permit operating crew members to perform their duties in a correct manner without unreasonable difficulty, fatigue or concentration, and to minimize the likelihood of injury to operating crew members in both normal and emergency conditions

15.3 Field of Vision from the Operating Compartment

15.3.1 The operating station shall be placed above all other superstructures so that the operating crew are able to gain a view all round the horizon from the navigating workstation. Where it is impractical to meet the requirements of this paragraph from a single navigating workstation, the operating station shall be designed so that an all-round view of the horizon is obtained by using two navigating workstations combined or by any other means to the satisfaction of the Administration.

15.3.2 Blind sectors shall be as few and as small as possible, and not adversely affect the keeping of a safe look-out from the operating station. If stiffeners between windows are to be covered, this shall not cause further obstruction inside the wheelhouse.

15.3.3 The total arc of blind sectors from right ahead to 22.5° abaft the beam on either side shall not exceed 20°. Each individual blind sector shall not exceed 5°. The clear sector between two blind sectors shall not be less than 10°.

15.3.4 Where it is considered necessary by the Administration, the field of vision from the navigating workstation shall permit the navigators from this position to utilize leading marks astern of the craft for track monitoring.

15.3.5 The view of the sea surface from the operating station, when the navigators are seated, shall not be obscured by more than one craft length forward of the bow to 90°on either side irrespective of the craft's draught, trim and deck cargo.

15.3.6 The field of vision from the docking workstation, if remote from the operating station, shall permit one navigator to safely manoeuvre the craft to a berth.

15.4 Operating Compartment

15.4.1 The design and arrangement of the operating compartment, including location and layout of the individual workstations, shall ensure the required field of vision for each function.

15.4.2 The craft's operating compartment shall not be used for purposes other than navigation, communications and other functions essential to the safe operation of the craft, its engines, passengers and cargo.

15.4.3 The operating compartment shall be provided with an integrated operating station for command, navigation, manoeuvring and communication and so arranged that it can accommodate those persons required to navigate the craft safely.

15.4.4 The arrangement of equipment and means for navigation, manoeuvring, control, communication and other essential instruments shall be located sufficiently close together to enable both the officer in charge and any assisting officer to receive all necessary information and to use the equipment and controls, as required, while they are seated. If necessary, the equipment and means serving these functions shall be duplicated.

15.4.5 If a separate workstation for supervision of engine performance is placed in the operating compartment, the location and use of this workstation shall not interfere with the primary functions to be performed in the operating station.

15.4.6 The location of the radio equipment shall not interfere with the primary navigational functions in the operating station.

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15.4.7 The design and layout of the compartment from which the crew operate the craft and the relative positions of the primary controls shall be assessed against the essential operational manning level. Where minimum manning levels are proposed, the design and layout of the primary and communication controls shall form an integrated operational and emergency control centre from which the craft can be controlled under all operational and emergency events by the operating crew without the necessity for any crew member to vacate the compartment.

15.4.8 The relative positions of the primary controls and the seats shall be such that each operating crew member, with the seat suitably adjusted and without prejudicing compliance with 15.2, can:

.1 without interference, produce full and unrestricted movement of each control both separately and with all practical combinations of movement of other controls; and

.2 at all workstations, exert adequate control forces for the operation to be performed.

15.4.9 When a seat at a station from which the craft may be operated has been adjusted so as to suit the occupant, subsequent change of seat position to operate any control shall not be acceptable.

15.4.10 In craft where the Administration considers the provision of a safety belt necessary for use by the operating crew, it shall be possible for those operating crew members, with their safety belts correctly worn, to comply with 15.4.4 except in respect of controls which it can be shown will only be required on very rare occasions and which are not associated with the need for safety restraint.

15.4.11 The integrated operating station shall contain equipment which provides relevant information to enable the officer in charge and any assisting officer to carry out navigational and safety functions safely and efficiently.

15.4.12 Adequate arrangements shall be made to prevent passengers from distracting the attention of the operating crew.

15.5 Instruments and Chart Table

15.5.1 Instruments, instrument panels and controls shall be permanently mounted in consoles or other appropriate places, taking into account operation, maintenance and environmental conditions. However, this shall not prevent the use of new control or display techniques, provided the facilities offered are not inferior to recognized standards.

15.5.2 All instruments shall be logically grouped according to their functions. in order to reduce to a minimum the risk of confusion, instruments shall not be rationalized by sharing functions or by interswitching.

15.5.3 Instruments required for use by any member of the operating crew shall be plainly visible and easily read:

.1 with minimum practicable deviation from his normal seating position and line of vision; and

.2 with the minimum risk of confusion under all likely operating conditions.

15.5.4 Instruments essential for the safe operation of the craft shall be clearly marked with any limitation if this information is not otherwise clearly presented to the operating crew. The instrument panels forming the emergency control for the launching of liferafts and the monitoring of the fire-fighting systems shall be in separate and clearly defined positions within the operating area.

15.5.5 The instruments and controls shall be provided with means for screening and dimming in order to minimize glare and reflections and prevent them being obscured by strong light.

15.5.6 The surfaces of console tops and instruments shall have dark glare-free colours.

15.5.7 Instruments and displays providing visual information to more than one person shall be located for easy viewing by all users concurrently. If this is not possible, the instrument or display shall be duplicated.

15.5.8 If considered necessary by the Administration, the operating compartment shall be provided with a suitable table for chart work. There shall be facilities for lighting the chart. Chart-table lighting shall be screened.

15.6 Lighting

15.6.1 A satisfactory level of lighting shall be available to enable the operating personnel to adequately perform all their tasks both at sea and in port, by day and night. There shall be only a limited reduction in the illumination of essential instruments and controls under likely system fault conditions.

15.6.2 Care shall be taken to avoid glare and stray image reflection in the operating area environment. High contrast in brightness between work area and surroundings shall be avoided. Non-reflective or matt surfaces shall be used to reduce indirect glare to a minimum.

15.6.3 A satisfactory degree of flexibility within the lighting system shall be available to enable the operating personnel to adjust the lighting intensity and direction as required in the different areas of the op-

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erating compartment and at individual instruments and controls.

15.6.4 *Red light shall be used to maintain dark adaptation whenever possible in areas or on items of equipment requiring illumination in the operational mode, other than the chart table.*

15.6.5 *During hours of darkness, it shall be possible to discern displayed information and control devices.*

15.6.6 *Reference is made to additional requirements on lighting in 12.7 and 12.8.*

15.7 Windows

15.7.1 *Divisions between windows, located in the front, on the sides and in the doors, shall be kept to a minimum. No division shall be installed immediately forward of the operating stations.*

15.7.2 *Administrations shall be satisfied that a clear view through the operating compartment windows is provided at all times regardless of weather conditions. The means provided for maintaining the windows in a clear condition shall be so arranged that no reasonably probable single failure can result in a reduction of the cleared field of vision such as to interfere seriously with the ability of the operating crew to continue the operation and bring the craft to rest.*

15.7.3 *Arrangements shall be provided so that the forward view from operating stations is not adversely affected by solar glare. Neither polarized nor tinted window glass shall be fitted.*

15.7.4 *Operating compartment windows shall be angled to reduce unwanted reflection.*

15.7.5 *The windows shall be made of material which will not break into dangerous fragments if fractured.*

15.8 Communication Facilities

15.8.1 *Such means as are necessary shall be provided to enable the crew to communicate between, and have access to, each other and with other occupants of the craft in both normal and emergency conditions.*

15.8.2 *Means to communicate between the operating compartment and spaces containing essential machinery, including any emergency steering position, irrespective of whether the machinery is remotely or locally controlled, shall be provided.*

15.8.3 *Means for making public address and safety announcements from control stations to all areas to which passengers and crew have access shall be provided.*

15.8.4 *Provisions shall be made for means to monitor, receive and transmit radio safety messages at the operating compartment.*

15.9 Temperature and Ventilation

The operating compartment shall be equipped with adequate temperature and ventilation control systems.

15.10 Colours

The surface materials inside the operating compartment shall have a suitable colour and finish to avoid reflections.

15.11 Safety Measures

The operating area shall be free of physical hazard to the operating personnel and have non-skid flooring in dry and wet conditions and adequate handrails. Doors shall be fitted with devices to prevent them moving, whether they are open or closed.

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Section 16

Stabilization Systems

16.1 Definitions

16.1.1 *Stabilization control system is a system intended to stabilize the main parameters of the craft's attitude: heel, trim, course and height and control the craft's motions: roll, pitch, yaw and heave. This term excludes devices not associated with the safe operation of the craft, e.g. motion-reduction or ride-control systems.*

The main elements of a stabilization control system may include the following:

.1 *devices such as rudders, foils, flaps, skirts, fans, water jets, tilting and steerable propellers, pumps for moving fluids;*

.2 *power drives actuating stabilization devices; and*

.3 *stabilization equipment for accumulating and processing data for making decisions and giving commands such as sensors, logic processors and automatic safety control.*

16.1.2 *Self-stabilization of the craft is stabilization ensured solely by the craft's inherent characteristics.*

16.1.3 *Forced stabilization of the craft is stabilization achieved by:*

.1 *an automatic control system; or*

.2 *a manually assisted control system; or*

.3 *a combined system incorporating elements of both automatic and manually assisted control systems.*

16.1.4 *Augmented stabilization is a combination of self-stabilization and forced stabilization.*

16.1.5 *Stabilization device means a device as enumerated in 16.1.1.1 with the aid of which forces for controlling the craft's position are generated.*

16.1.6 *Automatic safety control is a logic unit for processing data and making decisions to put the craft into the displacement or other safe mode if a condition impairing safety arises.*

16.2 General Requirements

16.2.1 *Stabilization systems shall be so designed that, in case of failure or malfunctioning of any one of the stabilization devices or equipment, it would be possible either to ensure maintaining the main parameters of the craft's motion within safe limits with the aid of working stabilization devices or to put the craft into the displacement or other safe mode.*

16.2.2 *In case of failure of any automatic equipment or stabilization device, or of its power drive, the parameters of craft motion shall remain within safe limits.*

16.2.3 *Craft fitted with an automatic stabilization system shall be provided with an automatic safety control unless the redundancy in the system provides equivalent safety. Where an automatic safety control is fitted, provision shall be made to override it and to cancel the override from the main operating station.*

16.2.4 *The parameters and the levels at which any automatic safety control gives the command to decrease speed and put the craft safely in the displacement or other safe mode shall take account of the safe values of heel, trim, yaw and combination of trim and draught appropriate to the particular craft and service; also to the possible consequences of power failure for propulsion, lift or stabilization devices.*

16.2.5 *The parameters and the degree of stabilization of the craft provided by the automatic stabilization system shall be satisfactory, having regard to the purpose and service conditions of the craft.*

16.2.6 *Failure mode and effect analysis shall include the stabilization system.*

16.3 Lateral and Height Control Systems

16.3.1 *Craft fitted with an automatic control system shall be provided with an automatic safety control. Probable malfunctions shall have only minor effects on automatic control system operation and shall be capable of being readily counteracted by the operating crew.*

16.3.2 *The parameters and levels at which any automatic control system gives the command to decrease speed and put the craft safely into the displacement or other safe mode shall take account of the safety levels as given in section 2.4 of annex 3 and of the safe values of motions appropriate to the particular craft and service.*

16.4 Demonstrations

16.4.1 *The limits of safe use of any of the stabilization control system devices shall be based on demonstrations and a verification process in accordance with annex 9.*

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16.4.2 Demonstration in accordance with annex 9 shall determine any adverse effects upon safe operation of the craft in the event of an uncontrollable total deflection of any one control device. Any limitation on the operation of the craft as may be necessary to ensure that the redundancy or safeguards in the systems provide equivalent safety shall be included in the craft operating manual.

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Section 17

Handling, Controllability and Performance

17.1 General

The operational safety of the craft in normal service conditions and in equipment failure situations of a craft to which this Code applies shall be documented and verified by full-scale tests, supplemented by model tests where appropriate, of the prototype craft. The objective of tests is to determine information to be included in the craft operating manual in relation to:

.1 operating limitations;

.2 procedures for operation of the craft within the limitations;

.3 actions to be taken in the event of prescribed failure; and

.4 limitations to be observed for safe operation subsequent to prescribed failures.

Operational information shall be available on board for guidance, or the craft shall have an instrument system for on-line check of operational performance which shall be approved by the Administration taking into account the standards for the processing and presentation of measurements developed by the Organization. As a minimum, the system shall measure accelerations in three axes close to the craft longitudinal centre of gravity.

17.2 Proof of Compliance

17.2.1 The information on controllability and manoeuvrability which shall be contained in the craft operating manual shall include the characteristics under 17.5 as applicable, the list of parameters of the worst intended conditions affecting the controllability and manoeuvrability according to 17.6, information on safe maximum speeds as described in 17.9 and the performance data verified in accordance with annex 9.

17.2.2 The information on operating limitations which shall be contained in the route operational manual shall include the characteristics under 17.2.1, 17.5.4.1 and 17.5.4.2.

17.3 Weight and Centre of Gravity

Compliance with each of the handling, controllability and performance requirements shall be established for all combinations of weight and centre of gravity position significant for the operational safety in the range of weights up to the maximum permissible weight.

17.4 Effect of Failures

The effect of any likely failure in handling and control devices, services or components (e.g. power operation, power assistance, trimming and stability augmentation) shall be assessed in order that a safe level of craft operation can be maintained. Effects of failure identified as being critical according to annex 4 shall be verified in accordance with annex 9.

17.5 Controllability and Manoeuvrability

17.5.1 Instructions to crew members shall be provided in the craft operating manual regarding required actions and craft limitations subsequent to prescribed failures.

17.5.2 It is necessary to ensure that the effort required to operate the controls in the worst intended conditions is not such that the person at the control will be unduly fatigued or distracted by the effort necessary to maintain the safe operation of the craft.

17.5.3 The craft shall be controllable and be capable of performing those manoeuvres essential to its safe operation up to the critical design conditions.

17.5.4.1 When determining the operating limitations of a craft, particular attention shall be paid to the following aspects during normal operation and during failures and subsequent to failures:

.1 yawing;

.2 turning;

.3 automatic pilot and steering performance;

.4 stopping in normal and emergency conditions;

.5 stability in the non-displacement mode about three axes and in heave;

.6 trim;

.7 roll;

.8 plough in;

.9 lift power limitations;

.10 broaching;

.11 slamming; and

.12 bow diving.

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17.5.4.2 The terms in 17.5.4.1.2, .6, .7 and .11 are defined as follows:

.1 "Turning" is the rate of change of direction of a craft at its normal maximum operating speed in specified wind and sea conditions.

.2 "Plough in" is an involuntary motion involving sustained increase in drag of an air-cushion vehicle at speed, usually associated with partial collapse of the cushion system.

.3 "Lift power limitations" are those limitations imposed upon the machinery and components which provide the lift.

.4 "Slamming" is the water impact on the underside of the hull in the bow area of the craft.

17.6 Change of Operating Surface and Mode

There shall be no unsafe change in the stability, controllability or attitude of the craft during transition from one type of operating surface or mode to another. Information on change in the behaviour characteristics of the craft during transition shall be available to the master.

17.7 Surface Irregularities

Factors which limit the ability of the craft to operate over sloping ground and steps or discontinuities shall be determined, as applicable, and made available to the master.

17.8 Acceleration and Deceleration

The Administration shall be satisfied that the worst likely acceleration or deceleration of the craft, due to any likely failure, emergency stopping procedures or other likely causes, would not hazard the persons on the craft.

17.9 Speeds

Safe maximum speeds shall be determined, taking account of the limitations from 4.3.1, modes of operation, wind force and direction and the effects of possible failures of any one lift or propulsion system over calm water, rough water and over other surfaces, as appropriate to the craft.

17.10 Minimum Depth of Water

The minimum depth of water and other appropriate information required for operations in all modes shall be determined.

17.11 Hard Structure Clearance

For amphibious craft, when cushion-borne, clearance of the lowest point of the hard structure above a hard flat surface shall be determined.

17.12 Night Operation

The schedule of tests shall include sufficient operation to evaluate the adequacy of internal and external lighting and visibility under conditions of normal and emergency electrical power supply during service, cruising and docking manoeuvres.

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Section 18

Operational Requirements

Part A General

18.1 Craft Operational Control

18.1.1 The High-Speed Craft Safety Certificate, the Permit to Operate High-Speed Craft or certified copies thereof, and copies of the route operational manual, craft operating manual, and a copy of such elements of the maintenance manual as the Administration may require shall be carried on board.

18.1.2 The craft shall not be intentionally operated outside the worst intended conditions and limitations specified in the Permit to Operate High-Speed Craft, in the High-Speed Craft Safety Certificate, or in documents referred to therein.

18.1.3 The Administration shall issue a Permit to Operate High-Speed Craft when it is satisfied that the operator has made adequate provisions from the point of view of safety generally, including the following matters specifically, and shall revoke the Permit to Operate if such provisions are not maintained to its satisfaction:

.1 the suitability of the craft for the service intended, having regard to the safety limitations and information contained in the route operational manual;

.2 the suitability of the operating conditions in the route operational manual;

.3 the arrangements for obtaining weather information on the basis of which the commencement of a voyage may be authorized;

.4 provision in the area of operation of a base port having functions and facilities in accordance with the requirements of this Code;

.5 the designation of the person responsible for decisions to cancel or delay a particular voyage, e.g. in the light of the weather information available;

.6 sufficient crew complement required for operating the craft, deploying and manning survival craft, the supervision of passengers, vehicles and cargo in both normal and emergency conditions as defined in the Permit to Operate. The crew complement shall be such that two officers are on duty in the operating compartment when the craft is under way, one of whom may be the master;

.7 crew qualifications and training, including competence in relation to the particular type of craft and service intended, and their instructions in regard to safe operational procedures;

.8 restrictions with regard to working hours, rostering of crews and any other arrangements to prevent fatigue, including adequate rest periods;

.9 the training of crew in craft operation and emergency procedures;

.10 the maintenance of crew competence in regard to operation and emergency procedures;

.11 safety arrangements at terminals and compliance with any existing safety arrangements, as appropriate;

.12 traffic control arrangements and compliance with any existing traffic control, as appropriate;

.13 restrictions and/or provisions relating to position fixing and to operation by night or in restricted visibility, including the use of radar and/or other electronic aids to navigation, as appropriate;

.14 additional equipment which may be required, due to the specific characteristics of the service intended, for example, night operation;

.15 communication arrangements between craft, coast radio stations, base ports radio stations, emergency services and other ships, including radio frequencies to be used and watch to be kept;

.16 the keeping of records to enable the Administration to verify:

.16.1 that the craft is operated within the specified parameters,

.16.2 the observance of emergency and safety drills/procedures;

.16.3 the hours worked by the operating crew;

.16.4 the number of passengers on board;

.16.5 compliance with any law to which the craft is subject;

.16.6 craft operations; and

.16.7 maintenance of the craft and its machinery in accordance with approved schedules;

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.17 arrangements to ensure that equipment is maintained in compliance with the Administration's requirements, and to ensure co-ordination of information as to the serviceability of the craft and equipment between the operating and maintenance elements of the operator's organization;

.18 the existence and use of adequate instructions regarding:

.18.1 loading of the craft so that weight and centre of gravity limitations can be effectively observed and cargo is, when necessary, adequately secured;

.18.2 the provision of adequate fuel reserves;

.18.3 action in the event of reasonable foreseeable emergencies; and

.19 provision of contingency plans by operators for foreseeable incidents including all land-based activities for each scenario. The plans shall provide operating crews with information regarding search and rescue (SAR) authorities and local administrations and organizations which may complement the tasks undertaken by crews with the equipment available to them. [1]

18.1.4 *The Administration shall determine the maximum allowable distance from a base port or place of refuge after assessing the provisions made under 18.1.3.*

18.1.5 *The master shall ensure that an effective system of supervision and reporting of the closing and opening of accesses referred to in 2.2.4.2 and 2.2.4.3 is implemented*

18.2 Craft Documentation

The company shall ensure that the craft is provided with adequate information and guidance in the form of technical manual(s) to enable the craft to be operated and maintained safely. The technical manual(s) shall consist of a route operational manual, craft operating manual, training manual, maintenance manual and servicing schedule. Arrangements shall be made for such information to be updated as necessary.

18.2.1 Craft operating manual

The craft operating manual shall contain at least the following information:

.1 leading particulars of the craft;

.2 description of the craft and its equipment;

.3 procedures for checking the integrity of buoyancy compartments;

.4 details arising from compliance with the requirements of Section 2 likely to be of direct practical use to the crew in an emergency;

.5 damage control procedures (e.g. information in a damage control plan required by SOLAS regulation II-1/23 or II-1/25-8.2, as appropriate);

.6 description and operation of machinery systems;

.7 description and operation of auxiliary systems;

.8 description and operation of remote control and warning systems;

.9 description and operation of electrical equipment;

.10 loading procedures and limitations, including maximum operational weight, centre of gravity position and distribution of load, including any cargo or car securing arrangement and procedures depending on operational restrictions or damaged conditions. Such arrangement and procedures shall not be included as a separate Cargo Securing Manual as required by chapter VI of the Convention;

.11 description and operation of fire-detection and fire-extinguishing equipment;

.12 drawings indicating the structural fire protection arrangements;

.13 description and operation of radio equipment and navigational aids;

.14 information regarding the handling of the craft as determined in accordance with Section 17;

.15 maximum permissible towing speeds and towing loads, where applicable;

.16 procedure for dry-docking or lifting, including limitations;

.17 in particular, the manual shall provide information, in clearly defined chapters, relating to:

.17.1 indication of emergency situations or malfunctions jeopardizing safety, required actions to be taken and any consequential restrictions on operation of the craft or its machinery;

.17.2 evacuation procedures;

.17.3 the worst intended conditions;

.17.4 limiting values of all machinery parameters requiring compliance for safe operation.

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[1] *Refer to the IMO Search and Rescue Manual (IMOSAR), adopted by the Organization by resolution A.439(XI), and Use of Radar Transponders for Search and Rescue Purposes, adopted by resolution A.530(13).*

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In regard to information on machinery or system failures, data shall take into account the results of any FMEA reports developed during the craft design.

18.2.2 Route operational manual

The route operational manual shall include at least the following information:

.1 evacuation procedures;

.2 operating limitations, including the worst intended conditions;

.3 procedures for operation of the craft within the limitations of .2;

.4 the elements of applicable contingency plans for primary and secondary rescue assistance in the case of foreseeable incidents, including land-based arrangements and activities for each incident;

.5 arrangements for obtaining weather information;

.6 identification of the "base port(s)";

.7 identification of the person responsible for decisions to cancel or delay voyages;

.8 identification of crew complement, functions and qualifications;

.9 restrictions on working hours of crew;

.10 safety arrangements at terminals;

.11 traffic control arrangements and limitations, as appropriate;

.12 specific route conditions or requirements relating to position fixing, operations by night and in restricted visibility, including the use of radar or other electronic aids to navigation; and

.13 communication arrangements between craft, coast radio stations, base ports radio stations, emergency services and other ships, including radio frequencies to be used and watch to be kept.

18.2.3 Training manual

The training manual, which may comprise several volumes, shall contain instructions and information, in easily understood terms, illustrated wherever possible, on evacuation, fire and damage control appliances and systems and on the best methods of survival. Any part of such information may be provided in the form of audio-visual aids in lieu of the manual. Where appropriate, the contents of the training manual may be included in the craft operating manual. The following shall be explained in detail:

.1 donning lifejackets and immersion suits, as appropriate;

.2 muster at the assigned stations;

.3 boarding, launching and clearing the survival craft and rescue boats;

.4 method of launching from within the survival craft;

.5 release from launching appliances;

.6 methods and use of devices for protection in launching areas, where appropriate;

.7 illumination in launching areas;

.8 use of all survival equipment;

.9 use of all detection equipment;

.10 with the assistance of illustrations, the use of radio life-saving appliances;

.11 use of drogues;

.12 use of engine and accessories;

.13 recovery of survival craft and rescue boats, including stowage and securing;

.14 hazards of exposure and the need for warm clothing;

.15 best use of the survival craft facilities in order to survive;

.16 methods of retrieval, including the use of helicopter rescue gear (slings, baskets, stretchers), breeches-buoy and shore life-saving apparatus and craft's line-throwing apparatus;

.17 all other functions contained in the muster list and emergency instructions;

.18 instructions for emergency repair of the life-saving appliances;

.19 instructions in the use of fire protection and fire-extinguishing appliances and systems;

.20 guidelines for use of firefighter's outfit in a fire, if fitted;

.21 use of alarms and communications associated with fire safety;

.22 methods for surveying damage;

.23 use of damage control appliances and systems, including operation of watertight doors and bilge pumps; and

.24 for passenger craft, control of and communication with passengers in an emergency.

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.17 arrangements to ensure that equipment is maintained in compliance with the Administration's requirements, and to ensure co-ordination of information as to the serviceability of the craft and equipment between the operating and maintenance elements of the operator's organization;

.18 the existence and use of adequate instructions regarding:

.18.1 loading of the craft so that weight and centre of gravity limitations can be effectively observed and cargo is, when necessary, adequately secured;

.18.2 the provision of adequate fuel reserves;

.18.3 action in the event of reasonable foreseeable emergencies; and

.19 provision of contingency plans by operators for foreseeable incidents including all land-based activities for each scenario. The plans shall provide operating crews with information regarding search and rescue (SAR) authorities and local administrations and organizations which may complement the tasks undertaken by crews with the equipment available to them. [1]

18.1.4 *The Administration shall determine the maximum allowable distance from a base port or place of refuge after assessing the provisions made under 18.1.3.*

18.1.5 *The master shall ensure that an effective system of supervision and reporting of the closing and opening of accesses referred to in 2.2.4.2 and 2.2.4.3 is implemented*

18.2 Craft Documentation

The company shall ensure that the craft is provided with adequate information and guidance in the form of technical manual(s) to enable the craft to be operated and maintained safely. The technical manual(s) shall consist of a route operational manual, craft operating manual, training manual, maintenance manual and servicing schedule. Arrangements shall be made for such information to be updated as necessary.

18.2.1 Craft operating manual

The craft operating manual shall contain at least the following information:

.1 leading particulars of the craft;

.2 description of the craft and its equipment;

.3 procedures for checking the integrity of buoyancy compartments;

.4 details arising from compliance with the requirements of Section 2 likely to be of direct practical use to the crew in an emergency;

.5 damage control procedures (e.g. information in a damage control plan required by SOLAS regulation II-1/23 or II-1/25-8.2, as appropriate);

.6 description and operation of machinery systems;

.7 description and operation of auxiliary systems;

.8 description and operation of remote control and warning systems;

.9 description and operation of electrical equipment;

.10 loading procedures and limitations, including maximum operational weight, centre of gravity position and distribution of load, including any cargo or car securing arrangement and procedures depending on operational restrictions or damaged conditions. Such arrangement and procedures shall not be included as a separate Cargo Securing Manual as required by chapter VI of the Convention;

.11 description and operation of fire-detection and fire-extinguishing equipment;

.12 drawings indicating the structural fire protection arrangements;

.13 description and operation of radio equipment and navigational aids;

.14 information regarding the handling of the craft as determined in accordance with Section 17;

.15 maximum permissible towing speeds and towing loads, where applicable;

.16 procedure for dry-docking or lifting, including limitations;

.17 in particular, the manual shall provide information, in clearly defined chapters, relating to:

.17.1 indication of emergency situations or malfunctions jeopardizing safety, required actions to be taken and any consequential restrictions on operation of the craft or its machinery;

.17.2 evacuation procedures;

.17.3 the worst intended conditions;

.17.4 limiting values of all machinery parameters requiring compliance for safe operation.

---

[1] *Refer to the IMO Search and Rescue Manual (IMOSAR), adopted by the Organization by resolution A.439(XI), and Use of Radar Transponders for Search and Rescue Purposes, adopted by resolution A.530(13).*

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In regard to information on machinery or system failures, data shall take into account the results of any FMEA reports developed during the craft design.

18.2.2 Route operational manual

The route operational manual shall include at least the following information:

.1 evacuation procedures;

.2 operating limitations, including the worst intended conditions;

.3 procedures for operation of the craft within the limitations of .2;

.4 the elements of applicable contingency plans for primary and secondary rescue assistance in the case of foreseeable incidents, including land-based arrangements and activities for each incident;

.5 arrangements for obtaining weather information;

.6 identification of the "base port(s)";

.7 identification of the person responsible for decisions to cancel or delay voyages;

.8 identification of crew complement, functions and qualifications;

.9 restrictions on working hours of crew;

.10 safety arrangements at terminals;

.11 traffic control arrangements and limitations, as appropriate;

.12 specific route conditions or requirements relating to position fixing, operations by night and in restricted visibility, including the use of radar or other electronic aids to navigation; and

.13 communication arrangements between craft, coast radio stations, base ports radio stations, emergency services and other ships, including radio frequencies to be used and watch to be kept.

18.2.3 Training manual

The training manual, which may comprise several volumes, shall contain instructions and information, in easily understood terms, illustrated wherever possible, on evacuation, fire and damage control appliances and systems and on the best methods of survival. Any part of such information may be provided in the form of audio-visual aids in lieu of the manual. Where appropriate, the contents of the training manual may be included in the craft operating manual. The following shall be explained in detail:

.1 donning lifejackets and immersion suits, as appropriate;

.2 muster at the assigned stations;

.3 boarding, launching and clearing the survival craft and rescue boats;

.4 method of launching from within the survival craft;

.5 release from launching appliances;

.6 methods and use of devices for protection in launching areas, where appropriate;

.7 illumination in launching areas;

.8 use of all survival equipment;

.9 use of all detection equipment;

.10 with the assistance of illustrations, the use of radio life-saving appliances;

.11 use of drogues;

.12 use of engine and accessories;

.13 recovery of survival craft and rescue boats, including stowage and securing;

.14 hazards of exposure and the need for warm clothing;

.15 best use of the survival craft facilities in order to survive;

.16 methods of retrieval, including the use of helicopter rescue gear (slings, baskets, stretchers), breeches-buoy and shore life-saving apparatus and craft's line-throwing apparatus;

.17 all other functions contained in the muster list and emergency instructions;

.18 instructions for emergency repair of the life-saving appliances;

.19 instructions in the use of fire protection and fire-extinguishing appliances and systems;

.20 guidelines for use of firefighter's outfit in a fire, if fitted;

.21 use of alarms and communications associated with fire safety;

.22 methods for surveying damage;

.23 use of damage control appliances and systems, including operation of watertight doors and bilge pumps; and

.24 for passenger craft, control of and communication with passengers in an emergency.

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18.2.4 Maintenance and servicing manual/system

The craft maintenance and servicing manual/system shall contain as a minimum:

.1 *detailed, illustrated description of all craft structure, machinery installations and all installed equipment and systems required for safe operation of the craft;*

.2 *specifications and quantities of all replenishable fluids and of structural materials which may be required for repairs;*

.3 *operational limitations of machinery in terms of values of parameters, vibration and consumption of replenished fluids;*

.4 *limitations of wear of structure or machinery components, including lives of components requiring calendar or operating time replacement;*

.5 *detailed description of procedures, including any safety precautions to be taken or special equipment required, to remove and install main and auxiliary machinery, transmissions, propulsion and lift devices and flexible structure components;*

.6 *test procedures to be followed subsequent to replacement of machinery or system components or for malfunction diagnosis;*

.7 *procedure for lifting or dry-docking the craft, including any weight or attitude limitations;*

.8 *procedure for weighing the craft and establishing the position of longitudinal centre of gravity (LCG);*

.9 *where craft may be dismantled for transportation, instructions shall be provided for dismantling, transport and re-assembly;*

.10 *a servicing schedule, included in the maintenance manual or published separately, detailing the routine servicing and maintenance operations required to maintain the operational safety of the craft and its machinery and systems.*

18.2.5 Information on passengers

18.2.5.1 *All persons on board passenger craft shall be counted prior to departure.*

18.2.5.2 *Details of persons who have declared a need for special care or assistance in emergency situations shall be recorded and communicated to the master prior to departure.*

18.2.5.3 *The names and gender of all persons on board, distinguished between adults, children and infants shall be recorded for search and rescue purposes.*

18.2.5.4 *The information required by 18.2.5.1, 18.2.5.2 and 18.2.5.3 shall be kept ashore and made readily available to search and rescue services when needed.*

18.2.5.5 *The Administration may exempt from the requirements of 18.2.5.3 passenger craft operating on voyages having a duration of 2 h or less between each port of call.*

18.3 Training and Qualifications

18.3.1 *The level of competence and the training considered necessary in respect of the master and each crew member shall be laid down and demonstrated in the light of the following guidelines to the satisfaction of the company in respect of the particular type and model of craft concerned and the service intended. More than one crew member shall be trained to perform all essential operational tasks in both normal and emergency situations.*

18.3.2 *The Administration shall specify an appropriate period of operational training for the master and each member of the crew and, if necessary, the periods at which appropriate retraining shall be carried out.*

18.3.3 *The Administration shall issue a type rating certificate to the master and all officers having an operational role following an appropriate period of operational/simulator training and on the conclusion of an examination including practical test commensurate with the operational tasks on board the particular type and model of craft concerned and the route followed. The type rating training shall cover at least the following items:*

.1 *knowledge of all on-board propulsion and control systems, including communication and navigational equipment, steering, electrical, hydraulic and pneumatic systems and bilge and fire pumping;*

.2 *the failure mode of the control, steering and propulsion systems and proper response to such failures;*

.3 *handling characteristics of the craft and the limiting operational conditions;*

.4 *bridge communication and navigation procedures;*

.5 *intact and damage stability and survivability of the craft in damage condition;*

.6 *location and use of the craft's life-saving appliances, including survival craft equipment;*

.7 *location and use of escapes in the craft and the evacuation of passengers;*

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.8 location and use of fire protection and fire-extinguishing appliances and systems in the event of fire on board;

.9 location and use of damage control appliances and systems, including operation of watertight doors and bilge pumps;

.10 cargo and vehicle stowage and securing systems;

.11 methods for control of and communication with passengers in an emergency; and

.12 location and use of all other items listed in the training manual.

18.3.4 *The type rating certificate for a particular type and model of craft should only be valid for service on the route to be followed when it is so endorsed by the Administration following the completion of a practical test over that route.*

18.3.5 *The type rating certificate shall be re-validated every two years and the Administration shall lay down the procedures for re-validation.*

18.3.6 *All crew members shall receive instructions and training, as specified in 18.3.3.6 to .12.*

18.3.7 *The Administration shall specify standards of physical fitness and frequency of medical examinations, having regard to the route and craft concerned.*

18.3.8 *The Administration of the country in which the craft is to operate, if other than the flag State, shall be satisfied with the training, experience and qualifications of the master and each crew member. A valid certificate of competency or a valid license appropriately endorsed, in accordance with the provisions of the International Convention on Standards of Training, Certification and Watchkeeping (STCW) 1978, as amended, held by the master or crew, shall be acceptable as evidence of satisfactory training and experience to the Administration of the country in which the craft is to operate.*

18.4 Manning of survival craft and supervision

The company and the master shall ensure that:

.1 a sufficient number of trained persons are on board for mustering and assisting untrained persons;

.2 a sufficient number of crew members, who may be deck officers or certificated persons, are on board for operating the survival craft, rescue boats and launching arrangements required for abandonment by the total number of persons on board;

.3 a deck officer or certificated person is placed in charge of each survival craft to be used recognizing, however, that the Administration, having due regard to the nature of the voyage, the number of persons on board and the characteristics of the craft, may permit a deck officer, certificated person or persons practised in the handling and operation of liferafts to be placed in charge of each liferaft or group of liferafts;

.4 the person in charge of survival craft has a list of the survival craft crew and sees that those crew members are acquainted with their duties;

.5 every rescue boat and lifeboat has a person assigned who is capable of operating the engine and carrying out minor adjustments; and

.6 the persons referred to in .1 to .3 are equitably distributed among the craft's survival craft.

18.5 Emergency Instructions and Drills

18.5.1 *The company shall ensure that the emergency instructions and drills referred to in 18.5.1 to 18.5.10 are implemented, and the master shall be responsible for the enforcement of these instructions and drills on board. On or before departure, passengers shall be instructed in the use of lifejackets and the action to be taken in an emergency. The attention of the passengers shall be drawn to the emergency instructions required by 8.4.1 and 8.4.3.*

18.5.2 *Emergency fire and evacuation drills for the crew shall be held on board the craft at intervals not exceeding one week for passenger craft and one month for cargo craft.*

18.5.3 *Each member of each crew shall participate in at least one evacuation, fire and damage control drill per month.*

18.5.4 *On-board drills shall, as far as practicable, be conducted to simulate an actual emergency. Such simulations shall include instruction and operation of the craft's evacuation, fire and damage control appliances and systems.*

18.5.5 *On-board instruction and operation of the craft's evacuation, fire and damage control appliances and systems shall include appropriate cross-training of crew members.*

18.5.6 *Emergency instructions including a general diagram of the craft showing the location of all exits, routes of evacuation, assigned assembly stations, emergency equipment, life-saving equipment and appliances and illustration of lifejacket donning shall be available to each passenger and crew member in appropriate languages. It shall be placed near each passenger and crew seat and conspicuously displayed at assembly stations and other passenger spaces.*

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18.5.7 Records

18.5.7.1 *The date when musters are held, details of abandon craft drills and fire drills, drills of other life-saving appliances and on-board training shall be recorded in such log-book as may be prescribed by the Administration. If a full muster, drill or training session is not held at the appointed time, an entry shall be made in the log-book stating the circumstances and the extent of the muster, drill or training session held. A copy of such information shall be forwarded to the operator's management.*

18.5.7.2 *The master shall ensure, before the craft leaves the berth on any voyage, that a record is made of the time of the last closing of the accesses referred to 2.2.4.2 and 2.2.4.3.*

18.5.8 Evacuation drills

18.5.8.1 *Evacuation drill scenarios shall vary each week so that different emergency conditions are simulated.*

18.5.8.2 *Each evacuation craft drill shall include:*

.1 *summoning of crew to assembly stations with the alarm required by 8.2.2.2 and ensuring that they are made aware of the order to abandon craft specified in the muster list;*

.2 *reporting to stations and preparing for the duties described in the muster list;*

.3 *checking that crew are suitably dressed;*

.4 *checking that lifejackets are correctly donned;*

.5 *operation of davits if any used for launching liferafts;*

.6 *donning of immersion suits or thermal protective clothing by appropriate crew members;*

.7 *testing of emergency lighting for mustering and abandonment; and*

.8 *giving instructions in the use of the craft's life-saving appliances and in survival at sea.*

18.5.8.3 Rescue boat drill

.1 *As far as is reasonable and practicable, rescue boats shall be launched each month as part of the evacuation drill, with their assigned crew aboard, and manoeuvred in the water. in all cases this requirement shall be complied with at least once every three months.*

.2 *If rescue boat launching drills are carried out with the craft making headway, such drills shall, because of the dangers involved, be practised in sheltered waters only and under the supervision of an officer experienced in such drills.* *

18.5.8.4 *Individual instructions may cover different parts of the craft's life-saving system, but all the craft's life-saving equipment and appliances shall be covered within any period of one month on passenger craft and two months on cargo craft. Each member of the crew shall be given instructions which shall include but not necessarily be limited to:*

.1 *operation and use of the craft's inflatable liferafts;*

.2 *problems of hypothermia, first-aid treatment of hypothermia and other appropriate first-aid procedures; and*

.3 *special instructions necessary for use of the craft's life-saving appliances in severe weather and severe sea conditions.*

18.5.8.5 *On-board training in the use of davit-launched liferafts shall take place at intervals of not more than four months on every craft fitted with such appliances. Whenever practicable, this shall include the inflation and lowering of a liferaft. This liferaft may be a special liferaft intended for training purposes only, which is not part of the craft's life-saving equipment. Such a special liferaft shall be conspicuously marked.*

18.5.9 Fire drills

18.5.9.1 *Fire drill scenarios shall vary each week so that emergency conditions are simulated for different craft compartments.*

18.5.9.2 *Each fire drill shall include:*

.1 *summoning of crew to fire stations;*

.2 *reporting to stations and preparing for the duties described in the muster list;*

.3 *donning of firefighter's outfits;*

.4 *operation of fire doors and fire dampers;*

.5 *operation of fire pumps and fire-fighting equipment;*

.6 *operation of communication equipment, emergency signals and general alarm;*

7 *operation of fire-detection system; and*

.8 *instruction in the use of the craft's fire-fighting equipment and sprinkler and drencher systems, if fitted.*

---

* *Refer to resolution A.624(15) concerning guidelines on training for the purpose of launching lifeboats and rescue boats from ships making headway through the water.*

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18.5.10 Damage control drills

18.5.10.1 Damage control drill scenarios shall vary each week so that emergency conditions are simulated for different damage conditions.

18.5.10.2 Each damage control drill shall include:

.1 summoning of crew to damage control stations;

.2 reporting to stations and preparing for the duties described in the muster list;

.3 operation of watertight doors and other watertight closures;

.4 operation of bilge pumps and testing of bilge alarms and automatic bilge pump starting systems; and

.5 instruction in damage survey, use of the craft damage control systems and passenger control in the event of an emergency.

Part B - Requirements for Passenger Craft

18.6 Type Rating Training

18.6.1 The company shall ensure that the type rating training is implemented. For all crew members, the type rating training shall cover the control and evacuation of passengers additionally to 18.3.5.

18.6.2 When a craft carries cargoes, the craft shall comply with the requirements of part C of this Section in addition to this part.

18.7 Emergency Instructions and Drills

18.7.1 The company shall ensure that the emergency instructions are implemented, and the master shall be responsible for communicating the provisions of the emergency instructions to passenger upon boarding.

Part C - Requirements for Cargo Craft

18.8 Type Rating Training

The company shall ensure that type rating training is implemented as provided in 18.3. For all crew members, the type rating training shall cover knowledge of cargo and vehicles storage area securement systems.

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Section 19

Inspection and Maintenance Requirements

19.1 The Administration shall be satisfied with the operator's organization or any organization on which he may call in the maintenance of his craft and shall specify the scope of the duties which any part of the organization may carry out, having regard to the number and competence of its staff, facilities available, arrangements for calling on specialist assistance should it be necessary, record-keeping, communication and allocation of responsibilities.

19.2 The craft and equipment shall be maintained to the satisfaction of the Administration; in particular:

.1 routine preventive inspection and maintenance shall be performed to a schedule approved by the Administration, which shall have regard at least in the first instance to the manufacturer's schedule;

.2 in the performance of maintenance tasks, due regard shall be paid to maintenance manuals, service bulletins acceptable to the Administration and to any additional instructions of the Administration in this respect;

.3 all modifications shall be recorded and their safety aspects investigated. Where it could have any effect on safety, the modification, together with its installation, shall be to the satisfaction of the Administration;

.4 appropriate arrangements shall be provided for informing the master of the serviceability state of his craft and its equipment;

.5 the duties of the operating crew in respect of maintenance and repairs and the procedure for obtaining assistance with repairs when the craft is away from the base port shall be clearly defined;

.6 the master shall report to the maintenance organization any defects and repairs which are known to have occurred during operations;

.7 records of defects and their correction shall be maintained and those defects of recurrent nature, or those which adversely affect craft or personal safety, shall be reported to the Administration.

19.3 The Administration shall be satisfied that arrangements are provided for ensuring adequate inspection, maintenance and recording of all life-saving appliances and distress signals carried.

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Annex 1

Form of High-Speed Craft Safety Certificate and Record of Equipment

HIGH-SPEED CRAFT SAFETY CERTIFICATE

This Certificate shall be supplemented by a Record of Equipment

(Official seal) *(State)*

Issued under the provisions of the

INTERNATIONAL CODE OF SAFETY FOR HIGH-SPEED CRAFT, 2000

(resolution MSC.97(73))

under the authority of the Government of

.....
(full designation of the State)

by.....
(full official designation of the competent person or organization authorized by the Administration)

Particulars of craft[1]

Name of craft .....

Manufacturer's model and hull number .....

Distinctive number or letters .....

IMO number[2].....

Port of registry .....

Gross tonnage .....

Sea areas in which the craft is certified to operate (paragraph 14.2.1).....

Design waterline corresponding to a height of .....below the reference line at the longitudinal centre of flotation, and draughts at the draught marks of ..... forward and ..... aft

The upper edge of the reference line is..... at (..... mm below uppermost deck at side) [3] *(..... mm above the underside of keel)** *at longitudinal centre of flotation.*

Category	*category A passenger craft/category B passenger craft/cargo craft* [3]
Craft type	*air-cushion vehicle/surface-effect ship/hydrofoil/monohull/multihull/other (give detail.....)*

---

[1] *Alternatively, the particulars of the craft may be placed horizontally in boxes.*

[2] *In accordance with the IMO ship identification number scheme, adopted by the Organization by resolution A.600(15).*

[3] *Delete as appropriate.*

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Date on which keel was laid or craft was at

a similar stage of construction or on which

a major conversion was commenced.....

THIS IS TO CERTIFY:

1 That the above-mentioned craft has been duly surveyed in accordance with the applicable provisions of the International Code of Safety for High-Speed Craft, 2000.

2 That the survey showed that the structure, equipment, fittings, radio station arrangements and materials of the craft and the condition thereof are in all respects satisfactory and that the craft complies with the relevant provisions of the Code.

3 That the life-saving appliances are provided for a total number of ..... persons and no more as follows:

.....

.....

4 That, in accordance with 1.11 of the Code, the following equivalents have been granted in respect of the craft:

paragraph	*equivalent arrangement* ....

This certificate is valid until [4] .....

Completion date of the survey on which this certificate is based: .....

(dd/mm/yyyy)

Issued at .....

(Place of issue of certificate)

....

(Date of issue) *(Signature of authorized official issuing the certificate)*

.....

(Seal or stamp of the issuing authority, as appropriate)

---

[4] *Insert the date of expiry as specified by the Administration in accordance with 1.8.4 of the Code. The day and the month of this date correspond to the anniversary date as defined in 1.4.3 of the Code, unless amended in accordance with 1.8.12.1 of the Code.*

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Endorsement for periodical surveys

This is to certify that, at a survey required by 1.5 of the Code, this craft was found to comply with the relevant provisions of the Code.

Periodical survey:	*Signed:* ..... *(Signature of authorized official)* *Place:* ..... *Date:* .....
..... *(Signature of authorized official)*	
Periodical survey:	*Signed:* ..... *(Signature of authorized official)* *Place:* ..... *Date:* .....
..... *(Signature of authorized official)*	
Periodical survey:	*Signed:* ..... *(Signature of authorized official)* *Place:* ..... *Date:* .....
..... *(Signature of authorized official)*	
Periodical survey:	*Signed:* ..... *(Signature of authorized official)* *Place:* ..... *Date:* .....
..... *(Signature of authorized official)*	

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Endorsement to extend the Certificate if valid for less than 5 years where 1.8.8 of the Code applies

This craft complies with the relevant requirements of the Code, and this Certificate shall, in accordance with 1.8.8 of the Code, be accepted as valid until .....

	Signed: ..... *(Signature of authorized official)* *Place:* ..... *Date:* .....
..... *(Signature of authorized official)*	

Endorsement where the renewal survey has been completed and 1.8.9 of the Code applies

This craft complies with the relevant requirements of the Code, and this Certificate shall, in accordance with 1.8.9 of the Code, be accepted as valid until .....

	Signed: ..... *(Signature of authorized official)* *Place:* ..... *Date:* .....
..... *(Signature of authorized official)*	

Endorsement to extend the validity of the Certificate until reaching the port of survey where 1.8.10 of the Code applies

This Certificate shall, in accordance with 1.8.10 of the Code, be accepted as valid until .....

	Signed: ..... *(Signature of authorized official)* *Place:* ..... *Date:* .....
..... *(Signature of authorized official)*	

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Endorsement for the advancement of the anniversary date where 1.8.12 of the Code applies

In accordance with 1.8.12 of the Code, the new anniversary date is .....

	Signed: ..... *(Signature of authorized official)* *Place:* ..... *Date:* .....
..... *(Signature of authorized official)*	

In accordance with 1.8.13 of the Code, the new anniversary date is .....

	Signed: ..... *(Signature of authorized official)* *Place:* ..... *Date:* .....
..... *(Signature of authorized official)*	

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RECORD OF EQUIPMENT FOR
HIGH-SPEED CRAFT SAFETY CERTIFICATE

This Record shall be permanently attached to the
High-Speed Craft Safety Certificate

RECORD OF EQUIPMENT FOR COMPLIANCE WITH THE
INTERNATIONAL CODE OF SAFETY
FOR HIGH-SPEED CRAFT, 2000

1 Particulars of craft

Name of craft .....

Manufacturer's model and hull number .....

Distinctive number or letters .....

IMO number[5] .....

Category: *category A passenger craft/category B passenger craft/cargo craft*[6]

Craft type: *air-cushion vehicle, surface-effect ship, hydrofoil, monohull, multihull, other (give detail .....)*[6]

Number of passengers for which certified .....

Minimum number of persons with required qualifications to operate the radio installations .....

---

[5] *In accordance with the IMO ship identification number scheme adopted by the Organization by resolution A.600(15).*
[6] *Delete as appropriate.*

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2 Details of live-saving appliances

1	*Total number of persons for which life-saving appliances are provided*	.....
2	*Total number of lifeboats*	.....
2.1	*Total number of persons accommodated by*	.....
2.2	*Number of partially enclosed lifeboats complying with section 4.5 of the LSA Code*	.....
2.3	*Number of partially enclosed lifeboats complying with sections 4.6 and 4.7 of the LSA Code*	.....
2.4	*Other lifeboats*	.....
2.4.1	*Number*	.....
2.4.2	*Type*	.....
3	*Number of rescue boat*	.....
3.1	*Number of rescue boats which are included in the total lifeboats shown above*	.....
4	*Liferafts complying with sections 4.1 to 4.3 of the LSA Code for which suitable means of launching are provided*	.....
4.1	*Number of liferafts*	.....
4.2	*Number of persons accommodated by them*	.....
5	*Open reversible lifeboats (Annex 11 of the Code)*	.....
5.1	*Number of liferafts*	.....
5.2	*Number of persons accommodated by them*	.....
6	*Number of Marine Evacuation System (MES)*	.....
6.1	*Number of persons served by them*	.....
7	*Number of lifebuoys*	.....
8	*Number of lifejackets*	.....
8.1	*Number of suitable for adults*	.....
8.2	*Number of suitable of children*	.....
9	*Immersion suits*	.....
9.1	*Total number*	.....
9.2	*Number of suits complying with the requirements for lifejackets*	.....
10	*Number of anti-explore suits*	.....
10.1	*Total number*	.....
10.2	*Number of suits complying with the requirements for lifejackets*	.....
11	*Radio installations used in life-saving appliances*	.....
11.1	*Number of radar transporters*	.....
11.2	*Number of two-way VHF radiotelephone apparatus*	.....

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*3 **Details of navigational systems and equipment***

1.1	*Magnetic compass*	.....
1.2	*Transmitting heading device (THD)*	.....
1.3	*Gyro-compass*	.....
2	*Speed and distance measuring device*	.....
3	*Echo-sounding device*	.....
4.1	*9 GHz radar*	.....
4.2	*Second radar (3 GHz/9 GHz [7])*	.....
4.3	*Automatic radar plotting aid (ARPA)/Automatic tracking aid (ATA)**	.....
5	*Receiver for global navigation satellite system/ Terrestrial navigation system/ Other means of position fixing [7,8]*	.....
6.1	*Rate of turn indicator*	.....
6.2	*Rudder angle indicator/Direction of steering thrust indicator [7]*	.....
7.1	*Nautical charts/Electronic Chart Display and Information System (ECDIS)**	.....
7.2	*Back-up arrangements for ECDIS*	.....
7.3	*Nautical publications*	.....
7.4	*Back-up arrangement for nautical publications*	.....
8	*Search light*	.....
9	*Daylight signalling lamp*	.....
10	*Night vision equipment*	.....
11	*Means to show the mode of the propulsion systems*	.....
12	*Automatic identification aid (Automatic pilot)*	.....
13	*Radar reflector/ Other means [7,8]*	.....
14	*Sound reception system*	.....
15	*Automatic identification system (AIS)*	.....
16	*Long-range identification and tracking system*	.....
17	*Voyage data recorder (VDR)*	.....

---

7 Delete as appropriate
8 In case of "other means" they shall be specified.

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4 Details of radio facilities

Item		*Actual provision*
1	*Primary systems*	.....
1.1	*VHF radio installations:*	.....
1.1.1	*DSC encoder*	.....
1.1.2	*DSC watch receiver*	.....
1.1.3	*Radiotelephony*	.....
1.2	*MF radio installations:*	.....
1.2.1	*DSC encoder*	.....
1.2.2	*DSC watch receiver*	.....
1.2.3	*Radiotelephony*	
1.3	*MF/HF radio installations:*	.....
1.3.1	*DSC encoder*	.....
1.3.2	*DSC watch receiver*	.....
1.3.3	*Radiotelephony*	.....
1.3.4	*Direct-printing radiotelephony*	.....
1.4	*Immarsat ship earth station*	.....
2	*Secondary means of alerting*	.....
3	*Facilities for reception of maritime safety information*	.....
3.1	*NAVTEX receiver*	.....
3.2	*EGC receiver*	.....
3.3	*HF direct-printing radiotelegraph receiver*	.....
4	*Satellite EPIRB*	.....
4.1	*COSPAS-SARSAT*	.....
4.2	*Immarsat*	.....
5	*VHF EPIRB*	.....
6	*Ship's radar transporter*	.....
7	*Two-way on-scene radiocommunications 121.5 MHz & 123.1 MHz*	.....

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5 ***Methods used to ensure availability of radio facilities***
(paragraphs 14.15.6, 14.15.7 and 14.15.8 of the Code)

5.1 *Duplication of equipment* .....

5.2 *Shore-based maintenance* .....

5.3 *At-sea maintenance capability* .....

THIS IS TO CERTIFY that this Record is correct in all respects

Issued at .....
(Place of issue of the Record)

....
(Date of issue) *(Signature of duly authorized official issuing the Record)*

.....
(Seal or stamp of the issuing authority, as appropriate)

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Annex 2

Form of Permit to Operate High-Speed Craft

Issued under the provisions of the

INTERNATIONAL CODE OF SAFETY FOR HIGH-SPEED CRAFT, 2000
(resolution MSC.97(73))

1 *Name of craft* .....

2 *Manufacturer's model and hull number* .....

3 *Distinctive number or letter* .....

4 *IMO number* [1] .....

5 *Port of registry* .....

6 *Category of craft* *category A passenger craft/category B passenger Craft/cargo craft* [2]

7 *Name of operator* .....

.....

8 *Areas or routes of operation* .....

.....

.....

9 *Base port(s)* .....

10 *Maximum distance from place of refuge* .....

.....

11 *Number of:*

.1 *passengers maximum permitted* .....

.2 *manning scale required* .....

12 *Worst intended conditions* .....

.....

13 *Other operational restrictions* .....

.....

.....

---

1 *In accordance with the IMO ship identification number sheme, adopted by the Organization by resolution A.600(15).*

2 *Delete as appropriate.*

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This permit confirms that the service mentioned above has been found to be in accordance with the general requirements of 1.2.2 to 1.2.7 of the Code.

THIS PERMIT is issued under the authority of the Government of .....

.....

THIS PERMIT is valid until .....

subject to the High-Speed Craft Safety Certificate remaining valid

Issued at .....
(Place of issue of permit)

....
(Date of issue) *(Signature of duly authorized official issuing the permit)*

.....
(Seal or stamp of the issuing authority, as appropriate)

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Annex 3

Use of Probability Concept

1. General

1.1 Absolute safety cannot be achieved in any human activity. Naturally, this fact shall be taken into account in developing safety requirements, which means that requirements shall not imply that safety is absolute. In the case of traditional craft, it has frequently been possible to specify certain aspects of design or construction in some detail, in a way which was consistent with some level of risk which had over the years been intuitively accepted without having to be defined.

1.2 For high-speed craft, however, it would often be too restrictive to include engineering specifications into the Code. Requirements therefore need to be written (where this question arises) in the sense of "... the Administration shall be satisfied on the basis of tests, investigations and past experience that the probability of --- is (acceptably low)". Since different undesirable events may be regarded as having different general orders of acceptable probability (e.g. temporary impairment of propulsion as compared with an uncontrollable fire), it is convenient to agree on a series of standardized expressions which can be used to convey the relative acceptable probabilities of various incidents, i.e. to perform a qualitative ranking process. A vocabulary is given below which is intended to ensure consistency between various requirements, where it is necessary to describe the level of risk which shall not be exceeded.

2. Terms associated with Probabilities

Different undesirable events may have different orders of acceptable probability. in connection with this, it is convenient to agree on standardized expressions to be used to convey the relatively acceptable probabilities of various occurrences, i.e. to perform a qualitative ranking process.

2.1 Occurrences

2.1.1 Occurrence is a condition involving a potential lowering of the level of safety.

2.1.2 Failure is an occurrence in which a part, or parts, of the craft fail or malfunction, e.g. runaway. A failure includes:

.1 a single failure;

.2 independent failures in combination within a system;

.3 independent failures in combinations involving more than one system, taking into account:

.3.1 any undetected failure that is already present;

.3.2 such further failures [1] as would be reasonably expected to follow the failure under consideration; and

.4 common cause failure (failure of more than one component or system due to the same cause).

2.1.3 Event is an occurrence which has its origin outside the craft (e.g. waves).

2.1.4 Error is an occurrence arising as a result of incorrect action by the operating crew or maintenance personnel.

2.2 Probability of occurrences

2.2.1 Frequent is one which is likely to occur often during the operational life of a particular craft.

2.2.2 Reasonably probable is one which is unlikely to occur often but which may occur several times during the total operational life of a particular craft.

2.2.3 Recurrent is a term embracing the total range of frequent and reasonably probable.

2.2.4 Remote is one which is unlikely to occur to every craft but may occur to a few craft of a type over the total operational life of a number of craft of the same type.

2.2.5 "Extremely remote" is one which is unlikely to occur when considering the total operational life of a number of craft of the type, but nevertheless shall be considered as being possible.

2.2.6 Extremely improbable is one which is so extremely remote that it shall not be considered as possible to occur.

2.3 Effects

2.3.1 Effect is a situation arising as a result of an occurrence.

---

[1] *In assessing the further failures which follow, account shall be taken of any resulting more severe operating conditions for items that have not up to that time failed.*

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2.3.2 Minor effect is an effect which may arise from a failure, an event, or an error, as defined in 2.1.2, 2.1.3, 2.1.4, which can be readily compensated for by the operating crew. It may involve:

.1 a small increase in the operational duties of the crew or in their difficulty in performing their duties; or

.2 a moderate degradation in handling characteristics; or

.3 slight modification of the permissible operating conditions.

2.3.3 Major effect is an effect which produces:

.1 a significant increase in the operational duties of the crew or in their difficulty in performing their duties which by itself shall not be outside the capability of a competent crew provided that another major effect does not occur at the same time; or

.2 significant degradation in handling characteristics; or

.3 significant modification of the permissible operating conditions, but will not remove the capability to complete a safe journey without demanding more than normal skill on the part of the operating crew.

2.3.4 "Hazardous effect" is an effect which produces:

.1 a dangerous increase in the operational duties of the crew or in their difficulty in performing their duties of such magnitude that they cannot reasonably be expected to cope with them and will probably require outside assistance; or

.2 dangerous degradation of handling characteristics; or

.3 dangerous degradation of the strength of the craft; or

.4 marginal conditions for, or injury to, occupants; or

.5 an essential need for outside rescue operations.

2.3.5 Catastrophic effect is an effect which results in the loss of the craft and/or in fatalities.

2.4 Safety level is a numerical value characterizing the relationship between craft performance represented as horizontal single-amplitude acceleration (g) and the severity of acceleration-load effects on standing and sitting humans. The safety levels and the corresponding severity of effects on passengers and safety criteria for craft performance shall be as defined in table 1.

3. Numerical Values

Where numerical probabilities are used in assessing compliance with requirements using the terms similar to those given above, the following approximate values may be used as guidelines to assist in providing a common point of reference. The probabilities quoted shall be on an hourly or per-journey basis, depending on which is more appropriate to the assessment in question.

Frequent	*More than 10^{-3}*
Reasonably probable	*10^{-3} to 10^{-5}*
Remote	*10^{-5} to 10^{-7}*
Extremely remote	*10^{-7} to 10^{-9}*
Extremely improbable	*Whilst no approximate numerical probability is given for this, the figures used shall be substantially less than 10^{-9}*

Note:
Different occurrences may have different acceptable probabilities, according to the severity of their consequences (see Table 2).

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Table 1

EFFECT	*CRITERIA NOT TO BE EXCEEDED*		*COMMENTS*
	Type of load	*Value*	
LEVEL 1 *MINOR EFFECT* *Moderate degradation of safety*	*Maximum acceleration measured horizontally* [1]	*0.20 g*	*0.08 g: Elderly person will kee balance when holding.* *0.15 g: Mean person will keep balance when holding.* *0.15 g: Sitting person will start holding.*
LEVEL 2 *MAJOR EFFECT* *Significant degradation of safety*	*Maximum acceleration measured horizontally* [1]	*0.35 g*	*0.25 g: Maximum load for mean person keeping balance when holding.* *0.45 g: Mean person falls out of seat when not wearing seat belts.*
LEVEL 3 *HAZARDOUS EFFECT* *Major degradation of safety*	*Collision design condition calculated* *Maximum structural design load, based on vertical acceleration at centre of gravity*	*Ref. 4.3.3* *Ref. 4.3.1*	*Risk of unjury to passengers; safe emergency operation aftercollision.* *1.0 g: Degradation of passenger safety*
LEVEL 4 *CATASTROPHIC EFFECT*			*Loss of craft or/and fatalities*

[1] *The accerometer used shall have an accuracy of at least 5 % full scale and shall not have a frequency response of less than 20 Hz. The sampling frequency should not be less than 5 times the maximum frequency response. Anti-alias filters, if used, should have a passband equal to the frequency response.*

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Table 2

SAFETY LEVEL	*1*	*1*	*1*	*2*	*3*	*4*
EFFECT ON CRAFT AND OCCUPANTS	*Normal*	*Nuisance*	*Operating limitations*	*Emergency procedures; significant reduction in safety margins; difficult for crew to cope with adverse conditions; passenger injuries.*	*Large reduction in safety margins; crew over-burden because of work-load or environ-mental conditions; serious injury to a small number of occupants.*	*Deaths, usually with loss of craft*
F.A.R. [1] ***PROBABILITY*** *(reference only)*	← *PROBABLE* →			← *IMPROBABLE* →		← *EXTREMELY IMPROBABLE* →
JAR-25 [2] ***PROBABILITY***	← *PROBABLE* →			← *IMPROBABLE* →		← *EXTREMELY IMPROBABLE* →
	← *FREQUENT* →		← *REASONABLY PROBABLE* →	← *REMOTE* →	← *EXTREMELY REMOTE* →	
	10^{-0} 10^{-1} 10^{-2}		10^{-3} 10^{-4}	10^{-5} 10^{-6}	10^{-7} 10^{-8}	10^{-9}
CATEGORY OF EFFECT	← *MINOR* →			← *MAJOR* →	← *HAZARDOUS* →	*CATASTROPHIC*

[1] *United States Federal Aviation Regulations.*
[2] *European Joint Airworthiness Regulations.*

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Annex 4

Procedures for Failure Mode and Effects Analysis

C0 Document to be submitted

FMEA report, including FMEA worksheets.

1. Introduction

1.1 In the case of traditional craft, it has been possible to specify certain aspects of design or construction in some level of detail, in a way which was consistent with some level of risk which had over the years been intuitively accepted without having to be defined.

1.2 With the development of large high-speed craft, this required experience has not been widely available. However, with the now broad acceptance of the probabilistic approach to safety assessments within industry as a whole, it is proposed that an analysis of failure performance may be used to assist in the assessment of the safety of operation of high-speed craft.

1.3 A practical, realistic and documented assessment of the failure characteristics of the craft and its component systems shall be undertaken with the aim of defining and studying the important failure conditions that may exist.

1.4 This annex describes a failure mode and effects analysis (FMEA) and gives guidance as to how it may be applied by:

.1 explaining basic principles;

.2 providing the procedural steps necessary to perform an analysis;

.3 identifying appropriate terms, assumptions, measures and failure modes; and

.4 providing examples of the necessary worksheets.

1.5 FMEA for high-speed craft is based on a single -failure concept under which each system at various levels of a system's functional hierarchy is assumed to fail by one probable cause at a time. The effects of the postulated failure are analysed and classified according to their severity. Such effects may include secondary failures (or multiple failures) at other level(s). Any failure mode which may cause a catastrophic effect to the craft shall be guarded against by system or equipment redundancy unless the probability of such failure is extremely improbable (refer to section 13). For failure modes causing hazardous effects, corrective measures may be accepted in lieu. A test programme shall be drawn to confirm the conclusions of FMEA.

1.6 Whilst FMEA is suggested as one of the most flexible analysis techniques, it is accepted that there are other methods which may be used and which in certain circumstances may offer an equally comprehensive insight into particular failure characteristics.

2. Objectives

2.1 The primary objective of FMEA is to provide a comprehensive, systematic and documented investigation which establishes the important failure conditions of the craft and assesses their significance with regard to the safety of the craft, its occupants and the environment.

2.2 The main aims of undertaking the analysis are to:

.1 provide the Administration with the results of a study into the craft's failure characteristics so as to assist in an assessment of the levels of safety proposed for the craft's operation;

.2 provide craft operators with data to generate comprehensive training, operational and maintenance programmes and documentation; and

.3 provide craft and system designers with data to audit their proposed designs.

3. Scope of Application

3.1 FMEA shall be conducted for each high-speed craft, before its entry into service, in respect of the systems as required under the provisions of 5.2, 9.1.10, 12.1.1 and 16.2.6 of this Code.

3.2 For craft of the same design and having the same equipment, one FMEA on the lead craft will be sufficient, but each of the craft shall be subject to the same FMEA conclusion trials.

4. System Failure Mode and Effects Analysis

4.1 Before proceeding with a detailed FMEA into the effects of the failure of the system elements on the system functional output it is necessary to perform a functional failure analysis of the craft's important systems. In this way only systems which fail the functional failure analysis need to be investigated by a more detailed FMEA.

4.2 When conducting a system FMEA the following typical operational modes within the normal de-

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sign environmental conditions of the craft shall be considered:

.1 normal seagoing conditions at full speed;

.2 maximum permitted operating speed in congested waters; and

.3 manoeuvring alongside.

4.3 The functional interdependence of these systems shall also be described in either block diagrams or fault-tree diagrams or in a narrative format to enable the failure effects to be understood. As far as applicable, each of the systems to be analysed is assumed to fail in the following failure modes:

.1 complete loss of function;

.2 rapid change to maximum or minimum output;

.3 uncontrolled or varying output;

.4 premature operation;

.5 failure to operate at a prescribed time; and

.6 failure to cease operation at a prescribed time.

Depending on the system under consideration, other failure modes may have to be taken into account.

4.4 If a system can fail without any hazardous or catastrophic effect, there is no need to conduct a detailed FMEA into the system architecture. For systems whose individual failure can cause hazardous or catastrophic effects and where a redundant system is not provided, a detailed FMEA as described in the following paragraphs shall be followed. Results of the system functional failure analysis shall be documented and confirmed by a practical test programme drawn up from the analysis.

4.5 Where a system, the failure of which may cause a hazardous or catastrophic effect, is provided with a redundant system, a detailed FMEA may not be required provided that:

.1 the redundant system can be put into operation or can take over the failed system within the time-limit dictated by the most onerous operational mode in 4.2 without hazarding the craft;

.2 the redundant system is completely independent from the system and does not share any common system element the failure of which would cause failure of both the system and the redundant system. Common system element may be acceptable if the probability of failure complies with section 13; and

.3 the redundant system may share the same power source as the system. in such case an alternative power source shall be readily available with regard to the requirement of .1.

The probability and effects of operator error to bring in the redundant system shall also be considered.

5. Equipment Failure Mode and Effects Analysis

The systems to be subject to a more detailed FMEA investigation at this stage shall include all those that have failed the system FMEA and may include those that have a very important influence on the safety of the craft and its occupants and which require an investigation at a deeper level than that undertaken in the system functional failure analysis. These systems are often those which have been specifically designed or adapted for the craft, such as the craft's electrical and hydraulic systems.

6. Procedures

The following steps are necessary to perform FMEA:

.1 to define the system to be analysed;

.2 to illustrate the interrelationships of functional elements of the system by means of block diagrams;

.3 to identify all potential failure modes and their causes;

.4 to evaluate the effects on the system of each failure mode;

.5 to identify failure detection methods;

.6 to identify corrective measures for failure modes;

.7 to assess the probability of failures causing hazardous or catastrophic effects, where applicable;

.8 to document the analysis;

.9 to develop a test programme;

.10 to prepare FMEA report.

7. System Definition

The first step in an FMEA study is a detailed study of the system to be analysed through the use of drawings and equipment manuals. A narrative description of the system and its functional requirements shall be drawn up including the following information:

.1 general description of system operation and structure;

.2 functional relationship among the system elements;

.3 acceptable functional performance limits of the system and its constituent elements in each of the typical operational modes; and

.4 system constraints.

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8. Development of System Block Diagrams

8.1 The next step is to develop block diagram(s) showing the functional flow sequence of the system, both for technical understanding of the functions and operation of the system and for the subsequent analysis. As a minimum the block diagram shall contain:

.1 breakdown of the system into major subsystems or equipment;

.2 all appropriate labelled inputs and outputs and identification numbers by which each subsystem is consistently referenced; and

.3 all redundancies, alternative signal paths and other engineering features which provide "fail-safe" measures.

An example of a system block diagram is given at appendix 1.

8.2 It may be necessary to have a different set of block diagrams prepared for each operational mode.

9. Identification of Failure Modes, Causes and Effects

9.1 Failure mode is the manner by which a failure is observed. It generally describes the way the failure occurs and its impact on the equipment or system. As an example, a list of failure modes is given in table 1. The failure modes listed in table 1 can describe the failure of any system element in sufficiently specific terms. When used in conjunction with performance specifications governing the inputs and outputs on the system block diagram, all potential failure modes can be thus identified and described. Thus, for example, a power supply may have a failure mode described as "loss of output" (29), and a failure cause "open (electrical)" (31).

9.2 A failure mode in a system element could also be the failure cause of a system failure. For example, the hydraulic line of a steering gear system might have a failure mode of "external leakage" (10). This failure mode of the hydraulic line could become a failure cause of the steering gear system's failure mode "loss of output" (29).

9.3 Each system shall be considered in a top-down approach, starting from the system's functional output, and failure shall be assumed by one possible cause at a time. Since a failure mode may have more than one cause, all potential independent causes for each failure mode shall be identified.

Table 1 - Example of a set of failure modes [1]

1	Structural failure (rupture)
2	Physical binding or jamming
3	Vibration
4	Fails to remain (in position)
5	Fails to open
6	Fails to close
7	Fails open
8	Fails closed
9	Internal leakage
10	External leakage
11	Fails out of tolerance (high)
12	Fails out to tolerance (low)
13	Inadvertent operation
14	Intermittent operation
15	Erratic operation
16	Erroneous indication
17	Restricted flow
18	False actuation
19	Fails to stop
20	Fails to start
21	Fails to switch
22	Premature operation
23	Delayed operation
24	Erroneous input (increased)
25	Erroneous input (decreased)
26	Erroneous output (increased)
27	Erroneous output (increased)
28	Loss of input
29	Loss of output
30	Shorted (electrical)
31	Open (electrical)
32	Leakage (electrical)
33	Other unique failure conditions as applicable to the system characteristics, requirements and operational constraints

9.4 If major systems can fail without any adverse effect there is no need to consider them further unless the failure can go undetected by an operator. To decide that there is no adverse effect does not mean just the identification of system redundancy. The redundancy shall be shown to be immediately effective or brought on line with negligible time lag. In addition, if the sequence is:

"failure - alarm - operator action - start of back up - back up in service",

the effects of delay shall be considered.

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[1] *Refer to IEC Publication: IEC 812 (1985), Analysis techniques for system reliability - procedure for failure mode and effects analysis (FMEA).*

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10. Failure effects

10.1 The consequence of a failure mode on the operation, function, or status of an equipment or a system is called a 'failure effect'. Failure effects on a specific sub-system or equipment under consideration are called local failure effects". The evaluation of local failure effects will help to determine the effectiveness of any redundant equipment or corrective action at that system level. In certain instances, there may not be a local effect beyond the failure mode itself.

10.2 The impact of an equipment or sub-system failure on the system output (system function) is called an "end effect". End effects shall be evaluated and their severity classified in accordance with the following categories:

.1 catastrophic;

.2 hazardous;

.3 major; and

.4 minor.

The definitions of these four categories of failure effects are given in 2.3 of annex 3 of this Code.

10.3 If the end effect of a failure is classified as hazardous or catastrophic, back-up equipment is usually required to prevent or minimize such effect. For hazardous failure effects corrective operational procedures may be accepted.

11. Failure Detection

11.1 The FMEA study in general only analyses failure effects based on a single failure in the system and therefore a failure detection means, such as visual or audible warning devices, automatic sensing devices, sensing instrumentation or other unique indications shall be identified.

11.2 Where the system element failure is non-detectable (i.e. a hidden fault or any failure which does not give any visual or audible indication to the operator) and the system can continue with its specific operation, the analysis shall be extended to determine the effects of a second failure, which in combination with the first undetectable failure may result in a more severe failure effect, e.g., hazardous or catastrophic effect.

12. Corrective Measures

12.1 The response of any back-up equipment, or any corrective action initiated at a given system level to prevent or reduce the effect of the failure mode of a system element or equipment, shall also be identified and evaluated.

12.2 Provisions which are features of the design at any system level to nullify the effects of a malfunction or failure, such as controlling or deactivating system elements to halt generation or propagation of failure effects, or activating back-up or standby items or systems, shall be described. Corrective design provisions include:

.1 redundancies that allow continued and safe operation;

.2 safety devices, monitoring or alarm provisions, which permit restricted operation or limit damage; and

.3 alternative modes of operation.

12.3 Provisions which require operator action to circumvent or mitigate the effects of the postulated failure shall be described. The possibility and effect of operator error shall be considered, if the corrective action or the initiation of the redundancy requires operator input, when evaluating the means to eliminate the local failure effects.

12.4 It shall be noted that corrective responses acceptable in one operational mode may not be acceptable at another, e.g., a redundant system element with considerable time lag to be brought into line, while meeting the operational mode "normal seagoing conditions at full speed" may result in a catastrophic effect in another operational mode, e.g., "maximum permitted operating speed in congested water".

13. Use of Probability Concept

13.1 If corrective measures or redundancy as described in preceding paragraphs are not provided for any failure, as an alternative the probability of occurrence of such failure shall meet the following criteria of acceptance:

.1 a failure mode which results in a catastrophic effect shall be assessed to be extremely improbable;

.2 a failure mode assessed as extremely remote shall not result in worse than hazardous effects; and

.3 a failure mode assessed as either frequent or reasonably probable shall not result in worse than minor effects.

13.2 Numerical values for various levels of probabilities are laid down in section 3 of annex 3 of this Code. In areas where there are no data from craft to determine the level of probabilities of failure other sources can be used such as:

.1 workshop test, or

.2 history of reliability used in other areas under similar operating conditions, or

.3 mathematical model if applicable.

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14. Documentation

14.1 It is helpful to perform FMEA on worksheet(s) as shown in appendix 2.

14.2 The worksheet(s) shall be organized to first display the highest system level and then proceed down through decreasing system levels.

15. Test Programme

15.1 An FMEA test programme shall be drawn up to prove the conclusions of FMEA. It is recommended that the test programme shall include all systems or system elements whose failure would lead to:

.1 major or more severe effects;

.2 restricted operations; and

.3 any other corrective action.

For equipment where failure cannot be easily simulated on the craft, the results of other tests can be used to determine the effects and influences on the systems and craft.

15.2 The trials shall also include investigations into:

.1 the layout of control stations with particular regard to the relative positioning of switches and other control devices to ensure a low potential for inadvertent and incorrect crew action, particularly during emergencies, and the provision of interlocks to prevent inadvertent operation for important system operation;

.2 the existence and quality of the craft's operational documentation with particular regard to the pre-voyage checklists. It is essential that these checks account for any unrevealed failure modes identified in the failure analysis; and

.3 the effects of the main failure modes as prescribed in the theoretical analysis.

15.3 The FMEA tests on board shall be conducted in conjunction with provisions specified in 5.3, 16.4 and 17.4 of this Code, before the craft enters into service.

16. FMEA Report

The FMEA report shall be a self-contained document with a full description of the craft, its systems and their functions and the proposed operation and environmental conditions for the failure modes, causes and effects to be understood without any need to refer to other plans and documents not in the report. The analysis assumptions and system block diagrams shall be included, where appropriate. The report shall contain a summary of conclusions and recommendations for each of the systems analysed in the system failure analysis and the equipment failure analysis. It shall also list all probable failures and their probability of failure, where applicable, the corrective actions or operational restrictions for each system in each of the operational modes under analysis. The report shall contain the test programme, reference any other test reports and the FMEA trials.

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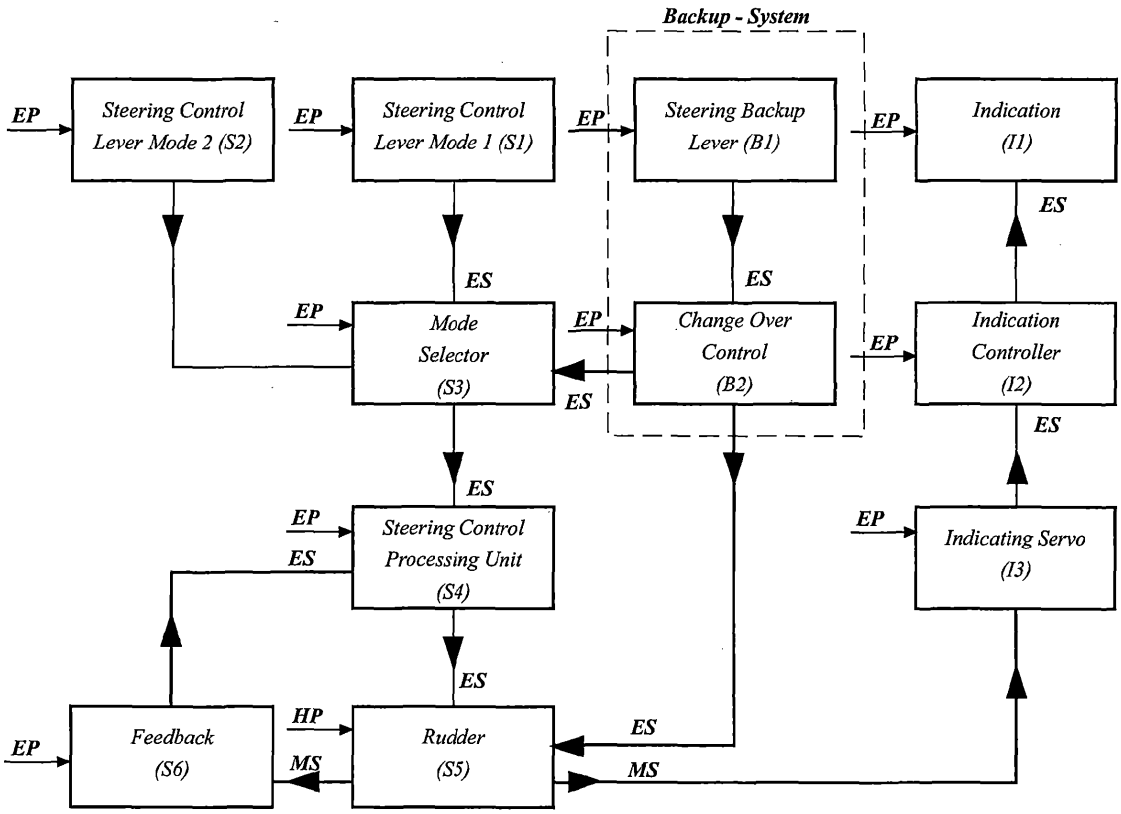
Appendix 1

Example of a system block diagram

Steering control system

Date .....

Analyst .....



where:

EP - electric power

HP - hydraulic power

ES - electrical signal

MS - mechanical signal

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Appendix 2

FMEA worksheet

Name of system .....
Mode of operation .....
Sheet No. .....
Date .....
Name of analyst .....

References .....
System block diagram .....
.....
.....
Drawings .....

Equipment name or number	*Function*	*Ident. No.*	*Failure mode*	*Failure cause*	*Failure mode*		*Failure detection*	*Corrective action*	*Severity of failure effect*	*Probability of failure (if applicable)*	*Remark*
					Local mode	*End mode*					

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Annex 5

Ice Accretion Applicable to all Types of Craft

1. Icing Allowances

1.1 For craft operating in areas where ice accretion is likely to occur, the following icing allowance shall be made in the stability calculations.

.1 30 kg/m² on exposed weather decks and gangways;

.2 7.5 kg/m² for projected lateral area of each side of the craft above the waterplane;

.3 the projected lateral area of discontinuous surfaces of rail, sundry booms, spars (except masts) and rigging and the projected lateral area of other small objects shall be computed by increasing the total projected area of continuous surfaces by 5 % and the static moments of this area by 10 %;

.4 reduction of stability due to asymmetric ice accumulations in cross-structure.

1.2 For craft operating in areas where ice accretion may be expected:

.1 Within the areas defined in 2.1, 2.3, 2.4 and 2.5 known to have icing conditions significantly different from those in 1.1, ice accretion requirements of one half to twice the required allowance may be applied.

.2 Within the area defined in 2.2, where ice accretion in excess of twice the allowance required by 1.1 may be expected, more severe requirements than those given in 1.1 may be applied.

1.3 Information shall be provided in respect of the assumptions made in calculating the condition of the craft in each of the circumstances set out in this annex for the following:

.1 duration of the voyage in terms of the period spent in reaching the destination and returning to port; and

.2 consumption rates during the voyage for fuel, water, stores and other consumables.

2. Areas of Icing Conditions

In the application of 1, the following icing areas shall apply:

.1 The area north of latitude 65° 0' N, between longitude 28° and the west coast of Iceland; north of the north coast of Iceland; north of the rhumb line running from latitude 66°, longitude 15° to latitude 73° 0' N, longitude 15°, north of latitude 73 °0' N between longitude 15° and 35°, and east of longitude 35°, as well as north of latitude 56° in the Baltic Sea.

.2 The area north of latitude 43° bounded in the west by the North American coast and the east by the rhumb line running from latitude 43°, longitude 48° to latitude 63°, longitude 28° and thence along longitude 28°.

.3 All sea areas north of the North American continent, west of the areas defined in subparagraphs .1 and .2 of this paragraph.

.4 The Bering and Okhotsk Seas and the Tartary Strait during the icing season.

.5 South of latitude 60°.

A chart to illustrate the areas is attached.

3. Special Requirements

Craft intended for operation in areas where ice accretion is known to occur shall be:

.1 designed to minimize the accretion of ice; and

.2 equipped with such means for removing ice as the Administration may require.

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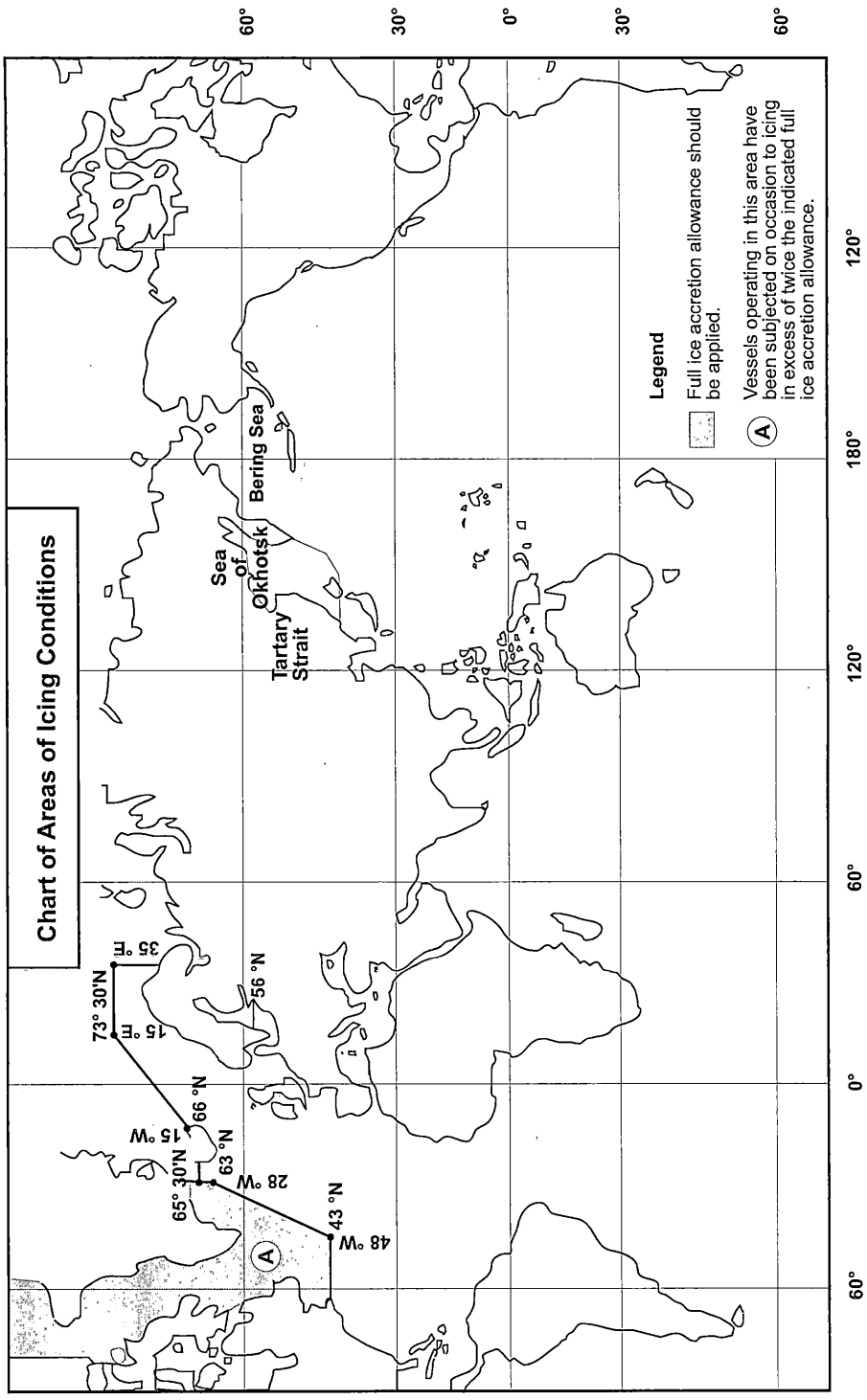

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Annex 6

Stability of Hydrofoil Craft

The stability of these craft shall be considered in the hull-borne, transitional and foil-borne modes. The stability investigation shall also take into account the effects of external forces. The following procedures are outlined for guidance in dealing with stability.

As required by 2.3.1, the stability of hydrofoil craft shall be assessed under all permitted conditions of loading.

The term "hull-borne mode" has the same meaning as "displacement mode" defined in 1.4.22 of the Code.

The term "foil-borne mode" has the same meaning as "non-displacement mode" defined in 1.4.38 of the Code.

1. Surface-piercing Hydrofoils

1.1 Hull-borne mode

1.1.1 *The stability shall be sufficient to satisfy the provisions of 2.3, 2.4 and 2.6 of this Code.*

1.1.2 *Heeling moment due to turning*

The heeling moment developed during manoeuvring of the craft in the displacement mode may be derived from the following formula:

$$M_R = 0{,}196 \cdot \frac{V_0^2}{L} \cdot \Delta \cdot KG \quad (kN\text{-}m)$$

where:

M_R = *moment of heeling;*

V_o = *speed of the craft in the turn (m/s);*

Δ = *displacement (t);*

L = *length of the craft on the waterline (m);*

KG = *height of the centre of gravity above keel (m).*

This formula is applicable when the ratio of the radius of the turning circle to the length of the craft is 2 to 4.

1.1.3 *Relationship between the capsizing moment and heeling moment to satisfy the weather criterion.*

The stability of a hydrofoil boat in the displacement mode can be checked for compliance with the weather criterion K as follows:

$$K = \frac{M_C}{M_V} \geq 1$$

where:

M_C = *minimum capsizing moment as determined when account is taken of rolling;*

M_V = *dynamically applied heeling moment due to the wind pressure.*

1.1.4 *Heeling moment due to wind pressure*

The heeling moment M_V shall be taken as constant during the whole range of heel angles and calculated by the following expression:

$$M_V = 0{,}001\, P_V\, A_V\, Z \quad (kN\text{-}m)$$

where :

P_V = *wind pressure = 750 $(V_W/26)^2$ (N/m^2)*

A_V = *windage area including the projections of the lateral surfaces of the hull, superstructure and various structures above the waterline (m^2)*

Z = *windage area lever (m) = the vertical distance to the geometrical centre of the windage area from the waterline*

V_W = *the wind speed corresponding to the worst intended conditions (m/s).*

1.1.5 *Evaluation of the minimum capsizing moment Mc in the displacement mode*

The minimum capsizing moment is determined from the static and dynamic stability curves taking rolling into account.

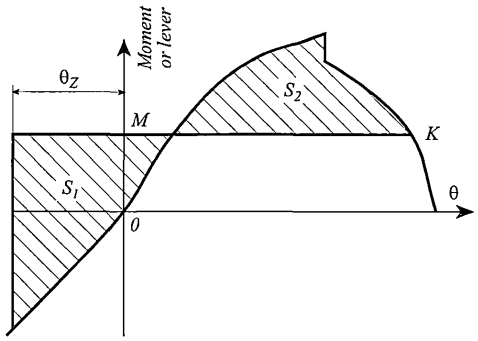

Figure 1 – Static stability curve

.1 *When the static stability curve is used, Mc is determined by equating the areas under the curves of the capsizing and righting moments (or levers) taking rolling into account, as indicated by figure 1, where θz is the amplitude of roll and MK is a line drawn parallel to the abscissa axis such that the shaded areas S1 and S2 are equal.*

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M_C = *OM, if the scale of ordinates represents moments,*

M_C = *OM · displacement, if the scale of ordinates represents levers.*

.2 When the dynamic stability curve is used, first an auxiliary point A shall be determined. For this purpose the amplitude of heeling is plotted to the right along the abscissa axis and a point A' is found (see figure 2). A line AA' is drawn parallel to the abscissa axis equal to the double amplitude of heeling (AA' = 2θz) and the required auxiliary point A is found. A tangent AC to the dynamic stability curve is drawn. From the point A the line AB is drawn parallel to the abscissa axis and equal to 1 radian (57.3°). From the point B a perpendicular is drawn to intersect with the tangent in point E. The distance BE is equal to the capsizing moment if measured along the ordinate axis of the dynamic stability curve. If, however, the dynamic stability levers are plotted along this axis, BE is then the capsizing lever, and in this case the capsizing moment Mc is determined by multiplication of ordinate BE (in metres) by the corresponding displacement in tonnes

Mc = 9.81 BE (kNm)

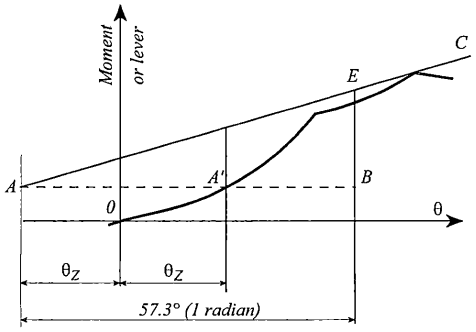

Figure 2 – Dynamic stability curve

.3 The amplitude of rolling θz is determined by means of model and full-scale tests in irregular seas as a maximum amplitude of rolling of 50 oscillations of a craft travelling at 90° to the wave direction in sea state for the worst design condition. If such data are lacking the amplitude is assumed to be equal to 15°.

.4 The effectiveness of the stability curves shall be limited to the angle of flooding.

1.2 Transitional and foil-borne modes

1.2.1 *The stability shall satisfy the provisions of 2.4 and 2.5 of this Code.*

1.2.1.1 *The stability in the transitional and foil-borne modes shall be checked for all cases of loading for the intended service of the craft.*

1.2.1.2 *The stability in the transitional and foil-borne modes may be determined either by calculation or on the basis of data obtained from model experiments and shall be verified by full-scale tests by imposition of a series of known heeling moments by off-centre ballast weights, and recording the heeling angles produced by these moments. When taken in the hull-borne , take-off, steady foil-borne and settling to hull-borne modes, these results will provide an indication of the values of the stability in the various situations of the craft during the transitional condition.*

1.2.1.3 *The angle of heel in the foil-borne mode caused by the concentration of passengers at one side shall not exceed 8° During the transitional mode the angle of heel due to the concentration of passengers on one side shall not exceed 12° The concentration of passengers shall be determined by the Administration, having regard to the guidance given at annex 7 to this Code.*

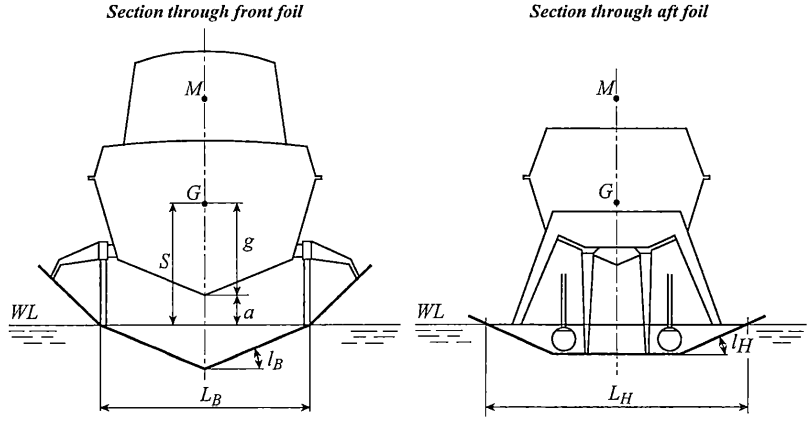

Figure 3

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1.2.2 One of the possible methods of assessing foil-borne metacentric height (GM) in the design stage for a particular foil configuration is given in figure 3.

$$GM = n_B \cdot \left(\frac{L_B}{2 \cdot \tan I_B} - S \right) + n_H \cdot \left(\frac{L_H}{2 \cdot \tan I_H} - S \right)$$

where:

n_B = *percentage of hydrofoil load borne by front foil*

n_H = *percentage of hydrofoil load borne by aft foil*

L_B = *clearance width of front foil*

L_H = *clearance width of aft foil*

a = *clearance between bottom of keel and water*

g = *height of centre of gravity above bottom of keel*

I_B = *angle at which front foil is inclined to horizontal*

I_H = *angle at which aft foil is inclined to horizontal*

S = *height of centre of gravity above water*

2. Fully submerged Hydrofoils

2.1 Hull-borne mode

2.1.1 The stability in the hull-borne mode shall be sufficient to satisfy the provisions of 2.3 and 2.6 of this Code.

2.1.2 Paragraphs 1.1.2 to 1.1.5 of this annex are appropriate to this type of craft in the hull-borne mode.

2.2 Transitional mode

2.2.1 The stability shall be examined by the use of verified computer simulations to evaluate the craft's motions, behaviour and responses under the normal conditions and limits of operation and under the influence of any malfunction.

2.2.2 The stability conditions resulting from any potential failures in the systems or operational procedures during the transitional stage which could prove hazardous to the craft's watertight integrity and stability shall be examined.

2.3 Foil-borne mode

The stability of the craft in the foil-borne mode shall be in compliance with the provisions of 2.4 of this Code. The provisions of paragraph 2.2 of this annex shall also apply.

2.4 Paragraphs 1.2.2.1, 1.2.2.2 and 1.2.2.3 of this annex shall be applied to this type of craft as appropriate and any computer simulations or design calculations shall be verified by full-scale tests.

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Annex 7

Stability of Multihull Craft

1. Stability Criteria in the Intact Condition

A multihull craft, in the intact condition, shall have sufficient stability when rolling in a seaway to successfully withstand the effect of either passenger crowding or high-speed turning as described in 1.4. The craft's stability shall be considered to be sufficient provided compliance with this paragraph is achieved.

1.1 Area under the GZ curve

The area (A_1) under the GZ curve up to an angle q shall be at least:

$$A_1 = 0.055 \times 30°/\theta \text{ (m.rad)}$$

where

θ is the least of the following angles:

.1 *the downflooding angle;*

.2 *the angle at which the maximum CZ occurs; and*

.3 *30°*

1.2 Maximum GZ

The maximum GZ value shall occur at an angle of at least 10°.

1.3 Heeling due to wind

The wind heeling lever shall be assumed constant at all angles of inclination and shall be calculated as follows:

$$HL_1 = \frac{P_i \cdot A \cdot Z}{9800\Delta} \quad (m)$$

$$HL_2 = 1.5\, HL_1 \quad (m) \quad \text{(see Figure 1)}$$

where:

$$P_i = 500\ (V_W / 26)^2 \ (N/m^2)$$

where:

V_W = *wind speed corresponding to the worst intended conditions (m/s)*

A = *projected lateral area of the portion of the craft above the lightest service waterline (m2)*

Z = *vertical distance from the centre of A to a point one half the lightest service draught (m)*

Δ = *displacement (t)*

1.4 Heeling due to passenger crowding or high-speed turning

Heeling due to the crowding of passengers on one side of the craft or to high-speed turning, whichever is the greater, shall be applied in combination with the heeling lever due to wind (HL_2).

1.4.1 Heeling due to passenger crowding

When calculating the magnitude of the heel due to passenger crowding, a passenger crowding lever

shall be developed using the assumptions stipulated in 2.10 of this Code.

1.4.2 Heeling due to high-speed turning

When calculating the magnitude of the heel due to the effects of high-speed turning, a high-speed turning lever shall be developed using either the following formula or an equivalent method specifically developed for the type of craft under consideration, or trials or model test data:

$$TL = \frac{1}{g}\frac{V_o^2}{R}\left(KG - \frac{d}{2}\right) \quad (m)$$

where:

TL = *turning lever (m)*

V_o = *speed of craft in the turn (m/s)*

R = *turning radius (m)*

KG = *height of vertical centre of gravity above keel (m)*

d = *mean draught (m)*

g = *acceleration due to gravity*

Alternatively, another method of assessment may be employed, as provided for in 2.1.4 of this Code.

1.5 Rolling in waves (figure 1)

The effect of rolling in a seaway upon the craft's stability shall be demonstrated mathematically. In doing so, the residual area under the GZ curve (A_2), i.e. beyond the angle of heel (θ_h), shall be at least equal to 0.028 m.rad up to the angle of roll θ_r. In the absence of model test or other data θ_r shall be taken as 15° or an angle of (θ_d - θ_h), whichever is less. The determination of θ_r using model test or other data shall be made using the method for determining θ_Z in 1.1.5.3 of annex 6

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*2. **Criteria for Residual Stability after Damage***

2.1 The method of application of criteria to the residual stability curve is similar to that for intact stability except that the craft in the final condition after damage shall be considered to have an adequate standard of residual stability provided:

.1 the required area A_2 shall be not less than 0.028 m.rad (figure 2 refers); and

.2 there is no requirement regarding the angle at which the maximum GZ value shall occur.

2.2 The wind heeling lever for application on the residual stability curve shall be assumed constant at all angles of inclination and shall be calculated as follows:

$$HL_3 = \frac{P_d \cdot A \cdot Z}{9800\Delta}$$

where:

P_d = 120 $(V_W/26)^2$ (N/m^2)

V_W = *wind speed corresponding to the worst intended conditions (m/s)*

A = *projected lateral area of the portion of the ship above the lightest service waterline (m^2)*

Z = *vertical distance from the centre of A to a point one half of the lightest service draught (m)*

Δ = *displacement (t)*

2.3 The same values of roll angle shall be used as for the intact stability, as determined in 1.5 of this annex.

2.4 The downflooding point is important and is regarded as terminating the residual stability curve. The area A_2 shall therefore be truncated at the downflooding angle.

2.5 The stability of the craft in the final condition after damage shall be examined and shown to satisfy the criteria, when damaged as stipulated in 2.6 of this Code.

2.6 In the intermediate stages of flooding, the maximum righting lever shall be at least 0.05 m and the range of positive righting lever shall be at least 7°. In all cases, only one breach in the hull and only one free surface need to be assumed.

*3. **Application of Heeling Levers***

3.1 In applying the heeling levers to the intact and damaged curves, the following shall be considered:

.1 for intact condition:

.1.1 wind heeling lever (including gusting effect) (HL_2); and

.1.2 wind heeling lever (including gusting effect) plus either the passenger crowding or speed turning levers whichever is the greater (HTL).

.2 for damage condition:

.2.1 wind heeling lever - steady wind (HL_3); and

.2.2 wind heeling lever plus heeling lever due to passenger crowding (HL_4)

3.2 Angles of heel due to steady wind

3.2.1 The angle of heel due to a wind gust when the heeling lever HL_2, obtained as in 1.3, is applied to the intact stability curve shall not exceed 10°.

3.2.2 The angle of heel due to a steady wind when the heeling lever HL_3, obtained as in 2.2, is applied to the residual stability curve after damage, shall not exceed 15° for passenger craft and 20° for cargo craft.

MULTIHULL CRAFT CRITERIA

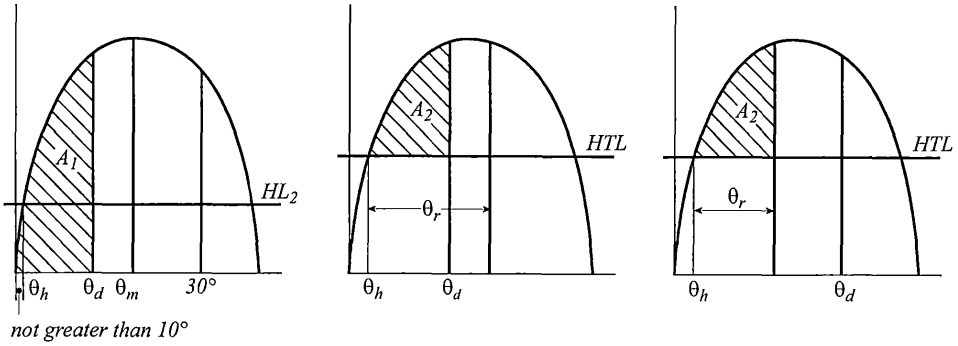

Figure 1 – Intact stability

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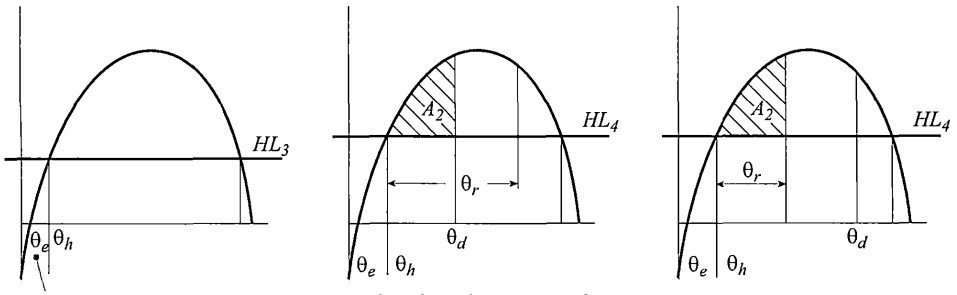

not greater than 15° for passenger craft and 20° for cargo craft

Figure 2 – Damage stability

Abbreviations used in figures 1 and 2

HL_2 = *Heeling lever due to wind + gusting*

HTL = *Heeling lever due to wind + gusting + (passenger crowding or turning)*

HL_3 = *Heeling lever due to wind*

HL_4 = *Heeling lever due to wind + passenger crowding*

θ_m = *Angle of maximum GZ*

θ_d = *Angle of downflooding*

θ_r = *Angle of roll*

θ_e = *Angle of equilibrium, assuming no wind, passenger crowding or turning effects*

θ_h = *Angle of heel due to heeling lever HL_2, HTL, HL_3 or HL_4*

A_1 ≥ *Area required by 1.1*

A_2 ≥ *0.028 m · rad*

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Annex 8

Stability of Monohull Craft

1. *Stability Criteria in the Intact Condition*

1.1 The weather criterion contained in paragraph 3.2 of the Intact Stability Code [1] shall apply. In applying the weather criterion, the value of wind pressure P (N/m2) shall be taken as:

$$500\{Vw/26\}^2$$

where Vw = wind speed (m/s) corresponding to the worst intended conditions.

The angle of heel due to wind, in applying paragraph 3.2.2.1.2 of the Intact Stability Code, shall not exceed 16° or 80 % of the angle of deck-edge immersion (whichever is less). Where the angle of heel due to wind exceeds 10°, efficient non-slip deck surfaces and suitable holding points shall be provided, in accordance with paragraph 2.13.1.1 of this Code. In applying the weather criterion, account shall also be taken of the roll damping characteristics of individual craft in assessing the assumed roll angle θ1, which may alternatively be derived from model or full scale tests using the method for determining θz in 1.1.5.3 of annex 6. Hulls with features which greatly increase damping, such as immersed sidehulls, substantial arrays of foils, or flexible skirts or seals, are likely to experience significantly smaller magnitudes of roll angle. For such craft, therefore, the roll angle shall be derived from model or full scale tests or, in the absence of such data, shall be taken as 15°.

1.2 The area under the righting lever curve (GZ curve) shall not be less than 0,07 m · rad up to θ = 15° when the maximum righting lever (GZ) occurs at θ = 15°, and 0,055 m · rad up to θ = 30° when the maximum righting lever occurs at θ = 30° or above. Where the maximum righting lever occurs at angles of between θ = 15° and θ = 30°, the corresponding area under the righting lever curve shall be:

$$A = 0{,}055 + 0{,}001\,(30° - \theta_{max})\ (m \cdot rad)$$

where:

θ_{max} is the angle of heel, in degrees, at which the righting lever curve reaches its maximum.

1.3 The area under the righting lever curve between θ = 30° and θ = 40° or between θ = 30° and the angle of flooding θ_F [2] if this angle is less than 40°, shall not be less than 0,03 m · rad.

1.4 The righting lever GZ shall be at least 0,2 m at an angle of heel equal to or greater than 30°.

1.5 The maximum righting lever shall occur at an angle of heel not less than 15°.

1.6 The initial metacentric height GMT shall not be less than 0,15 m.

2. *Criteria for Residual Stability after Damage*

2.1 The stability required in the final condition after damage, and after equalization where provided, shall be determined as specified in 2.1.1 to 2.1.4.

2.1.1 The positive residual righting lever curve shall have a minimum range of 15° beyond the angle of equilibrium. This range may be reduced to a minimum of 10°, in the case where the area under the righting lever curve is that specified in 2.1.2, increased by the ratio:

$$\frac{15}{range}$$

where the range is expressed in degrees. The range shall be taken as the difference between the equilibrium heel angle and the heel angle at which the residual righting lever subsequently becomes negative or the angle at which progressive flooding occurs, whichever is less.

2.1.2 The area under the righting lever curve shall be at least 0,015 m · rad, measured from the angle of equilibrium to the lesser of:

.1 the angle at which progressive flooding occurs; and

.2 27° measured from the upright.

2.1.3 A residual righting lever shall be obtained within the range of positive stability, taking into account the greatest of the following heeling moments:

.1 the crowding of all passengers towards one side;

.2 the launching of all fully loaded davit-launched survival craft on one side; and

---

[1] Refer to the Code on Intact Stability for All Types of Ships Covered by IMO Instruments, adopted by the Organization by resolution A.749(18), as amended by resolution MSC.75(69).

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.3 due to wind pressure, as calculated by the formula:

$$GZ = \frac{heeling\ moment}{displacement} + 0,04\,(m)$$

However, in no case, this righting lever shall be less than 0,1 m.

2.1.4 For the purpose of calculating the heeling moments referred to in 2.1.3, the following assumptions shall be made:

.1 Moments due to crowding of passengers. This should be calculated in accordance with paragraph 2.10 of the Code.

.2 Moments due to launching of all fully loaded davit-launched survival craft on one side:

.2.1 all lifeboats and rescue boats fitted on the side to which the ship has heeled after having sustained damage shall be assumed to be swung out fully loaded and ready for lowering;

.2.2 for lifeboats which are arranged to be launched fully loaded from the stowed position, the maximum heeling moment during launching shall be taken;

.2.3 a fully loaded davit-launched liferaft attached to each davit on the side to which the ship has heeled after having sustained damage shall be assumed to be swung out ready for lowering;

.2.4 persons not in the life-saving appliances which are swung out shall not provide either additional heeling or righting moment; and

.2.5 life-saving appliances on the side of the ship opposite to the side to which the ship has heeled shall be assumed to be in a stowed position.

.3 Moments due to wind pressure:

.3.1 the wind pressure shall be taken as (120 {V_W/ 26}2) (N/m^2), where V_W = wind speed (m/s), corresponding to the worst intended condition;

.3.2 the area applicable shall be the projected lateral area of the ship above the waterline corresponding to the intact condition; and

.3.3 the moment arm shall be the vertical distance from a point at one half of the mean draught corresponding to the intact condition to the centre of gravity of the lateral area.

2.2 In intermediate stages of flooding, the maximum righting lever shall be at least 0,05m and the range of positive righting levers shall be at least 7°. In all cases, only one breach in the hull and only one free surface need be assumed.

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Annex 9

Definitions, Requirements and Compliance Criteria related to Operational and Safety Performance

This annex applies to all types of craft. Tests to evaluate operational safety shall be conducted on the first craft of a new design or of a design incorporating new features which may modify the results of a previous testing. The tests shall be carried out to a schedule agreed between the Administration and the manufacturer. Where conditions of service warrant additional testing (e.g., low temperature), the Administration or base port State authorities as appropriate may require further demonstrations. Functional descriptions, technical and system specifications relevant to the understanding and evaluation of craft performance shall be available.

The objective of these tests is to provide essential information and guidance to enable the craft to be operated safely under normal and emergency conditions within the design speed and environmental envelope.

The following procedures are outlined as requirements in dealing with verification of craft performance.

1. Performance

1.1 General

1.1.1 The craft shall meet the applicable operational requirements in Section 17 of this Code and this annex for all extremes of passenger and load configurations for which certification is required. The limiting sea state related to the different modes of operation shall be verified by tests and analyses of a craft of the type for which certification is requested.

1.1.2 Operational control of the craft shall be in accordance with procedures established by the applicant for operation in service. Procedures to be established shall be start procedure, cruise procedures, normal and emergency stop and manoeuvre procedures.

1.1.3 The procedures established under 1.1.2 shall:

.1 demonstrate that normal manoeuvres and craft responses to failures are consistent in performance;

.2 use methods or devices that are safe and reliable; and

.3 include allowance for any time lag in the execution of procedures that may reasonably be expected in service.

1.1.4 Procedures required by this annex shall be conducted over water of sufficient depth such that craft performance will not be affected.

1.1.5 Tests shall be conducted at minimum practicable weight and additional testing shall be conducted at maximum weight sufficient to establish the need for additional restrictions and for testing to examine the effect of weight.

2. Stopping

2.1 This test is to establish the acceleration experienced when stopping the craft in calm water with no passenger load or cargo load during the following conditions:

.1 normal stop for 90 % of maximum speed;

.2 emergency stop for 90 % of maximum speed; and

.3 crash stop from 90 % of maximum speed and from any transitional mode speed.

2.2 The tests referred to in 2.1.1 and 2.1.2 shall document that the accelerations do not exceed safety level 1 in annex 3 when control levers are used in accordance to written procedures as given in the craft operating manual or in an automatic mode. Should safety level 1 be exceeded during normal stop, control systems shall be modified in order to avoid exceedance or passengers shall be required to be seated during normal stop. Should safety level 1 be exceeded during emergency stop, then written procedures in the craft operating manual shall include detailed information of how to avoid exceedance or the control system shall be modified to avoid exceedance.

2.3 The test referred to in 2.1.3 shall document that the accelerations do not exceed safety level 2 in annex 3 when control levers of automatic modes are used in a manner which will give the highest accelerations. If safety level 2 is exceeded then the craft operating manual shall include a warning that it is a risk to passengers being injured, if a crash stop is performed.

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2.4 Other tests shall be repeated during craft turning to establish the need or otherwise to impose any speed-related restrictions during manoeuvres.

3. Cruise Performance

3.1 This test is to establish the craft performance and accelerations experienced during cruise modes with no passenger load or cargo load during the following conditions:

.1 normal operation conditions are those in which the craft will safely cruise at any heading while manually operated, auto-pilot assisted operated or operated with any automatic control system in normal mode; and

.2 worst intended conditions, referred to in 1.4.57 of this Code, are those in which it shall be possible to maintain safe cruise without exceptional piloting skill. However, operations at all headings relative to the wind and sea may not be possible. For type of craft having a higher performance standard in non-displacement mode, the performance and accelerations shall also be established at displacement mode during operation in the worst intended condition.

3.2 Operation levels, as defined in 3.1, shall be established and documented by full-scale tests in at least two relevant sea conditions and in head, beam and following seas. It shall be shown that the period of every test (run) and the number of series are sufficient for achieving reliable measurements. In every sea state tested, the aggregate time in each direction shall not be less than 15 min. Model tests and mathematical simulations could be used to verify the performance in the worst intended conditions.

Limits for normal operation condition shall be documented by measurements of craft speed, heading to the wave and interpolation of measurements of maximum horizontal accelerations in accordance with 2.4 of annex 3. Measurement of wave height and period shall be made to the maximum extent practicable.

Limits for worst intended condition shall be documented by measurements of craft speed, wave height and period, heading to the wave and by root mean square (RMS) values of horizontal accelerations in accordance with 2.4 of annex 3 and of vertical accelerations close to the craft longitudinal centre of gravity. RMS values could be used for extrapolation of peak values. To obtain the expected peak values related to structural design load and safety levels (one per 5-min exceedance), multiply the RMS values by 3.0 or

where:

$$C = \sqrt{2 \ln N}$$

N is the number of successive amplitudes within the relevant period.

If not otherwise verified by model tests or by mathematical calculations, it might be assumed a linear relation between wave height and accelerations based on measurements in the two sea conditions. The worst intended conditions shall not exceed 150% of the more severe of the two measured sea conditions. Limits for worst intended condition shall be documented both related to passenger safety in accordance with 2.4 of annex 3 and related to the actual structural design load of the craft.

3.3 The tests and verification process shall document the limiting seas for safe operation of the craft:

.1 in normal operation at 90 % of maximum speed the accelerations shall not exceed safety level 1 in annex 3 with an average of one per 5-min period. The craft operating manual shall include detailed description of the effects of speed reduction or change of heading to the waves in order to prevent exceedance;

.2 in the worst intended conditions, with reduced speed as necessary, the accelerations shall not exceed safety level 2 in annex 3 with an average of one per 5-min period, nor shall any other craft characteristic motion as pitch, roll and yaw exceed levels that could impede the safety of passengers. In worst intended conditions, with reduced speed as necessary, craft shall be safely manoeuvrable and provide adequate stability in order that the craft can continue safe operation to the nearest place of refuge, provided caution is exercised in handling. Passengers shall be required to be seated when safety level 1 in annex 3 is exceeded; and

.3 within the actual structural design load for the craft, with reduced speed and change of heading, as necessary.

3.4 Turning and manoeuvrability

The craft shall be safely controllable and manoeuvrable during:

.1 hull-borne operation;

.2 operation in non-displacement mode;

.3 take-off, landing;

.4 any intermediate or transition modes, as applicable; and

.5 berthing operations, as applicable.

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4. Effects of Failures or Malfunction

4.1 General

The limits of safe operation, special handling procedures and any operational restrictions shall be examined and developed as a result of full-scale trials conducted by simulating possible equipment failures.

The failures to be examined shall be those leading to major or more severe effects as determined from evaluation of FMEA or similar analysis.

Failures to be examined shall be agreed between the craft manufacturer and the Administration and each single failure shall be examined in a progressive manner.

4.2 Objects of tests

Examination of each failure shall result in:

.1 determining safe limits of craft operation at the time of failure, beyond which the failure will result in degradation beyond safety level 2;

.2 determining crew member's actions, if any, to minimize or counter the effect of the failure; and

.3 determining craft or machinery restrictions to be observed to enable the craft to proceed to a place of refuge with the failure present.

4.3 Failures to be examined

Equipment failures shall include, but not be limited to, the following:

.1 total loss of propulsion power;

.2 total loss of lift power (for ACV and SES);

.3 total failure of control of one propulsion system;

.4 involuntary application of full propulsion thrust (positive or negative) on one system;

.5 failure of control of one directional control system;

.6 involuntary full deflection of one directional control system;

.7 failure of control of trim control syste m;

.8 involuntary full deflection of one trim control system element; and

.9 total loss of electrical power.

Failures shall be fully representative of service conditions and shall be simulated as accurately as possible in the most critical craft manoeuvre where the failure will have maximum impact.

4.4 "Dead ship" test

In order to establish craft motions and direction of laying to wind and waves, for the purposes of determining the conditions of a craft evacuation, the craft shall be stopped and all main machinery shut down for sufficient time that the craft's heading relative to wind and waves has stabilized. This test shall be carried out on an opportunity basis to establish patterns of the design's "dead ship" behaviour under a variety of wind and sea states.

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Annex 10

Criteria for Testing and Evaluation of Seats

1. Purpose and Scope

The purpose of these criteria is to provide requirements for revenue and crew seats, seat anchorage and seat accessories and their installation to minimize occupant injury and/or disruption of egress/ingress if the craft suffers a collision.

2. Static Seat Tests

2.1 The requirements of this section are applicable to all crew and revenue seats .

2.2 All seats to which this paragraph applies, along with their supports and deck attachments, shall be designed to withstand at least the following static forces applied in the direction of the craft:

.1 Forward direction: a force of 2,25 kN,

.2 After direction: a force of 1,5 kN,

.3 Transverse direction: a force of 1,5 kN,

.4 Vertically downward: a force of 2,25 kN, and

.5 Vertically upward: a force of 1,5 kN.

A seat shall comprise a frame, bottom and back. Forces applied in the fore or aft direction of the seat shall be applied horizontally to the seat back 350 mm above the seat bottom. Forces applied in the transverse seat direction shall be applied horizontally to the seat bottom. Vertical upward forces shall be evenly distributed to the corners of the seat bottom frame. Vertical downward forces shall be uniformly distributed over the seat bottom.

If a seating unit consists of more than one seating position, these forces shall be applied at each seating position concurrently during the tests.

2.3 When the forces are applied to a seat, consideration shall be given to the direction in which the seat is to face in the craft. For example, if the seat faces sideways, the transverse craft force would be applied fore and aft on the seat and the forward craft force would be applied transversely on the seat.

2.4 Each seating unit to be tested shall be attached to the support structure similar to the manner in which it will be attached to the deck structure in the craft. Although a rigid support structure can be used for these tests, a support structure, having the same strength and stiffness as the support structure in the craft, is preferred.

2.5 The forces described in 2.2.1 to 2.2.3 shall be applied to the seat through a cylindrical surface having a radius of 80 mm and a width at least equal to the width of the seat. The surface shall be equipped with at least one force transducer able to measure the forces applied.

2.6 The seat shall be considered acceptable if:

.1 under the influence of the forces referred to in 2.2.1 to 2.2.3, the permanent displacement measured at the point of application of the force is not more than 400 mm;

.2 no part of the seat, the seat mountings or the accessories become completely detached during the tests;

.3 the seat remains firmly held, even if one or more of the anchorages is partly detached;

.4 all of the locking systems remain locked during the entire test but the adjustment and locking systems need not be operational after the tests; and

.5 rigid parts of the seat with which the occupant may come into contact shall present a curved surface with a radius of at least 5 mm.

2.7 The requirements of section 3 may be used in lieu of the requirements of this section provided that the accelerations used for the tests are at least 3g.

3. Dynamic Seat Tests

3.1 The requirements of this section are applicable in addition to those in 2.1 for crew and revenue seats in craft having a design collision load of 3g or greater.

3.2 All seats for which this section applies, the seat supporting structure, the attachment to the deck structure, the lap belt, if installed, and shoulder harness, if installed, shall be designed to withstand the maximum acceleration force that can be imposed upon them during a design collision. Consideration shall be given to the orientation of the seat relative to the acceleration force (i.e. whether the seat is forward-, aft-, or side-facing).

3.3 The acceleration pulse to which the seat is subjected shall be representative of the collision time-history of the craft. If the collision time-history is not known, or cannot be simulated, the acceleration time-history envelope shown in the figure can be used.

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3.4 In the test frame, each seat unit and its accessories (e.g., lap belts and shoulder harnesses) shall be attached to the support structure similar to the manner in which it will be attached in the craft. The support structure can be a rigid surface; however, a support structure having the equivalent strength and stiffness as the support structure in the craft is preferred. Other seats and/or tables with which an occupant may come in contact during a collision shall be included in the test frame in an orientation and with a method of attachment typical of that in the craft.

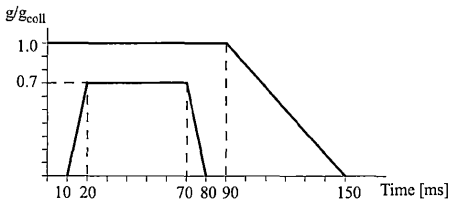

Figure – Acceleration time-history envelope

3.5 During the dynamic seat test, a fiftieth percentile anthropomorphic test dummy, suitable for the test being conducted, shall be placed in the seat in an upright seating position. If a typical seating unit is composed of more than one occupant seat, a test dummy shall be placed in each occupant seat in the unit. The dummy, or dummies, shall be secured in the seat unit in accordance with procedures of recognized national standards[1] and be secured using only the lap belt and shoulder harness if they are installed. Tray tables and other such devices shall be placed in the position that would cause the greatest potential for an occupant to become injured.

3.6 The test dummy shall be instrumented and calibrated, in accordance with the requirements of a recognized national standard, so as to permit, as a minimum, calculation of the head injury criterion, calculation of the thoracic trauma index, measurement of force in the femur, and measurement of extension and flexion of the neck.

3.7 If more than one dummy is used in the tests, the dummy located in the seat having the highest potential for an occupant to be injured shall be the one instrumented. The other dummy or dummies need not be instrumented.

3.8 The tests shall be conducted and the instrumentation shall be sampled at a rate sufficient to reliably show response of the dummy in accordance with the requirements of a recognized national standard[2].

3.9 The seat unit tested in accordance with the requirements of this section shall be considered acceptable if:

.1 the seat unit and tables installed in the seat unit or area do not become dislodged from the supporting deck structure and do not deform in a manner that would cause the occupant to become trapped or injured;

.2 the lap belt, if installed, remains attached and on the test dummy's pelvis during the impact. The shoulder harness, if installed, remains attached and in the immediate vicinity of the test dummy's shoulder during the impact. After the impact, the release mechanisms of any installed lap belt and shoulder harness shall be operative;

.3 the following acceptability criteria are met:

.3.1 the head injury criterion (HIC), calculated in accordance with the formula, does not exceed 500

$$HCI = (t_2 - t_1)\left[\frac{1}{t_2 - t_1}\int_{t_1}^{t_2} a(t)\,d_t\right]^{2.5}$$

where:

t_1 and t_2 are the beginning and ending times (in seconds) of the interval in which the HIC is a maximum. The term a(t) is the resultant measured acceleration in the head of the dummy in g;

.3.2 the thoracic trauma index (TTI), calculated in accordance with the formula, does not exceed 30g except for periods totalling less than 3 ms

$$TTI = \frac{g_R + g_{LS}}{2}$$

or acceleration at the centre of gravity

where:

g_R is the acceleration in g of either the upper or lower rib;

g_{LS} is the acceleration in g of the lower spine; and

.3.3 neck flexion does not exceed 88 Nm;

.3.4 neck extension does not exceed 48 Nm;

.3.5 in lieu of the requirements of subparagraphs .3.3 and .3.4 above, a seatback or headrest of at least 850 mm above the seat cushion is acceptable; and

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[1] *Refer to ECE 80 with addendum 79. Other national standards may be acceptable.*

[2] *Refer to the specifications of International Standard ISO 6487 - Technique of measurement in impact tests (1987) or SAE J211 - Instrumentation.*

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.3.6 the force in the femur does not exceed 10 kN except that it cannot exceed 8 kN for periods totalling more than 20 ms; and

.4 loads on the upper torso harness straps do not exceed 7,8 kN or a total of 8,9 kN if dual straps are used.

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Annex 11

Open Reversible Liferafts Craft

1. General

1.1 All open reversible liferafts shall :

.1 be constructed with proper workmanship and materials;

.2 not be damaged in stowage throughout the air temperature range of -18 °C to +65 °C;

.3 be capable of operating throughout an air temperature range of -18 °C to +65 °C and a seawater temperature range of -1 °C to +30 °C;

.4 be rot-proof, corrosion-resistant and not be unduly affected by seawater, oil or fungal attack;

.5 be stable and maintain their shape when inflated and fully laden; and

.6 be fitted with retro-reflective material, where it will assist in detection, and in accordance with the recommendations adopted by the Organization. [1]

2. Construction

2.1 The open reversible liferaft shall be so constructed that when it is dropped into the water in its container from a height of 10 m, the liferaft and its equipment will operate satisfactorily. If the open reversible liferaft is to be stowed at a height of more than 10 m above the waterline in the lightest seagoing condition, it shall be of a type which has been satisfactorily drop-tested from at least that height.

2.2 The open reversible floating liferaft shall be capable of withstanding repeated jumps on to it from a height of at least 4.5 m.

2.3 The open reversible liferaft and its fittings shall be so constructed as to enable it to be towed at a speed of 3 knots in calm water when loaded with its full complement of persons and equipment, with the sea-anchor deployed.

2.4 The open reversible liferaft when fully inflated shall be capable of being boarded from the water whichever way up it inflates.

2.5 The main buoyancy chamber shall be divided into:

.1 not less than two separate compartments, each inflated through a nonreturn inflation valve on each compartment; and

.2 the buoyancy chambers shall be so arranged that in the event of one of the compartments being damaged or failing to inflate, the intact compartment shall be able to support, with positive freeboard over the open reversible liferaft's entire periphery, the number of persons which the liferaft is permitted to accommodate, each having a mass of 75 kg and seated in their normal positions.

2.6 The floor of the open reversible liferaft shall be waterproof.

2.7 The open reversible liferaft shall be inflated with a non-toxic gas by an inflation system complying with the requirements of paragraph 4.2.2 of the LSA Code. Inflation shall be completed within the period of one minute at an ambient temperature of between 18 °C and 20 °C and within a period of three minutes at an ambient temperature of -18 °C After inflation the open reversible liferaft shall maintain its form when loaded with its full complement of persons and equipment.

2.8 Each inflatable compartment shall be capable of withstanding a pressure equal to at least three times the working pressure and shall be prevented from reaching a pressure exceeding twice the working pressure either by means of relief valves or by a limited gas supply. Means shall be provided for fitting the topping-up pump or bellows.

2.9 The surface of the buoyancy tubes shall be of non-slip material. At least 25 % of these tubes shall be of a highly visible colour.

2.10 The number of persons which an open reversible liferaft shall be permitted to ccommodate shall be equal to the lesser of:

.1 the greatest whole number obtained by dividing by 0,096 the volume, measured in cubic metres, of the main buoyancy tubes (which for this purpose shall not include the thwarts, if fitted) when inflated; or

.2 the greatest whole number obtained by dividing by 0,372 the inner horizontal cross-sectional area of the open reversible liferaft

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[1] *Refer to the Recommendation on the Use and Fitting of Retro-Reflective Materials on Life-Saving Appliances, adopted by the Organization by resolution A.658(16).*

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measured in square metres (which for this purpose may include the thwart or thwarts, if fitted) measured to the innermost edge of the buoyancy tubes; or

.3 the number of persons having an average mass of 75 kg, all wearing lifejackets, that can be seated inboard of the buoyancy tubes without interfering with the operation of any of the liferaft's equipment.

3. Open Reversible Liferaft Fittings

3.1 Lifelines shall be securely becketed around the inside and outside of the open reversible liferaft.

3.2 The open reversible liferaft shall be fitted with an efficient painter of a length suitable for automatic inflation on reaching the water. For open reversible liferafts accommodating more than 30 persons an additional bowsing-in line shall be fitted.

3.3 The breaking strength of the painter system, including its means of attachment to the open reversible liferaft, except the weak link required by paragraph 4.1.6.2 of the LSA Code, shall be:

.1 7,5 kN for open reversible liferafts accommodating up to 8 persons;

.2 10,0 kN for open reversible liferafts accommodating 9 to 30 persons; and

.3 15,0 kN for open reversible liferafts accommodating more than 30 persons.

3.4 The open reversible liferaft shall be fitted with at least the following number of inflated ramps to assist boarding from the sea whichever way up the raft inflates:

.1 one boarding ramp for open reversible liferafts accommodating up to 30 persons; or

.2 two boarding ramps for open reversible liferafts accommodating more than 30 persons; such boarding ramps shall be 180° apart.

3.5 The open reversible liferaft shall be fitted with water pockets complying with the following requirements:

.1 the cross-sectional area of the pockets shall be in the shape of an isosceles triangle with the base of the triangle attached to the buoyancy tubes of the open reversible liferaft;

.2 the design shall be such that the pockets fill to approximately 60 % of capacity within 15 s to 25 s of deployment;

.3 the pockets attached to each buoyancy tube shall normally have aggregate capacity of between 125 l and 150 l for inflatable open reversible liferafts up to and including the 10-person size;

.4 the pockets to be fitted to each buoyancy tube on liferafts certified to carry more than 10 persons shall have, as far as practicable, an aggregate capacity of 12 N litres, where N is the number of persons carried;

.5 each pocket on a buoyancy tube shall be attached so that when the pocket is in the deployed position it is attached along the full length of its upper edges to, or close to, the lowest part of the lower buoyancy tube; and

.6 the pockets shall be distributed symmetrically round the circumference of the liferaft with sufficient separation between each pocket to enable air to escape readily.

3.6 At least one manually controlled lamp complying with the requirements shall be fitted on the upper and lower surfaces of the buoyancy tubes.

3.7 Suitable automatic drain arrangements shall be provided on each side of the floor of the liferaft in the following manner:

.1 one for open reversible liferafts accommodating up to 30 persons; or

.2 two for open reversible liferafts accommodating more than 30 persons.

3.8 The equipment of every open reversible liferaft shall consist of:

.1 one buoyant rescue quoit, attached to not less than 30 m of buoyant line with a breaking strength of at least 1 kN;

.2 two safety knives of the non-folding type, having a buoyant handle, shall be fitted attached to open reversible liferaft by light lines. They shall be stowed in pockets so that, irrespective of the way in which the open reversible liferaft inflates, one will be readily available on the top surface of the upper buoyancy tube in a suitable position to enable the painter to be readily cut;

.3 one buoyant bailer;

.4 two sponges;

.5 one sea-anchor permanently attached to the open reversible liferaft in such a way as to be readily deployable when the open reversible liferaft inflates. The position of the sea-anchor shall be clearly marked on both buoyancy tubes;

.6 two buoyant paddles;

.7 one first-aid outfit in a waterproof case capable of being closed tightly after use;

.8 one whistle or equivalent sound signal;

.9 two hand flares;

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.10 one waterproof electric torch suitable for Morse signalling together with one spare set of batteries and one spare bulb in a waterproof container;

.11 one repair outfit for repairing punctures in buoyancy compartments; and

.12 one topping-up pump or bellows.

3.9 The equipment specified in 3.8 is designated an HSC Pack.

3.10 Where appropriate, the equipment shall be stowed in a container which, if it is not an integral part of, or permanently attached to, the open reversible liferaft, shall be stowed and secured to the open reversible liferaft and be capable of floating in water for at least 30 min without damage to its contents. Irrespective of whether the equipment container is an integral part of, or is permanently attached to, the open reversible liferaft, the equipment shall be readily accessible irrespective of which way up the open reversible liferaft inflates. The line which secures the equipment container to the open reversible liferaft shall have a breaking strength of 2 kN or a breaking strength of 3:1 based on the mass of the complete equipment pack, whichever is the greater.

4. Containers for Open Reversible Inflatable Liferafts

4.1 The open reversible liferafts shall be packed in a container that is:

.1 so constructed as to withstand conditions encountered at sea;

.2 of sufficient inherent buoyancy, when packed with the liferaft and its equipment, to pull the painter from within and to operate the inflation mechanism shall the craft sink; and

.3 as far as practicable, watertight, except for drain holes in the container bottom.

4.2 The container shall be marked with:

.1 maker's name or trademark;

.2 serial number;

.3 the number of persons it is permitted to carry;

.4 non-SOLAS reversible;

.5 type of emergency pack enclosed;

.6 date when last serviced;

.7 length of painter;

.8 maximum permitted height of stowage above waterline (depending on drop-test height); and

.9 launching instructions.

5. Markings on Open Reversible Inflatable Liferafts

The open reversible liferafts shall be marked with:

.1 maker's name or trademark;

.2 serial number;

.3 date of manufacture (month and year);

.4 name and place of service station where it was last serviced; and

.5 number of persons it is permitted to accommodate on the top of each buoyancy tube, in characters not less than 100 mm in height and of a colour contrasting with that of the tube.

6. Instructions and Information

Instructions and information required for inclusion in the craft's training manual and in the instructions for on-board maintenance shall be in a form suitable for inclusion in such training manual and instructions for on-board maintenance. Instructions and information shall be in a clear and concise form and shall include, as appropriate, the following:

.1 general description of the open reversible liferaft and its equipment;

.2 installation arrangements;

.3 operational instructions, including use of associated survival equipment; and

.4 servicing requirements.

7. Testing of Open Reversible Inflatable Liferafts

7.1 When testing open reversible liferafts in accordance with the recommendations of resolution MSC.81(70), part 1:

.1 tests No. 5.5, 5.12, 5.16, 5.17.2, 5.17.10, 5.17.11, 5.17.12, 5.18 and 5.20 may be omitted;

.2 the part of test No. 5.8 regarding closing arrangement may be omitted,

.3 the temperature – 30 °C in test No. 5.17.3 and 5.17.5 may be substituted with -18 °C; and

.4 the drop height of 18 m in test No. 5.1.2 may be substituted with 10 m.

Omittances and substitution, as described above, shall be reflected in the type approval certificate.

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Annex 12

Factors to be Considered in Determining Craft Operating Limitations [1]

1. Purpose and Scope

The purpose of this annex is to identify the parameters to which consideration should be given when determining the worst intended conditions (defined in 1.4.61) and other operational limitations (defined in 1.4.41) for insertion into the Permit to Operate, in order to facilitate consistent application of the Code.

2. Factors to be considered

As a minimum, the following factors shall be considered:

.1 *The maximum distance from refuge implied by 1.3.4.*

.2 *The availability of rescue resources to comply with 1.4.12.1 (category A craft only).*

.3 *Minimum air temperature (susceptibility to icing), visibility and depth of water for safe operation as addressed by 1.4.61.*

.4 *The significant wave height and maximum mean wind speed used when applying the requirements for stability and buoyancy in Section 2 and associated annexes.*

.5 *The safe seakeeping limitations (especially significant wave height) considering the known stability hazards listed in 2.1.5, the operating conditions on the intended route (see 18.1.3.2) and the motions experienced during operation defined in 3.3 of annex 9.*

.6 *The structural safety of the craft in critical design conditions according to Section 3.*

.7 *The safe deployment and operation of evacuation systems and survival craft as required by 8.6.5.*

.8 *The safe handling limitations determined in accordance with the sea trials required by Section 17 and annexes 3 and 9, identifying any limitations on weight and centre-of-gravity position according to 17.3, and the effects of failures and malfunctions according to 17.4.*

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[1] *Refer to the guidelines to be developed by the Organization.*

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General Information for the Rules and Regulations for the Classification of Special Service Craft

July 2012

Lloyd's Register

LIFE MATTERS

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General Information

1. The 2012 edition of the Rules and Regulations for the Classification of Special Service Craft is a complete reprint of the 2011 edition, consisting of 8 books.

Volume 1, Part 1	Regulations
Rules for the Manufacture, Testing and Certification of Materials	
Volume 3, Part 3	General Requirements and Constructional Arrangement
Volume 3, Part 4	Additional Requirements for Yachts
Volume 3, Part 5	Design and Load Criteria
Volume 4, Part 6	Hull Construction in Steel
Volume 5, Part 7	Hull Construction in Aluminium
Volume 6, Part 8	Hull Construction in Composite
Volume 7, Part 9	General Requirements for Machinery
Volume 7, Part 10	Prime Movers
Volume 7, Part 11	Transmission Systems
Volume 7, Part 12	Propulsion Devices
Volume 7, Part 13	Shaft Vibration and Alignment
Volume 7, Part 14	Steering Systems
Volume 7, Part 15	Piping Systems and Pressure Plant
Volume 7, Part 16	Control and Electrical Engineering
Volume 8, Part 17	Fire Protection, Detection and Extinction

2. A decimal notation system has been adopted throughout. Five sets of digits cover the divisions, i.e. Part, Chapter, Section, sub-Section and paragraph. The textual cross-referencing within the text is as follows, although the right-hand digits may be added or omitted depending on the degree of precision required:
   (a) In same Chapter, e.g. *see* 2.1.3 (i.e. down to paragraph).
   (b) In same Part but different Chapter, e.g. *see* Ch 3,2.1 (i.e. down to sub-Section).
   (c) In another Part, e.g. *see* Pt 5, Ch 1,3 (i.e. down to Section).

   The cross-referencing for Figures and Tables is as follows:
   (a) In same Chapter, e.g. as shown in Fig. 2.3.5 (i.e. Chapter, Section and Figure Number).
   (b) In same Part but different Chapter, e.g. as shown in Fig. 2.3.5 in Chapter 2.
   (c) In another Part, e.g. *see* Table 2.7.1 in Pt 3, Ch 2.

3. The primary changes from the 2011 edition of the Rules are identified in the Guide Book. The effective dates of the indicated changes are 1 January 2012 and 1 July 2012.

4. Until the next edition of the Rules and Regulations for the Classification of Special Service Craft is published, Rule change Notices and/or Corrigenda, as necessary, will be published on the LR Webstore — www.webstore.lr.org – and will be available for downloading free of charge. It is not intended at this time to publish hard copies of future Rule Notices to Existing Rules.

5. In this publication, a shortened version of the Notice has been reproduced listing all the paragraphs that have been altered since the last edition of the Rules. It is followed by a comprehensive Contents list of all books in the set, showing all the titles down to Section level.

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Notice – Summary of Changes

Summary of Changes from the 2011 Rules

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 1					**Effective Date 1 January 2012**
3	4	4.3.5	In-water surveys	Paragraph amended	3

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 1					**Effective Date 1 July 2012**
2	1	1.1.13 to 1.1.15	General	Paragraphs amended	4
2	3	3.5.5	Character of classification and class notations	Paragraph amended	4
2	3	3.6.2	Character of classification and class notations	Paragraph amended	4
2	3	3.8.1	Character of classification and class notations	Paragraph amended	4
2	3	3.8.5	Character of classification and class notations	New paragraph added	4

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Rules for the Manufacture, Testing and Certification of Materials					**Effective Date 1 July 2012**
1	4	4.1.1	General requirements for manufacture	Paragraph amended	1
1	5	5.4.2	Non-destructive examinations	Paragraph amended	1
1	5	5.4.3	Non-destructive examinations	New paragraph added	1
1	5	5.5.1	Non-destructive examinations	Paragraph amended	1
1	6	Table 1.6.1	References	Table amended	1
2	1	1.2.3	General requirements for testing	Paragraph amended	1
3	1	1.5.1	General requirements	New paragraph added	1
3	1	1.5.1 to 1.5.2	General requirements	Existing paragraphs renumbered and amended	1
3	1	1.5.4	General requirements	New paragraph added	1
3	1	1.5.3 to 1.5.4	General requirements	Paragraphs deleted	1
3	1	1.5.5	General requirements	Existing paragraph renumbered and amended	1
3	1	1.5.6 to 1.5.7	General requirements	Existing paragraphs renumbered	1
3	1	1.5.8	General requirements	Existing paragraph renumbered and amended	1
3	1	1.5.9	General requirements	Existing paragraph renumbered	1
3	1	1.5.10	General requirements	Paragraph deleted	1
3	1	1.5.11 to 1.5.12	General requirements	New paragraphs added	1
3	1	1.5.11	General requirements	Existing paragraph renumbered and amended	1
3	1	1.5.12	General requirements	Existing paragraph renumbered	1
3	1	1.5.15	General requirements	New paragraph added	1
3	1	1.7.4	General requirements	References amended	1
3	1	Fig. 3.1.1	General requirements	New Figure added	1
3	1	Fig. 3.1.1	General requirements	Existing Figure renumbered	1
3	3	3.1.2	High strength steels for ship and other structural applications	New paragraph added	1
3	3	3.1.2 to 3.1.5	High strength steels for ship and other structural applications	Existing paragraphs renumbered	1
3	3	3.4.1	High strength steels for ship and other structural applications	Paragraph amended	1
3	3	3.4.2	High strength steels for ship and other structural applications	References amended	1
3	3	3.4.4	High strength steels for ship and other structural applications	New paragraph added	1
3	3	3.4.4 to 3.4.7	High strength steels for ship and other structural applications	Existing paragraphs renumbered	1

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Notice – Summary of Changes

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Rules for the Manufacture, Testing and Certification of Materials (cont'd)					**Effective Date 1 July 2012**
3	3	3.5.1	High strength steels for ship and other structural applications	References amended	1
3	3	3.6.1	High strength steels for ship and other structural applications	References amended	1
3	3	3.6.7	High strength steels for ship and other structural applications	New paragraph added	1
3	3	3.6.7 to 3.6.9	High strength steels for ship and other structural applications	Existing paragraphs renumbered	1
3	3	3.6.8	High strength steels for ship and other structural applications	Reference amended	1
3	3	3.8.1	High strength steels for ship and other structural applications	Reference amended	1
3	3	Table 3.3.1	High strength steels for ship and other structural applications	Table amended	1
3	3	Table 3.3.3	High strength steels for ship and other structural applications	New Table added	1
3	3	Tables 3.3.3-3.3.6	High strength steels for ship and other structural applications	Existing Tables renumbered	1
3	3	Table 3.3.3	High strength steels for ship and other structural applications	Existing Table renumbered and amended	1
3	3	Table 3.3.4	High strength steels for ship and other structural applications	Existing Table renumbered and amended	1
3	3	Table 3.3.6	High strength steels for ship and other structural applications	Existing Table renumbered and amended	1
4	2	Table 4.2.2	Castings for ship and other structural applications	Table amended	1
5	1	1.8.7	General requirements	Paragraph amended	1
5	2	2.5.7	Forgings for ship and other structural applications	Paragraph amended	1
5	3	3.5.1	Forgings for shafting and machinery	Paragraph amended	1
5	3	3.5.4	Forgings for shafting and machinery	Paragraph amended	1
5	3	Table 5.3.4	Forgings for shafting and machinery	Table amended	1
8	1	1.1.3	Plates, bars and sections	Paragraph amended	1
8	1	1.1.5	Plates, bars and sections	New paragraph added	1
8	1	1.1.5 to 1.1.6	Plates, bars and sections	Existing paragraphs renumbered	1
8	1	1.8.3	Plates, bars and sections	Paragraph amended	1
8	1	Table 8.1.3	Plates, bars and sections	Table amended	1
8	1	Table 8.1.4	Plates, bars and sections	Table amended	1
10	4	4.6.8	Studless mooring chain cables	Reference amended	1
11	1	1.8.1	General	Paragraph amended	1
11	1	Table 11.1.1	General	Table amended	1
11	3	3.1.6 to 3.1.7	Electrodes for manual and gravity welding	Paragraphs amended	1
11	3	3.2.2	Electrodes for manual and gravity welding	New paragraph added	1
11	3	3.2.2 to 3.2.5	Electrodes for manual and gravity welding	Existing paragraphs renumbered	1
11	3	3.3.2	Electrodes for manual and gravity welding	New paragraph added	1
11	3	3.3.2 to 3.3.12	Electrodes for manual and gravity welding	Existing paragraphs renumbered	1
11	3	3.3.4	Electrodes for manual and gravity welding	Paragraph amended	1
11	3	3.5.2	Electrodes for manual and gravity welding	New paragraph added	1
11	3	3.5.2 to 3.5.5	Electrodes for manual and gravity welding	Existing paragraphs renumbered	1
11	3	3.5.3	Electrodes for manual and gravity welding	Reference amended	1
11	3	3.7.3	Electrodes for manual and gravity welding	Reference amended	1

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Notice – Summary of Changes

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Rules for the Manufacture, Testing and Certification of Materials (cont'd)					**Effective Date 1 July 2012**
11	3	Table 11.3.1	Electrodes for manual and gravity welding	Table deleted	1
11	3	Table 11.3.1	Electrodes for manual and gravity welding	New Table added	1
11	3	Table 11.3.2	Electrodes for manual and gravity welding	Table amended	1
11	3	Table 11.3.3	Electrodes for manual and gravity welding	Table amended	1
11	4	4.1.8 to 4.1.9	Wire-flux combinations for submerged-arc automatic welding	Paragraphs amended	1
11	4	4.3.2	Wire-flux combinations for submerged-arc automatic welding	New paragraph added	1
11	4	4.3.2 to 4.3.8	Wire-flux combinations for submerged-arc automatic welding	Existing paragraphs renumbered	1
11	4	4.4.2	Wire-flux combinations for submerged-arc automatic welding	Paragraph amended	1
11	4	4.7.1	Wire-flux combinations for submerged-arc automatic welding	Paragraph amended	1
11	4	Table 11.4.1	Wire-flux combinations for submerged-arc automatic welding	Table deleted	1
11	4	Table 11.4.1	Wire-flux combinations for submerged-arc automatic welding	New table added	1
11	4	Table 11.4.2	Wire-flux combinations for submerged-arc automatic welding	Table amended	1
11	4	Table 11.4.3	Wire-flux combinations for submerged-arc automatic welding	Table amended	1
11	5	5.1.14 to 5.1.15	Wires and wire-gas combinations for manual, semi-automatic and automatic welding	Paragraphs amended	1
11	5	5.2.3	Wires and wire-gas combinations for manual, semi-automatic and automatic welding	New paragraph added	1
11	5	5.2.3 to 5.2.11	Wires and wire-gas combinations for manual, semi-automatic and automatic welding	Existing paragraphs renumbered	1
11	5	5.2.7	Wires and wire-gas combinations for manual, semi-automatic and automatic welding	Reference amended	1
11	5	5.3.2	Wires and wire-gas combinations for manual, semi-automatic and automatic welding	Reference amended	1
11	5	5.3.3	Wires and wire-gas combinations for manual, semi-automatic and automatic welding	New paragraph added	1
11	5	5.3.3 to 5.3.6	Wires and wire-gas combinations for manual, semi-automatic and automatic welding	Existing paragraph renumbered	1
11	5	Table 11.5.1	Wires and wire-gas combinations for manual, semi-automatic and automatic welding	Table deleted	1
11	5	Table 11.5.1	Wires and wire-gas combinations for manual, semi-automatic and automatic welding	New Table added	1
11	7	7.1.9 to 7.1.10	Consumables for use in one-side welding with temporary backing materials	Paragraphs amended	1
11	7	7.2.2	Consumables for use in one-side welding with temporary backing materials	New paragraph added	1

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Notice – Summary of Changes

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Rules for the Manufacture, Testing and Certification of Materials (cont'd)					**Effective Date 1 July 2012**
11	7	7.2.2 to 7.2.7	Consumables for use in one-side welding with temporary backing materials	Existing paragraphs renumbered	1
11	7	7.2.4	Consumables for use in one-side welding with temporary backing materials	Reference amended	1
11	7	7.3.2	Consumables for use in one-side welding with temporary backing materials	New paragraph added	1
11	7	7.3.2	Consumables for use in one-side welding with temporary backing materials	Existing paragraph renumbered	1
11	7	7.3.3	Consumables for use in one-side welding with temporary backing materials	Existing paragraph renumbered and amended	1
11	7	7.3.4	Consumables for use in one-side welding with temporary backing materials	Reference amended	1
11	7	7.3.4 to 7.3.7	Consumables for use in one-side welding with temporary backing materials	Existing paragraphs renumbered	1
11	7	Table 11.7.1	Consumables for use in one-side welding with temporary backing materials	Table deleted	1
11	7	Table 11.7.1	Consumables for use in one-side welding with temporary backing materials	New table added	1
11	9	9.5.3	Consumables for welding aluminium alloys	Reference amended	1
12	2	2.12.4	Welding Procedure Qualification Tests for Steels	Paragraph amended	1
12	2	2.15.7	Welding Procedure Qualification Tests for Steels	Reference amended	1
12	2	2.15.8	Welding Procedure Qualification Tests for Steels	Paragraph amended	1
12	2	2.15.9	Welding Procedure Qualification Tests for Steels	References amended	1
12	2	Table 12.2.2	Welding Procedure Qualification Tests for Steels	Table amended	1
12	2	Table 12.2.3	Welding Procedure Qualification Tests for Steels	New Table added	1
12	2	Tables 12.2.3-5	Welding Procedure Qualification Tests for Steels	Existing Tables renumbered	1
12	2	Table 12.4.10	Welding Procedure Qualification Tests for Steels	Table amended	1
13	2	2.2.2	Specific requirements for ship hull structure and machinery	Paragraph amended	1
13	2	2.12.6	Specific requirements for ship hull structure and machinery	Paragraph amended	1
13	4	4.15.1	Specific requirements for fusion welded pressure vessels	Paragraph amended	1
13	8	8.3.2	Specific requirements for welded aluminium	New paragraph added	
13	8	8.3.2 to 8.3.3	Specific requirements for welded aluminium	Existing paragraphs renumbered	
13	8	8.4.1	Specific requirements for welded aluminium	References amended	
13	8	Table 13.8.1	Specific requirements for welded aluminium	New Table added	
13	8	Tables 13.8.1-2	Specific requirements for welded aluminium	Existing Tables renumbered	

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Notice – Summary of Changes

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Rules for the Manufacture, Testing and Certification of Materials (cont'd)					**Effective Date 1 July 2012**
14	2	2.6.4	Tests on polymers, resins, reinforcement and associated materials	Paragraph amended	1
14	2	2.11.2	Tests on polymers, resins, reinforcement and associated materials	Paragraph amended	1
14	3	Table 14.3.5	Testing procedures	Table amended	1
14	5	5.14 to 5.14.1	Control of material quality for composite construction	New sub-Section added	1
14	5	5.14	Control of material quality for composite construction	Existing sub-Section renumbered	1
14	5	Table 14.5.8	Control of material quality for composite construction	New Table added	1

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 3					**Effective Date 1 January 2012**
1	7	Table 1.7.1	Inspection, workmanship and testing procedures	Table amended	1
5	6	6.8.3	Anchor cable	Paragraph deleted	1
5	6	6.8.3 to 6.8.5	Anchor cable	New paragraphs added	1
5	9	9.4.1	Structural details	Paragraph amended	1
5	9	9.4.2	Structural details	Paragraph deleted	1

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 3					**Effective Date 1 July 2012**
2	6	6.6.4	Machinery space arrangements	Paragraph amended	4
2	8	8.5.1	Particular requirements for multi-hulls	Paragraph amended	4
2	9	9 to 9.5.1	Navigation in ice	New Section added	4
3	1	1.3.1	General	Paragraph amended	4
3	2	2.17.3 to 2.17.5	Rudders	Paragraphs deleted	4
3	2	2.17.2 to 2.17.3	Rudders	New paragraphs added	4
3	2	2.18.2	Rudders	Paragraph amended	4
3	2	2.19.8	Rudders	New paragraph added	4
4	7	7.5.3 to 7.5.4	Portlights, windows and viewing ports, skylights and glass walls	Paragraphs amended	4
4	7	7.9.1	Portlights, windows and viewing ports, skylights and glass walls	Paragraph amended	4
4	7	7.12.5	Portlights, windows and viewing ports, skylights and glass walls	Paragraph amended	4
4	7	7.16 to 7.16.8	Portlights, windows and viewing ports, skylights and glass walls	New sub-Section added	4
4	7	Fig. 4.7.2	Portlights, windows and viewing ports, skylights and glass walls	New Figure added	4
4	11	11.4.2	Ventilators	New paragraph added	4
4	11	11.4.2 to 11.4.7	Ventilators	Existing paragraphs renumbered	4
5	3	3.3.1	Service group factors	Paragraph amended	4
5	6	6.4.1	Anchor cable	Paragraph amended	4

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Notice – Summary of Changes

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 4					**Effective Date 1 July 2012**
2	8	8.1.1 to 8.1.2	Navigation in first-year ice conditions	Paragraphs deleted	4
2	8	8.1.1	Navigation in first-year ice conditions	New paragraph added	4
2	8	8.1.3	Navigation in first-year ice conditions	Existing paragraph renumbered	4
2	9	9 to 9.1.2	Support yacht craft	New Section added	4
3	1	1.2.1	Hull design and construction parameters	Paragraph amended	4
3	5	5.1.3	Deck fittings	Paragraph amended	4

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 5					**Effective Date 1 July 2012**
2	2	Table 2.2.1	Definitions and symbols	Table amended	4
3	2	Table 3.2.2	Nomenclature and design factors	Table amended	4
4	2	Table 4.2.1	Nomenclature and design factors	Table amended	4
5	2	2.2.1	Hull girder load criteria for mono-hull craft	Paragraph amended	4
5	3	3.2.1	Hull girder load criteria for multi-hull craft	Paragraph amended	4
5	4	4.2.1 to 4.2.3	Primary load criteria for multi-hull craft	Paragraphs amended	4
5	4	4.3.1	Primary load criteria for multi-hull craft	Paragraph amended	4
5	4	4.3.4 to 4.3.5	Primary load criteria for multi-hull craft	Paragraphs amended	4

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 6					**Effective Date 1 July 2012**
4	7	7.2.1	Bulkheads and deep tanks	Paragraph amended	4
5	3	Table 5.3.1	Vehicle decks	Table amended	4
5	6	6.3.1	Helicopter landing areas	Paragraph amended	4
5	6	6.3.2	Helicopter landing areas	Paragraph deleted	4
5	6	6.4	Helicopter landing areas	Sub-Section retitled	4
5	6	6.4.1	Helicopter landing areas	Paragraph amended	4
5	6	Table 5.6.2	Helicopter landing areas	Table amended	4
5	7	7.1.1	Strengthening requirements for navigation in ice conditions	New paragraph added	4
5	7	7.1.1 to 7.3.1	Strengthening requirements for navigation in ice conditions	Paragraphs deleted	4
5	7	7.4	Strengthening requirements for navigation in ice conditions	Existing sub-Section renumbered	4
5	7	7.4.1	Strengthening requirements for navigation in ice conditions	Paragraph deleted	4
5	7	7.4.2	Strengthening requirements for navigation in ice conditions	Existing paragraph renumbered	4
5	7	7.4.3 to 7.4.4	Strengthening requirements for navigation in ice conditions	Paragraphs deleted	4
5	7	7.4.5	Strengthening requirements for navigation in ice conditions	Existing paragraph renumbered	4
5	7	7.5 to 7.9.6	Strengthening requirements for navigation in ice conditions	Paragraphs deleted	4

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Notice – Summary of Changes

Ch	Section	Para	Section Title	Status	Notice
Part 7					**Effective Date 1 July 2012**
2	2	2.4.1	Materials	Paragraph amended	4
2	2	Table 2.2.1	Materials	Table deleted	4
4	7	7.2.1	Bulkheads and deep tanks	Paragraph amended	4
5	6	6.3.1	Helicopter landing areas	Paragraph amended	4
5	6	6.4	Helicopter landing areas	Sub-Section retitled	4
5	6	6.4.1	Helicopter landing areas	Paragraph amended	4
5	6	Table 5.6.2	Helicopter landing areas	Table amended	4
5	7	7.1.1	Strengthening requirements for navigation in ice conditions	New paragraph added	4
5	7	7.1.1 to 7.3.1	Strengthening requirements for navigation in ice conditions	Paragraphs deleted	4
5	7	7.4	Strengthening requirements for navigation in ice conditions	Existing sub-Section renumbered	4
5	7	7.4.1	Strengthening requirements for navigation in ice conditions	Existing paragraph renumbered and amended	4
5	7	7.4.2	Strengthening requirements for navigation in ice conditions	Existing paragarph renumbered	4
5	7	7.4.3 to 7.4.4	Strengthening requirements for navigation in ice conditions	Paragraphs deleted	4
5	7	7.4.5	Strengthening requirements for navigation in ice conditions	Existing paragraph renumbered	4
5	7	7.5	Strengthening requirements for navigation in ice conditions	Existing sub-Section renumbered	4
5	7	7.5.1 to 7.5.4	Strengthening requirements for navigation in ice conditions	Paragraphs deleted	4
5	7	7.5.5	Strengthening requirements for navigation in ice conditions	Existing paragraph renumbered	4
5	7	7.5.6 to 7.9.6	Strengthening requirements for navigation in ice conditions	Paragraphs deleted	4

Ch	Section	Para	Section Title	Status	Notice
Part 8					**Effective Date 1 July 2012**
2	1	1.4.1	General requirements	New paragraph added	4
2	1	1.4.1 to 1.4.3	General requirements	Existing paragraphs renumbered	4
2	2	2.16.1	Materials	Paragraph amended	4
2	3	3.3.4	General construction process	Paragraph amended	4
2	3	3.9.14 to 3.9.15	General construction process	Paragraphs deleted	4
2	3	3.9.16 to 3.9.19	General construction process	Existing paragraphs renumbered	4
2	4	4.5 to 4.5.2	Additional procedures for sandwich construction	Sub-Section deleted	4
2	5	5.7.2	Details and fastenings	Paragraph amended	4
2	5	5.9	Details and fastenings	Sub-Section retitled	4
2	5	5.12.1	Details and fastenings	Paragraph amended	4
2	5	5.12.2	Details and fastenings	Paragraph deleted	4
2	5	5.12.2	Details and fastenings	New paragraph added	4
3	1	1.2.3	General	Paragraph amended	4
3	1	1.2.4	General	New paragraph added	4
3	1	1.2.4	General	Existing paragraph renumbered	4
3	1	1.2.6	General	Paragraph deleted	4
3	1	1.5.1	General	Paragraph amended	4
3	1	1.13.11 to 1.13.13	General	Paragraphs deleted	4
3	1	1.13.14 to 1.13.16	General	Existnig paragraphs renumbered	4
3	1	1.20.2	General	Paragraph amended	4
3	1	Fig. 3.1.3	General	Figure deleted	4
3	1	Table 3.1.1	General	Table retitled and amended	4
3	1	Table 3.1.2	General	Table retitled and amended	4
3	1	Tables 3.1.3-7	General	New Tables added	4
3	1	Tables 3.1.3-5	General	Existing Tables renumbered	4

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Notice – Summary of Changes

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 8 (cont'd)					**Effective Date 1 July 2012**
3	1	Table 3.1.11-12	General	New Tables added	4
3	2	2.3.1	Minimum thickness requirements	Paragraph amended	4
3	2	2.4	Minimum thickness requirements	Sub-Section retitled	4
3	2	2.4.1 to 2.4.2	Minimum thickness requirements	Paragraphs amended	4
3	2	2.5 to 2.5.5	Minimum thickness requirements	New sub-Section added	4
3	2	2.5	Minimum thickness requirements	Existing sub-Section renumbered	4
3	2	2.5.2	Minimum thickness requirements	Existing paragraph renumbered and amended	4
3	2	2.6 to 2.6.4	Minimum thickness requirements	Sub-Section deleted	4
3	2	2.9.1	Minimum thickness requirements	Paragraph amended	4
3	2	Fig. 3.2.1	Minimum thickness requirements	Figure deleted	4
3	2	Table 3.2.2	Minimum thickness requirements	New Table added	4
3	3	3.4.5	Shell envelope laminate	Paragraph amended	4
3	3	3.5.5	Shell envelope laminate	Paragraph amended	4
3	3	3.6.1	Shell envelope laminate	Paragraph amended	4
3	3	3.14.1 to 3.14.2	Shell envelope laminate	Paragraphs amended	4
3	3	3.14.3	Shell envelope laminate	New paragraph added	4
3	3	3.15.1	Shell envelope laminate	Paragraph amended	4
3	3	Fig. 3.3.3	Shell envelope laminate	New Figure added	4
3	3	Fig. 3.3.3	Shell envelope laminate	Existing Figure renumbered	4
3	4	4.19.5	Shell evelopev framing	Paragraph amended	4
3	5	5.22.	Single bottom structure and appendages	Paragraph amended	4
3	6	6.6.4	Double bottom structure	Paragraph amended	4
3	6	6.9.6	Double bottom structure	Paragraph amended	4
3	7	7.3.6	Bulkheads and deep tanks	Paragraph amended	4
3	7	7.4.6	Bulkheads and deep tanks	Paragraph amended	4
3	7	7.16.5	Bulkheads and deep tanks	Paragraph amended	4
3	8	8.3.5	Deck structures	Paragraph amended	4
3	8	8.4.5	Deck structures	Paragraph amended	4
3	8	8.6.5	Deck structures	Paragraph amended	4
3	8	8.12.6	Deck structures	Paragraph amended	4
3	8	8.12.8	Deck structures	Paragraph amended	4
3	8	Fig. 3.8.2	Deck structures	Figure retitled	4
3	9	9.1.8	Superstructures, deckhouses and bulwarks	New paragraph added	4
3	9	9.3.5	Superstructures, deckhouses and bulwarks	Paragraph amended	4
3	9	9.4.5	Superstructures, deckhouses and bulwarks	Paragraph amended	4
3	9	9.5.5	Superstructures, deckhouses and bulwarks	Paragraph amended	4
3	9	9.6.5	Superstructures, deckhouses and bulwarks	Paragraph amended	4
3	9	9.7.5	Superstructures, deckhouses and bulwarks	Paragraph amended	4
3	9	9.8.5	Superstructures, deckhouses and bulwarks	Paragraph amended	4
3	9	9.25.6	Superstructures, deckhouses and bulwarks	Paragraph amended	4
3	9	9.25.14	Superstructures, deckhouses and bulwarks	Paragraph amended	4
4	2	2.1.1	Minimum thickness requirements	Paragraph amended	4
4	2	2.1.2	Minimum thickness requirements	New paragraph added	4
4	2	2.1.2	Minimum thickness requirements	Existing paragraph renumbered	4
4	2	Table 4.2.1	Minimum thickness requirements	New Table added	4
4	3	3.3.6	Shell envelope laminate	Paragraph amended	4
4	3	3.5.7	Shell envelope laminate	Paragraph amended	4
4	3	3.7.6	Shell envelope laminate	Paragraph amended	4
4	5	5.3.2	Single bottom structure and appendages	Paragraph amended	4
4	6	6.5.4	Double bottom structure	Paragraph amended	4

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Notice – Summary of Changes

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 8 (cont'd)					**Effective Date 1 July 2012**
4	8	8.4.5	Deck structures	Paragraph amended	4
5	2	2.9.4	Special features	Paragraph amended	4
5	3	3.1.5	Vehicle decks	Paragraph amended	4
5	6	6.1.1	Strengthening requirements for navigation in ice conditions	New paragraph added	4
5	6	6.1.1 to 6.3.1	Strengthening requirements for navigation in ice conditions	Paragraphs deleted	4
5	6	6.4 to 6.4.3	Strengthening requirements for navigation in ice conditions	Existing sub-Section renumbered	4
5	6	6.4.3	Strengthening requirements for navigation in ice conditions	Existing paragraph renumbered and amended	4
5	6	6.4.4	Strengthening requirements for navigation in ice conditions	Paragraph deleted	4
5	6	6.5	Strengthening requirements for navigation in ice conditions	Existing sub-Section renumbered	4
5	6	6.5.1	Strengthening requirements for navigation in ice conditions	Paragraph deleted	4
5	6	6.5.2 to 6.5.3	Strengthening requirements for navigation in ice conditions	Existing paragraphs renumbered	4
5	6	6.5.4	Strengthening requirements for navigation in ice conditions	Paragraph deleted	4
5	6	6.5.5	Strengthening requirements for navigation in ice conditions	Existing paragraph renumbered	4
5	6	6.6 to 6.6.2	Strengthening requirements for navigation in ice conditions	Existing sub-Section renumbered	4
5	6	6.7 to 6.9.6	Strengthening requirements for navigation in ice conditions	Sub-Sections deleted	4

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 9					**Effective Date 1 July 2012**
1	1	1.1.1	General requirements	Paragraph amended	5

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 10					**Effective Date 1 July 2012**
1	8	8.6.5	Piping systems	New paragraph added	5
1	13	13.3.2	Electronically controlled engines	Reference amended	5
1	13	13.6.1	Electronically controlled engines	Reference amended	5
1	14	14.2.6	Programme for trials of diesel engines to assess operational capability	Reference amended	5

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 13					**Effective Date 1 July 2012**
4	1	1.2.1	Shaft alignment	Paragraph amended	5

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 15					**Effective Date 1 July 2012**
1	8	8.2.4	Plastics	Reference amended	5
1	8	8.6.6	Plastics	Reference amended	5
1	9	9.1.2 to 9.1.3	Austenitic stainless steel	Paragraphs amended	2, 5

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Notice – Summary of Changes

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 16					**Effective Date 1 January 2012**
1	1	1.1.3	General requirements	Reference amended	5
1	1	1.1.4	General requirements	Reference amended	5
1	1	1.2.3	General requirements	Reference amended	5
1	1	1.2.4	General requirements	Paragraph amended	5
1	1	1.2.7	General requirements	Paragraph amended	5
1	1	1.2.9	General requirements	Paragraph deleted	5
1	1	1.2.10	General requirements	Existing paragraph renumbered and reference amended	5
1	2	2.1.1	Essential features for control, alarm and safety systems	Paragraph amended	5
1	2	2.2.1	Essential features for control, alarm and safety systems	Paragraph amended	5
1	2	2.2.3	Essential features for control, alarm and safety systems	New paragraph added	5
1	2	2.2.3 to 2.2.7	Essential features for control, alarm and safety systems	Existing paragraphs renumbered	5
1	2	2.3.1	Essential features for control, alarm and safety systems	Paragraph amended	5
1	2	2.3.3	Essential features for control, alarm and safety systems	Paragraph deleted	5
1	2	2.3.3 to 2.3.5	Essential features for control, alarm and safety systems	New paragraphs added	5
1	2	2.3.4	Essential features for control, alarm and safety systems	Existing paragraph renumbered	5
1	2	2.3.5	Essential features for control, alarm and safety systems	Existing paragraph renumbered and amended	5
1	2	2.3.6	Essential features for control, alarm and safety systems	Existing paragraph renumbered	5
1	2	2.3.7 to 2.3.8	Essential features for control, alarm and safety systems	Existing paragraphs renumbered and amended	5
1	2	2.3.9 to 2.3.14	Essential features for control, alarm and safety systems	Existing paragraphs renumbered	5
1	2	2.3.13	Essential features for control, alarm and safety systems	Reference amended	5
1	2	2.3.15	Essential features for control, alarm and safety systems	Existing paragraph renumbered and amended	5
1	2	2.3.16 to 2.3.17	Essential features for control, alarm and safety systems	Existing paragraphs renumbered	5
1	2	2.3.18	Essential features for control, alarm and safety systems	Existing paragraph renumbered and amended	5
1	2	2.5.8	Essential features for control, alarm and safety systems	Paragraph amended	5
1	2	2.5.11	Essential features for control, alarm and safety systems	Paragraph amended	5
1	2	2.8.4	Essential features for control, alarm and safety systems	Paragraph amended	5
1	2	2.8.6	Essential features for control, alarm and safety systems	Paragraph amended	5
1	2	2.8.7	Essential features for control, alarm and safety systems	Reference amended	5
1	2	2.9.3	Essential features for control, alarm and safety systems	Reference amended	5
1	2	2.9.5	Essential features for control, alarm and safety systems	Paragraph amended	5
1	2	2.10.7	Essential features for control, alarm and safety systems	Reference amended	5
1	2	2.10.12	Essential features for control, alarm and safety systems	References amended	5
1	2	2.10.16 to 2.10.19	Essential features for control, alarm and safety systems	Paragraphs deleted	5

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Notice – Summary of Changes

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 16 (cont'd)					**Effective Date 1 January 2012**
1	2	2.10.20	Essential features for control, alarm and safety systems	Existing paragraph renumbered and amended	5
1	2	2.10.21	Essential features for control, alarm and safety systems	Paragraph deleted	5
1	2	2.10.22 to 2.10.25	Essential features for control, alarm and safety systems	Existing paragraphs renumbered	5
1	2	2.11.6	Essential features for control, alarm and safety systems	Reference amended	5
1	2	2.11.9	Essential features for control, alarm and safety systems	Reference amended	5
1	2	2.13.1	Essential features for control, alarm and safety systems	Reference amended	5
1	2	2.13.7	Essential features for control, alarm and safety systems	Reference amended	5
1	2	2.14.1	Essential features for control, alarm and safety systems	Reference amended	5
1	3	3 to 3.6.15	Ergonomics of control stations	New Section added	5
1	3 to 6			Existing Sections renumbered	5
1	3	3.1.1	Unattended machinery space(s) – UMS notation	Reference amended	5
1	3	3.2.3	Unattended machinery space(s) – UMS notation	Existing paragraph renumbered, amended and reference amended	5
1	4	4.1.1	Machinery operated from a centralised control station – CCS notation	Reference amended	5
1	4	4.1.3	Machinery operated from a centralised control station – CCS notation	Reference amended	5
1	4	4.1.4	Machinery operated from a centralised control station – CCS notation	Reference amended	5
1	4	4.2.1	Machinery operated from a centralised control station – CCS notation	Reference amended	5
1	4	4.2.6	Machinery operated from a centralised control station – CCS notation	Reference amended	5
1	5	5.1.2	Requirements for craft which are not required to comply with the HSC Code	Reference amended	5
1	5	5.1.3	Requirements for craft which are not required to comply with the HSC Code	References amended	5
1	6	6.2.1	Trials	Reference amended	5
1	6	6.3.1	Trials	Reference amended	5
2	1	1.1.1	General requirements	References amended	5
2	1	1.2	General requirements	Sub-Section retitled	5
2	1	1.2.1	General requirements	Paragraph amended	5
2	1	1.2.3 to 1.2.4	General requirements	New paragraphs added	5
2	1	1.2.3 to 1.2.4	General requirements	Existing paragraphs renumbered	5
2	1	1.2.4	General requirements	Reference amended	5
2	1	1.2.6	General requirements	Reference amended	5
2	1	1.2.7	General requirements	New paragraph added	5
2	1	1.2.5 to 1.2.7	General requirements	Existing paragraphs renumbered	5
2	1	1.2.7	General requirements	Reference amended	5
2	1	1.2.8	General requirements	Existing paragraph renumbered and amended	5
2	1	1.2.9	General requirements	References amended	5
2	1	1.2.10	General requirements	Reference amended	5
2	1	1.2.12	General requirements	Existing paragraph renumbered	5
2	1	1.2.13	General requirements	Existing paragraph renumbered, amended and reference amended	5

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Notice – Summary of Changes

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 16 (cont'd)					**Effective Date 1 January 2012**
2	1	1.3 to 1.3.1	General requirements	New sub-Section title and paragraph added	5
2	1	1.2.10	General requirements	Existing paragraph renumbered	5
2	1	1.2.11	General requirements	Existing paragraph renumbered and amended	5
2	1	1.2.13	General requirements	Existing paragraph renumbered and amended	5
2	1	1.2.14	General requirements	Existing paragraph renumbered and reference amended	5
2	1	1.3 to 1.4	General requirements	Existing sub-Sections renumbered	5
2	1	1.3.4	General requirements	References amended	5
2	1	1.4.3	General requirements	References amended	5
2	1	1.4.4	General requirements	References amended	5
2	1	1.4.5	General requirements	References amended	5
2	1	1.5	General requirements	Existing sub-Section renumbered	5
2	1	1.5.3	General requirements	References amended	5
2	1	1.6.15 to 1.6.16	General requirements	New paragraphs added	5
2	1	1.6 to 1.9	General requirements	Existing sub-Sections renumbered	5
2	1	1.8.5	General requirements	Reference amended	5
2	1	1.8.6	General requirements	Reference amended	5
2	1	1.10	General requirements	Existing Sub-Section renumbered	5
2	1	1.10 to 1.10.7	General requirements	Existing paragraphs renumbered	5
2	1	1.10.1	General requirements	Reference amended	5
2	1	1.10.3	General requirements	References amended	5
2	1	1.10.4	General requirements	Reference amended	5
2	1	1.10.7	General requirements	Reference amended	5
2	1	1.10.12	General requirements	Reference amended	5
2	1	1.11.8	General requirements	New paragraph added	5
2	1	1.10.8 to 1.10.10	General requirements	Existing paragraphs renumbered	5
2	1	1.11.12	General requirements	New paragraph added	5
2	1	1.10.11 to 1.10.12	General requirements	Existing paragraphs renumbered	5
2	1	1.11	General requirements	Existing sub-Section renumbered	5
2	1	1.11.1 to 1.11.8	General requirements	Existing paragraphs renumbered	5
2	1	1.11.1	General requirements	Reference amended	5
2	1	1.11.2	General requirements	Reference amended	5
2	1	1.11.4	General requirements	Reference amended	5
2	1	11.1.6	General requirements	Reference amended	5
2	1	1.11.9	General requirements	Existing paragraph renumbered and amended	5
2	1	1.12	General requirements	Existing sub-Section renumbered	5
2	1	1.12.1 to 1.12.2	General requirements	Existing paragraphs renumbered	5
2	1	1.12.3	General requirements	Existing paragraph renumbered, amended and references amended	5
2	1	1.14 to 1.14.4	General requirements	New sub-Section added	5
2	1	Table 2.1.1	General requirements	New Table added	5
2	1	1.13	General requirements	Existing sub-Section renumbered	5
2	1	1.13.1	General requirements	Existing paragraph renumbered and amended	5
2	1	1.13.2 to 1.13.4	General requirements	Existing paragraphs renumbered	5
2	1	1.13.3	General requirements	Reference amended	5
2	1	1.13.4	General requirements	Reference amended	5
2	1	1.14	General requirements	Existing sub-Section renumbered	5
2	1	1.14.1	General requirements	Existing paragraph renumbered, amended and reference amended	5
2	1	1.14.2	General requirements	Reference amended	5
2	1	1.14.4	General requirements	Reference amended	5
2	1	1.15 to 1.16	General requirements	Existing sub-Sections renumbered	5
2	1	1.15.2	General requirements	Reference amended	5
2	1	1.16.2	General requirements	Reference amended	5
2	2	2.2.3	Main source of electrical power	Reference amended	5
2	2	2.4.1	Main source of electrical power	Reference amended	5
2	3	3.1.1	Emergency source of electrical power	Reference amended	5
2	3	3.2.7	Emergency source of electrical power	Reference amended	5
2	5	5.4.1	Supply and distribution	Paragraph amended	5

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Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 16 (cont'd)					**Effective Date 1 January 2012**
2	5	5.7.4	Supply and distribution	Reference amended	5
2	5	5.8.1	Supply and distribution	Reference amended	5
2	6	6.1.4	System design – Protection	References amended	5
2	6	6.1.7	System design – Protection	Reference amended	5
2	6	6.9.1	System design – Protection	Reference amended	5
2	6	6.11.1	System design – Protection	Reference amended	5
2	7	7.1.1	Switchgear and control gear assemblies	Paragraph amended	5
2	7	7.5.3	Switchgear and control gear assemblies	Paragraph deleted	5
2	7	7.5.3 to 7.5.6	Switchgear and control gear assemblies	New paragraphs added	5
2	7	7.8.2	Switchgear and control gear assemblies	New paragraph added	5
2	7	7.12.5	Switchgear and control gear assemblies	New paragraph added	5
2	7	7.18.2	Switchgear and control gear assemblies	Reference amended	5
2	7	Table 2.7.1	Switchgear and control gear assemblies	Table deleted	5
2	7	Tables 2.7.1-2	Switchgear and control gear assemblies	New Tables added	5
2	8	8 to 8.4.1	Protection of personnel from hazards resulting from electric arcs within electrical equipment assemblies and enclosures	New Section added	5
2	8 to 20			Existing Sections renumbered	5
2	8	8.1.2	Rotating machines	Reference amended	5
2	8	8.1.6	Rotating machines	Reference amended	5
2	8	8.2.1	Rotating machines	Reference amended	5
2	8	8.3.1	Rotating machines	References amended	5
2	8	8.3.2	Rotating machines	Reference amended	5
2	8	8.3.3	Rotating machines	Reference amended	5
2	8	8.8.3	Rotating machines	Reference amended	5
2	8	Table 2.8.1	Rotating machines	Reference amended	5
2	9	9.1.1	Converter equipment	Reference amended	5
2	9	9.1.2	Converter equipment	Reference amended	5
2	9	9.1.4	Converter equipment	Reference amended	5
2	9	9.1.6	Converter equipment	Reference amended	5
2	9	9.1.12	Converter equipment	References amended	5
2	9	9.2.1	Converter equipment	Reference amended	5
2	9	9.2.2	Converter equipment	Reference amended	5
2	9	9.2.11	Converter equipment	Reference amended	5
2	9	9.2.16	Converter equipment	Reference amended	5
2	9	9.2.18	Converter equipment	Reference amended	5
2	9	9.3.1	Converter equipment	Reference amended	5
2	9	9.3.8	Converter equipment	Reference amended	5
2	9	9.3.10	Converter equipment	Reference amended	5
2	9	9.3.12	Converter equipment	Reference amended	5
2	10	10.1.1	Electrical cables and busbar trunking systems (busways)	References amended	5
2	10	10.1.2	Electrical cables and busbar trunking systems (busways)	Reference amended	5
2	10	10.2.1	Electrical cables and busbar trunking systems (busways)	References amended	5
2	10	10.2.2	Electrical cables and busbar trunking systems (busways)	Reference amended	5
2	10	10.3.1	Electrical cables and busbar trunking systems (busways)	Reference amended	5
2	10	10.4.2	Electrical cables and busbar trunking systems (busways)	Reference amended	5

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Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 16 (cont'd)					**Effective Date 1 January 2012**
2	10	10.4.3	Electrical cables and busbar trunking systems (busways)	References amended	5
2	10	10.5.2	Electrical cables and busbar trunking systems (busways)	Reference amended	5
2	10	10.5.5	Electrical cables and busbar trunking systems (busways)	References amended	5
2	10	10.6.1	Electrical cables and busbar trunking systems (busways)	Reference amended	5
2	10	10.6.3	Electrical cables and busbar trunking systems (busways)	References amended	5
2	10	10.6.4	Electrical cables and busbar trunking systems (busways)	Reference amended	5
2	10	10.6.5	Electrical cables and busbar trunking systems (busways)	Reference amended	5
2	10	10.6.6	Electrical cables and busbar trunking systems (busways)	Reference amended	5
2	10	10.7.1	Electrical cables and busbar trunking systems (busways)	Reference amended	5
2	10	10.7.3	Electrical cables and busbar trunking systems (busways)	References amended	5
2	10	10.8.2	Electrical cables and busbar trunking systems (busways)	Reference amended	5
2	10	10.8.10	Electrical cables and busbar trunking systems (busways)	Paragraph deleted	5
2	10	10.8.11 to 10.8.22	Electrical cables and busbar trunking systems (busways)	Existing paragraphs renumbered	5
2	10	10.8.14	Electrical cables and busbar trunking systems (busways)	Reference amended	5
2	10	10.8.18	Electrical cables and busbar trunking systems (busways)	References amended	5
2	10	10.8.19	Electrical cables and busbar trunking systems (busways)	Reference amended	5
2	10	10.8.20	Electrical cables and busbar trunking systems (busways)	Reference amended	5
2	10	10.8.21	Electrical cables and busbar trunking systems (busways)	Reference amended	5
2	10	10.8.22	Electrical cables and busbar trunking systems (busways)	Reference amended	5
2	10	10.9.3	Electrical cables and busbar trunking systems (busways)	Reference amended	5
2	10	10.10.1	Electrical cables and busbar trunking systems (busways)	Reference amended	5
2	10	10.10.3	Electrical cables and busbar trunking systems (busways)	Reference amended	5
2	10	10.10.4	Electrical cables and busbar trunking systems (busways)	Reference amended	5
2	10	10.12.3	Electrical cables and busbar trunking systems (busways)	Reference amended	5
2	10	10.15.1	Electrical cables and busbar trunking systems (busways)	Reference amended	5
2	10	10.16.1	Electrical cables and busbar trunking systems (busways)	Existing paragraph renumbered and amended	5
2	10	10.16.3	Electrical cables and busbar trunking systems (busways)	Reference amended	5
2	10	10.17.1	Electrical cables and busbar trunking systems (busways)	Reference amended	5
2	10	10.17.2	Electrical cables and busbar trunking systems (busways)	Reference amended	5
2	10	10.17.4	Electrical cables and busbar trunking systems (busways)	Reference amended	5
2	11	11.3.4	Batteries	References amended	5

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Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 16 (cont'd)				**Effective Date 1 January 2012**	
2	11	11.3.5	Batteries	References amended	5
2	11	11.3.10	Batteries	Existing paragraph renumbered, amended and reference amended	5
2	11	11.3.11	Batteries	Reference amended	5
2	11	11.5.1	Batteries	Reference amended	5
2	11	11.5.5	Batteries	Reference amended	5
2	11	11.5.6	Batteries	References amended	5
2	11	11.5.11	Batteries	Reference amended	5
2	11	11.7.2	Batteries	Reference amended	5
2	11	11.7.3	Batteries	Reference amended	5
2	12	12.3.1	Equipment – Heating, lighting and accessories	Reference amended	5
2	12	12.4.1	Equipment – Heating, lighting and accessories	Reference amended	5
2	14	14.1.1	Navigation and manoeuvring systems	Reference amended	5
2	14	14.1.6	Navigation and manoeuvring systems	Reference amended	5
2	14	14.3.5	Navigation and manoeuvring systems	References amended	5
2	14	14.3.6	Navigation and manoeuvring systems	Reference amended	5
2	14	14.3.7	Navigation and manoeuvring systems	Reference amended	5
2	14	14.3.8	Navigation and manoeuvring systems	References amended	5
2	14	14.3.9	Navigation and manoeuvring systems	Reference amended	5
2	16	17.1.1	Fire safety systems	New paragraph added	5
2	16	16.1.1 to 16.1.7	Fire safety systems	Existing paragraphs renumbered	5
2	16	16.1.1	Fire safety systems	Reference amended	5
2	16	16.1.2	Fire safety systems	References amended	5
2	16	16.1.6	Fire safety systems	Reference amended	5
2	16	16.1.8	Fire safety systems	Existing paragraph renumbered and amended	5
2	16	16.1.9 to 16.1.18	Fire safety systems	Existing paragraphs renumbered	5
2	16	16.1.12	Fire safety systems	Reference amended	5
2	16	16.1.19 to 16.1.20	Fire safety systems	Paragraphs deleted	5
2	16	16.3.3	Fire safety systems	References amended	5
2	16	16.3.5	Fire safety systems	Reference amended	5
2	16	16.3.8	Fire safety systems	Reference amended	5
2	16	16.3.9	Fire safety systems	References amended	5
2	16	16.3.10	Fire safety systems	Reference amended	5
2	16	16.3.11	Fire safety systems	Reference amended	5
2	16	16.6.3	Fire safety systems	Reference amended	5
2	16	16.6.4	Fire safety systems	Reference amended	5
2	16	16.6.5	Fire safety systems	Reference amended	5
2	16	16.6.10	Fire safety systems	Reference amended	5
2	16	16.6.12	Fire safety systems	Reference amended	5
2	16	16.7.1	Fire safety systems	References amended	5
2	16	16.9.1	Fire safety systems	References amended	5
2	17	17.1.3	Crew and passenger emergency safety systems	Reference amended	5
2	17	17.2.1	Crew and passenger emergency safety systems	References amended	5
2	17	17.2.2	Crew and passenger emergency safety systems	References amended	5
2	17	17.2.6	Crew and passenger emergency safety systems	Reference amended	5
2	17	17.3.2	Crew and passenger emergency safety systems	References amended	5

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Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 16 (cont'd)					**Effective Date 1 January 2012**
2	17	17.3.9	Crew and passenger emergency safety systems	References amended	5
2	17	17.3.11	Crew and passenger emergency safety systems	Reference amended	5
2	17	17.4.2	Crew and passenger emergency safety systems	Reference amended	5
2	17	17.4.3	Crew and passenger emergency safety systems	References amended	5
2	18	18.2.2	Craft safety systems	Reference amended	5
2	19	19.2.1	Cargo craft, patrol and pilot craft, workboats and other similar craft of less than 500 tons gross tonnage for operation in Service Groups 1 to 3, and yachts less than 500 gt	References amended	5
2	19	19.2.5	Cargo craft, patrol and pilot craft, workboats and other similar craft of less than 500 tons gross tonnage for operation in Service Groups 1 to 3, and yachts less than 500 gt	Reference amended	5
2	19	19.3.1	Cargo craft, patrol and pilot craft, workboats and other similar craft of less than 500 tons gross tonnage for operation in Service Groups 1 to 3, and yachts less than 500 gt	Reference amended	5
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2	19	19.7.2	Cargo craft, patrol and pilot craft, workboats and other similar craft of less than 500 tons gross tonnage for operation in Service Groups 1 to 3, and yachts less than 500 gt	Reference amended	5
2	19	19.10.2	Cargo craft, patrol and pilot craft, workboats and other similar craft of less than 500 tons gross tonnage for operation in Service Groups 1 to 3, and yachts less than 500 gt	Reference amended	5
2	19	19.10.4	Cargo craft, patrol and pilot craft, workboats and other similar craft of less than 500 tons gross tonnage for operation in Service Groups 1 to 3, and yachts less than 500 gt	References amended	5
2	19	19.11.1	Cargo craft, patrol and pilot craft, workboats and other similar craft of less than 500 tons gross tonnage for operation in Service Groups 1 to 3, and yachts less than 500 gt	Reference amended	5

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Notice – Summary of Changes

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 16 (cont'd)					**Effective Date 1 January 2012**
2	19	19.14.1	Cargo craft, patrol and pilot craft, workboats and other similar craft of less than 500 tons gross tonnage for operation in Service Groups 1 to 3, and yachts less than 500 gt	Reference amended	5
2	19	19.15.1	Cargo craft, patrol and pilot craft, workboats and other similar craft of less than 500 tons gross tonnage for operation in Service Groups 1 to 3, and yachts less than 500 gt	References amended	5
2	20	20.1.1	Testing and trials	Reference amended	5
2	20	20.1.2	Testing and trials	Reference amended	5
2	20	20.1.4	Testing and trials	Reference amended	5
2	20	202.2.1	Testing and trials	Reference amended	5
2	20	20.2.2	Testing and trials	Reference amended	5
2	20	20.2.3	Testing and trials	References amended	5
2	20	20.2.4	Testing and trials	Existing paragraph renumbered and amended	5
2	20	20.2.5	Testing and trials	Paragraph deleted	5
2	20	21.2.5	Testing and trials	New paragraph added	5

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 16					**Effective Date 1 July 2012**
2	11	11.5.1 to 11.5.2	Batteries	Paragraphs amended	4

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part17					**Effective Date 1 July 2012**
1	1	1.1.2	General requirements	Paragraph amended	5
3	2	2.4.2	Fire safety measures for yachts of overall length greater than 24 m but less than 500 gt	Reference amended	5
3	2	2.8.1	Fire safety measures for yachts of overall length greater than 24 m but less than 500 gt	Reference amended	5
3	2	2.8.7	Fire safety measures for yachts of overall length greater than 24 m but less than 500 gt	Reference amended	5
3	2	2.20.1	Fire safety measures for yachts of overall length greater than 24 m but less than 500 gt	Reference amended	5
3	3	3.16.11	Fire safety measures for yachts 500 gt or more	Reference amended	5
3	3	3.24.5	Fire safety measures for yachts 500 gt or more	Reference amended	5
3	3	3.34.1	Fire safety measures for yachts 500 gt or more	Reference amended	5
4	1	1.2.1	Automatic sprinkler, fire detection and fire-alarm systems	Reference amended	5
4	2	2.1.2	Fixed fire detection and fire-alarm systems	Reference amended	5

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Notice – Summary of Changes

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Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Rules for the Manufacture, Testing and Certification of Materials					
3	9	Table 3.9.3	Bars for welded chain cables	Table amended	1
4	2	Table 4.2.2	Castings for ship and other structural applications	Table amended	1
5	4	Table 5.4.3	Forgings for crankshafts	Table amended	1
5	4	Table 5.4.5	Forgings for crankshafts	Table amended	1
12	4	Table 12.4.10	Welding procedure tests for non-ferrous alloys	Table amended	1

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Rules and Regulations for the Classification of Special Service Craft

Volume 1
Part 1
Regulations
July 2012

Lloyd's Register
LIFE MATTERS

002132

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A guide to the Rules

and published requirements

Rules and Regulations for the Classification of Special Service Craft

Introduction

The Rules are published as a complete set; individual Parts are, however, available on request. A comprehensive List of Contents is placed at the beginning of each Part.

Numbering and Cross-References

A decimal notation system has been adopted throughout. Five sets of digits cover the divisions, i.e. Part, Chapter, Section, sub-Section and paragraph. The textual cross-referencing within the text is as follows, although the right hand digits may be added or omitted depending on the degree of precision required:

(a) In same Chapter, e.g. *see* 2.1.3 (i.e. down to paragraph).
(b) In same Part but different Chapter, e.g. *see* Ch 3,2.1 (i.e. down to sub-Section).
(c) In another Part, e.g. *see* Pt 5, Ch 1,3 (i.e. down to Section).

The cross-referencing for Figures and Tables is as follows:

(a) In same Chapter, e.g. as shown in Fig. 2.3.5 (i.e. Chapter, Section and Figure Number).
(b) In same Part but different Chapter, e.g. as shown in Fig. 2.3.5 in Chapter 2.
(c) In another Part, e.g. *see* Table 2.7.1 in Pt 3, Ch 2.

Rules updating

The Rules are generally published annually and changed through a system of Notices. Subscribers are forwarded copies of such Notices when the Rules change.

Current changes to Rules that appeared in Notices are shown with a black rule alongside the amended paragraph on the left hand side. A solid black rule indicates amendments and a dotted black rule indicates corrigenda.

Rules programs

LR has developed a suite of Calculation Software that evaluates Requirements for Ship Rules, Special Service Craft Rules and Naval Ship Rules. For details of this software please contact LR.

Direct calculations

The Rules require direct calculations to be submitted for specific parts of the ship structure or arrangements and these will be assessed in relation to LR's own direct calculation procedures. They may also be required for ships of unusual form, proportion or speed, where intended for the carriage of special cargoes or for special restricted service and as supporting documentation for arrangements or scantlings alternative to those required by the Rules.

July 2012

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Lloyd's Register, its affiliates and subsidiaries and their respective officers, employees or agents are, individually and collectively, referred to in this clause as the 'Lloyd's Register Group'. The Lloyd's Register Group assumes no responsibility and shall not be liable to any person for any loss, damage or expense caused by reliance on the information or advice in this document or howsoever provided, unless that person has signed a contract with the relevant Lloyd's Register Group entity for the provision of this information or advice and in that case any responsibility or liability is exclusively on the terms and conditions set out in that contract.

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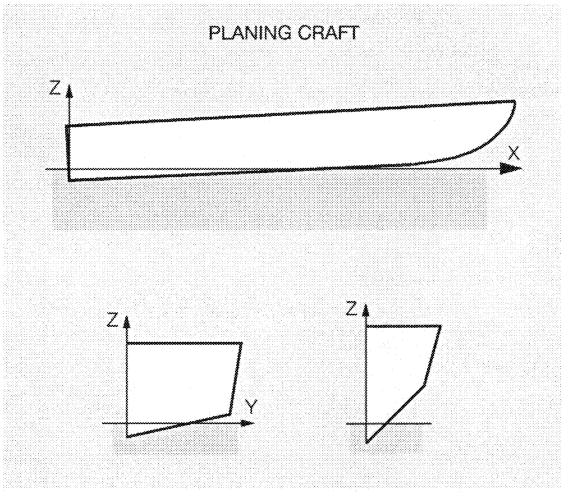
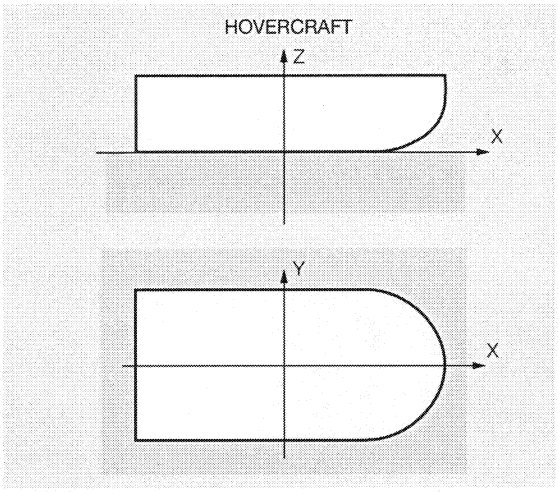
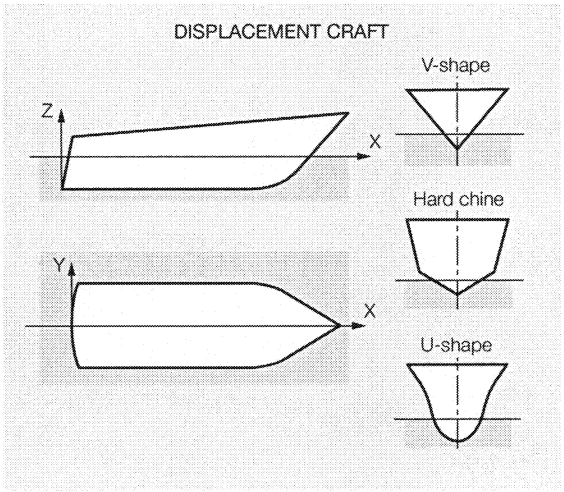
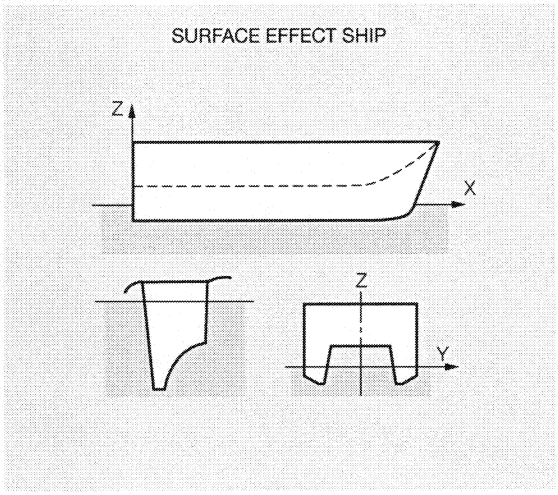
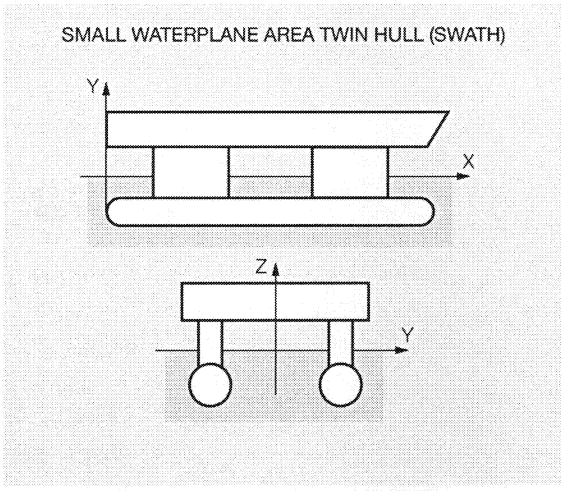
DIFFERENT TYPES OF HULL FORMS COVERED BY THE SPECIAL SERVICE CRAFT RULES

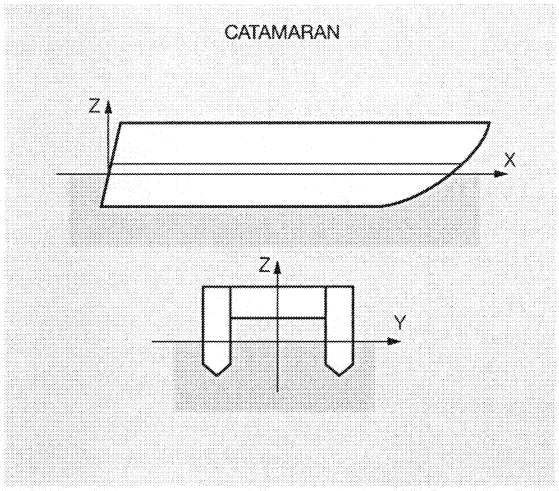












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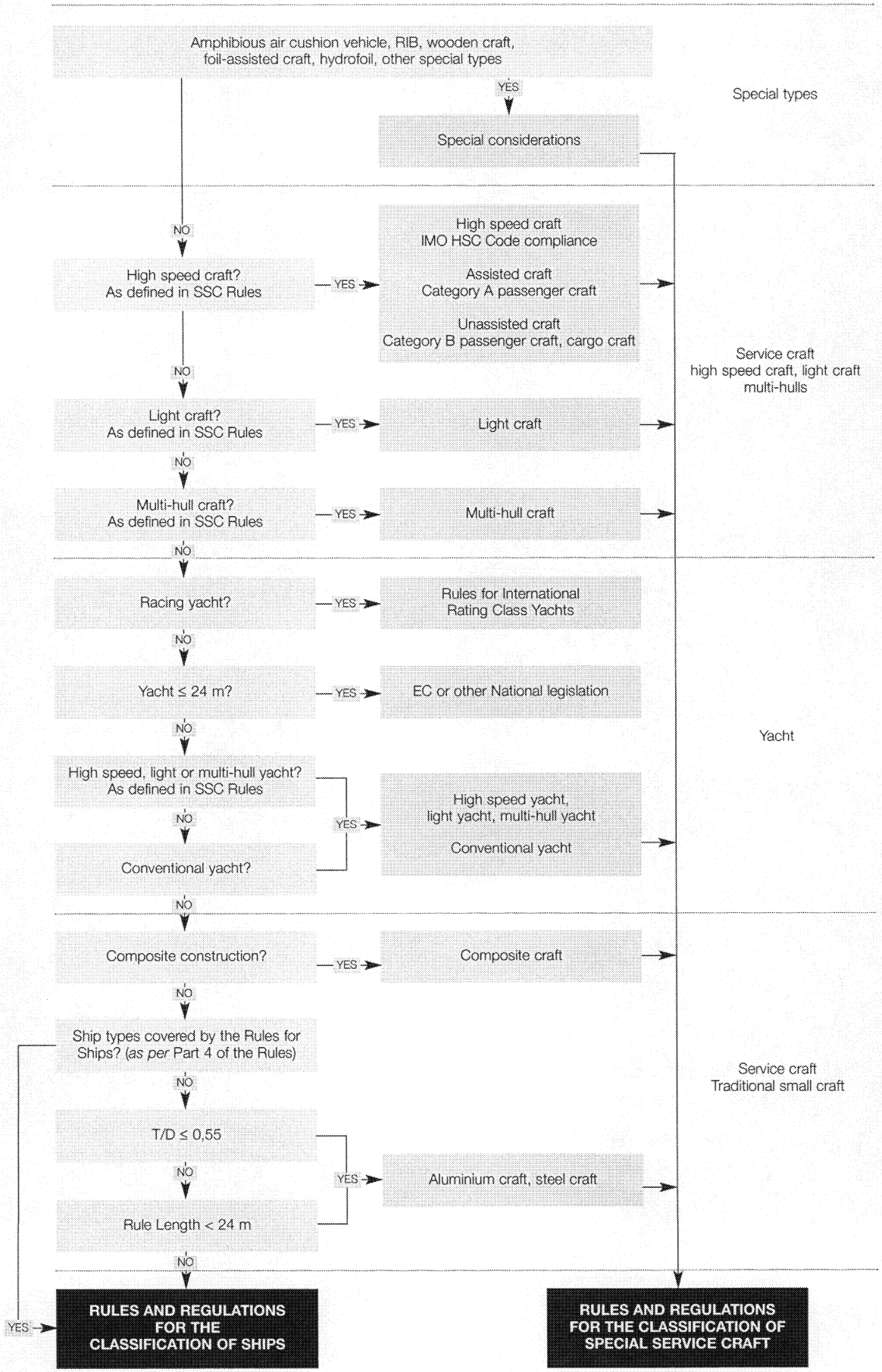
DIFFERENT TYPES OF CRAFT COVERED BY THE SPECIAL SERVICE CRAFT RULES



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Section 1

1.1 Lloyd's Register (hereinafter referred to as 'LR'), which is recognised under the laws of the United Kingdom as a corporate body and a charity established for the benefit of the community, was founded in 1760. It was established for the purpose of producing a faithful and accurate classification of merchant shipping. It now primarily produces classification Rules.

1.2 Classification services are delivered to clients by a number of other members of the Lloyd's Register Group, including: Lloyd's Register EMEA, Lloyd's Register Asia, Lloyd's Register North America, Inc., and Lloyd's Register Central and South America Limited.

1.3 The Lloyd's Register Group (hereinafter referred to as 'the LR Group') comprises charities, other forms of organisation and non-charitable companies, with the latter supporting the charities in their main goal of enhancing the safety of life and property, at sea, on land and in the air, for the benefit of the public and the environment.

Section 2

2.1 LR remains the sole classification society in the LR Group. LR is managed by a Board of Trustees (hereinafter referred to as 'the Board').

The Board has:

appointed a Classification Committee and determined its powers and functions and authorised it to delegate certain of its powers to a Classification Executive and Devolved Classification Executives;
appointed Technical Committees and determined their powers, functions and duties.

2.2 The LR Group has established National and Area Committees in the following:

Countries:
Australia (via Lloyd's Register Asia)
Canada (via Lloyd's Register North America, Inc.)
China (via Lloyd's Register Asia)
Egypt (via Lloyd's Register EMEA)
Federal Republic of Germany (via Lloyd's Register EMEA)
France (via Lloyd's Register EMEA)
Italy (via Lloyd's Register EMEA)
Japan (via Lloyd's Register)
New Zealand (via Lloyd's Register Asia)
Poland (via Lloyd's Register (Polska) Sp zoo)
Spain (via Lloyd's Register EMEA)
United States of America (via Lloyd's Register North America, Inc.)

Areas:
Benelux (via Lloyd's Register EMEA)
Central America (via Lloyd's Register Central and South America Ltd)
Nordic Countries (via Lloyd's Register EMEA)
South Asia (via Lloyd's Register Asia)
Asian Shipowners (via Lloyd's Register Asia)
Greece (via Lloyd's Register EMEA)

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■ *Section 3*

3.1 LR's Technical Committee is at present composed of a maximum of 80 members which includes:

Ex officio members:

- Chairman and Chief Executive Officer of LR .....
- Chairman of the Classification Committee of LR .....

Members Nominated by:

- Technical Committee .....
- Royal Institution of Naval Architects 2
- Institution of Engineers and Shipbuilders in Scotland 2
- Institute of Marine, Engineering, Science and Technology 2
- Institute of Materials, Minerals and Mining 1
- Honourable Company of Master Mariners 2
- Institution of Engineering and Technology 1
- Institute of Refrigeration 1
- Welding Institute 1
- Shipbuilders' and Shiprepairers' Association 2
- The Society of Consulting Marine Engineers and Ship Surveyors .....
- Community of European Shipyards Associations 1
- Society of Maritime Industries 2
- European Marine Equipment Council 1
- Chamber of Shipping 1
- Greek Shipping Co-operation Committee 1
- International Association of Oil and Gas Producers 1

3.2 In addition to the foregoing:

(a) Each National or Area Committee may appoint a representative to attend meetings of the Technical Committee.

(b) A maximum of five representatives from National Administrations may be co-opted to serve on the Technical Committee. Representatives from National Administrations may also be elected as members of the Technical Committee under one of the categories identified in 3.1.

(c) Further persons may be co-opted to serve on the Technical Committee by the Technical Committee.

3.3 All elections are subject to confirmation by the Board.

3.4 The function of the Technical Committee is to consider:

(a) any technical issues connected with LR's marine business;

(b) any proposed alterations in the existing Rules;

(c) any new Rules for classification;

Where changes to the Rules are necessitated by mandatory implementation of International Conventions, Codes or Unified Requirements adopted by the International Association of Classification Societies these may be implemented by LR without consideration by the Technical Committee.

3.5 The term of office of the Chairman and of all members of the Technical Committee is five years. Members may be re-elected to serve an additional term of office with the approval of the Board. The term of office of the Chairman may be extended with the approval of the Board.

3.6 In the case of continuous non-attendance of a member, the Technical Committee may withdraw membership.

3.7 Meetings of the Technical Committee are convened as often and at such times and places as is necessary, but there is to be at least one meeting in each year. Urgent matters may be considered by the Technical Committee by correspondence.

3.8 Any proposal involving any alteration in, or addition to, Part 1, Chapter 1 of Rules for Classification is subject to approval of the Board. All other proposals for additions to or alterations to the Rules for Classification other than Part 1, Chapter 1, will following consideration and approval by the Technical Committee either at a meeting of the Technical Committee or by correspondence, be recommended to the Board for adoption.

3.9 The Technical Committee is empowered to:

(a) appoint sub-Committees or panels; and

(b) co-opt to the Technical Committee, or to its sub-Committees or panels, representatives of any organisation or industry or private individuals for the purpose of considering any particular problem.

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Section 4

4.1 LR's Naval Ship Technical Committee is at present composed of a maximum of 50 members and includes:

Ex officio members

- Chairman and Chief Executive Officer of LR

Member nominated by:

- Naval Ship Technical Committee;
- The Royal Navy and the UK Ministry of Defence;
- UK Shipbuilders, Ship Repairers and Defence Industry;
- Overseas Navies, Governments and Governmental Agencies;
- Overseas Shipbuilders, Ship Repairers and Defence Industries;

4.2 All elections are subject to confirmation by the Board.

4.3 All members of the Naval Ship Technical Committee are to hold security clearance from their National Authority for the equivalent of NATO CONFIDENTIAL. All material is to be handled in accordance with NATO Regulations or, for non-NATO countries, an approved equivalent. No classified material shall be disclosed to any third party without the consent of the originator.

4.4 The term of office of the Naval Ship Technical Committee Chairman and of all members of the Naval Ship Technical Committee Chairman is five years. Members may be re-elected to serve an additional term of office with the approval of the Board. The term of the Chairman may be extended with the approval of the Board.

4.5 In the case of continuous non-attendance of a member, the Naval Ship Technical Committee may withdraw membership.

4.6 The function of the Naval Ship Technical Committee is to consider technical issues connected with Naval Ship matters and to approve proposals for new Naval Ship Rules, or amendments to existing Naval Ship Rules.

4.7 Meetings of the Naval Ship Technical Committee are convened as necessary but there will be at least one meeting per year. Urgent matters may be considered by the Naval Ship Technical Committee by correspondence.

4.8 Any proposal involving any alteration in, or addition to, Part 1, Chapter 1 of Rules for Classification of Naval Ships is subject to approval of the Board. All other proposals for additions to or alterations to the Rules for Classification of Naval Ships, other than Part 1, Chapter 1, will following consideration and approval by the Naval Ship Technical Committee, either at a meeting of the Naval Ship Technical Committee or by correspondence, be recommended to the Board for adoption.

4.9 The Naval Ship Technical Committee is empowered to:

(a) appoint sub-Committees or panels; and

(b) co-opt to the Naval Ship Technical Committee, or to its sub-Committees or panels, representatives of any organisation or industry or private individuals for the purpose of considering any particular problem.

Section 5

5.1 LR has the power to adopt, and publish as deemed necessary, Rules relating to classification and has (in relation thereto) provided the following:

(a) Except in the case of a special directive by the Board, no new Regulation or alteration to any existing Regulation relating to classification or to class notations is to be applied to existing ships.

(b) Except in the case of a special directive by the Board, or where changes necessitated by mandatory implementation of International Conventions, Codes or Unified Requirements adopted by the International Association of Classification Societies are concerned, no new Rule or alteration in any existing Rule is to be applied compulsorily after the date on which the contract between the ship builder and shipowner for construction of the ship has been signed, nor within six months of its adoption. The date of 'contract for construction' of a ship is the date on which the contract to build the ship is signed between the prospective shipowner and the ship builder. This date and the construction number (i.e. hull numbers) of all the vessels included in the contract are to be declared by the party applying for the assignment of class to a newbuilding. The date of 'contract for construction' of a series of sister ships, including specified optional ships for which the option is ultimately exercised, is the date on which the contract to build the series is signed between the prospective shipowner and the ship builder. In this section a 'series of sister ships' is a series of ships built to the same approved plans for classification purposes, under a single contract for construction. The optional ships will be considered part of the same series of sister ships if the option is exercised not later than 1 year after the contract to build the series was signed. If a contract for construction is later amended to include additional ships or additional options, the date of 'contract for construction' for such ships is the date

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on which the amendment to the contract is signed between the prospective shipowner and the ship builder. The amendment to the contract is to be considered as a 'new contract'. If a contract for construction is amended to change the ship type, the date of 'contract for construction' of this modified vessel, or vessels, is the date on which the revised contract or new contract is signed between the Owner, or Owners, and the shipbuilder. Where it is desired to use existing approved ship or machinery plans for a new contract, written application is to be made to LR. Sister ships may have minor design alterations provided that such alterations do not affect matters related to classification, classification, or if the alterations are subject to classification requirements, these alterations are to comply with the classification requirements in effect on the date on which the alterations are contracted between the prospective owner and the ship builder or, in the absence of the alteration contract, comply with the classification requirements in effect on the date on which the alterations are submitted to LR for approval.

(c) All reports of survey are to be made by surveyors authorised by members of the LR Group to survey and report (hereinafter referred to as 'the Surveyors') according to the form prescribed, and submitted for the consideration of the Classification Committee.

(d) Information contained in the reports of classification and statutory surveys will be made available to the relevant owner, National Administration, Port State Administration, P&I Club, hull underwriter and, if authorised in writing by that owner, to any other person or organisation.

(e) Notwithstanding the general duty of confidentiality owed by LR to its client in accordance with the LR Rules, LR clients hereby accept that, LR will participate in the IACS Early Warning System which requires each IACS member to provide its fellow IACS members and Associates with relevant technical information on serious hull structural and engineering systems failures, as defined in the IACS Early Warning System (but not including any drawings relating to the ship which may be the specific property of another party), to enable such useful information to be shared and utilised to facilitate the proper working of the IACS Early Warning System LR will provide its client with written details of such information upon sending the same to IACS Members and Associates.

(f) Information relating to the status of classification and statutory surveys and suspensions/withdrawals of class together with any associated conditions of class will be made available as required by applicable legislation or court order.

(g) A Classification Executive consisting of senior members of LR's Classification Department staff shall carry out whatever duties that may be within the function of the Classification Committee that the Classification Committee assigns to it.

■ *Section 6*

6.1 No LR Group employee is permitted under any circumstances, to accept, directly or indirectly, from any person, firm or company, with whom the work of the employee brings the employee into contact, any present, bonus, entertainment or honorarium of any sort whatsoever which is of more than nominal value or which might be construed to exceed customary courtesy extended in accordance with accepted ethical business standards.

■ *Section 7*

7.1 LR has the power to withhold or, if already granted, to suspend or withdraw any ship from class (or to withhold any certificate or report in any other case), in the event of non-payment of any fee to any member of the LR Group.

■ *Section 8*

8.1 When providing services LR does not assess compliance with any standard other than the applicable LR Rules, international conventions and other standards agreed in writing.

8.2 In providing services, information or advice, the LR Group does not warrant the accuracy of any information or advice supplied. Except as set out herein, LR will not be liable for any loss, damage or expense sustained by any person and caused by any act, omission, error, negligence or strict liability of any of the LR Group or caused by any inaccuracy in any information or advice given in any way by or on behalf of the LR Group even if held to amount to a breach of warranty. Nevertheless, if the Client uses LR's services or relies on any information or advice given by or on behalf of the LR Group and as a result suffers loss, damage or expense that is proved to have been caused by any negligent act, omission or error of the LR Group or any negligent inaccuracy in information or advice given by or on behalf of the LR Group, then a member of the LR Group will pay compensation to the client for its proved loss up to but not exceeding the amount of the fee (if any) charged for that particular service, information or advice.

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8.3 Notwithstanding the previous clause, the LR Group will not be liable for any loss of profit, loss of contract, loss of use or any indirect or consequential loss, damage or expense sustained by any person caused by any act, omission or error or caused by any inaccuracy in any information or advice given in any way by or on behalf of the LR Group even if held to amount to a breach of warranty.

8.4 Any dispute about LR's services is subject to the exclusive jurisdiction of the English courts and will be governed by English law.

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2 **Scope of the Rules**

3 **Character of classification and class notations**

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Section 1
Conditions for classification

1.1 General

1.1.1 The *Rules and Regulations for the Classification of Special Service Craft* (hereinafter referred to as the Rules for Special Service Craft), are applicable to those types of craft which are defined in 2.1. Where the word craft is used in the text of the Rules, it is to be taken as being applicable to yachts and other craft as stated herein unless specifically indicated otherwise.

1.1.2 The Rules are framed on the understanding:

(a) that the craft will at all times be properly loaded. They do not, unless stated or implied in the class notation, provide for special distributions or concentrations of loading associated with the operation of the craft. Lloyd's Register (hereinafter referred to 'LR') may require additional strengthening to be fitted in any craft, which, in their opinion, would otherwise be subjected to severe stresses due to particular features in the design or operation, or where it is desired to make provision for exceptional loading conditions. In such cases particulars and details of the required loadings are to be submitted for consideration,

(b) that the craft will at all times be properly handled, with particular reference to the placing on board of persons and equipment and the reduction of speed in heavy weather,

(c) that compliance with the Rules does not relieve the designer of his responsibilities to his client for compliance with the specification and the requirements for the overall design and in service performance of the craft,

(d) that the craft will not be operated outside of the para-meters specified in any operational envelope which may have been assigned, without the prior agreement of LR.

1.1.3 New craft built in accordance with the Rules, or in accordance with requirements equivalent thereto, will be assigned a class in the appropriate *Register Book* and will continue to be classed so long as they are found, upon examination at the prescribed surveys, to be maintained in accordance with the requirements of the Rules. Classification will be conditional upon compliance with LR's requirements for both hull and machinery.

1.1.4 The class notations of yachts will be recorded on the ClassDirect Live website. The class notations of other craft will be recorded on the ClassDirect Live website in the *Register of Ships.*

1.1.5 LR, in addition to requiring compliance with the Rules, will, in general, require to be satisfied that craft are suitable for the geographical or other limits or conditions of the service contemplated.

1.1.6 Loading conditions and any other preparations required to permit a craft with a notation specifying some service limitation to undertake a sea-going voyage, either from port of building to service area or from one service area to another, are to be in accordance with arrangements agreed by LR prior to the voyage.

1.1.7 Any damage, defect, breakdown or grounding, which could invalidate the conditions for which a class has been assigned, is to be reported to LR without delay. Any detention or arrest is also to be reported to LR without delay.

1.1.8 Where the provision of loading or stress monitoring equipment has been required by LR as the result of local, longitudinal or transverse strength calculations and the imposition of operating limitations, the necessary loading guidance information and operating instructions are to be incorporated in the relevant manuals supplied to the Master.

1.1.9 Where an onboard computer system having longitudinal strength computation capability, which is required by the Rules, is provided on a new craft, or newly installed on an existing craft, then the system is to be certified in respect of longitudinal strength use in accordance with LR's document entitled *Approval of Longitudinal Strength and Stability Calculation Programs.*

1.1.10 Where an onboard computer system having stability computation capability is provided on a new craft, then the system is to be certified in respect of stability aspects in accordance with LR's document entitled, *Approval of Longitudinal Strength and Stability Calculation Programs*. When provided, an onboard computer system having stability computation capability is to carry out the calculations and checks necessary to assess compliance with all the stability requirements applicable to the craft on which it is installed.

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1.1.11 For craft, the arrangements and equipment of which are required to comply with the requirements of the:

- *International Convention on Load Lines, 1966*:
- *International Convention for the Safety of Life at Sea, 1974* and its protocol of 1978, which includes the *International Code of Safety for High Speed Craft*:
- *International Convention for the Prevention of Pollution from ships, 1974*, as modified by the Protocol of 1978 relating thereto:

and applicable Amendments thereto, the Committee requires the applicable Convention Certificates to be issued by a National Administration, or by LR, or by an IACS Member when so authorised. Safety Management Certificates in accordance with the provisions of the *International Safety Management Code* (ISM Code) may be issued by an organisation complying with IMO Resolution A.739(18) and authorised by the National Authority with which the craft is registered. Cargo Ship Radio Certificates may be issued by an organisation authorised by the National Authority with which the craft is registered.

1.1.12 In the case of dual classed craft, Convention certificates may be issued by the other classification society with which the craft is classed provided this is recognised in a formal Dual Class Agreement with LR and provided the other classification society is also authorised by the National Authority.

1.1.13 Yachts with a load line length, of 24m and over, having a service type notation of **Yacht**, will be assigned class only after it has been demonstrated that the stability of the yacht complies with the stability requirements of the National Administration, provided these are as a minimum equivalent to the intact stability requirements of the UK MCA LY2 Code (as amended).

1.1.14 Yachts with a load line length of 24 m and above, and with a gross tonnage of less than 3000, will be assigned a service type notation **Yacht(S)** only after it has been demonstrated that both the intact and damage stability comply with the UK MCA LY2 Code.

1.1.15 Yachts with a load line length of 24 m and above, and with a gross tonnage of 3000 and above, will be assigned a service type notation **Yacht(S)** only after it has been demonstrated that both the intact and damage stability comply with enhanced stability requirements such as a recognised International Standard.

1.2 Application

1.2.1 Except in the case of a special directive by the Committee, no new Regulation or alteration to any existing Regulation relating to character of classification or to class notations is to be applied to existing craft.

1.3 Interpretation of the Rules

1.3.1 The interpretation of the Rules is the sole responsibility, and at the sole discretion, of LR.

1.4 Scope of classification

1.4.1 Classification covers the structural design, watertight integrity and standard of construction of the hull and construction, installation and testing of the propulsion machinery, essential auxiliary machinery, essential piping and electrical systems to the extent indicated within these Rules.

1.4.2 Outfit, other than that covered by 1.4.1, general finish, noise levels, vibration (other than shaft vibration where applicable), trim, design speed and stability, except as mentioned in 1.1.11, 1.1.13 and 1.1.14 are outside the scope of classification.

1.4.3 Where a craft is to be fitted with sails, the masts, rigging and sail arrangements are left to the judgment and experience of the Owner, the Builders and the designers, and LR does not accept responsibility for them. However, for classification purposes the attending Surveyor must be satisfied that they are being maintained in a satisfactory condition.

1.4.4 Where a craft is so badly damaged that class has to be suspended, LR is prepared to assist the Owner with advice if requested.

1.4.5 The attention of Owners and Builders is drawn to statutory requirements which may be imposed by the relevant National Administration and which may not be within the scope of classification.

1.5 Client's responsibilities

1.5.1 The Client is to give LR's Surveyors every facility and necessary access to carry out their survey duties. The Client should familiarise himself with the relevant LR Rules and, where appropriate, arrange that all sub-contractors, suppliers of components, materials or equipment do the same.

1.5.2 The survey procedures undertaken by LR when providing services are on the basis of periodical visits involving both monitoring and direct survey, and LR's Surveyors will not be in continual attendance at LR's Client's premises. As construction and outfitting are continuous processes, the Builder has the overall responsibility to his client to ensure and document that the requirements of the Rules, approved drawings and any agreed amendments made by the attending LR Surveyors have been complied with.

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Section 2
Scope of the Rules

2.1 Applicable craft types

2.1.1 The Rules are applicable to the following craft types constructed from steel, aluminium alloy, composite materials or combinations of these materials:

(a) High speed craft.
(b) Light displacement craft.
(c) Multi-hull craft.
(d) Yachts of overall length, L_{OA}, 24 m or greater.
(e) Craft with draught to depth ratio less than or equal to 0,55.

2.1.2 The following craft types will be considered upon request on the basis of the Rules:

(a) Amphibious air cushion vehicles.
(b) Rigid inflatable boats.
(c) Hydrofoil craft.
(d) Foil assisted craft.
(e) Craft as defined 2.1.1(a) to (e) constructed from wood or wood/composite combinations.
(f) Other craft constructed from composite materials.
(g) Craft with a Rule length, L_R, less than 24 m and draught to depth ratio greater than 0,55.

2.1.3 Existing yachts, regardless of length, are subject to the survey requirements defined in Chapter 4.

2.1.4 The Rules incorporate those requirements of the *International Convention for the Safety of Life at Sea, 1974* as amended (SOLAS 74) Chapter X – Safety Measures for High Speed Craft (*International Code of Safety for High Speed Craft*) hereinafter referred to as the HSC code, as applicable to the classification of such craft.

2.1.5 At the discretion of LR craft types which are specifically covered by LR's *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships) or other LR Rules and Regulations for Classification may be considered for classification in accordance with these Rules and Regulations.

2.1.6 Where any aspect of the design or construction is not covered by the Rules, the relevant requirements of the Rules for Ships or the *Rules and Regulations for the Classification of Naval Ships* (hereinafter referred to as the Rules for Naval Ships) will be applied as considered necessary.

2.2 Definitions

2.2.1 For the purpose of the Rules, the definitions given in 2.2.2 to 2.2.29 will apply.

2.2.2 **Air Cushion Vehicle.** An Air Cushion Vehicle (ACV) is a craft such that the whole or a significant part of its weight can be supported, whether at rest or in motion, by a continuously generated cushion of air dependent for its effectiveness on the proximity of the surface over which the craft operates.

2.2.3 **Assisted craft.** An assisted craft is any craft operating on a route where it has been demonstrated to the satisfaction of the Administrations concerned that there is a high probability that in the event of an evacuation at any point of the route, all passengers and crew can be rescued safely within the time specified in the HSC Code.

2.2.4 **Catamaran.** A catamaran is a craft with twin-hulls linked by a bridging structure.

2.2.5 **Composite materials.** Composite materials are those construction materials consisting principally of fibre reinforced plastics.

2.2.6 **Design waterline** is the waterline corresponding to the maximum operational weight of the craft with no lift or propulsion machinery active.

2.2.7 **Foil assisted craft.** A foil assisted craft is a craft designed such that a significant part of its weight, whilst in motion, is supported by hydrodynamic lift generated by foils.

2.2.8 **High speed craft.** A high speed craft is a craft capable of maximum speed, V, *see* 2.2.11, not less than:

$$V = 7{,}19\,\nabla^{1/6} \text{ knots}$$

where

∇ = moulded displacement, in m^3, of the craft corresponding to the design waterline.

2.2.9 **Hydrofoil craft.** A hydrofoil craft is a craft which is supported above the water surface in non-displacement mode by hydrodynamic forces generated by foils.

2.2.10 **Light displacement craft.** A light displacement craft is a craft with a displacement not exceeding:

$$\Delta = 0{,}04(L_R B)^{1,5} \text{ tonnes}$$

where

L_R and B are defined in Pt 3, Ch 1.

2.2.11 **Maximum speed.** Maximum speed is the speed, in knots, achieved at the maximum continuous power for which the craft is certified at maximum operational weight and in smooth water.

2.2.12 **Mono-hull craft.** A mono-hull craft is a craft whose single hull may be of displacement form or of a semi-planing or planing form subject to some support by hydrodynamic lift.

2.2.13 **Multi-hull craft.** A multi-hull craft is a craft with two or more hulls linked by a bridging structure which may be of displacement form or of a semi-planing or planing form subject to some support by hydrodynamic lift.

2.2.14 **Operational speed.** Operational speed is the speed, in knots, corresponding to that permitted by the operational envelope. For High Speed Craft it is not more than 90 per cent of the maximum speed.

2.2.15 **Operational envelope.** The operational envelope defines the craft's service in terms of operational speeds, wave heights, displacements, service area and time required to seek refuge.

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2.2.16 **Passenger.** A passenger is every person other than:
(a) The Master and the members of the crew or other persons employed or engaged in any capacity on board a craft on the business of that craft, and
(b) a child under one year of age.

2.2.17 **Passenger craft.** A passenger craft is a craft which carries more than twelve passengers.

2.2.18 **Patrol craft.** A patrol craft is a craft which may be operated by the harbour, police, customs, military authorities, search and rescue or similar organisations.

2.2.19 **Pilot launch.** A pilot launch is a craft designed to come alongside ships whilst at sea to embark or disembark pilots.

2.2.20 **Place of refuge.** A place of refuge is any naturally or artificially sheltered area which may be used as a shelter by a craft under conditions likely to endanger its safety.

2.2.21 **Range to refuge.** Range to refuge is the maximum allowable distance in nautical miles, measured along the shortest safe navigational track from any point on the intended voyage route of the craft to the nearest accessible harbour or place of refuge.

2.2.22 **Reasonable weather.** Reasonable weather is defined as wind strengths of force six or less on the Beaufort scale, associated with:
(a) Sea states within the operational envelope which are sufficiently moderate to ensure that green water is taken on board at infrequent intervals only or not at all.
(b) Motions such as do not impair the efficient operation of the craft and do not significantly reduce passenger comfort or safety or impose any undue loads on any cargo carried.

2.2.23 **Rigid Inflatable Boat.** A Rigid Inflatable Boat (RIB) is a craft combining a rigid hull enclosed by a watertight self-draining deck situated above the deepest operational load waterline and provided with a gas, air or foam-filled flotation collar/fender at the edge of the deck above the hull to improve the stability and to augment the reserve of buoyancy and sea-keeping ability of the rigid hull.

2.2.24 **Service craft.** Service craft is any craft within the scope of the Rules other than a yacht or an amphibious air cushion vehicle.

2.2.25 **Small Waterplane Area Twin Hull Ship.** A Small Waterplane Area Twin Hull Ship (SWATH) is a twin-hulled craft characterised by bulbous lower hulls (torpedoes) and relatively narrow struts connecting them to the haunches and deck structure.

2.2.26 **Surface Effect Ship.** A Surface Effect Ship (SES) is an air-cushion vehicle whose cushion is totally or partially retained by permanently immersed rigid structures.

2.2.27 **Unassisted craft.** An unassisted craft is any craft other than an assisted craft, with machinery and safety systems arranged such that, in the event of damage disabling any essential machinery and safety systems in one compartment, the craft retains the capability to navigate safely as defined in the HSC Code.

2.2.28 **Wave piercer.** A wave piercer is a particular type of catamaran with lower hulls of a displacement or semi-displacement form that provide a positive freeboard when at rest in smooth water but which are expected to become partially submerged when advancing in waves.

2.2.29 **Yacht.** A yacht is a recreational craft used for sport or pleasure and may be propelled mechanically, by sail or by a combination of both.

2.2.30 **Workboat.** A workboat is a general purpose service craft which may be adapted for duties such as line handling, towing, tender, survey, fishing, oil spill recovery, or diving support.

■ *Section 3*
Character of classification and class notations

3.1 General

3.1.1 This Section details the character symbols and notations which comprise the class assigned to special service craft.

3.1.2 The operational envelope assigned to craft built and classed in accordance with the Rules will be included in the operational manual of the craft where such a manual is required by the Rules. A reference to the operational envelope will be made in the Classification Certificate.

3.1.3 Craft built and classed in accordance with the Rules for restricted service but which are not assigned an operational envelope will have their geographical limits included in the Classification Certificate.

3.2 Character symbols

3.2.1 All craft, when classed, will be assigned a character of classification comprising one or more character symbols as applicable, e.g. **✠100A1 SSC.**

3.2.2 A full list of character symbols for which craft may be eligible is as follows:

✠ This distinguishing mark will be assigned, at the time of classing, to new craft constructed under LR's Special Survey, in compliance with the Rules, and to the satisfaction of the Committee.

$\overline{✠}$ This distinguishing mark will be assigned, at the time of classing, to new craft constructed under LR's Special Survey in accordance with plans approved by another recognised classification society.

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100 This character figure will be assigned to all craft considered suitable for sea-going service except those in Service Group 1, *see* 3.5.5.

A This character letter will be assigned to all craft which have been built or accepted into class in accordance with LR's Rules and Regulations, and which are maintained in good and efficient condition.

1 This character figure will be assigned to:
(a) Craft having on board, in good and efficient condition, anchoring and/or mooring equipment in accordance with the Rules.
(b) Craft classed for a specific service, having on board, in good and efficient condition, anchoring and/or mooring equipment approved by the Committee as suitable and sufficient for the particular service.

N This character letter will be assigned to craft on which the Committee has agreed that anchoring and mooring equipment need not be fitted in view of their particular service.

T This character letter will be assigned to ships which are intended to perform their primary designed service function only while they are anchored, moored, towed or linked, and which have, in good and efficient condition, adequately attached anchoring, mooring, towing or linking equipment which has been approved by the Committee as suitable and sufficient for the intended service.

SSC These character letters will be assigned to craft indicating that the craft has been constructed or accepted into class on the basis of the Rules.

3.2.3 For classification purposes the character figure **1** or the character letter **N** is to be assigned.

3.2.4 In cases where the anchoring and/or mooring equipment is found to be seriously deficient in quality or quantity, the class of the craft will be liable to be withheld.

3.3 Class notations (hull)

3.3.1 When considered necessary by the Committee, or when requested by an Owner and agreed by the Committee, a class notation will be appended to the character of classification assigned to the craft. The class notation will consist of one of, or a combination of:
(a) a high speed craft notation;
(b) a light displacement craft notation;
(c) a service area restriction notation;
(d) a service type notation; and
(e) a craft type notation;
(f) other hull notations;
e.g.

✠100A1 SSC Passenger (A) Catamaran HSC G3 'service area'

✠100A1 SSC Yacht Catamaran LDC G5.

3.3.2 A list of class notations (hull) for which a craft may be eligible is given in 3.4 to 3.10.

3.4 High speed craft and light displacement craft notations

3.4.1 **HSC – High speed craft notation.** This class notation will be assigned to high speed craft as defined in 2.2.8.

3.4.2 **LDC – Light displacement craft notation.** This class notation will be assigned to light displacement craft as defined in 2.2.10.

3.5 Service area restriction notations

3.5.1 All craft classed under the Rules will be assigned a service area restriction notation **G** followed by a number e.g. **G1.** Craft classed under the Rules for service groups **G1** to **G5** are not suitable for unrestricted service except as noted in the service area restriction notation, *see* 3.5.5.

3.5.2 Service area restriction notations, given in 3.5.5, are expressed in terms of range to refuge in nautical miles as defined in 2.2.20.

3.5.3 Where craft are required to satisfy limitations in respect of the maximum duration of time to a place of refuge from any point during the voyage, this time is to be determined by dividing the range to refuge by the permitted operational speed of the craft (when fully laden) in the prevailing conditions as imposed by the operational envelope.

3.5.4 For craft that are designed in accordance with an operational envelope, typically **HSC** or **LDC** craft as defined in 3.4:
- these craft are to be operated at reduced speeds and are to seek calmer waters or refuge when the weather conditions deteriorate or are predicted to deteriorate such that the limits of the operational envelope are exceeded.

For craft that are not assigned an operational envelope:
- these craft are to be operated at reduced speeds and are to seek calmer waters or refuge when the weather conditions deteriorate or are predicted to deteriorate.

All craft are to be aware of the weather forecast for the proposed and current areas of operation and area of refuge.

3.5.5 The service area restriction notations defined below describe the service area restriction for which the craft has been approved and constructed.

G1 **Service Group 1** covers craft intended for service in sheltered waters adjacent to sandbanks, estuaries, reefs, breakwaters or other coastal features and in similarly sheltered waters between islands in reasonable weather where the range to refuge is, in general, five nautical miles or less. The geographical limits of the intended service are to be identified by the Builder and agreed with LR. Craft in this group are not eligible for the assignment of the character figure **100.**

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G2 **Service Group 2** covers craft intended for service in reasonable weather, in waters where the range to refuge is 20 nautical miles or less. This group will usually cover craft intended for service in coastal waters, for which geographical limits are to be identified by the Builder and agreed with LR.

G2A **Service Group 2A** covers craft intended for service in reasonable weather in waters where the range to refuge is 60 nautical miles or less. The geographical limits of the intended service are to be reported to LR. Craft in this group are eligible for assignment of the service type notation **SRY**.

G3 **Service Group 3** covers craft intended for service in waters where the range to refuge is 150 nautical miles or less. The geographical limits of the intended service are to be reported to LR.

G4 **Service Group 4** covers craft intended for service in waters where the range to refuge is 250 nautical miles or less. The geographical limits of the intended service are to be reported to LR.

G5 **Service Group 5** covers craft intended for service in waters where the range to refuge is 350 nautical miles or less. The geographical limits of the intended service are to be reported to LR.

G6 **Service Group 6** covers yachts and steel patrol craft having unrestricted service.

3.5.6 Consideration may be given to requests for an increase in the permissible range to refuge subject to:

(a) The specific geographic limits and the period over which the extended service is to be operated being defined.
(b) Satisfactory statistical data in respect of wave height, being provided to demonstrate that the craft will be suitable for the extended service.
(c) Equipment consistent with that required for the extended service being provided onboard during the period of operation.
(d) Any maximum duration of voyage limitations imposed by 3.5.3 not being exceeded during the extended service.

3.6 Service type notations

3.6.1 The service type notation will be recorded in the appropriate *Register Book* indicating the primary purpose for which the craft has been designed and constructed.

3.6.2 A list of service type notations for which craft may be eligible is given below:

Cargo (A) This notation will be assigned to cargo craft other than Cargo (B) craft.

Cargo (B) This notation will be assigned to unassisted high speed cargo craft of 500 gross tons and over which do not proceed in the course of their voyage more than eight hours at operational speed from a place of refuge when fully laden. These craft correspond to 'Cargo Craft' as defined in the HSC Code.

Passenger This notation will be assigned to passenger craft other than **Passenger (A)** or **Passenger (B)** craft.

Passenger (A) This notation will be assigned to assisted high speed craft carrying not more than 450 passengers on board and which do not proceed in the course of their voyage more than four hours at operational speed from a place of refuge when fully laden. These craft correspond to 'Category A Craft' as defined in the HSC Code.

Passenger (B) This notation will be assigned to unassisted high speed craft which may carry more than 450 passengers on board and which do not proceed in the course of their voyage more than four hours at operational speed from a place of refuge when fully laden. These craft correspond to 'Category B Craft' as defined in the HSC Code.

Patrol This notation will be assigned to patrol craft complying with the relevant requirements of the Rules.

Pilot This notation will be assigned to pilot launches complying with the relevant requirements of the Rules.

Yacht or Support Yacht Craft This notation will be assigned to all yachts.

Workboat This notation will be assigned to workboats complying with the relevant requirements of the Rules.

3.7 Craft type notations

3.7.1 The craft type notation will be recorded in the appropriate *Register Book* indicating the type of hull form and mode of operation for which the craft has been designed and constructed.

3.7.2 A list of craft type notations for which craft may be eligible is given below:

ACV This notation will be assigned to amphibious air cushion vehicles.

Catamaran This notation will be assigned to catamarans including wave piercers.

Hydrofoil This notation will be assigned to hydrofoil craft.

Mono This notation will be assigned to mono-hull craft other than amphibious air cushion vehicles, hydrofoils and rigid inflatable boats.

Multi This notation will be assigned to multi-hull craft other than catamarans, swaths and surface effect ships.

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RIB This notation will be assigned to rigid inflatable boats.

SES This notation will be assigned to surface effect ships.

Swath This notation will be assigned to small water-plane area twin hull ships.

3.7.3 Where craft indicated in 3.7.2 are foil assisted the letters (FA) may be appended to the Craft Type Notation.

3.8 Other hull notations

3.8.1 **Ice class notation.** A class notation for navigation in first-year ice conditions will be specially considered.

3.8.2 ***IWS.** This notation (In-water Survey) may be assigned to a craft where the applicable requirements of LR's Rules and Regulations are complied with. (*See* Ch 3,4.3 and Ch 4,3.3, *see also* Pt 3, Ch 3,2.37).

3.8.3 **Special features notation.** A notation indicating that the craft incorporates special features which significantly affect the design, e.g. movable decks.

3.8.4 **LI.** This notation will be assigned where an approved loading instrument has been installed as a classification requirement.

3.8.5 **SRY**. This notation will be assigned to Short-Range Yachts with service area restriction G2A and in accordance with the MCA *Large Commercial Yacht Code*, MSN 1792(M) requirements for Short-Range Yachts.

3.9 Class notations (machinery)

3.9.1 The following class notations may be assigned as considered appropriate by the Committee:

✠LMC This notation will be assigned when the propelling and essential auxiliary machinery has been constructed, installed and tested under LR's Special Survey and in accordance with LR's Rules and Regulations.

$\overline{✠}$ LMC This notation will be assigned when the propelling and essential auxiliary machinery has been constructed under the survey of a recognised authority in accordance with the Rules and Regulations equivalent to those of LR. In addition, the whole of the machinery will be required to have been installed and tested under LR's Special Survey in accordance with LR's Rules and Regulations.

[✠]LMC This notation will be assigned when the propelling arrangements, steering systems, pressure vessels and the electrical equipment for essential systems have been constructed, installed and tested under LR's Special Survey and are in accordance with LR's Rules and Regulations. Other items of machinery for propulsion and electrical power generation including propulsion gearing arrangements and other auxiliary machinery for essential services that are in compliance with LR Rules and supplied with the manufacturer's certificate will be acceptable under this notation. The system arrangements of propelling and essential auxiliary machinery are required to be appraised by LR, and found to be acceptable to LR. *See* 3.10.2.

LMC This notation (without ✠) will be assigned when the propelling and essential auxiliary machinery has neither been constructed nor installed under LR's Special Survey but the existing machinery, its installation and arrangement, has been tested and found to be acceptable to LR. This notation is assigned to existing craft in service accepted or transferring into LR class.

MCH This notation will be assigned when the propelling and essential auxiliary machinery has been installed and tested under LR's survey requirements and found to be acceptable to LR. Items of machinery and equipment for propelling and auxiliary machinery for essential services supplied with the manufacturer's certificate will be acceptable under this class notation. The system arrangements of propelling and essential auxiliary machinery are required to be appraised by LR, and found to be acceptable to LR. *See* 3.10.1.

UMS This notation may be assigned when the control engineering equipment has been arranged, installed and tested in accordance with LR's Rules, or is equivalent thereto and the arrangements are such that the craft can be operated with the machinery spaces unattended.

CCS This notation may be assigned when the arrangements are such that the machinery may be operated with continuous supervision from a centralised control station. It denotes that the control engineering equipment has been arranged, installed and tested in accordance with LR's Rules, or is equivalent thereto.

3.9.2 Machinery class notations will not be assigned to craft the hulls of which are not classed or intended to be classed with LR.

3.9.3 The notation **✠LMC, $\overline{✠}$ LMC, [✠]LMC, LMC** (without ✠) and **MCH** will in general not be assigned to non-propelled craft, but individual cases will be considered on their merits.

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3.10 Application notes

3.10.1 Propelling and essential auxiliary machinery includes machinery, equipment and systems installed for the craft/yacht to be under seagoing conditions and that are necessary for the following:

(a) Maintaining the watertight and weathertight integrity of the hull and spaces within the hull.
(b) The safety of the craft/yacht, machinery and personnel on board.
(c) The functioning and dependability of propulsion, steering and electrical systems.
(d) The operation and functioning of control engineering systems for the monitoring and safety of propulsion, steering and electrical power systems.
(e) The operation and functioning of emergency machinery and equipment.

3.10.2 **Manufacturer's certificate** for assignment of the **[⊠]LMC** notation. Acceptance of the manufacturer's certificate for items of machinery for propulsion (including propulsion gearing with single input/output arrangements) and for electrical power generation and for other auxiliary machinery for essential services is subject to the following:

(a) For a craft: The craft is intended for the carriage of cargo (not passengers), is less than 500 gross tonnage or is of 500 gross tonnage or greater and is not required to comply with international conventions applicable to a craft with unrestricted service.
(b) For a yacht: The yacht has a gross tonnage of less than 500, or has a gross tonnage of 500 or more and is not required to comply with international conventions applicable to a yacht with unrestricted service.
(c) Propulsion power is provided by oil engines or gas turbines which have been type approved to LR requirements for marine application.
(d) Electrical power is provided by generators driven by oil engines or gas turbines which have been type approved to LR requirements for marine application.
(e) The design and manufacturing standards for all machinery and associated systems are the applicable LR Rules.
(f) The machinery and equipment is manufactured under a recognised quality control system.
(g) Propellers, propulsion shafting and multiple input/output gearboxes are not included within the scope of propulsion arrangements for acceptance of a manufacturer's certificate.

3.10.3 **Manufacturer's certificate** for assignment of the **MCH** notation. Acceptance of the manufacturer's certificate for propelling and essential auxiliary machinery is subject to the following:

(a) For a craft: The craft is intended for the carriage of cargo (not passengers), is less than 500 gross tonnage or is of 500 gross tonnage or greater and is not required to comply with international conventions applicable to a craft with unrestricted service.
(b) For a yacht: The yacht is less than 500 gross tonnage or is of 500 gross tonnage or more and is not required to comply with international conventions applicable to a yacht with unrestricted service.
(c) Propulsion power is provided by oil engines or gas turbines which have been type approved to LR requirements for marine application.
(d) Electrical power is provided by generators driven by oil engines or gas turbines which have been type approved to LR requirements for marine application.
(e) The power of any engine or gas turbine is less than 2,250 kW and the cylinder bore of any diesel engine is not greater than 300 mm.
(f) The design and manufacturing standards for machinery and associated systems are the applicable LR Rules or other marine standards acceptable to LR.
(g) The machinery and equipment is manufactured under a recognised quality control system.

3.11 Class notations (Environmental Protection)

3.11.1 The following class notations are associated with the design and operation of a Special Service Craft and may be assigned as considered appropriate by the Committee, on application from the Owners:

EP This notation may be assigned when the design and operation of a Special Service Craft are in accordance with the relevant requirements in Pt 7, Ch 11 of the Rules.

$\overline{\text{EP}}$ This notation may be assigned when the environmental protection provisions of the Special Service Craft are in accordance with the requirements of another recognised classification society and are broadly equivalent to the requirements in Pt 7, Ch 11 of the Rules. Prior to assignment of the notation, an audit, in accordance with the requirements in 4.1.3 and 4.1.4 of Pt 7, Ch 11 of the Rules, is to be undertaken by LR to confirm that the necessary Environmental Protection procedures are in place and implemented effectively.

3.12 Descriptive notes

3.12.1 In addition to any class notations, an appropriate descriptive note may be entered in column 6 of the appropriate *Register Book* indicating the type of craft in greater detail than is contained in the class notation, and/or providing additional information about the craft's design and construction. This descriptive note is not a LR classification notation and is provided solely for the information of users of the *Register Book*.

3.12.2 The descriptive note **SCM** (Screwshaft Condition Monitoring) may be assigned when oil lubricated screwshaft arrangements with approved oil glands are fitted and the requirements of Ch 3,11.3 or Ch 4,10.3 are complied with.

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Section 4
Surveys – General

4.1 Statutory surveys

4.1.1 The Committee will act, when authorised on behalf of Governments, in respect of National and International statutory safety and other requirements.

4.1.2 The Committee will also act, when authorised, in respect of National safety and other requirements relating to craft used for offshore mineral exploration and exploitation.

4.2 New construction surveys

4.2.1 When it is intended to build a craft for classification with LR, constructional plans and all particulars relevant to the hull, equipment and machinery, as detailed in the Rules, are to be submitted for the approval of the Committee before the work is commenced. Any subsequent modifications or additions to the scantlings, arrangements or equipment shown on the approved plans are also to be submitted for approval.

4.2.2 Where the proposed construction of any part of the hull or machinery is of novel design, or involves the use of unusual material, or where experience, in the opinion of the Committee, has not sufficiently justified the principle or mode of application involved, special tests or examinations before and during service may be required. In such cases a suitable notation may be entered in the appropriate *Register Book*.

4.2.3 The materials used in the construction of hulls and machinery intended for classification are to be of good quality and free from defects and are to comply with the requirements of the Rules.

4.2.4 The Surveyor is to be satisfied that the capability, organisation and facilities of the Builder are such that acceptable standards can be obtained both for the construction of the craft and the installation of machinery, electrical and control equipment.

4.2.5 In addition to 4.2.4, the hull construction of craft manufactured from composite materials is to be controlled by a documented quality control system covering the Builder's management, organisation and relevant construction processes and inspection procedures, *see* Pt 8, Ch 2.

4.2.6 New craft intended for classification are to be built under LR's Special Survey. The Surveyors are to be satisfied that the materials, workmanship and arrangements are in accordance with the Rules. Any items found not to be in accordance with the Rules or the approved plans, or any material, workmanship or arrangements found to be so, are to be rectified.

4.2.7 For compliance with 4.2.6 LR is prepared to consider methods of survey and inspection for hull construction which formally include procedures involving the shipyard management, organisation and quality systems as defined in Chapter 2 of Parts 6, 7 and 8 for steel, aluminium alloy and composite construction respectively.

4.2.8 Copies of approved plans (showing the craft as built), essential certificates and records, required loading and other instruction manuals are to be readily available for use when required by LR's Surveyors and may be required to be kept on board.

4.2.9 After completion, the craft is to be examined afloat, and trials are to be conducted as specified in the Rules.

4.2.10 When the machinery is constructed under LR's Special Survey, this survey is to relate to the period from the commencement of the work until the final test under working conditions. Any items found not to be in accordance with the Rules or the approved plans, or any material, workmanship or arrangements found to be unsatisfactory, are to be rectified.

4.2.11 When arrangements are such that essential machinery can be operated by remote and/or automatic control equipment, the control equipment is to be arranged, installed and tested in accordance with the Rules, as applicable.

4.2.12 The date of completion of the Special Survey during construction of craft built under LR's inspection will normally be taken as the date of build to be entered in the appropriate *Register Book*. If the period between launching and commissioning is, for any reason, unduly prolonged, the dates of launching and completion or commissioning may be separately indicated in the appropriate *Register Book*.

4.2.13 When a craft, upon completion, is not immediately commissioned but is laid-up for a period, the Committee, upon application by the Owner, prior to the craft proceeding to sea, will direct an examination to be made by LR's Surveyors which may include a survey in dry-dock. If, as the result of such survey, the hull and machinery be reported in all respects free from deterioration, the subsequent Special Survey and Complete Survey of the machinery will date from the time of such examination.

4.3 Existing craft

4.3.1 **Classification of craft not built under survey.** The requirements of the Committee for the classification of craft which have not been built under LR's Survey are indicated in Ch 3,12 or Ch 4,12 as applicable. Special consideration will be given to craft transferring class to LR from another recognised Classification Society.

4.3.2 **Reclassification.** When reclassification or class reinstatement is desired for a craft for which the class previously assigned by LR has been withdrawn or suspended, the Committee will direct that a survey, appropriate to the age of the craft and the circumstances of the case, be carried out by LR's Surveyors. If, at such survey, the craft be found or placed in a good and efficient condition in accordance with the requirements of the Rules, the Committee will be prepared to consider reinstatement of the original class or the assignment of such other class as may be deemed necessary.

4.3.3 In the case of existing yachts over 15 years of age, the requirements for classification of craft not built under survey or for reclassification will be specially considered.

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4.3.4 The Committee reserves the right to decline an application for classification or reclassification where the prior history or condition of the craft indicates this to be appropriate.

4.4 Damages, repairs and alterations

4.4.1 All repairs to hull, equipment and machinery which may be required in order that a craft may retain her class, *see* 1.1.7, are to be carried out to the satisfaction of LR's Surveyors. When repairs are effected at a port, terminal or location where the services of a Surveyor to LR are not available, the repairs are to be surveyed by one of LR's Surveyors at the earliest opportunity thereafter.

4.4.2 When at any survey the Surveyors consider repairs to be immediately necessary, either as a result of damage, or wear and tear, they are to communicate their recommendations at once to the Owner, or his representative. When such recommendations are not complied with, immediate notification is to be given to the Committee by the Surveyors.

4.4.3 Where repairs are to be carried out by a riding crew during a voyage then these must be planned in advance. A complete repair procedure, including the extent of proposed repair and the need for Surveyor's attendance during the voyage, is to be submitted reasonably in advance to the Surveyor for agreement. Failure to notify LR in advance of the repairs may result in the class of the ship being specially considered by the Classification Committee. Where emergency repairs are effected immediately due to an emergency circumstance, the repairs should be documented in the ship's log and submitted thereafter to LR for use in determining further survey requirements.

4.4.4 When at any survey it is found that any damage, defect, or breakdown (*see* 1.1.7) is of such a nature that it does not require immediate permanent repair, but is sufficiently serious to require rectification by a prescribed date in order to maintain class, a suitable condition of class is to be imposed by the Surveyors and recommended to the Committee for consideration.

4.4.5 If a craft which is classed with LR is to leave harbour limits or protected waters under tow, the Owner is to advise LR of the circumstances prior to her departure.

4.4.6 If a craft which is classed with LR is taken in tow whilst at sea, the Owner is to advise LR of the circumstances at the first practicable opportunity.

4.4.7 Plans and particulars of any proposed alterations to the approved scantlings and arrangements of hull, equipment, or machinery are to be submitted for approval by Owners or Builders or their representatives and such alterations are to be carried out to the satisfaction of LR's Surveyors.

4.4.8 The Owners should notify LR whenever a craft can be examined in dry-dock or on a slipway.

4.5 Existing service craft and yachts – Periodical Surveys

4.5.1 Service craft are to be submitted to the periodical survey requirements as defined in Chapter 3.

4.5.2 Yachts are to be submitted to the periodical survey requirements defined in Chapter 4, except in the case where LR issues Statutory Loadline SAFCON certification or Certificate of Compliance to 'Code of Practice' as a requirement of the National Authority of the country in which the yacht is registered. In these cases they are to be submitted to the periodical survey requirements as defined in Chapter 3.

4.5.3 Annual Surveys are to be held on all craft other than yachts within three months, before or after each anniversary of the completion, commissioning or Special Survey. The date of the last Annual Survey will be recorded on the ClassDirect Live website.

4.5.4 Intermediate Surveys are to be held on all craft other than yachts instead of the second or third Annual Survey after completion, commissioning or Special Survey. The date of the last Intermediate Survey will be recorded on the ClassDirect Live website.

4.5.5 Intermediate Surveys are to be held on yachts between the second and third anniversary after completion, commissioning or Special Survey.

4.5.6 The Owner should notify the Surveyors whenever a craft can be examined in dry-dock or on a slipway. A minimum of two Docking Surveys are to be held in each five-year Special Survey period and the maximum interval between successive Docking Surveys is not to exceed three years. One of the two Docking Surveys required in each five year period is to coincide with the Special Survey. Consideration may be given at the discretion of the Committee to any special circumstances justifying an extension of this interval and the Committee may accept an In-water Survey in lieu of the intermediate docking between Special Surveys, *see* Ch 3,4.3 and Ch 4,3.3. A Docking Survey is considered to coincide with the Special Survey when held within the 15 months prior to the due date of the Special Survey.

4.5.7 The interval between dry-dockings for craft operating in fresh water and for certain non self-propelled craft may at the discretion of the Committee, be greater than that given in 4.5.6.

4.5.8 Attention is to be given to any relevant statutory requirements of the National Authority of the country in which the craft is registered.

4.5.9 The date of the last examination in dry-dock or on a slipway will be recorded on the ClassDirect Live website.

4.5.10 Survey requirements for In-water Surveys are given in Ch 3,4.3 and Ch 4,3.3 as appropriate. The date of the last In-water Survey will be recorded on the ClassDirect Live website.

4.5.11 All craft classed with LR are also to be subjected to Special Surveys. These Surveys become due at five-yearly

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intervals, the first one five years from the date of build or date of Special Survey for Classification as recorded in the appropriate *Register Book*, and thereafter five years from the date recorded for the previous Special Survey. Consideration can be given at the discretion of the Committee to any exceptional circumstances justifying an extension of the hull classification to a maximum of three months beyond the fifth year. If an extension is agreed the next period of hull classification will start from the due date of the Special Survey before the extension was granted.

4.5.12 Special surveys may be commenced at the fourth Annual Survey or fourth anniversary, as appropriate, after completion, commissioning, or previous Special Survey, and be progressed during the succeeding year with a view to completion by the due date of the Special Survey.

4.5.13 Special Surveys which are commenced prior to their due date are not to extend over a period greater than 15 months, except with the prior approval of the Committee.

4.5.14 Craft which have satisfactorily passed a Special Survey will have a record entered indicating the date. Where the Special Survey is completed more than three months before the due date, the new record of Special Survey will be the final date of survey. In all other cases the date recorded will be the fifth anniversary. In the case of yachts this information will be recorded on the ClassDirect Live website.

4.5.15 At the request of an Owner, the Committee may agree that the Special Survey of the hull be carried out on the Continuous Survey basis, all compartments of the hull being opened for survey and testing, in rotation, with an interval of five years between consecutive examinations of each part. In general, approximately one fifth of the Special Survey is to be completed each year and all the requirements of the particular hull Special Survey must be completed at the end of the five year cycle. If the examination during Continuous Survey reveals any defects, further parts are to be opened up and examined as considered necessary by the Surveyor. For examination of items listed in Ch 3,2.2.17, 2.2.18, 3.2.2, 3.2.3, 3.2.4 or Ch 4,2.2.11, 2.2.12, 2.2.13 as applicable, the intervals for inspection will require to be specially agreed. Craft which have satisfactorily completed the cycle will have a record entered in the *Register Book* indicating the date of completion which will not be later than five years from the last assigned date of Complete Survey of the hull. The agreement for surveys to be carried out on Continuous Survey basis may be withdrawn at the discretion of the Committee.

4.5.16 Complete Surveys of machinery become due at five yearly intervals, the first one five years from the date of build or date of first classification as recorded in the appropriate *Register Book*, and thereafter five years from the date recorded for the previous Complete Survey. Consideration can be given at the discretion of the Committee to any exceptional circumstances justifying an extension of machinery class to a maximum of three months beyond the fifth year. If an extension is agreed to, the next period of machinery class will start from the due date of Complete Survey of machinery before extension was granted. Surveys which are commenced prior to their due date are not to extend over a period greater than 15 months, except with the prior approval of the Committee. Where the complete survey is completed more than three months before the due date, the recorded date of completion will be the final date of survey. In all other cases the date recorded will be the fifth anniversary.

4.5.17 Upon application by an Owner, the Committee may agree to the extension of the survey requirements for main engines, which, by the nature of the craft's normal service, do not attain the number of running hours recommended by the engines' manufacturer for major overhauls within the survey periods given in 4.5.16.

4.5.18 If it is found desirable that any part of the machinery should be examined again before the due date of the next survey, a certificate for a limited period will be granted in accordance with the nature of the case.

4.5.19 When, at the request of an Owner, it has been agreed by the Committee that the Complete Survey of the machinery may be carried out on the Continuous Survey basis, the various items of machinery are to be opened for survey in rotation, so far as is practicable, to ensure that the interval between consecutive examinations of each item will not exceed five years. In general, approximately one-fifth of the machinery is to be examined each year.

4.5.20 If any examination during Continuous Survey reveals defects, further parts are to be opened up and examined as considered necessary by the Surveyor, and the defects are to be made good to his satisfaction.

4.5.21 Upon application by an Owner, The Committee may agree to an arrangement whereby, subject to certain conditions, some items of machinery may be examined by the Chief Engineer of the craft at ports where LR is not represented, or, where practicable, at sea, followed by a limited confirmatory survey carried out at the next port of call where an Exclusive Surveyor is available. Particulars of this arrangement may be obtained from LR's Headquarters.

4.5.22 Where an approved planned maintenance scheme is in operation the confirmatory surveys of machinery as required by 4.5.21 may be held at annual intervals, at which time the records will be checked and the operation of the scheme verified. Particulars of this arrangement may be obtained from any of LR's Offices.

4.5.23 Where condition monitoring equipment is fitted, the Committee, upon application by the Owner, will be prepared to amend applicable Periodical Survey requirements where details of the equipment are submitted and found satisfactory. Where machinery installations are accepted for this method of survey, it will be a requirement that an Annual Survey be held, at which time monitored records will be analysed and the machinery examined under working conditions. An acceptable lubricating oil trend analysis programme may be required as part of the condition monitoring procedures.

4.5.24 Screwshaft and Waterjet Unit Surveys are to be carried out as stated in Ch 3,11 for service craft and Ch 4,10 for yachts.

4.5.25 Boiler surveys and steam pipe surveys, where applicable are to be carried out as stated in accordance with Pt 1, Ch 3,15 and 16 of the Rules for Ships.

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4.5.26 Craft of unusual design, type or arrangement may be subject to exceptional survey requirements. Such survey requirements will be detailed at the assignment of classification.

4.5.27 Where the Committee has agreed to an Owner's request to assign the notation 'laid-up', the vessel may be retained in class provided a satisfactory general examination of the hull and machinery is carried out at the Annual Survey/Intermediate Survey due date and in addition an Underwater Examination (UWE) is carried out at the Special Survey due date. The general examination may be carried out within three months before or after the Annual Survey due date.

4.6 Existing amphibious air cushion vehicles – Periodical Surveys

4.6.1 Amphibious Air Cushion Vehicles are to be submitted to the periodical survey requirements as defined in Chapter 5.

4.7 Certificates

4.7.1 When the required reports, on completion of the survey of new or existing craft which have been submitted for classification, have been received from the Surveyors and approved by the Committee, a certificate of First Entry of Classification, signed by the Chairman, or the Deputy Chairman and Chairman of the Sub-Committee of Classification, will be issued to Builders or Owners.

4.7.2 A Certificate of Class valid for five years subject to endorsement for Annual and/or Intermediate Surveys, as appropriate, will also be issued to the Owners.

4.7.3 LR's Surveyors are permitted to issue provisional (interim) certificates to enable a craft classed with LR to proceed on her voyage provided that in their opinion it is in a fit and efficient condition. Such certificates will embody the Surveyors' recommendations for continuance of class, but in all cases are subject to confirmation by the Committee.

4.8 Notice of surveys

4.8.1 It is the responsibility of the Owners to ensure that all surveys necessary for the maintenance of class are carried out at the proper time and in accordance with the instructions of the Committee. Information is available to Owners on the ClassDirect Live website.

4.8.2 LR will give timely notice to an Owner about forthcoming surveys by means of a letter or a computer print-out of a craft's *Quarterly Listing of Surveys, Conditions of Class and Memoranda*. The omission of such notice, however, does not absolve the Owner from his responsibility to comply with LR's survey requirements for maintenance of class, all of which are available to Owners on the ClassDirect Live website.

4.9 Withdrawal/Suspension of class

4.9.1 When the class of a craft, for which the Regulation as regards surveys on hull, equipment and machinery have been complied with, is withdrawn by the Committee in consequence of a request from the Owner the notation 'Class withdrawn at Owner's request' (with date) will be assigned.

4.9.2 When the Regulations as regards surveys on the hull, equipment or machinery have not been complied with and the craft is thereby not entitled to retain class, the class will be suspended or withdrawn, at the discretion of the Committee, and a corresponding notation will be assigned.

4.9.3 Class will be automatically suspended and the Certificate of Class will become invalid if the Annual or Intermediate Survey, as appropriate, is not completed within three months of the due date of the survey.

4.9.4 Class will be automatically suspended from the expiry date of the Certificate of Class in the event that the Special Survey has not been completed by the due date and an extension has not been agreed (*see* 4.5.11), or is not under attendance by the Surveyors with a view to completion prior to resuming trading.

4.9.5 When in accordance with 4.4.4 a condition of class is imposed, this will be assigned a due date for completion and the craft's class will be subject to a suspension procedure if the condition of class is not dealt with, or postponed by agreement, by the due date.

4.9.6 When it is found, from the reported condition of the hull or equipment or machinery of a craft, that an Owner has failed to comply with Regulations 1.1.7, 1.1.11, 4.4.1 or 4.4.6 above, the class will be liable to be suspended or withdrawn, at the discretion of the Committee, and a corresponding notation assigned. When it is considered that an Owner's failure to comply with these requirements is sufficiently serious the suspension or withdrawal of class may be extended to include other craft controlled by the same Owner, at the discretion of the Committee.

4.9.7 When any craft proceeds to sea with less freeboard than that approved by the Committee, or when the freeboard marks are placed higher on the sides of the craft than the position assigned or approved by the Committee, or, in cases of craft where freeboards are not assigned, the draught is greater than that approved by the Committee, the class will be liable to be withdrawn or suspended.

4.9.8 When it is found that a craft is being operated in a manner contrary to that agreed at the time of classification, i.e. out with the parameters of the operational envelope, the class will be liable to be automatically withdrawn or suspended.

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4.9.9 In all instances of class withdrawal or suspension, the assigned notation, with date of application, will appear in the *Register Book*. In cases where class has been suspended by the Committee and it becomes apparent that the Owners are no longer interested in retaining LR's class, the notation will be amended to withdrawn status. After class withdrawn status has been established in the appropriate *Register Book* for one year, it will be automatically amended to 'classed LR until' (with date). In the case of yachts this information will be recorded on the ClassDirect Live website.

4.9.10 For reclassification and reinstatement of class, *see* 4.3.2 and 4.3.3.

4.10 Survey of craft out of commission

4.10.1 The classification requirements for laid up vessels will be specially considered. Surveys for continuation of class may be required at the discretion of the Committee.

4.11 Appeal from Surveyors' recommendations

4.11.1 If the recommendations of LR's Surveyors are considered in any case to be unnecessary or unreasonable, appeal may be made to the Committee, who may direct a Special Examination to be held.

■ *Section 5* IACS QSCS Audits

5.1 Audit of Surveys

5.1.1 The surveys required by the Regulations may be subject to audit in accordance with the requirements of the International Association of Classification Societies Quality System Certification Scheme.

■ *Section 6* Type Approval/Type testing/ Quality control system

6.1 LR Type Approval – Marine Applications

6.1.1 LR Type Approval is an impartial certification system that provides independent third-party Type Approval Certificates attesting to a product's conformity with specific standards or specifications. It is based on design review and type testing or where testing is not appropriate, a design analysis.

6.1.2 The LR Type Approval System is a process whereby a product is assessed in accordance with a specification, standard or code to check that it meets the stated requirements and through selective testing demonstrates compliance with specific performance requirements. The testing is carried out on a prototype or randomly selected product(s) which are representative of the manufactured product under approval. Thereafter, the producer is required to use Quality Control procedures and processes to ensure that each item delivered is in conformity with that which has been Type Tested.

6.1.3 The selective testing required by 6.1.2 is to include environmental testing applicable to the product's installation on board a craft or yacht classed or intended to be classed with LR.

6.1.4 LR Type Approval does not remove the requirements for inspection and survey procedures required by the Rules for equipment to be installed in craft/yachts classed or intended to be classed with LR. Also, LR Type Approval does not remove the requirement for plan appraisal of a system that incorporates Type Approved equipment where required by the Rules.

6.1.5 LR Type Approval is subject to the understanding that the producer's recommendations and instructions for the product and any relevant requirements of the Rules for the Classification of Special Service Craft are fulfilled.

6.1.6 The producer supplying equipment or components under Quality Control procedures and processes is to have a recognised quality management system certified by an IACS member or Notified Body. The Quality Control procedures and processes are to address the production of the product consistent with 6.3.

6.1.7 Where equipment or components have been Type Approved in accordance with specifications and procedures other than LR's, details of the product, certification and testing are to be submitted for consideration where appropriate.

6.2 Type testing

6.2.1 Type testing is an impartial process that provides independent third-party verification that an item of machinery or equipment has satisfactorily undergone a functional type test.

6.2.2 Type testing is carried out against defined performance and test standards for a defined period of time with test conditions varying between minimum and maximum declared design conditions.

6.2.3 Type testing is carried out on a prototype or randomly selected product(s) which are representative of the manufactured product under assessment.

6.2.4 After type testing, mechanical equipment is to be opened out and inspected for damage or excessive wear.

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6.2.5 On application from the manufacturer, type tests may be waived for equipment and machinery that has been proven to be reliable in marine service and where compliance with the current applicable standards can be demonstrated. Equipment and machinery that has been previously type tested with satisfactory testing evidence and certification need not have the type tests repeated where previous testing is in compliance with the current testing standards.

6.2.6 The acceptance of type testing certification is subject to the understanding that the manufacturer's recommendations and instructions for the product and any relevant requirements of the applicable Rules are fulfilled.

6.3 Quality control system

6.3.1 A quality control system for the purposes of LR acceptance of materials and machinery refers to a scheme that covers the operational techniques and activities that is used to demonstrate that the quality requirements for a product are in accordance with declared standards.

6.3.2 The quality control system for a particular product extends to all parties involved in the supply chain from manufacture and testing through to delivery of the product.

6.3.3 LR acceptance of machinery and equipment manufactured under a quality control scheme is dependent on the scheme being maintained through a traceable process involving planned audits and spot inspections at the discretion of LR Surveyors. The purpose of the audits and spot inspections is to ensure that the procedures for manufacture and quality control are being maintained in a satisfactory manner.

6.3.4 The use of a quality control system does not remove the requirements for inspection processes that may be required by the Rules applicable to the equipment being supplied with a manufacturer's certificate. Also the use of a quality control system does not remove the requirement for plan appraisal of equipment or systems where required by the Rules.

■ *Section 7* Classification of machinery for craft/yachts with [✠]LMC or MCH notation

7.1 General

7.1.1 After delivery of machinery and equipment with the manufacturer's certificate to the build yard, Survey at the build yard and Periodical Surveys are to be in accordance with the requirements for craft/yacht built or accepted into class with the ✠**LMC** notation.

7.2 Appraisal and records

7.2.1 To facilitate survey and compilation of classification records, plans and information required for a craft/yacht being accepted into class with the ✠**LMC** notation are to be submitted for appraisal and information. Plans are not required where machinery and equipment has previously been type approved; in these cases it is only necessary to submit details of the machinery and equipment together with details of the previous approval.

7.3 Survey and inspection

7.3.1 The manufacturer's certificate for acceptance of machinery and equipment for assignment of the **[✠]LMC** or **MCH** notation is to be in the English language and include the following information:

(a) Design and manufacturing standard(s) used.
(b) Materials used for construction of key components and their sources.
(c) Details of the quality control system applied during design, manufacture and testing and any software maintenance.
(d) Details of any type approval or type testing.
(e) Details of installation and testing recommendations for the machinery or equipment.

The manufacturer is to have a recognised quality management system certified by an IACS member or a Notified Body.

7.3.2 The installation and testing of machinery and equipment at the build yard which has been supplied with a manufacturer's certificate is to be in accordance with the requirements applicable to a craft/yacht having the ✠**LMC** notation.

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Section

1 **General**

2 **Annual Surveys – Hull and machinery requirements**

3 **Intermediate Surveys – Hull and machinery requirements**

4 **Docking Surveys and In-water Surveys – Hull and machinery requirements**

5 **Special Survey – General – Hull requirements**

6 **Special Survey – Thickness measurement requirements for steel craft**

7 **Machinery surveys – General requirements**

8 **Gas turbines – Detailed requirements**

9 **Oil engines – Detailed requirements**

10 **Electrical equipment**

11 **Screwshafts, tube shafts, propellers and water jet units**

12 **Classification of craft not built under survey**

■ *Section 1* General

1.1 Frequency of surveys

1.1.1 The requirements of this Chapter are applicable to the Periodical Surveys set out in Ch 2,4.5. Except as amended at the discretion of the Committee, the periods between such surveys are as follows:

(a) Annual Surveys, as required by Ch 2,4.5.3.
(b) Intermediate Surveys as required by Ch 2,4.5.4.
(c) Docking Surveys as required by Ch 2,4.5.6 and 4.5.7.
(d) Special Surveys at five-yearly intervals, *see* Ch 2,4.5.11. For alternative arrangements, *see also* Ch 2,4.5.12, 4.5.13 and 4.5.15.
(e) Complete Surveys of machinery at five-yearly intervals, *see* Ch 2,4.5.16. For alternative arrangements, *see also* Ch 2,4.5.17, 4.5.19, 4.5.21, 4.5.22 and 4.5.23.

1.1.2 For vessels assigned the notation 'laid-up', in order to maintain the vessel in class a general examination of the hull and machinery is to be carried out in lieu of the Annual Survey/Intermediate Survey and in addition an Underwater Examination (UWE) is to be carried out in lieu of the Special Survey, *see* 2.1.3, 5.1.4 and 7.1.3.

1.1.3 When it has been agreed that the complete survey of the hull and machinery may be carried out on the Continuous Survey basis, all compartments of the hull and all items of machinery are to opened for survey in rotation to ensure that the interval between consecutive examinations of each part will not exceed five years, *see* Ch 2,4.5.15 and 4.5.19.

1.1.4 For the frequency of surveys of screwshafts, tube shafts propellers and water jet units, *see* Section 11.

1.2 Surveys for damage or alterations

1.2.1 At any time when a craft is undergoing alterations or damage repairs, any exposed parts of the structure normally difficult to access are to be specially examined, e.g. if any part of the main or auxiliary machinery is removed for any reason, the hull structure in way is to be carefully examined by the Surveyor, or when cement in the bottom or sheathing on decks is removed, the structure in way is to be examined before the cement or sheathing is relaid.

1.3 Unscheduled surveys

1.3.1 In the event that Lloyd's Register (hereinafter referred to 'LR') has cause to believe that its Rules and Regulations are not being complied with, LR reserves the right to perform unscheduled surveys of the hull or machinery.

1.3.2 In the event of significant damage or defect affecting any craft, LR reserves the right to perform unscheduled surveys of the hull or machinery of other similar craft classed by LR and deemed to be vulnerable.

1.4 Surveys for the issue of Convention certificates

1.4.1 Surveys are to be held by LR when so appointed, or by the Exclusive Surveyors to a National Administration or by an IACS Member when so authorised by the National Authority, or, in the case of Cargo Ship Safety Radio Certificates or Safety Management Certificates, by any organisation authorised by the National Authority. In the case of dual classed craft, Convention Certificates may be issued by the other Society with which the craft is classed provided this is recognised in a formal Dual Class Agreement with LR and provided the other Society is also authorised by the National Authority.

1.5 Definitions

1.5.1 **A Ballast tank** is a tank which is used solely for salt water ballast. A tank which is used for both cargo and salt water ballast will be treated as a salt water ballast tank when substantial corrosion has been found in that tank.

1.5.2 **Spaces** are separate hull compartments including integral tanks.

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1.5.3 **Suspect areas** are locations within the hull structure vulnerable to increased likelihood of structural deterioration and may include:

(a) For steel hulls, areas of substantial corrosion and/or fatigue cracking.
(b) For aluminium alloy hulls, areas of fatigue cracking and areas in the vicinity of bimetallic connections.
(c) For composite hulls, areas subject to impact damage.
(d) For high speed craft (as defined in Ch 2,2.2.7), areas of the bottom structure forward prone to slamming damage.

1.5.4 **Substantial corrosion** is wastage of individual steel or aluminium plates and stiffeners in excess of 75 per cent of allowable margins, but within acceptable limits.

1.5.5 **Protective coatings** for steel craft should usually be hard coatings. Other coating systems (e.g. soft coating) may be considered acceptable as alternatives provided they are applied and properly maintained in compliance with the manufacturer's specification.

1.5.6 **Coating condition** for steel craft is defined as follows:

GOOD condition with only minor spot rusting affecting not more than 20 per cent of areas under consideration.

■ *Section 2*
Annual Surveys – Hull and machinery requirements

2.1 General

2.1.1 Annual Surveys are to be held concurrently with any relevant statutory annual or other statutory surveys, wherever practicable.

2.1.2 At Annual Surveys, the Surveyor is to examine the hull and machinery, so far as necessary and practicable, in order to be satisfied as to their general condition.

2.1.3 For vessels assigned the notation 'laid-up', in lieu of the normal Annual Survey requirements a general examination of the hull and machinery is to be carried out.

2.2 Annual Surveys

2.2.1 The Surveyor is to be satisfied regarding:

(a) The efficient condition of hatchways on freeboard and superstructure decks, weather deck plating, ventilator coamings and air pipes, exposed casings, skylights, flush deck scuttles, deckhouses and companionways, superstructure bulkheads, side, bow and stern doors, windows and storm shutters, side scuttles and deadlights, chutes and other openings, together with all closing appliances and flame screens.
(b) The efficient operating condition of mechanically operated hatch covers including stowage, fit, securing, locking, sealing and operational testing of hydraulic power components, wires, chains, etc.
(c) The efficient condition of scuppers and sanitary discharges (so far as is practicable); valves on discharge lines (so far as is practicable) and their controls; guard rails and bulwarks; freeing ports, gangways and life-lines; fittings and appliances for timber deck cargoes.
(d) The efficient condition of bilge level detection and alarm systems on craft assigned a **UMS** notation.

2.2.2 Any cargo hatch covers and coamings together with any cargo doors or ramps which form part of the watertight integrity of the hull are to be examined to ensure that no alterations have been made to the approved arrangements.

(a) Mechanically operated cargo hatch covers or doors are to be tested for tightness and to confirm the satisfactory condition of securing and sealing arrangements; drainage channels; operating mechanisms; tracks and wheels.
(b) Cargo hatch covers of the portable type are to be examined to confirm that the covers and closing appliances are in a satisfactory condition.

2.2.3 The anchoring and mooring equipment including anchor warps or wire ropes is to be examined so far as is practicable.

2.2.4 The watertight doors in watertight bulkheads, their indicators and alarms are to be examined and operationally tested locally and where applicable remotely. Other watertight bulkhead penetrations, are to be examined so far as is practicable.

2.2.5 The Surveyor is to examine and test in operation all main and auxiliary steering arrangements including their associated equipment and control systems, and verify that log book entries have been made in accordance with statutory requirements where applicable.

2.2.6 Where applicable, the Surveyor is to be satisfied regarding the freeboard marks on the craft's side.

2.2.7 The Surveyor is to generally inspect the machinery spaces with particular attention being given to the propulsion system, auxiliary machinery and to the existence of any fire and explosion hazards. Where applicable, emergency escape routes are to be checked to ensure that they are free of obstruction.

2.2.8 The means of communication between the navigating bridge and the machinery control positions, as well as the bridge and the alternative steering position, if fitted, are to be tested.

2.2.9 The bilge pumping systems and bilge wells, including operation of extended spindles, self closing drain cocks and level alarms, where fitted, are to be examined so far as is practicable. Satisfactory operation of the bilge pumps, including any hand pumps, is to be proven.

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2.2.10 The boilers, other pressure vessels and their appurtenances, including foundations, controls, high pressure and waste steam piping, and insulation and gauges, are to be generally examined. Surveyors should confirm that Periodical Surveys of boilers and other pressure vessels have been carried out as required by the Rules.

2.2.11 For boilers, the safety devices are to be tested, and the safety valves are to be operated using the relieving devices. For exhaust gas heated economisers/boilers, the safety valves are to be tested at sea by the Chief Engineer and details recorded in the log book.

2.2.12 The operation and maintenance records, repair history and feed water chemistry records of boilers are to be examined.

2.2.13 For other pressure vessels, the safety devices are to be examined.

2.2.14 The electrical equipment and cabling forming the main and emergency electrical installations are to be generally examined under operating conditions so far as is practicable. The satisfactory operation of the main and emergency sources of power and electrical services essential for safety in an emergency is to be verified; where the sources of power are automatically controlled they should be tested in the automatic mode. Bonding straps for the control of static electricity and earthing arrangements are to be examined where fitted.

2.2.15 For main propulsion, essential auxiliary and emergency machinery control engineering systems, a general examination of the equipment and arrangements is to be carried out. Records of modifications are to be made available for review by the attending Surveyor. The documentation required by Pt 6, Ch 1, including configuration management, are to be reviewed following system modifications. Satisfactory operation of the safety devices and control systems is to be verified. For craft having **UMS** or **CCS** notation, a general examination of the control engineering equipment required for these notations is also to be carried out.

2.2.16 For craft fitted with an electronically controlled engine for main propulsion, essential auxiliary or emergency power purposes, the following is to be carried out to the satisfaction of the Surveyor:

(a) Verification of evidence of satisfactory operation of the engine and, where possible, this is to include a running test under load;
(b) Verification of satisfactory operation of the safety devices and control, alarm and monitoring systems; and
(c) Verification that any changes to the software or control, alarm, monitoring and safety systems that affect the operation of the engine have been assessed by LR and are under configuration management control.

2.2.17 For craft to which Pt 17, Ch 1 applies, the arrangements for fire protection, detection and extinction are to be examined and are to include the following items, as required to be fitted in accordance with the Rules:

(a) Verification, so far as is practicable, that no significant changes have been made to the arrangement of structural fire protection.
(b) Verification of the operation of manual and/or automatic doors where fitted.
(c) Verification that fire control plans are properly posted;
(d) Examination, so far as is possible, and testing as feasible, of the fire and/or smoke detection and alarm system(s).
(e) Examination of fire main system, and confirmation that each fire pump, including the emergency fire pump can be operated separately so that the required jets of water can be produced simultaneously from different hydrants.
(f) Verification that fire-hoses, nozzles, applicators and spanners are in good working condition and situated at their respective locations.
(g) Examination of fixed fire-fighting systems controls, piping, instructions and marking, checking for evidence of proper maintenance and servicing, including date of last systems tests.
(h) Verification that all portable and semi-portable fire-extinguishers are in their stowed positions, checking for evidence of proper maintenance and servicing, conducting random checks for evidence of discharged containers.
(j) Verification, so far as is practicable, that the remote control for stopping fans and machinery and shutting off fuel supplies in machinery spaces and, where fitted, the remote controls for stopping fans in accommodation spaces and the means of cutting off power to the galley are in good working order.
(k) Examination of the closing arrangements of ventilators, skylights and doorways where applicable.
(l) Verification that the fireman's outfits are complete and in good condition.
(m) Verification that gas installations for domestic purposes comply with the relevant statutory requirements.

2.2.18 For steel craft, the requirements of 3.2.2 and 5.4.2 regarding the survey of water ballast spaces, integral sanitary tanks and bilges are also to be complied with as applicable.

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Section 3
Intermediate Surveys – Hull and machinery requirements

3.1 General

3.1.1 Intermediate Surveys are to be held concurrently with statutory annual or other relevant statutory surveys wherever practicable.

3.2 Intermediate Surveys

3.2.1 The requirements of Section 2 are to be complied with so far as applicable.

3.2.2 For steel craft a general examination of salt water ballast tanks, integral sanitary tanks and bilges is to be carried out as required below. If such inspections reveal no visible structural defects then the examination may be limited to a verification that the protective coating remains in GOOD condition as defined in 1.5.6. When considered necessary by the Surveyor thickness measurement of the structure is to be carried out. Where the protective coating is found to be other than in GOOD condition, and it has not been repaired, maintenance of class will be subject to the spaces in question being internally examined and gauged as necessary at Annual Surveys.

(a) For all craft over five years of age and up to 10 years of age, representative salt water ballast tanks, integral sanitary tanks and bilges are to be generally examined. Where the protective coating is found to be other than in GOOD condition, as defined in 1.5.6, or other defects are found, the examination is to be extended to other spaces of the same type.

(b) For steel craft over 10 years of age all salt water ballast tanks, integral sanitary tanks and bilges are to be generally examined.

3.2.3 For all craft over 10 years of age the anchors are to be partially lowered and raised using the windlass.

3.2.4 The electrical generating sets are to be examined under working conditions.

3.2.5 Representative internal spaces including fore and aft peak spaces, machinery spaces, bilges, etc., are to be generally examined. These spaces should include all suspect areas, *see* 1.5.3.

Section 4
Docking Surveys and In-water Surveys – Hull and machinery requirements

4.1 General

4.1.1 At Docking Surveys or In-water Surveys the Surveyor is to examine the craft and machinery, so far as necessary and practicable, in order to be satisfied as to the general condition.

4.2 Docking Surveys

4.2.1 Where a craft is in dry-dock or on a slipway it is to be placed on blocks of sufficient height and proper staging is to be erected as may be necessary, for the examination of the outside of the hull, rudder(s) and underwater fittings. The outside surface of the hull is to be cleaned as may be required by the Surveyor.

4.2.2 Attention is to be given to parts of the external hull structure particularly liable to structural deterioration from causes such as high stresses, chafing and lying on the ground, and to areas of structural discontinuity.

4.2.3 The following parts of the external hull structure are to be specially examined:

(a) For steel hulls attention is to be given to parts of the structure particularly liable to excessive corrosion and to any undue unfairness of the plating of the bottom. The coating system is to be examined and made good as necessary.

(b) For aluminium alloy hulls attention is to be given to areas adjacent to any bimetallic connections at skin fittings, etc.

(c) For composite hulls the gelcoat or other protective finish is to be examined for surface cracking, blistering or other damage which may impair the efficiency of the protection to the underlying laminate.

4.2.4 Where required by the Rules, the satisfactory condition of the cathodic protection is to be confirmed.

4.2.5 The clearances in the rudder bearings and pintles are to be measured. Where considered necessary by the Surveyor rudders are to be lifted for examination of the stock. The securing of rudder couplings and/or pintle fastenings is to be confirmed.

4.2.6 The sea connections and overboard discharge valves, their attachments to the hull and the gratings at the sea inlets are to be examined.

4.2.7 The propeller and fastenings are to be examined. The sternbush is to be examined as far as is practicable.

4.2.8 The clearance in the sternbush or the efficiency of the oil glands is to be ascertained. The clearance of any shaft bracket bearings is to be ascertained.

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4.2.9 The inboard shaft seals or glands are to be examined. Where flexible sternglands are fitted, the satisfactory condition of the rubber hose and securing clips is to be confirmed.

4.2.10 Special attention is to be given to the hull in way of underwater fittings such as transverse thrusters, stabilisers, etc.

4.2.11 Where applicable, attention is to be given to the connection and/or intersection of the cross-deck structure to the hulls of multi hull craft.

4.2.12 Where water jet units are fitted, the impeller, hull ducting, grating, nozzle steering and reversing arrangements are to be examined as far as is practicable.

4.2.13 Where transom mounted propulsion units are fitted, the steering arrangements and any flexible transom seals are to be examined.

4.2.14 When chain cables are ranged, the anchors and cables are to be examined by the Surveyor, *see also* 5.3.7 and Table 3.5.1.

4.2.15 For SES craft any flexible skirts together with their attachment are to be examined.

4.2.16 For hydrofoil or foil assisted craft the attachment of foils is to be examined.

4.3 In-water Surveys

4.3.1 The Committee will accept an In-water Survey in lieu of the intermediate docking between Special Surveys required in a five year period on craft where an ***IWS** notation is assigned, *see* Ch 2,3.8.2.

4.3.2 The Committee may accept an In-water Survey in lieu of the intermediate docking between Special Surveys required in a five year period on craft where suitable protection is applied to the underwater portion of the hull. If requested, an ***IWS** class notation may be assigned on satisfactory completion of the survey, provided that the applicable requirements of the Rules are complied with, *see also* Ch 2,3.8.2.

4.3.3 The In-water Survey is to provide the information normally obtained from the Docking Survey, so far as is practicable.

4.3.4 Proposals for In-water Surveys are to be submitted in advance of the survey being required so that satisfactory arrangements can be agreed with LR.

4.3.5 The In-water Survey is to be carried out at agreed geographical locations under the surveillance of a Surveyor to LR, with the craft in sheltered waters; the in-water visibility and the cleanliness of the hull below the waterline is to be clear enough to permit a meaningful examination which allows the Surveyor and diver to determine the condition of the plating, appendages and the welding. The Surveyor is to be satisfied that the method of pictorial presentation is satisfactory. There is to be good two-way communication between the Surveyor and the diver.

4.3.6 Diving and In-water Survey operations are to be carried out by firms recognised by the Committee. Continued recognition by the Committee will be dependent on the standard of workmanship by the firm being maintained to the satisfaction of LR's Surveyors.

4.3.7 If the In-water Survey reveals damage or deterioration that requires early attention, the Surveyor may require that the craft be dry-docked in order that a fuller survey can be undertaken and the necessary work carried out.

4.3.8 Where a vessel has an ***IWS** notation, the condition of the high resistant paint is to be confirmed at each dry-docking in order that the ***IWS** notation can be maintained.

4.3.9 Some National Administrations may have requirements additional to those of 4.3.1 to 4.3.8.

Section 5
Special Survey – General – Hull requirements

5.1 General

5.1.1 The survey is to be of sufficient extent to ensure that the hull and related equipment is in satisfactory condition and is fit for its intended purpose, subject to proper maintenance and operation and to Periodical Surveys being carried out as required by the Regulations.

5.1.2 The requirements of Section 2 are to be complied with so far as applicable.

5.1.3 A Docking Survey in accordance with the requirements of 4.2 is to be carried out as part of the Special Survey.

5.1.4 For vessels assigned the notation 'laid-up', an Underwater Examination (UWE) and general examination of hull and machinery is to be carried out in lieu of the normal Special Survey requirements.

5.2 Preparation

5.2.1 The craft is to be prepared for survey in accordance with the requirements of Table 3.5.1. The preparation should be of sufficient extent to facilitate an examination to ascertain any excessive corrosion, erosion, deformation, fractures, damages and other structural deterioration.

5.2.2 Where, in accordance with Table 3.5.1, the craft is opened out by removal of linings, ceilings, cabin sole, etc., and defects are found, further opening out will be required in order that the Surveyor can confirm the full extent of the defects.

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Table 3.5.1 Survey preparation

Special Survey I (Craft 5 years old)	Special Survey II (Craft 10 years old)	Special Survey III (Craft 15 years old) and subsequent special surveys
(1) The interior of the craft is to be sufficiently opened out by the removal of lining, ceiling/cabin sole, portable tanks and ballast, etc as required in order that the Surveyor may be satisfied as to the condition of suspect areas of the structure, *see* 1.5.3. A record is to be made of those areas where lining, ceiling/cabin sole etc., were opened out and where equipment was removed during the survey. This record is to be retained for reference during subsequent surveys. (2) Machinery compartments, fore and aft peaks and other spaces as directed by the Surveyor, are to be cleared and cleaned as necessary, and the bilges and limbers all fore and aft are to be cleaned and prepared for examination. Platform plates in engine spaces are to be lifted as may be necessary for the examination of the structure below. Where necessary, pipework may be required to be removed for examination of the structure. (3) In way of the single and/or double bottom areas, a sufficient amount of ceiling/cabin sole is to be lifted to permit examination of the bilges and/or tanktops below. (4) All integral tanks are to be cleaned as necessary to permit examination. (For steel craft, *see* Table 3.5.2).	In addition to the requirements for Special Survey I, the following are to be complied with: (1) The chain locker is to be cleared and cleaned internally for examination of the structure and examination of the cable securing arrangements. The chain cables/anchor warps, as applicable, are to be ranged for inspection. The anchors are to be cleaned and placed in an accessible position for inspection. (2) The rudder is to be unshipped for examination of the rudder stock and trunk at the discretion of the Surveyor.	In addition to the requirements for Special Survey II the following are to be complied with: (1) Linings, ceiling/cabin soles, etc are to be removed as required in order that the Surveyor may be satisfied as to the condition of the structure. For steel craft: (2) Portions of wood sheathing, or other covering, on steel decks are to be removed, as considered necessary by the Surveyor, in order to ascertain the condition of the plating. (3) Where spaces are insulated, sufficient insulation is to be removed in each space to enable the Surveyors to be satisfied with the condition of the structure. (4) Linings are to be removed in way of shell plating immediately above tank top connections to the side shell, in way of galleys/washrooms and beneath portlights and windows.

Table 3.5.2 Tank internal examination requirements for steel craft

Tank	Special Survey I (Craft 5 years old)	Special Survey II (Craft 10 years old)	Special Survey III (Craft 15 years old)	Special Survey IV (Craft 20 years old)	All Subsequent Special Surveys
Peaks	All tanks	All tanks	All tanks	All tanks	All tanks
Salt water ballast	All tanks	All tanks	All tanks	All tanks	All tanks
Lubricating oil	None	None	*See* Note 2	*See* Note 3	All tanks
Fresh water	None	*See* Note 1	*See* Note 2	*See* Note 3	All tanks
Oil fuel	None	*See* Note 1	*See* Note 2	*See* Note 3	All tanks
Sanitary	All tanks	All tanks	All tanks	All tanks	All tanks

NOTES
1. Tanks (excluding peak tanks) used exclusively for oil fuel or fresh water need not all be examined internally provided that the Surveyor is satisfied with the condition, after both external examination and testing and from an internal examination of the after end of one forward double bottom tank, and of one selected deep tank.
2. Tanks (excluding peak tanks) used exclusively for oil fuel, oil fuel and fresh water ballast, or lubricating oil, need not all be examined internally provided that the Surveyor is satisfied with the condition, after both external examination and testing and from an internal examination of one double bottom tank forward and one aft and one deep tank.
3. Tanks (excluding peak tanks) used exclusively for oil fuel, oil fuel and fresh water ballast, or lubricating oil, need not all be examined internally provided that the Surveyor is satisfied with the condition, after both external examination and testing and from internal examination of a least one double bottom tank amidships, one forward and one aft and one deep tank.
4. When examining tanks internally the Surveyor is to verify that striking plates or other additional reinforcement is fitted under sounding pipes. In the case of tanks fitted only with remote gauging facilities, the satisfactory operation of the gauges is to be confirmed.

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5.3 Examination and testing – General

5.3.1 All spaces within the hull and superstructure including integral tanks are to be examined (*see also* 5.4.1 for tank examinations on steel craft). Special attention is to be paid to any suspect areas, *see* 1.5.3.

5.3.2 Double bottom compartments, peak tanks and all other integral tanks are to be tested by a head sufficient to give the maximum pressure that can be experienced in service. Tanks may be tested afloat provided that their internal examination is also carried out afloat.

5.3.3 Where repairs are effected to the hull shell or bulkheads, any integral tanks in way are to be tested to the Surveyor's satisfaction on completion of these repairs.

5.3.4 All decks, casings and superstructures are to be examined.

5.3.5 The satisfactory attachment of any wood or other deck sheathing is to be confirmed, *see also* 5.4.4.

5.3.6 Attention is to be given to the corners of openings and other discontinuities in the hull structure.

5.3.7 The anchors are to be examined. If the chain cables are ranged they are to be examined together with the chain locker, *see* Table 3.5.1. If any length of chain cable is found to be reduced in mean diameter at its most worn part by 12 per cent or more from its nominal diameter, it is to be renewed. The windlass is to be examined.

5.3.8 The Surveyor is to be satisfied that there are suitable towlines and mooring ropes when these are a Rule requirement.

5.3.9 Representative structural fastenings, e.g. bolts in way of resiliently mounted deckhouses, are to be tested to ascertain their soundness and may require to be drawn for examination at the discretion of the Surveyor.

5.3.10 For craft to which Pt 17, Ch 1 applies, the Surveyor is to be satisfied as to the efficient condition of the means of escape from crew and passenger spaces, and spaces in which crew are normally employed.

5.4 Examination and testing – Additional items for steel craft

5.4.1 All integral tanks are generally to be internally examined. However, in certain circumstances the internal examination of lubricating oil, fresh water and oil fuel tanks may be waived. For the minimum extent of tank internal examination, *see* Table 3.5.2.

5.4.2 In salt water ballast spaces, integral sanitary tanks and bilges where the protective coating is found to be other than in GOOD condition as defined in 1.5.6 and it has not been repaired, maintenance of class will be subject to the spaces in question being internally examined and gauged as necessary at Annual Surveys.

5.4.3 The protection of steelwork, other than as referred to in 5.4.2 should be examined and made good where necessary on satisfactory completion of the survey. In areas where the inner surface of the bottom plating is covered with cement, asphalt or other composition, the removal of this covering may be dispensed with, provided that it is found sound and adhering satisfactorily to the steel.

5.4.4 Wood deck sheathing is to be examined and the caulking is to be tested and recaulked as necessary. If decay or rot is found, or the wood is excessively worn, the wood is to be renewed. Attention is to be given to the condition of the plating under wood deck sheathing or other deck covering. If it is found that such coverings are broken, or are not adhering closely to the plating, sections are to be removed as necessary to ascertain the condition of the plating. *See also* 1.2.1.

5.4.5 The structure in way of bimetallic connections, e.g. to aluminium alloy deckhouses is to be examined.

5.4.6 The Surveyors may require to measure the thickness of the material in any portion of the structure where signs of wastage are evident or wastage is normally found. Any parts of the structure which are found defective or excessively reduced in scantlings are to be made good by materials of the approved scantlings and quality. The minimum requirements for thickness measurements are given in Section 6.

5.5 Examination and testing – Additional items for aluminium alloy craft

5.5.1 The structure in way of any bimetallic connections is to be examined and the efficiency of the insulation arrangements confirmed.

5.5.2 The Surveyor may require to measure the thickness of the material in any portion of the structure where signs of deterioration are evident or may normally be found. Any parts of the structure which are found defective or excessively reduced in scantlings are to be made good by materials of the approved scantlings and quality.

5.6 Examination and testing – Additional items for composite craft

5.6.1 The bonded attachments of frames, floors, bulkheads, structural joinery, engine bearers, sterntubes, rudder tubes, and integral tank boundaries are to be examined.

5.6.2 The hull to deck joint together with any joints between the deck and deckhouses or superstructures are to be examined.

5.6.3 The structure in way of the bolted attachment of fittings including guardrail stanchions, windlass, shaft brackets, fendering, mooring bitts, etc. is to be examined.

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Section 6
Special Survey – Thickness measurement requirements for steel craft

6.1 General

6.1.1 Thickness measurements, as required by Section 5 are to be carried out in accordance with the following requirements.

6.1.2 Thickness measurements are to be taken at the forward and aft areas of all plates. In all cases the measurements are to represent the average of the multiple measurements taken on each plate. The extent of local substantial corrosion of plates is to be established by intensive measurement in the affected areas. Where measured plates are renewed, the thicknesses of adjacent plates in the same strake are to be reported.

6.1.3 Thickness measurements are normally to be by means of ultrasonic test equipment and are to be carried out by a firm qualified as Grade 1 or Grade 2 according to LR Approval for Thickness Measurement of Hull Structures or by the Surveyor.

6.1.4 The degree of supervision or check testing by the Surveyor is dependent upon the grade of approval extended to the firm carrying out the thickness measurements.

(a) The work of firms having Grade 1 approval is subject to check testing by the Surveyor.

(b) Thickness measurements by firms having Grade 2 approval is to be carried out with the Surveyor substantially in attendance.

6.1.5 Thickness measurements may be carried out in association with the fourth Annual Survey.

6.1.6 The minimum requirements for thickness measurement are indicated in Table 3.6.1.

6.1.7 The Surveyor may extend the scope of thickness measurement if deemed necessary.

Table 3.6.1 Thickness measurement of steel craft

Special Survey I (Craft 5 years old)	Special Survey II (Craft 10 years old)	Special Survey III (Craft 15 years old) (Craft 20 years old and over)	Special Survey IV and subsequent
Suspect areas, as required by the Surveyor and may include areas where the coatings are found to be other than in GOOD condition, *see* Note 1.	Suspect areas, as required by the Surveyor and may include areas where the coatings are found to be other than in GOOD condition, *see* Note 1.	(1) Any exposed plating throughout the Main Deck. (2) Shell plating in way of the waterline throughout the length of the craft. (3) Suspect areas, as required by the Surveyor and may include areas where the coatings are found to be other than in GOOD condition, *see* Note 1.	(1) All Main Deck plating outside deckhouses or superstructures and including plating in way of wood deck planking or sheathing. (2) Shell plating in way of, and below, the waterline throughout the length of the craft. (3) 2 transverse sections of deck and shell plating within 0,5*L* amidships. (4) Suspect areas, as required by the Surveyor and to include as applicable: (a) Areas where the coatings are found to be other than in GOOD condition. (b) Shell and tanktop plating immediately adjacent to tank top margins. (c) Bottom shell in way of any cement, asphalt or other composition. (d) Shell plating below portlights and windows. (e) Tanktop plating below ceiling or cabin soles. (f) Deck plating and side shell plating in way of galleys, washrooms and refrigerated store spaces. (g) Structure in way of integral sanitary tanks.

NOTES
1. Suspect areas are locations within the hull structure vulnerable to increased likelihood of structural deterioration and may include, for steel hulls, areas of substantial corrosion and/or fatigue cracking, *see also* 1.5.3 and 5.4.6.
2. Coating condition for steel craft is defined in 1.5.6.

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6.2 Thickness measurement reporting

6.2.1 A report is to be prepared by the approved firm carrying out the thickness measurement. The report is to give the location of measurement, the thickness measured as well as the corresponding original thickness. The report is to give the date when the measurement was carried out, the type of measuring equipment, names of personnel and their qualifications and is to be signed by the operator and supervisor.

6.2.2 The thickness measurement report is to be verified and signed by the Surveyor.

■ *Section 7*
Machinery surveys – General requirements

7.1 Annual, Intermediate and Docking Surveys

7.1.1 For Annual, Intermediate and Docking Surveys, *see* Sections 2, 3 and 4.

7.1.2 For craft where an Approved Planned Maintenance Scheme is in operation an Annual Survey of the machinery is to be carried out together with an audit of the maintenance and monitoring records.

7.1.3 For vessels assigned the notation 'laid-up', a general examination of the machinery is to be carried out in lieu of the normal Annual Survey/Intermediate Survey requirements.

7.2 Complete Surveys

7.2.1 While the craft is in dry-dock, all openings to the sea in the machinery spaces and pump-rooms, together with the valves, cocks and the fastenings with which these are connected to the hull, are to be examined.

7.2.2 Athwartships thrust propellers are to be generally examined so far as is possible in dry dock and tested under working conditions afloat for satisfactory operation.

7.2.3 All shafts (except screwshafts and tube shafts, for which special arrangements are detailed in Section 11), thrust block and all bearings are to be examined. The lower halves of bearings need not be exposed if alignment and wear are found to be acceptable.

7.2.4 An examination is to be made as far as practicable of all propulsion gears complete with all wheels, pinions, shafts, bearings and gear teeth, thrust bearings and incorporated clutch arrangements.

7.2.5 The following auxiliaries and components are also to be examined:

(a) Auxiliary engines, auxiliary air compressors with their intercoolers, filters and/or oil separators and safety devices, and all pumps and components used for essential services.
(b) Steering machinery.
(c) Windlass and associated driving equipment, where fitted.
(d) The holding down bolts, chocks or resilient mounts of main and auxiliary engines, gearcases, thrust blocks and intermediate shaft bearings.

7.2.6 All air receivers for essential services, together with their mountings, valves and safety devices, are to be cleaned internally and examined internally and externally. If internal examination of the air receivers is not practicable, they are to be tested hydraulically to 1,3 times the working pressure.

7.2.7 The valves, cocks and strainers of the bilge system including bilge injection, are to be opened up as considered necessary by the Surveyor and together with pipes, are to be examined and tested under working conditions. The oil fuel, feed, lubricating oil and cooling water systems also any ballast connections together with all pressure filters, heaters and coolers used for essential services, are to be opened up and examined or tested, as considered necessary by the Surveyor. All safety devices for the foregoing items are to be examined.

7.2.8 Fuel tanks which do not form part of the craft's structure are to be examined, and if considered necessary by the Surveyor, they are to be tested to the pressure specified for new tanks. The tanks need not be examined internally at the first survey if they are found satisfactory on external inspection. The mountings, fittings and remote controls of all oil fuel tanks are to be examined, so far as is practicable.

7.2.9 Where remote and/or automatic controls are fitted for essential machinery, they are to be tested to demonstrate that they are in good working order.

7.2.10 In addition to the above, detailed requirements for gas turbines and oil engines and electrical installations are given in Sections 8, 9 and 10 respectively. In certain instances, upon application by the Owner or where indicated by the maker's servicing recommendations, the Committee will give consideration to the circumstances where deviation from these detailed requirements is warranted, taking account of design, appropriate indicating equipment (e.g. vibration indicators) and operational records, *see* Ch 2,4.5.17 and 4.5.23.

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Section 8
Gas turbines – Detailed requirements

8.1 Complete Surveys

8.1.1 The requirements of Section 7 are to be complied with. *See* 7.2.10 regarding any deviation from the following.

8.1.2 The following parts are to be opened out and examined:

- Compressor including impellers or blading, rotors and casing.
- Combustion chambers, burners, intercoolers and heat exchangers.
- Gas, air and fuel piping and fittings.
- Gas generator turbine and power turbine blading, rotors and casing.
- Rotors to include couplings, clutches, bearings and tie bolts.
- Auxiliary mounted fuel, L.O. and cooling water pumps, their drive transmissions and fittings.
- Starting system (for starting air pipes, *see* 9.1.3).
- All safety devices and local controls.
- Mountings and support frame.

8.1.3 The compressor/turbine units are to be operated and maintained in accordance with the manufacturer's instructions. Overhauls, including the prescribed replacement of limited life components, are to be undertaken at the specified intervals. Full service records are to be available for review by the Surveyor.

8.1.4 The manoeuvring of the propulsion system is to be tested under working conditions.

Section 9
Oil engines – Detailed requirements

9.1 Complete Surveys

9.1.1 The requirements of Section 7 are to be complied with. *See* 7.2.10 regarding any deviation from the following.

9.1.2 The following parts are to be opened out and examined:

- Cylinders and covers.
- Valves and valve gear.
- Pistons and connecting rods.
- Crankshafts and all bearings.
- Crankcases and entablatures.
- Crankcase door fastenings and explosion relief devices.
- Turbo-chargers and their associated coolers.
- Air compressors and their intercoolers.
- Filters and/or separators and safety devices.
- Fuel pumps and fittings.
- Camshaft drives and balancer units.
- Vibration dampers or detuners.
- Flexible couplings and clutches.
- Reverse gears.
- Attached pumps and cooling arrangements.

9.1.3 Selected pipes in the starting air system, if fitted, are to be removed for internal examination and are to be hammer tested. If any appreciable amount of lubricating oil is found in the pipes, the starting air system is to be thoroughly cleaned internally by steaming out, or other suitable means. Some of the pipes selected are to be those adjacent to the starting air valves at the cylinders and to the discharges from the air compressors.

9.1.4 The electric ignition system, if fitted, is to be examined and tested.

9.1.5 The manoeuvring of engines is to be tested under working conditions. Initial starting arrangements are to be tested.

Section 10
Electrical equipment

10.1 Annual and Intermediate Surveys

10.1.1 The requirements of 2.2.14 and 3.2.4 are to be complied with as far as applicable.

10.2 Complete Surveys

10.2.1 An electrical insulation resistance test is to be made on the electrical equipment and cables. The installation may be sub-divided, or equipment which may be damaged disconnected, for the purpose of this test.

10.2.2 The fittings on the main and emergency switchboards, section boards and distribution boards are to be examined and over-current protective devices and fuses inspected to verify that they provide suitable protection for their respective circuits.

10.2.3 Generator circuit-breakers are to be tested, so far as is practicable, to verify that protective devices including preference tripping relays, if fitted, operate satisfactorily.

10.2.4 The electric cables and their securing arrangements are to be examined, so far as is practicable, without undue disturbance of fixtures or casings unless opening up is considered necessary as a result of observation or of the tests required by 10.2.1.

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10.2.5 The generator prime movers are to be surveyed as required by Sections 8 and 9 and the governing of the engines tested. The motors concerned with essential services together with associated control and switch gear are to be examined and if considered necessary, are to be operated, so far as is practicable, under working conditions. All generators and steering gear motors are to be examined and are to be operated under working conditions, though not necessarily under full load or simultaneously.

10.2.6 Where transformers or electrical apparatus associated with supplies to essential services are liquid filled or cooled by a liquid in direct contact with current carrying parts, the owner is to arrange for samples of the liquid to be taken and tested, by a competent authority, in accordance with the equipment manufacturer's requirements, and a certificate giving the test results is to be furnished to the Surveyor.

10.2.7 Navigation light indicators are to be tried under working conditions, and correct operation on the failure of supply or failure of navigation lights verified.

10.2.8 The emergency sources of electrical power, where fitted, together with their automatic arrangements and associated circuits are to be tested.

10.2.9 Emergency lighting, transitional emergency lighting, supplementary emergency lighting, general emergency alarm and public address systems are to be tested as far as practicable.

10.2.10 Where the craft is electrically propelled, the propulsion motors, generators, cables and all ancillary electrical gear, exciters and ventilating plant (including coolers) associated therewith are to be examined, and the insulation resistance to earth is to be tested. Special attention is to be given to windings, commutators and slip-rings. The operation of protective gear and alarm devices is to be checked, so far as is practicable. Liquids for filling and cooling, if used, are to be tested in accordance with 10.2.6. Interlocks intended to prevent unsafe operations or unauthorised access are to be checked to verify that they are functioning correctly. Emergency overspeed governors are to be tested.

10.2.11 Where batteries provide the source of power for any essential services, their installation, including charging and ventilation arrangements, is to be examined.

Section 11
Screwshafts, tube shafts, propellers and water jet units

11.1 Frequency of surveys

11.1.1 Shafts with keyed propeller attachments and fitted with continuous liners or approved oil glands, or made of approved corrosion resistant materials, are to be surveyed at intervals of five years when the keyway complies fully with the present Rules.

11.1.2 Shafts having keyless type propeller attachments are to be surveyed at intervals of five years provided they are fitted with approved oil glands or are made of approved corrosion resistant materials.

11.1.3 Shafts having solid coupling flanges at the after end are to be surveyed at intervals of five years provided they are fitted with approved oil glands or are made of approved corrosion resistant materials.

11.1.4 All other shafts not covered by 11.1.1 to 11.1.3 are to be surveyed at intervals of $2^1/_2$ years.

11.1.5 Controllable pitch propellers for main propulsion purposes are to be surveyed at the same intervals as the screwshaft.

11.1.6 Directional propeller units for main propulsion purposes are to be surveyed at intervals not exceeding five years.

11.1.7 Water jet units for main propulsion purposes are to be surveyed at intervals not exceeding five years provided the impeller shafts are made of approved corrosion resistant material or have approved equivalent arrangements.

11.1.8 Athwartship thrust propellers and shaftings are to be surveyed at intervals not exceeding five years, *see* 7.2.2.

11.2 Normal surveys

11.2.1 All screwshafts are to be withdrawn for examination by LR's Surveyors at the intervals prescribed in 11.1.1 to 11.1.4. The after end of the cylindrical part of the shaft and forward one third of the shaft cone, or fillet of the flange, is to be examined by a magnetic particle crack detection method. In the case of a keyed propeller attachment at least the forward one third of the shaft cone is to be examined with the key removed. Weardown is to be measured and the sterntube bearings, oil glands, propellers and fastenings are to be examined. Controllable pitch propellers where fitted are to be opened up and the working parts examined, together with the control gear.

11.2.2 Directional propeller units are to be dismantled for examination of the propellers, shafts, gearing and control gear.

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11.2.3 Water Jet Units are to be dismantled for examination of the impeller, casing, shaft, shaft seal, shaft bearing, inlet and outlets channels, steering nozzle, reversing arrangements, and control gear.

11.3 Screwshaft Condition Monitoring (SCM)

11.3.1 Where oil lubricated shafts with approved oil glands are fitted, and the Owner has complied with the following requirements, the descriptive note **SCM** (Screwshaft Condition Monitoring) may be entered in column 6 of the *Register Book*:

(a) Lubricating oil analysis to be carried out regularly at intervals not exceeding six months. The lubricating oil analysis documentation is to be available on board. Each analysis is to include the following minimum parameters:
- water content
- chloride content
- bearing material and metal particles content
- oil ageing (resistance to oxidation).

(b) Oil samples are to be taken under service conditions and are to be representative of the oil within the sterntube.

(c) Oil consumption is to be recorded.

(d) Bearing temperatures are to be recorded (two temperature sensors or other approved arrangements are to be provided).

(e) Facilities are to be provided for measurement of bearing weardown.

(f) Oil glands are to be capable of being replaced without withdrawal of the screwshaft.

11.3.2 For maintenance of the descriptive note **SCM**, the records of analyses, consumption and temperatures, together with weardown readings, are to be retained on board and audited annually.

11.3.3 Where the requirements for the descriptive note **SCM** have been complied with, the screwshaft need not be withdrawn at surveys as required by 11.2.1 provided all condition monitoring data is found to be within permissible limits and all exposed areas of the shaft are examined by a magnetic particle crack detection method. The remaining requirements of 11.2.1 are to be complied with. Where the Surveyor considers that the data presented is not entirely to his satisfaction the shaft will be required to be withdrawn in accordance with 11.2.1.

11.4 Modified Survey

11.4.1 A Modified Survey may be accepted at alternate five-yearly surveys for shafts described in 11.1.1 provided they are fitted with oil lubricated bearings and approved oil glands, and also for those in 11.1.2 and 11.1.3.

11.4.2 The Modified Survey is to consist of the partial withdrawal of the shaft, sufficient to ascertain the condition of the stern bearing and shaft in way. For keyless propellers or shafts with a solid flange connection to the propeller a visual examination to confirm the good condition of the sealing arrangements is to be made. The oil glands are to be capable of being replaced without removal of the propeller. The forward bearing and all accessible parts including the propeller connection to the shaft are to be examined as far as possible. Wear down is to be measured and found satisfactory. Where a controllable pitch propeller is fitted, at least one of the blades is to be dismantled complete for examination of the working parts and the control gear.

11.4.3 For keyed propellers, the after end of the cylindrical part of the shaft and forward one third of the shaft cone is to be examined by a magnetic particle crack detection method, for which dismantling of the propeller and removal of the key will be required.

11.4.4 Where the descriptive note **SCM** has been assigned as described in 11.3.1 and all data is found to be within permissible limits, partial withdrawal of the shaft may not be required. Where doubt exists regarding any of the above findings the shaft is to be withdrawn to permit an entire examination.

11.5 Partial Survey

11.5.1 For shafts where the Modified Survey is applicable, upon application by the Owner, the Committee will be prepared to give consideration to postponement of the survey for a maximum period of half the specified cycle provided a Partial Survey is held.

11.5.2 The Partial Survey is to consist of the propeller being backed off in any keyed shaft and the top half of the cone examined by an efficient crack detection method for which removal of the key will be required. Oil gland and seals are to be examined and dealt with as necessary. Weardown is to be measured and found satisfactory. Propeller and fastenings are to be examined.

11.5.3 The Committee will be prepared to give consideration to the circumstances of any special case upon application by the Owner.

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Section 12
Classification of craft not built under survey

12.1 General

12.1.1 When classification is desired for a craft not built under the supervision of LR's Surveyors, application should be made to the Committee in writing.

12.1.2 Periodical Surveys of such craft, when classed, are subsequently to be held as in the case of craft built under survey.

12.1.3 Where classification is desired for a craft which is classed by another recognised Society, special consideration will be given to the scope of the survey.

12.2 Hull and equipment

12.2.1 Plans showing the main scantlings and arrangements of the actual craft together with any proposed alterations are to be submitted for approval.These should comprise plans of the midship section, longitudinal section and decks, and such other plans as may be requested. If plans cannot be obtained or prepared by the Owner, facilities are to be given for LR's Surveyor to obtain the necessary information from the craft.

12.2.2 Particulars of the process of manufacture and the testing of the material of construction are to be supplied. The requirements for composite craft will be specially considered.

12.2.3 The full requirements of Sections 5 and 6 are to be carried out as applicable. Craft of recent construction will receive special consideration.

12.2.4 During the survey, the Surveyors are to satisfy themselves regarding the workmanship and verify the approved scantlings and arrangements. For this purpose, and also in order to ascertain the amount of any deterioration of steel craft, parts of the structure will require to be gauged as necessary. Full particulars of the anchors, chain cables and equipment are to be submitted. For craft to which Pt 15, Ch 1 applies, fire protection, detection and extinction are to be in accordance with the Rules.

12.2.5 When the full survey requirements indicated in 12.2.3 and 12.2.4 cannot be completed at one time, the Committee may consider granting an interim record for a limited period. The conditions regarding the completion of the survey will depend on the merits of each particular case, which should be submitted for consideration.

12.3 Machinery

12.3.1 To facilitate the survey, the following plans and particulars (plans of piping are to be diagrammatic), together with the particulars of the materials used in the construction of any boilers, air receivers and important forgings are to be submitted:

- Name of manufacturer of engine and gearbox including the manufacturer's type designation of engine and gearbox, together with the continuous shaft power of the engine at the crankshaft coupling with the revolutions per minute of crankshaft and propeller.
- General pumping arrangements, including air and sounding pipes (Builder's plan).
- Bilge, ballast and oil fuel pumping arrangements including the capacities of the pumps on bilge service.
- Arrangement and dimensions of any steam pipes.
- Arrangement of oil fuel pipes and fittings at settling and service tanks.
- Arrangement of oil fuel piping in connection with oil burning installations.
- Oil fuel overflow systems, where these are fitted.
- Arrangement of boiler feed systems.
- Oil fuel settling, service and other oil fuel tanks not forming part of the craft's structure.
- Boilers and economisers.
- Air receivers.
- Crank, thrust, intermediate and screw shafting.
- Details of water jet or directional propeller units, if fitted.
- Clutch and reversing gear with methods of control.
- Reduction gearing.
- Propeller (including spare propeller if supplied) where the diameter exceeds 1 m.
- Electrical circuits.
- Arrangement of compressed air systems for main and auxiliary services.
- Arrangement of lubricating oil, other flammable liquids and cooling water systems for main and auxiliary services.
- Steering gear including control arrangement.
- Arrangement of exhaust system indicating materials, method of cooling, and if water spray injected, the method of draining.

12.3.2 Plans additional to those detailed in 12.3.1 are not to be submitted unless the machinery is of a novel or special character affecting classification.

12.3.3 Where remote and/or automatic controls are fitted to propulsion machinery and essential auxiliaries, a description of the scheme is to be submitted.

12.3.4 For new craft and craft which have been in service less than two years, calculations of the torsional vibration characteristics of the propelling machinery are to be submitted for consideration, as required for craft constructed under Special Survey. For older craft the circumstances will be specially considered in relation to their service record and type of machinery installed. Where calculations are not submitted, the Committee may require that the machinery certificate be endorsed to this effect. When desired by the Owner, the calculations and investigation of the torsional vibration characteristics of the machinery may be carried out by LR upon special request.

12.3.5 The main and auxiliary machinery, feed pipes, compressed air pipes and boilers are to be examined as required at Complete Surveys. Working pressures are to be determined from the actual scantlings in accordance with the Rules.

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12.3.6 The screwshaft is to be drawn and examined.

12.3.7 Any steam pipes or oil burning installations are to be examined and tested as required by Pt 1, Ch 3,15 or Ch 3,16 of the *Rules and Regulations for the Classification of Ships*.

12.3.8 The bilge, ballast and oil fuel pumping arrangements are to be examined and amended, as necessary, to comply with the Rules.

12.3.9 The electrical equipment is to be examined as required at Complete Surveys.

12.3.10 The whole of the machinery, including essential controls, is to be tried under working conditions to the Surveyor's satisfaction.

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Section

1 **General**

2 **Intermediate Surveys – Hull and machinery requirements**

3 **Docking Surveys and In-water Surveys – Hull and machinery requirements**

4 **Special Survey – General – Hull requirements**

5 **Special Survey – Thickness measurement requirements for steel yachts**

6 **Machinery surveys – General requirements**

7 **Gas turbines – Detailed requirements**

8 **Oil engines – Detailed requirements**

9 **Electrical equipment**

10 **Screwshafts, tube shafts, propellers and water jet units**

11 **Surveys of unclassed machinery in existing classed yachts**

12 **Classification of yachts not built under survey**

■ *Section 1* General

1.1 Frequency of surveys

1.1.1 The requirements of this Chapter are applicable to the Periodical Surveys set out in Ch 2,4.5. Except as amended at the discretion of the Committee, the periods between such surveys are as follows:

(a) Intermediate Surveys as required by Ch 2,4.5.5.
(b) Docking Surveys as required by Ch 2,4.5.6 and 4.5.7.
(c) Special Surveys at five-yearly intervals, *see* Ch 2,4.5.11. For alternative arrangements, *see also* Ch 2,4.5.12, 4.5.13 and 4.5.15.
(d) Complete Surveys of machinery at five-yearly intervals, *see* Ch 2,4.5.16. For alternative arrangements, *see also* Ch 2,4.5.17, 4.5.19, 4.5.21, 4.5.22 and 4.5.23.

1.1.2 When it has been agreed that the Complete Survey of the hull and machinery may be carried out on the Continuous Survey basis, all compartments of the hull and all items of machinery are to be opened for survey in rotation to ensure that the interval between consecutive examinations of each part will not exceed five years, *see* Ch 2,4.5.15 and 4.5.19.

1.1.3 For the frequency of surveys of screwshafts, tube shafts, propellers and water jet units, *see* Section 10.

1.2 Surveys for damage or alterations

1.2.1 At any time when a yacht is undergoing alterations or damage repairs, any exposed parts of the structure normally difficult to access are to be specially examined, e.g. if any part of the main or auxiliary machinery is removed for any reason, the hull structure in way is to be carefully examined by the Surveyor, or when cement in the bottom or sheathing on decks is removed the structure in way is to be examined before the cement or sheathing is relaid.

1.3 Unscheduled surveys

1.3.1 In the event that Lloyd's Register (hereinafter referred to as 'LR') has cause to believe that its Rules and Regulations are not being complied with, LR reserves the right to perform unscheduled surveys of the hull or machinery.

1.3.2 In the event of significant damage or defect affecting any yacht, LR reserves the right to perform unscheduled surveys of the hull or machinery of other similar yachts classed by LR and deemed to be vulnerable.

1.4 Surveys for the issue of Convention certificates

1.4.1 Surveys are to be held by LR when so appointed, or by the Exclusive Surveyors to a National Administration or by an IACS Member when so authorised by the National Authority, or, in the case of Cargo Ship Safety Radio Certificates or Safety Management Certificates, by any organisation authorised by the National Authority. In the case of dual classed yachts, Convention Certificates may be issued by the other Society with which the yacht is classed provided this is recognised in a formal Dual Class Agreement with LR and provided the other Society is also authorised by the National Authority.

1.5 Definitions

1.5.1 A **Ballast tank** is a tank which is used primarily for salt water ballast.

1.5.2 **Spaces** are separate hull compartments including integral tanks.

1.5.3 **Suspect areas** are locations within the hull structure vulnerable to increased likelihood of structural deterioration and may include:

(a) For steel hulls, areas of substantial corrosion and/or fatigue cracking.
(b) For aluminium alloy hulls, areas of fatigue cracking and areas in the vicinity of bimetallic connections.
(c) For composite hulls, areas subject to impact damage.
(d) For wood hulls, areas subject to decay as a result of fresh water ingress or poor ventilation.
(e) For high speed craft (as defined in Ch 2,2.2.7), areas of the bottom structure forward prone to slamming damage.
(f) For sailing craft, areas subject to high local stresses due to rigging loads and ballast keel attachments.

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1.5.4 **Substantial corrosion** is wastage of individual steel or aluminium plates and stiffeners in excess of 75 per cent of allowable margins, but within acceptable limits.

1.5.5 **Protective coatings** for steel craft should usually be hard coatings. Other coating systems (e.g. soft coating) may be considered acceptable as alternatives provided they are applied and maintained in compliance with the manufacturer's specification.

1.5.6 **Coating condition** for steel yacht is defined as follows:

GOOD condition with only minor spot rusting affecting not more than 20 per cent of areas under consideration.

■ *Section 2*
Intermediate Surveys – Hull and machinery requirements

2.1 General

2.1.1 At Intermediate Surveys, the Surveyor is to examine the hull and machinery, so far as necessary and practicable, in order to be satisfied as to their general condition.

2.2 Intermediate Surveys

2.2.1 The Surveyor is to be satisfied regarding:

(a) The efficient condition of hatchways on freeboard and superstructure decks, weather deck plating, ventilator coamings and air pipes, exposed casings, skylights, flush deck scuttles, deckhouses and companionways, superstructure bulkheads, side, bow and stern doors, windows and storm shutters, side scuttles and deadlights, chutes and other openings, together with all closing appliances and flame screens.

(b) The efficient condition of scuppers and sanitary discharges (so far as is practicable); valves on discharge lines (so far as is practicable) and their controls; guard rails and bulwarks; freeing ports, gangways and life-lines.

(c) The efficient condition of bilge level detection and alarm systems on yachts assigned a **UMS** notation.

2.2.2 The anchoring and mooring equipment including anchor warps or wire ropes is to be examined so far as is practicable. For all yachts over 10 years of age the anchors are to be partially lowered and raised using the windlass.

2.2.3 The watertight doors in watertight bulkheads are to be examined and operationally tested locally and where applicable remotely. Other watertight bulkhead penetrations, are to be examined so far as is practicable.

2.2.4 The Surveyor is to examine and test in operation all main and auxiliary steering arrangements including their associated equipment and control systems.

2.2.5 The Surveyor is to generally inspect the machinery spaces with particular attention being given to the propulsion system, auxiliary machinery and to the existence of any fire and explosion hazards. Where applicable, emergency escape routes are to be checked to ensure that they are free of obstruction.

2.2.6 The means of communication between the navigating bridge and the machinery control positions, as well as the bridge and the alternative steering position, if fitted, are to be tested.

2.2.7 The bilge pumping systems and bilge wells, including operation of extended spindles, self closing drain cocks and level alarms, where fitted, are to be examined so far as is practicable. Satisfactory operation of the bilge pumps, including any hand pumps, is to be proven.

2.2.8 Any pressure vessels including safety devices, foundations, controls, relieving gear, associated piping systems, insulation and gauges, are to be generally examined. Surveyors should confirm that Periodical Surveys of pressure vessels have been carried out as required by the Rules and that the safety devices have been tested.

2.2.9 The electrical equipment and cabling forming the main and emergency electrical installations are to be generally examined under operating conditions so far as is practicable. The satisfactory operation of the main and emergency sources of power and electrical services essential for safety in an emergency is to be verified; where the sources of power are automatically controlled they should be tested in the automatic mode. Bonding straps for the control of static electricity and earthing arrangements are to be examined where fitted.

2.2.10 The electrical generating sets are to be examined under working conditions.

2.2.11 For yachts having **UMS** or **CCS** notation, a General Examination of automation equipment is to be carried out. Satisfactory operation of safety devices and control systems is to be verified.

2.2.12 For yachts to which Pt 17, Ch 1 applies, the arrangements for fire protection, detection and extinction are to be examined and are to include the following items, as required to be fitted in accordance with the Rules:

(a) Verification, so far as is practicable, that no significant changes have been made to the arrangement of structural fire protection.

(b) Verification of the operation of manual and/or automatic doors where fitted.

(c) Verification that fire control plans are properly posted.

(d) Examination, so far as is possible, and testing as feasible, of the fire and/or smoke detection and alarm system(s).

(e) Examination of fire main system, and confirmation that each fire pump, including the emergency fire pump can be operated separately so that the required jets of water can be produced simultaneously from different hydrants.

(f) Verification that fire-hoses, nozzles, applicators and spanners are in good working condition and situated at their respective locations.

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(g) Examination of fixed fire-fighting systems controls, piping, instructions and marking, checking for evidence of proper maintenance and servicing, including date of last systems tests.
(h) Verification that all portable and semi-portable fire-extinguishers are in their stowed positions, checking for evidence of proper maintenance and servicing, conducting random checks for evidence of discharged containers.
(j) Verification, so far as is practicable, that the remote control for stopping fans and machinery and shutting off fuel supplies in machinery spaces and, where fitted, the remote controls for stopping fans in accommodation spaces and the means of cutting off power to the galley are in good working order.
(k) Examination of the closing arrangements of ventilators, skylights and doorways where applicable.
(l) Verification that the fireman's outfits are complete and in good condition.
(m) Verification that gas installations for domestic purposes comply with the relevant statutory requirements.

2.2.13 For steel yachts a general examination of salt-water ballast tanks, integral sanitary tanks and bilges is to be carried out as required below. If such inspections reveal no visible structural defects then the examination may be limited to a verification that the protective coating remains in GOOD condition as defined in 1.5.6. When considered necessary by the Surveyor thickness measurement of the structure is to be carried out. Where the protective coating is found to be other than in GOOD condition, and it has not been repaired, maintenance of class will be subject to the spaces in question being internally examined and gauged as necessary annually.
(a) For all yachts over five years of age and up to 10 years of age, representative salt water ballast tanks, integral sanitary tanks and bilges are to be generally examined. Where the protective coating is found to be other than in GOOD condition, as defined in 1.5.6, or other defects are found, the examination is to be extended to other spaces of the same type.
(b) For steel yachts over 10 years of age all salt water ballast tanks, integral sanitary tanks and bilges are to be generally examined.

2.2.14 Representative internal spaces including fore and aft peak spaces, machinery spaces, bilges, etc are to be generally examined. These spaces should include all suspect areas, *see* 1.5.3.

2.2.15 In sailing and auxiliary yachts, the mast(s), mast steps, spars, standing and running rigging, rigging screws, chainplates and sails are to be examined so far as is practicable.

Section 3
Docking Surveys and In-water Surveys – Hull and machinery requirements

3.1 General

3.1.1 At Docking Surveys or In-water Surveys the Surveyor is to examine the yacht and machinery, so far as necessary and practicable, in order to be satisfied as to the general condition.

3.2 Docking Surveys

3.2.1 Where a yacht is in dry-dock or on a slipway it is to be placed on blocks of sufficient height and proper staging is to be erected as may be necessary, for the examination of the outside of the hull, rudder(s) and underwater fittings. The outside surface of the hull is to be cleaned as may be required by the Surveyor.

3.2.2 Attention is to be given to parts of the external hull structure particularly liable to structural deterioration from causes such as high stresses, chafing and lying on the ground, and to areas of structural discontinuity.

3.2.3 The following parts of the external hull structure are to be specially examined:
(a) For steel hulls attention is to be given to parts of the structure particularly liable to excessive corrosion and to any undue unfairness of the plating of the bottom. The coating system is to be examined and made good as necessary.
(b) For aluminium alloy hulls attention is to be given to areas adjacent to any bimetallic connections at skin fittings, etc.
(c) For composite hulls the gelcoat or other protective finish is to be examined for surface cracking, blistering or other damage which may impair the efficiency of the protection to the underlying laminate.
(d) For wood hulls the condition of any caulking or sheathing is to be examined as applicable. The condition of external fastenings may require to be confirmed by removal at the discretion of the Surveyor.
(e) For sailing or auxiliary yachts fitted with external ballast, the attachment of bilge or centreline ballast keels is to be examined.

3.2.4 Where required by the Rules, the satisfactory condition of the cathodic protection is to be confirmed.

3.2.5 The clearances in the rudder bearings and pintles are to be measured. Where considered necessary by the Surveyor rudders are to be lifted for examination of the stock. The securing of rudder couplings and/or pintle fastenings is to be confirmed.

3.2.6 The sea connections and overboard discharge valves, their attachments to the hull and the gratings at the sea inlets are to be examined.

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3.2.7 The propeller and fastenings are to be examined. The sternbush is to be examined as far as is practicable.

3.2.8 The clearance in the sternbush or the efficiency of the oil gland is to be ascertained. The clearance of any shaft bracket bearings is to be ascertained.

3.2.9 The inboard shaft seals or glands are to be examined. Where flexible sternglands are fitted, the satisfactory condition of the rubber hose and securing clips is to be confirmed.

3.2.10 Special attention is to be given to the hull in way of underwater fittings such as transverse thrusters, stabilisers, etc.

3.2.11 Where applicable, attention is to be given to the connection and/or intersection of the cross-deck structure to the hulls of multi hull craft.

3.2.12 Where water jet units are fitted, the impeller, hull ducting, grating, nozzle steering and reversing arrangements are to be examined as far as is practicable.

3.2.13 Where transom mounted propulsion units are fitted, the steering arrangements and any flexible transom seals are to be examined.

3.2.14 When chain cables are ranged, the anchors and cables are to be examined by the Surveyor, *see also* 4.3.7 and Table 4.4.1.

3.3 In-water Surveys

3.3.1 The Committee will accept an In-water Survey in lieu of the intermediate docking between Special Surveys required in a five year period on yachts where an ***IWS** notation is assigned, *see* Ch 2,3.8.2.

3.3.2 The Committee may accept an In-water Survey in lieu of the intermediate docking between Special Surveys required in a five year period on yachts where suitable protection is applied to the underwater portion of the hull. If requested, an ***IWS** class notation may be assigned on satisfactory completion of the Survey, provided that the applicable requirements of the Rules are complied with, *see also* Ch 2,3.8.2.

3.3.3 The In-water Survey is to provide the information normally obtained from the Docking Survey, so far as is practicable.

3.3.4 Proposals for In-water Surveys are to be submitted in advance of the survey being required so that satisfactory arrangements can be agreed with LR.

3.3.5 The In-water Survey is to be carried out at agreed geographical locations under the surveillance of a Surveyor to LR, with the yacht in sheltered waters; the in-water visibility is to be good and the hull below the waterline is to be clean. The Surveyor is to be satisfied that the method of pictorial presentation is satisfactory. There is to be good two-way communication between the Surveyor and the diver.

3.3.6 Diving and In-water Survey operations are to be carried out by firms recognised by the Committee. Continued recognition by the Committee will be dependent on the standard of workmanship by the firm being maintained to the satisfaction of LR's Surveyors.

3.3.7 If the In-water Survey reveals damage or deterioration that requires early attention, the Surveyor may require that the yacht be dry-docked in order that a fuller survey can be undertaken and the necessary work carried out.

3.3.8 Where a yacht has an ***IWS** notation, the condition of the high resistant paint is to be confirmed at each dry-docking in order that the ***IWS** notation can be maintained.

3.3.9 Some National Administrations may have requirements additional to those of 3.3.1 to 3.3.8.

■ *Section 4*
Special Survey – General – Hull requirements

4.1 General

4.1.1 The survey is to be of sufficient extent to ensure that the hull and related equipment is in satisfactory condition and is fit for its intended purpose, subject to proper maintenance and operation and to Periodical Surveys being carried out as required by the Regulations.

4.1.2 The requirements of Section 2 are to be complied with so far as applicable.

4.1.3 A Docking Survey in accordance with the requirements of 3.2 is to be carried out as part of the Special Survey.

4.1.4 For sailing and auxiliary yachts fitted with unclassed machinery installations the requirements of 11.3.1 are to be complied with.

4.2 Preparation

4.2.1 The yacht is to be prepared for survey in accordance with the requirements of Table 4.4.1. The preparation should be of sufficient extent to facilitate an examination to ascertain any excessive corrosion, erosion, deformation, fractures, damages and other structural deterioration.

4.2.2 Where, in accordance with Table 4.4.1, the yacht is opened out by removal of linings, cabin sole, etc., and defects are found, further opening out will be required in order that the Surveyor can confirm the full extent of the defects.

4.3 Examination and testing – General

4.3.1 All spaces within the hull and superstructure including integral tanks are to be examined (*see also* 4.4.1 for tank examinations on steel craft). Special attention is to be paid to any suspect areas, *see* 1.5.3.

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Table 4.4.1 Survey preparation

Special Survey I (Yachts 5 years old)	Special Survey II (Yachts 10 years old)	Special Survey III (Yachts 15 years old) and subsequent special surveys
(1) The interior of the yacht is to be sufficiently opened out by the removal of lining, ceiling/cabin sole, portable tanks and ballast, etc as required in order that the Surveyor may be satisfied as to the condition of suspect areas of the structure (*see* 1.5.3). A record is to be made of those areas where lining, cabin sole, etc., were opened out and where equipment was removed during the survey. This record is to be retained for reference during subsequent surveys. (2) Machinery compartments, fore and aft peaks and other spaces as directed by the Surveyor, are to be cleared and cleaned as necessary, and the bilges and limbers all fore and aft are to be cleaned and prepared for examination. Platform plates in engine spaces are to be lifted as may be necessary for the examination of the structure below. Where necessary, pipework may be required to be removed for examination of the structure. (3) In way of the single and/or double bottom areas, a sufficient amount of cabin sole is to be lifted to permit examination of the bilges and/or tanktops below. (4) All integral tanks are to be cleaned as necessary to permit examination. (For steel yachts, *see* Table 4.4.2). (5) In sailing and auxiliary yachts the sails are to be laid out so that they can be properly examined.	In addition to the requirements for Special Survey I, the following are to be complied with: (1) The chain locker is to be cleared and cleaned internally for examination of the structure and examination of the cable securing arrangements. The chain cables/anchor warps, as applicable, are to be ranged for inspection. The anchors are to be cleaned and placed in an accessible position for inspection. (2) The rudder is to be unshipped for examination of the rudder stock and trunk at the discretion of the Surveyor. For sailing or auxiliary yachts: (3) On yachts fitted with an external ballast keel, fastenings are to be drawn for examination as may be required by the Surveyor. (4) On yachts fitted with a centreplate or lifting keel, the pivot bolts and lifting arrangements are to be dismantled for examination as required by the Surveyor. For wood yachts: (5) Where the hull is sheathed with metal, such sheathing as will permit an examination of the stem, wood keel, garboards, plank ends and sternpost is to be removed as required by the Surveyor. (6) Fastenings are to be drawn as may be required by the Surveyor. (7) The outside surface of the planking is to be scraped bright at the discretion of the Surveyor.	In addition to the requirements for Special Survey II the following are to be complied with: (1) Linings, ceiling/cabin soles, etc. are to be removed as required in order that the Surveyor may be satisfied as to the condition of the structure. For steel yachts: (2) Portions of wood sheathing, or other covering, on steel decks are to be removed, as considered necessary by the Surveyor, in order to ascertain the condition of the plating. (3) Where spaces are insulated, sufficient insulation is to be removed in each space to enable the Surveyors to be satisfied with the condition of the structure. (4) Linings are to be removed in way of shell plating immediately above tank top connections to the side shell, in way of galleys/washrooms and beneath portlights and windows. For sailing or auxiliary yachts: (5) The masts are to be unshipped for survey. The whole of the standing rigging, including rigging screws, bolts, pins and fittings, is to be dismantled as considered necessary by the Surveyor. NOTE This requirement may be waived at alternate Special Surveys provided the masts and rigging are thoroughly examined *in situ*. (6) On yachts fitted with an external ballast keel, a minimum of 50% of the total number of ballast keel fastenings are to be drawn for examination as required by the Surveyor. If defects are found the remaining fastenings should be drawn for sexamination. For wood yachts: (7) Where iron or mild steel fastenings are used, as a minimum requirement the following are to be drawn for examination where applicable: • 6 floor arm fastenings each side. • 4 hanging knee fastenings each side. • 4 chain plate fastenings each side at each mast. • 18 frame to plank fastenings each side. • 12 garboard and 12 plank end fastenings each side.

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4.3.2 Double bottom compartments, peak tanks and all other integral tanks are to be tested by a head sufficient to give the maximum pressure that can be experienced in service. Tanks may be tested afloat provided that their internal examination is also carried out afloat.

4.3.3 Where repairs are effected to the hull shell or bulkheads, any integral tanks in way are to be tested to the Surveyor's satisfaction on completion of these repairs.

4.3.4 All decks, casings and superstructures are to be examined.

4.3.5 The satisfactory attachment of any wood or other deck sheathing is to be confirmed, *see also* 4.4.4.

4.3.6 Attention is to be given to the corners of openings and other discontinuities in the hull structure.

4.3.7 The anchors are to be examined. If the chain cables are ranged they are to be examined together with the chain locker, *see* Table 4.4.1. If any length of chain cable is found to be reduced in mean diameter at its most worn part by 12 per cent or more from its nominal diameter, it is to be renewed. The windlass is to be examined.

4.3.8 The Surveyor is to be satisfied that there are suitable towlines and mooring ropes when these are a Rule requirement.

4.3.9 Representative structural fastenings, are to be tested to ascertain their soundness and may require to be drawn for examination at the discretion of the Surveyor.

4.3.10 For yachts to which Pt 17, Ch 1 applies, the Surveyor is to be satisfied as to the efficient condition of the means of escape from crew and passenger spaces, and spaces in which crew are normally employed.

4.4 Examination and testing – Additional items for steel yachts

4.4.1 All integral tanks are generally to be internally examined. However, in certain circumstances the internal examination of lubricating oil, fresh water and oil fuel tanks may be waived. For the minimum extent of tank internal examination, *see* Table 4.4.2.

4.4.2 In salt water ballast spaces, integral sanitary tanks and bilges, where the protective coating is found to be other than in GOOD condition as defined in 1.5.6 and it has not been repaired, maintenance of class will be subject to the spaces in question being internally examined and gauged as necessary annually.

4.4.3 The protection of steelwork, other than as referred to in 4.4.2 should be examined and made good where necessary on satisfactory completion of the survey. In areas where the inner surface of the bottom plating is covered with cement, asphalt or other composition, the removal of this covering may be dispensed with, provided that it is found sound and adhering satisfactorily to the steel.

4.4.4 Wood decks or sheathing are to be examined and the caulking is to be tested and recaulked as necessary. If decay or rot is found, or the wood is excessively worn, the wood is to be renewed. When a wood deck, laid on stringers and ties, has worn by 20 per cent or more in thickness, it is to be renewed. Attention is to be given to the condition of the plating under wood deck sheathing or other deck covering. If it is found that such coverings are broken, or are not adhering closely to the plating, sections are to be removed as necessary to ascertain the condition of the plating, *see also* 1.2.1.

4.4.5 The structure in way of bimetallic connections, e.g. to aluminium alloy deckhouses is to be examined.

Table 4.4.2 Tank internal examination requirements for steel yachts

Tank	Special Survey I (Yachts 5 years old)	Special Survey II (Yachts 10 years old)	Special Survey III (Yachts 15 years old)	Special Survey IV (Yachts 20 years old)	All Subsequent Special Surveys
Peaks	All tanks	All tanks	All tanks	All tanks	All tanks
Salt water ballast	All tanks	All tanks	All tanks	All tanks	All tanks
Lubricating oil	None	None	*See* Note 2	*See* Note 3	All tanks
Fresh water	None	*See* Note 1	*See* Note 2	*See* Note 3	All tanks
Oil fuel	None	*See* Note 1	*See* Note 2	*See* Note 3	All tanks
Sanitary	All tanks	All tanks	All tanks	All tanks	All tanks

NOTES
1. Tanks (excluding peak tanks) used exclusively for oil fuel or fresh water need not all be examined internally provided that the Surveyor is satisfied with the condition, after both external examination and testing and from an internal examination of the after end of one forward double bottom tank, and of one selected deep tank.
2. Tanks (excluding peak tanks) used exclusively for oil fuel, oil fuel and fresh water ballast, or lubricating oil, need not all be examined internally provided that the Surveyor is satisfied with the condition, after both external examination and testing and from an internal examination of one double bottom tank forward and one aft and one deep tank.
3. Tanks (excluding peak tanks) used exclusively for oil fuel, oil fuel and fresh water ballast, or lubricating oil, need not all be examined internally provided that the Surveyor is satisfied with the condition, after both external examination and testing and from internal examination of a least one double bottom tank amidships, one forward and one aft and one deep tank.
4. When examining tanks internally the Surveyor is to verify that striking plates or other additional reinforcement is fitted under sounding pipes. In the case of tanks fitted only with remote gauging facilities, the satisfactory operation of the gauges is to be confirmed.

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4.4.6 The Surveyors may require to measure the thickness of the material in any portion of the structure where signs of wastage are evident or wastage is normally found. Any parts of the structure which are found defective or excessively reduced in scantlings are to be made good by materials of the approved scantlings and quality. The minimum requirements for thickness measurements are given in Section 5.

4.5 Examination and testing – Additional items for aluminium alloy yachts

4.5.1 The structure in way of any bimetallic connections is to be examined and the efficiency of the insulation arrangements confirmed.

4.5.2 The Surveyor may require to measure the thickness of the material in any portion of the structure where signs of deterioration are evident or may normally be found. Any parts of the structure which are found defective or excessively reduced in scantlings are to be made good by materials of the approved scantlings and quality.

4.6 Examination and testing – Additional items for composite yachts

4.6.1 The bonded attachments of frames, floors, bulkheads, structural joinery, engine bearers, sterntubes, rudder tubes, and integral tank boundaries are to be examined.

4.6.2 The hull to deck joint together with any joints between the deck and deckhouses or superstructures are to be examined.

4.6.3 The structure in way of the bolted attachment of fittings including guardrail stanchions, windlass, shaft brackets, fendering, mooring bitts, mast steps, rigging chainplates, etc., is to be examined.

4.7 Examination and testing – Additional items for wood yachts

4.7.1 Where hulls are provided with metal sheathing, the condition of the structure in way of any sheathing is to be confirmed. For the extent of removal of metal sheathing *see* Table 4.4.1. The satisfactory adhesion of any glass/nylon reinforced plastic sheathing is also to be confirmed.

4.7.2 Wood decks or sheathing are to be examined and the caulking is to be tested and re-caulked as necessary. If decay or rot is found or the wood has worn by 20 per cent or more in thickness, the wood is to be renewed. Attention is to be given to the condition of the structure under wood decks, and to fabric deck coverings. If it is found that such coverings are damaged or are not adhering closely to the deck, sections are to be removed as necessary to ascertain the condition of the deck under.

4.7.3 Fastenings as may be required by the Surveyor are to be drawn for examination, *see* Table 4.4.1.

4.8 Examination and testing – Additional items for sailing and auxiliary yachts

4.8.1 The mast(s), mast steps, spars, standing and running rigging, rigging screws, chainplates and sails are to be examined, *see* Table 4.4.1.

4.8.2 The structure in way of the attachment of bilge or centreline ballast keels is to be examined. Ballast keel bolts are to be tested to ascertain their soundness and may require to be drawn for examination, *see* Table 4.4.1.

4.8.3 On yachts fitted with a centreplate or lifting keel, the pivot bolt and lifting arrangements are to be examined as far as is practicable.

■ *Section 5*
Special Survey – Thickness measurement requirements for steel yachts

5.1 General

5.1.1 Thickness measurements, as required by Section 4 are to be carried out in accordance with the following requirements.

5.1.2 Thickness measurements are to be taken at the forward and aft areas of all plates. In all cases the measurements are to represent the average of the multiple measurements taken on each plate. The extent of local substantial corrosion of plates is to be established by intensive measurement in the affected areas. Where measured plates are renewed, the thicknesses of adjacent plates in the same strake are to be reported.

5.1.3 Thickness measurements are normally to be by means of ultrasonic test equipment and are to be carried out by a firm qualified as Grade 1 or Grade 2 according to LR's *Approval for Thickness Measurement of Hull Structures* or by the Surveyor.

5.1.4 The degree of supervision or check testing by the Surveyor is dependent upon the grade of approval extended to the firm carrying out the thickness measurements:

(a) The work of firms having Grade 1 approval is subject to check testing by the Surveyor.

(b) Thickness measurements by firms having Grade 2 approval is to be carried out with the Surveyor substantially in attendance.

5.1.5 Thickness measurements may be carried out in association with the fourth Annual Survey.

5.1.6 The minimum requirements for thickness measurement are indicated in Table 4.5.1.

5.1.7 The Surveyor may extend the scope of thickness measurement if deemed necessary.

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Table 4.5.1 Thickness measurement of steel yachts

Special Survey I (Yachts 5 years old)	Special Survey II (Yachts 10 years old)	Special Survey III (Yachts 15 years old)	Special Survey IV and subsequent (Yachts 20 years old and over)
Suspect areas, as required by the Surveyor and may include areas where the coatings are found to be other than in GOOD condition, *see* Note 1.	Suspect areas, as required by the Surveyor and may include areas where the coatings are found to be other than in GOOD condition, *see* Note 1.	(1) Any exposed plating throughout the Main Deck. (2) Shell plating in way of the waterline throughout the length of the craft. (3) Suspect areas, as required by the Surveyor may include areas where the coatings are found to be other than in GOOD condition, *see* Note 1.	(1) All Main Deck plating outside deckhouses or superstructures and including plating in way of wood deck planking or sheathing. (2) Shell plating in way of, and below, the waterline throughout the length of the craft. (3) 2 transverse sections of deck and shell plating within 0,5*L* amidships. (4) Suspect areas, as required by the Surveyor and to include as applicable: (a) Areas where the coatings are found to be other than in GOOD condition. (b) Shell and tanktop plating immediately adjacent to tank top margins. (c) Bottom shell in way of any cement, asphalt or other composition. (d) Shell plating below portlights and windows. (e) Tanktop plating below ceiling or cabin soles. (f) Deck plating and side shell plating in way of galleys, washrooms and refrigerated store spaces. (g) Structure in way of integral sanitary tanks.

NOTES
1. Suspect areas are locations within the hull structure vulnerable to increased likelihood of structural deterioration and may include, for steel hulls, areas of substantial corrosion and/or fatigue cracking, *see also* 1.5.3 and 4.4.6.
2. Coating condition for steel craft is defined in 1.5.6.

5.2 Thickness measurement reporting

5.2.1 A report is to be prepared by the approved firm carrying out the thickness measurement. The report is to give the location of measurement, the thickness measured as well as the corresponding original thickness. The report is to give the date when the measurement was carried out, the type of measuring equipment, names of personnel and their qualifications and is to be signed by the operator and supervisor.

5.2.2 The thickness measurement report is to be verified and signed by the Surveyor.

■ *Section 6* Machinery surveys – General requirements

6.1 Intermediate and Docking Surveys

6.1.1 For Intermediate and Docking Surveys, *see* Sections 2 and 3.

6.1.2 For yachts where an Approved Planned Maintenance Scheme is in operation an Annual Survey of the machinery is to be carried out together with an audit of the maintenance and monitoring records.

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6.2 Complete Surveys

6.2.1 While the yacht is in dry-dock, all openings to the sea in the machinery spaces and pump-rooms, together with the valves, cocks and the fastenings with which these are connected to the hull, are to be examined. For athwartships thrust propellers, *see* 10.1.8.

6.2.2 Athwartships thrust propellers are to be generally examined as far as is possible in dry dock and tested under working conditions afloat for satisfactory operation.

6.2.3 All shafts (except screwshafts and tube shafts, for which special arrangements are detailed in Section 10), thrust block and all bearings are to be examined. The lower halves of bearings need not be exposed if alignment and wear are found to be acceptable.

6.2.4 An examination is to be made as far as practicable of all propulsion gears complete with all wheels, pinions, shafts, bearings and gear teeth, thrust bearings and incorporated clutch arrangements.

6.2.5 The following auxiliaries and components are also to be examined:

(a) Auxiliary engines, auxiliary air compressors with their intercoolers, filters and/or oil separators and safety devices, and all pumps and components used for essential services.
(b) Steering machinery.
(c) Windlass and associated driving equipment, where fitted.
(d) The holding down bolts, chocks or resilient mounts of main and auxiliary engines, gearcases, thrust blocks and intermediate shaft bearings.

6.2.6 All air receivers for essential services, together with their mountings, valves and safety devices, are to be cleaned internally and examined internally and externally. If internal examination of the air receivers is not practicable, they are to be tested hydraulically to 1,3 times the working pressure.

6.2.7 The valves, cocks and strainers of the bilge system including bilge injection, are to be opened up as considered necessary by the Surveyor and together with pipes, are to be examined and tested under working conditions. The oil fuel, feed, lubricating oil and cooling water systems also any ballast connections together with all pressure filters, heaters and coolers used for essential services, are to be opened up and examined or tested, as considered necessary by the Surveyor. All safety devices for the foregoing items are to be examined.

6.2.8 Fuel tanks which do not form part of the yacht's structure are to be examined, and if considered necessary by the Surveyor, they are to be tested to the pressure specified for new tanks. The tanks need not be examined internally at the first survey if they are found satisfactory on external inspection. The mountings, fittings and remote controls of all oil fuel tanks are to be examined, so far as is practicable.

6.2.9 Where remote and/or automatic controls are fitted for essential machinery, they are to be tested to demonstrate that they are in good working order.

6.2.10 In addition to the above, detailed requirements for gas turbines and oil engines and electrical installations are given in Sections 7, 8 and 9 respectively. In certain instances, upon application by the Owner or where indicated by the maker's servicing recommendations, the Committee will give consideration to the circumstances where deviation from these detailed requirements is warranted, taking account of design, appropriate indicating equipment (e.g. vibration indicators) and operational records, *see* Ch 2,4.5.17 and 4.5.23.

■ *Section 7*
Gas turbines – Detailed requirements

7.1 Complete Surveys

7.1.1 The requirements of Section 6 are to be complied with. *See* 6.2.10 regarding any deviation from the following.

7.1.2 The following parts are to be opened out and examined:

- Compressor including impellers or blading, rotors and casing.
- Combustion chambers, burners, intercoolers and heat exchangers.
- Gas, air and fuel piping and fittings.
- Gas generator turbine and power turbine blading, rotors and casing.
- Rotors to include couplings, clutches, bearings and tie bolts.
- Auxiliary mounted fuel, L.O. and cooling water pumps, their drive transmissions and fittings.
- Starting system (for starting air pipes, *see* 8.1.3).
- All safety devices and local controls.
- Mountings and support frame.

7.1.3 The compressor/turbine units are to be operated and maintained in accordance with the manufacturer's instructions. Overhauls, including the prescribed replacement of limited life components, are to be undertaken at the specified intervals. Full service records are to be available for review by the Surveyor.

7.1.4 The manoeuvring of the propulsion system is to be tested under working conditions.

■ *Section 8*
Oil engines – Detailed requirements

8.1 Complete Surveys

8.1.1 The requirements of Section 6 are to be complied with. *See* 6.2.10 regarding any deviation from the following.

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8.1.2 The following parts are to be opened out and examined:

- Cylinders and covers.
- Valves and valve gear.
- Pistons and connecting rods.
- Crankshafts and all bearings
- Crankcases and entablatures.
- Crankcase door fastenings and explosion relief devices.
- Turbo-chargers and their associated coolers.
- Air compressors and their intercoolers.
- Filters and/or separators and safety devices.
- Fuel pumps and fittings.
- Camshaft drives and balancer units.
- Vibration dampers or detuners.
- Flexible couplings and clutches.
- Reverse gears.
- Attached pumps and cooling arrangements.

8.1.3 Selected pipes in the starting air system, if fitted, are to be removed for internal examination and are to be hammer tested. If any appreciable amount of lubricating oil is found in the pipes, the starting air system is to be thoroughly cleaned internally by steaming out, or other suitable means. Some of the pipes selected are to be those adjacent to the starting air valves at the cylinders and to the discharges from the air compressors.

8.1.4 The electric ignition system, if fitted, is to be examined and tested.

8.1.5 The manoeuvring of engines is to be tested under working conditions. Initial starting arrangements are to be tested.

■ *Section 9* Electrical equipment

9.1 Intermediate Surveys

9.1.1 The requirements of 2.2.9 and 2.2.13 are to be complied with as far as applicable.

9.2 Complete Surveys

9.2.1 An electrical insulation resistance test is to be made on the electrical equipment and cables. The installation may be sub-divided or equipment, which may be damaged, disconnected for the purpose of this test.

9.2.2 The fittings on the main and emergency switch-boards, section boards and distribution boards are to be examined and over-current protective devices and fuses inspected to verify that they provide suitable protection for their respective circuits.

9.2.3 Generator circuit-breakers are to be tested, so far as is practicable, to verify that protective devices including preference tripping relays, if fitted, operate satisfactorily.

9.2.4 The electric cables and their securing arrangements are to be examined, so far as is practicable, without undue disturbance of fixtures or casings unless opening up is considered necessary as a result of observation or of the tests required by 9.2.1.

9.2.5 The generator prime movers are to be surveyed as required by Sections 7 and 8 and the governing of the engines tested. The motors concerned with essential services together with associated control and switch gear are to be examined and if considered necessary, are to be operated, so far as is practicable, under working conditions. All generators and steering gear motors are to be examined and are to be operated under working conditions, though not necessarily under full load or simultaneously.

9.2.6 Where transformers or electrical apparatus associated with supplies to essential services are liquid filled or cooled by a liquid in direct contact with current carrying parts, the owner is to arrange for samples of the liquid to be taken and tested, by a competent authority, in accordance with the equipment manufacturer's requirements, and a certificate giving the test results is to be furnished to the Surveyor.

9.2.7 Navigation light indicators are to be tried under working conditions, and correct operation on the failure of supply or failure of navigation lights verified.

9.2.8 The emergency sources of electrical power, where fitted, together with their automatic arrangements and associated circuits are to be tested.

9.2.9 Emergency lighting, transitional emergency lighting, supplementary emergency lighting, general emergency alarm and public address systems are to be tested as far as practicable.

9.2.10 Where the yacht is electrically propelled, the propulsion motors, generators, cables and all ancillary electrical gear, exciters and ventilating plant (including coolers) associated therewith are to be examined, and the insulation resistance to earth is to be tested. Special attention is to be given to windings, commutators and slip-rings. The operation of protective gear and alarm devices is to be checked, so far as is practicable. Liquids for filling and cooling, if used, are to be tested in accordance with 9.2.6. Interlocks intended to prevent unsafe operations or unauthorised access are to be checked to verify that they are functioning correctly. Emergency overspeed governors are to be tested.

9.2.11 Where batteries provide the source of power for any essential services, their installation, including charging and ventilation, is to be examined.

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Section 10
Screwshafts, tube shafts, propellers and water jet units

10.1 Frequency of surveys

10.1.1 Shafts with keyed propeller attachments and fitted with continuous liners or approved oil glands, or made of approved corrosion resistant materials, are to be surveyed at intervals of five years when the keyway complies fully with the present Rules.

10.1.2 Shafts having keyless type propeller attachments are to be surveyed at intervals of five years provided they are fitted with approved oil glands or are made of approved corrosion resistant materials.

10.1.3 Shafts having solid coupling flanges at the after end are to be surveyed at intervals of five years provided they are fitted with approved oil glands or are made of approved corrosion resistant materials.

10.1.4 All other shafts not covered by 10.1.1 to 10.1.3 are to be surveyed at intervals of $2^1/_2$ years.

10.1.5 Controllable pitch propellers for main propulsion purposes are to be surveyed at the same intervals as the screwshaft.

10.1.6 Directional propeller units for main propulsion purposes are to be surveyed at intervals not exceeding five years.

10.1.7 Water jet units for main propulsion purposes are to be surveyed at intervals not exceeding five years provided the impeller shafts are made of approved corrosion resistant material or have approved equivalent arrangements.

10.1.8 Athwartship thrust propellers and shaftings are to be surveyed at intervals not exceeding five years, *see* 6.2.2.

10.2 Normal surveys

10.2.1 All screwshafts are to be withdrawn for examination by LR's Surveyors at the intervals prescribed in 10.1.1 to 10.1.4. The after end of the cylindrical part of the shaft and forward one third of the shaft cone, or fillet of the flange, is to be examined by a magnetic particle crack detection method. In the case of a keyed propeller attachment at least the forward one third of the shaft cone is to be examined with the key removed. Weardown is to be measured and the sterntube bearings, oil glands, propellers and fastenings are to be examined. Controllable pitch propellers where fitted are to be opened up and the working parts examined, together with the control gear.

10.2.2 Directional propeller units are to be dismantled for examination of the propellers, shafts, gearing and control gear.

10.2.3 Water jet units are to be dismantled for examination of the impeller, casing, shaft, shaft seal, shaft bearing, inlet and outlets channels, steering nozzle, reversing arrangements, and control gear.

10.3 Screwshaft Condition Monitoring (SCM)

10.3.1 Where oil lubricated shafts with approved oil glands are fitted, and the Owner has complied with the following requirements, the descriptive note **SCM** (Screwshaft Condition Monitoring) may be assigned:

(a) Lubricating oil analysis to be carried out regularly at intervals not exceeding six months. The lubricating oil analysis documentation is to be available on board. Each analysis is to include the following minimum parameters:
- water content
- chloride content
- bearing material and metal particles content
- oil ageing (resistance to oxidation).

(b) Oil samples are to be taken under service conditions and are to be representative of the oil within the sterntube.

(c) Oil consumption is to be recorded.

(d) Bearing temperatures are to be recorded, (two temperature sensors or other approved arrangements are to be provided).

(e) Facilities are to be provided for measurement of bearing weardown.

(f) Oil glands are to be capable of being replaced without withdrawal of the screwshaft.

10.3.2 For maintenance of the descriptive note **SCM**, the records of analyses, consumption and temperatures, together with weardown readings are to be retained on board and audited annually.

10.3.3 Where the requirements for the descriptive note **SCM** have been complied with, the screwshaft need not be withdrawn at surveys as required by 10.2.1 provided all condition monitoring data is found to be within permissible limits and all exposed areas of the shaft are examined by a magnetic particle crack detection method. The remaining requirements of 10.2.1 are to be complied with. Where the Surveyor considers that the data presented is not entirely to his satisfaction the shaft will be required to be withdrawn in accordance with 10.2.1.

10.4 Modified Survey

10.4.1 A Modified Survey may be accepted at alternate five-yearly surveys for shafts described in 10.1.1 provided they are fitted with oil lubricated bearings and approved oil glands, and also for those in 10.1.2 and 10.1.3.

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10.4.2 The Modified Survey is to consist of the partial withdrawal of the shaft, sufficient to ascertain the condition of the stern bearing and shaft in way. For keyless propellers or shafts with a solid flange connection to the propeller a visual examination to confirm the good condition of the sealing arrangements is to be made. The oil glands are to be capable of being replaced without removal of the propeller. The forward bearing and all accessible parts including the propeller connection to the shaft are to be examined as far as possible.

Wear-down is to be measured and found satisfactory. Where a controllable pitch propeller is fitted, at least one of the blades is to be dismantled complete for examination of the working parts and the control gear.

10.4.3 For keyed propellers, the after end of the cylindrical part of the shaft and forward one third of the shaft cone is to be examined by a magnetic particle crack detection method, for which dismantling of the propeller and removal of the key will be required.

10.4.4 Where the descriptive note **SCM** has been assigned as described in 10.3.1 and all data is found to be within permissible limits, partial withdrawal of the shaft may not be required. Where doubt exists regarding any of the above findings the shaft is to be withdrawn to permit an entire examination.

10.5 Partial Survey

10.5.1 For shafts where the Modified Survey is applicable, upon application by the Owner, the Committee will be prepared to give consideration to postponement of the survey for a maximum period of half the specified cycle provided a Partial Survey is held.

10.5.2 The Partial Survey is to consist of the propeller being backed off in any keyed shaft and the top half of the cone examined by an efficient crack detection method for which removal of the key will be required. Oil gland and seals are to be examined and dealt with as necessary. Weardown is to be measured and found satisfactory. Propeller and fastenings are to be examined.

10.5.3 The Committee will be prepared to give consideration to the circumstances of any special case upon application by the Owner.

■ *Section 11* Surveys of unclassed machinery in existing classed yachts

11.1 General

11.1.1 The requirements of this survey are considered necessary in order to establish, so far as practicable, that the unclassed machinery installation does not constitute a hazard to the classed hull. The survey is applicable only to existing sailing yachts fitted with unclassed auxiliary propulsion engines not exceeding 37 kW.

11.1.2 At any time when unclassed machinery in an existing classed yacht is undergoing alteration and/or replacement, the requirements of Ch 2,4.4.6 are to be complied with.

11.2 Intermediate and Docking Surveys

11.2.1 For Intermediate and Docking Surveys, *see* Sections 2 and 3.

11.3 Complete Surveys

11.3.1 At each Special Survey of the hull the requirements of 11.2.1 and the following are to be complied with:

(a) The bilge pumping system is to be examined and tested under working conditions.
(b) A general examination is to be made of the fuel tanks and fuel system with their valves, pipes and fittings, and of the engine exhaust system, piping and fittings.
(c) A general examination of the electrical equipment is to be made and, if considered necessary, a test of the insulation resistance is to be carried out in accordance with 9.2.1.
(d) The starting arrangements are to be examined.
(e) The screwshafts and tube shafts are to be withdrawn for examination.
(f) The main and essential auxiliary machinery is to be examined under full working conditions in accordance with 8.1.4.

■ *Section 12* Classification of yachts not built under survey

12.1 General

12.1.1 When classification is desired for a yacht not built under the supervision of LR's Surveyors, application should be made to the Committee in writing.

12.1.2 Periodical Surveys of such yachts, when classed, are subsequently to be held as in the case of yachts built under survey.

12.1.3 Where classification is desired for a yacht which is classed by another recognised Society, special consideration will be given to the scope of the survey.

12.2 Hull and equipment

12.2.1 Plans showing the main scantlings and arrangements of the actual yacht together with any proposed alterations are to be submitted for approval.These should comprise plans of the midship section, longitudinal section and decks, and such other plans as may be requested. If plans cannot be obtained or prepared by the Owner, facilities are to be given for LR's Surveyor to obtain the necessary information from the yacht.

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12.2.2 Particulars of the process of manufacture and the testing of the material of construction are to be supplied. The requirements for composite yachts will be specially considered.

12.2.3 The full requirements of Sections 4 and 5 are to be carried out as applicable. Yachts of recent construction will receive special consideration.

12.2.4 During the survey, the Surveyors are to satisfy themselves regarding the workmanship and verify the approved scantlings and arrangements. For this purpose, and also in order to ascertain the amount of any deterioration of steel yachts, parts of the structure will require to be gauged as necessary. Full particulars of the anchors, chain cables and equipment are to be submitted. For yachts to which Pt 17, Ch 1 applies, fire protection, detection and extinction are to be in accordance with the Rules.

12.2.5 When the full survey requirements indicated in 12.2.3 and 12.2.4 cannot be completed at one time, the Committee may consider granting an interim record for a limited period. The conditions regarding the completion of the survey will depend on the merits of each particular case, which should be submitted for consideration.

12.3 Machinery

12.3.1 To facilitate the survey, the following plans and particulars (plans of piping are to be diagrammatic), together with the particulars of the materials used in the construction of any boilers, air receivers and important forgings are to be submitted:

- Name of manufacturer of engine and gearbox including the manufacturer's type designation of engine and gearbox, together with the continuous shaft power of the engine at the crankshaft coupling with the revolutions per minute of crankshaft and propeller.
- General pumping arrangements, including air and sounding pipes (Builder's plan).
- Bilge, ballast and oil fuel pumping arrangements including the capacities of the pumps on bilge service.
- Arrangement and dimensions of any steam pipes.
- Arrangement of oil fuel pipes and fittings at settling and service tanks.
- Arrangement of oil fuel piping in connection with oil burning installations.
- Oil fuel overflow systems, where these are fitted.
- Arrangement of boiler feed systems.
- Oil fuel settling, service and other oil fuel tanks not forming part of the craft's structure.
- Boilers and economisers.
- Air receivers.
- Crank, thrust, intermediate and screw shafting.
- Details of water jet or directional propeller units, if fitted.
- Clutch and reversing gear with methods of control.
- Reduction gearing.
- Propeller (including spare propeller if supplied) where the diameter exceeds 1m.
- Electrical circuits.
- Arrangement of compressed air systems for main and auxiliary services.
- Arrangement of lubricating oil, other flammable liquids and cooling water systems for main and auxiliary services.
- Steering gear including control arrangement.
- Arrangement of exhaust system indicating materials, method of cooling, and if water spray injected, the method of draining.

12.3.2 Plans additional to those detailed in 12.3.1 are not to be submitted unless the machinery is of a novel or special character affecting classification.

12.3.3 Where remote and/or automatic controls are fitted to propulsion machinery and essential auxiliaries, a description of the scheme is to be submitted.

12.3.4 For new yachts and yachts which have been in service less than two years, calculations of the torsional vibration characteristics of the propelling machinery are to be submitted for consideration, as required for yachts constructed under Special Survey. For older yachts the circumstances will be specially considered in relation to their service record and type of machinery installed. Where calculations are not submitted, the Committee may require that the machinery certificate be endorsed to this effect. When desired by the Owner, the calculations and investigation of the torsional vibration characteristics of the machinery may be carried out by LR upon special request.

12.3.5 The main and auxiliary machinery, feed pipes, compressed air pipes and boilers are to be examined as required at Complete Surveys. Working pressures are to be determined from the actual scantlings in accordance with the Rules.

12.3.6 The screwshaft is to be drawn and examined.

12.3.7 Any steam pipes or oil burning installations are to be examined and tested as required by Pt 1, Ch 3,15 or Ch 3,16 of the *Rules and Regulations for the Classification of Ships*.

12.3.8 The bilge, ballast and oil fuel pumping arrangements are to be examined and amended, as necessary, to comply with the Rules.

12.3.9 The electrical equipment is to be examined as required at Complete Surveys.

12.3.10 The whole of the machinery, including essential controls, is to be tried under working conditions to the Surveyor's satisfaction.

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Periodical Survey Regulations for Amphibious Air Cushion Vehicles (ACV)

Section

1 **General**

2 **Annual Surveys – Hull and machinery requirements**

3 **Intermediate Surveys – Hull and machinery requirements**

4 **Special Surveys (Hull and machinery)**

5 **Classification of ACVs not built under survey**

Section 1
General

1.1 Frequency of surveys

1.1.1 Except as amended at the discretion of the Committee, the periods between surveys are as follows:

(a) Annual Surveys are to be held within three months before or after each anniversary of the completion, commissioning or Special Survey.

(b) Intermediate Surveys are to be held instead of the second or third Annual Survey after completion, commissioning or Special Survey.

(c) Special Surveys (hull and machinery) are to be held at the fifth anniversary after completion, commissioning or previous Special Survey.

1.2 Machinery surveys

1.2.1 The manufacturer's approved operating and service instructions for the main and auxiliary power units, transmission systems, propellers and lift fans are to be incorporated into an approved planned maintenance scheme for the ACV.

1.2.2 Maintenance, overhaul or replacement will then normally be determined by the specified condition/performance monitoring limits and running hours.

1.2.3 It is a requirement of this arrangement that any significant defect, damage repair or alteration be reported to Lloyd's Register (hereinafter referred to 'LR') without delay, *see also* Ch 2,1.1.7.

1.3 Surveys for damage, repairs or alterations

1.3.1 At any time when an ACV is undergoing alterations or damage repairs, any exposed parts of the structure normally difficult to access are to be specially examined, e.g. if any part of the main or auxiliary machinery is removed for any reasons, the hull structure in way is to be carefully examined by the Surveyor.

1.3.2 All significant repairs, alterations, approved modifications and replacements are to be recorded in the ACV's Log Books in a manner that will enable their later identification by the Surveyors, *see also* Ch 2,4.4.1 and 4.4.6.

1.3.3 Trials are to be made on any craft which have been significantly modified, overhauled or repaired, prior to returning to service, to ensure to the Surveyor's satisfaction that the ACV has been returned in a satisfactory condition for its intended service.

1.4 Unscheduled surveys

1.4.1 In the event that LR has cause to believe that its Rules and Regulations are not being complied with, LR reserves the right to perform unscheduled surveys of the hull or machinery.

1.5 Surveys for the issue of Convention Certificates

1.5.1 Surveys are to be held either by LR when so appointed or by the Exclusive Surveyors of a National Administration when so delegated by a Flag State.

Section 2
Annual Surveys – Hull and machinery requirements

2.1 General

2.1.1 Annual Surveys are to be held concurrently with any relevant statutory annual or other statutory surveys, wherever practicable.

2.1.2 The Surveyor is to audit the approved planned maintenance scheme. The records will be checked and the satisfactory operation of the scheme verified. Condition monitoring data will be reviewed and trends analysed.

2.1.3 The Surveyor is to examine the Log Book to verify that a proper record has been kept in respect of servicing, maintenance and overhaul requirements for those aspects not covered by the approved planned maintenance scheme.

2.1.4 Certification for replacement units/parts will be required.

2.2 Preparation

2.2.1 The ACV is to be slung or jacked up to permit a thorough inspection of all underside parts, fittings and attachments.

2.2.2 Panelling, floor coverings, etc. need not be removed at these surveys, unless they are of portable type or unless the Surveyor has reason to suspect they may conceal significant damage.

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2.3 Hull items

2.3.1 The Surveyor is to be satisfied as to the efficient condition of the following items:

(a) Bottom and side plating, any external stiffeners, and side walls or skirts, including flexible keels, if any.
(b) Weather doors, ventilators, windows and emergency or other hatches.
(c) Weather decks, houses, etc.
(d) Machinery casings and seats.
(e) Anchoring and mooring equipment when required by the Rules.
(f) Fire equipment including fire detection, alarm systems and means of escape , where the survey of such items is not covered by statutory certification.
(g) Where applicable, passenger seat foundations and cargo tie down points.
(h) Skirt attachment and operating mechanisms.
(j) Air propeller shroud structures.
(k) Side body attachments and supports (when fitted).
(l) Operation of ramps, and their closing and locking arrangements.
(m) The structural attachment and retention arrangements for external fuel tanks (when fitted).

2.4 Machinery items

2.4.1 The Surveyor is to be satisfied as to the efficient condition of the following items:

(a) Fuel tanks and associated fuel system with pumps, filters, etc.
(b) Lubricating oil tanks and associated lubricating system with coolers, pumps, filters, etc.
(c) The bilge pumping system.
(d) Machinery alarm arrangements.
(e) The electrical machinery, the switchgear and other electrical equipment are to be generally examined under operating conditions so far as practicable. The satisfactory operation of the emergency source of power, including the automatic controls as fitted, is to be verified.
(f) Hydraulic, electrical and pneumatic control systems, including steering, are to be examined under operating conditions.
(g) Engine starting arrangements.
(h) All drive belts, associated running surfaces and tension adjustment (where fitted).
(j) Air propellers, including (where fitted) hub assemblies, servos and actuating equipment of controllable pitch propellers.
(k) The overall operation of the machinery including propulsion and lift machinery. A machinery proving trial of short duration is to demonstrate to the Surveyor the satisfactory operation of the machinery.

■ *Section 3*
Intermediate Surveys – Hull and machinery requirements

3.1 General

3.1.1 The requirements of Section 2 are to be complied with.

3.2 Preparation

3.2.1 A sufficient amount of panelling, floor covering, insulation and paint etc., is to be removed to enable the Surveyors to satisfy themselves that all major structural items are in a satisfactory condition.

3.3 Examination and testing

3.3.1 Representative integral tanks and buoyancy spaces are to be examined as necessary to ensure that they continue to be in a satisfactory condition.

3.3.2 At the discretion of the Surveyor, tanks or buoyancy spaces may require to be tested to ensure that they continue to be tight.

■ *Section 4*
Special Surveys (Hull and machinery)

4.1 General

4.1.1 The requirements of Sections 2 and 3 are to be complied with.

4.2 Hull Surveys

4.2.1 All integral tanks and buoyancy spaces are to be examined and tested to ensure that they continue to be tight and in a satisfactory condition.

4.2.2 All other hull compartments are to be examined.

4.2.3 The anchoring and mooring equipment, when required by the Rules, is to be examined to ensure its efficiency, accessibility and readiness for use. Anchor cables or warps are to be ranged for examination.

4.3 Machinery Surveys

4.3.1 The main and essential auxiliary machinery is to be generally examined with particular attention given to safety devices, fastening arrangements and resilient mountings. A limited opening up, e.g. removal of inspection covers, should be undertaken in order that the Surveyor can confirm the satisfactory condition of these items.

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4.3.2 Where not carried out as a regular monitoring procedure, lubricating oil analysis may be required.

4.3.3 Items that have not been overhauled as part of the approved planned maintenance scheme since installation, commissioning or the previous Special Survey may require to be opened up for examination.

4.3.4 The insulation resistance of the electrical equipment and connections is to be tested.

■ *Section 5* Classification of ACVs not built under survey

5.1 General

5.1.1 The requirements for classification of an ACV not built under the supervision of LR's Surveyors are to be in accordance with the applicable sub-Sections of Pt 1, Ch 3,12.

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Rules for the Manufacture, Testing and Certification of Materials

July 2012

Lloyd's Register

LIFE MATTERS

002191

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A guide to the Rules

and published requirements

Rules for the Manufacture, Testing and Certification of Materials

Introduction

The Rules are published as a complete set; individual Parts are, however, available on request. A comprehensive List of Contents is placed at the beginning of each Part.

Numbering and Cross-References

A decimal notation system has been adopted throughout. Five sets of digits cover the divisions, i.e. Part, Chapter, Section, sub-Section and paragraph. The textual cross-referencing within the text is as follows, although the right hand digits may be added or omitted depending on the degree of precision required:

(a) In same Chapter, e.g. *see* 2.1.3 (i.e. down to paragraph).

(b) In another set of Lloyd's Register Rules, e.g. *see* Pt 5, Ch 3,2.1 of the Rules and Regulations for the Classification of Ships.

The cross-referencing for Figures and Tables is as follows:

(a) In same Chapter, e.g. as shown in Fig. 2.3.5 (i.e. Chapter, Section and Figure Number).

(b) In another set of Lloyd's Register Rules, e.g. *see* Table 2.7.1 in Pt 3, Ch 2 of the Rules and Regulations for the Classification of Special Service Craft.

Rules updating

The Rules are generally published annually and changed through a system of Notices. Subscribers are forwarded copies of such Notices when the Rules change.

Current changes to Rules that appeared in Notices are shown with a black rule alongside the amended paragraph on the left hand side. A solid black rule indicates amendments and a dotted black rule indicates corrigenda.

July 2012

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■ *Section 1* Scope

1.1 General

1.1.1 Materials used for the construction, conversion, modification or repair of ships, other marine structures and associated machinery which are classed or are intended for classification by Lloyd's Register (hereinafter refered to as LR), are to be manufactured, tested and inspected in accordance with these Rules.

1.1.2 Wrought, cast and extruded materials are to comply with the requirements of Chapters 1 and 2, and the appropriate specific requirements of Chapters 3 to 9 of these Rules. Mooring and anchoring equipment is to comply with the requirements of Chapters 1 and 2, and the appropriate specific requirements of Chapter 10. Manufacturers of these materials must be approved by LR according to the requirements in Sections 2 or 3. Only those materials within a manufacturer's scope of approval may be used.

1.1.3 Welding consumables are to comply with the requirements of Chapter 11 of these Rules.

1.1.4 Where welding is used for the construction, conversion, modification or repair of ships, other marine structures and associated machinery which are classed or are intended for classification by LR, welding qualifications and tests shall be performed according to Chapter 12 of these Rules. All welding shall be performed according to Chapter 13 of these Rules.

1.1.5 Plastics materials are to comply with the requirements of Chapter 14 of these Rules.

1.1.6 The materials and components which are to comply with these requirements for the purposes of classification are defined in the relevant Rules dealing with design and construction.

■ *Section 2* Approval and survey requirements

2.1 Approval and survey requirements – General

2.1.1 Marine materials manufactured in accordance with Chapters 3 to 10 of these Rules are to be made at works which have been approved by LR for the type and grade of product being supplied.

2.1.2 Materials manufactured in accordance with Chapters 3 to 10 of these Rules are to be manufactured, tested and inspected under Survey according to the requirements of one of the following two schemes:
(a) The Materials Survey Scheme, *see* 2.3.
(b) The Materials Quality Scheme, *see* 2.4.

2.1.3 For the purposes of survey, LR Surveyors are to be allowed access to all relevant parts of the works, and are to be provided with the necessary facilities and information to enable them to verify that the manufacture is being carried out in accordance with the approved procedures. Facilities are also to be provided for the selection of test material, the witnessing of mechanical tests and the examination of materials, as required by these Rules.

2.1.4 Where a production process, testing or examination of materials is sub-contracted, this must be with the approval of LR. Surveyors are to be allowed access to the sub-contractor's premises in order to conduct Surveys according to the requirements of these Rules.

2.1.5 Products manufactured in accordance with Chapters 11 and 14 are to be approved in accordance with the requirements therein. For these materials, approval is given for a specific product on a type approval basis, rather than the approved manufacturer/survey arrangements applied to materials covered by Chapters 3 to 10.

2.2 LR Approval – General

2.2.1 Unless specifically stated in other Chapters of these Rules, all LR approvals apply to materials used in applications intended for marine service, as described in 1.1.

2.2.2 The procedures for application for approval of manufacturers and products, the details of the information to be supplied by the manufacturer, and the test programme to be conducted on the products are given in the appropriate book of LR's *Materials and Qualification Procedures for Ships* (MQPS). This is published in the CD Live section of LR's web site at http://www.lr.org.

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2.2.3 LR publishes lists of approved manufacturers and approved products. The lists are published in the CD Live section of LR's website, http://www.lr.org.
The lists are as follows:

- *List of Approved Manufacturers of Materials*.
- *Approved Welding Consumables for Use in Ship Construction*.
- *Lists of Paints, Resins, Reinforcements and Associated Materials*.
- *Lists of Approved Anchors*.

2.2.4 For initial LR approval as an Approved Manufacturer for a particular material, the manufacturer is required to demonstrate to the satisfaction of LR, that the necessary manufacturing and testing facilities are available, and are supervised by suitably qualified personnel. A specified programme of tests is to be carried out under the supervision of LR Surveyors, and the results are to be to the satisfaction of LR.

2.2.5 If the results of the initial assessment of the manufacturer, and the test programme are considered satisfactory, the manufacturer will be added to the list of approved manufacturers of materials, and a certificate of approval will be issued to the manufacturer by LR, showing the scope of materials and grades covered by the approval. Initial approval will generally be under the Materials Survey Scheme, *see* 2.3.

2.2.6 Approved manufacturers who meet the entry requirements, may apply for approval under the Materials Quality Scheme, *see* 2.4.

2.2.7 When a manufacturer has more than one works, the manufacturer's approval shall only be valid for the works where the test programme was conducted.

2.2.8 It is the manufacturer's responsibility to advise LR of all changes to the manufacturing process parameters that may affect the application of the material, prior to the adoption of the changes in production. Additional approval tests may be required to maintain the approval.

2.2.9 Maintenance of approval is dependent on the manufacturer continuing to meet the requirements of the applicable sections of these Rules.

2.2.10 Where it is considered that an approved manufacturer is not maintaining its responsibilities to comply with these Rules, the approval may be suspended by LR until such time that agreed corrective and preventive actions are considered to have been satisfactorily carried out. If considered necessary, LR may require that the normal level of testing and inspection is increased.

2.2.11 In all instances, LR will reduce the scope of, or withdraw approval from, a manufacturer where it becomes apparent that the manufacturer is unable to maintain compliance with these Rules, or the scope of approval.

2.2.12 Where a manufacturer disagrees with any decisions made with regard to LR approval, they may appeal in writing to LR.

2.2.13 Any documents, data or other information received as part of the approval process, will be treated as strictly confidential, and will not be disclosed to any third party, without the manufacturer's prior written consent.

2.3 Materials Survey Scheme

2.3.1 Materials according to Chapters 3 to 10 of these Rules and produced under the Materials Survey Scheme will be subject to Direct Survey by an LR Surveyor. The scheme requires the Surveyor to survey and certify all materials according to the requirements of these Rules.

2.3.2 Approved manufacturers are to request a survey of the material by an LR Surveyor, when required. Manufacturers must provide the Surveyor with details of the order, specification and any special conditions additional to the requirements of these Rules.

2.3.3 All mechanical tests required by these Rules are to be witnessed. The Surveyor may allow part of this task to be carried out by a member of the works staff by prior written agreement.

2.3.4 Before final acceptance, all materials are to be submitted to the specified tests and examinations under conditions acceptable to the Surveyor. The results are to comply with the Rules, and all materials are to be to the satisfaction of the Surveyor.

2.3.5 The specified tests and examinations are to be carried out prior to the despatch of finished materials from the manufacturer's works. Where materials are supplied in the rough or unfinished condition, as many as possible of the specified tests are to be carried out by the manufacturer, and any tests or examinations that are not completed are to be carried out under survey at a subsequent stage of manufacture.

2.3.6 In the event of any material proving unsatisfactory during subsequent working, machining or fabrication, such material is to be rejected, notwithstanding any previous certification.

2.3.7 In addition to witnessing test results, the Surveyor is responsible for ensuring that the manufacturing process, inspection, testing, identification and certification are properly conducted. As part of the Materials Survey Scheme, regular visits will be made to all relevant parts of the works to check for compliance against the requirements of these Rules, and to ensure that the manufacturer is maintaining the capability to consistently produce approved materials.

2.3.8 The Surveyor, when satisfied that the material fully meets the requirements of these Rules, will certify the material in accordance with Section 3 and the appropriate Chapter of these Rules.

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2.3.9 For a manufacturer to maintain approval under this scheme, the works will be subject to a periodic inspection of all relevant parts of the works, at intervals not exceeding three years. The procedure for this periodic inspection is given in Book B of LR's *Materials and Qualification Procedures for Ships* (MQPS). This periodic inspection is in addition to the regular visits made according to 2.3.7.

2.4 Materials Quality Scheme

2.4.1 The manufacturer may apply to be approved under the Materials Quality Scheme, where the following requirements are met:

(a) The manufacturer has been approved by LR for a minimum of three years; and

(b) The manufacturer has a quality management system, which has been certified as meeting the requirements of ISO 9001 by a certification body recognised by LR, which is one accredited by a member of the International Accreditation Forum; and

(c) The manufacturer has a satisfactory history of quality performance in the manufacture and supply of LR approved materials.

2.4.2 Special consideration may be given to manufacturers who have not been approved under the Materials Survey Scheme, and may be considered onto the Materials Quality Scheme providing:

(a) They have a quality management system, which has been certified as meeting the requirements of ISO 9001 by a certification body recognised by LR, which is one accredited by a member of the International Accreditation Forum.

(b) They can demonstrate a history of satisfactory supply of materials, which LR deems to be equivalent to those for which approval under the Materials Quality Scheme is requested.

In this case, the initial assessment of the manufacturer will include the product testing regime, as required for initial approval under the Materials Survey Scheme, *see* 2.2.4.

2.4.3 The Scheme is based on a Scheme Certification Schedule, made between LR and each individual manufacturer. The schedule will stipulate:

(a) The scope of approved products covered by the approval.

(b) The process route applied by the manufacturer for each approved product.

(c) The arrangements for LR scheme, audits, including scope, frequency, schedule, etc.

(d) Agreed procedures for certification of approved materials.

(e) Information to be supplied periodically to LR by the manufacturer.

(f) Procedures for the use of the scheme mark.

2.4.4 The contents of the Scheme Certification Schedule are to remain confidential between LR and the manufacturer.

2.4.5 The Materials Quality Scheme is based on a technical audit approach, and is designed to complement the quality management systems audits performed to ISO 9001. The role of the Surveyor in scheme audits is to:

(a) Verify that the quality management system is being maintained and audited to the requirements of ISO 9001.

(b) Verify that the requirements of these Rules are being implemented.

(c) Verify that the requirements of this Scheme are being implemented.

(d) Perform Scheme audits, which focus on the technical aspects of the product realisation process, particularly with regard to Rule requirements.

(e) Perform witness testing as required.

(f) Verify the data supplied to LR periodically by the manufacturer, as part of the Scheme requirements.

2.4.6 The Materials Quality Scheme may be applied to any approved manufacturer who meets the eligibility requirements, and who applies to be approved under the scheme. If approved under the scheme, the manufacturer's name will appear on the List of Approved Manufacturers published by LR, with an indication that they are approved under this scheme.

2.4.7 The scheme is available to manufacturers producing approved materials according to Chapters 3 to 10 of these Rules.

2.4.8 The procedures for application for approval for the Materials Quality Scheme are given in Book M of LR's *Materials and Qualification Procedures for Ships* (MQPS).

2.4.9 Where LR is satisfied that the manufacturer meets all of the requirements of the Scheme, and that it is appropriate for the products being manufactured, a Scheme Certification Schedule will be issued, which must be signed by an authorised representative of the manufacturer.

2.4.10 Once the Scheme Certification Schedule has been signed by both parties, LR will issue the manufacturer with a certificate of approval according to the Materials Quality Scheme.

2.4.11 Maintenance of approval will be according to the Scheme Certification Schedule, agreed between LR and the manufacturer, and these Rules.

2.4.12 It is the responsibility of the attending Surveyor, to perform regular Scheme audits at the manufacturer's works in accordance with the Scheme Certification Schedule, and the requirements of these Rules.

2.4.13 It is not the intention to repeat the audit according to ISO 9001, conducted by the recognised certification body. The Surveyor is, however, to be satisfied that these audits are being conducted effectively. Where appropriate, the Surveyor may conduct a partial audit to ISO 9001 to verify this.

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2.4.14 Witness tests may be conducted as part of the Scheme audit. This will involve the selection of material, and the witness of sampling and testing according to the requirements of the appropriate chapter of these Rules. Such witness testing may be on LR grades, or materials which the Surveyor deems to be equivalent (for the purposes of audit testing only).

2.4.15 Once every three years, a full assessment of scheme compliance will be conducted by a Surveyor who is not the regular attending Surveyor.

2.4.16 In the event of any change, which means that the manufacturer no longer meets the requirements for the Materials Quality Scheme (for example the loss of ISO 9001 approval), the Scheme certificate of approval will be revoked. The manufacturer will revert to the Materials Survey Scheme, and will be subject to survey according to that scheme.

■ *Section 3* Certification of materials

3.1 General

3.1.1 All materials subject to these Rules are to be supplied with appropriate certification, as required by the relevant requirements of these Rules. This will normally be a LR certificate or a manufacturer's certificate validated by LR, although a manufacturer's certificate may be accepted where allowed by the relevant requirements of these Rules.

3.1.2 Manufacturers approved under the Materials Quality Scheme are licensed to apply the scheme mark to manufacturer's certificates according to the requirements of the scheme, *see* 2.4.

3.1.3 The following certificate types are to be used, (a) and (b) for the Materials Survey Scheme, and (d) for the Materials Quality Scheme:

(a) **LR Certificate**
This type of certificate is issued by LR based on the results of testing and inspection being satisfactorily carried out in accordance with the requirements of these Rules.

(b) **Manufacturer's certificate validated by LR**
A manufacturer's certificate, validated by LR on the basis of inspection and testing carried out on the delivered product in accordance with the requirements of these Rules may be accepted. In this case, the certificate will include the following statement:
"We hereby certify, that the material has been made by an approved process and satisfactorily tested in accordance with the Rules of Lloyd's Register."

(c) **Manufacturer's certificate**
This type of certificate is issued by the manufacturer, based on the results of testing and inspection being satisfactorily carried out in accordance with the requirements of these Rules, or the applicable National or International standard. The certificate is to be validated by the manufacturer's authorised representative, independent of the manufacturing department. The certificate will contain a declaration that the products are in compliance with the requirements of these Rules or the applicable National or International standard.

(d) **Manufacturer's certificate issued under the Materials Quality Scheme**
Where a manufacturer is approved according to the Materials Quality Scheme, they will issue manufacturer's certificates bearing the scheme mark. The certificates must also bear the following statement:
"This certificate is issued under the arrangements authorised by Lloyd's Register (operating group) in accordance with the requirements of the Materials Quality Scheme and certificate number MQS ....."

3.1.4 Where these Rules allow for the issue of a manufacturer's certificate for materials, either validated by an LR Surveyor, or bearing the Materials Quality Scheme mark, the manufacturer is to ensure that a copy of the certificate is supplied to LR.

3.2 Materials Survey Scheme

3.2.1 The requirements for certification of materials according to the Materials Survey Scheme, are established by the relevant requirements of these Rules.

3.2.2 The manufacturer is to supply the surveyor with any additional customer order requirements that are in addition to the requirements of these Rules, when the request for the issue or validation of the certificate is made.

3.3 Materials Quality Scheme

3.3.1 Part of the certification schedule, will include an agreement for the manufacturer, to apply the scheme mark to manufacturer's certificates, relating to approved products within the scope of approval of the manufacturer.

3.3.2 The use of the scheme mark is governed by the following:

(a) The use of the scheme mark is not transferable. It is only to be used in conjunction with the manufacturer and works name and location shown on the certificate of approval.

(b) The scheme mark must be applied to all manufacturers' certificates relating to approved materials produced under the Scheme.

(c) In no circumstances is the scheme mark to be applied to test certificates relating to non-approved products.

(d) The scheme mark is not to be used in any way which may imply approval for products which are not covered within the manufacturer's scope of approval.

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(e) Where a manufacturer is removed or suspended from the scheme, use of the scheme mark must cease immediately.

3.3.3 The certificate as given in 3.1.3(d) is to be validated by an authorised representative of the manufacturer. The size and position of the scheme mark and statement on the manufacturer's certificate must be agreed by LR.

3.3.4 Where manufacturers are approved under this scheme, the manufacturer's certificate, issued according to these requirements, fully meets the materials certification requirements of these Rules.

3.4 Electronic certification

3.4.1 Where these Rules allow the issue of manufacturers' test certificates, under either the Materials Survey Scheme or the Materials Quality Scheme, these may be issued in electronic format provided that:

(a) All tests and inspections have been satisfactorily completed, according to the requirements of these Rules.

(b) Procedures are in place to ensure that electronic certificates are only issued, according to the requirements of these Rules.

(c) The certification system is subject to regular inspection by the attending Surveyor.

(d) A copy of the electronic certificate is supplied to LR. This copy will be deemed to be the original of the test certificate.

3.4.2 In addition to the requirements of 3.4.1, for items certified under the Materials Survey Scheme, the LR office stamp and Surveyor's name may be applied electronically. This is only allowed where the Surveyor has access to the results of the relevant tests and inspections, and is able to authorise by access to the electronic system, the application of the LR office stamp and Surveyor's name on the test certificate. The name of the authorising Surveyor is to be the name included on the certificate. The authorisation may be conducted electronically either at the manufacturers' works, or remotely by the Surveyor.

3.4.3 If the LR office stamp and name are being applied electronically according to 3.4.2, then the manufacturer is to ensure that the Surveyor is provided with all relevant information regarding the customer order, when the request for authorisation is made.

■ *Section 4* General requirements for manufacture

4.1 General

4.1.1 The following definitions are applicable to these Rules:

Item: A single forging, casting, plate, tube or other rolled product as delivered.

Piece: The rolled product from a single slab or billet or from a single ingot if this is rolled directly into plates, strip, sections or bars.

Batch: A number of similar items or pieces presented as a group for acceptance testing.

Wide flat: Flat product of a width over 150 mm, up to and including 1250 mm and thickness generally over 4 mm. Edges are square cut, i.e., hot rolled on the four sides. Supplied in lengths, not coils.

Plate/sheet: Flat rolled product whereby the edges are allowed to deform freely. Supplied flat and generally in square or rectangular shapes with a width of 600 mm or over, but other shapes may also apply.

4.1.2 Where a manufacturer purchases semi-finished products (e.g., slabs) for the purpose of re-processing (e.g., rolling), the manufacturer is to ensure that the materials are from an LR approved manufacturer, and manufactured within the scope of approval of that manufacturer. The aim of chemical analysis, dimensions, surface and internal quality checks are to be agreed between the manufacturer and purchaser. The semi-finished materials must be supplied with appropriate certification, according to these Rules.

4.1.3 It is the responsibility of the manufacturer, to ensure compliance with all relevant aspects of these Rules. All deviations are to be recorded as non-compliances, and brought to the attention of the Surveyor, along with corrective actions taken. Failure to do this is considered to render the material as not complying with these Rules.

4.1.4 The manufacturer is to maintain all test and inspection records required by these Rules for at least seven years. Records are to be made available to LR on request.

4.1.5 Where material is produced which does not meet all aspects of these Rules, the manufacturer may apply to LR for a concession to certify the material as approved. LR will consider each application on a case-by-case basis, although concession will only normally be granted in exceptional circumstances. If the concession is granted, a formal written numbered concession will be issued to the manufacturer. The concession number must be applied to the approval certificate, whether it is an LR certificate or a validated manufacturer's certificate.

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4.2 Chemical composition

4.2.1 The ladle analysis used for certification purposes is to be determined after all alloying elements have been added and sufficient time allowed for such additions to equalise throughout the ladle.

4.2.2 The method of taking samples is to ensure that the reported analysis is representative of the cast. In addition, the manufacturer must determine and certify the chemical composition of every heat of material.

4.2.3 Where more than one sample is taken, the method of averaging for the final certificate result and the determination of acceptable variations in composition are to be agreed with the Surveyor.

4.2.4 The chemical composition of ladle samples is to be determined by the manufacturer in an adequately equipped and competently staffed laboratory. The manufacturer's analysis will be accepted, but may be subject to occasional independent checks if required by the Surveyor.

4.2.5 The analysis is to include the content of all the elements detailed in the relevant Sections of the Rules and, where appropriate, the National or International Standard applied.

4.2.6 At the discretion of the Surveyors, a check chemical analysis of suitable samples from products may also be required. These samples are to be taken from the material used for mechanical tests but, where this is not practicable, an alternative procedure for obtaining a representative sample is to be agreed with the manufacturer. For product samples, the permissible limits of deviation from the specified ladle analysis are to be in accordance with an appropriate International or National Standard specification.

4.3 Heat treatment

4.3.1 Materials are to be supplied in the condition specified in, or permitted by, the relevant Chapters of these Rules.

4.3.2 Heat treatment is to be carried out in properly constructed furnaces, which are efficiently maintained and have adequate means for control and recording of temperature. The furnace dimensions are to be such as to allow the whole item to be uniformly heated to the necessary temperature. In the case of very large components, which require heat treatment, alternative methods will be specially considered.

4.3.3 The manufacturer is to maintain the records, including the temperature charts of all heat treatments, for at least seven years.

4.4 Test material

4.4.1 Sufficient test material is to be provided for the preparation of the test specimen detailed in the specific requirements. It is, however, in the interests of manufacturers to provide additional material for any re-tests which may be necessary, as insufficient or unacceptable test material may be a cause for rejection.

4.4.2 The test material is to be representative of the item or batch and is not to be separated until all the specified heat treatment has been completed, except where provision for an alternative procedure is made in subsequent Chapters of these Rules.

4.4.3 All test material is to be selected by the Surveyor or an authorised deputy and identified by suitable markings which are to be maintained during the preparation of the test specimens.

4.5 Mechanical tests

4.5.1 The dimensions, number and direction of test specimens are to be in accordance with the requirements of Chapter 2 and the specific requirements for the product.

4.5.2 Where Charpy impact tests are required, a set of three test specimens is to be prepared and the average energy value is to comply with the requirements of subsequent Chapters. One individual value may be less than the required average value, provided that it is not less than 70 per cent of that value.

4.5.3 In the Rules, mechanical properties are specified in SI units, but alternative units may be used for acceptance testing. In such cases, the specified values are to be converted in accordance with the appropriate conversions given in Table 1.4.1. It is preferred that test results be reported in SI units, but alternative units may be used provided that the test certificate gives, in the same units, the equivalent specification values.

Table 1.4.1 Conversions from SI units to metric and Imperial units

1 N/mm^2 or MPa	=	0,102 kgf/mm^2
1 N/mm^2 or MPa	=	0,0647 $tonf/in^2$
1 N/mm^2 or MPa	=	0,145 x 10^3 lbf/in^2
1J	=	0,102 kgf m
1J	=	0,738 ft lbs
1 kgf/mm^2	=	9,81 N/mm^2 or MPa
1 $tonf/in^2$	=	15,4 N/mm^2 or MPa
1 lbf/in^2	=	6,89 x 10^{-3} N/mm^2 or MPa
1 kgf m	=	9,81 J
1 ft lbf	=	1,36 J

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4.6 Re-test procedures

4.6.1 Re-test procedures are to be in accordance with the requirements of Ch 2,1.4.

4.7 Rectification of defective material

4.7.1 Small surface imperfections may be removed by mechanical means provided that, after such treatment, the dimensions are acceptable, the area is proved free from defects and the rectification has been completed in accordance with any applicable requirements of subsequent Chapters of these Rules and to the satisfaction of the Surveyor.

4.7.2 The repair of defects by welding, can be accepted only when permitted by the appropriate specific requirements and provided that the agreement of the Surveyor is obtained before the work is commenced. When a repair has been agreed, it is necessary in all cases to prove by suitable methods of non-destructive examination that the defects have been completely removed before welding is commenced. Welding procedures and inspection on completion of the repair, are to be in accordance with the appropriate specific require-ments and are to be to the satisfaction of the Surveyor.

4.7.3 Manufacturers wishing to carry out welding work must have at their disposal the necessary workshops, lifting gear, welding equipment, pre-heating, and where necessary annealing facilities and testing devices, as well as certified welders and supervisors to enable them to perform the work properly. Proof shall be furnished to the Surveyor that these conditions are satisfied before welding work begins.

4.8 Identification of materials

4.8.1 The manufacturer is to adopt a system of identification, which will enable all finished materials to be traced to the original cast, and the Surveyors are to be given full facilities for tracing the material when required. When any item has been identified by the personal mark of a Surveyor, or his deputy, this is not to be removed until an acceptable new identification mark has been made by a Surveyor. Failure to comply with this condition will render the item liable to rejection.

4.8.2 Before any item is finally accepted, it is to be clearly marked by the manufacturer in at least one place with the particulars detailed in the appropriate specific requirements.

4.8.3 Where hard stamps such as the LR brand stamp are issued to manufacturers to carry out the stamping on behalf of LR, the procedure for issue, maintenance and use of stamps is to be agreed in writing.

4.8.4 Hard stamping is to be used except where this may be detrimental to the material, in which case stencilling, painting or electric etching is to be used. Paints used to identify alloy steels are to be free from lead, copper, zinc or tin, i.e., the dried film is not to contain any of these elements in quantities of more than 250 ppm.

4.8.5 Where a number of identical items are securely fastened together in bundles, the manufacturer need only brand the top item of each bundle. Alternatively, a durable label giving the required particulars may be attached to each bundle.

■ *Section 5* Non-destructive examination

5.1 General NDE requirements

5.1.1 Prior to the final acceptance of materials, surface inspection and verification of dimensions, non-destructive examination is to be carried out in accordance with the requirements detailed in this Section and subsequent Chapters of these Rules.

5.1.2 It is the manufacturer's responsibility for maintaining the required tolerances and making the necessary measurements. Periodic surveys by the Surveyor do not absolve the manufacturer from this responsibility.

5.1.3 When there is visible evidence to doubt the soundness of any material or component, such as flaws in test specimens or suspicious surface marks, the manufacturer is expected to prove the quality of the material by a suitable method.

5.1.4 Acceptance criteria are detailed in subsequent Chapters of these Rules. Alternative specifications may be submitted for consideration, provided they demonstrate equivalence to these Rules.

5.2 Personnel qualifications

5.2.1 The shipyard, fabricator or manufacturer is to ensure that personnel carrying out non-destructive examination or interpreting the results of non-destructive examination are qualified to the appropriate level of a nationally recognised scheme such as ISO 9712, EN 473, PCN, ACCP or SNT-TC-1A. Level 1 personnel are not permitted to interpret results to Codes or Standards.

5.2.2 When certification of personnel is made on an in-house basis under a scheme such as SNT-TC-1A, practical examinations are to be relevant to material, product type, joint configuration, material thickness and acceptance criteria of items inspected for Classification purposes.

5.2.3 Personnel qualifications of NDE operators are to be randomly checked by the Surveyor.

5.3 Non-destructive examination methods

5.3.1 Non-destructive examination methods are to comply with the relevant requirements of these Rules.

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5.4 Non-destructive examination procedures

5.4.1 All non-destructive examinations are to be carried out to a procedure that is representative of the item under inspection. As a minimum the procedures are to be in accordance with the following:

(a) Procedures are to identify the component to be examined, the NDE method, equipment to be used and the full extent of the examinations including any test restrictions.

(b) Procedures are to specify the qualification and certification requirements of the inspection personnel to be employed.

(c) Procedures are to state the degree of surface preparation required and the methods of preparation to be used before the examinations are made.

(d) Procedures are to state the reference standards for testing and the acceptance criteria to be applied to the results of the inspections.

(e) Procedures are to include the requirement for components to be positively identified and for a datum system or marking system to be applied to ensure repeatability of inspections.

(f) Procedures are to identify any requirements for increasing the extent of applied NDE where defects have been found during spot examination.

(g) Procedures are to identify reporting requirements.

(h) Procedures are to be reviewed by the Surveyor to ensure they are appropriate for the product type.

(j) Procedures for radiography are to specify the acceptable optical density within the area of interest on the radiograph.

(k) The minimum optical density within the area of interest on a radiograph is to be equal to or greater than 2,0 for gamma ray and 1,8 for X-ray. A maximum density of 4,0 is acceptable.

(l) Procedures are to include the method and requirements for equipment calibrations and functional checks.

(m) Procedures are to be approved by an operator qualified to a minimum of Level III in accordance with a recognised standard.

(n) The Surveyor will review procedures for compliance with this Section.

5.4.2 The shipyard, fabricator or manufacturer may submit other Codes or Standards for consideration by LR, providing they are equivalent to these Rules. Where no agreed acceptance standard is in place, the acceptance levels contained in the subsequent Chapters of these Rules are to apply.

5.4.3 In the event that proposed acceptance criteria are not considered to be equivalent to these Rules, the criteria may be submitted for special consideration.

5.5 Non-destructive examination reports

5.5.1 NDE reports are to include all information required to identify how the examination was executed and are to include the following information where appropriate:

(a) Date of test.

(b) Name and qualification of operator with signatures of the operator.

(c) Details of the component identification, description of test location and volume examined.

(d) Heat treatment status.

(e) Weld type, procedure and configuration.

(f) Surface condition.

(g) Test procedure.

(h) Equipment used.

(j) Test results with a map or record of reportable and/or reject indications, giving location, dimensions and nature of indications.

(k) Reference to acceptance criteria and evaluation in accordance to these criteria.

(l) Material type and thickness.

(m) Calibration.

■ *Section 6* References

6.1 General

6.1.1 The locations of National and International Standards referenced in these Rules are shown in Table 1.6.1.

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Table 1.6.1 List of National and International Standards

Rule reference	Standard
Chapter 1 – General Requirements	ISO 9001: 2008
Chapter 2 – Testing Procedures for Metallic Materials	ISO 6892-1: 2009 ISO 185: 2005 ISO 2566-1: 1999 ISO 148-1: 2009 ISO 7500-1: 2004 ASTM E23-07ae1
Chapter 3 – Rolled Steel Plates, Strip, Sections and Bars	EN 10160: 1999 ASTM A578-07 ASTM E112-96 (2004)e2 ASTM E381-01 (2006) ASTM A255-10
Chapter 4 – Steel Castings	ISO 1161: 1984/Amendment 1: 2007
Chapter 5 – Steel Forgings	ASTM E112-10
Chapter 8 – Aluminium Alloys	ASTM G66-99 (2005)e1 ASTM G67-04
Chapter 9 – Copper Alloys	ASTM E272-10
Chapter 10 – Equipment for Mooring and Anchoring	ISO 1704: 2008 ISO 1834: 1999 ISO 4565: 1986 ASTM E112-10 ASTM E381-01 (2006) ASTM A255-10
Chapter 11 – Approval of Welding Consumables	ISO 3690: 2000 ISO 10042: 2005 ASTM G48-03 (2009)
Chapter 12 – Welding Qualifications	ISO 6947: 1997 ISO 5817: 2007 ISO 6520-1: 2007 ISO 6507-1: 2005 ISO 10042: 2005
Chapter 13 – Requirements for Welded Construction	ISO 9712/Cor1: 2006 EN 473: 2008 ISO 6520-1: 2007 SNT-TC-1A: 2006 ISO 10042: 2005
Chapter 14 – Plastics Materials	ISO 527-2: 1993/corr1:1994 ISO 178: 2010 ISO 62: 2008 ISO 75-2: 2004 ISO 604: 2002 ISO 527-4: 1997 ISO 14125: 1998/ amd1:2011 ISO 14130: 1997/ corr1:2003 ISO 1172: 1996 ISO 1922- 2001 ASTM C273/C273M-07[a] ASTM C393/C393M-06 ISO 845- 2006 ASTM C297/C297M-04 ISO 844-2007 ISO 1922-2001 ISO 180-2000 ASTM D2583-07 BS 2782-10 Method 1001: 1977 ISO 175: 2010

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Testing Procedures for Metallic Materials

Section

1 **General requirements for testing**

2 **Tensile tests**

3 **Impact tests**

4 **Ductility tests for pipes and tubes**

5 **Embrittlement tests**

6 **Crack tip opening displacement tests**

7 **Bend tests**

8 **Corrosion tests**

Section 1
General requirements for testing

1.1 Preparation of test specimens

1.1.1 The requirements specified below detail all the tests that may be applied to metallic materials. The specific tests and the test specimen types required for each material type, grade and product type are detailed in the subsequent Chapter of these Rules.

1.1.2 Where test material is cut from products by shearing or flame cutting, a reasonable margin is required to allow sufficient material to be removed from the cut edges during machining of the test specimens.

1.1.3 Test specimens are to be prepared in such a manner that they are not subjected to any significant work hardening, cold straining or heating during straightening or machining.

1.1.4 Test samples are not to be removed from the material they represent until heat treatment is complete. For castings in cases where test samples are separately cast, the castings and samples are to be heat treated together.

1.1.5 Dimensional tolerances are to comply with a relevant ISO specification.

1.2 Testing machines

1.2.1 All tests are to be carried out by competent personnel. Testing machines are to be maintained in a satisfactory and accurate condition and are to be recalibrated at approximately annual intervals. This calibration is to be carried out by organisations of standing that have been approved or recognised by a National Authority and are to be to the satisfaction of the Surveyor. A record of all calibrations is to be kept available in the test house.

1.2.2 Tensile testing machine load cells are to be calibrated with an accuracy of ± one per cent in accordance with ISO 7500-1 or another recognised National Standard.

1.2.3 Impact tests are to be carried out on Charpy V-notch machines calibrated to ISO 148 or ASTM E23 dependent on the testing machine type. The testing machines are to be calibrated using either a direct or indirect method. Other National Standards equivalent to ISO 148 may be considered.

1.3 Discarding of test specimens

1.3.1 If a test specimen fails because of faulty preparation or incorrect operation of the testing machine it may be discarded and replaced by a new test specimen prepared from material adjacent to the original test.

1.3.2 In addition to the discarding of test specimens as indicated in 1.3.1, a tensile test specimen may also be discarded when the specified minimum elongation is not obtained and the distance between the fracture and the nearest gauge mark is less than one-quarter of the gauge length.

1.4 Re-testing procedures

1.4.1 Where the result of any test, other than an impact test, does not comply with the requirements, two additional tests of the same type are to be made from the same test sample, or if sufficient material is not available, a further representative sample taken from the item under test. For acceptance of the material, satisfactory results are to be obtained from both of these additional tests.

1.4.2 Where the result of any test taken from a weld procedure approval test, other than an impact test, does not comply with the requirements, two additional tests of the same type are to be made from the same weld test assembly. Where insufficient original welded assembly is available, a new assembly is to be prepared using the same conditions as the original test weld. For acceptance, satisfactory results are to be obtained from both of these additional tests.

1.4.3 Where the result of any test taken from a welding consumable approval test, other than an impact test, does not comply with the requirements, two additional tests of the same type are to be made from the same weld test assembly. Where insufficient original welded assembly is available, a new assembly is to be prepared using welding consumables from the same batch. If the new assembly is made with the same procedure (particularly the same number of runs) as the original assembly, only the duplicate re-test specimens need be prepared and tested. For acceptance of a weld consumable batch, satisfactory results are to be obtained from both of these additional tests.

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1.4.4 Where the results from a set of three impact test specimens do not comply with the requirements, an additional set of three impact test specimens may be tested provided that, of the original set tested, not more than two individual values are less than the required average value and, of these, not more than one is less than 70 per cent of this average value. The results obtained are to be combined with the original results to form a new average which, for acceptance, is to be not less than the required average value. Additionally, for these combined results, not more than two individual values are to be less than the required average value and, of these, not more than one is to be less than 70 per cent of this average value.

1.4.5 The additional tests detailed in 1.4.1 and 1.4.2 are, where possible, to be made on material adjacent to the original samples. For castings, where insufficient material remains in the original test samples, the additional test may be made on other test samples representative of the castings. *See also* 1.3 for discarding of test specimens.

1.4.6 When unsatisfactory results are obtained from tests representative of a batch of material, the item or piece from which the tests were taken is to be rejected. The remainder of the material in the batch may be accepted provided that two further items or pieces are selected and tested with satisfactory results. If the tests from one or both or these additional items or pieces give unsatisfactory results, the batch is to be rejected.

1.4.7 When a batch of material is rejected, the remaining items or pieces in the batch may be resubmitted individually for test, and those which give satisfactory results may be accepted.

1.4.8 At the option of the manufacturer, rejected material may be resubmitted as another grade and may then be accepted, provided that the test results comply with the appropriate requirements.

1.4.9 When material which is intended to be supplied in the 'as-rolled' or 'hot-finished' condition fails test, it may be suitably heat treated and resubmitted for test. Similarly, materials supplied in the heat treated condition may be reheat treated and resubmitted for test. Unless otherwise agreed by the Surveyor, such reheat treatment is to be limited to one repeat of the final heat treatment cycle.

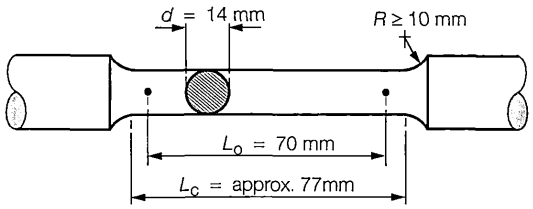
■ *Section 2* Tensile tests

2.1 Dimensions of test specimens

2.1.1 Proportional test specimens with a gauge length L_o of 5,65 $\sqrt{S_o}$ or $5d$, where S_o is the cross-sectional area, d the diameter and L_c the parallel test length, have been adopted as the standard form of test specimen, and in subsequent Chapters in these Rules the minimum percentage elongation values are given for test specimens of these proportions.

2.1.2 The gauge length is to be greater than 20 mm and may be rounded off to the nearest 5 mm provided that the difference between the adjusted gauge length and the calculated one is less than 10 per cent of the calculated gauge length.

2.1.3 For forgings and castings (excluding those in grey cast iron) proportional test specimens of circular cross-section are to be machined to the dimensions shown in Fig. 2.2.1.

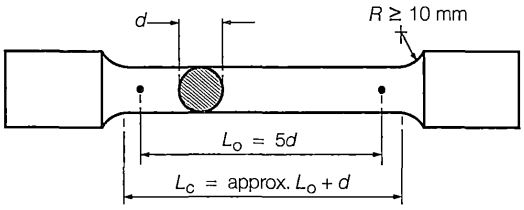


NOTE: For nodular cast iron and materials with a specified elongation less than 10%, $R \geq 20$ mm

Fig. 2.2.1
Test specimen dimensions for forgings and castings – I

2.1.4 For hot rolled bars and similar products, the test specimens are to be as in Fig. 2.2.1, except that for small sizes they may consist of a suitable length of bar or other product tested in the full cross-section.

2.1.5 As an alternative to 2.1.3 and 2.1.4, proportional or non-proportional test specimens of other dimensions may be used, subject to any requirements for minimum cross-sectional area given in subsequent Chapters of these Rules. Where the size of proportional test specimens is other than as shown in Fig. 2.2.1, the general dimensions are to conform with Fig. 2.2.2.



NOTE: For nodular cast iron and materials with a specified elongation less than 10%, $R \geq 1{,}5d$

Fig. 2.2.2
Test specimen dimensions for forgings and castings – II and aluminium alloys

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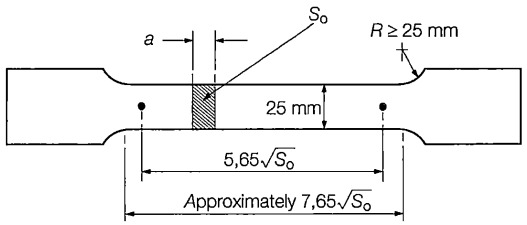
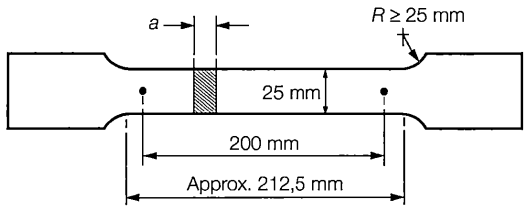
2.1.6 For plates, strip and sections, the test specimens are to be machined to the dimensions shown in Fig. 2.2.3 or Fig. 2.2.4. Where the capacity of the available testing machine is insufficient to allow the use of a test specimen of full thickness, this may be reduced by machining one of the rolled surfaces. Alternatively, for materials over 40 mm thick, test specimens of circular cross-section machined to the dimensions shown in Fig. 2.2.1 may be used. The axes of these test specimens are to be located at approximately one quarter of the thickness from one of the rolled surfaces.



a = thickness of material

Fig. 2.2.3
Test specimen dimensions for plates, strip and sections – I and aluminium alloys



a = thickness of material

Fig. 2.2.4
Test specimen dimensions for plates, strip and sections – II

2.1.7 As an alternative to 2.1.6, test specimens with a width of other than 25 mm may be used subject to any requirements for minimum cross-sectional area given in subsequent Chapters of these Rules. A ratio of width/thickness of 8:1 should not be exceeded.

2.1.8 For pipes and tubes, the test specimens may consist of a suitable length tested in full cross-section with the ends plugged. The gauge length is to be 5,65 $\sqrt{S_o}$ or 50 mm, and the length of the test specimen between the grips or plugs, whichever is the smaller, is to be not less than the gauge length plus D, where D is the external diameter. Alternatively, test specimens may be prepared from strips cut longitudinally and machined to the dimensions shown in Fig. 2.2.5 or Fig. 2.2.6. The parallel test length is not to be flattened, but the enlarged ends may be flattened for gripping in the testing machine.

The cross-sectional area of this type of test specimen is to be calculated from:

$$S_o = ab$$

where

S_o = cross-sectional area
a = average radial thickness
b = average width

Test specimens of circular cross-section may also be used provided that the wall thickness is sufficient to allow the machining of such specimens to the dimensions shown in Fig. 2.2.1, with their axes located at the mid-wall thickness.

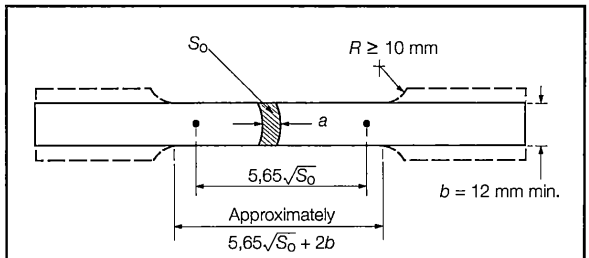


Fig. 2.2.5
Test specimen dimensions for pipes and tubes – I

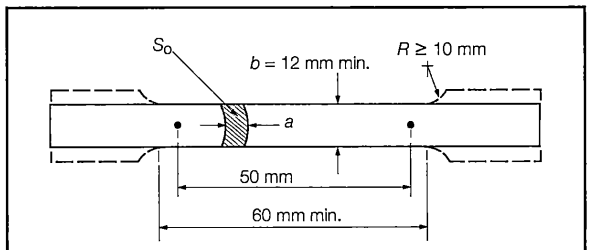


Fig. 2.2.6
Test specimen dimensions for pipes and tubes – II

2.1.9 For wire, the test specimen may consist of a suitable length tested in full cross-section. The gauge length is to be 200 mm and the parallel test length 250 mm.

2.1.10 For grey iron castings, the test specimens are to be machined to the dimensions shown in Fig. 2.2.7 or Fig. 2.2.8.

2.1.11 For aluminium alloy plates and sections of thickness, a, less than or equal to 12,5 mm; the dimensions of rectangular cross-sectioned test specimens are to be as shown in Fig. 2.2.3. The rectangular cross-sectioned test specimen surfaces should remain as rolled/extruded. Where the thickness, a, is greater than 12,5 mm the test specimens are to be of round type as shown in Fig. 2.2.2.

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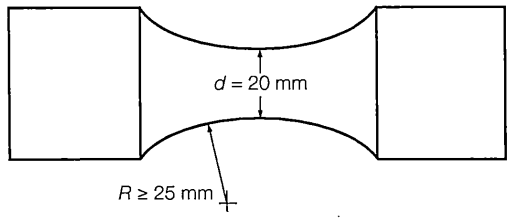

Fig. 2.2.7
Test specimen dimensions for grey iron castings – I

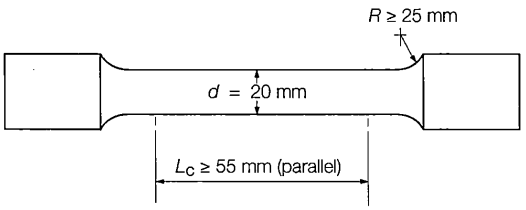

Fig. 2.2.8
Test specimen dimensions for grey iron castings – II

2.1.12 Deposited weld metal tensile test specimens are to be machined to the dimensions shown in Fig. 2.2.9, and may be heated to a temperature not exceeding 250°C for a period not exceeding 16 hours for hydrogen removal, prior to testing.

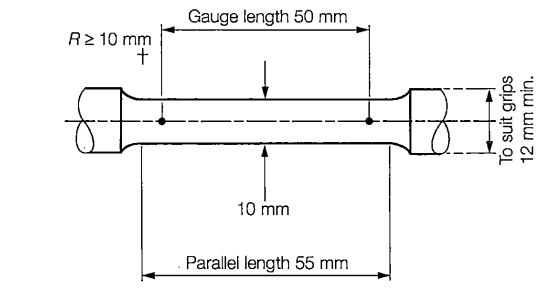

Fig. 2.2.9
Test specimen for deposited weld metal tensile

2.1.13 Butt weld tensile test specimens are to be machined to the dimensions shown in Fig. 2.2.10. For thicknesses of more than 2 mm, the test width is to be 25 mm. For thicknesses less than 2 mm, the test width is to be reduced to 12 mm. The upper and lower surfaces of the weld are to be filed, ground or machined flush with the surface of the plate.

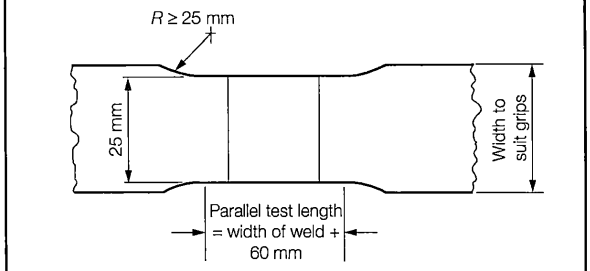

Fig. 2.2.10 Test specimen for butt weld

2.1.14 Through-thickness tensile test specimens may be, at the option of the steelmaker, either plain test specimens or test specimens with welded extensions in accordance with a Recognised Standard. The extension pieces are to be of steel with a tensile strength exceeding that of the plate to be tested and may be attached to the plate surfaces by manual, resistance or friction welding carried out in such a way as to ensure a minimal heat affected zone.

2.1.15 Tolerances on tensile specimen dimensions are to be in accordance with ISO 6892-1 or another Recognised Standard as appropriate.

2.2 Definition of yield stress for steel

2.2.1 The yield phenomenon is not exhibited by all the steels detailed in these Rules but, except for austenitic and duplex stainless steels, the term 'yield stress' is used throughout when requirements are specified for acceptance testing at ambient temperature. For the purposes of the Rules, the terms 'yield stress' and 'yield strength' are to be regarded as synonymous.

2.2.2 Where reference is made to 'yield stress' in the requirements for carbon, carbon-manganese and alloy steel products and in the requirements for the approval of welding consumables, either the upper yield stress or, where this is not clearly exhibited, the 0,2 per cent proof stress or the 0,5 per cent proof stress under load is to be determined. In cases of dispute, the 0,2 per cent proof stress is to be determined.

2.2.3 For austenitic and duplex stainless steel products and welding consumables, both the 0,2 and the 1,0 per cent proof stresses are to be determined.

2.3 Procedure for testing at ambient temperature

2.3.1 Except as provided in 2.3.5, the elastic stress rate for the determination of the upper yield for steels and copper alloys is to be between 6 and 60 N/mm^2 per second and between 2 and 20 N/mm^2 per second for aluminium. After reaching the yield or proof load, the straining rate may be increased to a maximum of $0{,}008s^{-1}$ for the determination of the tensile strength.

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2.3.2 For steel, the upper yield stress is to be calculated from:

(a) the value of stress measured at the commencement of plastic deformation, or

(b) on a load/extension diagram using the value of stress measured at the first peak obtained during yielding even when the peak is equal to or less than any subsequent peaks observed during plastic deformation at yield.

2.3.3 When a well defined yield point cannot be obtained, the 0,2 or 1,0 per cent proof stress (non-proportional elongation) is to be determined from an accurate load/extension diagram by drawing a line parallel to the straight elastic portion and a distance from it where the amount represents 0,2 or 1,0 per cent of the extensometer gauge length. The point of intersection of this line with the plastic portion of the diagram represents the proof load, from which the 0,2 or 1,0 per cent proof stress can be calculated.

2.3.4 For stainless steels, the 1,0 per cent proof stress and/or 0,2 per cent proof stress is specified as required by the relevant Chapters in these Rules.

2.3.5 For the determination of the tensile strength of flake graphite cast iron, the stress rate is not to exceed 10 N/mm^2 per second.

2.3.6 A measured elongation value is to be regarded as valid only if the fracture occurs within the gauge length and at least the following distances from the gauge marks:

Round test specimen: 1,25*d*

Flat test specimen: *a* plus width of specimen

The measurement is valid irrespective of the position of the fracture, if the percentage elongation after fracture reaches at least the specified value, and this is to be stated in the test report.

2.4 Equivalent elongations

2.4.1 When a gauge length other than $5{,}65\sqrt{S_o}$ is used, the equivalent percentage elongation value is to be calculated using the following formula:

$$A = \frac{A_R}{2}\left(\frac{L_o}{\sqrt{S_o}}\right)^{0,40}$$

where

A_R = actual measured percentage elongation of test specimen

S_o = actual cross-sectional area of test specimen

L_o = actual gauge length of test piece

A = equivalent percentage elongation for a test specimen with a gauge length of $5{,}65\sqrt{S_o}$

2.4.2 Alternatively, where a number of test specimens of similar material and dimensions are involved, the actual percentage elongation values may be recorded, provided that the equivalent specified minimum elongation value appropriate for the test specimen dimensions is calculated from the formula in 2.4.1 and is recorded on the test certificate.

2.4.3 For proportional test specimens having a gauge length other than $5{,}65\sqrt{S_o}$, the equivalent elongation may be calculated using the following factors (*d* is the diameter of the test specimen):

Actual gauge length	Factor for equivalent elongation on $5{,}65\sqrt{S_o}$
$4\sqrt{S_o}$	x 0,870
$8{,}16\sqrt{S_o}$	x 1,158
$11{,}3\sqrt{S_o}$	x 1,317
4*d*	x 0,916
8*d*	x 1,207

2.4.4 For non-proportional test specimens with gauge lengths of 50 mm and 200 mm, the equivalent elongation values tabulated in ISO 2566 are to apply.

2.4.5 The above conversions are reliable only for carbon, carbon-manganese and low alloy steels with a tensile strength not exceeding 700 N/mm^2 in the hot rolled, annealed, normalised, or normalised and tempered condition.

2.4.6 For alloy steels in the quenched and tempered condition, the following conversions may be used for proportional test specimens with a gauge length of $4\sqrt{S_o}$:

Actual percentage elongation on $4\sqrt{S_o}$	Equivalent elongation on $5{,}65\sqrt{S_o}$
22	17
20	15
18	13
17	12
16	12
15	11
14	10
12	8
10	7
8	5

2.4.7 Any proposals to use conversion factors for equivalent elongation values for the following materials are to be agreed with the Surveyors:

(a) Carbon, carbon-manganese and alloy steels in the normalised or normalised and tempered condition with a tensile strength exceeding 700 N/mm^2.

(b) Cold-worked steels.

(c) Austenitic stainless steels.

(d) Non-ferrous alloys.

2.5 Procedure for testing at elevated temperatures

2.5.1 The test specimens used for the determination of lower yield or 0,2 per cent proof stress at elevated temperatures are to have an extensometer gauge length of not less than 50 mm and a cross-sectional area of not less than 65 mm^2. Where, however, this is precluded by the dimensions of the product or by the test equipment available, the test specimen is to be of the largest practicable dimensions.

2.5.2 The heating apparatus is to be such that the temperature of the specimen during testing does not deviate from that specified by more than ±5°C.

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2.5.3 The straining rate when approaching the lower yield or proof load is to be controlled within the range 0,1 to 0,3 per cent of the extensometer gauge length per minute.

2.5.4 The time intervals used for estimation of strain rate from measurements of strain are not to exceed 6 seconds.

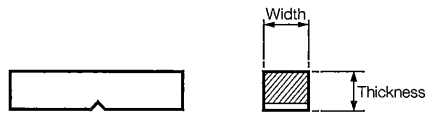
■ *Section 3* Impact tests

3.1 Dimensions of test specimens

3.1.1 Impact tests are to be of the Charpy V-notch type. The test specimens are to be machined to the dimensions and tolerances given in Table 2.3.1 and are to be carefully checked for dimensional accuracy.

Table 2.3.1 Dimensions and tolerances for Charpy V-notch impact test specimens

Dimension	Nominal	Tolerance
Length, mm	55	±0,60
Width, mm– standard specimen	10	±0,11
– standard subsidiary specimen	7,5	±0,11
– standard subsidiary specimen	5	±0,06
Thickness, mm	10	±0,06
Angle of notch	45°	±2°
Depth below notch, mm	8	±0,06
Root radius, mm	0,25	±0,025
Distance of notch from end of test specimen, mm	27,5	±0,42
Angle between plane of symmetry of notch and longitudinal axis of test specimen	90°	±2°



3.1.2 For material under 10 mm in thickness, the largest possible size of standard subsidiary Charpy V-notch test specimen is to be prepared with the notch cut on the narrow face. Generally, impact tests are not required when the thickness of the material is less than 6 mm.

3.2 Testing procedures

3.2.1 All impact tests are to be carried out on Charpy machines approved by Lloyd's Register (hereinafter referred as LR) and having a striking energy of not less than 150 J.

3.2.2 Charpy V-notch impact tests may be carried out at ambient or lower temperatures in accordance with the specific requirements given in subsequent Chapters of these Rules. Where the test temperature is other than ambient, the temperature of the test specimen is to be controlled to within ±2°C for sufficient time to ensure uniformity throughout the cross-section of the test specimen, and suitable precautions are to be taken to prevent any significant change in temperature during the actual test. In cases of dispute, ambient temperature is to be considered as 18°C to 25°C.

3.2.3 For acceptance, the average energy value for a set of three impact tests must be equal to or greater than the appropriate specified minimum average value. Additionally, only one individual value may be less than the required average value but not less than 70 per cent of this average value.

3.2.4 Where standard subsidiary Charpy V-notch test specimens are necessary, the minimum energy values required are to be reduced as follows:

Specimen 10 x 7,5 mm: 5/6 of tabulated energy.
Specimen 10 x 5 mm: 2/3 of tabulated energy.

3.2.5 When reporting results, the specimen dimensions and the units used for expressing the energy absorbed (Joules) and the testing temperature are to be clearly stated.

■ *Section 4* Ductility tests for pipes and tubes

4.1 Bend tests

4.1.1 The test specimens are to be cut as circumferential strips of full wall thickness and with a width of not less than 40 mm. For thick walled pipes, the thickness of the test specimens may be reduced to 20 mm by machining. The edges of the specimens may be rounded to a radius of 1,6 mm.

4.1.2 Testing is to be carried out at ambient temperature, and the specimens are to be doubled over a former whose diameter is to be in accordance with the specific requirements for the material. For submerged arc welded tube the test piece is to be bent with the root of the weld in tension. For other tubes, the test piece is to be bent in the original direction of curvature. In all cases, the welds are to be in the middle of the test specimen. The test is considered to be satisfactory if, after bending, the specimens are free from cracks and laminations. Small cracks at the edges of the test specimens are to be disregarded.

4.2 Flattening tests

4.2.1 Ring test specimens are to be cut with the ends perpendicular to the axis of the pipe or tube. The length of the specimen is to be equal to 1,5 times the external diameter of the pipe or tube, but is to be not less than 10 mm or greater than 100 mm. Alternatively, the length of the test specimen may be 40 mm irrespective of the external diameter.

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4.2.2 Testing is to be carried out at ambient temperature and is to consist of flattening the specimens in a direction perpendicular to the longitudinal axis of the pipe. Flattening is to be carried out between two plain parallel and rigid platens which extend over both the full length and the width after flattening of the test specimen. Flattening is to be continued until the distance between the platens, measured under load, is not greater than the value given by the formula:

$$H = \frac{t(1+C)}{C+\frac{t}{D}}$$

where

H = distance between plates, in mm
t = specified thickness of the pipe, in mm
D = specified outside diameter, in mm
C = a constant dependent on the steel type and detailed in the specific requirements

After flattening, the specimens are to be free from cracks or other flaws. Small cracks at the ends of the test specimens may be disregarded.

4.2.3 For welded pipes or tubes, the weld is to be placed at 90° to the direction of flattening.

4.3 Drift expanding tests

4.3.1 The test specimens are to be cut with the ends perpendicular to the axis of the tube. The edges of the end to be tested may be rounded by filing.

4.3.2 For metallic tubes, the length of the specimen is to be at least 1,5 times the external diameter of the tube except when a mandrel with an included angle of 30° is used, in which case the length of the specimen is to be twice the external diameter of the tube. In all cases the length of section remaining cylindrical after test is not be less than 0,5 times the external diameter.

4.3.3 Testing is to be carried out at ambient temperature and is to consist of expanding the end of the tube symmetrically by means of a hardened conical steel mandrel having a total included angle of 30°, 45° or 60°, *see* Fig. 2.4.1. The mandrel is to be forced into the test specimen at a rate not exceeding 50 mm/min until the percentage increase in the outside diameter of the end of the test specimen is not less than the value given in the specific requirements for boiler and superheater tubes, *see* Chapter 6. The mandrel is to be lubricated, but there is to be no rotation of the tube or mandrel during the test. The expanded portion of the tube is to be free from cracks or other flaws.

4.4 Flanging tests

4.4.1 The test specimens are to be cut with the ends perpendicular to the axis of the tube. The length of the specimens is to be at least equal to the external diameter of the tube and such that after testing the portion that remains cylindrical is not less than half the external diameter. The edges of the end to be tested may be rounded by filing.

4.4.2 Testing is to be carried out at ambient temperature and is to consist of flanging the end of the tube symmetrically by means of hardened conical steel mandrels. The rate of flanging is not to exceed 50 mm/min.

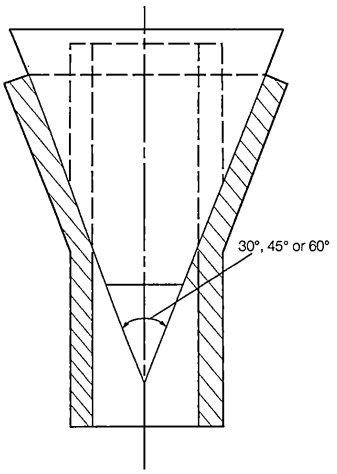

Fig. 2.4.1 Drift expanding test

4.4.3 The first stage of flanging is to be carried out with a conical angled mandrel having an included angle of approximately 90°, *see* Fig. 2.4.2(a). The completion of the test is achieved with a second forming tool as shown in Fig. 2.4.2(b). The mandrels are to be lubricated and there is to be no rotation of the tube or mandrels during the test. The test is to continue until the drifted portion has formed a flange perpendicular to the axis of the test specimens. The percentage increase in the external diameter of the end of the specimens is to be not less than the value given in the specific requirements for boiler and superheater tubes, *see* Chapter 6. The cylindrical and flanged portion of the tube is to be free from cracks or other flaws.

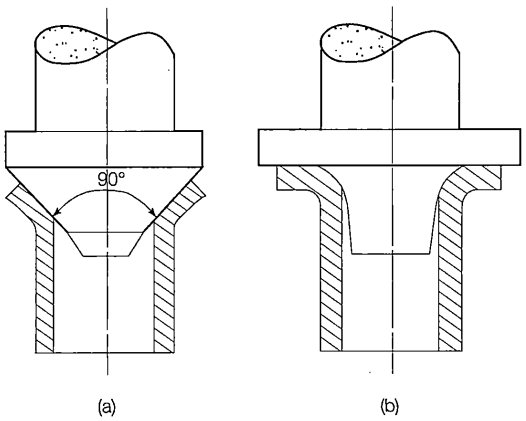

Fig. 2.4.2 Flanging test

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■ *Section 5* Embrittlement tests

5.1 Temper embrittlement tests

5.1.1 The test material is to be heat treated in accordance with the specification except that after tempering:

(a) half the material is to be water quenched;

(b) the other half is to be cooled from the tempering temperature to 300°C at a rate not exceeding 10°C per minute.

5.1.2 Impact tests in accordance with Section 3 are to be made on the material in each condition at temperatures over a range wide enough to establish the upper and lower shelf energies and temperatures, tests being made at no less than three intermediate temperatures.

5.1.3 A set of three specimens is to be tested at each temperature. The results are to be plotted separately for each condition, in the form illustrated in Fig. 2.5.1. In addition, the test temperatures, proportions of crystallinity and absorbed energies for all the specimens tested are to be reported.

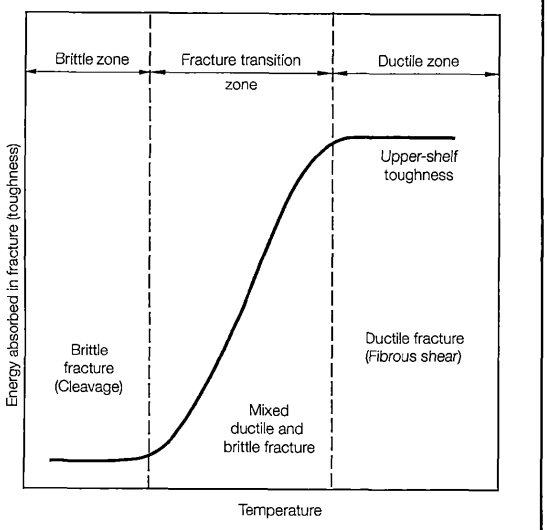

Fig. 2.5.1 Idealised transition curve

5.1.4 The transition temperature for each condition is to be taken as the mid-temperature of the fracture transition zone. The difference between the two transition temperatures is to be reported.

5.2 Strain age embrittlement tests

5.2.1 The test material is to be heat treated in accordance with the specification and then subjected to five per cent strain. Half of the test material is then to be heated to 250°C and held for one hour.

5.2.2 Impact tests in accordance with 5.1.2 are to be made in both the strained and unstrained conditions.

5.2.3 The tests are to comply with 5.1.3.

5.2.4 The test results are treated in accordance with 5.1.4.

5.3 Hydrogen embrittlement tests

5.3.1 Two specimens are to be tested. The specimens are to be of a diameter of 20 mm. Where this is not practicable a diameter of 14 mm may be accepted.

5.3.2 One specimen is to be tested within a maximum of 3 hours after machining. Where the specimen diameter is 14 mm, the time limit is 1,5 hours. Alternatively, the specimen may be cooled to –60°C immediately after machining and kept at that temperature for a maximum period of 5 days before being tested.

5.3.3 The other specimen is to be tested after baking at 250°C for 4 hours. Where the specimen diameter is 14 mm the baking time is to be 2 hours.

5.3.4 A strain rate not exceeding $0{,}0003s^{-1}$ is to be used during the entire test, until fracture occurs.

5.3.5 Tensile strength, elongation and reduction of area are to be reported.

5.3.6 The ratio Z_1/Z_2 is to be reported, where Z_1 is the reduction in area without baking and Z_2 the reduction in area after baking.

■ *Section 6* Crack tip opening displacement tests

6.1 Dimensions of test specimens

6.1.1 Unless agreed otherwise, tests are to be made on specimens of the full section thickness and which conform to a nationally agreed standard.

6.1.2 Normally the specimens are to be rectangular with the main dimensions as indicated in Fig. 2.6.1 and are to be tested in three point bending.

6.1.3 A subsidiary specimen as in Fig. 2.6.2 may be used by agreement.

6.1.4 In each case the notch is to be positioned at the centre of the loading span; its root radius is not to exceed 0,10 mm. The notch is to be extended by the generation of a fatigue crack to give an effective crack length of the dimension *a*. For this purpose, the fatigue stress ratio, R_1, is to be within the range 0 to 0,1 and the fatigue intensity is not to exceed $0{,}63\sigma_\gamma B^{1/2}$ where σ_γ is the 0,2 per cent proof stress at the test temperature.

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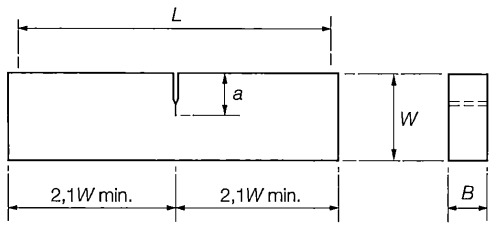
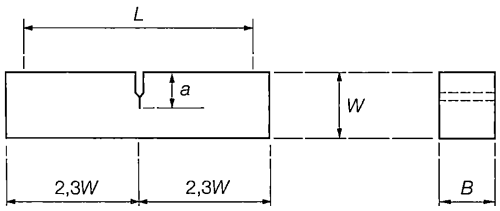


B = thickness
W = width = 2*B*
a = effective crack length = 0,45*W* to 0,55*W*
L = loading span = 4*W*

Fig. 2.6.1
Outline dimensions of the preferred specimen



B = thickness
W = width = *B*
a = effective crack length (to be agreed between the purchaser and manufacturer)
L = loading span = 4*W*

Fig. 2.6.2
Outline dimensions of the subsidiary specimen

6.2 Test equipment

6.2.1 Whenever possible, tests are to be made using machines operating under displacement control. The type of control is to be recorded.

6.2.2 The test equipment is to be calibrated annually.

6.2.3 The crack opening displacement gauge is to have an accuracy of at least one per cent. It is to be calibrated at least once every day of testing and at intervals of no more than 10 tests. It should be demonstrated that the calibration is satisfactory for the test conditions.

6.3 Testing procedures

6.3.1 Tests are to be made in a recognised test house in accordance with a nationally accepted standard.

6.3.2 Unless otherwise agreed, all tests on unwelded wrought material are to be made on specimens taken transverse to the principal working direction and are to be through-thickness notched.

6.3.3 Where tests are made on weld material, the fatigue crack should be arranged to sample the maximum amount of unrefined weld metal.

6.3.4 Where tests are made on the Heat Affected Zone (H.A.Z.) of a weld, a K or single bevel weld preparation is recommended. The region of lowest fracture toughness in the Heat Affected Zone should be identified for the particular steel and weld procedure by means of preliminary tests. The fatigue crack is to be accurately positioned to sample as high a proportion of this critical region as possible and after testing has been completed, the specimen is to be sectioned to check that this has been achieved. Sufficient tests should be made to ensure that the critical region has been sampled in at least three specimens.

6.3.5 At least three valid tests are to be made for each material condition. Invalid tests are to be disregarded and the tests repeated.

6.3.6 Local pre-compression of the test specimen ahead of the notch is acceptable in order to provide an acceptably even fatigue crack front.

6.3.7 The temperature of the test piece is to be measured to within ±2°C over the range minus 196°C to +200°C and to within ±5°C outside this range. The temperature should be measured at a point on the specimen not farther than 2 mm away from the crack tip.

6.4 Validity requirements

6.4.1 The test is to be regarded as invalid if:
(a) the fatigue crack front is not in a single plane;
(b) any part of the fatigue crack surface lies in a plane whose angle with the plane of the notch exceeds 10°;
(c) the length of any part of the fatigue crack is less than 0,025*W* or 1,25 mm, whichever is the greater;
(d) the difference between the maximum and minimum lengths of the fatigue crack exceeds 0,1*W*;
(e) the difference between any two of the lengths of the fatigue crack at 0,25*B*, 0,5*B* and 0,75*B* exceeds 0,05*W*.

6.4.2 In addition, for tests on welds and Heat Affected Zones (H.A.Z.), the following criteria are to be complied with:
(a) Weld metal. The fatigue crack front shall not extend outside the weld metal deposit and 80 per cent should be within 2 mm of the fusion line.
(b) Grain coarsened H.A.Z The fatigue crack should be within 0,5 mm of the fusion line and should sample all of the grain coarsened H.A.Z present. However, if fusion line irregularities prevent this, a sample including as much grain coarsened H.A.Z as possible may be accepted.
(c) Subcritical/intercritical H.A.Z boundary. The fatigue crack is to sample the boundary between the subcritical and intercritical regions of the H.A.Z However, if fusion line irregularities prevent this, a sample including as much relevant microstructure as possible may be accepted.

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6.5 Test reports

6.5.1 The test report is to include:

(a) details of the material, its condition and size;
(b) the thickness and width of the test specimen;
(c) the fatigue pre-cracking conditions;
(d) the test temperature and environment;
(e) the test machine control system and rate of change of displacement or load;
(f) crack length measurements;
(g) force/displacement records, preferably in the form of an autographic record;
(h) the critical crack opening displacement;
(j) a photograph of the fracture;
(k) any observation on the fracture surface.

■ *Section 7* Bend tests

7.1 Dimensions of test specimens

7.1.1 Flat bend test specimens are to be of rectangular cross-section with dimensions as defined in Fig. 2.7.1.

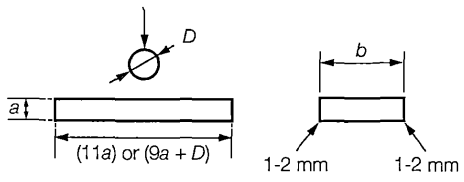

Fig. 2.7.1 Bend test specimen

7.1.2 For plates, sections and strip the dimensions shall be full thickness and width 30 mm. Where the rolled thickness exceeds 25 mm the compression face may be reduced to 25 mm.

7.1.3 For forgings, castings and semi-finished products the thickness shall be 20 mm and width 25 mm.

7.1.4 Butt weld face and root bend test specimens are to be 30 mm in width and of the full plate thickness. Where the thickness exceeds 25 mm, two side bend test specimens may be tested in place of the face and root specimens specified. The side bend specimens should be 10 mm minimum thickness. The upper and lower surfaces of the weld are to be filed, ground or machined flush with the surface of the plate.

7.1.5 The edges on the tension side of bend samples are to be rounded to a radius of 1 to 2 mm.

7.2 Testing procedures

7.2.1 The bend sample is plastically deformed by plunging a mandrel between two fixed points as shown in Fig. 2.7.2.

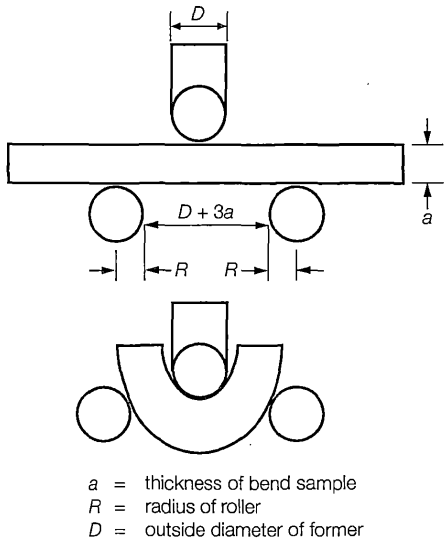

Fig. 2.7.2 Bend test

7.2.2 For aluminium welds a guided bend is required to ensure even deformation as shown in Fig. 2.7.3.

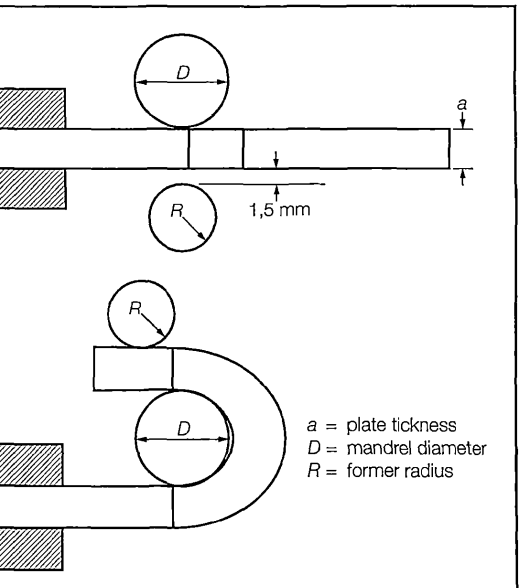

Fig. 2.7.3 Guide bend test for aluminium

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7.2.3 Bend tests are to be conducted at ambient temperature at the highest convenient rate of bending (but not impact).

■ *Section 8* Corrosion tests

8.1 Intergranular corrosion test

8.1.1 For all products other than pipes, the material for the test specimens is to be taken adjacent to that for the tensile test and is to be machined to suitable dimensions for either a round or rectangular section bend test. The diameter or thickness is to be not more than 12 mm, and the total surface area is to be between 1500 mm^2 and 3500 mm^2.

8.1.2 For pipes with an outside diameter not exceeding 40 mm, the test specimens are to consist of a full cross-section. For larger pipes, the test specimens are to be cut as circumferential strips of full wall thickness and having a width of not less than 12,5 mm. In both cases the total surface area is to be between 1500 mm^2 and 3500 mm^2.

8.1.3 Specimens are to be heated to a temperature of 700 ± 10°C for 30 minutes, followed by rapid cooling in water. They are then to be placed on a bed of copper turnings (50 g per litre of test solution) and immersed for 15 to 24 hours in a boiling solution of the following composition:

- 100 g of hydrated copper sulphate granules ($CuSO_4.5H_2O$)
- 184 g (100 ml) sulphuric acid (density 1,84 g/ml) added dropwise to distilled water to make 1 litre of solution.

Precautions are to be taken during boiling to prevent concentration of the solution by evaporation.

8.1.4 After immersion, the full cross-section test specimens from pipes are to be subjected to a flattening test in accordance with Ch 2,4.2. All other test specimens are to be bent, at ambient temperature, through 90° over a former with a diameter equal to twice the diameter or thickness of the test specimen.

8.1.5 After flattening or bending, the test specimens are to be free from cracks on the outer, convex surface.

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Rolled Steel Plates, Strip, Sections and Bars

Chapter 3

Section 1

Section

1 **General requirements**

2 **Normal strength steels for ship and other structural applications**

3 **Higher strength steels for ship and other structural applications**

4 **Steels for boilers and pressure vessels**

5 **Steels for machinery fabrications**

6 **Ferritic steels for low temperature service**

7 **Austenitic and duplex stainless steels**

8 **Plates with specified through thickness properties**

9 **Bars for welded chain cables**

10 **High strength quenched and tempered steels for welded structures**

Section 1 General requirements

1.1 Scope

1.1.1 This Section gives the general requirements for hot rolled plates and sections intended for use in the construction of ships, other marine structures, machinery, boilers and pressure vessels.

1.1.2 This Chapter is not applicable to hot rolled bars intended for the manufacture of bolts, plain shafts, etc., by machining operations only. Where used for this purpose, hot rolled bars are to comply with the requirements of Chapter 5.

1.1.3 Plate and strip which is hot coiled after rolling and subsequently uncoiled, cold flattened and cut to the required dimensions are also subject to the appropriate requirements of this Chapter.

1.1.4 Plates, strip, sections and bars are to be manufactured and tested in accordance with the requirements of Chapters 1 and 2, the general requirements of this Section and the appropriate specific requirements given in Sections 2 to 10.

1.1.5 As an alternative to 1.1.4, materials which comply with National or proprietary specifications may be accepted, provided that these specifications give equivalence to the requirements of this Chapter or are approved for a specific application. Particular attention is to be taken of the minimum required under thickness tolerance, *see* 1.5. Generally, survey and certification of such materials are to be carried out in accordance with the requirements of Chapter 1.

1.1.6 Steels intended for high heat input welding above 50 kJ/cm are to be specially approved. Approval will be indicated on the manufacturer's approval certificate by adding a high heat input welding notation to the grade approved e.g., EH36-W300, indicating approval up to 300 kJ/cm.

1.2 Steel with guaranteed through thickness properties – 'Z' grade steel

1.2.1 When plate material, intended for welded construction, will be subject to significant strains in a direction perpendicular to the rolled surfaces, it is recommended that consideration be given to the use of special plate material with specified through thickness properties, 'Z' grade steel. These strains are usually associated with thermal contraction and restraint during welding, particularly for full penetration 'T'-butt welds, but may also be associated with loads applied in service or during construction. Where these strains are of sufficient magnitude, lamellar tearing may occur. Requirements for 'Z' grade plate material are detailed in Section 8. It is the responsibility of the fabricator to make provision for the use of this material.

1.2.2 Steels intended to have guaranteed through thickness properties will include the supplementary suffix Z25 or Z35 in the designation, for example: LR DH36 Z35.

1.3 Manufacture

1.3.1 All materials are to be manufactured at works which have been approved by LR for the type and grade of steel which is being supplied and for the relevant steelmaking and processing route.

1.3.2 Steel is to be cast in metal ingot moulds or by the continuous casting process. The size of the ingot, billet or slab is to be proportional to the dimensions of the final product such that the reduction ratio is normally to be at least 3 to 1. Sufficient discard is to be taken to ensure soundness in the portion used for further processing.

1.3.3 The cast analysis to be used for certification purposes is to be determined after all alloying additions have been carried out and sufficient time allowed for such an addition to homogenise.

1.3.4 Material may be supplied either as-rolled, normalised, normalising rolled, or thermomechanically controlled rolled. The following definitions apply:

(a) As-rolled (AR) refers to rolling of steel at high temperature followed by air cooling. The rolling and finishing temperatures are typically in the austenite recrystallisation region and above the normalising temperature. The strength and toughness properties of steel produced by this process are generally less than those of steel heat treated, after rolling, or steel produced by advanced processes.

(b) Normalising (N) refers to an additional heating cycle of rolled steel above the critical temperature, A_{c3}, and in the lower end of the austenite recrystallisation region followed by air cooling. The process improves the mechanical properties of as-rolled steel by refining the grain size.

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(c) Normalising rolling (NR), also known as controlled rolling, is a rolling procedure in which the final deformation is carried out in the normalising temperature range, resulting in a material condition generally equivalent to that obtained by normalising.

(d) Thermomechanically controlled rolling (TM) is a procedure which involves the strict control of both the steel temperature and the rolling reduction. Generally a high proportion of the rolling reduction is carried out close to the A_{r3} temperature and may involve the rolling in the dual phase temperature region. Unlike normalising rolling the properties conferred by TM (TMCP) cannot be reproduced by subsequent normalising or other heat treatment. The use of accelerated cooling on completion of TM may also be accepted subject to the special approval by LR.

(e) Accelerated Cooling, (AcC) is a process which aims to improve mechanical properties by controlled cooling with rates higher than air cooling immediately after the final TM operation. Direct quenching is excluded from accelerated cooling. The material properties conferred by TM and AcC cannot be reproduced by subsequent normalising or other austenitising heat treatment.

(f) Quenching and Tempering (QT),is a heat treatment process in which steel is heated to an appropriate temperature above the A_{c3} and then cooled with an appropriate coolant for the purpose of hardening the microstructure, followed by tempering, a process in which the steel is re-heated to an appropriate temperature, not higher than the A_{c1} to restore the toughness properties by improving the microstructure.

1.3.5 Where material is being produced by a normalising rolling or a thermomechanically controlled process (T.M.) an additional program of tests for approval is to be carried out under the supervision of the Surveyors and the results are to be to the satisfaction of Lloyd's Register (hereinafter referred to as 'LR').

1.3.6 Weldable high strength steels may be supplied in the quenched and tempered condition for other marine structures, *see* Section 10.

1.4 Quality of materials

1.4.1 Surface and internal imperfections not prejudicial to the proper application of the steel are not, except by special agreement, to be grounds for rejection. Where necessary, suitable methods of non-destructive examination may be used for the detection of harmful surface and internal defects. The extent of this examination, together with an appropriate acceptance standard, is to be agreed between the purchaser, steelmaker and Surveyor and is to be included in the manufacturing specification.

1.5 Dimensional tolerances

1.5.1 The tolerances on thickness of a given product are defined as:

(a) Minus tolerance is the lower limit of the acceptable range below the nominal thickness.

(b) Plus tolerance is the upper limit of the acceptable range above the nominal thickness.

Nominal thickness is defined by the purchaser at the time of enquiry and order.

1.5.2 The average thickness of a product or products is defined as the arithmetic mean of the measurements made in accordance with the requirements in 1.5.10.

1.5.3 For materials of nominal thickness 5 mm and more intended for hull structural purposes as detailed in Sections 2, 3 and 10, the minus tolerance on thickness of plates, strip and wide flats is 0,3 mm, irrespective of nominal thickness. For wide flats, this applies only where the width is greater than or equal to 600 mm. The average thickness of a product or products is not to be less than the nominal thickness. For thickness below 5 mm, the thickness tolerances are to be specially agreed.

1.5.4 Class C of ISO 7452 may be applied in lieu of 1.5.3. Where this standard is applied, both the requirements in 1.5.11 and the portion of the footnote of Table B.2 in ISO 7542, that reads; "Also a minus side of thickness of 0,3 mm is permitted," are not applicable. Additionally, if ISO 7452 is applied, the steel mill is to ensure that the number of measurements and measurement distribution is appropriate to establish that the plates produced are greater than or equal to the specified nominal thickness.

1.5.5 The minus tolerance on bars and sections (except for wide flats with a width $\geq$ 600 mm) is to be in accordance with the requirements of a recognised National or International Standard.

1.5.6 The Shipbuilder and Owner may agree in individual cases whether they wish to specify a more stringent minus tolerance than that given in this Chapter.

1.5.7 The minus tolerances for plates and wide flats intended for machinery structures are given in Section 5.

1.5.8 For materials intended for applications as detailed in Sections 4 and 6, no minus tolerance is permitted in the thickness of plates and strip. The minus tolerances on sections are to comply with the requirements of a recognised National or International Standard.

1.5.9 For the materials detailed in Section 7, the minus tolerance of material intended for use in the construction of cargo tanks is not to exceed 0,3 mm. For other applications, no minus tolerance is permitted in the thickness of plates and strip.

1.5.10 Dimensional tolerances for material detailed in Section 9 are given in Table 3.9.3.

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1.5.11 The average thickness and thickness tolerance is to be measured at locations of a product or products as defined below:

(a) An automated method or manual method may be applied to the thickness measurements. The procedure and the records of measurements are to be made available to the Surveyor and copies provided on request.

(b) At least two lines among Line 1, Line 2 or Line 3, as shown in Fig. 3.1.1, are to be selected for the thickness measurements and at least three points on each selected line as shown in Fig. 3.1.1 are to be selected for thickness measurement. If more than three points are taken on each line, then the number of points shall be equal on each line.

(c) For automated methods, the measuring points at sides are to be located not less than 10 mm but not greater than 300 mm from the transverse or longitudinal edges of the product.

(d) For manual methods, the measuring points at sides are to be located not less than 10 mm but not greater than 100 mm from the transverse or longitudinal edges of the product.

(e) Additional measurements may be requested by the Surveyor.

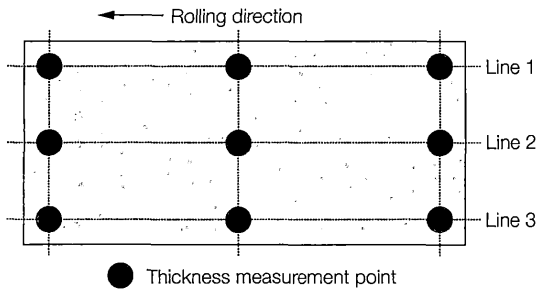

Fig. 3.1.1 Location of thickness measuring points

1.5.12 Local surface depressions resulting from imperfections and ground areas resulting from the elimination of defects may be disregarded provided that they are in accordance with the requirements of a recognised National or International Standard.

1.5.13 Tolerances relating to length, width, flatness and plus thickness are to comply with a National or International Standard.

1.5.14 The responsibility for maintaining the required tolerances and making the necessary measurements rests with the manufacturer. Occasional checking by the Surveyor does not absolve the manufacturer from this responsibility.

1.5.15 The Shipbuilder is responsible for the storage and maintenance of product(s) delivered with acceptable surface conditions.

1.6 Heat treatment

1.6.1 Acceptable conditions of supply are specified in subsequent Sections of this Chapter.

1.6.2 The manufacturer is to carry out any heat treatment which may be necessary to prevent hydrogen cracking or to make the material in a safe condition for transit. The Surveyor is to be advised of any heat treatment proposed.

1.6.3 Where material is manufactured using a thermo-mechanically controlled process consideration must be given to the possibility of consequent reduction in mechanical properties if it is subjected to heating for forming or stress relieving or is welded using a high heat input.

1.7 Test material and mechanical tests

1.7.1 Depending on the type of product, provision is made in subsequent Sections of this Chapter for the testing of individual items or for batch testing. Where the latter is permitted, all materials in a batch presented for acceptance tests are to be of the same product form, (e.g., plates, flats, sections, etc.), from the same cast and in the same condition of supply.

1.7.2 The test samples are to be fully representative of the material and, where appropriate, are not to be cut from the material until heat treatment has been completed. The test specimens are not to be separately heat treated in any way.

1.7.3 The test material is to be taken from the thickest piece in each batch, *see* Ch 1,4.1.

1.7.4 Test material is to be taken from the following positions:

(a) At the square cut end of plates and flats greater than 600 mm wide, approximately one-quarter width from an edge, *see* Fig. 3.1.2(a).

(b) For flats 600 mm or less in width, bulb flats and other solid sections, at approximately one-third of the width from an edge, *see* Fig. 3.1.2(b), (c) and (d). Alternatively, in the case of channels, beams or bulb angles, at approximately one-quarter of the width from the centreline of the web, *see* Fig. 3.1.2(c).

(c) For rectangular hollow sections, at approximately the centre of any side, *see* Fig. 3.1.2(e). For circular hollow sections, at any position on the periphery.

(d) For bars intended for purposes as detailed in Sections 2, 3, 5 and 9, at approximately one-third of the radius or half-diagonal from the outer surface, *see* Fig. 3.1.2(f). For smaller bars, the position of the test material is to be as close as is possible to the above.

(e) For bars intended for the applications detailed in Sections 4, 6 and 7 at approximately 12,5 mm below the surface. For bars up to 25 mm diameter, the test specimens may be machined coaxially.

(f) For plates and flats with thicknesses in excess of 40 mm, full thickness specimens may be prepared, but when instead a machined round specimen is used then the axis is to be located at a position lying one-quarter of the product thickness from the surface as shown in Fig. 3.1.2(g).

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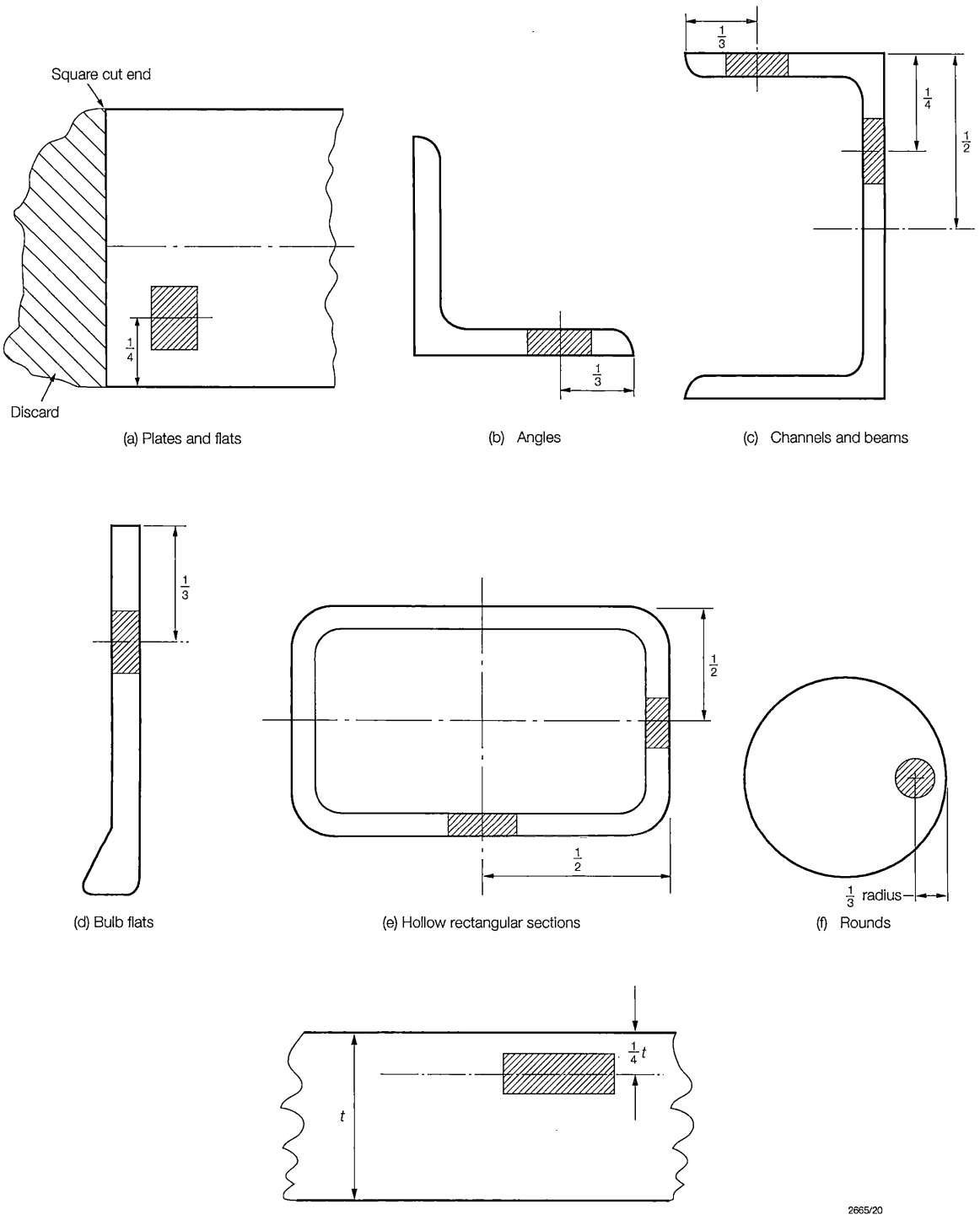

Fig. 3.1.2 Position of test material

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1.7.5 Tensile test specimens and impact test specimens, where required for the type and grade of product being supplied, are to be prepared from each item or batch of material submitted for acceptance.

1.7.6 Where the finished width of plates and flats is greater than 600 mm, the tensile test specimens are to be cut with their principal axes perpendicular to the final direction of rolling. For all other rolled products, the principal axes are to be parallel to the final direction of rolling.

1.7.7 The tensile test specimens are to be machined to the dimensions detailed in Ch 2,2.1.6 and 2.1.7.

1.7.8 Impact test specimens are to be cut with their principal axes either parallel (longitudinal test) or perpendicular (transverse test) to the final direction of rolling, as required by subsequent Sections of this Chapter. Where both longitudinal and transverse impact properties are shown for a particular grade, only the longitudinal test is required to be carried out, unless otherwise specified by the purchase order or subsequent Sections of this Chapter. However, for plates and wide flats, by certifying that the product meets the requirements of the Rules, the manufacturer guarantees that the acceptance values will be met if tested in the transverse direction. The Surveyor may request testing in this direction to confirm conformity.

1.7.9 Impact test specimens are to be of the Charpy V-notch type, machined to the dimensions detailed in Chapter 2. They are to be taken from a position within 2 mm of one of the rolled surfaces, except that for plates and sections over 40 mm thick, the axes of the test specimens are to be at one-quarter of the thickness from one of the rolled surfaces. For bars and other similar products the axes of the test specimens are to be as specified in 1.7.4(d).

1.7.10 Standard test specimens 10 mm square are to be used, except where the thickness of the material does not allow this size of test specimen to be prepared. In such cases the largest possible size of subsidiary test specimen, in accordance with Table 2.3.1 is to be prepared, with the notch cut on the narrow face. Alternatively, for material of suitable thickness, the rolled surfaces may be retained so that the test specimen width will be the full thickness of the material. In such cases the tolerances for width given in Table 2.3.1 in Chapter 2 are not applicable. The notch is to be cut in a face of the test specimen which was originally perpendicular to the rolled surface. The position of the notch is to be not nearer than 25 mm to a flame-cut or sheared edge.

1.7.11 Impact tests are not required when the nominal material thickness is less than 6 mm.

1.7.12 The test procedures used for all tensile and impact tests are to be in accordance with the requirements of Chapter 2.

1.8 Visual and non-destructive examination

1.8.1 Surface inspection and verification of dimensions are the responsibility of the steelmaker and are to be carried out on all material prior to despatch. Acceptance by the Surveyors of material later found to be defective shall not absolve the steelmaker from this responsibility.

1.8.2 With the exception of 'Z' grade plate material (*see* Section 8) and bars for offshore mooring cable (*see* Section 9), the non-destructive examination of materials is not required for acceptance purposes, *see also* 1.4.1. However, manufacturers are expected to employ suitable methods of non-destructive examination for the general maintenance of quality standards.

1.9 Rectification of defects

1.9.1 For materials intended for structural purposes as detailed in Sections 2, 3 and 5, surface defects may be removed by local grinding provided that:

(a) the thickness is in no place reduced to less than 93 per cent of the nominal thickness, but in no case by more than 3 mm,
(b) each single ground area does not exceed 0,25 m^2,
(c) the total area of local grinding does not exceed two per cent of the total surface,
(d) the ground areas have smooth transitions to the surrounding surface.

Where necessary, the entire surface may be ground to a maximum depth as given by the underthickness tolerances of the product. The extent of such rectification is to be agreed in each case with the Surveyors and is to be carried out under their supervision, unless otherwise agreed. They may request that complete removal of the defect is proven by suitable non-destructive examination of the affected area.

1.9.2 Surface defects which cannot be dealt with as in 1.9.1 may be repaired by chipping or grinding followed by welding, subject to the Surveyor's consent and under his supervision, provided that:

(a) after removal of the defect and before welding, the thickness of the item is in no place reduced by more than 20 per cent,
(b) each single weld does not exceed 0,125 m^2,
(c) the total area of welding does not exceed two per cent of the surface of the side involved,
(d) the distance between any two welds is not less than their average width,
(e) the welds are of reasonable size and made with an excess layer of beads which is then ground smooth to the surface level,
(f) elimination of the defect is proven by suitable non-destructive examination of the affected area,
(g) welding is carried out by an approved procedure and by competent operators using approved electrodes and the repaired area is ground smooth to the correct nominal thickness,
(h) when requested by the Surveyor, the item is normalised or otherwise suitably heat treated after welding and grinding, and
(j) at the discretion of the Surveyor, the repaired area is proven free from defects by suitable non-destructive examination.

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1.9.3 For materials intended for applications as detailed in Sections 4, 6 and 7, surface defects may be removed by grinding in accordance with 1.9.1, except that when the thickness is reduced below that given in the approved plans, acceptance will be subject to special consideration. Weld repairs may also be carried out generally in accordance with 1.9.2, except that in all cases suitable heat treatment after welding and non-destructive testing of the repaired areas is required. The fabricator is to be advised regarding the position and extent of all repairs.

1.9.4 For plates which have been produced by a T.M. process or by normalising rolling, repair by welding will be approved by the Surveyor only after procedure tests have shown that the mechanical properties have not been impaired.

1.9.5 Cracks, shells, sand patches and sharp edged seams are always considered defects which would impair the end use of the product and which require rejection or repair irrespective of their size and number. The same applies to other imperfections exceeding the acceptable limits.

1.10 Identification of materials

1.10.1 Every finished item is to be clearly marked by the manufacturer in at least one place with LR's brand ℛ and the following particulars:

(a) The manufacturer's name or trade mark.
(b) The grade of steel. The designations given in subsequent Sections of this Chapter may be preceded by the letters 'LR' in order to fully describe the grade, e.g. LR A, LR 490FG. LR LT-FH40, LR 316L, etc.
(c) When the material complies with the requirements of Section 8, the grade is to include the suffix Z25 or Z35, e.g., LR AH36 Z35.
(d) Identification number and/or initials which will enable the full history of the item to be traced.
(e) If required by the purchaser, his order number or other identification mark.

The above particulars, but excluding the manufacturer's name or trade mark where this is embossed on finished products, are to be encircled with paint or otherwise marked so as to be easily recognisable.

1.10.2 Where a number of light materials are securely fastened together in bundles, the manufacturer may brand only the top piece of each bundle or, alternatively, a firmly fastened durable label containing the identification may be attached to each bundle.

1.10.3 In the event of any material bearing LR's brand failing to comply with the test requirements, the brand is to be unmistakably defaced, *see also* Ch 1,4.8.

1.11 Certification of materials

1.11.1 Unless a LR certificate is specified in other parts of the Rules, a manufacturer's certificate validated by LR is to be issued (*see* Ch 1,3.1) and is to include the following particulars:

(a) Purchaser's name and order number.
(b) If known, the contract number for which the material is intended.
(c) Address to which material is dispatched.
(d) Name of steelworks.
(e) Description and dimensions of the material.
(f) Specification or grade of the steel.
(g) Identification number of piece, including test specimen number where appropriate.
(h) Cast number and chemical composition of ladle samples.
(j) Mechanical test results (not required on shipping statements).
(k) Condition of supply.

1.11.2 Before the test certificates are signed by the Surveyor, the steelmaker is required to provide a written declaration stating that the material has been made by an approved process, and that it has been subjected to and has withstood satisfactorily the required tests in the presence of the Surveyor, or an authorised deputy. The following form of declaration will be accepted if stamped or printed on each test certificate with the name of the steelworks and signed by an authorised representative of the manufacturer:

'We hereby certify that the material has been made by an approved process and satisfactorily tested in accordance with the Rules of Lloyd's Register'.

1.11.3 When steel is not produced at the works at which it is rolled, a certificate is to be supplied by the steelmaker stating the process of manufacture, the cast number and the chemical composition of ladle samples. The works at which the steel was produced must be approved by LR.

1.11.4 The manufacturer of coiled plate is required to issue a certificate which clearly identifies the material as coil. The certificate issued should include the words; 'Coils covered by this certificate require further processing at a works approved by Lloyd's Register before being certified as plate in accordance with the Rules of Lloyd's Register' in addition to the requirements of 1.11.2.

1.11.5 The supplier of plate cut from coil is required to issue a certificate which clearly identifies the product as finished plate meeting the requirements of the Rules in accordance with 1.11.2.

1.11.6 The form of certificates produced by computer systems is to be agreed with the Surveyor.

■ *Section 2*
Normal strength steels for ship and other structural applications

2.1 Scope

2.1.1 The requirements of this Section are primarily intended to apply to steel plates and wide flats not exceeding 100 mm in thickness and sections and bars not exceeding 50 mm in thickness in Grades A, B, D and E. For greater thicknesses, variations in the requirements may be permitted or required for particular applications.

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Table 3.2.1 Chemical composition and deoxidation practice

Grade	A	B	D	E
Deoxidation	For $t \leq 50$ mm: Any method (for rimmed steel, *see* Note 1)	For $t \leq 50$ mm: Any method except rimmed steel	For $t \leq 25$ mm: Killed	Killed and fine grain treated with aluminium
	For $t > 50$ mm: Killed	For $t > 50$ mm: Killed	For $t > 25$ mm: Killed and fine grain treated with aluminium	
Chemical composition % (*see* Note 5)				
Carbon	0,21 max. (*see* Note 2)	0,21 max.	0,21 max.	0,18 max.
Manganese	2,5 x C% min.	0,80 min. (*see* Note 3)	0,60 min.	0,70 min.
Silicon	0,50 max.	0,35 max.	0,10 – 0,35	0,10 – 0,35
Sulphur	0,035 max.	0,035 max.	0,035 max.	0,035 max.
Phosphorus	0,035 max.	0,035 max.	0,035 max.	0,035 max.
Aluminium (acid soluble)	—	—	0,015 min. (*see* Note 4)	0,015 min. (*see* Note 4)
	Carbon + $^1/_6$ of the manganese content is not to exceed 0,40%			

NOTES
1. For Grade A, rimmed steel may only be accepted for sections up to a maximum thickness of 12,5 mm, provided that it is stated on the test certificates or shipping statements to be rimmed steel.
2. The maximum carbon content for Grade A steel may be increased to 0,23% for sections.
3. Where Grade B is impact tested the minimum manganese content may be reduced to 0,60%.
4. The total aluminium content may be determined instead of the acid soluble content. In such cases the total aluminium content is to be not less than 0,020%.
5. Where additions of any other elements are made as part of the steelmaking practice, the content is to be recorded.

2.1.2 Additional approval tests may be required to verify the suitability for forming and welding of Grade E plate exceeding 50 mm in thickness.

2.2 Manufacture and chemical composition

2.2.1 The method of deoxidation and the chemical composition of ladle samples are to comply with the requirements given in Table 3.2.1.

2.2.2 Small variations from the chemical compositions given in Table 3.2.1 may be allowed for Grade E steel in thicknesses exceeding 50 mm or when any Grade of steel is supplied in a thermo-mechanically controlled processed condition, provided that these variations are documented and approved in advance.

2.2.3 The manufacturer's declared analysis will be accepted subject to occasional checks if required by the Surveyors.

2.2.4 For plate supplied from coil, the chemical analysis can be transposed from the certificate of the coil manufacture onto the re-processor's certificate.

2.3 Condition of supply

2.3.1 All materials are to be supplied in a condition complying with the requirements given in Table 3.2.2. Where alternative conditions are permitted these are at the option of the steelmaker, unless otherwise expressly stated in the order for the material, but a steelmaker is to supply materials only in those conditions for which he has been approved by LR.

2.3.2 Where normalising rolling and thermomechanically controlled rolling (T.M.) processes are used, it is the manufacturer's responsibility to ensure that the programmed rolling schedules are adhered to. Where deviation from the programmed rolling schedule occurs, the manufacturer must ensure that each affected piece is tested and that the local Surveyor is informed.

2.3.3 If a steel product supplied in the T.M. condition is to be subjected to heating for forming or stress relieving or is to be welded by a high energy input process, consideration must be given to the possibility of a consequent reduction in mechanical properties.

2.4 Mechanical tests

2.4.1 The results of all tensile tests and the average energy value from each set of three impact tests are to comply with the appropriate requirements given in Table 3.2.3 except where enhanced by the requirements of this Section.

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Table 3.2.2 Condition of supply

Grade	Thickness, mm	Conditions of supply			
A and B	≤50	Any			(*see* Note 1)
	>50 ≤100	N	NR	TM	(*see* Note 2)
D	≤35	Any			(*see* Note 1)
	>35 ≤100	N	NR	TM	(*see* Note 3)
E	≤100	N		TM	(*see* Note 4)

N = normalised
NR = normalising rolled
TM = thermomechanically controlled-rolled

NOTES
1. 'Any' includes as-rolled, normalised, normalising rolled and thermomechanically controlled-rolled.
2. Plates, wide flats, sections and bars may be supplied in the as-rolled condition, subject to special approval from LR.
3. Sections in Grade D steel may be supplied in thicknesses greater than 35 mm in the as-rolled condition provided that satisfactory results are consistently obtained from Charpy V-notch impact tests.
4. Sections in Grade E steel may be supplied in the as-rolled and normalising rolled conditions provided that satisfactory results are consistently obtained from Charpy V-notch impact tests.

2.4.2 With the exception given in 2.4.4, one tensile test is to be made for each batch presented unless the mass of finished material is greater than 50 tonnes, in which case one test is to be made from a different piece from each 50 tonnes or fraction thereof. Additional tests are to be made for every variation of 10 mm in the thickness or diameter of products from the same cast. For sections, the thickness to be considered is the thickness of the product at the point at which samples are taken for mechanical tests. A piece is to be regarded as the rolled product from a single slab or billet, or from a single ingot if this is rolled directly into plates, strip, sections or bars.

2.4.3 For Grades A and B where plate is supplied from coil, results of the tensile test can be transposed from the certificate of the coil manufacture onto the certificate issued by the re-processor. If the coil mass exceeds 50 tonnes, testing will additionally be required from two locations representing the start and end of the coil. For Grades D and E, the mechanical properties must be sampled from the de-coiled plate in accordance with the frequency specified in the Rules.

2.4.4 For plates of thickness exceeding 50 mm in Grade E steel, one tensile test is to be made on each piece.

Table 3.2.3 Mechanical properties for acceptance purposes

Grade	Yield stress N/mm² minimum	Tensile strength N/mm²	Elongation on $5{,}65\sqrt{S_o}$ % minimum	Charpy V-notch impact test (*see* Notes 3, 4, 5, 6 and 7)		
				Thickness mm	Average energy J minimum	
					Longitudinal	Transverse (*see* Note 3)
A	235	400 – 520 (*see* Note 1)	22 (*see* Note 2)	≤50	27	20
B				>50 ≤70	34	24
D				>70 ≤100	41	27
E						

Impact tests are to be made on the various grades at the following temperatures:

A grade	not required
B grade	0°C
D grade	–20°C
E grade	–40°C

NOTES
1. For sections in Grade A, the upper limit of the tensile strength range may be exceeded at the discretion of the Surveyor.
2. For full thickness tensile test specimens with a width of 25 mm and a gauge length of 200 mm (*see* Fig. 2.2.4 in Chapter 2), the minimum elongation is to be:

Thickness mm	≤5	>5 ≤10	>10 ≤15	>15 ≤20	>20 ≤25	>25 ≤30	>30 ≤35	>35 ≤50
Elongation %	14	16	17	18	19	20	21	22

3. Tests are to be taken in the longitudinal direction. Normally, transverse test specimens are not required. Transverse test results for plates and wide flats are to be garenteed by the supplier.
4. *See* 2.4.5 and 2.4.6.
5. *See* 2.4.7.
6. *See* 1.7.11.
7. *See* 2.4.14.

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2.4.5 For Grade A steel, Charpy V-notch impact tests are not required when the thickness does not exceed 50 mm, or up to 100 mm thick if the material is supplied in either the normalised or thermo-mechanically controlled-rolled condition and has been fine grain treated. However, the manufacturer should confirm, by way of regular in-house checks, that the material will meet a requirement of 27 J at +20°C. The results of these checks shall be reported to the Surveyor. The frequency of these checks should as a minimum be every 250 tonnes.

2.4.6 When Grade A steel is supplied in a thickness greater than 50 mm and either, in the normalising rolled condition, or when special approval has been given to supply in the as-rolled condition, a set of three impact test specimens is to be tested from each batch of 50 tonnes or fraction thereof.

2.4.7 Impact tests are not required for Grade B steel of 25 mm or less in thickness. However, the manufacturer is to confirm, by way of regular in-house tests, and on occasional material selected by the Surveyor, that the material meets the requirement in Table 3.2.3. The results of the tests are to be reported to the Surveyor. The frequency of the in-house checks are to be, as a minimum, one set of three impact test specimens for every 250 tonnes.

2.4.8 For Grade B steels of thicknesses above 25 mm, supplied in the as-rolled or normalising rolled condition, one set of three impact test specimens is to be made from the thickest item in each batch presented. If the mass of finished material is greater than 25 tonnes, one extra set of tests is to be made from a different piece from each 25 tonnes or fraction thereof.

2.4.9 For Grade B steels of thicknesses above 25 mm, supplied in the furnace normalised or thermomechanically controlled-rolled condition, one set of three impact test specimens is to be made from the thickest item in each batch presented. If the mass of finished material is greater than 50 tonnes, one extra set of tests is to be made from a different piece from each 50 tonnes or fraction thereof.

2.4.10 For Grade D steels supplied in the as-rolled or normalising rolled condition, one set of three impact test specimens is to be made from the thickest item in each batch presented. If the mass of finished material is greater than 25 tonnes, one extra set of tests is to be made from a different piece from each 25 tonnes or fraction thereof.

2.4.11 For Grade D steels, supplied in the furnace normalised or thermomechanically controlled-rolled condition, one set of three impact test specimens is to be made from the thickest item in each batch presented. If the mass of finished material is greater than 50 tonnes, one extra set of tests is to be made from a different piece from each 50 tonnes or fraction thereof.

2.4.12 For plates in Grade E steel, one set of three impact test specimens is to be made from each piece. For bars and sections in Grade E steel, one set of three test specimens is to be made from each 25 tonnes or fraction thereof. When, subject to the special approval of LR, sections are supplied in the as-rolled or normalising rolled conditions, one set of impact tests is to be taken from each batch of 15 tonnes or fraction thereof.

2.4.13 The results of all tensile tests and the average energy values from each set of three impact tests are to comply with the appropriate requirements given in Table 3.2.3. For impact tests, one individual value may be less than the required average value provided that it is not less than 70 per cent of this average value. *See* Ch 1,4.6 for re-test procedures.

2.4.14 For batch tested Grade B and D steel plates supplied in a condition other than furnace normalised, with a thickness equal to, or greater than 25 mm and 12 mm respectively, and where the average value of one set of tests is less than 40 J, two further items from the same batch are to be selected and tested. If these fail to achieve an average of 40 J on either set, each individual piece of the heat is to be tested. The plates are acceptable provided they meet the requirements of Table 3.2.3. Additional testing is not required where the manufacturer can demonstrate to the satisfaction of the Surveyor that the plate was rolled outside the limits of the programmed rolling schedule. In this instance the plate should be rejected, *see also* 2.3.2.

2.4.15 Where standard subsidiary Charpy V-notch test specimens are necessary, *see* Ch 2,3.2.4.

2.5 Identification of materials

2.5.1 The particulars detailed in 1.10 are to be marked on all materials which have been accepted. Where a number of light materials are bundled, the bundle is to be identified in accordance with 1.10.2.

2.6 Certification of materials

2.6.1 At least two copies of each test certificate are to be provided. They are to be of the type and give the information detailed in 1.11 and, additionally, are to indicate if sections in Grade A steel of rimming quality have been supplied. As a minimum, the chemical composition is to include the contents of any grain refining elements used and the residual elements, as detailed in Table 3.2.1.

■ *Section 3*
Higher strength steels for ship and other structural applications

3.1 Scope

3.1.1 Provision is made for material to be supplied in four strength levels, 27S, 32, 36 and 40.

3.1.2 Provisions for material supplied in H47 strength grades are specifically intended for hatch comings and deck structure of container ships.

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3.1.3 The required notch toughness is designated by subdividing the strength levels into Grades AH, DH, EH and FH.

3.1.4 For the designation to fully identify a steel and its properties the appropriate grade letters should precede the strength level number, e.g. AH32 or FH40.

3.1.5 The requirements of this Section are primarily intended to apply to plates, wide flats, sections and bars not exceeding the thickness limits given in Table 3.3.1. For greater thicknesses, variations in the requirements may be permitted or required for particular applications but a reduction of the required impact energy is not allowed.

3.1.6 It should be noted that the fatigue strength of weldments in steels of high strength levels may not be greater than those of steels of lower strength levels.

3.2 Alternative specifications

3.2.1 Steels differing from the requirements of this Section in respect of chemical composition, deoxidation practice, condition of supply or mechanical properties may be accepted subject to special approval by LR. Such steels are to be given a special designation, *see* 3.7.2.

3.3 Manufacture

3.3.1 All the grades of steel are to be in the killed and fine grain treated condition.

Table 3.3.1 Maximum thickness limits

Steel designation				Maximum thickness mm	
				Plates and wide flats	Sections and bars
AH 27S	DH 27S	EH 27S	FH27S	100 (see Note 1)	50
AH 32	DH 32	EH 32	FH32		
AH 36	DH 36	EH 36	FH36		
AH 40	DH 40	EH40	FH40		
AH 47 (*see* Note 2)	DH 47	EH 47	FH 47		Not applicable

NOTES
1. Where the thickness exceeds 50 mm, the steel must initially be approved by way of a Nil Ductility Test, in accordance with ASTM E208, to show adequate crack arrest properties. The Nil Ductility Test Temperature is to be agreed for the thickness approved to ensure the crack arrest temperature is below the minimum design temperature. Where the thickness exceeds 70 mm and the material is used specifically as a crack arrest plate, the material must be specially approved with a crack arrest fracture toughness Kca ≥ 6000 $N/mm^{1,5}$.
2. Minimum thickness for H47 strength level is 50 mm, *see* 3.1.2.

3.4 Chemical composition

3.4.1 The chemical compositions of ladle samples for all grades of steel are to comply with the requirements given in Table 3.3.2. The requirements for H47 strength grade steels are given in Table 3.3.3.

3.4.2 The carbon equivalent is to be calculated from the ladle analysis using the formula given below and is not to exceed the maximum value agreed between the fabricator and the steelmaker when the steel is ordered.

$$\text{Carbon equivalent} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

For TM steels, the agreed carbon equivalent is not to exceed the values given in Table 3.3.4.

3.4.3 The cold cracking susceptibility, P_{cm}, may be used instead of the carbon equivalent for evaluating weldability, in which case the following formula is to be used for calculating the P_{cm} from the ladle analysis:

$$P_{cm} = C + \frac{Si}{30} + \frac{Mn + Cr + Cu}{20} + \frac{Ni}{60} + \frac{Mo}{15} + \frac{V}{10} + 5B$$

The maximum allowable P_{cm} is to be agreed with LR and is to be included in the manufacturing specification and reported on the certificate.

3.4.4 The cold cracking susceptibility, P_{cm}, is to have a maximum value of 0,22 per cent for steels of H47 strength grade.

3.4.5 Small deviations in chemical composition from that given in Table 3.3.2 for plates exceeding 50 mm in thickness in Grades EH36, EH40, FH36 and FH40 may be approved provided that these deviations are documented and approved in advance.

3.4.6 Where the grain refining elements Niobium, Titanium and Vanadium are used either singly or in combination, the chemical composition is to be specifically approved for each Grade in combination with the rolling procedure to be used.

3.4.7 When any grade is supplied in an approved thermomechanically controlled processed condition, variations in the specified chemical composition may be considered, provided that these variations are documented and approved in advance.

3.4.8 For plate supplied from coil, the chemical analysis can be transposed from the certificate of the coil manufacture onto the re-processor's certificate.

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Table 3.3.2 Chemical composition

Grades	AH, DH, EH	FH
Carbon % max. Manganese % Silicon % max. Phosphorus % max. Sulphur % max.	0,18 0,9 – 1,60 (*see* Note 1) 0,50 0,035 0,035	0,16 0,9 – 1,60 0,50 0,025 0,025
Grain refining elements (*see* Note 2) Aluminium (acid soluble) % Niobium % Vanadium % Titanium % Total (Nb + V + Ti) % (*see* Note 5)	 0,015 min. (*see* Note 3) 0,02 – 0,05 0,05 – 0,10 0,02 max. 0,12 max.	
Residual elements Nickel % max. Copper % max. Chromium % max. Molybdenum % max. Nitrogen % max.	 0,40 0,35 0,20 0,08	 0,80 0,35 0,20 0,08 0,009 (0,012 max. if Al is present)

NOTES
1. For AH grade steels in all strength levels and thicknesses up to 12,5 mm, the specified minimum manganese content is 0,70%.
2. The steel is to contain aluminium, niobium, vanadium or other suitable grain refining elements, either singly or in any combination. When used singly, the steel is to contain the specified minimum content of the grain refining element. When used in combination, the specified minimum content of each element is not applicable.
3. The total aluminium content may be determined instead of the acid soluble content. In such cases the total aluminium content is to be not less than 0,020%.
4. Alloying elements other than those listed above are to be included in the approved manufacturing specification.
5. The grain refining elements are to be in accordance with the approved specification.

Table 3.3.3 Chemical composition for Grade AH 47, DH 47, EH 47 and FH 47

Chemical element	max. (%)
Carbon	0,20
Manganese	2,00
Silicon	0,55
Phosphorus	0,030
Sulphur	0,030
Nickel	2,00
Chromium	0,25
Molybdenum	0,080
Grain refining elements (*see* Note 1) Aluminium (acid soluble)	0,015 min (*see* Note 2)
Residual elements Copper 0,35	

NOTES
1. The grain refining elements niobium, vanadium and titanium are to be in accordance with the approved specification.
2. The total aluminium content may be determined instead of the acid soluble content. In these cases the total aluminium content is to be not less than 0,020%.

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3.5 Condition of supply

3.5.1 All materials are to be supplied in a condition complying with the requirements given in Table 3.3.5 or Table 3.3.6. Where alternative conditions are permitted, these are at the option of the steelmaker, unless otherwise expressly stated in the order for the material.

3.5.2 Where normalising rolling and thermomechanically controlled rolling (T.M.) processes are used, it is the manufacturer's responsibility to ensure that the programmed rolling schedules are adhered to. Where deviation from the programmed rolling schedule occurs, the manufacturer must ensure that each affected piece is tested and that the local Surveyor is informed.

3.5.3 The use of precipitation hardening steels is not acceptable, except where such hardening is incidental to the use of grain refining elements.

3.6 Mechanical tests

3.6.1 The results of all tensile tests and the average energy value from each set of three Charpy V-notch impact tests are to comply with the appropriate requirements given in Table 3.3.7 except where enhanced by the requirements of this Section.

3.6.2 For steels in the as-rolled, normalised, normalising rolled or T.M. conditions, one tensile test is to be made for each batch of 50 tonnes or fraction thereof. Additional tests are to be made for every variation of 10 mm in the thickness or diameter of products from the same cast.

3.6.3 Where plate is supplied from coil, both the tensile tests and the Charpy V-notch tests are to be taken from the de-coiled plate in accordance with the frequency specified for the Grade as required by this Section.

3.6.4 For steels in the quenched and tempered condition a tensile test is to be made on each plate as heat treated. For continuously heat treated plates, one tensile test is to be made for each 50 tonnes or fraction thereof from a single cast. Additional tests are to be made for every variation of 10 mm in the thickness of the products from a single cast. The tensile test specimens are to be taken with their axes transverse to the main direction of rolling.

3.6.5 For products in the AH and DH grades, at least one set of three impact tests is to be made on the thickest piece in each batch of 50 tonnes when supplied in either the normalised or thermomechanically controlled condition. When the products are supplied in the as-rolled or normalising rolled conditions a set of impact test specimens is to be taken from a different piece from each 25 tonnes or fraction thereof. When supplied in the quenched and tempered condition, a set of impact tests is to be made on each length as heat treated. Test specimens from the quenched and tempered plates are to have their axes transverse to the main rolling direction.

3.6.6 For plates and wide flats in the EH and FH grades supplied in the normalised or thermomechanically controlled conditions, one set of impact tests is to be made on each piece. For plates supplied in the quenched and tempered condition a set of impact tests is to be made on each length as heat treated. Test specimens from the quenched and tempered plates are to have their axes transverse to the main rolling direction.

3.6.7 For plates and wide flats in H47 strength grade, one set of impact tests is to be made on each piece.

3.6.8 For sections and bars in the EH and FH grades supplied in the normalised or thermomechanically controlled conditions, one set of impact tests is to be made on the thickest piece in a batch not exceeding 25 tonnes. For sections supplied in the as-rolled or normalising rolled conditions the batch size is not to exceed 15 tonnes.

3.6.9 For batch tested plates in a condition other than furnace normalised, with a thickness equal to 12 mm or greater, and where the average value of one set of tests is less than 50 J, two further items from the same batch are to be selected and tested. If these fail to achieve an average of 50 J on either set, each individual piece of the heat is to be tested. The plates are acceptable provided they meet the requirements of Table 3.3.7. Additional testing is not required where the manufacturer can demonstrate to the satisfaction of the Surveyor that the plate was rolled outside the limits of the programmed rolling schedule. In this instance the plate should be rejected, *see also* 3.5.2.

3.6.10 Where standard subsidiary impact specimens are necessary, *see* Ch 2,3.2.4.

Table 3.3.4 Carbon equivalent requirements for higher tensile strength steels up to 100 mm in thickness when supplied in the TM condition

Grade				Carbon Equivalent, max. (%)	
				$t \leq 50$	$50 < t \leq 100$
AH 27S	DH 27S	EH 27S	FH 27S	0,36	0,38
AH 32	DH 32	EH 32	FH 32	0,36	0,38
AH 36	DH 36	EH 36	FH 36	0,38	0,40
AH 40	DH 40	EH 40	FH 40	0,40	0,42
AH 47	DH 47	EH 47	FH 47	Not applicable (*see* Table 3.3.1)	0,49

NOTE
t = thickness, in mm.

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Table 3.3.5 Conditions of supply for plates and wide flats

Grade	Grain refining practice (*see* Note 1)	Thickness range mm	Conditions of supply (*see* Note 2)				
AH 27S AH 32 AH 36	Al or Al + Ti	≤ 20	AR	N	NR	TM	
		>20 ≤ 100	—	N	NR	TM	(*see* Note 3)
	Nb or V or Al + (Nb or V) or Al + (Ti) + (Nb or V)	≤ 12,5	AR	N	NR	TM	
		>12,5 ≤ 100	–	N	NR	TM	
AH 40	Any practice	≤ 12,5	AR	N	NR	TM	
		>12,5 ≤ 50	—	N	NR	TM	
		>50 ≤ 100	—	N	—	TM	QT
AH 47 DH 47 EH 47 FH 47	Any practice	≤ 50	Not applicable				
		>50 ≤100	TM				
DH 27S DH 32 DH 36	Al or Al + Ti	≤ 20	AR	N	NR	TM	
		>20 ≤ 100	—	N	NR	TM	(*see* Note 4)
	Nb or V or Al + (Nb or V) or Al + (Ti) + (Nb or V)	≤ 12,5	AR	N	NR	TM	
		>12,5 ≤ 100	—	N	NR	TM	
DH 40	Any practice	≤ 50	—	N	NR	TM	
		>50 ≤ 100	—	N	—	TM	QT
EH 27S EH 32 EH 36	Any practice	≤ 100	—	N	—	TM	
EH 40	Any practice	≤ 100	—	N	—	TM	QT
FH 27S FH 32 FH 36 FH 40	Any practice	≤ 100	—	N	—	TM	QT

NOTES
1. Grain refining elements used singly or in any combination, require specific approval from Materials and NDE Department, London office.
2. AR = as-rolled N = furnace normalised NR = normalising rolled
   TM = thermomechanically controlled-rolled QT = quenched and tempered
3. Material up to 35 mm thick may be supplied in the as-rolled condition provided that prior approval has been obtained from LR.
4. Material up to 25 mm thick may be supplied in the as-rolled condition provided that prior approval has been obtained from LR.

3.7 Identification of materials

3.7.1 The particulars detailed in 1.10 are to be marked on all materials which have been accepted and, for ease of recognition, are to be encircled or otherwise marked with paint. Where a number of light products are bundled, the bundle is to be identified in accordance with 1.10.2.

3.7.2 Steels which have been specially approved and which differ from the requirements of this Section are to have the letter 'S' after the agreed identification mark.

3.8 Certification of materials

3.8.1 At least two copies of each test certificate are to be provided. They are to be of the type and give the information detailed in 1.11 and, additionally, are to state the specified maximum carbon equivalent. As a minimum, the chemical composition is to include the contents of any grain refining elements used and of the residual elements.

3.8.2 For steels which have been specially approved, the agreed identification mark, the specified minimum yield stress and, if applicable, the contents of alloying elements are additionally to be stated on the test certificate or shipping statement.

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Table 3.3.6 Conditions of supply for sections and bars

Grade	Grain refining practice (*see* Note 1)	Thickness range mm	Conditions of supply (*see* Note 2)			
AH 27S AH 32 AH 36	Al or Al + Ti	≤20	Any			
		>20 ≤50	N	NR	TM	(*see* Note 3)
	Nb or V or Al + Nb or Al + V or Al + (Ti) + (Nb or V)	≤12,5	Any			
		>12,5 ≤50	N	NR	TM	(*see* Note 3)
AH 40	Any practice	≤12,5	Any			
		>12,5 ≤50	N	NR	TM	
DH 27S DH 32 DH 36	Al or Al + Ti	≤20	Any			
		>20 ≤50	N	NR	TM	(*see* Note 3)
	Nb or V or Al + Nb or Al + V or Al + (Ti) + (Nb or V)	≤12,5	Any			
		>12,5 ≤50	N	NR	TM	(*see* Note 3)
DH 40	Any practice	≤50	N	NR	TM	
EH 27S EH 32 EH 36	Any practice	≤50	N	TM		(*see* Notes 3 and 4)
EH 40	Any practice	≤50	N	TM	QT	
FH 27S FH 32 FH 36 FH 40	Any practice	≤50	N	TM	QT	(*see* Note 4)

NOTES
1. Grain refining elements used singly or in any combination require specific approval from Materials and NDE Department, London Office.
2. N = furnace normalised NR = normalising rolled
   TM = thermomechanically controlled-rolled QT = quenched and tempered
3. Subject to the special approval of LR, sections may be supplied in the as-rolled condition provided satisfactory results are consistently obtained from Charpy V-notch impact tests.
4. Subject to the special approval of LR, sections may be supplied in the NR condition.

3.8.3 The steelmaker is to provide the Surveyor with a written declaration as detailed in 1.11.2.

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Table 3.3.7 Mechanical properties for acceptance purposes (*see* Note 1)

Grades (*see* Note 3)	Yield Stress N/mm^2 min.	Tensile Strength N/mm^2	Elongation on 5,65 $\sqrt{S_o}$ % min. (*see* Note 2)	Charpy V-notch impact tests (*see* Notes 3, 4 and 5) Average energy J minimum					
				$t \leq 50$ mm		$50 < t \leq 70$ mm		$70 < t \leq 100$ mm	
				Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse
AH 27S DH 27S EH 27S FH 27S	265	400 – 530	22	27	20	34	24	41	27
AH 32 DH 32 EH 32 FH 32	315	440 – 570	22	31	22	38	26	46	31
AH 36 DH 36 EH 36 FH 36	355	490 – 630	21	34	24	41	27	50	34
AH 40 DH 40 EH 40 FH 40	390	510 – 650	20	39	26	46	31	55	37
AH 47 DH 47 EH 47 FH 47	460	570 – 720	17	—	—	53	35	64	42

Impact tests are to be made on the various grades at the following temperatures:

AH grades 0°C
DH grades –20°C
EH grades –40°C
FH grades –60°C

NOTES

1. The requirements for products thicker than those detailed in the table are subject to agreement, *see* 3.1.4.
2. For full thickness tensile test specimens with a width of 25 mm and a gauge length of 200 mm, *see* Fig. 2.2.4 in Chapter 2, the minimum elongation is to be:

Thickness mm		≤5	>5 ≤10	>10 ≤15	>15 ≤20	>20 ≤25	>25 ≤30	>30 ≤40	>40 ≤50	>50
Elongation %	Strength levels 27S, 32	14	16	17	18	19	20	21	22	To be specially agreed
	Strength level 36	13	15	16	17	18	19	20	21	
	Strength level 40	12	14	15	16	17	18	19	20	

3. Subject to special approval by LR, the minimum tensile strength may be reduced to 470 N/mm^2, for grades AH36, DH36, EH36 and FH36, in the TM condition when micro-alloying elements Nb, Ti or V are used singly and not in combination and provided the yield to tensile strength ratio does not exceed 0,89. For plates with a thickness ≤12 mm, the yield to tensile strength ratio is to be specially considered.
4. Tests are to be taken in the longitudinal direction. Normally, transverse test specimens are not required. Transverse test results for plates and wide flats are to be guaranteed by the supplier.
5. *See* 1.7.11
6. *See* 3.6.9.
7. For steel of H47 strength grade, the yield to tensile strength ratio is not to exceed 0,94.

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■ *Section 4* Steels for boilers and pressure vessels

4.1 Scope

4.1.1 Provision is made in this Section for carbon, carbon-manganese and alloy steels intended for use in the construction of boilers and pressure vessels. In addition to specifying mechanical properties at ambient temperature for the purposes of acceptance testing, these requirements also give details of appropriate mechanical properties at elevated temperatures which may be used for design purposes.

4.1.2 Where it is proposed to use a carbon or carbon-manganese steel with a specified minimum tensile strength intermediate to those given in this Section, corresponding minimum values for the yield stress, elongation and mechanical properties at elevated temperatures may be obtained by interpolation.

4.1.3 Carbon and carbon-manganese steels with a specified minimum tensile strength of greater than 490 N/mm^2 but not exceeding 520 N/mm^2 may be accepted, provided that details of the proposed specification are submitted for approval.

4.1.4 Where it is proposed to use alloy steels other than as given in this Section, details of the specification are to be submitted for approval. In such cases the specified minimum tensile strength is not to exceed 600 N/mm^2.

4.1.5 Materials intended for use in the construction of the cargo tanks and process pressure vessels storage tanks for liquefied gases and for other low temperature applications are to comply with the requirements of Section 6 or 7, as appropriate.

4.2 Manufacture and chemical composition

4.2.1 The method of deoxidation and the chemical composition of ladle samples are to comply with the appropriate requirements of Table 3.4.1.

4.2.2 For plate supplied from coil, the chemical analysis may be transposed from the certificate of the coil manufacture onto the re-processor's certificate.

4.3 Heat treatment

4.3.1 All materials are to be supplied in a condition complying with the requirements given in Table 3.4.2 except that, when agreed, material intended for hot forming may be supplied in the as-rolled condition.

4.4 Mechanical tests

4.4.1 For plates, a tensile test specimen is to be taken from one end of each piece when the mass does not exceed 5 tonnes and the length does not exceed 15 m. When either of these limits is exceeded, tensile test specimens are to be taken from both ends of each piece. A piece is to be regarded as the rolled product from a single slab or from a single ingot if this is rolled directly into plates.

4.4.2 For strip, tensile test specimens are to be taken from both ends of each coil.

4.4.3 Sections and bars are to be presented for acceptance test in batches containing not more than 50 lengths, as supplied. The material in each batch is to be of the same section size, from the same cast and in the same condition of supply. One tensile test specimen is to be taken from material representative of each batch, except that additional tests are to be taken when the mass of a batch exceeds 10 tonnes.

4.4.4 Where plates are required for hot forming and it has been agreed that the heat treatment will be carried out by the fabricator, the tests at the steelworks are to be made on material which has been cut from the plates and given a normalising and tempering heat treatment in a manner simulating the treatment which will be applied to the plates.

4.4.5 If required by the Surveyors or by the fabricator, test material may be given a simulated stress relieving heat treatment prior to the preparation of the test specimens. This has to be stated on the order together with agreed details of the simulated heat treatment and the mechanical properties which can be accepted.

4.4.6 The results of all tensile tests are to comply with the appropriate requirements given in Tables 3.4.3 to 3.4.5.

4.4.7 Where plate is supplied from coil, the tensile tests are to be taken from the de-coiled plate in accordance with the frequency specified for the Grade as required by this Section.

4.4.8 All test specimens are to be taken in the transverse direction unless otherwise agreed.

4.4.9 When material will be subject to strains in a through thickness direction, it is recommended that it should have specified through thickness properties in accordance with the requirements of Section 8.

4.5 Identification of materials

4.5.1 The particulars detailed in 1.10 are to be marked on all materials which have been accepted.

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Table 3.4.1 Chemical composition and deoxidation practice

Grade of steel	Deoxidation	Chemical composition %						
Carbon and carbon-manganese steels		C max.	Si	Mn	P	S	Al	Residual elements
360 AR	Any method except rimmed steel	0,18	0,50 max.	0,40 – 1,20	0,040 max.		–	Cr 0,25 max. Cu 0,30 max. Mo 0,10 max. Ni 0,30 max. Total 0,70 max.
410 AR		0,21		0,40 – 1,30			–	
460 AR		0,23		0,80 – 1,50			–	
360	Any method except rimmed steel	0,17	0,35 max.	0,40 – 1,20	0,035 max.		–	
410		0,20		0,50 – 1,30			–	
460		0,20 (*see* Note 1)	0,40 max.	0,80 – 1,40			–	
490	Killed		0,10 – 0,50	0,90 – 1,60			–	
360 FG	Killed fine grained	0,17	0,35 max.	0,40 – 1,20	0,035 max.		(*see* Note 2)	
410 FG		0,20		0,50 – 1,30				
460 FG		0,20 (*see* Note 1)	0,40 max.	0,80 – 1,50				
490 FG			0,10 – 0,50	0,90 – 1,60				
510 FG		0,22						

Alloy steel		C	Si	Mn	P S	Al	Cr	Mo	Residual elements
13Cr Mo 45	Killed	0,10–0,18	0,15–0,35	0,4–0,8	0,035 max.	(*see* Note 3)	0,70–1,30	0,40–0,60	Cu 0,30 max.
11Cr Mo 910		0,08–0,18	0,15–0,50				2,00–2,50	0,90–1,10	Ni 0,30 max.

NOTES
1. For thicknesses greater than 30 mm, carbon 0,22% max.
2. Aluminium (acid soluble) 0,015% min. or
   Aluminium (total) 0,018% min.
   Niobium, vanadium or other suitable grain refining elements may be used either in place of or in addition to aluminium.
3. Aluminium (acid soluble or total) 0,020% max.

Table 3.4.2 Condition of supply

Grade of steel	Condition of supply
Carbon and carbon-manganese 360 AR to 460 AR	As-rolled Maximum thickness or diameter is 40 mm
Carbon and carbon-manganese 360 to 490	Normalised or normalised rolled
Carbon and carbon-manganese 360 FG to 510 FG	Normalised or normalised rolled
13Cr Mo 45	Normalised and tempered
11Cr Mo 910	Normalised and tempered

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Table 3.4.3 Mechanical properties for acceptance purposes: carbon and carbon-manganese steels – As-rolled

Grade of steel	Thickness mm	Yield stress N/mm² minimum	Tensile strength N/mm²	Elongation on $5{,}65\sqrt{S_o}$ % minimum
360 AR	≤ 40	190	360–480	24
410 AR		215	410–530	22
460 AR		240	460–580	21

Table 3.4.4 Mechanical properties for acceptance purposes: carbon and carbon-manganese steels – Normalised or normalised rolled

Grade of steel	Thickness mm (*see* Note)	Yield stress N/mm² minimum	Tensile strength N/mm²	Elongation on $5{,}65\sqrt{S_o}$ % minimum
360	>3 ≤16	205	360 – 480	26
	>16 ≤40	195		26
	>40 ≤63	185		25
410	>3 ≤16	235	410 – 530	24
	>16 ≤40	225		24
	>40 ≤63	215		23
460	>3 ≤16	285	460 – 580	22
	>16 ≤40	255		22
	>40 ≤63	245		21
490	>3 ≤16	305	490 – 610	21
	>16 ≤40	275		21
	>40 ≤63	265		20
360 FG	>3 ≤16	235	360 – 480	26
	>16 ≤40	215		26
	>40 ≤63	195		25
410 FG	>3 ≤16	265	410 – 530	24
	>16 ≤40	245		24
	>40 ≤63	235		23
460 FG	>3 ≤16	295	460 – 580	22
	>16 ≤40	285		22
	>40 ≤63	275		21
490 FG	>3 ≤16	315	490 – 610	21
	>16 ≤40	315		21
	>40 ≤63	305		21
510 FG	>3 ≤16	355	510 – 650	21
	>16 ≤40	345		
	>40 ≤63	335		

NOTE
For thicknesses greater than 63 mm, the minimum values for yield stress may be reduced by 1% for each 5 mm increment in thickness over 63 mm. The minimum elongation values may also be reduced one unit, for all thicknesses over 63 mm. For thicknesses over 100 mm, the above values are to be agreed.

Table 3.4.5 Mechanical properties for acceptance purposes: alloy steels – Normalised and tempered

Grade of steel	Thickness mm (see Note)	Yield stress N/mm² minimum	Tensile strength N/mm²	Elongation on $5{,}65\sqrt{S_o}$ % minimum
13Cr Mo45	≤63	305	470–620	20
11Cr Mo910	≤16	275		
	>16 ≤63	265	480–630	18

NOTE
For thicknesses greater than 63 mm, the minimum values for yield stress may be reduced by 1% for each 5 mm increment in thickness over 63 mm. The minimum elongation values may also be reduced one unit, e.g. for all thicknesses over 63 mm. For thicknesses over 100 mm, the above values are to be agreed.

4.6 Certification of materials

4.6.1 At least two copies of each test certificate are to be provided. They are to be of the type and to give the information detailed in 1.11 and, additionally, are to state the specified maximum carbon equivalent. As a minimum, chemical composition is to include the content of any grain refining elements used and of the residual elements, as detailed in Table 3.4.1.

4.7 Mechanical properties for design purposes

4.7.1 Nominal values for the minimum lower yield or 0,2 per cent proof stress at temperatures of 50°C and higher are given in Tables 3.4.6 to 3.4.8.

4.7.2 These values are intended for design purposes only, and verification is not required except for materials complying with National or proprietary specifications where the elevated temperature properties used for design purposes are higher than given in Tables 3.4.6 to 3.4.8.

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Table 3.4.6 Mechanical properties for design purposes (*see* 4.7.1) **: carbon and carbon-manganese steels – As-rolled**

Grade of steel	Thickness mm	Design temperature °C (*see* Note)						
		50	100	150	200	250	300	350
		Nominal minimum lower yield or 0,2% proof stress N/mm^2						
360 AR	≤ 40	154	153	152	145	128	108	102
410 AR	≤ 40	186	183	181	174	155	134	127
460 AR	≤ 40	218	213	210	203	182	161	153

NOTE
Maximum permissible design temperature is 350°C.

4.7.3 In such cases, at least one tensile test at the proposed design or other agreed temperature is to be made on material from each cast. Where materials of more than one thickness are supplied from one cast, the thickest material is to be tested. The test specimens are to be prepared from material adjacent to that used for tests at ambient temperature. The axis of the test specimens, is to be between mid and quarter thickness of the material and the test specimens are to be machined to dimensions in accordance with the requirements of Chapter 2. The test procedure is also to be as detailed in Chapter 2, and the results are to comply with the requirements of the National or proprietary specifications.

4.7.4 As an alternative to 4.7.3, a manufacturer may carry out an agreed comprehensive test program for a stated grade of steel to demonstrate that the specified minimum mechanical properties at elevated temperatures can be consistently obtained. This test program is to be carried out under supervision of the Surveyors, and the results submitted for assessment and approval. When a manufacturer is approved on this basis, tensile tests at elevated temperatures are not required for acceptance purposes but, at the discretion of the Surveyors, occasional check tests of this type may be requested.

Table 3.4.7 Mechanical properties for design purposes (*see* 4.7.1)**: carbon and carbon-manganese steels – Normalised or controlled-rolled**

Grade of steel	Thickness mm (*see* Note)	Design temperature °C								
		50	100	150	200	250	300	350	400	450
		Nominal minimum lower yield or 0,2% proof stress N/mm^2								
360	>3 ≤16	183	175	172	168	150	124	117	115	113
	>16 ≤40	173	171	169	162	144	124	117	115	113
	>40 ≤63	166	162	158	152	141	124	117	115	113
410	>3 ≤16	220	211	208	201	180	150	142	138	136
	>16 ≤40	204	201	198	191	171	150	142	138	136
	>40 ≤63	196	192	188	181	168	150	142	138	136
460	>3 ≤16	260	248	243	235	210	176	168	162	158
	>16 ≤40	235	230	227	220	198	176	168	162	158
	>40 ≤63	227	222	218	210	194	176	168	162	158
490	>3 ≤16	280	270	264	255	228	192	183	177	172
	>16 ≤40	255	248	245	237	214	192	183	177	172
	>40 ≤63	245	240	236	227	210	192	183	177	172
360 FG	>3 ≤16	214	204	185	165	145	127	116	110	106
	>16 ≤40	200	196	183	164	145	127	116	110	106
	>40 ≤63	183	179	172	159	145	127	116	110	106
410 FG	>3 ≤16	248	235	216	194	171	152	141	134	130
	>16 ≤40	235	228	213	192	171	152	141	134	130
	>40 ≤63	222	215	204	188	171	152	141	134	130
460 FG	>3 ≤16	276	262	247	223	198	177	167	158	153
	>16 ≤40	271	260	242	220	198	177	167	158	153
	>40 ≤63	262	251	235	217	198	177	167	158	153
490 FG	>3 ≤16	297	284	265	240	213	192	182	173	168
	>16 ≤40	293	279	260	237	213	192	182	173	168
	>40 ≤63	286	272	256	234	213	192	182	173	168
510 FG	>3 ≤63	313	290	270	255	235	215	200	180	—

NOTE
For thicknesses greater than 63 mm, the values for lower yield or 0,2% proof stress are to be reduced by 1% for each 5 mm increment in thickness up to 100 mm. For thicknesses over 100 mm, the values are to be agreed and verified by test.

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Table 3.4.8 Mechanical properties for design purposes (*see* 4.7.1)**: alloy steels – Normalised and tempered**

Grade of steel	Thickness mm (see Note)	Design temperature °C									
		50	100	200	300	350	400	450	500	550	600
		Nominal minimum lower yield or 0,2% proof stress N/mm^2									
13CrMo 45	>3 ≤63	284	270	248	216	203	199	194	188	181	174
11CrMo 910	>3 ≤63	255	249	233	219	212	207	194	180	160	137

NOTE
For thicknesses greater than 63 mm, the values for lower yield or 0,2% proof stress are to be reduced by 1% for each 5 mm increment in thickness up to 100 mm. For thicknesses over 100 mm, the values are to be agreed and verified by test.

4.7.5 Values for the estimated average stress to rupture in 100 000 hours are given in Table 3.4.9 and may be used for design purposes.

Table 3.4.9 Mechanical properties for design purposes (*see* 4.7.5)**: estimated average values for stress to rupture in 100 000 hours (units N/mm^2)**

Temperature °C	Grades of steel				
	Carbon and carbon-manganese			Low alloy	
	360FG 410FG 460FG	360 410 460	490 490FG 510FG	13CrMo 45	11CrMo 910
380	171	219	227	—	—
390	155	196	203	—	—
400	141	173	179	—	—
410	127	151	157	—	—
420	114	129	136	—	—
430	102	109	117	—	—
440	90	92	100	—	—
450	78	78	85	290	—
460	67	67	73	262	—
470	57	57	63	235	210
480	47	48	55	208	186
490	36	—	47	181	165
500	—	—	—	155	145
510	—	—	—	129	128
520	—	—	—	103	112
530	—	—	—	80	98
540	—	—	—	62	84
550	—	—	—	49	72
560	—	—	—	42	61
570	—	—	—	36	51
580	—	—	—	—	44

Section 5
Steels for machinery fabrications

5.1 General

5.1.1 Steel plates, sections or bars intended for use in the construction of major components of welded machinery structures, such as bedplates, crankcases, frames and entablatures, are to comply with one of the following alternatives:

(a) Any grade of normal strength structural steel as detailed in Section 2.

(b) Any grade of higher tensile structural steel as detailed in Section 3.

(c) Any grade of carbon-manganese boiler or pressure vessel steel as detailed in Section 4, except that for this application batch testing is acceptable. The size of a batch and the number of tensile tests are to be as detailed in Section 2.

5.1.2 The minus tolerances for products for machinery structures are to be in accordance with Table 3.5.1.

Table 3.5.1 Under thickness tolerances

Nominal thickness, t (mm)	Minus tolerance (mm)
$5 \leq t < 8$	–0,4
$8 \leq t < 15$	–0,5
$15 \leq t < 25$	–0,6
$25 \leq t < 40$	–0,8
$t \geq 40$	–1,0

5.2 Certification of materials

5.2.1 At least two copies of each test certificate are to be provided. They are to be of the type and give the information detailed in 1.11 and, additionally, are to state the specified maximum carbon equivalent. As a minimum, chemical composition is to include the contents of any grain refining elements used and of the residual elements.

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■ *Section 6*
Ferritic steels for low temperature service

6.1 Scope

6.1.1 This Section gives specific requirements for carbon-manganese and nickel alloy steels intended for use in the construction of cargo tanks, storage tanks and process pressure vessels for liquefied gases.

6.1.2 The requirements of this Section are also applicable for other types of pressure vessels where the use of steels with guaranteed impact properties at low temperatures is required.

6.1.3 Provision is made for plates and sections up to 40 mm thick.

6.1.4 Steels with alternative chemical compositions or mechanical properties or in a different supply condition may be given special consideration.

6.2 Manufacture and chemical composition

6.2.1 All steels are to be in the killed and fine grain treated condition.

6.2.2 The chemical compositions of carbon-manganese steels are to comply with the appropriate requirements for Grades AH, DH, EH and FH strength levels 27S, 32, 36 and 40, *see* Table 3.3.2. For the uses defined in 6.1.1 and 6.1.2, however, these grades are to be designated LT–AH, LT–DH, LT–EH and LT–FH respectively.

6.2.3 The chemical compositions of nickel alloy steels are to comply with the appropriate requirements of Table 3.6.1.

6.2.4 For plate supplied from coil, the chemical analysis may be transposed from the certificate of the coil manufacture onto the re-processor's certificate.

6.3 Heat treatment

6.3.1 All materials are to be supplied in a condition complying with the requirements given in Table 3.6.2.

Table 3.6.2 Supply conditions

Grade	Plates	Sections and bars
LT – AH	N TM	Any
LT – DH		
LT – EH	Normalised (*see* Note) T.M.C.P. Quenched and tempered	
LT – FH		N TM
1 1/2 Ni 3 1/2 Ni 5Ni	Normalised (*see* Note) Normalised and tempered Quenched and tempered	
9Ni	Double normalised and tempered Quenched and tempered	
NOTE Where the term 'Normalised' is used it does not include normalising rolling.		

6.4 Mechanical tests

6.4.1 For plates, a tensile test specimen is to be taken from one end of each piece when the mass does not exceed 5 tonnes and the length does not exceed 15 m. When either of these limits is exceeded, tensile test specimens are to be taken from both ends of each piece. A piece is to be regarded as the rolled product from a single slab or from a single ingot if this is rolled directly into plates.

6.4.2 For strips, tensile test specimens are to be taken from both ends of each coil.

Table 3.6.1 Chemical compositions of nickel alloy steels

Grade of steel	C	Si	Mn	Ni	P	S	Residual elements	Aluminium
1 1/2 Ni	0,18 max.	0,10 – 0,35	0,30 – 1,50	1,30 – 1,70	0,025 max.	0,020 max.	Cr 0,25 max. Cu 0,35 max. Mo 0,08 max. Total 0,60 max.	Total 0,020% min. Acid soluble 0,015% min.
3 1/2 Ni	0,15 max.		0,30 – 0,90	3,20 – 3,80				
5Ni	0,12 max.			4,70 – 5,30				
9Ni	0,10 max.			8,50 – 10,0				

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6.4.3 Sections and bars are to be presented for acceptance test in batches containing not more than 50 lengths, as supplied. The material in each batch is to be of the same section size, from the same cast and in the same condition of supply. One tensile test specimen is to be taken from material representative of each batch, except that additional tests are to be taken when the mass of a batch exceeds 10 tonnes.

6.4.4 One set of three Charpy V-notch impact test specimens is to be taken for each tensile test specimen required.

6.4.5 For plates, these impact test specimens are to be cut with the principal axis perpendicular to the final direction of rolling. For sections, the impact test specimens are to be taken longitudinally.

6.4.6 The results of all tensile tests are to comply with the appropriate requirements given in Table 3.6.3. The ratio between the yield stress and the tensile strength is not to exceed 0,9 for normalised and TM steels and 0,94 for QT steels.

6.4.7 The average value for the three impact tests is to comply with the appropriate requirements given in Table 3.6.3. One individual value may be less than the required value provided that it is not less than 70 per cent of this average value. *See* Ch 2,1.4 for re-test procedures.

6.4.8 Where standard subsidiary impact specimens are necessary, *see* Ch 2,3.2.4.

6.4.9 Where plate is supplied from coil, both the tensile tests and the Charpy V-notch tests are to be taken from the de-coiled plate in accordance with the frequency specified for the Grade as required by this Section.

6.5 Identification of materials

6.5.1 The particulars detailed in 1.10 are to be marked on all materials which have been accepted.

Table 3.6.3 Mechanical properties for acceptance purposes (*see* Note 1)

Grade of steel		Yield stress N/mm² min.	Tensile strength N/mm²	Elongation on 5,65 $\sqrt{S_o}$ % min.	Charpy V-notch impact tests (*see* Note 3)	
					Test temp. °C	Impact energy
LT – AH	27S	265	400 – 530	22	0	Plates – transverse tests Average energy 27 J min Sections and bars – longitudinal tests Average energy 41 J min
	32	315	440 – 590	22		
	36	355	490 – 620	21		
	40	390	510 – 650	20		
LT – DH	27S	265	400 – 530	22	–20	
	32	315	440 – 590	22		
	36	355	490 – 620	21		
	40	390	510 – 650	20		
LT – EH	27S	265	400 – 530	22	–40	
	32	315	440 – 590	22		
	36	355	490 – 620	21		
	40	390	510 – 650	20		
LT – FH	27S	265	400 – 530	22	–60	
	32	315	440 – 590	22		
	36	355	490 – 620	21		
	40	390	510 – 650	20		
1 1/2 Ni		275	490 – 640	22	–65	
3 1/2 Ni		285	450 – 610	21	–95	
5Ni		390	540 – 740	21	–110	
9Ni		490	640 – 790	18	–196	

NOTES
1. These requirements are applicable to products not exceeding 40 mm in thickness. The requirements for thicker products are subject to agreement.
2. The minimum design temperatures at which plates of different thicknesses in the above grades may be used are given in Fig. 3.6.1 and Fig. 3.6.2. Consideration will be given to the use of thicknesses greater than those in the Tables or to the use of design temperatures below –165°C.
3. Impact tests are not required on thicknesses less than 6 mm.

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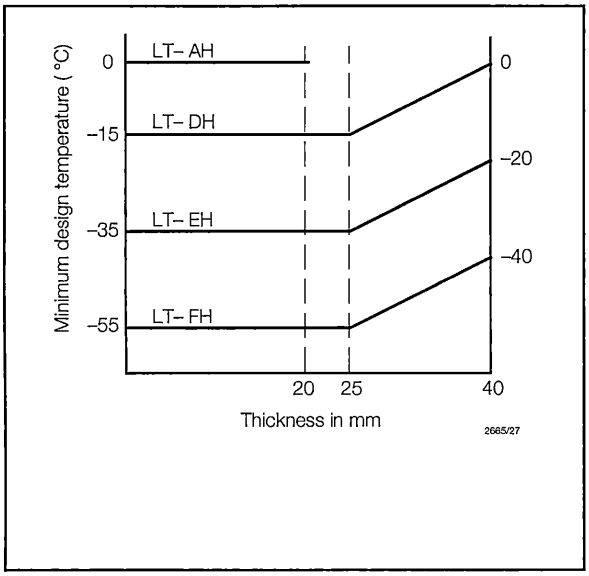
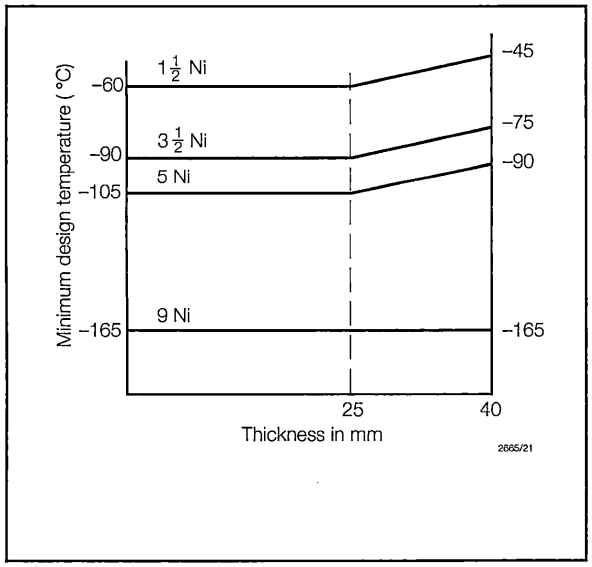
6.6 Certification of materials

6.6.1 At least two copies of each test certificate are to be provided. They are to be of the type and give the information detailed in 1.11 together with general details of the heat treatment. As a minimum, chemical composition is to include the contents of any grain refining elements used and of the residual elements as detailed in Tables 3.3.2 or 3.6.1.





Section 7
Austenitic and duplex stainless steels

7.1 Scope

7.1.1 Provision is made in this Section for rolled products in austenitic and duplex (austenite plus ferrite) stainless steels intended for use in the construction of cargo tanks, storage tanks and process pressure vessels for chemicals and liquefied gases.

7.1.2 Austenitic stainless steels are suitable for applications where the lowest design temperature is not lower than –165°C.

7.1.3 Austenitic stainless steels are also suitable for service at elevated temperatures, and for such applications the proposed specification should contain, in addition to the requirements of 7.1.6, minimum values for 0,2 and 1,0 per cent proof stresses at the design temperature.

7.1.4 Duplex stainless steels are suitable for applications where the lowest design temperature is above 0°C. Any requirement to use duplex stainless steels below 0°C will be subject to special consideration.

7.1.5 Duplex stainless steels are also suitable for service at temperatures up to 300°C, and for such applications the proposed specification should include, in addition to the requirements of 7.1.6, a minimum value for 0,2 per cent proof stress at the design temperature.

7.1.6 A specification giving details of the chemical composition, heat treatment and mechanical properties, including, for the austenitic grades, both the 0,2 and 1,0 per cent proof stresses, is to be submitted for consideration and approval.

7.2 Chemical composition

7.2.1 The chemical composition of ladle samples is to comply with the requirements given in Table 3.7.1.

7.2.2 Consideration will be given to the use of steels whose compositions are outside the scope of Table 3.7.1.

7.3 Heat treatment

7.3.1 All materials are to be supplied in the solution treated condition.

7.4 Mechanical tests

7.4.1 Tensile test specimens are to be taken in accordance with the appropriate requirements of 4.4 and 6.4.1.

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Table 3.7.1 Chemical composition

Type and grade of steel	Chemical composition % (*see* Note)									
	C	Si	Mn	P	S	Cr	Ni	Mo	N	Other
Austenitic										
304 L						17,0—20,0	8,0—13,0	—	0,10	—
304 LN						17,0—20,0	8,0—12,0	—	0,10—0,22	—
316 L	0,03					16,0—18,5	10,0—15,0	2,0—3,0	0,10	—
316 LN		1,0	2,0	0,045	0,03	16,0—18,5	10,0—14,5	2,0—3,0	0,10—0,22	—
317 L						18,0—20,0	11,0—15,0	3,0—4,0	0,10	—
317 LN						18,0—20,0	12,5—15,0	3,0—4,0	0,10—0,22	—
321	0,08					17,0—19,0	9,0—12,0	—	0,10	$5 \times C \leq Ti \leq 0,7$
347	0,08					17,0—19,0	9,0—13,0	—	0,10	$10 \times C \leq Nb \leq 1,0$
Duplex										
UNS S 31803	0,03	1,0	2,0	0,03	0,02	21,0—23,0	4,5—6,5	2,5—3,5	0,08—0,20	—
UNS S 32750	0,03	0,80	1,2	0,035	0,02	24,0—26,0	6,0—8,0	3,0—5,0	0,24—0,32	Cu 0,50 max.

NOTE
All figures are a maximum value except where a range is shown.

Table 3.7.2 Mechanical properties for acceptance purposes

Type and grade of steel	0,2% Proof stress (N/mm^2) minimum	1% Proof stress (N/mm^2) minimum	Tensile strength (N/mm^2) minimum	Elongation on $5,65\sqrt{S_o}$ % minimum
Austenitic				
304L	170	210	485	40
304LN	205	245	515	40
316L	170	210	485	40
316LN	205	245	515	40
317L	205	245	515	40
317LN	240	280	550	40
321	205	245	515	40
347	205	245	515	40
Duplex				
UNS S 31803	450	—	620	25
UNS S 32750	550	—	795	15

7.4.2 For the duplex grades, one set of three Charpy V-notch impact test specimens machined from the longitudinal direction for each tensile test is to be tested at –20°C. The average energy value of the three specimens is to be not less than 41 Joules.

7.4.3 Unless otherwise agreed, impact tests are not required from the austenitic grades of steel given in this Section.

7.4.4 Where standard subsidiary Charpy V-notch test specimens are necessary, *see* Ch 2,3.2.4.

7.4.5 The results of all tensile tests are to comply with the requirements of Table 3.7.2 or the approved specification.

7.5 Through thickness tests

7.5.1 Where material will be strained in a through thickness direction during welding or in service, through thickness tests are required on plates over 10 mm thick in all the grades of steels listed in Table 3.7.1, apart from Grades 304L, 304 LN, 321 and 347.

7.5.2 Testing is to conform with the requirements of Section 8, with the exception given in 7.5.3.

7.5.3 When the reduction in area is less than 35 per cent, metallographic or other evidence is required to show that no significant amount of any detrimental phase, such as sigma, is present.

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7.6 Intergranular corrosion tests

7.6.1 For certain specific applications such as storage tanks for chemicals, it may be necessary to demonstrate that the material used is not susceptible to intergranular corrosion resulting from grain boundary precipitation of chromium-rich carbides.

7.6.2 When required, one test of this type is to be carried out for each tensile test. The material for the test is to be taken adjacent to that for the tensile test.

7.6.3 Unless otherwise agreed or required for a particular chemical cargo, the testing procedure is to be as given in 7.6.4, *see* Ch 2,8.

7.6.4 Wherever practical, exposed cut edges should be avoided. However, where any such edges are to remain after fabrication is completed, it is to be shown by an appropriate test, that the corrosion resistance is adequate for the cargoes expected to be encountered.

7.7 Clad plates

7.7.1 Carbon or carbon-manganese steel plates, clad on one or both surfaces with a suitable grade of austenitic or duplex stainless steel, may be used for the construction of cargo or storage tanks for chemicals.

7.7.2 The carbon or carbon-manganese steel base plates are to comply with the requirements of Section 4, and the austenitic cladding material generally with the requirements of this Section.

7.7.3 The process of manufacture is to be specially approved and may be either by roll cladding, or by explosive bonding.

7.7.4 Where the use of clad materials is proposed, the material specification is to be submitted for consideration, together with details of the extent, and the acceptance standards for non-destructive examination.

7.8 Identification of materials

7.8.1 The particulars detailed in 1.10 are to be marked on all materials which have been accepted.

7.9 Certification of materials

7.9.1 At least two copies of each test certificate are to be provided. They are to be of the type and give the information detailed in 1.11 and, where applicable, the results obtained from intercrystalline corrosion tests, and, additionally, are to state the specified maximum carbon equivalent. As a minimum, chemical composition is to include the contents of any grain refining elements used and of the residual elements, as detailed in Table 3.7.1.

■ *Section 8*
Plates with specified through thickness properties

8.1 Scope

8.1.1 Provision is made in this Section for 'Z' grade plate and wide flat material with improved ductility in the through thickness or 'Z' direction, *see* Fig. 3.8.1. The use of this material is recommended for certain types of welded structures (*see* 1.2) in order to minimise the possibility of lamellar tearing either during fabrication or erection.

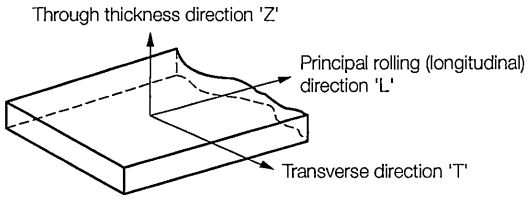

Fig. 3.8.1 Schematic of testing directions

8.1.2 Through thickness properties are characterised by specified values for reduction of area in a through thickness tensile test.

8.1.3 Provision is made for two grades Z25 and Z35. For normal ship applications the Z25 grade is applicable, whilst the Z35 grade is for more severe applications.

8.1.4 This 'Z' grade material is to comply with the requirements of Sections 2, 3, 4, 5 and 6 as appropriate, and the additional requirements of this Section.

8.1.5 The test procedure detailed in this Section may also be used to demonstrate that no unacceptable amount of banding of any detrimental phase, such as sigma is present, *see* 7.5.

8.2 Manufacture

8.2.1 All plates and wide flats are to be manufactured at works, which have been approved by LR for this quality of material.

8.2.2 It is recommended that the steel should be efficiently vacuum de-gassed. The sulphur content is not to exceed 0,008 per cent.

8.2.3 Consideration will be given to proposals for alternative methods of improving through thickness properties.

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8.3 Test material

8.3.1 Unless otherwise agreed, through thickness tensile tests are only required for plate materials where the thickness exceeds 15 mm for carbon and alloy steels, or 10 mm in the case of austenitic and duplex stainless steels.

8.3.2 For plates and wide flats, one test sample is to be taken close to the longitudinal centreline from one end of each rolled piece representing the batch, *see* Table 3.8.1 and Fig. 3.8.2. The test sample must be large enough to accommodate the preparation of 6 specimens. 3 test specimens are to be prepared while the rest of the sample remains for possible retest.

8.3.3 The dimensions of the test specimens are to be in accordance with Ch 2,2.1.12.

Table 3.8.1 Batch size dependent on product and sulphur content

Product	$S > 0{,}005\%$	$S \leq 0{,}005\%$
Plates	Each piece (parent plate)	Maximum 50 *t* of products of the same cast, thickness and heat treatment
Wide flats of nominal thickness ≤ 25 mm	Maximum 10 *t* of products of the same cast, thickness and heat treatment	Maximum 50 *t* of products of the same cast, thickness and heat treatment
Wide flats of nominal thickness > 25 mm	Maximum 20 *t* of products of the same cast, thickness and heat treatment	Maximum 50 *t* of products of the same cast, thickness and heat treatment

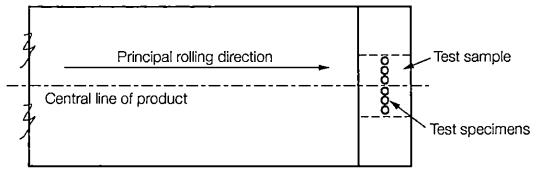

Fig. 3.8.2
Plate and wide flat sampling position

8.3.4 Alternatively, test sampling may be carried out in accordance with an accepted National or International Standard.

8.4 Mechanical tests

8.4.1 The three through thickness tensile test specimens are to be tested at ambient temperature, and for acceptance are to give a minimum average reduction of area value of not less than that shown in Table 3.8.2. Only one individual value may be below the minimum average, but should not be less than the minimum individual value shown for the appropriate grade.

Table 3.8.2 Reduction of area acceptance values

Grade	Z25	Z35
Minimum average	25%	35%
Minimum individual	15%	25%

8.4.2 If the average value fails to comply with 8.4.1, three additional tests may be made on specimens from the same test sample. The results of these tests are to be added to those previously obtained to form a new average, which for acceptance is to be not less than 25 per cent for grade Z25 or 35 per cent for grade Z35. No individual results in the re-test shall be below 25 per cent for grade Z25 or 35 per cent for grade Z35, *see* Fig. 3.8.3.

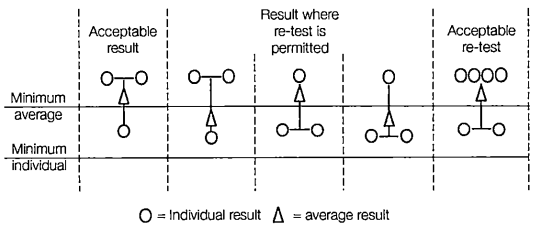

Fig. 3.8.3
Diagram showing acceptance/rejection and re-test criteria

8.4.3 Where batch testing is permitted, and failure after re-test occurs, the tested piece is to be rejected. Each remaining piece in the batch may be individually tested and accepted, based on satisfactory results.

8.4.4 If the fracture of a test specimen occurs in the weld or in the heat affected zone the test is to be regarded as invalid and is to be repeated on a new test specimen.

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8.5 Non-destructive examination

8.5.1 All 'Z' grade plates are to be ultrasonically tested in the final supply condition with a probe frequency of 3-5 MHz. The testing is to be performed in accordance with and in compliance with either EN 10160 Level S1/E1 or ASTM A 578 Level C.

8.6 Identification of materials

8.6.1 Products which comply with the requirements of this Section are to have the notation Z25 or Z35 added to the steel grade designation.

8.7 Certification of materials

8.7.1 The following information is required to be included on the certificate in addition to the appropriate steel grade requirements:

(a) Through thickness reduction in area (%), individual results and average.
(b) Steel grade with Z25 or Z35 notation.

8.7.2 Steel grade requirements are to comply with Sections 1 to 7.

■ *Section 9*
Bars for welded chain cables

9.1 Scope

9.1.1 Provision is made in this Section for rolled steel bars intended for the manufacture of three Grades (U1, U2 and U3) of stud link chain cable for the anchoring and mooring of ships and five Grades (R3, R3S, R4, R4S and R5) of offshore mooring cable.

9.1.2 For the ship grades, U1, U2 and U3, approval will permit the supply of bars of the appropriate grades and size to any chain cable manufacturer.

9.1.3 For the offshore grades, R3, R3S, R4, R4S and R5, approval is confined to bar to be supplied to a nominated chain manufacturer and will be given only after successful testing of a completed chain. Separate approvals are required if bar is to be supplied to more than one cable manufacturer. Approval of a higher grade does not cover approval of a lower grade, as all grades must be individually approved.

9.1.4 For all grades, approval is normally given for diameters of bars no greater than those of the bars used in procedure tests.

9.2 Manufacture

9.2.1 All grades of bar material are to be made from killed steel, and all grades of bar material except for Grade U1 chain cables are to be fine grained. For Grades R4S and R5 the austenite grain size is to be 6 or finer, in accordance with ASTM E112.

9.2.2 The bars are to be made to a specification approved by LR which should include the manufacturing procedure, deoxidation practice, heat treatment and mechanical properties.

9.2.3 The rolling reduction ratio of bars for Grades R3, R3S, R4, R4S and R5 must be at least 5:1.

9.3 Chemical composition

9.3.1 For Grades U1, U2 and U3 the chemical composition should be generally within the limits given in Table 3.9.1.

9.3.2 For Grades R3, R3S, R4, R4S and R5 the chemical composition is to comply with an approved specification, *see* 9.2.2.

9.3.3 For Grades R4, R4S and R5 chain cable the steel should contain a minimum of 0,2 per cent molybdenum. The reported composition is to include the contents of antimony, arsenic, tin, copper, nitrogen, aluminium and titanium.

Table 3.9.1 Chemical composition of killed steel bars

Grade	Chemical composition %												
	C max.	Si	Mn	P max.	S max.	Al	Nb max.	V max.	N max.	Cr max.	Cu max.	Ni max.	Mo max.
U1	0,20	0,15–0,35	0,40 min.	0,04	0,04	–	–	–	–	–	–	–	–
U2	0,24	0,15–0,55	1,60 max.	0,035	0,035	0,02 min. *see* Note 1	–	–	–	–	–	–	–
U3	0,33	0,15–0,35	1,90 max.	0,04	0,04	0,065 max. *see* Note 2	0,05 *see* Note 2	0,10 *see* Note 2	0,015	0,25	0,35	0,40	0,08

NOTES
1. Aluminium may be partly replaced by other grain refining elements.
2. To obtain fine grain steel, at least one of these grain refining elements must be present in sufficient amount.

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9.3.4 For Grades R4S and R5 the steel used must be vacuum degassed.

9.4 Heat treatment

9.4.1 Unless stipulated otherwise, the bars are to be supplied in the as-rolled condition, but the supplier is to be advised by the chain manufacturer of the heat treatment to be used for the completed chain in order that the mechanical test specimens may be tested in the condition of heat treatment used for the chain.

9.4.2 For Grades U1 and U2, the samples selected from each batch may be tested either in the as-rolled condition, or after heat treatment where the chain is to be used in the heat treated condition, in full cross-section and in a manner simulating the heat treatment applied to the finished cable.

9.4.3 For Grades U3, R3, R3S, R4, R4S and R5 the sample is to be tested after heat treatment as detailed in 9.4.2.

9.5 Embrittlement tests

9.5.1 For Grades R3, R3S, R4, R4S and R5 the bar manufacturer is to provide evidence that the material is not susceptible to strain ageing, or to temper brittleness under the conditions of manufacture of the chain. The results of the relevant tests are to be reported to LR at the approval stage. Approval will be restricted to the specified steel composition and if later this is altered then re-approval will be required. Temper brittleness testing may be waived, if the chain is to be quenched after tempering.

9.5.2 Each heat of steel bars of grades R3S, R4, R4S and R5 is to be tested for hydrogen embrittlement (*see* Ch 2,5.3). In the case of continuous casting, test samples representing both the beginning and the end of the charge are to be taken. In the case of ingot casting, test samples representing two different ingots are to be taken.

9.5.3 Each sample is to be heat treated in a manner simulating the heat treatment of the finished chain. From each sample, two specimens are to be prepared from the mid-diameter of the bar and tested in accordance with Ch 2,5.3.

9.5.4 The ratio Z_1/Z_2 is to be greater than or equal to 0,85, where Z_1 is the reduction in area without baking and Z_2 the reduction in area after baking.

9.5.5 If the requirement is not met, the material is to be subjected to a hydrogen degassing treatment which is subject to approval by LR. Further tests are to be performed after degassing.

9.6 Mechanical tests

9.6.1 Bars of the same nominal diameter are to be presented for test in batches of 50 tonnes or fraction thereof from the same cast. A suitable length from one bar in each batch is to be selected for test purposes. Test pieces are to be taken from the positions as shown in Fig. 3.9.1.

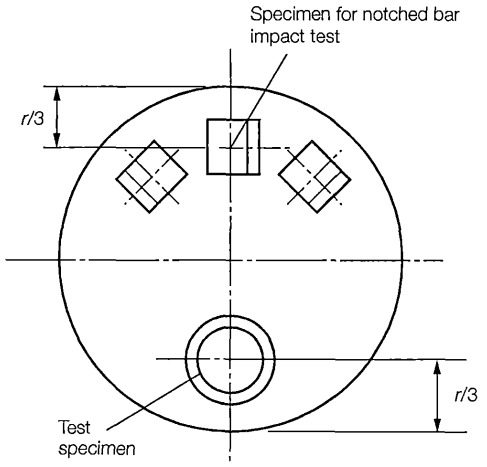

Fig. 3.9.1 Sampling of steel bars

9.6.2 For all grades, one tensile test is to be taken from each sample length selected. Additionally, for Grades U3, R3, R3S, R4, R4S and R5 material, one set of three Charpy V-notch impact test specimens is to be prepared. Impact tests are also required for Grade U2 when the chain is to be supplied in as-welded condition.

9.6.3 The results of all tensile and, where applicable, impact tests are to be in accordance with the appropriate requirements of Table 3.9.2.

9.6.4 Failure to meet the requirements will result in the rejection of a batch of material, unless it is clearly attributed to improper simulated heat treatment. This is to be confirmed to be to the satisfaction of LR, and further heat treatment and testing will be required prior to acceptance.

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9.7 Structure and hardenability tests

9.7.1 For Grades R4S and R5, the following tests are to be carried out on each heat:

(a) Assessment and quantification of the level of non-metallic micro inclusion. These must be acceptable for the final product.

(b) Macro etching on a representative sample, in accordance with ASTM E381 or equivalent. This must be free from any injurious segregation or porosity.

(c) Jominy hardenability tests in accordance with ASTM A255 or equivalent.

9.8 Dimensional tolerances

9.8.1 The tolerances on diameter and ovality of the bar are to be in accordance with Table 3.9.3.

9.9 Non-destructive examination

9.9.1 For the R3, R3S, R4, R4S and R5 grades all bars are to be inspected by a magnetic particle or eddy current method, and are also to be subjected to ultrasonic examination.

9.9.2 All non-destructive examination is to be carried out in accordance with approved procedures, in accordance with Ch 1,5.

9.9.3 All non-destructive examination operators are to be qualified in the method of non-destructive examination, to a minimum of Level II in accordance with a recognised standard.

9.9.4 The bars are to be free from pipes, cracks, flakes, and injurious surface defects such as seams, laps, and rolled-in mill scale. Longitudinal discontinuities may be removed by blending to a smooth contour provided that their depth is not greater than 1 per cent of the bar diameter, and that the required diameter tolerances are not compromised. The contour radiuses are to be a minimum of four times the excavation depth.

9.9.5 The frequency of non-destructive testing may be reduced at the discretion of LR, provided statistical evidence is available that the required quality is achieved consistently.

Table 3.9.2 Mechanical properties

Grade	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation on 5,65 $\sqrt{S_o}$ % minimum	Reduction of area % minimum	Charpy V-notch impact tests		
					Test temperature °C	Average energy J minimum	Average energy flash weld J minimum
U1	–	370–490	25	—	—	—	—
U2	295	490–690	22	—	0 (*see* Note 1)	27	—
U3	410	690 minimum	17	40	0 –20 (*see* Note 2)	60 35	— —
R3	410 (*see* Note 3)	690 minimum (*see* Note 3)	17	50	0 –20 (*see* Note 2)	60 40	50 30
R3S	490 (*see* Note 3)	770 minimum (*see* Note 3)	15	50	0 –20 (*see* Note 2)	65 45	53 33
R4	580 (*see* Note 3)	860 minimum (*see* Note 3)	12	50	–20	50	36
Grade R4S (*see* Note 4)	700 (*see* Note 3)	960 minimum (*see* Note 3)	12	50	–20	56	40
Grade R5 (*see* Note 4)	760 (*see* Note 3)	1000 minimum (*see* Note 3)	12	50	–20	58	42

NOTES
1. Impact tests may be waived when the chain cable is to be supplied in one of the heat treated conditions given in Table 10.2.3.
2. Testing may be carried out at either 0°C or –20°C, at the option of LR.
3. The ratio of yield strength to tensile strength should not exceed 0,92.
4. The maximum hardness for R4S is to be HB330, and for R5 is to be HB340.

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Table 3.9.3 Dimensional tolerance of bar stock

Nominal diameter mm	Tolerance on diameter mm	Tolerance on roundness ($d_{max} - d_{min}$) mm
≤20	–0/+1,0	0,60
>20 ≤25	–0/+1,0	0,60
>26 ≤35	–0/+1,2	0,80
>36 ≤50	–0/+1,6	1,10
>51 ≤80	–0/+2,0	1,50
>81 ≤100	–0/+2,6	1,95
>101 ≤120	–0/+3,0	2,25
>121 ≤160	–0/+4,0	3,00
>161 ≤210	–0/+5,0	4,00

9.10 Identification

9.10.1 Each bar is to be identified in accordance with 1.10 and, in addition, is to be marked with the appropriate grade of chain cable.

9.11 Certification of materials

9.11.1 Each consignment of bars is to be accompanied by a certificate of a type and in accordance with 1.11, but with the addition of the grade of chain cable, the rolling reduction ratio, the results of the micro inclusion, macro etch and hardenability tests, where required by each grade.

■ *Section 10* High strength quenched and tempered steels for welded structures

10.1 Scope

10.1.1 Provision is made in this Section for weldable high strength quenched and tempered steel plates and wide flats up to 70 mm thick. However, special consideration will be given to thicknesses up to 50 mm supplied in the TM rolled condition.

10.1.2 Plates and wide flats exceeding 70 mm in thickness as well as other product forms may also be supplied in accordance with the requirements of this Section, provided that the prior agreement of LR is obtained.

10.1.3 The steels may be supplied in six strength levels with minimum yield stresses of 420, 460, 500, 550, 620 and 690 N/mm^2 respectively.

10.1.4 Each strength level is sub-divided into four grades AH, DH, EH and FH, differing essentially in the required levels of notch toughness.

10.1.5 For the designation to fully identify a steel and its properties, the appropriate grade letter should precede the strength level number, e.g., EH 42.

10.1.6 Steels differing in strength level, mechanical properties and chemical composition from those detailed in this Section may be supplied, subject to special approval from LR. Such steels are to have the letter 'S' after the agreed identification mark.

10.2 Manufacture and chemical composition

10.2.1 The steels are to be fully killed and fine grain treated.

10.2.2 The chemical composition is to comply with the requirements of the approved manufacturing specification and the limits set in Table 3.10.1.

10.2.3 The cold cracking susceptibility, P_{cm}, may be used as an alternative to the carbon equivalent for evaluating weldability. It is to be calculated from the ladle analysis using the following formula:

$$P_{cm} = C + \frac{Si}{30} + \frac{Mn + Cr + Cu}{20} + \frac{Ni}{60} + \frac{Mo}{15} + \frac{V}{10} + 5B$$

The maximum allowable P_{cm} is to be agreed with LR and is to be included in the approved manufacturing specification.

10.3 Mechanical properties

10.3.1 At least one tensile test piece and one set of three Charpy V-notch impact tests specimens are to be taken from each piece as heat treated.

10.3.2 For continuously heat treated products, one tensile test piece and a set of three impact test specimens are to be taken from each plate as heat treated.

10.3.3 For plates and wide flats with widths exceeding 600 mm, the tensile and impact test specimens are to be taken with their axes transverse to the final direction of rolling. For other products, the impact test specimens are to be taken in the longitudinal direction but the tensile test specimens may be taken in either the longitudinal or transverse direction as agreed with LR.

10.3.4 The results of all tests are to comply with the appropriate requirements of Table 3.10.2.

10.3.5 Where standard subsidiary impact test specimens are necessary, *see* Ch 2,3.2.4.

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Table 3.10.1 Chemical composition

Grade	AH	DH EH	FH
Carbon % max	0,21	0,20	0,18
Manganese % max	1,70	1,70	1,60
Silicon % max	0,55	0,55	0,55
Phosphorus % max	0,035	0,030	0,025
Sulphur % max	0,035	0,030	0,025
Nitrogen % max	0,020	0,020	0,020
Grain refining elements (*see* Note 1)			
Aluminium (acid soluble) % min (*see* Note 2)		0,015	
Niobium %		0,02—0,05	
Vanadium %		0,03—0,10	
Titanium % max		0,02	
Total (Nb + V + Ti) % max		0,12	

NOTES
1. The steel is to contain aluminium, niobium, vanadium or other suitable grain refining elements, either singly or in any combination. When used singly, the content is to be within the limits given in the Table. When used in combination, these limits are not applicable but the proportions of the grain refining elements are to be in accordance with the approved manufacturing specification.
2. The total aluminium content may be determined instead of the acid soluble content. In such cases the total aluminium content is not to be less than 0,020%.
3. Alloying elements and residual elements other than those listed in the Table (e.g., Ni, Cr, Cu, Mo and B) are to be included in the approved manufacturing specification.

10.4 Identification of materials

10.4.1 The particulars detailed in 1.10 are to be marked on each piece which has been accepted and, for ease of recognition, are to be encircled or otherwise marked with paint.

10.5 Certification of materials

10.5.1 At least two copies of each test certificate are to be provided. They are to be of the type and give the information detailed in 1.11 and, additionally, are to state the specified maximum carbon equivalent. As a minimum, chemical composition is to include the contents of any grain refining elements used and of the residual elements as detailed in Table 3.10.1.

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Table 3.10.2 Mechanical properties for acceptance purposes

Grade	Yield stress N/mm² min. (*see* Note 1)	Tensile strength N/mm²	Elongation on $5{,}65\sqrt{S_o}$ % minimum (*see* Note 2)		Charpy V-notch impact tests (*see* Note 4)		
					Test temperature	Average energy J minimum	
			Transverse	Longitudinal	°C	Transverse	Longitudinal
AH 42 DH 42 EH 42 FH 42	420	530 – 680	18	20	0 –20 –40 –60	28	42
AH 46 DH 46 EH 46 FH 46	460	570 – 720	17	19	0 –20 –40 –60	31	46
AH 50 DH 50 EH 50 FH 50	500	610 – 770	16	18	0 –20 –40 –60	33	50
AH 55 DH 55 EH 55 FH 55	550	670 – 830	16	18	0 –20 –40 –60	37	55
AH 62 DH 62 EH 62 FH 62	620	720 – 890	15	17	0 –20 –40 –60	41	62
AH 69 DH 69 EH 69 FH 69	690	770 – 940	14	16	0 –20 –40 –60	46	69

NOTES

1. Where a distinct yield stress indication is not obtainable during tensile testing the 0,2% proof stress is applicable.
2. For full thickness tensile test specimens with a width of 25 mm and a gauge length of 200 mm (*see* Fig. 2.2.4 in Chapter 2) the minimum elongation is to be:

Thickness mm		≤10	>10 ≤15	>15 ≤20	>20 ≤25	>25 ≤40	>40 ≤50	>50 ≤70
Strength levels								
Elongation %	42	11	13	14	15	16	17	18
	46	11	12	13	14	15	16	17
	50 and 55	10	11	12	13	14	16	16
	62	9	11	12	12	13	14	15
	69	9	10	11	11	12	13	14

These values apply to transverse specimens. Where the use of longitudinal specimens has been agreed, the values are to be increased by 2%.

3. The ratio of yield strength to tensile strength should not exceed 0,94.
4. Impact tests are not required on thicknesses less than 6 mm.

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Steel Castings

Chapter 4

Section 1

Section

1 **General requirements**

2 **Castings for ship and other structural applications**

3 **Castings for machinery construction**

4 **Castings for crankshafts**

5 **Castings for propellers**

6 **Castings for boilers, pressure vessels and piping systems**

7 **Ferritic steel castings for low temperature service**

8 **Stainless steel castings**

9 **Steel castings for container corner fittings**

Section 1
General requirements

1.1 Scope

1.1.1 This Section gives the general requirements for steel castings intended for use in the construction of ships, other marine structures, machinery, boilers, pressure vessels and piping systems.

1.1.2 Where required by the relevant Rules dealing with design and construction, castings are to be manufactured and tested in accordance with Chapters 1 and 2, together with the general requirements given in this Section and the appropriate specific requirements given in Sections 2 to 9.

1.1.3 As an alternative to 1.1.2, castings which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Chapter or alternatively are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

1.1.4 Where small castings are produced in large quantities, or where castings of the same type are produced in regular quantities, alternative survey procedures, in accordance with Ch 1,2.4 may be adopted.

1.2 Manufacture

1.2.1 Castings are to be made at foundries approved by LR. The steel used is to be manufactured by a process approved by Lloyd's Register (hereinafter referred to as 'LR').

1.2.2 All flame cutting, scarfing or arc-air gouging to remove surplus metal is to be undertaken in accordance with recognised good practice and is to be carried out before the final heat treatment. Preheating is to be employed where necessitated by the chemical composition and/or thickness of the casting. The affected areas are to be either machined or ground smooth for a depth of about 2 mm unless it has been shown that the material has not been damaged by the cutting process. Special examination will be required to find any cracking in way of the cut surfaces.

1.2.3 Where two or more castings are joined by welding to form a composite item, details of the proposed welding procedure are to be submitted for approval. Welding approval procedure tests will be required, *see also* the requirements of 1.9.

1.3 Quality of castings

1.3.1 All castings are to be free from surface or internal defects which would be prejudicial to their proper application in service. The surface finish is to be in accordance with good practice and any specific requirements of the approved specification.

1.3.2 The surfaces are not to be hammered, peened or treated in any way which may obscure defects.

1.3.3 The locations of all chaplets are to be noted and to be subject to close visual inspection (and when necessary ultrasonic examination) to ensure complete fusion.

1.4 Chemical composition

1.4.1 All castings are to be made from killed steel. The chemical composition of the ladle sample is to be within the limits given in the relevant Section of this Chapter. Where general overall limits are specified, the chemical composition is to be appropriate for the type of steel, dimensions and required mechanical properties of the castings.

1.4.2 Except where otherwise specified, suitable grain refining elements may be used at the discretion of the manufacturer. The content of such elements is to be reported in the ladle analysis.

1.5 Heat treatment

1.5.1 All castings are to be heat treated in accordance with the requirements given in the relevant Section of this Chapter.

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1.5.2 Heat treatment is to be carried out in a properly constructed furnace which is efficiently maintained and has adequate means of temperature control and is fitted with pyrometers which measure and record the temperature of the furnace charge. The furnace dimensions are to be such as to allow the whole furnace charge to be uniformly heated to the necessary temperature. Sufficient thermocouples are to be connected to the furnace charge to show that its temperature is adequately uniform and the temperatures are to be recorded throughout the heat treatment. Alternative procedures are to be approved by LR, Materials and NDE department. Copies of these records are to be presented to the Surveyor together with a sketch showing the positions at which the temperature measurements were carried out. The records are to identify the furnace that was used and give details of the charge, the heat treatment temperature and time at temperature and the date. The Surveyor is to examine the charts and confirm the details on the certificate. In the case of very large components which require heat treatment, alternative methods will be specially considered.

1.5.3 If a casting is locally reheated, or any straightening operation is performed after the final heat treatment, a subsequent stress relieving heat treatment may be required in order to avoid the possibility of harmful residual stresses.

1.6 Test material and test specimens

1.6.1 Test material sufficient for the tests specified in Sections 2 to 9 and for possible re-test purposes is to be provided for each casting. The test samples are to be either integrally cast or gated to the casting and are to have a thickness of not less than 30 mm.

1.6.2 The test samples are not to be detached from the casting until the heat treatment specified in 1.5.1 has been completed and they have been properly identified.

1.6.3 As an alternative to 1.6.1 and 1.6.2, where a number of small castings of about the same size, each of which is under 1000 kg in mass, are made from one cast and heat treated in the same furnace charge, a batch testing procedure may be adopted, using separately cast test samples of suitable dimensions. The test samples are to be properly identified and heat treated together with the castings which they represent. At least one test sample is to be provided for each batch of castings.

1.6.4 The test specimens are to be prepared in accordance with the requirements of Chapter 2. Tensile test specimens are to have a cross-sectional area of not less than 150 mm^2.

1.6.5 Re-test procedures are to be in accordance with Ch 2,1.4.

1.7 Visual and non-destructive examination

1.7.1 This Section gives the general requirements for non-destructive examination of steel castings. As an alternative, castings may be examined in accordance with a National Specification, provided it gives reasonable equivalence to these Rules.

1.7.2 All castings are to be cleaned and adequately prepared for inspection. Suitable methods include pickling, caustic cleaning, wire brushing, local grinding, shot or sand blasting.

1.7.3 The surfaces are not to be hammered, peened or treated in any way which may obscure defects.

1.7.4 Unless otherwise agreed, the accuracy and verification of dimensions are the responsibility of the manufacturer.

1.7.5 All castings are to be presented to the Surveyor for visual examination. Where applicable, this is to include the examination of internal surfaces. Castings are to be subject to magnetic particle examination or dye penetrant inspection (for austenitic stainless steel castings, *see* Section 8) in accordance with 1.7.9, unless more specific requirements for non-destrutive examination are included in subsequent Sections of this Chapter, other parts of the Rules or the agreed specification.

1.7.6 Where specified or required by the Rules non-destructive examination is to be carried out before acceptance. All tests are to be in accordance with the requirements of Ch 1,5.

1.7.7 The manufacturer is to provide the Surveyor with a signed report confirming that non-destructive examination has been carried out and that such inspection has not revealed any significant defects.

1.7.8 Where magnetic particle examination is specified or required, this is to be carried out using a suspension of magnetic particles in a suitable fluid. The dry powder method is not acceptable for the final inspection. Prods are not permitted on finished machined surfaces.

1.7.9 Where required, magnetic particle or dye penetrant testing is to be carried out by the manufacturer whenever appropriate and also when the castings are in the finished condition. The tests are to be made in the presence of the Surveyor unless otherwise specially agreed. The castings are to be examined in the following areas:

(a) At all accessible fillets and changes of section.
(b) At positions where surplus metal has been removed by flame cutting, scarfing or arc-air gouging.
(c) In way of fabrication weld preparations, for a distance not less than 50 mm form the edge.
(d) In way of welds.
(e) In way of chaplets.
(f) At other positions agreed with the Surveyor to include areas which may be subjected to high stress in service.

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1.7.10 Where required by subsequent Sections or by the agreed specification, ultrasonic examination is to be carried out by the manufacturer, but Surveyors may request to be present in order to verify that the examination is carried out in accordance with the agreed procedure. This examination is to be carried out in the following areas:

(a) At positions which may be subjected to high stresses in service, as agreed with the Surveyor.
(b) In way of fabrication weld preparations, for a distance not less than 50 mm form the edge.
(c) At positions where subsequent machining may expose filamentary shrinkage or other defects (e.g., bolt holes, bearing bores).
(d) In way of welding.
(e) In way of riser positions.
(f) At positions where experience shows that significant internal defects may occur: these are to be agreed between the manufacturer and the Surveyor.

1.7.11 Radiographic examination, where required, is to be carried out by the manufacturer in areas generally as indicated for ultrasonic examination in 1.7.10. All radiographs are to be submitted to the Surveyor for examination and acceptance. The radiographic technique and acceptance standards are to be to the satisfaction of the Surveyor and in accordance with any requirements of the approved specification.

1.7.12 In the event of any casting proving to be defective during subsequent machining or testing it is to be rejected notwithstanding any previous certification.

1.7.13 The general acceptance criteria given in 2.5.2 are to be applied where no specific acceptance criteria are stated in the subsequent Sections of this Chapter.

1.8 Pressure testing

1.8.1 Where required by the relevant Rules, castings are to be pressure tested in the final machined condition before final acceptance. These tests are to be carried out in the presence of the Surveyors and are to be to their satisfaction.

1.9 Rectification and dressing of castings

1.9.1 When unacceptable defects are found in a casting, these are to be removed by machining or chipping. Flame-scarfing or arc-air gouging may also be used provided that preheating is employed when necessary and that the surfaces of the resulting excavation are subsequently ground smooth. Complete elimination of the defective material is to be proven by adequate non-destructive examination. Shallow grooves or excavations resulting from the removal of defects may, at the discretion of the Surveyor, be accepted provided that they will cause no appreciable reduction in the strength of the castings and that they are suitably blended by grinding. Complete elimination of the defective material is to be verified by magnetic particle or dye penetrant testing.

1.9.2 Where flame scarfing or arc-air gouging is used, the requirements detailed in 1.2.2 are to apply.

1.9.3 Grinding wheels for use on austenitic stainless steels are to be of an iron-free type and shall have been used only on stainless steels.

1.9.4 All proposals to repair a defective casting by welding are to be submitted to the Surveyor before this work is commenced. The Surveyor is to satisfy himself that the number, position and size of the defects are such that the casting can be effectively repaired.

1.9.5 A statement and/or sketch detailing the extent and position of all welds is to be prepared by the manufacturer. Copies of these sketches are to be submitted to LR, and copies are to be attached to the certificates for the castings.

1.9.6 All welding is to be carried out by an approved welder and in accordance with an approved welding procedure which includes the features referred to in 1.9.6 to 1.9.13.

1.9.7 Where welding is required, a grain refining heat treatment is to be given to the whole casting prior to carrying out welding unless agreed otherwise with the Surveyor. Grain refining heat treatment requires heating above the upper critical temperature.

1.9.8 Any excavations are to be of suitable shape to allow good access for welding and, after final preparation for welding, are to be re-examined by suitable non-destructive testing methods to ensure that all defective material has been eliminated.

1.9.9 All castings in alloy steels other than austenitic and duplex stainless steels are to be suitably preheated prior to welding. Castings in carbon-manganese steels may also be required to be preheated, depending on their chemical composition, the dimensions, configuration and positions of the welds.

1.9.10 Welding is to be carried out under cover, in positions free from draughts and adverse weather conditions. As far as possible, all welding is to be carried out in the downhand (flat) position.

1.9.11 The welding consumables used are to be of an appropriate composition, giving a weld deposit with mechanical properties similar and in no way inferior to those of the parent castings. The use of low hydrogen type welding consumables is preferred. Welding procedure tests are to be carried out by the manufacturer to demonstrate that satisfactory mechanical properties can be obtained after heat treatment as detailed in 1.9.12, and the results of these tests are to be presented to the Surveyor.

1.9.12 After welding is completed, the castings are to be given the heat treatment specified in Sections 2 to 9, or a stress relieving heat treatment at a temperature of not less than 550°C. The type of heat treatment required will be dependent on the chemical composition of the casting and the dimensions, positions and nature of the repairs.

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1.9.13 Special consideration may be given to a local stress relieving heat treatment. where both the welded area is small and machining of the casting has reached an advanced stage, prior agreement is to be obtained from LR in writing. The welding procedure is to be such that residual stresses are minimised.

1.9.14 On completion of heat treatment, all welds and adjacent material are to be ground smooth and examined by magnetic particle, or liquid penetrant testing, ultrasonic or radiographic examination. The Surveyor is to attend at these inspections, to witness the results of magnetic particle or liquid penetrant examination and to examine any radiographs. Satisfactory results are to be obtained from all forms of non-destructive examination used.The acceptance criteria for the NDE of welds are to be in accordance with subsequent Sections of this Chapter or where these do not exist, Tables 13.2.4 to 13.2.6 in Chapter 13, as appropriate.

1.9.15 Where no welding has been made on a casting, the manufacturer is to provide the Surveyor with a written statement that this is the case.

1.9.16 The foundry is to maintain full records detailing the weld procedure, heat treatment and the extent and location of all welds made to each casting. These records are to be available for review by the Surveyor, and copies of individual records are to be supplied to the Surveyor on request.

1.9.17 For rectification of defective steel castings for crankshafts, *see* 4.7.

1.10 Identification of castings

1.10.1 The manufacturer is to adopt a system of identification, which will enable all finished castings to be traced to the original cast, and the Surveyor is to be given full facilities to trace the castings when required.

1.10.2 Before acceptance, all castings which have been tested and inspected with satisfactory results are to be clearly marked by the manufacturer with the following particulars:

(a) Identification number, cast number or other marking which will enable the full history of the casting to be traced.
(b) Manufacturer's name or trade mark.
(c) LR or Lloyd's Register and the abbreviated name of LR's local office.
(d) Personal stamp of Surveyor responsible for inspection.
(e) Test pressure, where applicable.
(f) Date of final inspection.

1.10.3 Where small castings are manufactured in large numbers, modified arrangements for identification may be specially agreed with the Surveyor.

1.11 Certification of materials

1.11.1 A LR certificate is to be issued, *see* Ch 1,3.1.

1.11.2 The manufacturer is to provide the Surveyor with a written statement giving the following particulars for each casting or batch of castings which has been accepted:

(a) Purchaser's name and order number.
(b) Description of castings and steel grade.
(c) Identification number.
(d) Steel making process, cast number, chemical analysis of ladle samples and, in the case of the Special grade (*see* Section 2), the chemical analysis of the product or test bar.
(e) General details of heat treatment including the temperature and time at temperature.
(f) Results of mechanical tests.
(g) Test pressure, where applicable.

1.11.3 Where applicable, the manufacturer is to provide a signed report regarding non-destructive examination as required by 1.7.7 together with a statement and/or sketch detailing the extent and position of all weld repairs made to each casting as required by 1.9.5 or the statement detailed in 1.9.15.

■ *Section 2*
Castings for ship and other structural applications

2.1 Scope

2.1.1 The requirements for carbon-manganese steel castings, intended for ship and other structural applications where the design and acceptance tests are related to mechanical properties at ambient temperature, are given in this Section.

2.1.2 Provision is made for two quality grades, Normal and Special.

2.1.3 Where it is proposed to use carbon-manganese steels of higher specified minimum tensile strength than required by 2.4.3, or alloy steels, particulars of the chemical composition, mechanical properties and heat treatment are to be submitted for approval.

2.2 Chemical composition

2.2.1 The chemical composition of ladle samples is to comply with Table 4.2.1.

2.2.2 For the Special grade, the product of the aluminium and nitrogen contents is to comply with the following formula:

$$(\%\ Al_{acid\ sol} \times \%\ N)\ 10^5 \leq 60$$

2.2.3 For the Special grade, a check chemical analysis on the product or a test bar is mandatory. The check analysis on the product or test bar is to comply with the requirements of Table 4.2.1.

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Table 4.2.1 Chemical composition

Quality grade	Normal	Special (*see* Note 3)
Carbon	0,23% max.	0,23% max.
Silicon	0,60% max.	0,60% max.
Manganese	0,70–1,60%	0,70–1,60%
Sulphur	0,040% max.	0,035% max.
Phosphorus	0,040% max.	0,035% max.
Aluminium – (acid soluble)	—	0,015–0,080% (*see* Notes 1 and 2)
Residual elements:		
Copper	0,30% max.	0,30% max.
Chromium	0,30% max.	0,30% max.
Nickel	0,40% max.	0,40% max.
Molybdenum	0,15% max.	0,15% max.
Total	0,80% max.	0,80% max.

NOTES
1. The total aluminium content may be determined instead of the acid soluble content, in which case the total aluminium content is to be 0,020–0,10%.
2. Grain refining elements other than aluminium may be used subject to special agreement with LR.
3. For the Special grade, the nitrogen content is to be determined.

2.3 Heat treatment

2.3.1 Castings are to be supplied:
(a) fully annealed; or
(b) normalised; or
(c) normalised and tempered at a temperature of not less than 550°C; or
(d) quenched and tempered at a temperature of not less than 550°C.

2.3.2 For larger castings where a coarse of microstructure may be present in heavier thickness, a double austenising heat treatment may be required to ensure adequate grain refinement. A coarse microstructure will be indicated by an increased attenuation of approxiamtely 30 dB/m at 2 MHz during ultrasonic examination.

2.3.3 Following weld repair and or the attachment of handling brackets, all castings are to be subject to post weld heat treatment at a temperature of not less than 550°C before delivery.

2.4 Mechanical tests

2.4.1 At least one tensile test is to be made on material representing each casting or batch of castings.

2.4.2 Where the casting is of complex design, or where the finished mass exceeds 10 tonnes, two test samples are to be provided. Where large castings are made from two or more casts which are not mixed in a ladle prior to pouring, two or more test samples are required corresponding to the number of casts involved. These are to be integrally cast at locations as widely separated as possible.

2.4.3 The results of these tests are to comply with the following requirements:

Yield stress	200 N/mm^2 min.
Tensile strength	400 N/mm^2 min.
Elongation on $5{,}65\sqrt{S_o}$	25% min.
Reduction of area	40% min.

2.4.4 A set of three Charpy V-notch impact test specimens is to be provided with each casting in the Special grade. These may be taken from a small extension of the thickest part of the casting or from a block cast integrally with the casting and having dimensions representative of the largest section thickness of the casting. These are to be tested in accordance with Chapter 2 and are to have an average energy of not less than 27J at 0°C.

2.5 Non-destructive examination

2.5.1 Castings used in ship construction for the sternframe, rudder and propeller shaft supports are to be examined by ultrasonic and magnetic particle methods in accordance with 1.7. The type and extent of non-destructive examination of castings for other structural applications are to be specially agreed by the Surveyor.

2.5.2 The extent and methods of non-destructive examination to be applied to typical hull steel castings are shown in Figs. 4.2.1 to 4.2.6 in addition to the areas specified in 1.7.9 and 1.7.10.

2.5.3 Acceptance levels for Visual Inspection are to be taken as follows:
(a) No cracks or hot tears are permitted.
(b) Castings are to be free of other injurious indications to the satisfaction of the Surveyor.
(c) Additional magnetic particle, dye penetrant or ultrasonic testing may be required for a more detailed evaluation of surface irregularities at the request of the Surveyor. These examinations are in addition to those required by 2.6.

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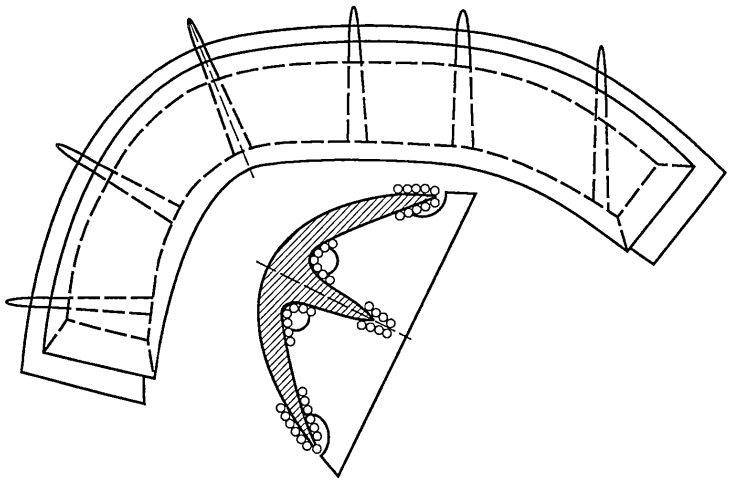
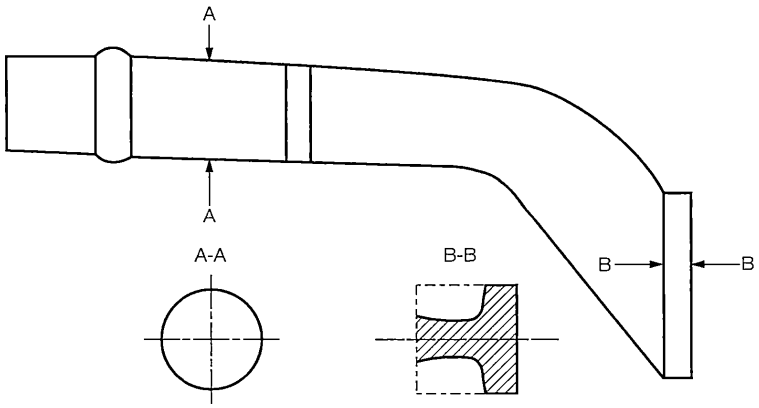


Location of non-destructive examination

1. All surfaces: Visual examination
2. Location indicated with (ooo): Magnetic particle and Ultrasonic testing

Fig. 4.2.1 Extent of non-destructive evaluation for stern frame castings



Location of non-destructive examination

All surfaces: Visual examination
Magnetic particle and ultrasonic testing

Fig. 4.2.2 Extent of non-destructive evaluation for rudder stock castings

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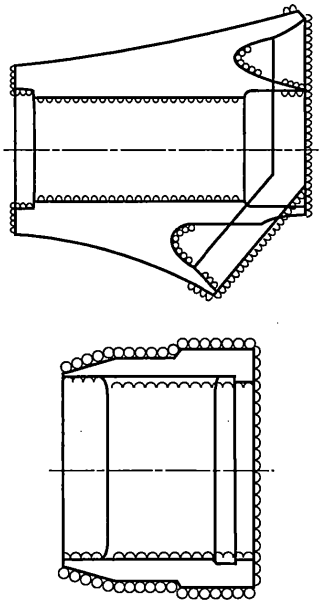
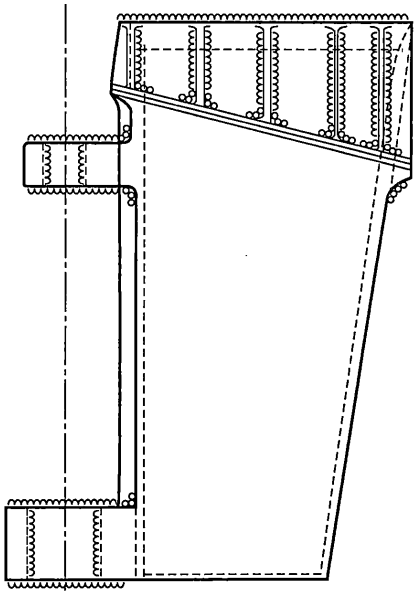


Location of non-destructive examination

1.	All surfaces:	Visual examination
2.	Location indicated with (ooo):	Magnetic particle and ultrasonic testing
3.	Location indicated with (~~~):	Ultrasonic testing

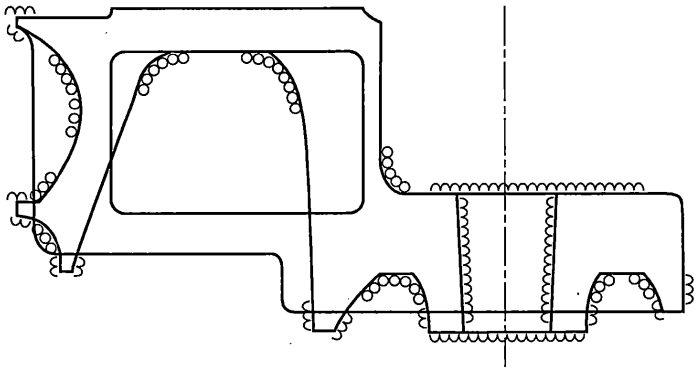
Fig. 4.2.3
Extent of non-destructive evaluation for stern boss castings



Location of non-destructive examination

1.	All surfaces:	Visual examination
2.	Location indicated with (ooo):	Magnetic particle and Ultrasonic testing
3.	Location indicated with (~~~):	Ultrasonic testing

Fig. 4.2.4
Extent of non-destructive evaluation for rudder hanging castings



Location of non-destructive examination

1.	All surfaces:	Visual examination
2.	Location indicated with (ooo):	Magnetic particle and Ultrasonic testing
3.	Location indicated with (~~~):	Ultrasonic testing

Fig. 4.2.5 Extent of non-destructive evaluation for rudder (upper part) castings

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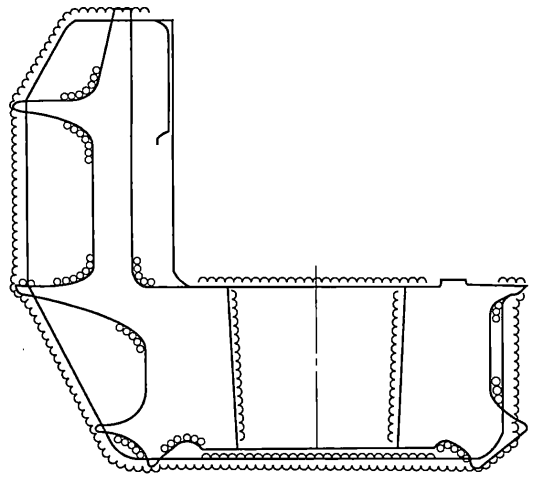

Location of non-destructive examination

1.	All surfaces:	Visual examination
2.	Location indicated with (ooo):	Magnetic particle and Ultrasonic testing
3.	Location indicated with (~~~):	Ultrasonic testing

Fig. 4.2.6
Extent of non-destructive evaluation for rudder (lower part) castings

2.6 Acceptance levels for surface crack detection

2.6.1 The following definitions apply to indications associated with magnetic particle and dye penetrant inspection:

(a) **Linear indication**. An indication in which the length is at least three times the width.

(b) **Non-linear indication**. An indication of circular or elliptical shape with a length less than three times the width.

(c) **Aligned indication**. Three or more indications in a line, separated by 2 mm or less, edge-to-edge.

(d) **Open indication**. An indication visible after removal of the magnetic particles, or that can be detected by the use of contrast dye penetrant.

(e) **Non-open indication**. An indication that is not visually detectable after removal of the magnetic particles, or that cannot be detected by the use of contrast dye penetrant.

(f) **Relevant indication**. An indication that is caused by a condition or type of discontinuity that requires evaluation. Only indications which have any dimension greater than 1,5 mm are to be considered relevant.

2.6.2 For the purpose of evaluating indications, the surface is to be divided into reference band length of 150 mm for level MT1/PT1 and into reference areas of 225 cm^2 for level MT2/PT2. The band length and/or area is to be taken in the most unfavourable location, relative to the indications being evaluated.

2.6.3 The following quality levels recommended for magnetic particle testing (MT) and/or dye penetrant testing (PT) are;

(a) Level MT1/PT1 – fabrication weld preparation areas.

(b) Level MT2/PT2 – other locations indicated on Figs. 4.2.1 to 4.2.6.

The acceptance criteria are shown in Table 4.2.2. Cracks and hot tears are not acceptable.

2.6.4 Acceptance criteria for ultrasonic testing are shown in Table 4.2.3 as UT1 and UT2. Discontinuities within the examined zones interpreted to be cracks or hot tears, are not acceptable.

2.6.5 Level UT1 is applicable to the following:

(a) Fabrication weld preparations for a distance of 50 mm.

(b) 50 mm depth from the final machined surface including boltholes.

(c) Fillet radii to a depth of 50 mm and within a distance of 50 mm from the radius end.

(d) Castings subject to cyclic bending stresses, e.g., rudder horn, rudder castings and rudder stocks, the outer one third of thickness in the zones shown in Figs. 4.2.1 to 4.2.6

2.6.6 Level UT2 is applicable to the following:

(a) For locations which are not specified in 2.6.5, nominated for ultrasonic testing in Figs. 4.2.1 to 4.2.6 or on the inspection plan.

(b) Positions outside locations nominated for level UT1 examination where feeders and gates have been removed.

(c) Castings subject to cyclic bending stresses, at the central one third of thickness in the zones shown in Figs. 4.2.1 to 4.2.6.

Table 4.2.2 Acceptance criteria for surface inspection evaluation

Quality level	Maximum number of indication	Type of indication	Maximum number each type	Maximum dimension of single indication, mm (*see* Note 2)
MT1/PT1	4 in 150 mm length	Non-linear Linear Aligned	4, *see* Note 1 4, *see* Note 1 4, *see* Note 1	5 3 3
MT2/PT2	20 in 22500 mm^2 area	Non-Linear Linear Aligned	10 6 6	7 5 5

NOTES
1. Minimum of 30 mm between relevant indications.
2. In weld repairs, the maximum dimension is 2 mm.

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Table 4.2.3 Ultrasonic acceptance criteria for marine steel castings

Quality level	Allowable disc shape according to the Distance-Gain Size (DGS), mm	Maximum number of indications to be registered, *see* Note 1	Allowable length of linear indications, mm, *see* Note 2
UT1	>6	0	0
UT2	12–15 >15	5 0	50 0

NOTES
1. Grouped in an area measuring 300 x 300 mm.
2. Measured on the scanning surface.

2.6.7 Ultrasonic acceptance criteria for casting areas not nominated in Figs. 4.2.1 to 4.2.6 will be subject to special consideration, based on the anticipated stress levels and the type, size and position of the discontinuity.

2.6.8 Parts which are welded are to be examined by the same method as at the initial inspection as well as by additional methods as required by the Surveyor.

■ *Section 3* Castings for machinery construction

3.1 Scope

3.1.1 This Section gives the material requirements for carbon-manganese steel castings intended for use in machinery construction and which are not within the scope of Sections 4 to 7.

3.1.2 Where it is proposed to use steels of higher carbon content than is indicated in 3.2.1, or alloy steels, particulars of the chemical composition, mechanical properties and heat treatment are to be submitted for approval.

3.1.3 The manufacture or repair of cast steel connecting rods is not permitted, except where the manufacturing and quality control procedures have been approved by LR. For approval purposes, tests are to be carried out at the place of manufacture using the proposed process to demonstrate that the castings are sound. Tests are to be carried out to confirm that the appropriate mechanical properties are attained within the casting, including areas where weld repairs have been performed. Any changes to manufacturing, repair and quality control procedures are to be submitted to LR for approval, *see also* Ch 1,2.2.

3.2 Chemical composition

3.2.1 The chemical composition of ladle samples is to comply with the following limits, except as specified in 3.2.2:

Carbon	0,40% max.
Silicon	0,60% max.
Manganese	0,50–1,60%
Sulphur	0,040% max.
Phosphorus	0,040% max.
Residual elements:	
Copper	0,30% max.
Chromium	0,30% max.
Nickel	0,40% max.
Molybdenum	0,15% max.
	Total 0,80% max.

3.2.2 Castings which are intended for parts of a welded fabrication are to be of weldable quality with a carbon content generally not exceeding 0,23 per cent.

3.2.3 Proposals to use steels with higher carbon content, or alloy steels, for welded construction will be subject to special consideration.

3.3 Heat treatment

3.3.1 Castings are to be supplied:
(a) fully annealed; or
(b) normalised; or
(c) normalised and tempered at a temperature of not less than 550°C; or
(d) quenched and tempered at a temperature of not less than 550°C.

3.3.2 Engine bedplate castings, turbine castings and any other castings where dimensional stability and freedom from internal stresses are important, are to be given a stress relief heat treatment. This is to be at a temperature not lower than 550°C, followed by furnace cooling to 300°C or lower. Alternatively, full annealing may be used provided that the castings are furnace cooled to 300°C or lower.

3.4 Mechanical tests

3.4.1 At least one tensile test is to be made on material representing each casting or batch of castings.

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3.4.2 Where the casting is of complex design, or where the finished mass exceeds 10 tonnes, two test samples are to be provided. Where large castings are made from two or more casts which are not mixed in a ladle prior to pouring, two or more test samples are required corresponding to the number of casts involved. The test samples are to be integrally cast at locations as widely separated as possible.

3.4.3 Table 4.3.1 gives the minimum requirements for yield stress, elongation and reduction of area corresponding to different strength levels, but it is not intended that these should necessarily be regarded as specific grades. Intermediate levels of minimum tensile strength may be specified, in which case minimum values for yield stress, elongation and reduction of area may be obtained by interpolation.

Table 4.3.1 Mechanical properties for acceptance purposes: carbon and carbon-manganese steel castings for machinery construction

Tensile strength N/mm^2	Yield stress N/mm^2 minimum	Elongation on $5{,}65\sqrt{S_o}$ % minimum	Reduction of area % minimum
400–550	200	25	40
440–590	220	22	30
480–630	240	20	27
520–670	260	18	25
560–710	300	15	20
600–750	320	13	20

3.4.4 Castings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Table 4.3.1.

3.4.5 The results of all tensile tests are to comply with the requirements of Table 4.3.1 appropriate to the specified minimum tensile strength.

3.4.6 For alloy steel castings and carbon-manganese steel castings containing more than 0,40 per cent carbon, the results of all mechanical tests are to comply with an approved specification.

3.4.7 When a casting, or a batch of castings, has failed to meet the mechanical test requirements, it may be re-heat treated and re-submitted for acceptance tests but this may not be carried out more than twice, *see* Ch 1,4.6.

3.5 Non-destructive examination

3.5.1 All piston crowns and cylinder covers are to be examined by ultrasonic testing. In addition, where these castings are intended for engines having a bore size larger than 400 mm, they are to be examined by magnetic particle or dye penetrant testing in accordance with 1.7.

3.5.2 Engine bedplate castings are to be examined by ultrasonic and magnetic particle or dye penetrant testing in accordance with 1.7.

3.5.3 Turbine castings are to be examined by magnetic particle or dye penetrant testing in accordance with 1.7. In addition, an ultrasonic or radiographic examination is to be made in way of fabrication weld preparations.

3.5.4 Other castings are to be examined by non-destructive methods where specified.

■ *Section 4* Castings for crankshafts

4.1 Scope

4.1.1 This Section gives the requirements for carbon and carbon-manganese steel castings for semi-built crankshafts.

4.1.2 Where it is proposed to use steels of higher carbon content than is indicated in 4.3.1, or alloy steels, particulars of the chemical composition, mechanical properties and heat treatment are to be submitted for approval. For alloy steels, the specified minimum tensile strength is not to exceed 700 N/mm^2.

4.2 Manufacture

4.2.1 The method of producing combined web and pin castings is to be approved. For this purpose, tests to demonstrate the soundness of the casting and the properties at important locations may be required.

4.3 Chemical composition

4.3.1 The chemical composition of ladle samples is to comply with the following limits:

Carbon	0,40% max. (*but see* 4.7.4(c))
Silicon	0,60% max.
Manganese	0,50–1,60%
Sulphur	0,040% max.
Phosphorus	0,040% max.
Residual elements:	
Copper	0,30% max.
Chromium	0,30% max.
Nickel	0,40% max.
Molybdenum	0,15% max.
	Total 0,80% max.

4.4 Heat treatment

4.4.1 Castings are to be supplied either:

(a) fully annealed and cooled in the furnace to a temperature of 300°C or lower; or

(b) normalised and tempered at a temperature of not less than 550°C, and cooled in the furnace to a temperature of 300°C or lower.

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4.5 Mechanical tests

4.5.1 Proposals for the number of tests and the location of test material on the casting are to be submitted by the manufacturer.

4.5.2 Not less than one tensile test and three impact tests are to be made on material representing each casting. The impact tests are to be carried out at ambient temperature.

4.5.3 Table 4.4.1 gives the minimum requirements for yield stress and elongation corresponding to different strength levels, and it is not intended that these should necessarily be regarded as specific grades. The strength levels have been given in multiples of 40 N/mm^2 to facilitate interpolation for intermediate values of specified minimum tensile strength.

Table 4.4.1 Mechanical properties for acceptance purposes: carbon-manganese steel castings for crankshafts

Tensile strength N/mm^2	Yield stress N/mm^2 minimum	Elongation on $5{,}65\sqrt{S_o}$ % minimum	Reduction of area % minimum	Charpy V-notch impact tests average energy J minimum (*see* Note)
400–550	200	28	45	32
440–590	220	26	45	28
480–630	240	24	40	25
520–670	260	22	40	20
550–700	275	20	35	18

NOTE
Impact tests are to be made at ambient temperature.

4.5.4 Castings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Table 4.4.1.

4.5.5 The results of all tests are to comply with the requirements of Table 4.4.1 appropriate to the specified minimum tensile strength. For the impact tests, one individual value may be less than the required average value provided that it is not less than 70 per cent of this average value. *See* Ch 1,4.6 for re-test procedures.

4.6 Non-destructive examination

4.6.1 Magnetic particle examination is to be carried out over all surfaces in accordance with Fig. 4.4.1.

4.6.2 Each casting is to be examined by ultrasonic testing, and the extent of examination and defect acceptance criteria, using the DGS (Distance Gain Size) technique, are to be as shown in Fig. 4.4.2. Alternative ultrasonic procedures may be submitted for approval.

4.7 Rectification of defective castings

4.7.1 The requirements of 1.9 apply, except where amended by this Section.

4.7.2 Where castings have shallow surface defects, consideration is first to be given to removing such defects by grinding and blending or by machining the surface where there is excess metal on the Rule dimension.

4.7.3 Subject to prior agreement and submission of the detailed welding procedure for approval by LR, welding may be carried out prior to the final austenitising heat treatment.

4.7.4 Approval for welding will not be given in the following circumstances:

(a) For the rectification of repetitive defects caused by improper foundry technique or practice.

(b) For the building up by welding of surfaces or large shallow depressions.

(c) Where the carbon content of the steel exceeds 0,30 per cent.

(d) Where the carbon equivalent of the steel, given by $C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$ exceeds 0,65 per cent.

4.7.5 Provided that the Surveyors are satisfied that welding is justified, they may also authorise welding to the surfaces of crankwebs, following the final austenitising heat treatment, within the following limits:

(a) In general, the volume of the largest groove which is to be welded is not to exceed $3{,}2t$ cm^3, where t is the web axial thickness, in cm. The total volume of all grooves which are to be welded is not to exceed $9{,}6t$ cm^3 per crankweb.

(b) The welds do not extend within the cross-hatched zones marked on Fig. 4.4.3 for semi-built crank throws.

(c) Larger welds on balance weights may be permitted at the discretion of the Surveyor, provided that such repairs are wholly contained within the balance weight and do not affect the strength of the crankweb.

4.7.6 Subsequent to the final austenitising heat treatment, welding may be authorised in the surface of the bore for the journal (or pin) within the following limits:

(a) In general, the welds are to be not less than 125 mm apart.

(b) The welds are not to be located within circumferential bands of $\frac{t}{5}$ from the edges of the bores, nor at any position within the inner 120° arc of the bores, as cross-hatched on Fig. 4.4.3.

(c) The volume of the largest weld is to be not more than $1{,}1t$ cm^3, where t is the web axial thickness at the bore, in cm, and not more than three welds are to be made in any one bore surface.

4.7.7 After all defective material has been removed from a region, and this has been proven in the presence of the Surveyor by magnetic particle inspection or other suitable method, the excavation is to be suitably shaped to allow good access for welding.

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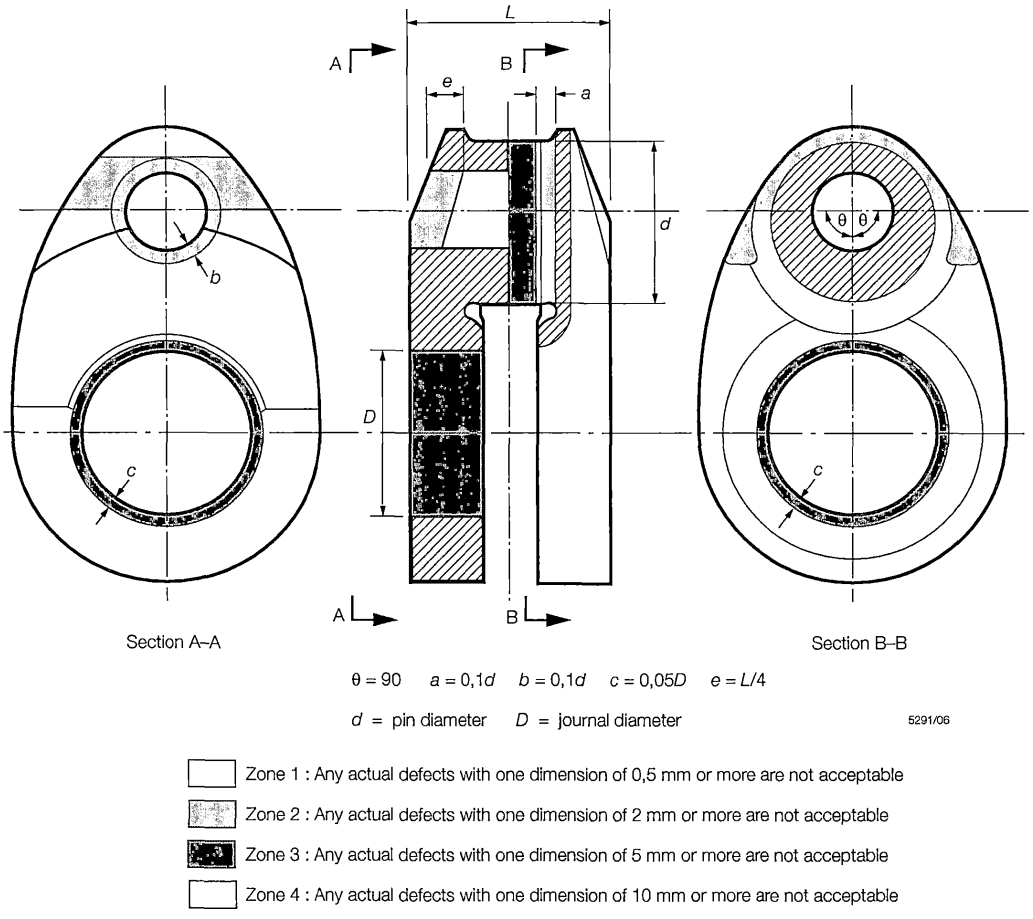

Fig. 4.4.1 Magnetic particle inspection acceptance levels

4.7.8 At the discretion of the Surveyor, the size of a groove may be increased beyond the limiting sizes given in 4.7.5 or 4.7.6, if the removal of further metal will facilitate welding.

4.7.9 Welding is to be carried out by approved welders using approved procedures. The welds are to be made by an electric arc process using low hydrogen type consumables which will produce a deposited metal that is not inferior in properties to the parent metal.

4.7.10 All castings are to be given a preliminary refining heat treatment prior to the commencement of welding. Before welding, the material is to be preheated in accordance with the qualified procedure. Where possible, preheating is to be carried out in a furnace. The preheat temperature is to be maintained until welding is completed, and preferably until the casting is charged to the furnace for post-weld heat treatment.

4.7.11 Where welding is carried out after the final austenitising heat treatments, a post-weld stress relieving heat treatment is to be applied at a temperature of not less than 600°C, *see also* 1.5.2.

4.7.12 Welds are to be dressed smooth by grinding. The surfaces of the welds and adjacent parent steel are to be proven by magnetic particle and, where appropriate, ultrasonic inspection, *see* 1.9.15 and 1.9.14.

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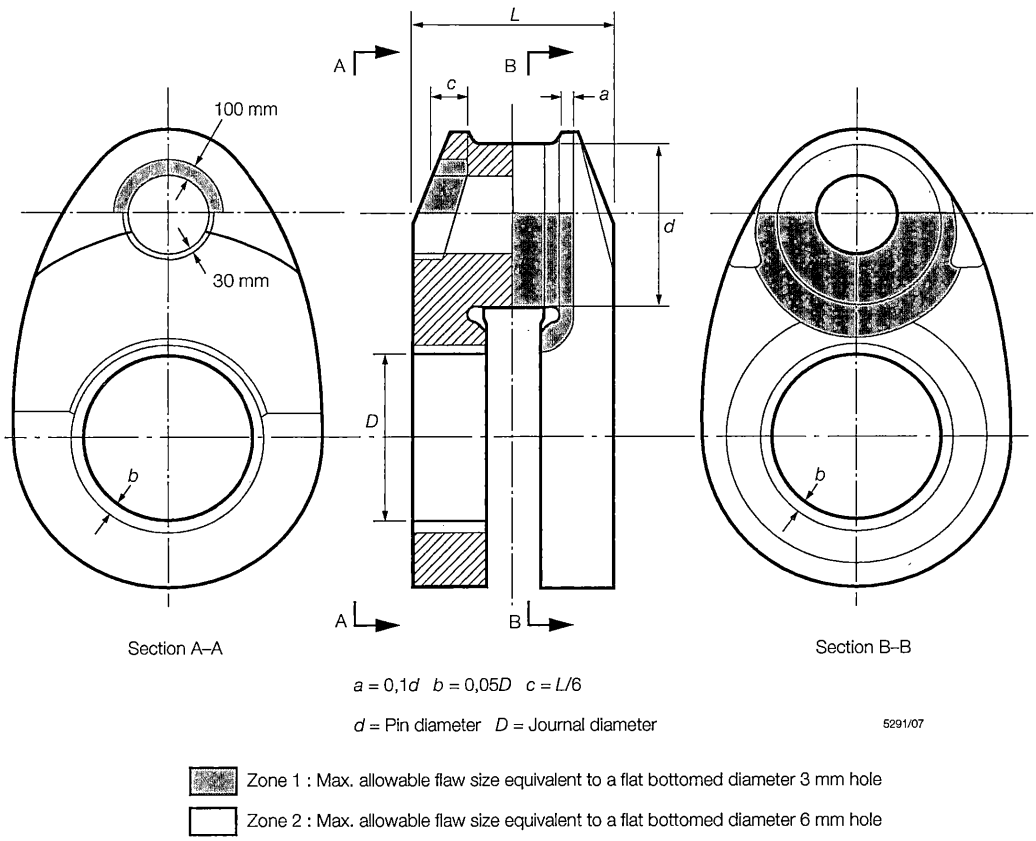

Fig. 4.4.2 Ultrasonic examination acceptance levels

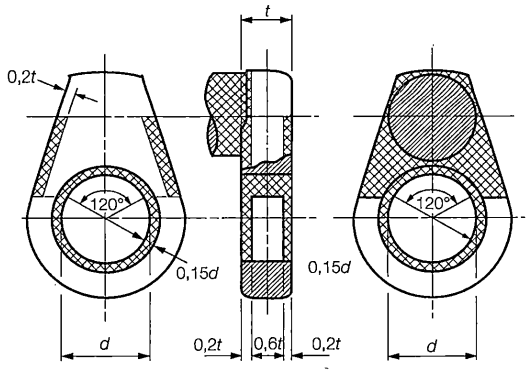

Fig. 4.4.3
Areas of semi-built crank throws to which weld repairs are not permitted

■ *Section 5*
Castings for propellers

5.1 Scope

5.1.1 This Section gives the requirements for steel castings for one-piece propellers and separately cast blades and hubs for fixed pitch and controllable pitch propellers (CPP). These include contra-rotating propellers, azipods and azimuth thrusters. The requirements for copper alloy propellers, blades and hubs are given in Ch 9,1.

5.1.2 These castings are to be manufactured and tested in accordance with the appropriate requirements of Chapters 1 and 2 and Ch 4,1 as well as the requirements of this Section.

5.1.3 Full details of the manufacturer's specification are to be submitted for approval. These should include the chemical composition, heat treatment, mechanical properties, microstructure and repair procedures.

5.1.4 Special requirements are given for castings which are intended for ice service in Table 4.5.2.

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5.2 Chemical composition

5.2.1 The chemical composition of ladle samples is to comply with the approved specification, *see* 5.1.3.

5.2.2 Typical cast steel propeller alloys are given in Table 4.5.1.

5.3 Heat treatment

5.3.1 Martensitic stainless steel castings are to be austenitised, quenched and tempered in accordance with the approved specification, *see* 5.1.3.

5.3.2 Austenitic stainless steel castings are to be solution treated in accordance with the approved specification, *see* 5.1.3.

5.4 Mechanical tests

5.4.1 The test material is to be cast integral with the boss of propeller castings, or with the flange of separately cast propeller blades. Alternatively, the test material may be attached on blades in an area between 0,5 and 0,6*R*, where *R* is the radius of the propeller.

5.4.2 The test material is not to be removed from the casting until final heat treatment has been carried out. Removal is to be by non-thermal procedures.

5.4.3 At least one tensile test and for the martensitic stainless steel grades one set of three Charpy V-notch impact tests are to be made on material representing each casting. The results are to comply with the requirements of Table 4.5.2 or the approved specification.

5.4.4 As an alternative to 5.4.3, where a number of small propeller castings of about the same size, and less than 1 m in diameter, are made from one cast and heat treated in the same furnace charge, a batch testing procedure may be adopted using separately cast test samples of suitable dimensions. At least one set of mechanical tests is to be provided for each multiple of five castings in the batch.

5.4.5 Separately cast test bars may be used subject to prior approval of the Surveyor. Test bars must be cast from the same heat, or heats, and must also be heat treated with castings they represent.

5.5 Non-destructive examination

5.5.1 On completion of machining and grinding, the whole surface of each casting is to be examined in accordance with Ch 9,1.8.

5.5.2 When appropriate, magnetic particle inspection may be used in lieu of liquid penetrant testing.

5.5.3 Castings are to be free from cracks and hot tears.

Table 4.5.1 Typical chemical composition for steel propeller castings

Alloy type	C Max. (%)	Mn Max. (%)	Cr (%)	Mo Max. (%) (*see* Note)	Ni (%)
Martensitic (12Cr 1Ni)	0,15	2,0	11,5–17,0	0,5	Max. 2,0
Martensitic (13Cr 4Ni)	0,06	2,0	11,5–17,0	1,0	3,5–5,0
Martensitic (16Cr 5Ni)	0,06	2,0	15,0–17,5	1,5	3,5–6,0
Austenitic (19Cr 11Ni)	0,12	1,6	16,0–21,0	4,0	8,0–13,0

NOTE
Minimum values are to be in accordance with the agreed specification or recognised National or International Standards.

Table 4.5.2 Typical mechanical properties for steel propeller castings

Alloy type	Yield stress or, 0,2% proof stress minimum, N/mm^2	Tensile strength minimum N/mm^2	Elongation on $5{,}65\sqrt{S_o}$ % minimum	Reduction of area % minimum	Charpy V-notch impact tests J minimum (*see* Notes 1 and 2)
Martensitic (12Cr 1Ni)	440	590	15	30	20
Martensitic (13Cr 4Ni)	550	750	15	35	30
Martensitic (16Cr 5Ni)	540	760	15	35	30
Austenitic (19Cr 11Ni)	180 (*see* Note 3)	440	30	40	—

NOTES
1. When a general service notation **Ice Class 1AS, 1A, 1B or 1C** is required, the tests are to be made at –10°C.
2. For general service or where the notation **Ice Class 1D** is required, the tests are to be made at 0°C.
3. $R_{p1,0}$ value is 205 N/mm^2.

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5.6 Rectification of defective castings

5.6.1 The rectification of defective castings is to be undertaken in accordance with 1.9 and the following paragraphs.

5.6.2 Removal of defective material is to be by mechanical means, e.g., by grinding, chipping or milling. The resultant grooves are to be blended into the surrounding surface so as to avoid any sharp contours.

5.6.3 Grinding in severity zone A may be carried out to an extent that maintains the blade thickness. Repair by welding is generally not permitted in zone A and will only be allowed after special consideration.

5.6.4 Defects in severity zone B that are not deeper than $t/40$ mm (t is the minimum local thickness according to the Rules) or 2 mm, whichever is the greater, are to be removed by grinding. Those defects that are deeper may be repaired by welding subject to prior approval of the Surveyor.

5.6.5 Repair welding is generally permitted in severity zone C.

5.6.6 Welds having an area of less than 5 cm^2 are to be avoided. The maximum surface area of repairs is to be in accordance with Table 9.1.4 in Chapter 9.

5.6.7 Welding is to be in accordance with the approved specification, *see* 5.1.3.

5.6.8 After weld repair, the propeller or blade is to be heat treated in such fashion as will minimise the residual stresses. For martensitic stainless steels, this will involve full heat treatment as specified in the approved specification.

5.6.9 LR reserves the right to restrict the amount of repair work accepted from a manufacturer when it appears that repetitive defects are the result of improper foundry techniques or practices.

5.6.10 All welds are to be inspected by the appropriate NDE method, *see* 1.7.

5.7 Identification

5.7.1 Castings are to be clearly marked by the manufacturer in accordance with the requirements of Chapter 1. The following details are to be shown on all castings which have been accepted:

(a) Identification mark which will enable the full history of the item to be traced.
(b) Type of steel, this should include or allow identification of the chromium and nickel contents.
(c) LR or Lloyd's Register and the abbreviated name of Lloyd's Register's local office.
(d) Personal stamp of Surveyor responsible for the final inspection.
(e) LR certificate number.
(f) Skew angle, if in excess of 25°.
(g) Ice class symbol, where applicable.
(h) Date of final inspection.

5.8 Certification of materials

5.8.1 In addition to the requirements in Ch 4,1.11, the manufacturer is to provide the Surveyor with a written statement giving the following particulars for each casting:

(a) Description of casting with drawing number.
(b) Diameter, number of blades, pitch, direction of turning.
(c) Skew angle, if in excess of 25°.
(d) Final mass.
(e) Vessel identification, where known.

■ *Section 6* Castings for boilers, pressure vessels and piping systems

6.1 Scope

6.1.1 This Section gives the requirements for carbon-manganese and alloy steel castings for boilers, pressure vessels and piping systems for use at temperatures not lower than 0°C.

6.1.2 Where it is proposed to use alloy steels other than as given in this Section, details of the specification are to be submitted for approval. In such cases, the specified minimum tensile strength is not to exceed 600 N/mm^2.

6.1.3 Castings which comply with these requirements are acceptable for liquefied gas piping systems where the design temperature is not lower than 0°C. Where the design temperature is lower than 0°C, and for other applications where guaranteed impact properties at low temperatures are required, the castings are to comply with the requirements of Section 7 or 8.

6.2 Chemical composition

6.2.1 The chemical composition of ladle samples is to comply with the limits specified in Table 4.6.1.

6.3 Heat treatment

6.3.1 Castings are to be supplied:

(a) fully annealed; or
(b) normalised; or
(c) normalised and tempered; or
(d) quenched and tempered.

6.4 Mechanical tests

6.4.1 A tensile test is to be made on material representing each casting, unless a batch testing procedure has been agreed, *see* 1.6.

6.4.2 The tensile test is to be carried out at ambient temperature, and unless agreed otherwise with the Surveyor, the results are to comply with the requirements of Table 4.6.2.

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Table 4.6.1 Chemical composition of steel castings for boilers, pressure vessels and piping systems

Type of steel	Chemical composition %											
	C max.	Si max.	Mn	S max.	P max.	Residual elements						
Carbon-manganese	0,25	0,60	0,50-1,20	0,040	0,040	Cr 0,30 max. Mo 0,15 max. Cu 0,30 max. Ni 0,40 max. Total 0,80 max.						
						Cr	Mo	V	Residual elements Cr	Cu	Ni	
1/2 Mo	0,20	0,60	0,50–1,00	0,040	0,040	—	0,45-0,65	—	0,30 max.	0,30 max.	0,40 max.	
1 Cr 1/2 Mo	0,20	0,60	0,50-0,80	0,040	0,040	1,00-1,50	0,45-0,65	—	—	0,30 max.	0,40 max.	
2 1/4 Cr1 Mo	0,18	0,60	0,40-0,70	0,040	0,040	2,00-2,75	0,90-1,20	—	—	0,30 max.	0,40 max.	
1/2 Cr 1/2 Mo 1/4 V	0,10–0,15	0,45	0,40-0,70	0,030	0,030	0,30-0,50	0,40-0,60	0,22-0,30	—	0,30 max.	0,30 max.	

Table 4.6.2 Mechanical properties for acceptance purposes: steel castings for boilers, pressure vessels and piping systems

Type of steel	Yield stress minimum N/mm^2	Tensile strength N/mm^2	Elongation on $5,65\sqrt{S_o}$ % minimum	Reduction of area % minimum
Carbon-manganese	275	485-655	22	25
1/2Mo	260	460-590	18	30
1Cr1/2Mo	280	480-630	17	20
2 1/4 Cr1 Mo	325	540-630	17	20
1/2Cr1/2Mo1/4V	295	510-660	17	20

6.4.3 Where it is proposed to use a carbon-manganese steel with a specified minimum tensile strength intermediate to those given in this Section, corresponding minimum values for the yield stress, elongation and reduction of area may be obtained by interpolation.

6.4.4 Carbon-manganese steels with a specified minimum tensile strength of greater than 490 N/mm^2, but not exceeding 520 N/mm^2, may be accepted provided that details of the proposed specification are submitted for approval.

6.5 Non-destructive examination

6.5.1 The non-destructive examination of castings is to be carried out in accordance with the appropriate requirements of 1.7.7 to 1.7.11 and additionally as agreed between the manufacturer, purchaser and Surveyor.

6.6 Mechanical properties for design purposes

6.6.1 Nominal values for the minimum lower yield or 0,2 per cent proof stress at temperatures of 100°C and higher are given in Table 4.6.3. These values are intended for design purposes only, and verification is not required except for materials complying with National or proprietary specifications where the elevated temperature properties used for design purposes are higher than those given in Table 4.6.3.

6.6.2 In such cases, at least one tensile test at the proposed design or other agreed temperature is to be made on each casting or each batch of castings. The test specimen is to be taken from material adjacent to that used for tests at ambient temperature, and the test procedure is to be in accordance with the requirements of Chapter 2. The results of all tests are to comply with the requirements of the National or proprietary specification.

6.6.3 Values for the estimated average stress to rupture in 100 000 hours are given in Table 4.6.4 and may be used for design purposes.

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Table 4.6.3 Mechanical properties for design purposes (*see* 6.6.1)

Type of steel	Nominal minimum lower yield or 0,2% proof stress N/mm²										
	Temperature °C										
	100	150	200	250	300	350	400	450	500	550	600
Carbon-manganese	225	214	201	186	163	156	152	—	—	—	—
½Mo	242	236	226	207	186	175	169	158	145	136	126
1Cr½Mo	240	—	212	—	196	—	184	—	160	—	117
2¼Cr1 Mo	323	312	305	296	290	280	273	258	240	211	180
½Cr½Mo¼V	264	—	244	—	230	—	214	—	194	—	144

Table 4.6.4 Mechanical properties for design purposes (*see* 6.6.3)**: estimated average stresses to rupture in 100,000 hours (N/mm²)**

Temperature °C	Type of steel			
	½Mo	1Cr½Mo	2¼Cr1Mo	½Cr½Mo¼V
430	308	—	—	—
440	276	—	—	—
450	245	—	222	277
460	212	—	199	237
470	174	236	177	206
480	133	186	156	181
490	103	148	139	159
500	84	120	124	140
510	71	100	111	124
520	60	84	99	109
530	—	70	—	96
540	—	58	—	85
550	—	—	—	75
560	—	—	—	66

Section 7
Ferritic steel castings for low temperature service

7.1 Scope

7.1.1 This Section gives the requirements for castings in carbon-manganese and nickel alloy steels, intended for use in liquefied gas piping systems where the design temperature is lower than 0°C, and for other applications where guaranteed impact properties at low temperatures are required.

7.1.2 Where it is proposed to use alternative steels, particulars of the specified chemical composition, mechanical properties and heat treatment are to be submitted for approval.

7.2 Chemical composition

7.2.1 The chemical composition of ladle samples is to comply with the limits specified in Table 4.7.1. Carbon-manganese steels are to be made by fine grain practice.

7.3 Heat treatment

7.3.1 Castings are to be supplied:
(a) normalised; or
(b) normalised and tempered; or
(c) quenched and tempered.

7.4 Mechanical tests

7.4.1 One tensile test and one set of three Charpy V-notch impact test specimens are to be prepared from material representing each casting or batch of castings.

7.4.2 The tensile test is to be carried out at ambient temperature, and the results are to comply with the appropriate requirements given in Table 4.7.2.

7.4.3 The average value for impact test specimens is to comply with the appropriate requirements given in Table 4.7.2. One individual value may be less than the required average value provided that it is not less than 70 per cent of this average value. *See* Ch 2,1.4 for re-test procedure.

7.5 Non-destructive examination

7.5.1 The non-destructive examination of castings is to be carried out in accordance with the appropriate requirements of 1.7.7 to 1.7.11 and additionally agreed between the manufacturer, purchaser and Surveyor.

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Table 4.7.1 Chemical composition of ferritic steel castings for low temperature service

Type of steel	Chemical composition %						
	C max.	Si max.	Mn	S max.	P max.	Ni	Residual elements max.
Carbon-manganese	0,25	0,60	0,70-1,60	0,030	0,030	0,80 max.	Cr 0,25 Cu 0,30 Mo 0,15 V 0,03 Total 0,60
2 1/4Ni	0,25	0,60	0,50-0,80	0,025	0,030	2,00-3,00	
3 1/2Ni	0,15	0,60	0,50-0,80	0,020	0,025	3,00-4,00	

Table 4.7.2 Mechanical properties for acceptance purposes: ferritic steel castings for low temperature service

Type of steel	Grade	Yield stress N/mm² minimum	Tensile strength N/mm²	Elongation on $5{,}65\sqrt{S_o}$ % minimum	Reduction or area % minimum	Charpy V-notch impact test	
						Test temperature °C	Average energy J minimum
Carbon-manganese	400 430 460	200 215 230	400-550 430-580 460-610	25 23 22	40 35 30	–60 (*see* Note)	27
2 1/4Ni	490	275	490-640	20	35	–70	34
3 1/2Ni	490	275	490-640	20	35	–95	34

NOTE
The test temperature for carbon-manganese steels may be 5°C below the design temperature if the latter is above –55°C, with a maximum test temperature of –20°C.

■ *Section 8*
Stainless steel castings

8.1 Scope

8.1.1 This Section gives the requirements for castings in austenitic and duplex stainless steels for machinery, marine structures, piping systems in ships for liquefied gases, and in bulk chemical tankers.

8.1.2 Austenitic stainless steels castings are suitable for applications where the lowest design temperature is not lower than –165°C.

8.1.3 Duplex stainless steels castings are suitable for applications where the lowest design temperature is above 0°C. Any requirement to use duplex stainless steels castings below 0°C will be subject to special consideration.

8.1.4 Where it is proposed to use alternative steels, particulars of the specified chemical composition, mechanical properties and heat treatment are to be submitted for approval.

8.2 Chemical composition

8.2.1 The chemical composition of ladle samples is to comply with the requirements given in Table 4.8.1.

8.3 Heat treatment

8.3.1 Austenitic stainless steel castings are to be solution treated, at a temperature of not less than 1000°C and cooled rapidly in water.

8.3.2 Duplex stainless steels castings are to be solution treated at a temperature of not less that 1100°C and cooled rapidly in water.

8.4 Mechanical tests

8.4.1 One tensile test specimen is to be prepared from material representing each casting or batch of castings. In addition, where the castings are intended for liquefied gas applications, where the design temperature is lower than –55°C, one set of three Charpy V-notch impact test specimens is to be prepared.

8.4.2 The tensile test is to be carried out at ambient temperature, and the results are to comply with the requirements given in Table 4.8.2.

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Table 4.8.1 Chemical composition of stainless steel castings

Type of steel	Chemical composition %								
	C	Si	Mn	S	P	Cr	Mo	Ni	Others
Austenitic									
304L	0,03	0,20-1,5	0,50-2,0	0,040		17,0-21,0	—	8,0–12,0	—
304	0,08						—	8,0–12,0	—
316L	0,03						2,0–3,0	9,0–13,0	—
316	0,08						2,0–3,0	9,0–13,0	—
317	0,08						3,0–4,0	9,0–12,0	—
347 (*see* Note 1)	0,06						—	9,0–12,0	Nb ≥ 8 x C ≤ 0,90
Duplex									
UNS S 31803	0,03	1,00	2,00	0,025	0,035	21,0–23,0	2,5–3,5	4,5–6,5	N 0,08–0,20

NOTES
1. When guaranteed impact values at low temperature are not required, the maximum carbon content may be 0,08% and the maximum niobium may be 1,00%.
2. Where a single value is shown (and not a range of values), the value is to be taken as maximum.

Table 4.8.2 Mechanical properties for acceptance purposes: stainless steel castings

Type of steel	Tensile strength N/mm^2 minimum	1,0% proof stress N/mm^2 minimum	Elongation on $5,65\sqrt{S_o}$ % minimum	Reduction of area % minimum	Charpy V-notch impact tests	
					Test temperature °C	Average energy J minimum
Austenitic						
304L	430	215	26	40	–196	41
304	480	220				
316L	430	215	26	40	–196	41
316	480	220				
317	480	240				
347	480	215	22	35	–196	41
Duplex						
UNS S 31803	600	420	20	35	0	41

8.4.3 The average value for impact test specimens is to comply with the appropriate requirements given in Table 4.8.2. One individual value may be less than the required average value, provided that it is not less than 70 per cent of this average value. *See* Ch 2,1.4 for re-test procedures.

8.5 Intergranular corrosion tests

8.5.1 Where corrosive conditions are anticipated in service, intergranular corrosion tests are required on castings in grades 304, 316, 317 and all duplex stainless steels. Such tests may not be required for grades 304L, 316L and 347.

8.5.2 Where an intergranular corrosion test is specified, it is to be carried out in accordance with the procedure given in Ch 2,8.1.

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8.6 Non-destructive examination

8.6.1 The non-destructive examination of castings is to be carried out in accordance with the appropriate requirements of 1.7.7 to 1.7.11 and additionally agreed between the manufacturer, purchaser and Surveyor.

■ *Section 9*
Steel castings for container corner fittings

9.1 General

9.1.1 This Section gives the requirements for cast steel corner fittings used in the fabrication of freight and tank containers. The fittings are also to comply with the requirements of the latest edition of International Standard ISO 1161.

9.1.2 The castings are to be made in foundries approved by LR. These foundries are also to be specially approved for the manufacture of container corner castings. In order to comply with these requirements, the manufacturer is required to verify that the casting soundness, mechanical properties, weldability and dimensional tolerances required by this Section and the manufacturing specification are met.

9.1.3 Castings may be released on the basis of an LR survey or, alternatively, the manufacturer may be approved by means of a Quality Assurance Scheme as detailed in Ch 1,2.

9.2 Chemical composition

9.2.1 Chemical analysis is to be carried out on each cast.

9.2.2 The chemical composition of the ladle samples is to comply with the limits given in Table 4.9.1.

9.2.3 The carbon equivalent:

$$C_{eq} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15} \ (\%)$$

must not exceed 0,45 per cent.

9.3 Heat treatment

9.3.1 Castings are to be supplied either:

(a) normalised; or

(b) water or oil quenched and tempered at a temperature of not less than 550°C.

9.4 Mechanical tests

9.4.1 At least one tensile test is to be made on each batch of castings, using separately cast test bars which are to be from the same cast and heat treatment lot as the castings they represent.

9.4.2 The results of the tensile tests are to comply with the following:

Yield stress	220 N/mm^2 min.
Tensile strength	430–600 N/mm^2
Elongation on $\sqrt{S_o}$	25% min.
Reduction of area	40% min.

9.4.3 Impact tests are not required on all casts, but may be required on a random basis at the discretion of the Surveyor.

9.4.4 When required, the impact test specimens are to be tested in accordance with Ch 1,4.5 and Ch 2,3.2. In general, tests are to be made at a temperature of –20°C and the minimum average energy obtained is to be 27J.

9.5 Non-destructive examination

9.5.1 Ultrasonic or radiographic testing is to be carried out, in accordance with 1.7.10 or 1.7.11 respectively, on at least one casting from each cast or from every 400 castings, whichever is the lesser.

9.6 Repair of defects

9.6.1 Minor defects may be removed by grinding provided that the allowable minus tolerance is not exceeded.

Table 4.9.1 Chemical composition of steel castings for container corner fittings

Chemical composition %										
C max.	Mn	Si max.	P max.	S max.	Cr max.	Ni max.	Cu max.	Mo max.	Al acid soluble min. (See Notes)	Cr + Ni + Cu + Mo max.
0,20	0,90 to 1,50	0,50	0,035	0,035	0,25	0,30	0,20	0,08	0,015	0,70

NOTES
1. The total aluminium content may be determined instead of the acid soluble content. In such cases, the total aluminium content is to be not less than 0,02%.
2. Aluminium may be replaced partly or totally by other grain refining elements as stated in the approved specification.

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9.6.2 Defects which exceed the allowable minus tolerance may be removed by grinding or chipping followed by welding, provided the weld depth does not exceed 40 per cent of the wall thickness and that the following requirements are met:

(a) welding is not to be carried out in the as-cast condition; the grain structure has to be refined by heat treatment,
(b) the casting is to be preheated to 80–100°C,
(c) welding is to be performed only by qualified welders in accordance with a qualified welding procedure,
(d) all welded castings are to be post-weld heat treated at a temperature not less than 550°C,
(e) the welded areas are to be ground or machined flush with the adjacent surface and inspected by magnetic particle or dye penetrant examination as appropriate.

9.7 Identification

9.7.1 Each casting is to be clearly marked by the manufacturer with at least the following:

(a) manufacturer's name or trade mark,
(b) cast number or identification number which will enable the full history of the casting to be traced.

9.7.2 Where the casting has been inspected and found acceptable it is to be marked with the Surveyor's personal stamp.

9.7.3 The markings may be stamped or cast on the inner surface of the casting.

9.8 Certification of materials

9.8.1 For each consignment a manufacturer's certificate is to be issued (*see* Ch 1,3.1), containing at least the following:

(a) Purchaser's name and order number.
(b) Grade of steel.
(c) Drawing and/or specification number.
(d) Cast number and chemical composition.
(e) Details of the heat treatment.
(f) Number and weight of the castings.
(g) Results of inspections and mechanical tests.

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Steel Forgings

Chapter 5

Section 1

Section

1 **General requirements**

2 **Forgings for ship and other structural applications**

3 **Forgings for shafting and machinery**

4 **Forgings for crankshafts**

5 **Forgings for gearing**

6 **Forgings for turbines**

7 **Forgings for boilers, pressure vessels and piping systems**

8 **Ferritic steel forgings for low temperature service**

9 **Austenitic stainless steel forgings**

■ *Section 1* General requirements

1.1 Scope

1.1.1 This Section gives the general requirements for steel forgings intended for use in the construction of ships, other marine structures, machinery, boilers, pressure vessels and piping systems. These requirements are also applicable to rolled slabs and billets used as a substitute for forgings and to rolled bars used for the manufacture (by machining operations only) of shafts, bolts, studs and other components of similar shape.

1.1.2 When required by the relevant Rules dealing with design and construction, forgings are to be manufactured and tested in accordance with Chapters 1 and 2, together with the general requirements given in this Section and the appropriate specific requirements given in Sections 2 to 9.

1.1.3 As an alternative to 1.1.2, steel forgings which comply with National or proprietary specifications, may be accepted provided that these specifications give reasonable equivalence to the requirements of this Chapter, or alternatively are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

1.1.4 Normalised forgings with mass up to 1000 kg each and quenched and tempered forgings with mass up to 500 kg each may be batch tested. A batch is to consist of forgings of similar shape and dimensions, made from the same heat of steel, heat treated in the same furnace charge and with a total mass not exceeding 6 tonnes for normalised forgings and 3 tonnes for quenched and tempered forgings, respectively.

1.1.5 A batch testing procedure may also be used for hot rolled bars, *see* 3.4.3.

1.1.6 Where small forgings are produced in large quantities, or where forgings of the same type are produced in regular quantities, alternative survey procedures in accordance with Ch 1,2.4 may be adopted.

1.2 Manufacture

1.2.1 Forgings are to be made at works which have been approved by Lloyd's Register (hereinafter referred to as LR). The steel used, is to be manufactured in accordance with the requirements of Ch 3,1.3.

1.2.2 When forgings are made directly from ingots, or from blooms or billets forged from ingots, the ingots are to be cast in chill moulds with the larger cross-section uppermost and with efficient feeder heads.

1.2.3 Adequate top and bottom discards are to be made to ensure freedom from piping and harmful segregations in the finished forgings.

1.2.4 The forgings are to be gradually and uniformly hot worked and are to be formed as closely as possible to the finished shape and size. The plastic deformation is to be such as to ensure soundness, uniformity of structure and satisfactory mechanical properties after heat treatment.

1.2.5 For certain components, such as crankshafts, where grain flow is required in the most favourable direction, having regard to the mode of stressing in service, the proposed method of manufacture may require special approval by LR. In such cases, tests may be required to demonstrate that a satisfactory structure and grain flow are obtained.

1.2.6 The reduction ratio (reduction of area expressed as a ratio) is to be calculated with reference to the average cross-sectional area of the ingot or continuously cast material, where appropriate. Where an ingot is initially upset, this reference area may be taken as the average cross-sectional area after this operation.

1.2.7 For components forged directly from ingots or from forged blooms or billets, and in which the fibre deformation is mainly longitudinal, the reduction ratio is not to be less than 3:1.

1.2.8 For forgings made from rolled billets, or where fibre deformation has taken place in more than one direction, the reduction ratio is not to be less than 4:1.

1.2.9 Where rolled bars are used as a substitute for forgings and the requirements of 1.2.2 are not complied with, the reduction ratio is to be not less than 6:1.

1.2.10 Where the length of any section of a shaft forging is less than its diameter (e.g., a collar), the reduction ratio is to be not less than half that given in 1.2.7, 1.2.8 or 1.2.9 respectively.

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1.2.11 Disc type forgings, such as gear wheels, are to be made by upsetting, and the thickness of any part of the disc is to be not more than one-half of the length of the billet from which it was formed, provided that this billet has received an initial forging reduction of not less than 1,5:1. Where the piece used has been cut directly from an ingot, or where the billet has received an initial reduction of less than 1,5:1, the thickness of any part of the disc is to be not more than one-third of the length of the original piece.

1.2.12 Rings and other types of hollow forgings are to be made from pieces cut from ingots or billets and which have been suitably punched, bored or trepanned prior to expanding or hollow forging. Alternatively, pieces from hollow cast ingots may be used. The wall thickness of the forging is to be not more than one-half of the thickness of the prepared hollow piece from which it was formed. Where this is not practicable, the forging procedure is to be such as to ensure that adequate work is given to the piece prior to punching, etc. This may be either longitudinal or upset working of not less than 2:1.

1.2.13 The shaping of forgings or rolled slabs and billets by flame cutting, scarfing or arc-air gouging is to be undertaken in accordance with recognised good practice and, unless otherwise approved, is to be carried out before the final heat treatment. Preheating is to be employed where necessitated by the composition and/or thickness of the steel. For certain components, subsequent machining of all flame cut surfaces may be required, *see* 4.2.4.

1.2.14 Where two or more forgings are joined by welding to form a composite component, details of the proposed welding procedure are to be submitted for approval. Welding approval procedure tests may be required.

1.3 Quality

1.3.1 All forgings are to be free from surface or internal defects which would be prejudicial to their proper application in service.

1.4 Chemical composition

1.4.1 All forgings are to be made from killed steels, and the chemical composition of ladle samples is to comply with the requirements detailed in subsequent Sections in this Chapter. Where general overall limits are specified, the chemical composition selected is to be appropriate for the type of steel, dimensions and required mechanical properties of the forgings being manufactured.

1.4.2 Except where otherwise specified, suitable grain refining elements such as aluminium, niobium or vanadium may be used at the discretion of the manufacturer. The content of such elements is to be reported in the ladle analysis.

1.4.3 For alloy steel forgings, the chemical composition of ladle samples is to generally comply with the following overall limits and the requirements of the approved specifications:

Carbon	0,45% max.
Silicon	0,45% max.
Manganese	0,30% min.
Sulphur	0,035% max.
Phosphorus	0,035% max.
Copper	0,30% max.

And at least one of the following elements is to comply with the minimum content:

Chromium	0,40% min.
Molybdenum	0,15% min.
Nickel	0,40% min.

The contents of all alloying elements and significant impurities detailed in the specification are to be reported.

1.5 Heat treatment

1.5.1 At an appropriate stage of manufacture, after completion of all hot working operations, forgings are to be suitably heat treated to refine the grain structure and to obtain the required mechanical properties. Acceptable heat treatment procedures are to be such as to avoid the formation of hair-line cracks and are detailed in Sections 2 to 9.

1.5.2 Heat treatment is to be carried out in properly constructed furnaces, which are efficiently maintained and have adequate means for control and recording of temperature. The furnace dimensions are to be such as to allow the whole furnace charge to be uniformly heated to the necessary temperature. In the case of very large forgings, alternative methods of heat treatment will be specially considered. Sufficient thermocouples are to be connected to the furnace charge to measure and record that its temperature is adequately uniform. Alternative procedures are to be approved by LR, Materials and NDE Department.

1.5.3 Where forgings are to be quenched and tempered and cannot be hot worked close to size and shape, they are to be suitably rough machined or flame cut prior to being subjected to this treatment.

1.5.4 If for any reason a forging is subsequently heated for further hot working, the forging is to be reheat treated.

1.5.5 If any straightening operation is performed after the final heat treatment, consideration should be given to a subsequent stress relieving heat treatment in order to avoid the possibility of harmful residual stresses.

1.5.6 Where it is intended to surface harden forgings, full details of the proposed procedure and specification are to be submitted for approval. For the purposes of this approval, the manufacturer will be required to demonstrate by tests that the proposed procedure gives a uniform surface layer of the required hardness and depth and that it does not impair the soundness and properties of the steel.

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1.5.7 Where induction hardening or nitriding is to be carried out after machining, forgings are to be heat treated at an appropriate stage to a condition suitable for this subsequent surface hardening.

1.5.8 Where carburising is to be carried out after machining, forgings are to be heat treated at an appropriate stage (generally either by full annealing or by normalising and tempering) to a condition suitable for subsequent machining and carburising.

1.5.9 The forge is to maintain records of heat treatment identifying the furnace used, furnace charge, thermocouple location, date, temperature and time at temperature. The records are to be presented to the Surveyor on request.

1.6 Test material

1.6.1 Test material, sufficient for the required tests and for possible re-test purposes, is to be provided with a cross-sectional area of not less than that part of the forging which it represents. This test material is to be integral with each forging, except in the case of small forgings which are batch tested, *see* 1.6.4.

1.6.2 Where a forging is subsequently divided into a number of components, all of which are heat treated together in the same furnace charge, for test purposes this may be regarded as one forging and the number of tests required is to be related to the total length and mass of the original multiple forging, *see* 2.4.2.

1.6.3 Except for components which are to be carburised, test material is not to be cut from a forging until the heat treatment detailed in Sections 2 to 9 has been completed. The testing procedure for components which are to be carburised is to be in accordance with the details given in Section 5.

1.6.4 Where a number of small forgings of about the same size are made from one cast and heat treated in the same furnace charge, batch testing procedures (*see* 1.1.4) may be adopted using one of the forgings for test purposes, or alternatively using separately forged test samples. These test samples are to have a forging reduction similar to that used for the forgings which they represent. They are to be properly identified and heat treated together with the forgings.

1.7 Mechanical tests

1.7.1 Specimens for mechanical tests are to be prepared as required by Sections 2 to 9.

1.7.2 Test specimens are normally to be cut with their axes mainly parallel (longitudinal test) or mainly tangential (tangential test) to the principal axial direction of each product.

1.7.3 Unless otherwise agreed, the longitudinal axis of the test specimens is to be positioned as follows:

(a) for thickness or diameter ≤ 50 mm, the axis is to be at the mid-thickness or the centre of the cross-section;

(b) for thickness or diameter > 50 mm, the axis is to be at one quarter thickness (mid-radius) or 80 mm, whichever is less, below any heat treated surface;

Test pieces shall be taken in such a way that no part of the gauge length is machined from material closer than 12,5 mm to any heat treated surface. For impact testing, this requirement is to apply to the complete test piece.

1.7.4 Tensile test specimens are to be machined to the dimensions detailed in Chapter 2. Where this is precluded by the dimensions of the forging, the test specimen is to be of the largest practicable cross-sectional area.

1.7.5 Impact test specimens are to be prepared in accordance with the requirements of Chapter 2.

1.7.6 The procedures used for the tensile and impact tests are to be in accordance with the requirements of Chapter 2.

1.7.7 Hardness tests, preferably of the Brinell type, are to be carried out when specified in subsequent Sections in this Chapter.

1.8 Visual and non-destructive examination

1.8.1 Before acceptance, all forgings are to be presented to the Surveyor for visual examination. Where applicable, this is to include the examination of internal surfaces and bores.

1.8.2 Forgings are to be examined in the condition for final delivery. Surfaces are to be clean and free from dirt, grease, paint, etc. Black forgings are to be suitably descaled by either shotblasting or flame descaling methods.

1.8.3 All forgings are to be free of cracks, crack-like indications, laps, seams, folds, or other injurious indications. At the request of the Surveyor, additional magnetic particle, dye penetrant and ultrasonic testing may be required for a more detailed evaluation of surface irregularities.

1.8.4 When specified in subsequent Sections in this Chapter, or by an approved procedure for welding composite components, *see* 1.2.14, appropriate non-destructive examination is also to be carried out before acceptance. All tests are to be carried out in accordance with the requirements of Ch 1,5.

1.8.5 Magnetic particle and dye penetrant testing is to be carried out when the forgings are in the finished machined condition, *see also* Ch 1,2.3.5. For magnetic particle testing, attention is to be paid to the contact between the forging and the clamping devices of stationary magnetisation benches in order to avoid local overheating or burning damage on its surface. Prods are not permitted on finished machined items. Unless otherwise agreed, these tests are to be carried out in the presence of the Surveyor.

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1.8.6 The following definitions apply to indications associated with magnetic particle and dye penetrant inspection:

(a) **Linear indication**. An indication in which the length is at least three times the width.

(b) **Nonlinear indication**. An indication of circular or elliptical shape with a length less than three times the width.

(c) **Aligned indication**. Three or more indications in a line, separated by 2 mm or less edge-to-edge.

(d) **Open indication**. An indication visible after removal of the magnetic particles or that can be detected by the use of contrast dye penetrant.

(e) **Non-open indication**. An indication that is not visually detectable after removal of the magnetic particles or that cannot be detected by the use of contrast dye penetrant.

(f) **Relevant indication**. An indication that is caused by a condition or type of discontinuity that requires evaluation. Only indications which have any dimension greater than 1,5 mm are to be considered relevant.

1.8.7 Acceptance standards for defects found by visual or non destructive examinations are to be in accordance with any specific requirements of the approved plan, and with equivalence to any additional requirements of this Chapter. In all cases they are to be to the satisfaction of the Surveyor.

1.8.8 Where required, ultrasonic examination is to be carried out after the forgings have been machined to a condition suitable for this type of examination and after the final heat treatment. Both radial and axial scanning are to be carried out where appropriate for the shape and the dimensions of the forgings being examined. Unless otherwise agreed, this examination is to be carried out by the manufacturer, although Surveyors may request to be present in order to verify that the examination is being carried out in accordance with the agreed procedure.

1.8.9 If the forging is supplied in the black condition for machining at a separate works, the manufacturer is to ensure that a suitable ultrasonic examination is carried out to verify the internal quality of the forging.

1.8.10 In the circumstance detailed in either 1.8.8 or 1.8.9, the manufacturer is to provide the Surveyor with a signed report confirming that ultrasonic examination has been carried out and that such inspection has not revealed any significant internal defects.

1.8.11 Unless otherwise agreed, the accuracy and verification of dimensions are the responsibility of the manufacturer.

1.8.12 In the event of any forging proving defective during subsequent machining or testing, it is to be rejected notwithstanding any previous certification.

1.8.13 When required by the conditions of approval for surface hardened forgings (*see* 1.5.6) additional test samples are to be processed at the same time as the forgings which they represent. These test samples are subsequently to be sectioned in order to determine the hardness, shape and depth of the locally hardened zone and which are to comply with the requirements of the approved specification.

1.9 Rectification of defects

1.9.1 Small surface imperfections may be removed by grinding or by chipping and grinding. Complete elimination of these imperfections is to be proved by magnetic particle or dye penetrant examination (as appropriate to the material). At the discretion of the Surveyor, the resulting shallow grooves or depressions can be accepted, provided that they are blended by grinding.

1.9.2 Repairs by welding are not generally permitted, but special consideration will be given to such repairs where they are of a minor nature and in areas of low working stresses. In such cases, full details of the proposed repair and subsequent inspection procedures are to be submitted for review by the Surveyors prior to the commencement of the proposed rectification. A report and/or sketch detailing the extent and location of all repairs, together with details of the post-weld heat treatment and non-destructive examination are to be provided for record purposes and are to be attached to the certificate.

1.9.3 Repair welding is not permitted for crankshafts or similar rotating components.

1.9.4 Where fabrication welding is involved, *see* 1.2.14, any repair of defects is to be carried out in accordance with the approved welding procedure.

1.9.5 The forging manufacturer is to maintain records of repairs and subsequent inspections traceable to each forging. The records are to be presented to the Surveyor on request.

1.9.6 Non-open indications evaluated as segregation are acceptable.

1.10 Identification

1.10.1 The manufacturer is to adopt a system of identification, which will enable all finished forgings to be traced to the original cast, forging process and heat treatment batch, and the Surveyor is to be given full facilities for so tracing the castings when required.

1.10.2 Forgings are to be clearly marked by the manufacturer in accordance with the requirements of Chapter 1. The following details are to be shown on all forgings which have been accepted:

(a) Identification number, cast number or other marking which will enable the full history of the forging to be traced.

(b) LR or Lloyd's Register and the abbreviated name of LR's local office.

(c) Personal stamp of Surveyor responsible for inspection.

(d) Test pressure, where applicable.

(e) Date of final inspection.

1.10.3 Modified arrangements for the identification of small forgings manufactured in large numbers, as with closed-die forgings may be agreed with the Surveyor.

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1.11 Certification of materials

1.11.1 A LR certificate is to be issued, *see* Ch 1,3.1.

1.11.2 The manufacturer is to provide the Surveyor with a written statement giving the following particulars for each forging or batch of forgings which has been accepted:
(a) Purchaser's name and order number.
(b) Description of forgings and steel quality.
(c) Identification number.
(d) Steelmaking process, cast number and chemical analysis of ladle samples.
(e) General details of heat treatment.
(f) Results of mechanical tests.
(g) Test pressure, where applicable.

1.11.3 As a minimum, the chemical composition of ladle samples is to include the content of all the elements detailed in the specific requirements.

1.11.4 Where applicable, the manufacturer is also to provide a signed report regarding ultrasonic examination as required by 1.8.8, a report of magnetic particle inspection and a statement and/or sketch detailing all repairs by welding as required by 1.9.2.

1.11.5 When steel is not produced at the works at which it is forged, a certificate is to be supplied by the steelmaker stating the process of manufacture, cast number and the chemical composition of ladle samples. The works at which the steel was produced is to have been approved by LR, *see* 1.4.3.

■ *Section 2*
Forgings for ship and other structural applications

2.1 Scope

2.1.1 This Section gives the specific requirements for carbon-manganese steel forgings intended for ship and other structural applications such as rudder stocks, pintles, etc.

2.1.2 Where it is proposed to use an alloy steel, particulars of the chemical composition, mechanical properties and heat treatment are to be submitted for approval, *see* 1.4.3.

2.2 Chemical composition

2.2.1 For forgings to which structural items are to be attached by welding or which are intended for parts of a fabricated component, or are to be weld cladded or may be subject to weld repair in service, the chemical composition of ladle samples is to comply with the following:

Carbon	0,23% max.
Silicon	0,45% max.
Manganese	0,30–1,50% but not less than 3 times the actual carbon content for components which are not given a post-weld heat treatment
Sulphur	0,035% max.
Phosphorus	0,035% max.
Residual elements:	
Copper	0,30% max.
Chromium	0,30% max.
Molybdenum	0,15% max.
Nickel	0,40% max.
Total	0,85% max.

For samples from forgings, the carbon content is not to exceed 0,26 per cent.

2.2.2 It is recommended that forgings for rudder stocks, pintles and rudder coupling bolts comply with 2.2.1 in order to obtain satisfactory weldability for any future repairs by welding in service.

2.2.3 For forgings not intended for welding the carbon content may be 0,65 per cent max., *see* 3.2.1.

2.3 Heat treatment

2.3.1 Carbon-manganese steel forgings are to be:
(a) fully annealed; or
(b) normalised; or
(c) normalised and tempered at a temperature of not less than 550°C.
(d) quenched and tempered.

2.3.2 Alloy steel forgings are to be quenched and then tempered at a temperature of not less than 550°C. Alternatively, they may be supplied in the normalised and tempered condition, in which case the specified mechanical properties are to be agreed by LR.

2.4 Mechanical tests

2.4.1 At least one tensile specimen is to be taken from each forging or batch of forgings.

2.4.2 Where a forging exceeds both 4 tonnes in mass and 3 m in length, tensile test specimens are to be taken from each end. These limits refer to the 'as forged' mass and length but exclude the test material.

2.4.3 Unless otherwise agreed between the manufacturer and the Surveyor, the test specimens are to be cut in a longitudinal direction.

2.4.4 The results of all tensile tests are to comply with the requirements given in Table 5.2.1 appropriate to the specified minimum tensile strength. Forgings may be supplied to any specified minimum tensile strength within the general limits given in Table 5.2.1, and intermediate values may be obtained by interpolation. *See* 2.4.6 for rudder stocks, pintles, and rudder coupling keys and bolts.

2.4.5 For large forgings, where tensile tests are taken from each end, the variation in tensile strength is not to exceed 70 N/mm^2.

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Table 5.2.1 Mechanical properties for ship and other structural applications

Steel type	Yield stress N/mm² minimum	Tensile strength N/mm²	Elongation on $5{,}65\sqrt{S_o}$ min.%		Reduction of area min. %	
			Long.	Tang.	Long.	Tang.
C and C-Mn	180	360-480	28	20	50	35
	200	400-520	26	19	50	35
	220	440-560	24	18	50	35
	235	470-590	23	17	45	35
	240	480-600	22	16	45	30
	260	520-640	21	15	45	30
	280	560-680	20	14	40	27
	300	600-750	18	13	40	27
	320	640-790	17	12	40	27
	340	680-830	16	12	35	24
	360	720-870	15	11	35	24
	380	760-910	14	10	35	24
Alloy	350	550-570	20	14	50	35
	400	600-750	18	13	50	35
	450	650-800	17	12	50	35

2.4.6 For rudder stocks, pintles, and rudder coupling keys and bolts, the minimum specified yield strength is not to be less than 200 N/mm², *see* Table 13.2.4 in Pt 3, Ch 13.

2.4.7 Impact tests are required for rudder stocks to be fitted to vessels which have an ice class notation. The tests are to be carried out at minus 10°C and the average energy value is to be not less than 27J.

2.5 Non-destructive examination

2.5.1 Surface inspections are to be carried out by visual examination and magnetic particle testing (or dye penetrant testing where appropriate).

2.5.2 Surface inspections are to be carried out in the zones I and II as indicated in Fig. 5.2.1.

2.5.3 For the purpose of evaluating indications, the surface is to be divided into reference areas of 225 cm². The area is to be taken in the most unfavourable location relative to the indication being evaluated.

2.5.4 The allowable number and size of indications in the reference area is given in Table 5.2.2.

2.5.5 Volumetric inspection is to be carried out by ultrasonic testing using the contact method.

2.5.6 Ultrasonic testing is to be carried out on rudder stocks having a finished diameter of 200 mm or greater.

2.5.7 Ultrasonic testing is to be carried out in the zones I to III as indicated in Fig. 5.2.2. Areas may be upgraded to a higher zone at the discretion of the Surveyors.

Table 5.2.2 Steel forgings surface inspection

Inspection zone	Maximum number of indications	Type of indication	Maximum number each type	Maximum dimension, mm
I	3	Linear Non-linear Aligned	0, *see* Note 3 0, *see* Note	— 3,0 —
II	10	Linear Non-linear Aligned	3, *see* Note 7 3, *see* Note	3,0 5,0 3,0

NOTE
Linear or aligned indications are not permitted on bolts, which receive a direct fluctuating load, e.g., main bearing bolts, connecting rod bolts, crosshead bearing bolts and cylinder cover bolts.

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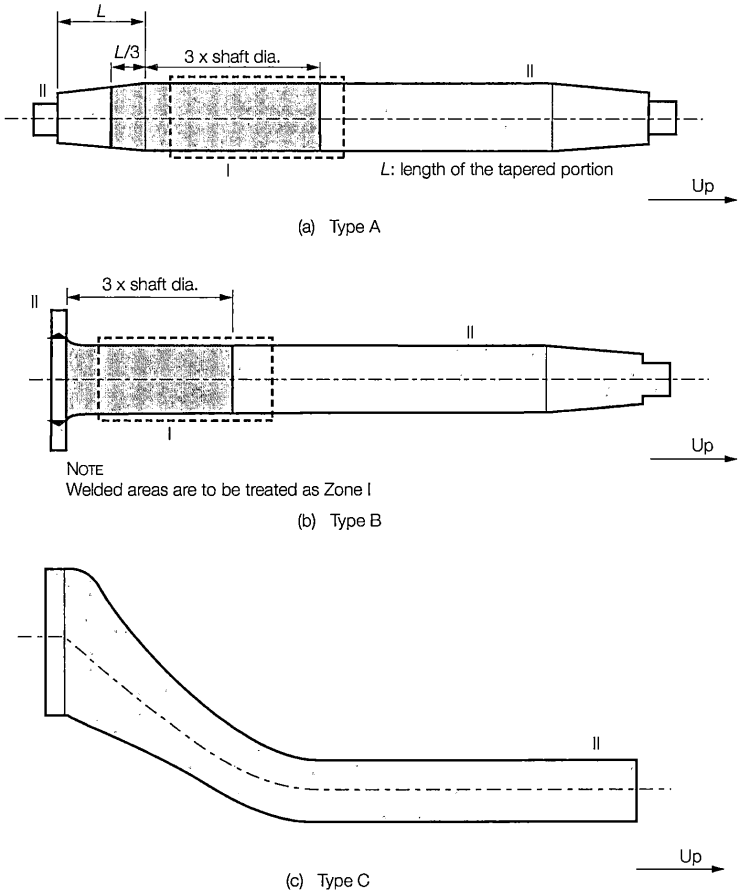

Fig. 5.2.1 Inspection zones for magnetic particle/dye penetrant testing on rudder stocks

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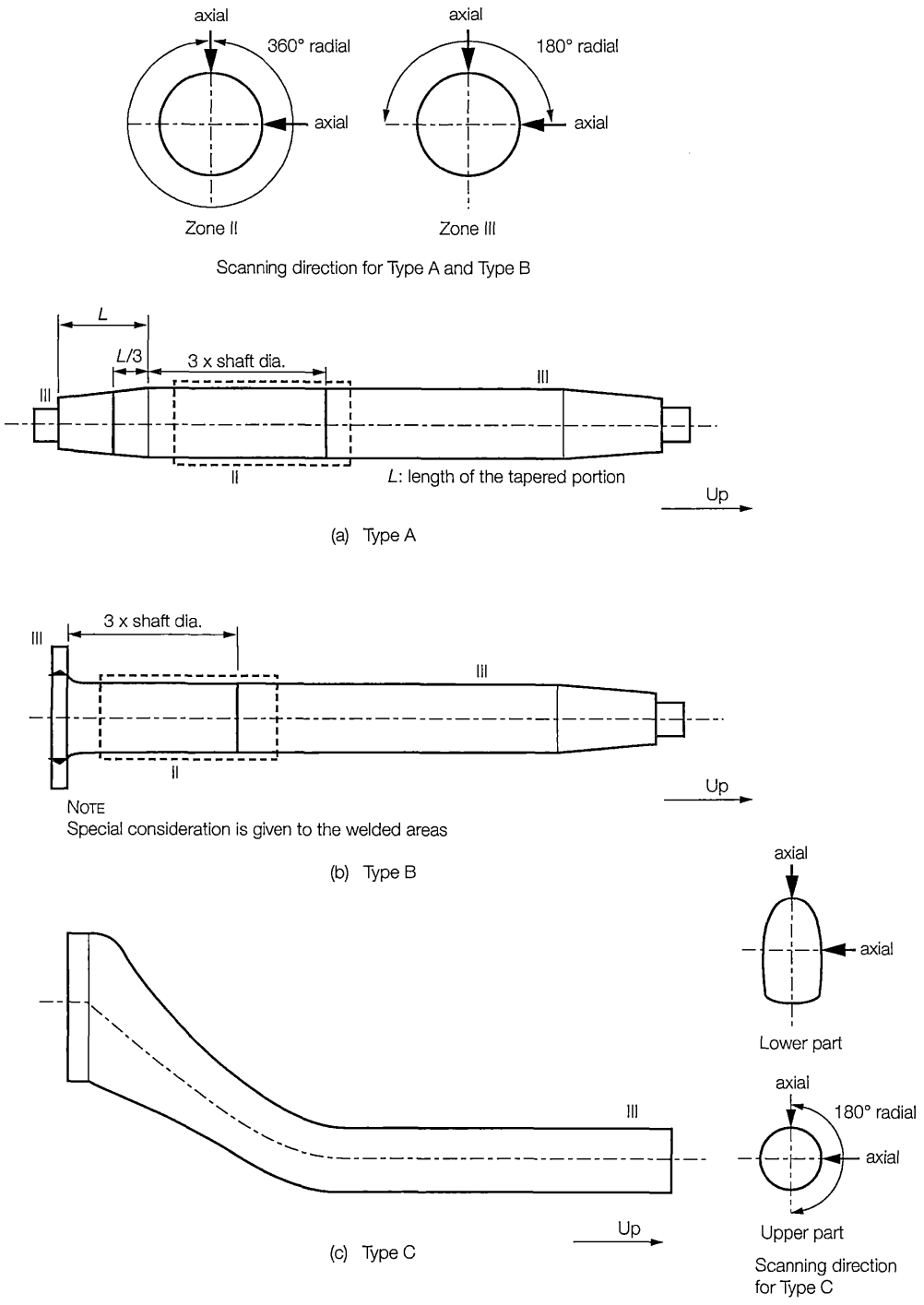

Fig. 5.2.2 Inspection zones for ultrasonic testing on rudder stocks

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Section 3
Forgings for shafting and machinery

3.1 Scope

3.1.1 Detailed in this Section are the requirements for carbon-manganese steel forgings for shafting and other items of machinery which are not within the scope of Sections 4 to 8.

3.1.2 Where it is proposed to use alloy steel forgings, particulars of the chemical composition, mechanical properties and heat treatment are to be submitted for approval. For main propulsion shafting in alloy steels, the specified minimum tensile strength is not to exceed 800 N/mm^2 (800–950 N/mm^2 acceptance range) and for other forgings is not to exceed 1100 N/mm^2 (1100–1300 N/mm^2 acceptance range).

3.2 Chemical composition

3.2.1 The chemical composition of ladle samples for carbon and carbon-manganese steels is to comply with the following overall limits:

Carbon	0,65% max.
Silicon	0,45% max.
Manganese	0,30–1,50%
Sulphur	0,035% max.
Phosphorus	0,035% max.
Residual elements:	
Copper	0,30% max.
Chromium	0,30% max.
Molybdenum	0,15% max.
Nickel	0,40% max.
Total	0,85% max.

3.2.2 For alloy steels, *see* 1.4.3.

3.2.3 For forgings to which structural items are to be attached by welding, or which are intended for parts of a fabricated component, are to be of weldable quality, *see* 2.2.1.

3.3 Heat treatment

3.3.1 Forgings are to be:
(a) fully annealed; or
(b) normalised; or
(c) normalised and tempered; or
(d) quenched and tempered.
The tempering temperature is to be not less than 550°C.

3.4 Mechanical tests

3.4.1 At least one tensile test is to be made on each forging, or each batch of forgings. Impact tests are not required except on screwshafts for ice service, *see* 3.4.12.

3.4.2 Where a forging exceeds both 4 tonnes in mass and 3 m in length, a tensile test is to be taken from each end. These limits refer to the 'as forged' mass and length but exclude the test material.

3.4.3 A batch testing procedure may be used for hot rolled bars not exceeding 250 mm diameter, which are intended for the manufacture (by machining operations only) of straight shafting, bolts, studs and other machinery components of similar shape. A batch is to consist of either:
(a) material from the same piece provided that where this is cut into individual lengths, these are all heat treated in the same furnace charge; or
(b) bars of the same diameter and cast, heat treated in the same furnace charge and with a total mass not exceeding 2,5 tonnes.

3.4.4 The test specimens are to be taken in the longitudinal direction but, at the discretion of the manufacturer and if agreed by the Surveyor, alternative directions or positions as shown in Figs. 5.3.1 to 5.3.3 may be used.

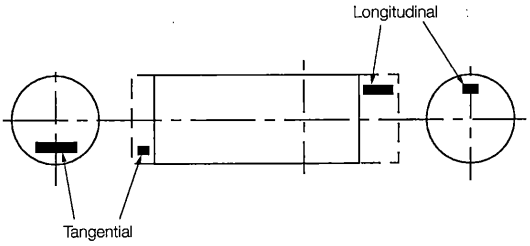

Fig. 5.3.1
Directions and positions of test specimens

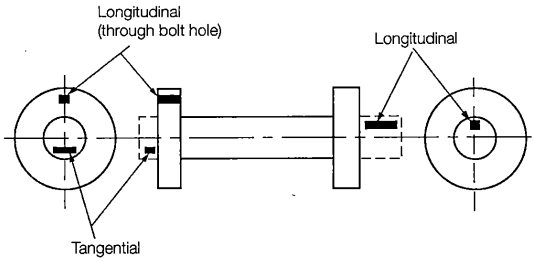

Fig. 5.3.2
Directions and positions of test specimens

3.4.5 For carbon-manganese steels, Table 5.3.1 gives the minimum requirements for yield stress, elongation and reduction of area, corresponding to different strength levels, but it is not intended that these should necessarily be regarded as specific grades. Intermediate values for other specified minimum tensile strengths should be calculated by interpolation.

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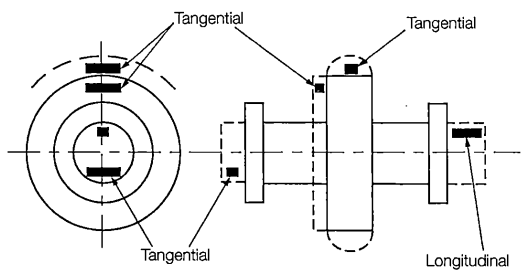

Fig. 5.3.3
Directions and positions of test specimens

3.4.6 Forgings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Table 5.3.1, except that for main propulsion shafting forgings the specified minimum tensile strength is to be not less than 400 N/mm^2 (400–520 N/mm^2 acceptance range) and not greater than 600 N/mm^2 (600–750 N/mm^2 acceptance range) *see* shaded area of Table 5.3.1.

3.4.7 The results of all tensile tests are to comply with the requirements given in Table 5.3.1 appropriate to the specified minimum tensile strength.

3.4.8 The minimum requirements for yield stress, elongation and reduction of area, corresponding to different strength levels in alloy steel forgings are given in Table 5.3.2.

Table 5.3.1 Mechanical properties for acceptance purposes: carbon and carbon-manganese steel forgings for machinery and shafting

Tensile strength N/mm^2	Yield stress N/mm^2	Elongation on $5{,}65\sqrt{S_o}$ min.%		Reduction of area min. %	
		Long.	Tang.	Long.	Tang.
360-480	180	28	20	50	35
400-520	200	26	19	50	35
440-560	220	24	18	50	35
470-590	235	23	17	45	35
480-600	240	22	16	45	30
520-640	260	21	15	45	30
560-680	280	20	14	40	27
600-750	300	18	13	40	27
640-790	320	17	12	40	27
680-830	340	16	12	35	24
700-850 [2]	350	15	11	35	24
720-870 [2]	360	15	11	35	24
760-910 [2]	380	14	10	35	24

NOTES
1. For main propulsion shafting forgings, the specified minimum tensile strength is to be between 400 and 600 N/mm^2 (shaded area of Table) *see* 3.4.6.
2. Where the specified minimum tensile strength exceeds 700 N/mm^2, forgings are to be supplied only in the quenched and tempered condition.

Table 5.3.2 Mechanical properties for acceptance purposes: alloy steel forgings for machinery and shafting

Tensile strength N/mm^2	Yield stress N/mm^2	Elongation on $5{,}65\sqrt{S_o}$ min.%		Reduction of area min. %	
		Long.	Tang.	Long.	Tang.
600-750	420	18	14	50	35
650-800	450	17	13	50	35
700-850	480	16	12	45	30
750-900	530	15	11	45	30
800 -950	580	14	10	40	27
850-1000	630	13	9	40	27
900-1100	690	13	9	40	27
950-1150	750	12	8	35	24
1000-1200	810	12	8	35	24
1050-1250	870	11	7	35	24
1100-1300	930	11	7	35	24

NOTE
For main propulsion shafting forgings, the minimum specified tensile strength is not to exceed 800 N/mm^2, *see* 3.4.9 (shaded area of Table).

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3.4.9 Forgings in alloy steels may be supplied to any specified minimum tensile strength selected within the general limits detailed in Table 5.3.2, and minimum yield stress, elongation and reduction of area, obtained by interpolation, except that for main propulsion shafting forgings the specified minimum tensile strength is not to exceed 800 N/mm^2 (800–950 N/mm^2 acceptance range) *see* shaded area of Table 5.3.2.

3.4.10 The results of all tensile tests are to comply with the requirements given in Table 5.3.2 appropriate to the specified minimum tensile strength.

3.4.11 Where more than one tensile test is taken from a forging, the variation in tensile strength is not to exceed the following:

Specified minimum tensile strength N/mm^2	Difference in tensile strength N/mm^2
<600	70
≥600 < 900	100
≥900	120

3.4.12 For screwshafts intended for ships with the notation **Ice Class 1AS** or **1A** and where the connection between the propeller and the screwshaft is by means of a key, a set of three Charpy V-notch impact tests (longitudinal test) is to be made on material from the propeller end of each shaft. The tests are to be carried out at –10°C and the average energy value is to be not less than 20 J.

3.5 Non-destructive examination

3.5.1 Magnetic particle or dye penetrant testing (where appropriate) is to be carried out on forgings for main propulsion shafting (including propeller shafts, intermediate shafts, and thrust shafts with minimum diameter not less than 100 mm), on all connecting rod forgings and on the following components when they are intended for engines having a bore diameter larger than 400 mm:

- Cylinder covers
- Piston crowns
- Piston rods
- Tie rods
- Gear wheels for camshaft drives
- Bolts and studs for:
  - Cylinder covers
  - Crossheads
  - Main bearings
  - Connecting rod bearings
  - Propeller blade fastening bolts
  - Crankpin bolts
  - Tie rod bolts

  Additionally, bolts for engine bore diameters of less than 400 mm but having a minimum diameter 50 mm or greater (which are subjected to dynamic stress), are also to be subjected to surface examinations.

3.5.2 The areas to be tested by magnetic particle or dye penetrate testing are shown in Fig. 5.3.4 and Fig. 5.3.5. Areas of other components not shown in these figures are to be agreed with the Surveyor. For tie rods, only threaded portions and the adjacent material over a length equal to that of the thread need be tested.

3.5.3 Surface inspection acceptance criteria are to be in accordance with 2.5. Other acceptance criteria may be applied, providing they meet these minimum criteria, and are to the satisfaction of the Surveyor.

3.5.4 Ultrasonic testing is to be carried out in accordance with 2.5 on the following items:

(a) Shafts having a finished diameter of 200 mm or larger when intended for main propulsion or other essential services.
(b) All piston crowns and cylinder covers.
(c) Piston rods and connecting rods for engines having a bore diameter greater than 400 mm.

The areas to be tested are shown in Fig. 5.3.6 and Fig. 5.3.7. Areas of other components not shown in these drawings are to be agreed with the Surveyor.

3.5.5 Ultrasonic acceptance criteria are shown in Table 5.3.4. Other acceptance criteria may be applied, providing they meet these minimum criteria, and are to the satisfaction of the Surveyor.

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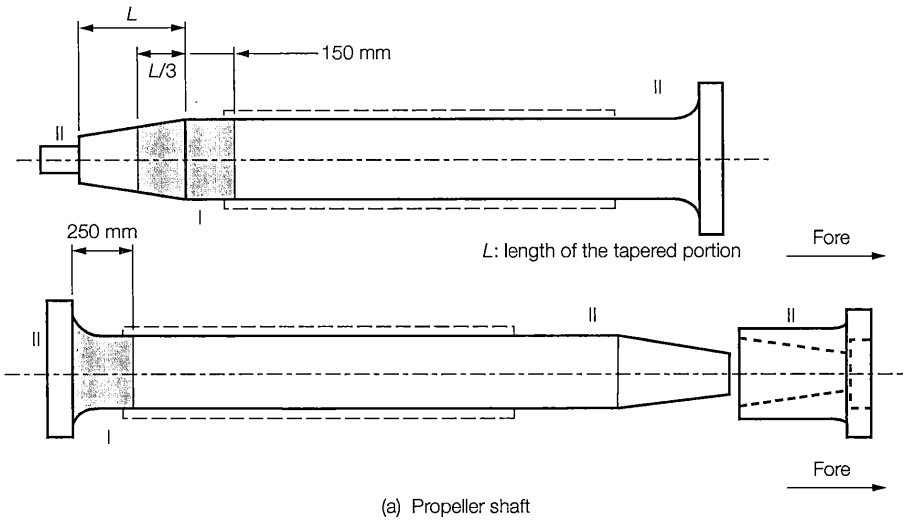
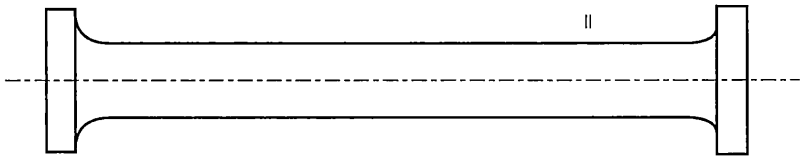
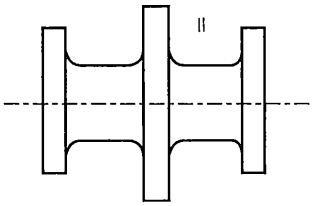


(a) Propeller shaft



(b) Intermediate shaft



(c) Thrust shaft

NOTE
For propeller shaft, intermediate shafts and thrust shafts, all areas with stress raisers such as radial holes, slots and key ways are to be treated as Zone I.

Fig. 5.3.4 Zones for magnetic particle/dye penetrant testing on machinery components

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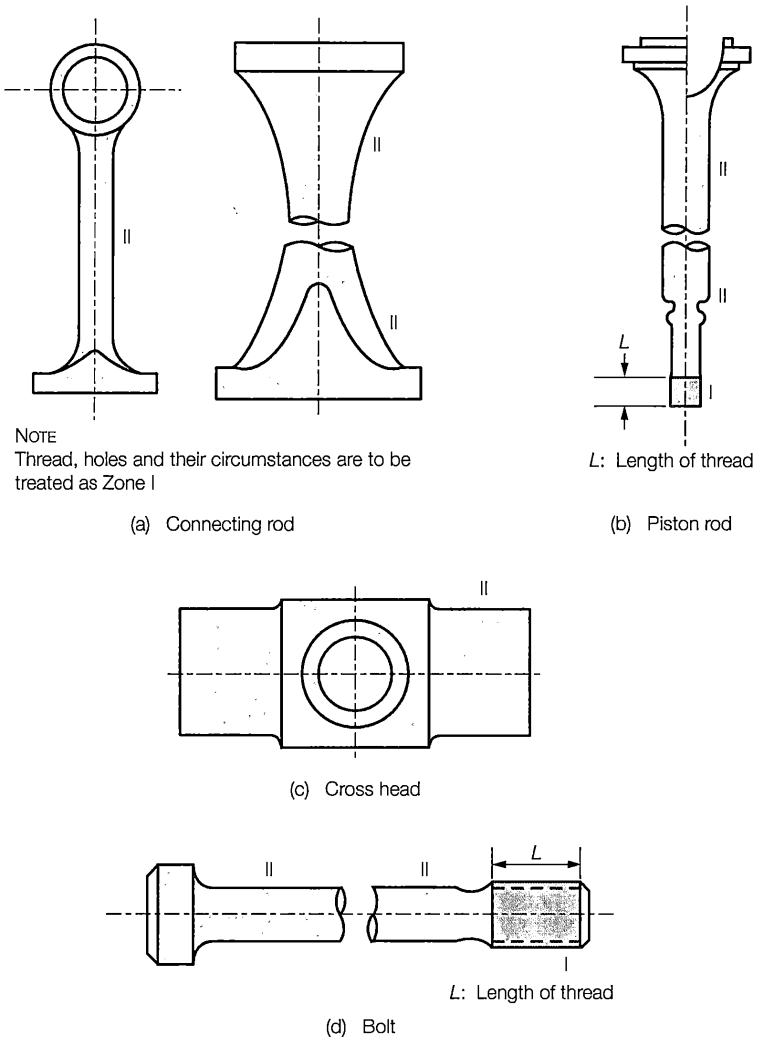

NOTE
Thread, holes and their circumstances are to be treated as Zone I

(a) Connecting rod

(b) Piston rod

(c) Cross head

(d) Bolt

Fig. 5.3.5 Zones for magnetic particle/dye penetrant testing on machinery components

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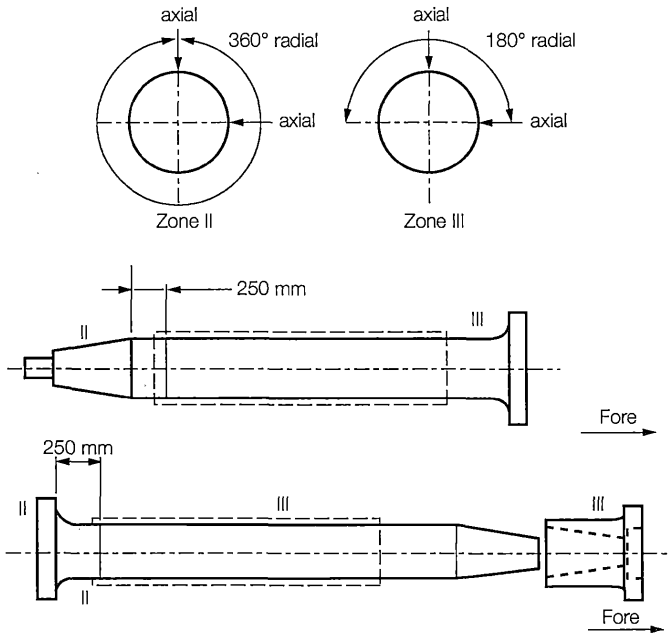
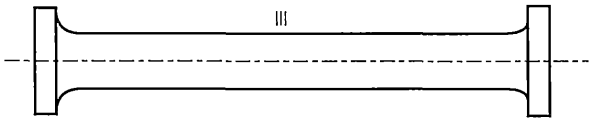
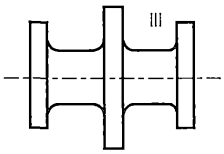


(a) Propeller shaft



(b) Intermediate shaft



(c) Thrust shaft

NOTES
1. For hollow shafts, 360° radial scanning applies to Zone III
2. Circumferences of the bolt holes in the flanges are to be treated as Zone II

Fig. 5.3.6 Zones for ultrasonic testing on shafts

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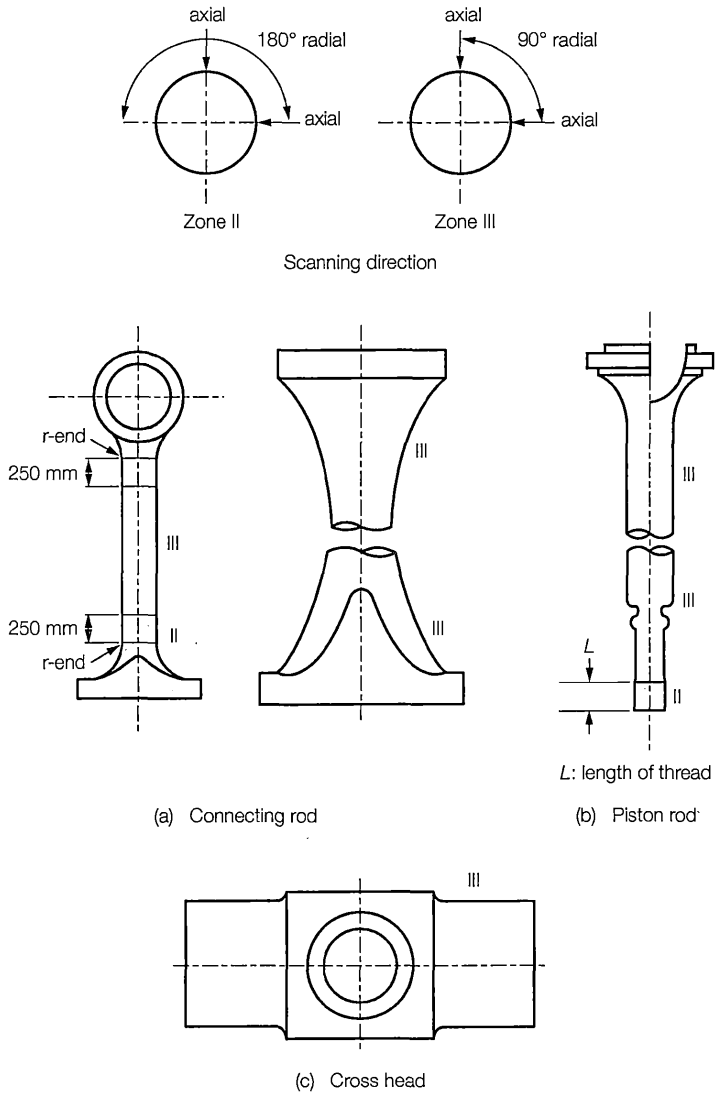

Fig. 5.3.7 Zones for ultrasonic testing on machinery components

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Table 5.3.4 Acceptance criteria for ultrasonic testing

Type of forging	Zone	Allowable disc shape according to Distance Gain Size (DGS), *see* Note 1, mm	Allowable length of indication, mm *see* Note 2
Propeller shaft Intermediate shaft	II	Outer $d \leq 2$ Inner $d \leq 4$	≤10 ≤15
Thrust shaft Rudder stock	III	Outer $d \leq 3$ Inner $d \leq 6$	≤10 ≤15
Connecting rod Piston rod	II	$d \leq 2$	≤10
	III	$d \leq 4$	≤10

NOTES
1. Outer part means the part beyond one third of the shaft radius from the centre. The inner part means the remaining core area.
2. For accumulations of two or more isolated indications which are subjected to registration, the minimum distance between two neighbouring indications is to be at least the length of the larger indication.

■ *Section 4*
Forgings for crankshafts

4.1 Scope

4.1.1 The specific requirements for solid forged crankshafts and forgings for use in the construction of fully built and semi-built crankshafts are detailed in this Section.

4.1.2 Where it is proposed to use alloy steel forgings, particulars of the chemical composition (*see* 1.4.3), heat treatment and mechanical properties are to be submitted for approval. The specified minimum tensile strength is not to exceed 1000 N/mm^2 (1000–1200 N/mm^2 acceptance range).

4.2 Manufacture

4.2.1 For closed die and continuous grain flow crankshafts forgings, where an allowance is given for design purposes, full details of the proposed method of manufacture are to be submitted for approval. In such cases, tests will be required to demonstrate that a satisfactory structure and grain flow are obtained. The number and positions of test specimens are to be agreed with LR.

4.2.2 For the manufacture of welded crankshafts, approval is required for the welding procedure.

4.2.3 For combined crankweb and pin forgings, the proposed method of forging is to be submitted for approval. It is recommended that these forgings be made by a folding method. Other methods which can be shown to produce sound forgings with satisfactory mechanical properties will be considered, but where the gapping method is used for cranks having a pin diameter exceeding 510 mm this will only be accepted provided that an upsetting operation is included in the manufacturing sequence. In general, the amount of work during the upsetting operation is to be such that the reduction in the original length of the ingot (after discard) or bloom is not less than 50 per cent.

4.2.4 Where crankwebs are flame cut from forged or rolled slabs, the procedure used is to be in accordance with 1.2.13, and additionally, unless specially agreed, a depth of at least 7,5 mm is to be removed by machining from all flame-cut surfaces.

4.3 Chemical composition

4.3.1 The chemical composition of ladle samples is to comply with 3.2.1 for carbon and carbon-manganese steels and 1.4.3 for alloy steels.

4.3.2 For alloy steel forgings which are to be nitrided, the phosphorus or sulphur contents are not to exceed 0,02 per cent.

4.4 Heat treatment

4.4.1 For forgings in all types of steels, heat treatment is to be either:
(a) normalising and tempering, or
(b) quenching and tempering.
The temperature used for tempering is to be not less than 550°C.

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4.4.2 Where it is proposed to surface harden crankshaft forgings by nitriding or induction hardening, full details of the proposed procedure are to be submitted as required by 1.5.6.

4.5 Mechanical tests

4.5.1 At least one tensile test specimen is to be taken from each forging.

4.5.2 For solid forged crankshafts, tests are to be taken in the longitudinal direction from the coupling end of each forging (test position A in Fig. 5.4.1). Where the mass, as heat treated but excluding test material, exceeds 3 tonnes, a second set of tests is to be taken from the end opposite the coupling, in addition (test position B in Fig. 5.4.1). Where the crankthrows are formed by machining or flame cutting, the second set of tests is to be taken in a tangential direction from material removed from the crankthrow at the end opposite the coupling (test position C in Fig. 5.4.1).For continuous grain flow (CGF) crankshaft forgings, where insufficient material exists for a second longitudinal test, the second set of tests may be taken in a tangential direction from the crankthrow (test position C in Fig. 5.4.2).

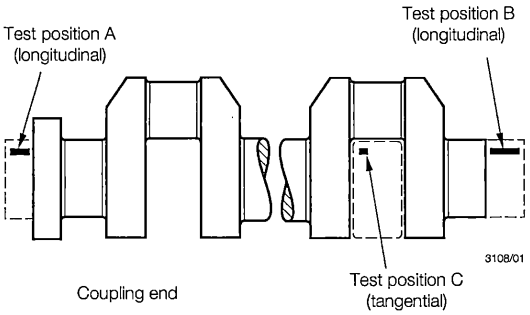

Fig. 5.4.1 Solid forged crankshaft

4.5.3 The number and position of test specimens from combined crankweb and pin forgings are to be in accordance with the requirements of the approved method of manufacture.

4.5.4 For other crankshaft forgings, tests are to be taken as detailed in Section 3, except that for crankwebs the test specimens are to be cut in a tangential direction.

4.5.5 As an alternative to 4.5.2, small solid forged crankshafts may be batch tested in accordance with 1.6.4, provided that, in addition, hardness tests are carried out on each forging.

4.5.6 Tables 5.4.1 to 5.4.3 give the minimum requirements for yield stress and elongation corresponding to different strength levels, but it is not intended that these should necessarily be regarded as specific grades. The strength levels have been given in multiples of 40 N/mm^2, or 50 N/mm^2 in the case of alloy steels, to facilitate interpolation for intermediate values of specified minimum tensile strength.

Table 5.4.1 Mechanical properties for acceptance purposes: carbon-manganese steel forgings for crankshafts

Tensile strength N/mm^2	Yield stress N/mm^2 minimum	Elongation on $5{,}65\sqrt{S_o}$ % minimum		Hardness Brinell
		Long.	Tang.	
400–520	200	26	19	110–150
440–560	220	24	18	125–160
480–600	240	22	16	135–175
520–640	260	21	15	150–185
560–680	280	20	14	160–200
600–750	300	18	13	175–215
640–790	320	17	12	185–230
680–830	340	16	12	200–240
720–870	350	15	11	210–250
760–910	380	14	18	225–265

Intermediate values may be obtained by interpolation.

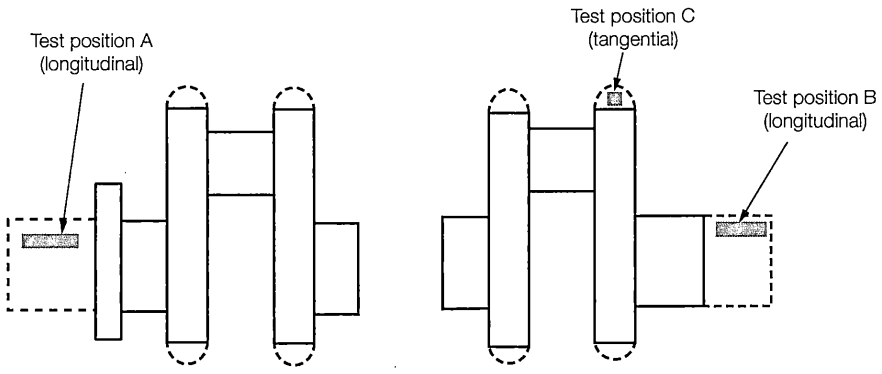

Fig. 5.4.2 CGF Crankshaft

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Table 5.4.2 Mechanical properties for acceptance purposes: alloy steel forgings for crankshafts – Normalised and tempered

Tensile strength N/mm²	Yield stress N/mm² minimum	Elongation on $5,65\sqrt{S_o}$ % minimum		Hardness Brinell
		Long.	Tang.	
600–750	330	18	14	175–215
650–800	355	17	13	190–235
700–850	380	16	12	205–245
750–900	405	15	11	215–260
800–950	430	14	10	235–275
Intermediate values may be obtained by interpolation.				

Table 5.4.3 Mechanical properties for acceptance purposes: alloy steel forgings for crankshafts – Quenched and tempered

Tensile strength N/mm²	Yield stress N/mm² minimum	Elongation on $5,65\sqrt{S_o}$ % minimum		Hardness Brinell
		Long.	Tang.	
600–750	420	18	14	175–215
650–800	450	17	13	190–235
700–850	480	16	12	205–245
750–900	530	15	11	215–260
800–950	590	14	10	235–275
850–1000	640	13	9	245–290
900–1100	690	13	9	260–320
950–1150	750	12	8	275–340
1000–1200	810	12	8	290–365
Intermediate values may be obtained by interpolation.				

4.5.7 Forgings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Tables 5.4.1 to 5.4.3.

4.5.8 The results of all tensile tests are to comply with the requirements of Table 5.4.1, 5.4.2 or 5.4.3 appropriate to the specified minimum tensile strength.

4.5.9 Where more than one tensile test is taken from a forging, the variation in tensile strength is not to exceed the following:

Specified minimum tensile strength N/mm²	Difference in tensile strength N/mm²
<600	70
≥600 <900	100
≥900	120

4.5.10 For small crankshaft forgings which have been batch tested, the hardness values are to be not less than those given in Tables 5.4.1 to 5.4.3, as appropriate. The variation in hardness in each batch is to comply with the following:

Specified minimum tensile strength (N/mm²)	Difference in hardness (Brinell number)
<600	not more than 25
≥600 <900	not more than 35
≥900	not more than 42

4.6 Non-destructive examination

4.6.1 Magnetic particle or dye penetrant testing as detailed in 1.8.5 and 2.5 is to be carried out on all forgings for crankshafts. Where applicable, this is to include all surfaces which have been flame-cut, but not subsequently machined during manufacture. Particular attention is to be given to the testing of the pins, journals and associated fillet radii of solid forged crankshafts and to the pins and fillet radii of combined web and pin forgings. The extent of testing is shown in Fig. 5.4.3.

4.6.2 The manufacturer is to carry out an ultrasonic examination of all forgings as detailed in 1.8.8 and 2.5, except that for closed-die forgings this examination may, subject to approval, be confined to the initial production and to subsequent occasional checks. The extent of ultrasonic testing is shown in Fig. 5.4.4.

4.6.3 Surface inspection acceptance criteria are to be in accordance with 2.5 and with Table 5.4.4. Other acceptance criteria may be applied, providing they meet these minimum criteria, and is to the satisfaction of the Surveyor.

4.6.4 Ultrasonic acceptance criteria are shown in Table 5.4.5. Other acceptance criteria may be applied, providing they meet these minimum criteria, and is to the satisfaction of the Surveyor.

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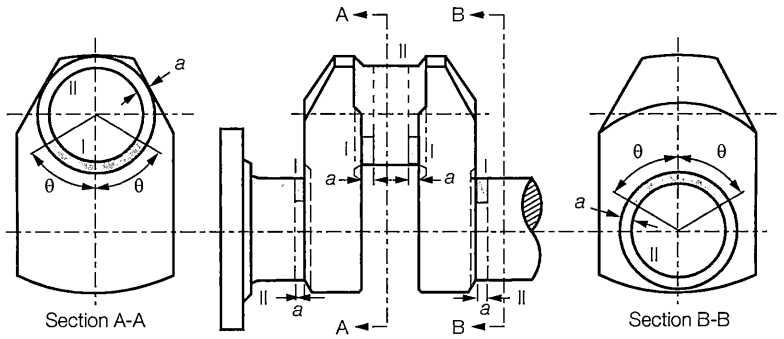
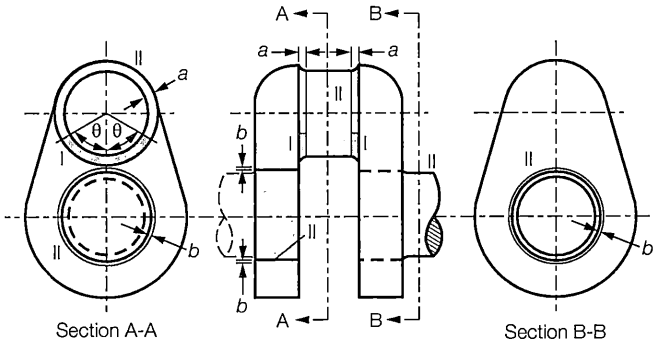


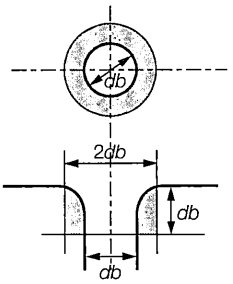
(a) Soild crankshaft



(b) Semi built-up crankshaft

NOTES

1. Where the crankpin or journal has oil holes, the circumferential surfaces of the oil are to be treated as Zone I, (*see* the figure on the right)
2. In the above figures:
   $\theta = 60°$
   $a = 1{,}5r$
   $b = 0{,}05d$ (: circumferential surfaces of shrinkage fit)
   where
   r : fillet radius
   d : journal diameter
3. Identification of the Zones:
   : Zone I
   : Zone II



db: Oil hole bore diameter

Fig. 5.4.3 Zones for magnetic particle/dye penetrant testing on crankshafts

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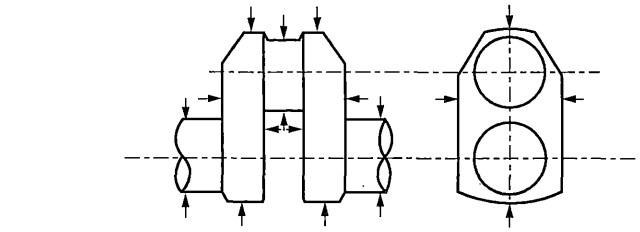
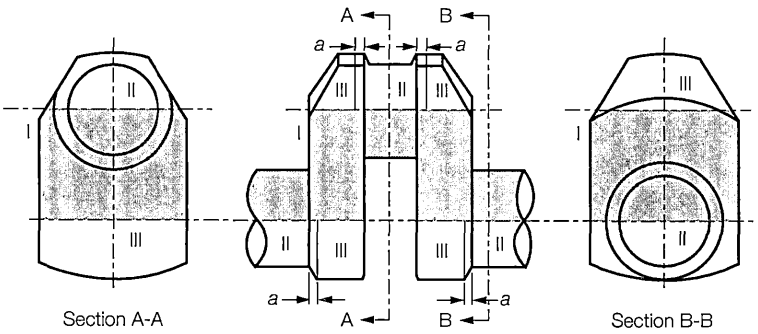
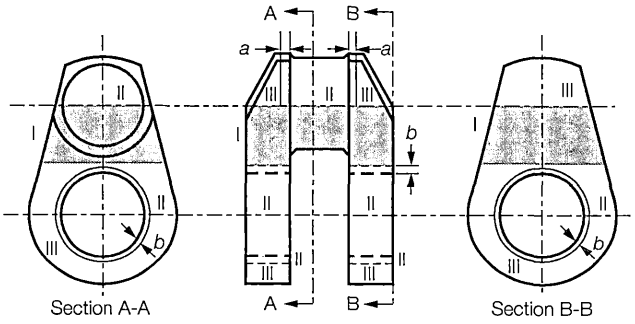




(a) Solid crankshaft



(b) Semi built-up crankshaft

NOTES

1. In the above figures:
   $a = 0{,}1d$ or 25 mm, whichever is greater
   $b = 0{,}05d$ or 25 mm, whichever is greater (: circumstances of shrinkage fit)
   where
   d : pin or journal diameter
2. The mid third area of crank pins and/or journals within a raduis of $0{,}25d$ between the webs may generally be coordinated to Zone II
3. Identification of the Zones:
   : Zone I
   : Zone II
   : Zone III

Fig. 5.4.4 Zones for ultrasonic testing on crankshafts

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Table 5.4.4 Surface inspection acceptance for crankshaft forgings – Allowable number and size of indications in a reference area of 225 cm²

Inspection zone	Maximum number of indication	Type of indication	Maximum number each type	Maximum dimension of single indication, mm
I Critical fillet area	0	Linear Non-linear Aligned	0 0 0	— — —
II Important fillet area	3	Linear Non-linear Aligned	0 3 0	— 3,0 —
III Journal surfaces	3	Linear Non-linear Aligned	0 3 0	— 5,0 —

Table 5.4.5 Ultrasonic acceptance criteria for crankshafts

Type of forging	Zone	Allowable disc shape according to Distance Gain Size (DGS), mm	Allowable length of indication, mm *see* Note
Crank shaft	I II III	$d \leq 2,0$ $d \leq 3,0$ $d \leq 4,0$	— ≤10 ≤15
NOTE For accumulations of two or more isolated indications which are subjected to registration, the minimum distance between two neighbouring indications is to be at least the length of the larger indication. This applies to the distance in axial direction as to the distance in depth. *Isolated indications* with less distance are to be determined as one single indication.			

■ *Section 5*
Forgings for gearing

5.1 Scope

5.1.1 Provision is made in this Section for carbon-manganese and alloy steel forgings intended for use in the construction of gearing for main propulsion and for driving electric generators.

5.1.2 Gear wheel and rim forgings with a specified minimum tensile strength not exceeding 760 N/mm² (760–910 N/mm² acceptance range) may be made in carbon-manganese steel. Gear wheel or rim forgings where the specified minimum tensile strength is in excess of 760 N/mm², and all pinion or pinion sleeve forgings, are to be made in a suitable alloy steel. Specifications for alloy steel components and for quill shafts, giving chemical composition, heat treatment and mechanical properties, are to be submitted for approval.

5.1.3 Forgings for flexible couplings, quill shafts and gear wheel shafts are to comply with the requirements of Section 3.

5.1.4 Manufacturers' test certificates for forgings may be accepted where the transmitted power does not exceed 220 kW (300 shp) for main propulsion and 100 kW (150 shp) for auxiliary drives.

5.2 Manufacture

5.2.1 All forgings are to be made with sufficient material to allow an adequate machining allowance on all surfaces for the removal of unsound or decarburised material.

5.2.2 The hardenability of the forged material is to be checked at random intervals using an end quench test complying with a National or International Standard.

5.2.3 The grain size is to be checked on a random basis in accordance with the testing and reporting procedures of ASTM E 112, or an equivalent National Standard, and is to be within the range 5 to 8.

5.2.4 The microstructure of the hardened case is to be mainly martensite, with a maximum content of 15 per cent of retained austenite.

5.3 Chemical composition

5.3.1 The chemical composition of ladle samples is to comply with 3.2.1. for carbon and carbon-manganese steels and 1.4.3 for alloy steels.

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5.4 Heat treatment

5.4.1 Except as provided in 5.4.4 and 5.4.5, forgings may be either normalised and tempered or quenched and tempered in accordance with the approved specification. The tempering temperature is to be not less than 550°C.

5.4.2 Where forgings are machined prior to heat treatment, the allowance left for final machining is to be sufficient to remove the decarburised surface material, taking into account any bending or distortion which may occur.

5.4.3 When the teeth of a pinion or gear wheel are to be surface hardened, i.e, carburised, nitrided or induction hardened, the proposed specification together with details of the process and practice are to be submitted for approval. For purposes of initial approval, the gear manufacturer is required to demonstrate by test that the surface hardening of the teeth is uniform and of the required depth and that it does not impair the soundness and quality of the steel.

5.4.4 Where induction hardening of nitriding is to be carried out after machining of the gear teeth, the forgings are to be heat treated at an appropriate stage to a condition suitable for this subsequent surface hardening.

5.4.5 Forgings for gears which are to be carburised after final machining are to be supplied in either the fully annealed or the normalised and tempered condition, suitable for subsequent machining and carburising.

5.5 Mechanical tests for through hardened, induction hardened or nitrided forgings

5.5.1 At least one tensile test specimen is to be taken from each forging in carbon or carbon-manganese steel, and at least one tensile test specimen from forgings in alloy steel. Sufficient test material is to be provided for this purpose and the test specimens are to be taken as follows:

(a) For pinion forgings where the finished diameter of the toothed portion exceeds 200 mm, tests are to be taken in a tangential direction and adjacent to the toothed portion (test position B in Fig. 5.5.1). Where the dimensions preclude the preparation of tests from this position, tests in a tangential direction are to be taken from the end of the journal (test position C in Fig. 5.5.1). If, however, the journal diameter is 200 mm or less, tests are to be taken in a longitudinal direction (test position A in Fig. 5.5.1). Where the finished length of the toothed portion exceeds 1250 mm, tests are to be taken from each end.

(b) For small pinion forgings where the finished diameter of the toothed portion is 200 mm or less, tests are to be taken in a longitudinal direction (test position A in Fig. 5.5.1).

(c) For gear wheel forgings, tests are to be taken in a tangential direction (from one of the test positions B in Fig. 5.5.2).

(d) For gear wheel rim forgings, tests are to be taken in a tangential direction (from one of the test positions A in Fig. 5.5.3). Where the finished diameter exceeds 2500 mm or the mass (as heat treated but excluding test material) exceeds 3 tonnes, tests are to be taken from two diametrically opposite positions (test positions A in Fig. 5.5.3).

(e) For pinion sleeve forgings, tests are to be taken in a tangential direction (from one of the test positions C in Fig. 5.5.4). Where the finished length exceeds 1250 mm, tests are to be taken from each end.

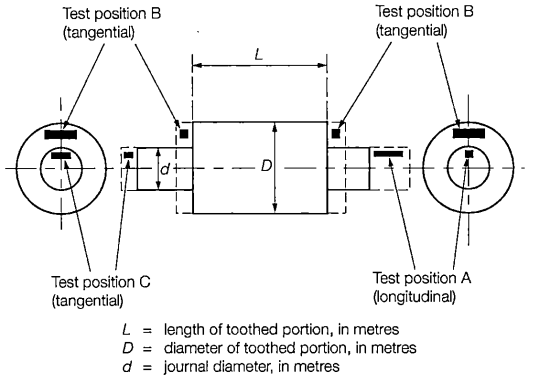

Fig. 5.5.1 Test positions for forgings for gearing

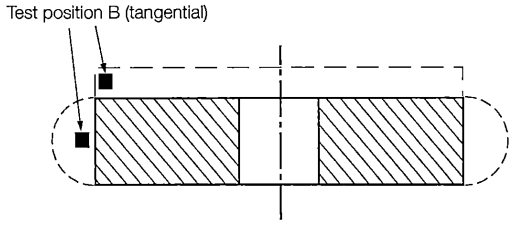

Fig. 5.5.2 Test position B

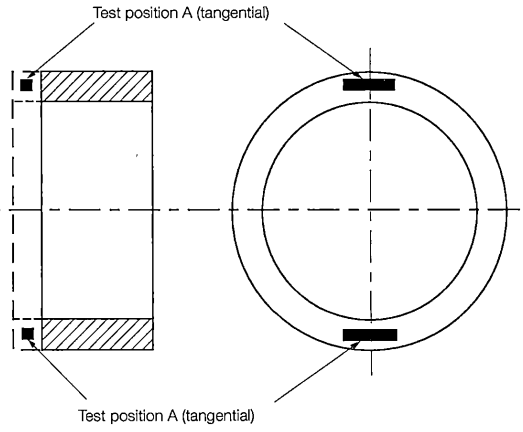

Fig. 5.5.3 Test position A

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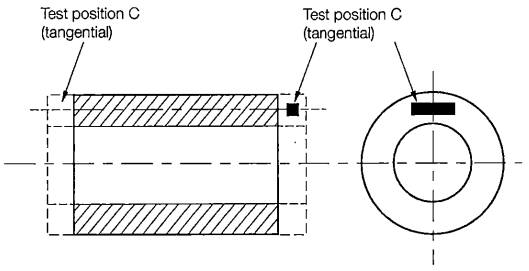

Fig. 5.5.4 Test position C

5.5.2 As an alternative to 5.5.1, small forgings may be batch tested in accordance with 1.6.4 provided that, in addition, hardness tests are carried out on each forging.

5.5.3 Tables 5.5.1 to 5.5.3 give the minimum requirements for yield stress and elongation corresponding to different strength levels, but it is not intended that these should necessarily be regarded as specific grades. The strength levels have been given in multiples of 40 N/mm^2, or 50 N/mm^2 in the case of alloy steels, to facilitate interpolation for intermediate values of specified minimum tensile strength.

Table 5.5.1 Mechanical properties for acceptance purposes: carbon-manganese steels for gear wheel and rim forgings

Tensile strength N/mm^2 (*see* Note)	Yield stress N/mm^2 minimum	Elongation on $5{,}65\sqrt{S_o}$ % minimum		Hardness Brinell
		Rims	Wheels	
400–520	200	26	22	110–150
440–560	220	24	21	125–160
480–600	240	22	19	135–175
520–640	260	21	18	150–185
560–680	280	20	17	160–200
600–750	300	18	15	175–215
640–790	320	17	14	185–230
680–830	340	16	14	200–240
720–870	360	15	13	210–250
760– 910	380	14	12	225–265

Intermediate values may be obtained by interpolation.

NOTE
When the specified minimum tensile strength exceeds 700 N/mm^2 forgings are to be supplied only in the quenched and tempered condition.

5.5.4 Forgings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Tables 5.5.1 to 5.5.3.

5.5.5 The results of all tensile tests are to comply with the requirements of Table 5.5.1, 5.5.2 or 5.5.3, appropriate to the specified minimum tensile strength. Unless otherwise agreed, the specified minimum tensile strength is to be not less than 800 N/mm^2 (800–950 N/mm^2 acceptance range) for induction hardened or nitrided gear forgings.

Table 5.5.2 Mechanical properties for acceptance purposes: alloy steel gear wheel and rim forgings – Normalised and tempered

Tensile strength N/mm^2	Yield stress N/mm^2 minimum	Elongation on $5{,}65\sqrt{S_o}$ % minimum		Hardness Brinell
		Rims	Wheels	
600–750	330	18	16	175–215
650–800	355	17	15	190–235
700–850	380	16	14	205–245
750–900	405	15	13	215–260
800–950	430	14	12	235–275
850–1000	455	13	11	245–290

Intermediate values may be obtained by interpolation.

Table 5.5.3 Mechanical properties for acceptance purposes: alloy steel gear forgings – Quenched and tempered

Tensile strength N/mm^2 (*see* Notes 1 and 2)	Yield stress N/mm^2 minimum (*see* Note 2)	Elongation on $5{,}65\sqrt{S_o}$ % minimum			Hardness Brinell
		A	B	C	
600–750	420	18	16	14	175–215
650–800	450	17	15	13	190–235
700–850	480	16	14	12	205–245
750–900	530	15	13	11	215–260
800–950	590	14	12	10	235–275
850–1000	640	13	11	9	245–290
900–1050	690	13	11	9	260–310
950–1100	750	12	10	8	275–330
1000–1150	810	12	10	8	290–340
1050–1200	870	11	9	7	310–365

Column A is applicable to tests from gear rims and to longitudinal tests from pinions.
Column B is applicable to tests from gear wheels and to tangential tests from pinions.
Column C is applicable to tests from pinion sleeves.

Intermediate values may be obtained by interpolation.

NOTES
1. For gear wheel and rim forgings the specified minimum tensile strength is not to exceed 850 N/mm^2.
2. For carburised gear forgings the requirements for minimum yield stress and maximum tensile strength are not applicable.

5.5.6 Where more than one tensile test is taken from a forging, the variation in tensile strength is not to exceed the following:

Specified minimum tensile strength N/mm^2	Difference in tensile strength N/mm^2
<600	70
≥600 <900	100
≥900	120

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5.5.7 Hardness tests are to be carried out on all forgings after completion of heat treatment and prior to machining the gear teeth. The hardness is to be determined at four positions equally spaced around the circumference of the surface where teeth will subsequently be cut. Where the finished diameter of the toothed portion exceeds 2500 mm, the number of test positions is to be increased to eight. Where the width of a gear wheel rim forging exceeds 1250 mm, the hardness is to be determined at eight positions at each end of the forging.

5.5.8 For small gear forgings which are batch tested, at least one hardness test is to be carried out on each forging.

5.5.9 The results of all hardness tests are to comply with the appropriate requirements of Tables 5.5.1 to 5.5.3. The difference between the highest and lowest values on any one forging is not to exceed the following:

Specified minimum tensile strength (N/mm^2)	Difference in hardness (Brinell number)
<600	25
≥600 <900	35
≥900	42

5.5.10 On nitrided or induction hardened components, hardness tests are also to be made on the teeth when surface hardening and grinding have been completed. The results are to comply with the approved specification.

5.6 Mechanical tests for carburised forgings

5.6.1 Sufficient test material is to be provided for preliminary tests at the forge and for final tests after completion of carburising. For this purpose, duplicate sets of test material are to be taken from positions as detailed in 5.5.1, except that, irrespective of the dimensions or mass of the forging, tests are required from one position only, and in the case of forgings with integral journals are to be cut in a longitudinal direction. The test material which is to be used for measurements of case depth, hardness, grain size and residual austenite as well as mechanical properties is to be machined to a coupon of diameter of $\frac{D}{4}$ or 30 mm, whichever is less, where D is the finished diameter of the toothed portion.

5.6.2 For small forgings, where a system of batch testing is adopted, the test material may be prepared from surplus steel from the same cast provided that the forging reduction approximates to that of the actual gear forgings. The test samples are to be correctly identified and heat treated with the forgings they represent.

5.6.3 For preliminary tests at the forge, one set of test material is to be given a blank carburising and heat treatment cycle simulating that which will be subsequently applied to the forgings.

5.6.4 For final acceptance tests, the second set of test material is to be blank carburised and heat treated together with the forgings which it represents.

5.6.5 At the discretion of the forgemaster or gear manufacturer, test samples of larger cross-section than in 5.6.1 may be either carburised or blank carburised, but these are to be machined to the required diameter prior to the final quenching and stress relieving heat treatment.

5.6.6 At least one tensile specimen is to be prepared from each sample of test material.

5.6.7 Unless otherwise agreed, the specified minimum tensile strength is to be not less than 750 N/mm^2, and the results of all tensile tests are to comply with the requirements given in Table 5.5.3.

5.6.8 Where it is proposed to adopt alternatives to the requirements of 5.6.1 to 5.6.7, full details are to be submitted to the Surveyor for consideration.

5.7 Non-destructive examination

5.7.1 Magnetic particle or liquid penetrant testing is to be carried out on the teeth of all surface hardened forgings. This examination may also be requested on the finished machined teeth of through hardened gear forgings.

5.7.2 The manufacturer is to carry out an ultrasonic examination of all forgings where the finished diameter of the surfaces, where teeth will be cut, is in excess of 200 mm, and is to provide the Surveyor with a signed statement that such inspection has not revealed any significant internal defects.

5.7.3 On gear forgings where the teeth have been surface hardened, additional test pieces may be required to be processed with the forgings and subsequently sectioned to determine the depth of the hardened zone. These tests are to be carried out at the discretion of the Surveyor, and for induction or carburised gearing the depth of the hardened zone is to be in accordance with the approved specification. For nitrided gearing, the full depth of the hardened zone, (i.e., depth to core hardness), is to be not less than 0,5 mm and the hardness at a depth of 0,25 mm is to be not less than 500 HV.

■ *Section 6* Forgings for turbines

6.1 Scope

6.1.1 Provision is made in this Section for ferritic steel forgings for turbine rotors, discs and spindles, turbine-driven generator rotors and compressor rotors.

6.1.2 Plans for rotor forgings are to state whether the rotor is intended for propulsion or auxiliary machinery and the shaft power of auxiliary turbines. In the case of a rotor which is to be tested for thermal stability, the maximum operating temperature and the proposed test temperature are also to be stated.

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6.1.3 Specifications of alloy steel forgings giving the proposed chemical composition, heat treatment and mechanical properties are to be submitted for approval with the plans of the components.

6.1.4 Where it is proposed to use rotors of welded construction, the compositions of the steels for the forgings are to be submitted for special consideration, together with details of the proposed welding procedure. Welding procedure tests may be required.

6.2 Manufacture

6.2.1 Forgings are to be manufactured in accordance with the requirements of Section 1, except that for rotors the forging reduction is to be not less than 2,5 to 1. Where an upsetting operation is included in the manufacturing procedure, the above requirement applies to the cross-sectional area of the upset bloom and not to that of the ingot.

6.3 Chemical composition

6.3.1 The chemical composition of ladle samples is to comply with 3.2.1 for carbon and carbon-manganese steels and 1.4.3 for alloy steels.

6.4 Heat treatment

6.4.1 Forgings are to be supplied in the heat treated condition, and the thermal treatment at all stages is to be such as to avoid the formation of hair-line cracks. At a suitable stage of manufacture, the forgings are to be reheated above the upper critical point to refine the grain, cooled in an approved manner and then tempered to produce the desired mechanical properties.

6.4.2 Where forgings receive their main heat treatment before machining, they are to be stress relieved after rough machining. Forgings which are heat treated in the rough machined condition need not be stress relieved provided that they have been slowly cooled from the tempering temperature.

6.4.3 The tempering and stress relieving temperatures are to be not less than 550°C for carbon and carbon-manganese steels, and not less than 600°C for alloy steels. The holding times and subsequent cooling rates are to be such that the forging in its final condition is free from harmful residual stresses.

6.4.4 Details of the proposed heat treatment for rotors of welded construction are to be submitted for approval.

6.5 Mechanical tests

6.5.1 At least one tensile test specimen, cut in a longitudinal direction, is to be taken from each rotor forging. For forgings exceeding both 3 tonnes in mass and 2000 mm in length, tests are to be taken from each end.

6.5.2 For rotor forgings of all main propulsion machinery and of auxiliary turbines exceeding 1100 kW, tangential and, where the dimensions permit, radial tensile tests are to be taken from the end of the body corresponding to the top end of the ingot, *see* Fig. 5.6.1.

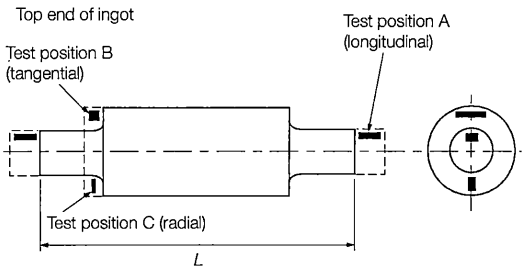

Fig. 5.6.1 Test positions for turbine rotor forgings

6.5.3 For each turbine disc, at least one tensile test specimen is to be cut in a tangential direction from material at the hub, *see* Fig. 5.6.2.

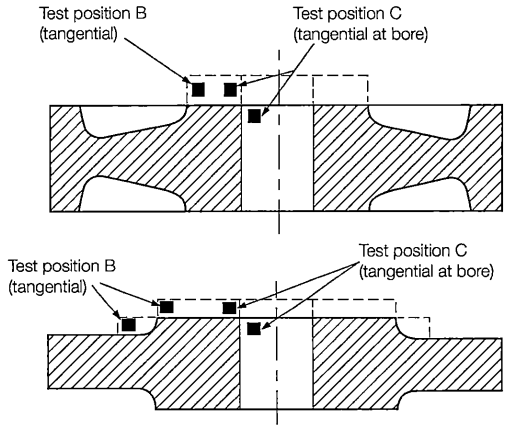

Fig. 5.6.2 Test positions for turbine disc forgings

6.5.4 For the tests required by 6.5.1 to 6.5.3, sufficient test material is to be left on each forging and is not to be removed until all heat treatment, including stress relieving, has been completed. In this connection, a thermal stability test does not form part of the heat treatment of a turbine forging. Any excess test material is not to be completely severed from a forging until all the mechanical tests have been completed with satisfactory results.

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6.5.5 Tables 5.6.1 and 5.6.2 give the minimum requirements for yield stress, elongation and reduction of area corresponding to different strength levels, but it is not intended that these should necessarily be regarded as specific grades. The strength levels have been given in multiples of 40 N/mm^2, or 50 N/mm^2 for alloy steels, to facilitate interpolation for intermediate values of specified minimum tensile strength.

Table 5.6.1 Mechanical properties for acceptance purposes: carbon-manganese steel forgings for turbines – Normalised and tempered

Tensile strength N/mm^2	Yield stress N/mm^2 minimum	Elongation $5{,}65\sqrt{S_o}$ % minimum			Reduction of area % minimum		
		A	B	C	A	B	C
400–520	200	26	22	18	50	40	35
440–560	220	24	21	17	50	40	35
480–600	240	22	19	15	45	35	30
520–640	260	21	18	14	45	35	30
560–680	280	20	17	13	40	30	25
600–720	300	18	15	12	40	30	25

NOTES
Columns A are applicable to longitudinal tests from rotor and spindle forgings.
Columns B are applicable to tangential tests from rotor forgings.
Columns C are applicable to radial tests from rotor forgings.
Intermediate values may be obtained by interpolation.

6.5.6 Forgings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Table 5.6.1 or Table 5.6.2.

6.5.7 The results of all tensile tests are to comply with the requirements of Table 5.6.1 or Table 5.6.2 appropriate to the specified minimum tensile strength. For monobloc rotor forgings, the specified minimum tensile strength is not to exceed 800 N/mm^2.

6.6 Non-destructive examination

6.6.1 The end faces of the body of rotor forgings and the end faces of the boss and the bore surface of each turbine disc are to be machined to a fine smooth finish for visual and magnetic particle examination.

6.6.2 The manufacturer is to carry out an ultrasonic examination of each forging and is to provide the Surveyor with a signed statement that such inspection has not revealed any significant internal defects.

6.6.3 Rotor forgings for propulsion machinery and for auxiliary turbines exceeding 1100 kW are to be hollow bored for internal examination. The surface of the bore is to have a fine smooth finish and is to be examined by means of an optical instrument of suitable magnification. Where the bore size permits, magnetic particle examination is also to be carried out. These examinations are to be confirmed by the Surveyor. Alternatively, an approved method of ultrasonic examination may be accepted instead of hollow boring. Details of the proposed method of ultrasonic examination are to be submitted for special consideration.

Table 5.6.2 Mechanical properties for acceptance purposes: alloy steel forgings for turbines – Quenched and tempered or normalised and tempered

Tensile strength N/mm^2 (*see* Note)	Yield stress N/mm^2 minimum Normalised and tempered	Yield stress N/mm^2 minimum Quenched and tempered	Elongation on $5{,}65\sqrt{S_o}$ % minimum			Reduction of area %minimum		
			A	B	C	A	B	C
500 – 650	275	–	22	20	18	50	40	35
550 – 700	300	–	20	18	16	50	40	35
600 – 750	330	410	18	16	14	50	40	35
650 – 800	355	450	17	15	13	50	40	35
700 – 850	385	490	16	14	12	45	35	30
750 – 900	–	530	15	13	11	45	35	30
800 – 950	–	590	14	12	10	45	35	30
850 – 1000	–	640	13	11	9	40	30	25
900 – 1050	–	690	13	11	9	40	30	25
950 – 1100	–	750	12	10	8	40	30	25
1000 – 1150	–	810	12	10	8	40	30	25

NOTES
Columns A are applicable to longitudinal tests from rotor and spindle forgings.
Columns B are applicable to tangential tests from rotor and spindle forgings, and to tangential tests from discs – test position B in Fig. 5.6.2.
Columns C are applicable to radial test from rotor forgings and to tangential tests from discs – test position C in Fig. 5.6.2.
Intermediate values may be obtained by interpolation.

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6.7 Thermal stability tests

6.7.1 Thermal stability tests after heat treatment and rough machining of the turbine rotors, referred to in the relevant Rules dealing with design and construction, are to be undertaken in properly constructed furnaces, using accurate and reliable measuring equipment. Each test is to be carried out in accordance with the following recommended procedure:

(a) Five bands are to be machined concentric with the axis of rotation. Two of these are to be reference bands and are to be positioned at or near the locations of the bearings. The remaining three bands are to be test bands located one as near as possible to the mid-length, and the other two near each end of the body. Where the length of a rotor is such that five bands cannot be provided, alternative proposals are to be submitted to the Surveyor for his approval.

(b) Four positions, 90° apart, are to be stamped A, B, C and D on the coupling end of the rotor.

(c) The whole of the body, and as much of the shaft at either end as will include the positions of the glands, is to be enclosed in the furnace. In the case of a rotor having an overhung astern wheel, the astern wheel is also to be enclosed in the furnace during the first test.

(d) The rotor is to be rotated at a uniform and very low speed.

(e) The deflections at all bands are to be recorded at the A, B, C and D positions. Initial cold readings are to be taken prior to heating.

(f) The rotor is to be heated uniformly and slowly. Temperatures are to be recorded continuously at the surface of the rotor and, if practicable, in the bore at the mid-length of the body. In no circumstances is the surface temperature to exceed the temperature at which the rotor was tempered. During heating, the rate of rise of temperature is to be such as to avoid excessive temperature gradients in the rotor.

(g) The maximum or holding temperature is to be not less than 28°C above the maximum operating temperature of the rotor. For the purposes of the test, the holding period is to start when the rotor has attained a uniform and specified temperature. The rotor is to be held under the specified temperature conditions until not less than three consecutive hourly readings of deflections show the radial eccentricity to be constant within 0,006 mm on all test bands.

(h) The turbine rotor is to be rotated during cooling until the temperature is not more than 100°C. The rate of cooling is to be such as to avoid excessive temperature gradients in the rotor.

(j) Final cold readings are to be taken.

6.7.2 The movements of the axis of the rotor in relation to the reference bands are to be determined from polar plots of the deflection readings. The radial movement of the shaft axis, as determined by the difference between the final hot and the final cold movements, is not to exceed 0,025 mm on any one band. As verification that test equipment and conditions are satisfactory, it is required that similar determinations of differences between initial cold and final cold movements do not exceed 0,025 mm on any one band.

6.7.3 If the results of the test on a rotor fail to meet either or both of the requirements in 6.7.2, the test may be repeated if requested by the maker and agreed by the Surveyor. In the case of a rotor failing to meet the requirements of a thermal stability test, the rotor is deemed unacceptable. Proposals for the rectification of thermal instability of a rough machined rotor are to be submitted for special consideration.

■ *Section 7*
Forgings for boilers, pressure vessels and piping systems

7.1 Scope

7.1.1 Provision is made in this Section for carbon-manganese and low alloy steel forgings intended for use in the construction of boilers, pressure vessels and piping systems where the design temperature is not lower than 0°C.

7.1.2 In addition to specifying mechanical properties at ambient temperature for the purposes of acceptance testing, these requirements give details of appropriate mechanical properties at elevated temperatures to be used for design purposes.

7.1.3 Forgings used in the construction of equipment for the containment of liquefied gases are to comply with the requirements of Section 8, except for those used in piping systems, where the design temperature is not lower than 0°C. Forgings for other pressure vessels and piping systems, where the use of steels with guaranteed impact properties at low temperatures is required, are also to comply with Section 8.

7.2 Chemical composition

7.2.1 The chemical composition of ladle samples is to comply with the appropriate requirements of Table 5.7.1.

7.3 Heat treatment

7.3.1 Carbon-manganese steel forgings are to be normalised, normalised and tempered or quenched and tempered.

7.3.2 Alloy steel forgings are to be normalised and tempered or quenched and tempered.

7.3.3 No forging is to be fully heat treated more than twice.

7.4 Mechanical tests

7.4.1 Except as provided in 7.4.2 and 7.4.4, at least one tensile test is to be taken from each forging and, where the dimensions and shape allow, the test specimen is to be cut in the longitudinal direction.

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Table 5.7.1 Chemical composition

Type of steel	Tensile strength N/mm²	Chemical composition of ladle samples %							
		C max.	Si	Mn	P max.	S max.	Al	Residual elements	
Carbon-manganese	410–530	0,20	0,10–0,40	0,50–1,20	0,030	0,025	(*See* Notes 1 and 3)	Ni 0,40 max. Cr 0,25 max. Mo 0,10 max. Cu 0,30 max. Total 0,80 max.	
	460–580	0,23		0,80–1,40					
	490–610	0,25		0,90–1,70					
								Cr	Mo
Alloy steel 1Cr1/2Mo	440–590	0,18	0,15–0,40	0,40–0,70	0,030	0,025	0,020 max. (*See* Note 2)	0,85–1,15	0,45–0,65
2 1/4 Cr1Mo	490–640	0,15						2,0–2,5	0,90–1,20

NOTES
1. Fine grained steels are to contain:
   aluminium (acid soluble) 0,015% min. or
   aluminium (total) 0,018% min.
2. For alloy steels, aluminium (acid soluble) 0,020% max.
   The determination of the aluminium (total) content is acceptable provided the above value is not exceeded.
3. Niobium may be used as a grain refiner in place of aluminium, in which case the content is to be in the range 0,01% to 0,06%.

7.4.2 On seamless drums and headers which are initially forged with open ends, test material is to be provided at each end of each forging. Where forged with one solid end, test material is to be provided at the open end only. Except where the ends are to be subsequently closed by forging, the test material is not to be removed until heat treatment has been completed. Where the ends are to be closed, rings of test material are to be cut off prior to the closing operation and are to be heat treated with the finished forging. In all cases, the test specimens are to be cut in the circumferential direction.

7.4.3 Unless otherwise agreed, tensile test specimens are to be taken with their axis at approximately 12,5 mm below the surface of the forging.

7.4.4 Small forgings may be batch tested in accordance with 1.6.4 provided that hardness tests are carried out on each forging. In such cases, the mass of each forging is not to exceed 1 tonne and that of the batch is not to exceed 10 tonnes and the hardness values are to accord with Table 5.7.2.

Table 5.7.2 Mechanical properties for acceptance purposes

Type of steel	Diameter or equivalent thickness mm	Yield stress N/mm²	Tensile strength N/mm²	Elongation on $5{,}65\sqrt{S_o}$ % minimum	Hardness Brinell
Carbon-manganese not specifically fine grained	≤100	215	410–530	20	110–155
	>100 ≤500	205			
	≤100	245	460–580	18	130–170
	>100	235			
	≤100	265	490–610	16	140–180
	>100	255			
Carbon-manganese, fine grained	≤100	235	410–530	20	110–155
	>100 ≤250	220			
	≤100	275	460–580	18	130–170
	>100 ≤250	255			
	≤100	305	490–610	16	140–180
	>100 ≤250	280			
Alloy steel 1Cr1/2Mo	–	275	440–590	19	110–160
2 1/4Cr1Mo	–	275	490–640	18	140–185

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7.4.5 If required by the Surveyors or by the Fabricators, test material may be given a simulated stress relieving heat treatment prior to the preparation of the test specimens. This has to be stated on the order, together with agreed details of the simulated heat treatment and the mechanical properties which can be expected.

7.4.6 Except as provided in 7.4.7, the results of all tensile tests are to comply with the requirements given in Table 5.7.2 appropriate to the specified minimum tensile strength.

7.4.7 Where tests are taken at a depth greater than 12,5 mm from the surface or where they are taken in a transverse direction, the mechanical properties which can be expected are to be agreed.

7.4.8 On seamless drums and headers where tests are taken from each end, the variation in tensile strength is not to exceed 70 N/mm^2.

7.4.9 For small batch-tested forgings, the hardness values are to comply with the requirements of Table 5.7.2 appropriate to the specified minimum tensile strength. If forgings of more than one thickness are to be supplied from one cast, then the test is to be made on the thickest forging.

7.5 Non-destructive examination

7.5.1 Non-destructive testing is to be carried out in accordance with the requirements of the approved forging drawing and specification, or as otherwise agreed between the manufacturer, purchaser and Surveyor.

7.6 Pressure tests

7.6.1 Where applicable, pressure tests are to be carried out in accordance with the requirements of the relevant Rules.

7.7 Mechanical properties for design purposes

7.7.1 Nominal values for the minimum lower yield or 0,2 per cent proof stress at temperatures of 50°C and higher are given in Table 5.7.3. These values are intended for design purposes only, and verification is not required except for materials complying with National or proprietary specifications where the elevated temperature properties used for design purposes are higher than those given in Table 5.7.3.

Table 5.7.3 Mechanical properties for design purposes

Type of steel	Diameter or equivalent thickness mm	Tensile strength N/mm^2	Nominal minimum lower yield or 0,2% proof stress N/mm^2											
			Temperature °C											
			50	100	150	200	250	300	350	400	450	500	550	600
Carbon-manganese not specifically fine grained	≤100	410–530	196	192	188	181	168	150	142	138	136	—	–	—
	>100		183	178	175	170	162	150	142	138	136	—	—	—
	≤100	460–580	227	222	218	210	194	176	168	162	158	—	—	—
	>100		212	206	203	197	188	176	168	162	158	—	—	—
	≤100	490–610	245	240	236	227	210	192	183	177	172	—	—	—
	>100		229	222	219	212	203	192	183	177	172	—	—	—
Carbon-manganese fine grained	≤100	410–530	222	215	204	188	171	152	141	134	130	—	—	—
	>100		207	200	190	175	164	152	141	134	130	—	—	—
	≤100	460–580	262	251	236	217	198	177	167	158	153	—	—	—
	>100		244	233	220	202	190	177	167	158	153	—	—	—
	≤100	490–610	286	272	256	234	213	192	182	173	168	—	—	—
	>100		266	253	238	218	205	192	182	173	168	—	—	—
Alloy steel 1Cr1/2Mo	—	410–560	254	241	224	213	197	184	170	162	157	151	146	145
2 1/4 Cr1Mo	—	490–640	268	261	253	245	236	230	224	218	205	189	167	145

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7.7.2 Where verification is required, at least one tensile test at the proposed design or other agreed temperature is to be made on each forging or each batch of forgings. The test specimen is to be taken from material adjacent to that used for tests at ambient temperature, and the test procedure is to be in accordance with the requirements of Chapter 2. The results of all tests are to comply with the requirements of the National or proprietary specification.

7.7.3 Values for the estimated average stress to rupture in 100 000 hours are given in Table 5.7.4 and may be used for design purposes.

Table 5.7.4 Mechanical properties for design purposes: estimated average values for stress to rupture in 100 000 hours (units N/mm²)

Temperature °C	Grades of steel		
	Carbon-manganese	1 Cr 1/2 Mo	2 1/4 Cr 1Mo
380	227	—	—
390	203	—	—
400	179	—	—
410	157	—	—
420	136	—	—
430	117	—	—
440	100	—	—
450	85	290	—
460	73	262	—
470	63	235	210
480	55	208	186
490	—	181	165
500	—	155	145
510	—	129	128
520	—	103	112
530	—	80	98
540	—	62	84
550	—	49	72
560	—	42	61
570	—	36	49
580	—	32	—
590	—	29	—

Section 8
Ferritic steel forgings for low temperature service

8.1 Scope

8.1.1 The requirements for carbon-manganese and nickel steels suitable for low temperature service are detailed in this Section. They are applicable to all forgings used for the construction of cargo tanks, storage tanks and process pressure vessels for liquefied gases and, where the design temperature is less than 0°C, to forgings for the piping systems.

8.1.2 The requirements are also applicable to forgings for other pressure vessels and pressure piping systems where the use of steels with guaranteed impact properties at low temperatures is required.

8.1.3 In all cases, details of the proposed chemical composition, heat treatment and mechanical properties are to be submitted for approval.

8.1.4 In addition to the steels in this Section, the austenitic stainless steels detailed in Section 9 may also be used for low temperature applications.

8.2 Chemical composition

8.2.1 The chemical composition of ladle samples is, in general, to comply with the requirements given in Table 5.8.1.

8.3 Heat treatment

8.3.1 Forgings are to be normalised, normalised and tempered or quenched and tempered in accordance with the approved specification.

8.4 Mechanical tests

8.4.1 At least one tensile and three Charpy V-notch impact test specimens are to be taken from each forging or each batch of forgings. Where the dimensions and shape allow, the test specimens are to be cut in a longitudinal direction.

8.4.2 The impact tests are to be carried out at a temperature appropriate to the type of steel and for the proposed application. Where forgings are intended for ships for liquefied gases, the test temperature is to be in accordance with the requirements given in Table 3.6.3 in Chapter 3.

8.4.3 The results of all tensile tests are to comply with the approved specification.

8.4.4 The average energy values for impact tests are also to comply with the approved specification and generally with the requirements of Ch 3,6. One individual value may be less than the required average value provided that it is not less than 70 per cent of this value. *See* Ch 2,1.4 for re-test procedures.

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Table 5.8.1 Chemical composition of ferritic steel forgings

Grade of steel	C %	Si %	Mn %	Ni %	P %	S %	Residual elements %	Grain refiners % Al	Grain refiners % Other
LT–AH (AH40) LT–DH (DH40) LT–EH (EH40)	0,18 max.	0,50 max.	0,90–1,60	0,40 max.	0,035 max.	0,030 max.	Cu 0,35 max. Cr 0,20 max. Mo 0,08 max. Total 0,60 max.		(*See* Note) Nb 0,02 – 0,05 V 0,03 – 0,10 Ti 0,02 max.
LT–FH (FH40)	0,16 max.			0,80 max.		0,025 max.			
1½Ni	0,18 max.	0,10 – 0,35	0,30–1,50	1,30–1,70	0,025 max.	0,020 max.	Cu 0,35 max. Cr 0,25 max. Mo 0,08 max. Total 0,60 max.	Total 0,020 min. Acid soluble 0,015 min.	
3½Ni	0,15 max.		0,30–0,90	3,20–3,80					
5Ni	0,12 max.			4,70–5,30					
9 Ni	0,10 max.			8,50–10,0					

NOTE
The steel is to contain aluminium, niobium, vanadium or other suitable grain refining elements, either singly or in any combination. When used singly, the steel is to contain the specified minimum content of the grain refining element. When used in combination, the specified minimum content of each element is not applicable.

8.5 Non-destructive examination

8.5.1 Non-destructive testing is to be carried out in accordance with the requirements of the approved forging drawing and specification, or as otherwise agreed between the manufacturer, purchaser and Surveyor.

8.6 Pressure tests

8.6.1 When applicable, pressure tests are to be carried out in accordance with the requirements of the relevant Rules.

■ *Section 9*
Austenitic stainless steel forgings

9.1 General

9.1.1 Forgings in austenitic stainless steels are acceptable for use in the construction of cargo tanks, storage tanks and piping systems for chemicals and liquefied gases. They may also be accepted for elevated temperature service in boilers.

9.1.2 Where it is proposed to use forgings in these types of steels, details of the chemical composition, heat treatment and mechanical properties are to be submitted for approval. These are to comply, in general, with the requirements of Ch 3,7 for austenitic steel plates.

9.1.3 Unless otherwise agreed, impact tests are not required for acceptance purposes. Where they are required, tests are to be made on longitudinal specimens at minus 196°C and the minimum average energy requirement is to be 41J.

9.2 Mechanical properties for design purposes

9.2.1 Where austenitic stainless steel forgings are intended for service at elevated temperatures, the nominal values for the minimum one per cent proof stress at temperatures of 100°C and higher given in Table 5.9.1 may be used for design purposes. Verification of these values is not required except for material complying with a National or proprietary specification in which the elevated temperature properties proposed for design purposes are higher than those given in Table 5.9.1.

9.3 Non-destructive examination

9.3.1 Non-destructive examination is to be carried out in accordance with the requirements of the approved forging drawing and specification or as otherwise agreed between the manufacturer, purchaser and Surveyor.

9.4 Intergranular corrosion tests

9.4.1 Where corrosive conditions are anticipated in service, intergranular corrosion tests are required on forgings in Grades 304, 316 and 317. Such tests may not be required for Grades 304L, 316L, 321 and 347.

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Table 5.9.1 Mechanical properties for design purposes: austenitic stainless steels

Grade	Nominal 1% proof stress (N/mm^2) at a temperature of												
	100°C	150°C	200°C	250°C	300°C	350°C	400°C	450°C	500°C	550°C	600°C	650°C	700°C
304L	168	150	137	128	122	116	110	108	106	102	100	96	93
316L	177	161	149	139	133	127	123	119	115	112	110	107	105
316LN	238	208	192	180	172	166	161	157	152	149	144	142	138
321	192	180	172	164	158	152	148	144	140	138	135	130	124
347	204	192	182	172	166	162	159	157	155	153	151	—	—

9.4.2 When an intergranular corrosion test is specified, it is to be carried out in accordance with the procedure given in Ch 2,8.1.

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Steel Pipes and Tubes

Chapter 6

Section

1 **General requirements**

2 **Seamless pressure pipes**

3 **Welded pressure pipes**

4 **Ferritic steel pressure pipes for low temperature service**

5 **Austenitic stainless steel pressure pipes**

6 **Boiler and superheater tubes**

Section 1
General requirements

1.1 Scope

1.1.1 This Section gives the general requirements for boiler tubes, superheater tubes and pipes intended for use in the construction of boilers, pressure vessels and pressure piping systems.

1.1.2 In addition to specifying mechanical properties for the purpose of acceptance testing, these requirements give details of appropriate mechanical properties at elevated temperatures to be used for design purposes.

1.1.3 Except for pipes for Class III pressure systems (as defined in the relevant Rules), all pipes and tubes are to be manufactured and tested in accordance with the requirements of Chapters 1 and 2, the general requirements of this Section and the appropriate specific requirements given in Sections 2, 3, 4, 5 and 6.

1.1.4 Steels intended for the piping systems for liquefied gases where the design temperature is less than 0°C are to comply with the specific requirements of Section 4 or 5.

1.1.5 As an alternative to 1.1.3 and 1.1.4, pipes or tubes which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Chapter or alternatively are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

1.1.6 At the discretion of the Surveyor, a modified testing procedure may be adopted for small quantities of materials. In such cases, these may be accepted on the manufacturer's declared chemical composition and hardness tests or other evidence of satisfactory properties.

1.1.7 Pipes for Class III pressure systems are to be manufactured and tested in accordance with the requirements of an acceptable National specification. The manufacturer's test certificate will be acceptable and is to be provided for each consignment of material. Forge butt welded pipes are not acceptable for oil fuel systems, heating coils in oil tanks, primary refrigerant systems and other applications where the pressure exceeds 4,0 bar (4,1 kgf/cm^2).

1.2 Manufacture

1.2.1 Pipes for Class I and II pressure systems, boiler and superheater tubes are to be manufactured at works approved by Lloyd's Register (hereinafter referred to as 'LR'). The steel used is to be manufactured and cast in ingot moulds or by an approved continuous casting process as detailed in Ch 3,1.3.

1.2.2 Unless a particular method is requested by the purchaser, pipes and tubes may be manufactured by any of the following methods:

- Hot finished seamless.
- Cold finished seamless.
- Electric resistance or induction welded.
- Cold finished electric resistance or induction welded.
- Electric fusion welded.

1.2.3 Care is to be taken during manufacture that the pipe or tube surfaces coming in contact with any non-ferrous metals or their compounds are not contaminated to such an extent as could prove harmful during subsequent fabrication and operation.

1.3 Quality

1.3.1 All pipes and tubes are to have a workmanlike finish and are to be clean and free from such surface and internal defects as can be established by the specified tests.

1.3.2 All pipes and tubes are to be reasonably straight. The ends are to be cut nominally square with the axis of the pipe or tube, and are to be free from excessive burrs.

1.4 Dimensional tolerances

1.4.1 The tolerances on the wall thickness and diameter of pipes and tubes are to be in accordance with an acceptable National specification.

1.5 Chemical composition

1.5.1 The requirements for the chemical composition of ladle samples and acceptable methods of deoxidation are detailed in subsequent Sections in this Chapter.

1.6 Heat treatment

1.6.1 All pipes and tubes are to be supplied in the condition detailed in the relevant specific requirements.

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1.7 Test material

1.7.1 Pipes and tubes are to be presented for test in batches. The size of a batch and the number of tests to be performed are dependent on the application.

1.7.2 Where heat treatment has been carried out, a batch is to consist of pipes or tubes of the same size, manufactured from the same types of steel and subjected to the same finishing treatment in a continuous furnace, or heat treated in the same furnace charge in a batch type furnace.

1.7.3 Where no heat treatment has been carried out, a batch is to consist of pipes or tubes of the same size manufactured by the same method from material of the same type of steel.

1.7.4 For pipes for Class I pressure systems and boiler and superheater tubes, at least two per cent of the number of lengths in each batch is to be selected at random for the preparation of tests at ambient temperature.

1.7.5 For pipes for Class II pressure systems, each batch is to contain not more than the number of lengths given in Table 6.1.1. Tests are to be carried out on at least one pipe selected at random from each batch or part thereof.

Table 6.1.1 Batch sizes for pipes for Class II pressure systems

Outside diameter mm	Number in batch
≤323,9	200 pipes as made
>323,9	100 pipes as made

1.8 Dimensions of test specimens and test procedures

1.8.1 The procedures for mechanical tests and the dimensions of the test specimens are to be in accordance with Chapter 2.

1.9 Visual and non-destructive testing

1.9.1 All pipes for Class I and II pressure systems, boiler and superheater tubes, are to be presented for visual examination and verification of dimensions. The manufacturer is to provide adequate lighting conditions to enable an internal and external examination of the pipes and tubes to be carried out.

1.9.2 For welded pipes and tubes, the manufacturer is to employ suitable non-destructive methods for the quality control of the welds. It is preferred that this examination is carried out on a continuous basis.

1.10 Hydraulic test

1.10.1 Each pipe and tube is to be subjected to a hydraulic test at the manufacturer's works.

1.10.2 The hydraulic test pressure is to be determined from the following formula, except that the maximum test pressure need not exceed 140 bar (143 kgf/cm^2):

$$P = \frac{20st}{D} \left(P = \frac{200st}{D}\right)$$

where

P = test pressure, in bar (kgf/cm^2)
D = nominal outside diameter, in mm
t = nominal wall thickness, in mm
s = 80 per cent of the specified minimum yield stress, in N/mm^2 (kgf/mm^2), for ferritic steels and 70 per cent of the specified minimum, 1,0 per cent proof stress, in N/mm^2 (kgf/mm^2), for austenitic steels. These relate to the values specified for acceptance testing at ambient temperature.

1.10.3 The test pressure is to be maintained for sufficient time to permit proof and inspection. Unless otherwise agreed, the manufacturer's certificate of satisfactory hydraulic test will be accepted. Where it is proposed to adopt a test pressure other than that determined as in 1.10.2, the proposal will be subject to special consideration.

1.10.4 Subject to special approval, either an ultrasonic or eddy current test can be accepted in lieu of the hydraulic test.

1.11 Rectification of defects

1.11.1 Surface imperfections may be removed by grinding provided that the thickness of the pipe or tube after dressing is not less than the required minimum thickness. The dressed area is to be blended into the contour of the tube.

1.11.2 By agreement with the Surveyor, the repair of minor defects by welding can be accepted, subject to welding procedure tests which demonstrate acceptable properties appropriate for the grade of pipe to be repaired. Weld procedure tests are to be subjected to the same heat treatment as will be applied to the actual pipes after weld repair.

1.11.3 The repaired area is to be tested by magnetic particle examination, or, for austenitic steels, by liquid penetrant examination on completion of welding, heat treatment and surface grinding.

1.12 Identification

1.12.1 Pipes and tubes are to be clearly marked by the manufacturer in accordance with the requirements of Chapter 1. The following details are to be shown on all materials which have been accepted:

(a) LR or Lloyd's Register.
(b) Manufacturer's name or trade mark.
(c) Identification mark for the specification or grade of steel.
(d) Identification number and/or initials which will enable the full history of the item to be traced.
(e) The personal stamp of the Surveyor responsible for the final inspection.

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1.12.2 It is recommended that hard stamping be restricted to the end face, but it may be accepted in other positions in accordance with National Standards and practices.

1.13 Certification of materials

1.13.1 Unless a LR certificate is specified in other parts of the Rules, a manufacturer's certificate validated by LR is to be issued, *see* Ch 1,3.1.

1.13.2 The manufacturer is to provide LR with the following information:

(a) Purchaser's name and order number.
(b) If known, the contract number for which the material is intended.
(c) Address to which material is despatched.
(d) Specification or the grade of material.
(e) Description and dimensions.
(f) Identification number and/or initials.
(g) Cast number and chemical composition of ladle samples.
(h) Mechanical test results, and results of the intercrystalline corrosion tests where applicable.
(j) Condition of supply.

1.13.3 As a minimum, the chemical composition stated on the certificate is to include the content of all the elements detailed in the specific requirements. Where rimming steel is supplied, this is to be stated on the certificate.

1.13.4 When steel is not produced at the pipe or tube mill, a certificate is to be supplied by the steelmaker stating the process of manufacture, the cast number and the ladle analysis.

1.13.5 The steel manufacturer's works is to be approved by LR.

■ *Section 2* Seamless pressure pipes

2.1 Scope

2.1.1 Provision is made in this Section for seamless pressure pipes in carbon, carbon-manganese and low alloy steels.

2.1.2 Where pipes are used for the manufacture of pressure vessel shells and headers, the requirements for forgings in Ch 5,7 are applicable where the wall thickness exceeds 40 mm.

2.2 Manufacture and chemical composition

2.2.1 Pipes are to be manufactured by a seamless process and may be hot or cold finished.

2.2.2 The method of deoxidation and the chemical composition of ladle samples are to comply with the appropriate requirements given in Table 6.2.1.

Table 6.2.1 Chemical composition of seamless pressure pipes

Type of steel	Grade	Method of deoxidation	Chemical composition of ladle samples %																
			C	Si	Mn	S max.	P max.	Residual elements											
Carbon and carbon-manganese	320	Semi-killed or killed	≤0,16	–	0,40–0,70	0,050	0,050	Ni 0,30 max. Cr 0,25 max. Mo 0,10 max. Cu 0,30 max. Total 0,70 max.											
	360		≤0,17	≤0,35	0,40–0,80	0,045	0,045												
	410	Killed	≤0,21	≤0,35	0,40–1,20	0,045	0,045												
	460		≤0,22	≤0,35	0,80–1,40	0,045	0,045												
	490		≤0,23	≤0,35	0,80–1,50	0,045	0,045												
								Ni	Cr	Mo	Cu	Sn	V	Al					
1Cr½Mo	440	Killed	0,10–0,18	0,10–0,35	0,40–0,70	0,040	0,040	0,30 max.	0,70–1,10	0,45 – 0,65	0,25 max.	0,03 max.	–	≤0,020					
2¼Cr1Mo	410 490	Killed	0,08–0,15	0,10–0,50	0,40–0,70	0,040	0,040	0,30 max.	2,0–2,5	0,90–1,20	0,25 max.	0,03 max.	–	≤0,020					
½Cr½Mo¼V	460	Killed	0,10–0,18	0,10–0,35	0,40–0,70	0,040	0,040	0,30	0,30–0,60	0,50–0,70	0,25 max.	0,03 max.	0,22–0,32	≤0,020					

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2.3 Heat treatment

2.3.1 Pipes are to be supplied in the condition given in Table 6.2.3.

2.4 Mechanical tests

2.4.1 All pipes are to be presented in batches as defined in Section 1.

2.4.2 Each pressure pipe selected for test is to be subjected to tensile and flattening or bend tests.

2.4.3 The results of all mechanical tests are to comply with the appropriate requirements given in Table 6.2.2.

2.5 Mechanical properties for design

2.5.1 Values for nominal minimum lower yield or 0,2 per cent proof stress at temperatures of 50°C and higher are given in Table 6.2.4 and are intended for design purposes only. Verification of these values is not required, except for materials complying with National or proprietary specification where the elevated temperature properties used for design are higher than those given in Table 6.2.4.

2.5.2 In such cases, at least one tensile test at the proposed design or other agreed temperature is to be made on each cast. The test specimen is to be taken from material adjacent to that used for tests at ambient temperature and tested in accordance with the procedures given in Chapter 2. If tubes or pipes of more than one thickness are supplied from one cast, the test is to be made on the thickest tube or pipe.

Table 6.2.3 Heat treatment

Type of steel		Condition of supply
Carbon and carbon-manganese		
Hot finished		Hot finished (*see* Note 1) Normalised (*see* Note 2)
Cold finished		Normalised (*see* Note 2)
Alloy steel		
1Cr1/2Mo		Normalised and tempered
2 1/4Cr1Mo	Grade 410	Fully annealed
	Grade 490	Normalised and tempered 650—780°C
	Grade 490	Normalised and tempered 650—750°C
1/2Cr1/2Mo1/4V		Normalised and tempered

NOTES
1. Provided that the finishing temperature is sufficiently high to soften the material.
2. Normalised and tempered at the option of the manufacturer.

2.5.3 As an alternative to 2.5.2, a manufacturer may carry out an agreed comprehensive test program for a stated grade of steel to demonstrate that the specified minimum mechanical properties at elevated temperatures can be consistently obtained. This test program is to be carried out under the supervision of the Surveyors, and the results submitted for assessment and approval. When a manufacturer is approved on this basis, tensile tests at elevated temperatures are not required for acceptance purposes, but at the discretion of the Surveyors occasional check tests of this type may be requested.

2.5.4 Values for the estimated average stress to rupture in 100 000 hours are given in Table 6.2.5 and may be used for design purposes.

Table 6.2.2 Mechanical properties for acceptance purposes: seamless pressure pipes (maximum wall thickness 40 mm), *see* 2.1.2

Type of steel	Grade	Yield stress N/mm^2	Tensile strength N/mm^2	Elongation on $5{,}65\sqrt{S_o}$ % minimum	Flattening test constant *C*	Bend test diameter of former (*t* = thickness)
Carbon and carbon-manganese	320	195	320—440	25	0,10	4*t*
	360	215	360—480	24	0,10	
	410	235	410—530	22	0,08	
	460	265	460—580	21	0,07	
	490	285	490—610	21	0,07	
1Cr1/2Mo	440	275	440—590	22	0,07	4*t*
2 1/4Cr1Mo	410 (*see* Note 1)	135	410—560	20	0,07	4*t*
	490 (*see* Note 2)	275	490—640	16		
1/2Cr1/2Mo1/4V	460	275	460—610	15	0,07	4*t*

NOTES
1. Annealed condition.
2. Normalised and tempered condition.

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Table 6.2.4 Mechanical properties for design purposes: seamless pressure pipes

Type of steel	Grade	Nominal minimum lower yield or 0,2% proof stress N/mm^2											
		Temperature °C											
		50	100	150	200	250	300	350	400	450	500	550	600
Carbon and carbon-manganese	320	172	168	158	147	125	100	91	88	87	—	—	—
	360	192	187	176	165	145	122	111	109	107	—	—	—
	410	217	210	199	188	170	149	137	134	132	—	—	—
	460	241	234	223	212	195	177	162	159	156	—	—	—
	490	256	249	237	226	210	193	177	174	171	—	—	—
1Cr^1/$_2$Mo	440	254	240	230	220	210	183	169	164	161	156	151	—
2^1/$_2$Cr1Mo	410 (*see* Note 1)	121	108	99	92	85	80	76	72	69	66	64	62
	490 (*see* Note 2)	268	261	253	245	236	230	224	218	205	189	167	145
^{1}/$_2$Cr^1/$_2$Mo^1/$_4$V	460	266	259	248	235	218	192	184	177	168	155	148	—

NOTES
1. Annealed condition.
2. Normalised and tempered condition.

Table 6.2.5 Mechanical properties for design purposes: seamless pressure pipes – Estimated values for stress to rupture in 100 000 hours (units N/mm^2)

Temperature °C	Carbon and carbon-manganese		1Cr^1/$_2$Mo	2^1/$_4$Cr1Mo		^{1}/$_2$Cr^1/$_2$Mo^1/$_4$V
	Grade 320 360 410	Grade 460 490	Grade 440	Grade 410 Annealed	Grade 490 Normalised and tempered (*see* Note)	Grade 460
380	171	227	—	—	—	—
390	155	203	—	—	—	—
400	141	179	—	—	—	—
410	127	157	—	—	—	—
420	114	136	—	—	—	—
430	102	117	—	—	—	—
440	90	100	—	—	—	—
450	78	85	—	196	221	—
460	67	73	—	182	204	—
470	57	63	—	168	186	—
480	47	55	210	154	170	218
490	36	47	177	141	153	191
500	—	41	146	127	137	170
510	—	—	121	115	122	150
520	—	—	99	102	107	131
530	—	—	81	90	93	116
540	—	—	67	78	79	100
550	—	—	54	69	69	85
560	—	—	43	59	59	72
570	—	—	35	51	51	59
580	—	—	—	44	44	46

NOTE
When the tempering temperature exceeds 750°C, the values for Grade 410 are to be used.

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■ *Section 3*
Welded pressure pipes

3.1 Scope

3.1.1 Provision is made in this Section for welded pressure pipes in carbon, carbon-manganese and low alloy steels.

3.2 Manufacture and chemical composition

3.2.1 Pipes are to be manufactured by the electric resistance or induction welding process and, if required, may be subsequently hot reduced or cold finished.

3.2.2 Where it is proposed to use other welding processes, details of the welding processes and procedures are to be submitted for review.

3.2.3 In all cases, welding procedure tests are required. Test samples are to be subjected to the same heat treatment as the pipe.

3.2.4 The method of deoxidation and the chemical composition of ladle samples are to comply with the appropriate requirements given in Table 6.3.1.

3.3 Heat treatment

3.3.1 Pipes are to be supplied in the heat treated condition given in Table 6.3.3.

3.4 Mechanical tests

3.4.1 All pipes are to be presented in batches as defined in Section 1.

3.4.2 Each pressure pipe selected for test is to be subjected to tensile and flattening or bend tests.

3.4.3 The results of all mechanical tests are to comply with the appropriate requirements given in Table 6.3.2.

3.5 Mechanical properties for design

3.5.1 The mechanical properties at elevated temperature for carbon and carbon-manganese steels in Grades 320 to 460 and 1Cr½Mo steel can be taken from the appropriate Tables in Section 2.

Table 6.3.1 Chemical composition of welded pressure pipes

Type of steel	Grade	Method of deoxidation	Chemical composition of ladle samples %																
			C	Si	Mn	S max.	P max.	Residual elements											
Carbon and carbon-manganese	320	Any method (see Note)	≤0,16	—	0,30—0,70	0,050	0,050	Ni 0,30 max. Cr 0,25 max. Mo 0,10 max. Cu 0,30 max. Total 0,70 max.											
	360		≤0,17	≤0,35	0,40—1,00	0,045	0,045												
	410	Killed	≤0,21	≤0,35	0,40—1,20	0,045	0,045												
	460		≤0,22	≤0,35	0,80—1,40	0,045	0,045												
1Cr½Mo	440	Killed	0,10—0,18	0,10—0,35	0,40—0,70	0,040	0,040	Ni	0,30 max.	Cr	0,70—1,10	Mo	0,45—0,65	Cu	0,25 max.	Sn	0,03 max.	Al	≤0,020

NOTE
For rimming steels, the carbon content may be increased to 0,19% max.

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Table 6.3.2 Mechanical properties for acceptance purposes: welded pressure pipes

Type of steel	Grade	Yield stress N/mm^2	Tensile strength N/mm^2	Elongation on $5{,}65\sqrt{S_o}$ % minimum	Flattening test constant *C*
Carbon and carbon-manganese	320	195	320 – 440	25	0,10
	360	215	360 – 480	24	0,10
	410	235	410 – 530	22	0,08
	460	265	460 – 580	21	0,07
1Cr^1/$_2$Mo	440	275	440 – 590	22	0,07

Table 6.3.3 Heat treatment: welded pressure pipes

Type of steel	Condition of supply
Carbon and carbon-manganese, *see* Note	Normalised (Normalised and tempered at the option of the manufacturer)
1Cr^1/$_2$Mo	Normalised and tempered
NOTE Subject to special approval, electric resistance welded (ERW) pipes and tubes in grades 320 and 360 may be supplied without heat treatment for the following applications: (a) Class 2 piping systems, except for liquefied gases or other low temperature applications. (b) Class 3 piping systems.	

■ *Section 4*
Ferritic steel pressure pipes for low temperature service

4.1 Scope

4.1.1 Provision is made in this Section for carbon, carbon-manganese and nickel pipes intended for use in the piping arrangements for liquefied gases where the design temperature is less than 0°C. These requirements are also applicable for other types of pressure piping systems where the use of steels with guaranteed impact properties at low temperatures is required.

4.2 Manufacture and chemical composition

4.2.1 Carbon and carbon-manganese steel pipes are to be manufactured by a seamless, electric resistance or induction welding process.

4.2.2 Nickel steel pipes are to be manufactured by a seamless process.

4.2.3 Seamless pipes may be hot finished or cold finished. Welded pipes may be as-welded, hot finished or cold finished. The terms 'hot finished', 'cold finished' and 'as-welded' apply to the condition of the pipes before final heat treatment.

4.2.4 The method of deoxidation and the chemical composition of ladle samples are to comply with the appropriate requirements given in Table 6.4.1.

4.3 Heat treatment

4.3.1 Pipes are to be supplied in the condition given in Table 6.4.3.

4.4 Mechanical tests

4.4.1 All pipes are to be presented for test in batches as defined in Section 1 for Class 1 pressure piping systems, but in addition the material in each batch is to be from the same cast.

4.4.2 At least two per cent of the number of lengths in each batch is to be selected at random for the preparation of tests.

4.4.3 Each pressure pipe selected for test is to be subjected to tensile, flattening or bend test at room temperature and, where the wall thickness is 6 mm or greater, an impact test at the test temperature specified in Table 6.4.2.

4.4.4 The impact tests are to consist of a set of three Charpy V-notch test specimens cut in the longitudinal direction with the notch perpendicular to the original surface of the pipe. The dimensions of the test specimens are to be in accordance with the requirements of Chapter 2.

4.4.5 The results of all tensile, flattening and bend tests are to comply with the appropriate values in Table 6.4.2.

4.4.6 The average value for impact test specimens is to comply with the appropriate requirements of Table 6.4.2. One individual value may be less than the required average value provided that it is not less than 70 per cent of this value. *See* Ch 2,1.4.1 for re-test procedures.

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Table 6.4.1 Chemical composition

Type of steel	Grade	Method of deoxidation	Chemical composition of ladle sample %							
			C max.	Si	Mn	P max.	S max.	Ni	Al_{sol} *see* Note	Residual elements
Carbon	360	Fully killed	0,17	0,10—0,35	0,40—1,00	0,030	0,025	—	0,015 min.	Cr 0,25 Cu 0,30 Mo 0,10 Ni 0,30 Total 0,70
Carbon-manganese	410 and 460		0,20	0,10—0,35	0,60—1,40	0,030	0,025	—	0,015 min.	
3 1/2Ni	440		0,15	0,15—0,35	0,30—0,90	0,025	0,020	3,25—3,75	—	Cr 0,25 Cu 0,30 Mo 0,10
9Ni	690		0,13	0,15—0,30	0,30—0,90	0,025	0,020	8,50—9,50	—	Total 0,60

NOTE
Where a minimum Al_{sol} of 0,015% is specified, the determination of the total aluminium is acceptable provided that the result is not less than 0,020%.

Table 6.4.2 Mechanical properties for acceptance purposes

Type of steel	Grade	Yield stress N/mm^2	Tensile strength N/mm^2	Elongation on $5,65\sqrt{S_o}$ % minimum	Flattening test constant C	Bend test diameter of former (t = thickness)	Charpy V-notch impact tests	
							Test temperature °C	Average energy J minimum
Carbon	360	210	360—480	24	0,10	4t	–40	27
Carbon-manganese	410 460	235 260	410—530 460—580	22 21	0,08 0,07	4t	–50	27
3 1/2Ni	440	245	440—590	16	0,08	4t	–95	34
9Ni	690	510	690—840	15	0,08	4t	–196	41

For standard subsidiary impact test specimens, the minimum energy values are to be as follows:

Required average energy value for standard 10 mm x 10 mm	Subsidiary 10 mm x 7,5 mm	Subsidiary 10 mm x 5 mm
	Average energy	Average energy
27 J	22 J	18 J
34 J	28 J	23 J
41 J	34 J	27 J

Table 6.4.3 Heat treatment

Type of steel	Condition of supply
Carbon and carbon-manganese	Hot finished Normalised Normalised and tempered
3 1/2 Ni	Normalised Normalised and tempered
9Ni	Double normalised and tempered Quenched and tempered

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■ *Section 5* Austenitic stainless steel pressure pipes

5.1 Scope

5.1.1 Provision is made in this Section for austenitic stainless steel pipes suitable for use in the construction of the piping systems for chemicals and for liquefied gases where the design temperature is not less than minus 165°C and for bulk chemical tankers.

5.1.2 Austenitic stainless steels are also suitable for service at elevated temperatures. Where such applications are proposed, details of the chemical composition, heat treatment and mechanical properties are to be submitted for consideration and approval.

5.1.3 Where it is intended to supply seamless pipes in the direct quenched condition, a programme of tests for approval is to be carried out under the supervision of the Surveyors, and the results are to be to the satisfaction of LR, *see* Ch 1,2.2.

5.2 Manufacture and chemical composition

5.2.1 Pipes are to be manufactured by a seamless or a continuous automatic electric fusion welding process.

5.2.2 Welding is to be in a longitudinal direction, with or without the addition of filler metal.

5.2.3 The chemical composition of the ladle samples is to comply with the appropriate requirements of Table 6.5.1.

5.3 Heat treatment

5.3.1 Pipes are generally to be supplied by the manufacturer in the solution treated condition over their full length.

5.3.2 Alternatively, seamless pipes may be direct quenched immediately after hot forming, while the temperature of the pipes is not less than the specified minimum solution treatment temperature.

5.4 Mechanical tests

5.4.1 All pipes are to be presented in batches as defined in Section 1 for Class I and II piping systems.

5.4.2 Each pipe selected for test is to be subjected to tensile and flattening or bend tests.

5.4.3 The results of all mechanical tests are to comply with the appropriate requirements given in Table 6.5.2.

Table 6.5.1 Chemical composition

Type of steel	Grade	Chemical composition of ladle sample %								
		C max.	Si	Mn	P max.	S max.	Cr	Mo	Ni	Others
304L	490	0,03	<1,00	<2,00	0,045	0,030	17,0 – 19,0	—	9,0 – 13,0	—
316L	490	0,03	<1,00	<2,00	0,045	0,030	16,0 – 18,5	2,0–3,0	11,0 – 14,5	—
321	510	0,08	<1,00	<2,00	0,045	0,030	17,0 – 19,0	—	9,0 – 13,0	Ti ≥5 x C ≤0,80
347	510	0,08	<1,00	<2,00	0,045	0,030	17,0 – 19,0	—	9,0 – 13,0	Nb ≥10 x C ≤1,00

Table 6.5.2 Mechanical properties for acceptance purposes

Type of steel	Grade	0,2% proof stress N/mm^2 (*see* Note)	1,0% proof stress N/mm^2	Tensile strength N/mm^2	Elongation on $5{,}65\sqrt{S_o}$ % minimum	Flattening test constant *C*	Bend test diameter of former (*t* = thickness)
304L	490	175	205	490 – 690	30	0,09	3*t*
316L	490	185	215	490 – 690	30	0,09	3*t*
321	510	195	235	510 – 710	30	0,09	3*t*
347	510	205	245	510 – 710	30	0,09	3*t*

NOTE
The 0,2% proof stress values given for information purposes and unless otherwise agreed are not required to be verified by test.

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5.5 Intergranular corrosion tests

5.5.1 For materials used for piping systems for chemicals, intercrystalline corrosion tests are to be carried out on one per cent of the number of pipes in each batch, with a minimum of one pipe.

5.5.2 For pipes with an outside diameter not exceeding 40 mm, the test specimens are to consist of a full cross-section. For larger pipes, the test specimens are to be cut as circumferential strips of full wall thickness and having a width of not less than 12,5 mm. In both cases, the total surface area is to be between 15 and 35 cm^2.

5.5.3 Unless otherwise agreed or required for a particular chemical cargo, the testing procedure is to be in accordance with Ch 2,8.

5.5.4 After immersion, the full cross-section test specimens are to be subjected to a flattening test in accordance with the requirements of Chapter 2. The strip test specimens are to be subjected to a bend test through 90° over a mandrel of diameter equal to twice the thickness of the test specimen.

5.6 Fabricated pipework

5.6.1 Fabricated pipework is to be produced from material manufactured in accordance with 5.2, 5.3, 5.4 and 5.5.

5.6.2 Welding is to be carried out in accordance with an approved and qualified procedure by suitably qualified welders.

5.6.3 Fabricated pipework may be supplied in the as-welded condition without subsequent solution treatment provided that welding procedure tests have demonstrated satisfactory material properties including resistance to intercrystalline corrosion.

5.6.4 In addition, butt welds are to be subjected to 5 per cent radiographic examination for Class I, and 2 per cent for Class II pipes.

5.6.5 Fabricated pipework in the as-welded condition and intended for systems located on deck is to be protected by a suitable corrosion control coating.

5.7 Certification of materials

5.7.1 Each test certificate is to be of the type and give the information detailed in Ch 1,3.1 together with general details of heat treatment and, where applicable, the results obtained from intercrystalline corrosion tests. As a minimum, the chemical composition is to include the content of all the elements detailed in Table 6.5.1.

■ *Section 6* Boiler and superheater tubes

6.1 Scope

6.1.1 Provision is made in this Section for boiler and superheater tubes in carbon, carbon-manganese and low alloy steels.

6.1.2 Austenitic stainless steels may also be used for this type of service. Where such applications are proposed, details of the chemical composition, heat treatment and mechanical properties are to be submitted for consideration and approval.

6.2 Manufacture and chemical composition

6.2.1 Tubes are to be seamless or welded and are to be manufactured in accordance with the requirements of Sections 2 and 3, respectively.

6.2.2 The method of deoxidation and the chemical composition of ladle samples are to comply with the requirements given in Table 6.2.1 or 6.3.1, as appropriate.

6.3 Heat treatment

6.3.1 All tubes are to be supplied in accordance with the requirements given in Table 6.2.3 or 6.3.3 as appropriate, except that 1Cr½Mo steel may be supplied in the normalised only condition when the carbon content does not exceed 0,15 per cent.

6.4 Mechanical tests

6.4.1 Tubes are to be presented for test in batches as defined in Section 1.

6.4.2 Each boiler and superheater tube selected for test is to be subjected to at least the following:
(a) Tensile test.
(b) Flattening or bending test.
(c) Expanding or flanging test.

6.4.3 The results of all mechanical tests are to comply with the appropriate requirements given in Table 6.6.1.

6.5 Mechanical properties for design

6.5.1 The mechanical properties at elevated temperature for carbon and carbon-manganese steels in Grades 320 to 460, 1Cr½Mo and 2¼Cr1Mo steels can be taken from the appropriate Tables in Section 2.

6.5.2 Where rimming steel is used, the design temperature is limited to 400°C.

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Table 6.6.1 Mechanical properties for acceptance purposes: boiler and superheater tubes

Type of steel	Grade	Yield stress N/mm^2	Tensile strength N/mm^2	Elongation on $5{,}65\sqrt{S_o}$ % minimum	Flattening test constant *C*	Bend test diameter of former (*t* = thickness)	Drift expanding and flanging test minimum % increase in outside diameter		
							Ratio $\frac{\text{Inside diameter}}{\text{Outside diameter}}$		
							≤0,6	>0,6 ≤0,8	>0,8
Carbon and carbon-manganese	320	195	320–440	25	0,10	4*t*	12	15	19
	360	215	360–480	24	0,10		12	15	19
	410	235	410–530	22	0,08		10	12	17
	460	265	460–580	21	0,07		8	10	15
1Cr^1/$_2$Mo	440	275	440–590	22	0,07	4*t*	8	10	15
2^1/$_2$Cr1Mo	410 (*see* Note 1)	135	410–560	20	0,07	4*t*	8	10	15
	490 (*see* Note 2)	275	490–640	16					

NOTES
1. Annealed condition.
2. Normalised and tempered condition.

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Iron Castings

Section

1 **General requirements**

2 **Grey iron castings**

3 **Spheroidal or nodular graphite iron castings**

4 **Iron castings for crankshafts**

Section 1
General requirements

1.1 Scope

1.1.1 This Section gives the general requirements for both grey (flake) and spheroidal (nodular) graphite iron castings intended for use in the construction of ships, other marine structures, machinery, boilers, pressure vessels and piping systems.

1.1.2 Where required by the relevant Rules dealing with design and construction, castings are to be manufactured and tested in accordance with Chapters 1 and 2, together with the requirements given in this Section and either Section 2 for grey iron castings or Section 3 for spheroidal graphite iron castings. Castings for crankshafts are additionally to comply with the requirements detailed in Section 4.

1.1.3 As an alternative to 1.1.2, castings which comply with National or proprietary specifications may be accepted, provided that these specifications give reasonable equivalence to the requirements of this Chapter or alternatively are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

1.1.4 Where small castings are produced in large quantities, or where castings of the same type are produced in regular quantities, alternative survey procedures, in accordance with Ch 1,2.2, may be adopted subject to approval by Lloyd's Register (hereinafter referred to as 'LR').

1.2 Manufacture

1.2.1 Castings as designated in 1.1.2 are to be made at foundries approved by LR.

1.2.2 Suitable mechanical methods are to be employed for the removal of surplus material from castings. Thermal cutting processes are not acceptable, except as a preliminary operation to mechanical methods.

1.3 Quality of castings

1.3.1 Castings are to be free from surface or internal defects which would be prejudicial to their proper application in service. The surface finish is to be in accordance with good practice and any specific requirements of the approved plan.

1.4 Chemical composition

1.4.1 The chemical composition of the iron used is left to the discretion of the manufacturer, who is to ensure that it is suitable to obtain the mechanical properties specified for the castings.

1.5 Heat treatment

1.5.1 Except as required by 1.5.2, castings may be supplied in either the as cast or heat treated condition.

1.5.2 For some applications, such as elevated temperature service, or where dimensional stability is important, castings may require to be given a suitable tempering or stress relieving heat treatment. This is to be carried out after any refining heat treatment and before machining.

1.5.3 Where it is proposed to carry out local hardening of the surface of a casting, full details of the proposed procedure are to be submitted for approval.

1.6 Test material

1.6.1 At least one test sample is to be provided for each casting or batch of castings. For large castings, where more than one ladle of metal is used, one test sample is to be provided, from each ladle used.

1.6.2 A batch testing procedure may be adopted for castings with a fettled mass of 1 tonne or less. All castings in a batch are to be of similar type and dimensions, and cast from the same ladle of metal. One test sample is to be provided for each multiple of two tonnes of fettled castings in the batch.

1.6.3 Where separately cast test samples are used, they are to be cast in moulds made from the same type of material as used for the castings and are not to be stripped from the moulds until the temperature is below 500°C.

1.6.4 All test samples are to be suitably marked to identify them with the castings which they represent.

1.6.5 Where castings are supplied in the heat treated condition, the test samples are to be heat treated together with the castings which they represent. For cast-on test samples, the sample is not to be separated from the casting until after heat treatment.

1.7 Mechanical tests

1.7.1 One tensile specimen is to be prepared from each test sample. The dimensions of the test specimens and the testing procedures used are to be in accordance with Chapter 2.

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1.7.2 The results of all tensile tests are to comply with the requirements given in Section 2, 3 or 4, as appropriate.

1.7.3 In the case of castings supplied in the as cast condition which initially do not meet the requirements of 1.7.2, the manufacturer, by agreement with the purchaser, has the right to heat treat the castings, together with the representative test samples, and re-submit them for acceptance.

1.7.4 In the case of a batch of castings supplied in the heat treated condition which initially do not meet the requirements of 1.7.2, the manufacturer has the right to re-heat treat the batch together with the representative test samples, and re-submit the castings for acceptance. The number of reheat treatments and retestings will be restricted to two.

1.8 Visual and non-destructive examination

1.8.1 All castings are to be cleaned and adequately prepared for examination. The surfaces are not to be hammered, peened or treated in any way which may obscure defects.

1.8.2 The accuracy and verification of dimensions are the responsibility of the manufacturer, unless otherwise agreed.

1.8.3 All castings are to be presented to the Surveyor for visual examination and this is to include the examination of internal surfaces where applicable.

1.8.4 The non-destructive examination of castings is not required unless otherwise stated in the approved plan or where there is reason to suspect the soundness of the casting.

1.8.5 In the event of any casting proving defective during subsequent machining or testing it is to be rejected notwithstanding any previous certification.

1.9 Rectification of defective castings

1.9.1 At the discretion of the Surveyor, small surface blemishes may be removed by local grinding.

1.9.2 Subject to the prior approval of the Surveyor, castings containing local porosity may be rectified by vacuum impregnation with a suitable plastic filler, provided that the extent of the porosity is such that it does not adversely affect the strength of the casting.

1.9.3 Repairs by welding are not permitted on grey cast iron parts and generally not permitted for spheroidal or nodular graphite iron castings, but may be considered in special circumstances for spheroidal or nodular graphite iron castings. In such cases, full details of the proposed repair procedure are to be submitted for approval prior to the commencement of the proposed rectification.

1.10 Pressure testing

1.10.1 When required by the relevant Rules, castings are to be pressure tested before final acceptance. These tests are to be carried out in the presence and to the satisfaction of the Surveyor.

1.11 Identification of castings

1.11.1 The manufacturer is to adopt a system of identification which will enable all finished castings to be traced to the original cast, and the Surveyor is to be given full facilities for tracing the castings when required.

1.11.2 Before acceptance, all castings which have been tested and inspected with satisfactory results are to be clearly marked by the manufacturer with the following particulars:

(a) Type and grade of cast iron.
(b) Identification number, cast number or other marking which will enable the full history of the casting to be traced.
(c) Manufacturer's name or trade mark.
(d) LR or Lloyd's Register and the abbreviated name of LR's local office.
(e) Personal stamp of Surveyor responsible for inspection.
(f) Test pressure, where applicable.
(g) Date of final inspection.

1.11.3 Where small castings are manufactured in large numbers, modified arrangements for identification may be specially agreed with the Surveyor.

1.12 Certification of materials

1.12.1 A LR certificate is to be issued, *see* Ch 1,3.1.

1.12.2 The manufacturer is to provide the Surveyor with a written statement giving the following particulars for each casting or batch of castings which has been accepted:

(a) Purchaser's name and order number.
(b) Description of castings and quality of cast iron.
(c) Identification number.
(d) General details of heat treatment, where applicable.
(e) Results of mechanical tests.
(f) Test pressure, where applicable.
(g) When specially required, the chemical analysis of ladle samples.

1.12.3 Where applicable, the manufacturer is to provide a signed statement regarding non-destructive testing as required by 1.8, together with a statement and/or a sketch detailing the extent and position of all weld repairs made to each casting as required by 1.9.

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■ *Section 2* Grey iron castings

2.1 Scope

2.1.1 This Section gives the specific requirements for grey cast iron castings.

2.2 Test material

2.2.1 Separately cast test samples in the form of cylindrical bars, 30 mm diameter and of a suitable length, are to be used unless otherwise agreed by LR. Test samples of other dimensions may be specially required for some components as may cast-on samples. In these circumstances, the tensile strength requirements are to be agreed.

2.2.2 When two or more test samples are cast simultaneously in a single mould, the bars are to be at least 50 mm apart.

2.2.3 Test samples may be cast integrally when a casting is both more than 20 mm thick and its mass exceeds 200 kg, subject to agreement between the manufacturer and the purchaser. The type and location of the samples are to be such as to provide approximately the same cooling conditions as for the casting it represents and are also subject to agreement.

2.2.4 For continuous melting of the same grade of cast iron in large tonnages the mass of a batch may be taken as the output of two hours of pouring.

2.2.5 Where 2.2.4 applies and production is carefully monitored by systematic checking of the melting process by, for example, chill testing, chemical analysis or thermal analysis, test samples may be taken at longer intervals as agreed by the Surveyor.

2.3 Mechanical tests

2.3.1 Only the tensile strength is to be determined, and the results obtained from tests are to comply with the minimum value specified for the castings being supplied. Except for crankshaft castings (*see* Section 4), the specified tensile strength is to be not less than 200 N/mm^2 subject to any additional requirements of the relevant Rules. The fractured surfaces of all tensile test specimens are to be granular and entirely grey in appearance.

■ *Section 3* Spheroidal or nodular graphite iron castings

3.1 Scope

3.1.1 This Section gives the specific requirements for spheroidal or nodular graphite iron castings.

3.1.2 These requirements are generally applicable to castings intended for use at ambient temperatures. Additional requirements will be necessary when the castings are intended for service at either low or elevated temperatures. Impact test requirements are given for low temperature service in 3.4.2.

3.2 Heat treatment

3.2.1 The special qualities with 350 N/mm^2 and 400 N/mm^2 nominal tensile strength and impact test are to undergo a ferritising heat treatment, *see* 3.4.2.

3.3 Test material

3.3.1 The test samples are to be as detailed in Figs. 7.3.1, 7.3.2 or 7.3.3 The dimensions of the test specimens and testing procedures used are to be in accordance with Chapter 2. Test samples of other dimensions may be specially required for some castings and these are to be agreed with the Surveyor.

3.3.2 The test samples may be either gated to the casting or separately cast.

3.3.3 Where separately cast test samples are used, they are to be taken towards the end of pouring of the castings.

3.4 Mechanical tests

3.4.1 The tensile strength and elongation are to be determined and are to comply with the requirements of Table 7.3.1. Minimum values for the 0,2 per cent proof stress are also included in this Table but are to be determined only if included in the specification. Typical ranges of hardness values are also given in Table 7.3.1 and are intended for information purposes.

3.4.2 Impact tests may be required for some applications in which case the selection of the grade is to be confined to those listed in Table 7.3.2. These castings are to be given a ferritising heat treatment. The mechanical test results are to comply with Table 7.3.2.

3.4.3 Castings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Tables 7.3.1 and 7.3.2 but subject to any additional requirements of the relevant Rules.

3.5 Metallographic examination

3.5.1 Samples for metallographic examination are to be prepared for spheroidal or nodular graphite iron castings. These samples are to be representative of each ladle used and may conveniently be taken from the tensile test specimens. Alternative arrangements for the provision of these samples may, however, be adopted subject to the concurrence of the Surveyor. They are, however, to be taken towards the end of the pour.

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Dimension	Standard sample, mm	Alternative samples when specially required, mm		
u	25	12	50	75
v	55	40	90	125
x	40	30	60	65
y	100	80	150	165
Z	To suit testing machine			
Rs	Approximately 5			

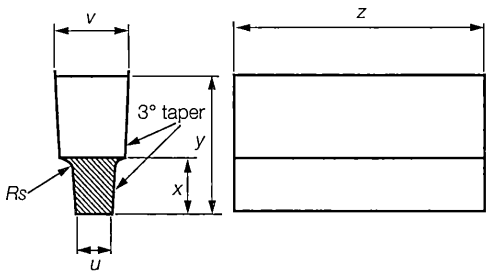

Fig. 7.3.1 Type A (U-type) test samples

Dimension	Standard sample, mm
u	25
v	90
x	40
y	100
Z	To suit testing machine
Rs	Approximately 5

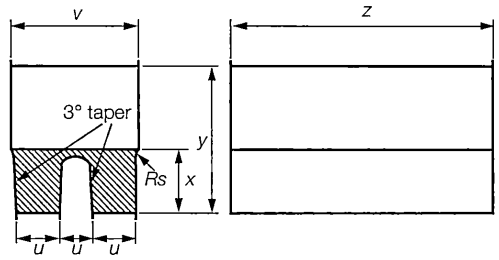

Fig. 7.3.2 Type B (Double U-type) test samples

3.5.2 Examination of the samples is to show that at least 90 per cent of the graphite is in a dispersed spheroidal or nodular form. Details of typical matrix structures are given in Table 7.3.1 and are intended for information purposes.

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Dimension	Standard sample, mm	Alternative samples when specially required, mm		
u	25	12	50	75
v	55	40	100	125
x	40	25	50	65
y	140	135	150	175
Z	To suit testing machine			
Minimum thickness of mould surrounding test sample	40	40	80	80

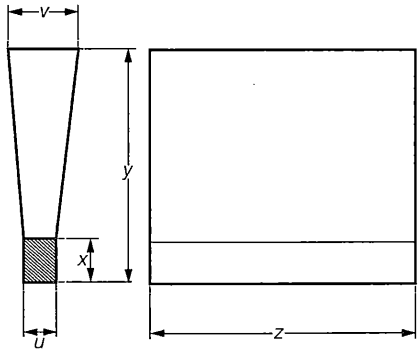

Fig. 7.3.3 Type C (Y-type) test samples

Table 7.3.1 Mechanical properties for acceptance purposes: spheroidal or nodular graphite iron castings

Specified minimum tensile strength N/mm^2	0,2% proof stress (*see* Note) N/mm^2 minimum	Elongation on $5,65\sqrt{S_o}$ % minimum	Typical hardness value HB (*see* 3.4.1)	Typical structure of matrix (*see* 3.5.1)
370	230	17	120 – 180	Ferrite
400	250	12	140 – 200	Ferrite
500	320	7	170 – 240	Ferrite/pearlite
600	370	3	190 – 270	Pearlite/ferrite
700	420	2	230 – 300	Pearlite
800	480	2	250 – 350	Pearlite or tempered structure

NOTE
Proof stresses need only be determined if specifically requested.

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Table 7.3.2 Mechanical properties: special qualities

Specified minimum tensile strength N/mm^2	0,2% proof stress minimum (*see* Note 1) N/mm^2	Elongation on 5,65 $\sqrt{S_o}$ minimum % (*see* Note 2)	Typical hardness value	Charpy V-notch impact tests	
				Test temperature °C (*see* Note 3)	Average energy J minimum (*see* Note 4)
350	220	22	110 – 170	20 –40	17 (14) 12 (10)
400	250	18	140 – 200	20 –20	14 (11) 12 (10)

NOTES
1. Proof stresses need only be determined if specifically requested.
2. In the case of integrally cast samples, the acceptable elongation may be taken as 2 percentage points less.
3. Tests need only be made at either of the temperatures listed, as appropriate.
4. The average value measured on three Charpy V-notch specimens. One of the three values may be below the specified minimum average value, but not less than the value shown in brackets.
5. Typical structure of the matrix is ferrite.

Section 4
Iron castings for crankshafts

4.1 Scope

4.1.1 This Section gives additional requirements for cast iron crankshafts intended for diesel engines and compressors. For both of these applications, details of the proposed specification are to be submitted for approval.

4.1.2 Crankshaft castings in grey iron are acceptable only for compressors, and the specified minimum tensile strength is to be not less than 300 N/mm^2.

4.1.3 For crankshaft castings in spheroidal or nodular graphite iron, the specified minimum tensile strength is to be not less than 370 N/mm^2.

4.2 Manufacture

4.2.1 Details of the method of manufacture, including the arrangements proposed for the provision of test material, are to be submitted for approval.

4.2.2 Tests to demonstrate the soundness of prototype castings and the mechanical properties at important locations will be required.

4.3 Heat treatment

4.3.1 In general, crankshaft castings other than those which are fully annealed, normalised or oil quenched and tempered, are to receive a suitable stress relief heat treatment before machining.

4.3.2 Where it is proposed to harden the surfaces of machined pins and/or journals of cast iron crankshafts, details of the process are to be submitted for approval. Before such a process is applied to a crankshaft it is to be demonstrated by procedure tests, and to the satisfaction of the Surveyor, that the process is suitably controlled and does not impair the strength or soundness of the material.

4.4 Test material

4.4.1 Unless otherwise approved, the dimensions of the test samples are to be such as to ensure that they have mechanical properties representative of those of the average section of the crankshaft casting.

4.4.2 For large crankshaft castings, the test samples are to be cast integral with, or gated from, each casting.

4.4.3 The batch testing procedure detailed in 1.6.2 may be adopted only where small and identical crankshaft castings are produced in quantity. Generally, the fettled mass of each casting in a batch is not to exceed 100 kg, and in addition to tensile tests, the hardness of each casting is to be determined. For this purpose, a small flat is to be ground on each crankshaft, and Brinell hardness tests are to be carried out. The results obtained from these tests are to comply with the approved specification.

4.5 Non-destructive examination

4.5.1 Cast crankshafts are to be subjected to a full magnetic particle or dye penetrant examination after final machining and completion of any surface hardening operations.

4.5.2 Particular attention is to be given to the testing of the pins, journals and associated fillet radii.

4.5.3 Cracks and crack-like defects are not acceptable. Fillet radii are to be free from any indications.

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4.6 Rectification of defective castings

4.6.1 Cast iron crankshafts are not to be repaired by welding, and blemishes are not to be plugged with a filler.

4.7 Certification of materials

4.7.1 The chemical composition of ladle samples is to be given in addition to the other particulars detailed in 1.12.2.

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Aluminium Alloys

Chapter 8

Section 1

Section

1 **Plates, bars and sections**

2 **Aluminium alloy rivets**

3 **Aluminium alloy castings**

4 **Aluminium/steel transition joints**

■ *Section 1*
Plates, bars and sections

1.1 Scope

1.1.1 This Section makes provision for aluminium alloy plates, bars and sections intended for use in the construction of ships and other marine structures and for cryogenic applications.

1.1.2 Except as provided in 1.1.4, all items are to be manufactured and tested in accordance with the appropriate requirements of Chapters 1 and 2 and those detailed in this Section.

1.1.3 The thickness of plates, sections and bars described by these requirements will be in the range between 3 and 50 mm. Plates and sections less than 3,0 mm thick may be manufactured and tested in accordance with the requirements of an acceptable national specification.

1.1.4 Plates less than 3,0 mm thick and sections less than 40 mm x 40 mm x 3,0 mm may be manufactured and tested in accordance with the requirements of an acceptable National specification.

1.1.5 Where the section thickness exceeds 50 mm, the requirements will be subject to special consideration.

1.1.6 Materials intended for the construction of cargo tanks or storage for liquefied gases, and for other low temperature applications, are to be manufactured in the 5083 alloy in the annealed condition.

1.1.7 As an alternative to 1.1.2 and 1.1.4, materials which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Section and are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

1.2 Manufacture

1.2.1 Aluminium alloys are to be manufactured at works approved by Lloyd's Register (hereinafter referred to as 'LR').

1.2.2 The alloys may be cast either in ingot moulds or by an approved continuous casting process. Plates are to be formed by rolling and may be hot or cold finished. Bars and sections may be formed by extrusion, rolling or drawing.

1.2.3 All melts are to be suitably degassed prior to casting such that the aim hydrogen content is less than 0,2 ml per 100 g.

1.3 Quality of materials

1.3.1 Materials are to be free from surface or internal defects of such a nature as would be harmful in service.

1.3.2 The manufacturer is to verify the integrity of pressure welds of closed extrusion profiles in accordance with 1.10.

Table 8.1.1 Underthickness tolerances for rolled products for marine construction

Nominal thickness range, mm	Underthickness tolerance for nominal width range, mm		
	≤1500	>1500 ≤2000	>2000 ≤3500
≥3,0 <4,0	0,10	0,15	0,15
≥4,0 <8,0	0,20	0,20	0,25
≥8,0 <12	0,25	0,25	0,25
≥12 <20	0,35	0,40	0,50
≥20 <50	0,45	0,50	0,65

1.4 Dimensional tolerances

1.4.1 Underthickness tolerances for rolled products for marine construction are given in Table 8.1.1.

1.4.2 Underthickness tolerances for extruded products are to comply with an acceptable National or International Standard.

1.4.3 There are to be no underthickness tolerances for materials for application in cryogenic process pressure vessels.

1.4.4 Dimensional tolerances other than permitted underthicknesses are to comply with an acceptable National or International Standard.

1.4.5 Verification of dimensions is the responsibility of the manufacturer. Acceptance by Surveyors of material which is later found to be defective does not absolve the manufacturer from this responsibility.

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Table 8.1.2 Chemical composition, percentage

Element	5083	5383	5059	5086	5754	5456	6005–A (*see* Note 1)	6061 (*see* Note 1)	6082
Copper	0,10 max.	0,20 max.	0,25 max.	0,10 max.	0,10 max.	0,10 max.	0,30 max.	0,15—0,40	0,10 max.
Magnesium	4,0—4,9	4,0—5,2	5,0—6,0	3,5—4,5	2,6—3,6	4,7—5,5	0,40—0,70	0,80—1,20	0,60—1,20
Silicon	0,40 max.	0,25 max.	0,45 max.	0,40 max.	0,40 max.	0,25 max.	0,50—0,90	0,40—0,80	0,70—1,30
Iron	0,40 max.	0,25 max.	0,50 max.	0,50 max.	0,40 max.	0,40 max.	0,35 max.	0,70 max.	0,50 max.
Manganese	0,40—1,00	0,7—1,0	0,6—1,2	0,20—0,70	0,50 max. (*see* Note 2)	0,50—1,00	0,50 max. (*see* Note 3)	0,15 max.	0,40—1,00
Zinc	0,25 max.	0,40 max.	0,40—0,90	0,25 max.	0,20 max.	0,25 max.	0,20 max.	0,25 max.	0,20 max.
Chromium	0,05—0,25	0,25 max	0,25 max.	0,05—0,25	0,30 max. (*see* Note 2)	0,05—0,20	0,30 max. (*see* Note 3)	0,04—0,35	0,25 max.
Titanium	0,15 max.	0,15 max.	0,20 max.	0,15 max.	0,15 max.	0,20 max.	0,10 max.	0,15 max.	0,10 max.
Zirconium		0,20 max.	0,05—0,25						
Other elements:									
each	0,05 max.	0,05 max.	0,05 max.	0,05 max.	0,05 max.	0,05 max.	0,05 max.	0,05 max.	0,05 max.
total	0,15 max.	0,15 max.	0,15 max.	0,15 max.	0,15 max.	0,15 max.	0,15 max.	0,15 max.	0,15 max.

NOTES
1. These alloys are not normally acceptable for application in direct contact with sea-water.
2. Mn + Cr = 0,10 min., 0,60 max.
3. Mn + Cr = 0,12 min., 0,50 max.

1.5 Chemical composition

1.5.1 Samples for chemical analysis are to be taken representative of each cast, or the equivalent where a continuous melting process is involved.

1.5.2 The chemical composition of these samples is to comply with the requirements of Table 8.1.2.

1.6 Heat treatment

1.6.1 The Aluminium 5000 series alloys, capable of being strain hardened, are to be supplied in any of the following temper conditions:

- O annealed
- H111 annealed with slight strain hardening
- H112 strain hardened from working at elevated temperatures
- H116 strain hardened and with specified resistance to exfoliation corrosion for alloys where the magnesium content is 4 per cent or more
- H321 strain hardened and stabilised.

1.6.2 The H116 temper is specially developed for use in a marine environment.

1.6.3 The Aluminium 6000 series alloys, capable of being age hardened, are to be supplied in either of the following temper conditions:

- T5 hot worked and artificially aged
- T6 solution treated and artificially aged.

1.7 Test material

1.7.1 Materials of the same product form, (i.e., plates, sections or bars) and thickness and from a single cast or equivalent, are to be presented for test in batches of not more than 2 tonnes, with the exceptions of those given in 1.7.2, 1.7.3 and 1.7.4.

1.7.2 For single plates or coils weighing more than 2 tonnes, only one tensile specimen per plate or coil is to be taken.

1.7.3 A tensile test specimen is required from each plate to be used in the construction of cargo tanks, secondary barriers and process pressure vessels with design temperatures below –55°C.

1.7.4 Extrusions, bars and sections of less than 1 kg/m in nominal weight are to be tested in batches of 1 tonne. Where the nominal weight is greater than 5 kg/m, one tensile test is to be carried out for every three tonnes produced, or fractions thereof.

1.7.5 If the material is supplied in the heat treated condition, each batch is to be treated in the same furnace charge or subjected to the same finishing treatment when a continuous furnace is used.

1.7.6 For plates over 300 mm in width, tensile test specimens are to be cut with their length transverse to the principal direction of rolling. For narrow plates and for sections and bars, the test specimens are to be cut in the longitudinal direction. Longitudinal tensile test specimens are accepted for the strain hardenable 5000 series alloys.

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Table 8.1.3 Minimum mechanical properties for acceptance purposes of selected rolled aluminium alloy products

Alloy and temper condition	Thickness, t, mm	0,2% proof stress R_p, N/mm^2	Tensile strength R_m N/mm^2	Elongation on $5{,}65\sqrt{S_o}$ $4d$, %	Elongation on $5{,}65\sqrt{S_o}$ $5d$,%
5083-O	$3 \le t \le 50$ (*see* Note 3)	125	275–350	16	14
5083-H111	$3 \le t \le 50$	125	275–350	16	14
5083-H112	$3 \le t \le 50$	125	275	12	10
5083-H116	$3 \le t \le 50$	215	305	10 (*see* Note 1)	10
5083-H321	$3 \le t \le 50$	215–295	305–380	12	10
5086-O	$3 \le t \le 50$	100	240–305	16	14
5086-H111	$3 \le t \le 50$	100	240–305	16	14
5086-H112	$3 \le t \le 12{,}5$ $12{,}5 < t \le 50$	125 105	250 240	8 —	— 9
5086-H116	$3 \le t \le 50$	195	275	10 (*see* Note 2)	9
5059-O	$3 \le t \le 50$	160	330	24	24
5059-H111	$3 \le t \le 50$	160	330	24	24
5059-H116	$3 \le t \le 20$ $20 < t \le 50$	270 260	370 360	10 10	10 10
5059-H321	$3 \le t \le 20$ $20 < t \le 50$	270 260	370 360	10 10	10 10
5383-O	$3 \le t \le 50$	145	290	17	17
5383-H111	$3 \le t \le 50$	145	290	17	17
5383-H116	$3 \le t \le 50$	220	305	10	10
5383-H321	$3 \le t \le 50$	220	305	10	10
5456-O	$3 \le t \le 6{,}3$ $6{,}3 \le t \le 50$	130–205 125–205	290–365 285–360	16 16	— 14
5456-H116	$3 \le t \le 30$ $30 < t \le 40$ $40 < t \le 50$	230 215 200	315 305 285	10 — —	10 10 10
5456-H321	$3 \le t \le 12{,}5$ $12{,}5 \le t \le 40$ $40 \le t \le 50$	230–315 215–305 200–295	315–405 305–385 285–370	12 — —	— 10 10
5754-O	$3 \le t \le 50$	80	190–240	18	17

NOTES
1. 10% for thickness up to and including 12,5 mm.
2. 8% for thickness up to and including 6,3 mm.
3. For application to liquefied natural gas carriers or liquefied natural gas tankers where thicknesses are in excess of 50 mm, the mechanical properties given in this table are, in general, to be complied with.

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Table 8.1.4 Minimum mechanical properties for acceptance purposes of selected extruded aluminium alloy products

Alloy and temper condition	Thickness, t, mm	0,2% proof stress R_p, N/mm^2	Tensile strength R_m N/mm^2	Elongation on $5{,}65\sqrt{S_o}$ $4d$, %	Elongation on $5{,}65\sqrt{S_o}$ $5d$,%
5083-O	$3 \le t \le 50$	110	270–350	14	12
5083-H111	$3 \le t \le 50$	165	275	12	10
5083-H112	$3 \le t \le 50$	110	270	12	10
5086-O	$3 \le t \le 50$	95	240–315	14	12
5086-H111	$3 \le t \le 50$	145	250	12	10
5086-H112	$3 \le t \le 50$	95	240	12	10
5059-H112	$3 \le t \le 50$	200	330	10	10
5383-O	$3 \le t \le 50$	145	290	17	17
5383-H111	$3 \le t \le 50$	145	290	17	17
5383-H112	$3 \le t \le 50$	190	310	13	13
6005A-T5	$3 \le t \le 50$	215	260	9	8
6005A-T6	$3 \le t \le 10$ $10 < t \le 50$	215 200	260 250	8 8	6 6
6061-T6	$3 \le t \le 50$	240	260	10	8
6082-T5	$3 \le t \le 50$	230	270	8	6
6082-T6	$3 \le t \le 5$ $5 < t \le 50$	250 260	290 310	6 10	– 8

NOTE
The values are applicable for longitudinal and transverse tensile test specimens as well.

1.7.7 Longitudinal tensile test specimens from a plate are to be taken at 1/3 width from the longitudinal edge. Longitudinal tensile test specimens taken from extruded sections should be taken in the range from 1/3 to 1/2 of the distance from the edge to the centre of the thickest region of the section.

1.8 Mechanical tests

1.8.1 At least one tensile test specimen is to be prepared from each batch of material submitted for acceptance.

1.8.2 Tensile test specimens are to be machined to the dimensions given in Fig. 2.2.3 in Chapter 2. Alternatively, machined proportional test specimens of circular cross-section in accordance with Fig. 2.2.2 in Chapter 2 may be used provided that the diameter is not less than 10 mm. Round bars may be tested in full section, or test specimens may be machined in accordance with the dimensions given in Fig. 2.2.2 in Chapter 2.

1.8.3 The results of all tensile tests are to comply with the values given in Tables 8.1.3 and 8.1.4, as applicable.

1.9 Corrosion tests

1.9.1 Rolled 5000 series alloys of type 5083, 5383, 5059, 5456 and 5086 in the H116 and H321 tempers intended for use in marine hull construction or in marine applications with frequent direct contact with seawater are to be corrosion tested with respect to exfoliation and intergranular corrosion resistance.

1.9.2 The manufacturer is to establish the relationship between microstructure and resistance to corrosion when the above alloys are approved. A reference photomicrograph taken at 500x, is to be prepared for each of the alloy-tempers and thickness ranges relevant. The reference photographs are to be taken from samples which have exhibited no evidence of exfoliation corrosion and a pitting rating of PB or better, when subjected to the test described in ASTM G66 (ASSET).The samples are also to have exhibited resistance to intergranular corrosion at a mass loss no greater than 15 mg/cm^2, when subjected to the test described in ASTM G67. Upon satisfactory establishment of the relationship between microstructure and resistance to corrosion, the master photomicrographs and the results of the corrosion tests are to be approved by LR. Production

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practices are not to be changed after approval of the reference micrographs.

1.9.3 For batch acceptance of 5000 series alloys in the H116 and H321 tempers, metallographic examination of one sample selected from mid width at one end of a coil or random sheet or plate is to be carried out. The microstructure of the sample is to be compared to the reference photomicrograph of acceptable material in the presence of the Surveyor. A longitudinal section perpendicular to the rolled surface is to be prepared for metallographic examination. If the microstructure shows evidence of continuous grain boundary network of aluminium-magnesium precipitate in excess of the reference photomicrographs of acceptable material, the batch is either to be rejected or tested for exfoliation corrosion resistance and intergranular corrosion resistance subject to the agreement of the Surveyor. The corrosion tests are to be in accordance with ASTM G66 and G67 or equivalent standards. If the results from testing satisfy the acceptance criteria stated in 1.9.2 the batch is accepted, otherwise it is to be rejected.

1.9.4 As an alternative to metallographic examination, each batch may be tested for exfoliation corrosion resistance and intergranular corrosion resistance, in accordance with ASTM G66 and G67 or equivalent standards.

1.9.5 Tempers that are corrosion tested in accordance with 1.9.3 are to be marked 'M' after the temper condition, e.g., 5083 H321 M.

1.10 Pressure weld tests

1.10.1 The integrity of pressure welds of closed profile extrusions is to be verified by examination of macrosections or drift expansion tests.

1.10.2 Every closed profile extrusion is to be sampled, except where the closed profile extrusions are equal to or shorter than 6,0 m long, in which case a batch is to comprise five profiles. Every sample is to be tested at both ends after final heat treatment.

1.10.3 Where verification is by examination of macrosections, no indication of lack of fusion is permitted.

1.10.4 Where verification of fusion at pressure welds of closed profile extrusions is by drift expansion test, testing is to be generally in accordance with Ch 2,4.3. The minimum included angle of the mandrel is to be 60°, and the minimum specimen length, 50 mm. For acceptance, there is to be no failure by a clean split along the weld line.

1.11 Visual and non-destructive examination

1.11.1 Surface inspection and verification of dimensions are the responsibility of the manufacturer, and acceptance by the Surveyors of material later found to be defective shall not absolve the manufacturer from this responsibility.

1.11.2 In general, the non-destructive examination of materials is not required for acceptance purposes. Manufacturers are expected, however, to employ suitable methods of non-destructive examination for the general maintenance of quality standards.

1.11.3 For applications where the non-destructive examination of materials is considered to be necessary, the extent of this examination, together with appropriate acceptance standards, are to be agreed between the purchaser, manufacturer and Surveyor.

1.12 Rectification of defects

1.12.1 Slight surface imperfections may be removed by mechanical means, provided that the prior agreement of the Surveyor is obtained, that the work is carried out to his satisfaction and that the final dimensions are acceptable. The repair of defects by welding is not allowed.

1.13 Identification

1.13.1 The manufacturer is to adopt a system of identification which will ensure that all finished material in a batch presented for test is of the same nominal chemical composition.

1.13.2 Products are to be clearly marked by the manufacturer in accordance with the requirements of Chapter 1. The following details are to be shown on all materials which have been accepted:

(a) Manufacturer's name or trade mark.
(b) Alloy grade and temper condition.
(c) Identification mark which will enable the full history of the item to be traced.
(d) The stamp of the LR brand, ℛ.

1.14 Certification of materials

1.14.1 A manufacturer's certificate validated by LR is to be issued, *see* Ch 1,3.1.

1.14.2 Each test certificate is to include the following particulars:

(a) Purchaser's name and order number.
(b) Contract number.
(c) Address to which material is to be despatched.
(d) Description and dimensions.
(e) Alloy grade and temper condition.
(f) Identification mark which will enable the full history of the item to be traced.
(g) Chemical composition.
(h) Mechanical test results (not required on shipping statement).
(j) Details of temper condition and heat treatment, where applicable.

1.14.3 Where the alloy is not produced at the works at which it is wrought, a certificate is to be supplied by the manufacturer of the alloy stating the cast number and chemical composition. The works at which the alloy was produced must be approved by LR.

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■ *Section 2* Aluminium alloy rivets

2.1 Scope

2.1.1 Provision is made in this Section for aluminium alloy rivets intended for use in the construction of marine structures.

2.1.2 They are to be manufactured and tested in accordance with the appropriate requirements of Section 1 and those detailed in this Section.

2.2 Chemical composition

2.2.1 The chemical composition of bars used for the manufacture of rivets is to comply with the requirements of Table 8.2.1.

Table 8.2.1 Chemical composition, percentage

Element	5154A	6082
Copper	0,10 max.	0,10 max.
Magnesium	3,1 – 3,9	0,6 – 1,2
Silicon	0,50 max.	0,7 – 1,3
Iron	0,50 max.	0,50 max.
Manganese	0,1 – 0,5	0,4 – 1,0
Zinc	0,20 max.	0,20 max.
Chromium	0,25 max.	0,25 max.
Titanium	0,20 max.	0,10 max.
Other elements: each	0,05 max.	0,05 max.
total	0,15 max.	0,15 max.
Aluminium	Remainder	Remainder

2.3 Heat treatment

2.3.1 Rivets are to be supplied in the following condition:

5154A – annealed
6082 – solution treated.

2.4 Test material

2.4.1 Bars intended for the manufacture of rivets are to be presented for test in batches of not more than 250 kg. The material in each batch is to be the same diameter and nominal chemical composition.

2.4.2 At least one test sample is to be selected from each batch and, prior to testing, is to be heat treated in full cross-section and in a manner simulating the heat treatment applied to the finished rivets.

2.5 Mechanical tests

2.5.1 At least one tensile and one dump test specimen are to be prepared from each test sample.

2.5.2 The tensile test specimen may be either a suitable length of bar tested in full cross-section or a specimen machined to the dimensions given in Fig. 2.2.2 in Chapter 2.

2.5.3 The dump test specimen is to consist of a section cut from the bar with the ends perpendicular to the axis. The length of this section is to be equal to the diameter of the bar.

2.5.4 The results of tensile tests are to comply with the appropriate requirements of Table 8.2.2.

Table 8.2.2 Mechanical properties for acceptance purposes

Mechanical properties	5154A	6082
0,2% proof stress N/mm^2 min.	90	120
Tensile strength N/mm^2 min.	220	190
Elongation on $5{,}65\sqrt{S_0}$ % min.	18	16

2.5.5 The dump test is to be carried out at ambient temperature and is to consist of compressing the specimen until the diameter is increased to 1,6 times the original diameter. After compression, the specimen is to be free from cracks.

2.6 Tests from manufactured rivets

2.6.1 At least three samples are to be selected from each consignment of manufactured rivets. Dump tests as detailed in 2.5 are to be carried out on each sample.

2.7 Identification

2.7.1 Each package of manufactured rivets is to be identified with attached labels giving the following details:

(a) Manufacturer's name or trade mark.
(b) Alloy grade.
(c) Rivet size.

2.8 Certification of materials

2.8.1 A manufacturer's certificate is to be issued (*see* Ch 1,3.1) and for each consignment of manufactured rivets is to include the following particulars:

(a) Purchaser's name and order number.
(b) Description and dimensions.
(c) Specification.

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■ *Section 3* Aluminium alloy castings

3.1 Scope

3.1.1 Provision is made in this Section for aluminium alloy castings intended for use in the construction of ships, ships for liquid chemicals and other marine structures and liquefied gas piping systems where the design temperature is not lower than minus 165°C. These materials should not be used for piping systems outside cargo tanks except for short lengths of pipes attached to the cargo tanks in which case fire-resisting insulation should be provided.

3.1.2 Castings are to be manufactured and tested in accordance with Chapters 1 and 2 and also with the requirements of this Section.

3.1.3 As an alternative to 3.1.2, castings which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Section or are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

3.2 Manufacture

3.2.1 Castings are to be manufactured at foundries approved by LR.

3.3 Quality of castings

3.3.1 All castings are to be free from surface or internal defects which would be prejudicial to their proper application in service.

3.4 Chemical composition

3.4.1 The chemical composition of a sample from each cast is to comply with the requirements given in Table 8.3.1. Suitable grain refining elements may be used at the discretion of the manufacturer. The content of such elements is to be reported in the ladle analysis.

3.4.2 Where it is proposed to use alloys not specified in Table 8.3.1, details of the chemical composition, heat treatment and mechanical properties are to be submitted for approval.

3.4.3 When a cast is wholly prepared from ingots for which an analysis is already available, and provided that no significant alloy additions are made during melting, the ingot maker's certified analysis can be accepted subject to occasional checks as required by the Surveyor.

Table 8.3.1 Chemical composition, percentage

Alloy Element	Al–Mg 3	Al–Si 12	Al–Si 10 Mg	Al–Si 7 High purity
Copper	0,1 max.	0,1 max.	0,1 max.	0,1 max.
Magnesium	2,5—4,5	0,1 max.	0,15—0,4	0,25—0,45
Silicon	0,5 max.	11,0—13,5	9,0—11,0	6,5—7,5
Iron	0,5 max.	0,7 max.	0,6 max.	0,2 max.
Manganese	0,6 max.	0,5 max.	0,6 max.	0,1 max.
Zinc	0,2 max.	0,1 max.	0,1 max.	0,1 max.
Chromium	0,1 max.	—	—	—
Titanium	0,2 max.	0,2 max.	0,2 max.	0,2 max.
Others each	0,05 max.	0,05 max.	0,05 max.	0,05 max.
Total	0,15 max.	0,15 max.	0,15 max.	0,15 max.
Aluminium	Remainder	Remainder	Remainder	Remainder

3.5 Heat treatment

3.5.1 Castings are to be supplied in the following conditions:

Grade Al-Mg 3 – as-manufactured
Grade Al-Si 12 – as-manufactured
Grade Al-Si 10 Mg – as-manufactured or solution heat treated and precipitation hardened
Grade Al-Si 7 Mg (high purity) – solution heat treated and precipitation hardened.

3.6 Mechanical tests

3.6.1 At least one tensile specimen is to be tested from each cast and, where heat treatment is involved, for each heat treatment batch from each cast. Where continuous melting is employed, 500 kg of fettled castings may be regarded as a cast.

3.6.2 The test samples are to be separately cast in moulds made from the same type of material as used for the castings. These moulds should conform to National Standards.

3.6.3 The method and procedures for the identification of the test specimens, and the castings they represent, are to be agreed with the Surveyor. The identification marks are to be maintained during the preparation of test specimens.

3.6.4 Where castings are supplied in the heat treated condition, the test samples are to be heat treated together with the castings which they represent prior to testing.

3.6.5 The results of all tensile tests are to comply with the appropriate requirements given in Table 8.3.2 and/or Table 8.3.3.

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Table 8.3.2 Minimum mechanical properties for acceptance purposes of sand-cast and investment cast reference test pieces

Alloy	Temper (*see* Note)	Tensile strength N/mm^2	Elongation %
Al–Mg 3	M	150	5
Al–Si 12	M	150	3
Al–Si 10 Mg	M	150	2
Al–Si 10 Mg	TF	220	1
Al–Si 7 Mg	TF	230	5

NOTE
M refers to as cast condition.
TF refers to solution heat treated and precipitation hardened condition.

Table 8.3.3 Minimum mechanical properties for acceptance purposes of chill-cast reference test piece

Alloy	Temper (*see* Note)	Tensile strength N/mm^2	Elongation %
Al–Mg 3	M	150	5
Al–Si 12	M	170	3
Al–Si 10 Mg	M	170	3
Al–Si 10 Mg	TF	240	1,5
Al–Si 7 Mg	TF	250	5

NOTE
M refers to as cast condition.
TF refers to solution heat treated and precipitation hardened condition.

3.6.6 Where the results of a test do not comply with the requirements, the re-test procedure detailed in Ch 2,1.4 is to be applied. Where castings are to be used in the heat treated condition, the re-test sample must have been heat treated together with the castings it represents.

3.7 Visual examination

3.7.1 All castings are to be cleaned and adequately prepared for inspection.

3.7.2 The accuracy and verification of dimensions are the responsibility of the manufacturer, unless otherwise agreed.

3.7.3 Before acceptance, all castings are to be presented to the Surveyor for visual examination.

3.8 Rectification of defective castings

3.8.1 At the discretion of the Surveyor, small surface blemishes may be removed by local grinding.

3.8.2 Where appropriate, repair by welding may be accepted at the discretion of the Surveyor. Such repair is to be made in accordance with an approved procedure.

3.9 Pressure testing

3.9.1 Where required by the relevant Rules, castings are to be pressure tested before final acceptance. Unless otherwise agreed, these tests are to be carried out in the presence and to the satisfaction of the Surveyor.

3.10 Identification

3.10.1 The manufacturer is to adopt a system of identification which will enable all finished castings to be traced to the original cast and the Surveyor is to be given full facilities for tracing the casting when required.

3.10.2 All castings which have been tested and inspected with satisfactory results are to be clearly marked with the following details:
(a) Identification number, cast number or other markings which will enable the full history of the casting to be traced.
(b) LR or Lloyd's Register and the abbreviated name of LR's local office.
(c) Personal stamp of the Surveyor responsible for the inspection.
(d) Test pressure where applicable.
(e) Date of final inspection.

3.10.3 Where small castings are manufactured in large numbers, modified arrangements for identification may be specially agreed with the Surveyor.

3.11 Certification of materials

3.11.1 A LR certificate is to be issued (*see* Ch 1,3.1) giving the following particulars for each casting or batch of castings which have been accepted:
(a) Purchaser's name and order number.
(b) Description of castings and alloy type.
(c) Identification number.
(d) Ingot or cast analysis.
(e) General details of heat treatment, where applicable.
(f) Results of mechanical tests.
(g) Test pressure, where applicable.

■ *Section 4* Aluminium/steel transition joints

4.1 Scope

4.1.1 Provision is made in this Section for explosion bonded composite aluminium/steel transition joints used for connecting aluminium structures to steel plating.

4.1.2 Each individual application is to be separately approved as required by the relevant Rules dealing with design and construction.

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4.2 Manufacture

4.2.1 Transition joints are to be manufactured by an approved producer in accordance with an approved specification which is to include the maximum temperature allowable at the interface during welding.

4.2.2 The aluminium material is to comply with the requirements of Section 1 and the steel is to be of an appropriate grade complying with the requirements of Ch 3,2.

4.2.3 Alternative materials which comply with International, National or proprietary specifications may be accepted provided that they give reasonable equivalence to the requirements of 4.2.2 or are approved for a specific application.

4.2.4 Intermediate layers between the aluminium and steel may be used, in which case the material of any such layer is to be specified by the manufacturer and is to be recorded in the approval certificate. Any such intermediate layer is then to be used in all production transition joints.

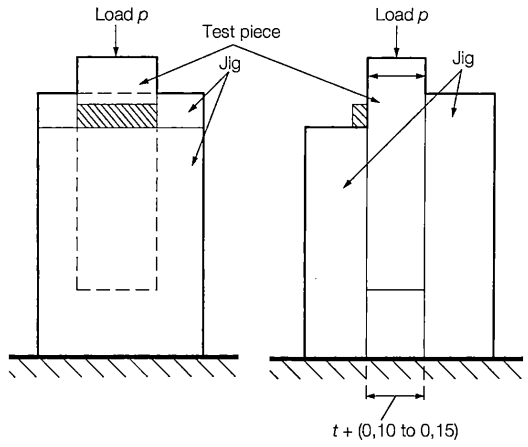

Fig. 8.4.1 Specimen and procedure for shear tests

4.3 Visual and non-destructive examination

4.3.1 Each composite plate is to be subjected to 100 per cent visual and ultrasonic examination in accordance with a relevant National Standard to determine the extent of any unbonded areas. Unbonded areas are unacceptable and any such area plus 25 mm of surrounding sound material is to be discarded.

4.4 Mechanical tests

4.4.1 Two shear test specimens and two tensile test specimens are to be taken from each end of each composite plate for tests to be made on the bond strength. One shear and one tensile test specimen from each end are to be tested at ambient temperature after heating to the maximum allowable interface temperature, *see* 4.2.1; the other two specimens are to be tested without heat treatment.

4.4.2 Shear tests may be made on a specimen as shown in Fig. 8.4.1 or an appropriate equivalent. Tensile tests may be made across the interface by welding extension pieces to each surface or by the ram method shown in Fig. 8.4.2 or by an appropriate alternative method.

4.4.3 The shear and tensile strengths of all the test specimens are to comply with the requirements of the manufacturing specification.

4.4.4 If either the shear or tensile strength of the bond is less than the specified minimum but not less than 70 per cent of the specified minimum, two additional shear and two tensile test specimens from each end of the composite plate are to be tested and, in addition, bend tests as described in 4.4.6 and Table 8.4.1 are to be made.

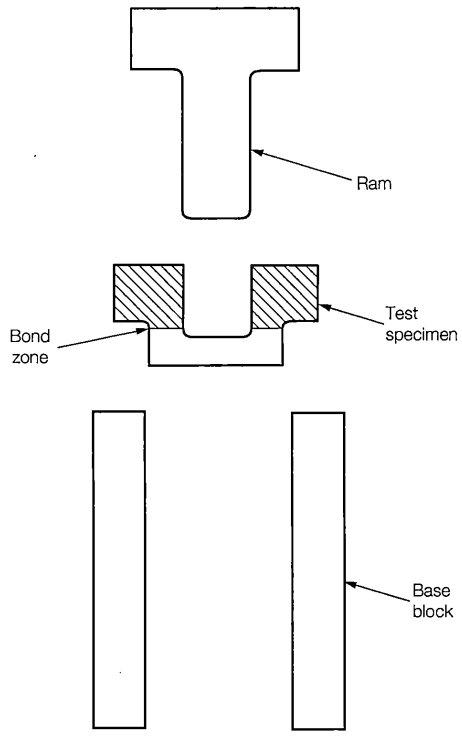

Fig. 8.4.2 Ram tensile test

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Table 8.4.1 Bend tests on explosion bonded aluminium/steel composites

Type of test	Minimum bend, degrees	Diameter of former
Aluminium in tension	90	3*T*
Steel in tension	90	3*T*
Side bend	90	6*T*

NOTE
T is the total thickness of the composite plate.

4.4.5 If either the shear or tensile strength of the bond is less than 70 per cent of the specified minimum the cause is to be investigated. After evaluation of the results of this investigation, LR will consider the extent of composite plate which is to be rejected.

4.4.6 Bend tests, when required, are to be made under the following conditions, as listed in Table 8.4.1:
(a) The aluminium plate is in tension.
(b) The steel plate is in tension.
(c) A side bend is applied.

4.5 Identification

4.5.1 Each acceptable transition strip is to be clearly marked with the following particulars:
(a) LR or Lloyd's Register and the abbreviated name of LR's local office.
(b) Manufacturer's name or trade mark.
(c) Identification mark for the grade of aluminium.
(d) Identification mark for the grade of steel.
The particulars are to be stamped on the aluminium surface at one end of the strip.

4.6 Certification of materials

4.6.1 A manufacturer's certificate validated by LR is to be issued (*see* Ch 1,3.1) and as a minimum is to include the following particulars:
(a) Purchaser's name and order number.
(b) The contract number for which the material is intended, if known.
(c) Address to which the material is dispatched.
(d) Description and dimensions of the material.
(e) Specifications or grades of both the aluminium alloy and the steel and any intermediate layer.
(f) Cast numbers of the steel and aluminium plates.
(g) Identification number of the composite plate.
(h) Mechanical test results (not required on shipping statement).

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Section

1 **Castings for propellers**

2 **Castings for valves, liners and bushes**

3 **Tubes**

■ *Section 1* Castings for propellers

1.1 Scope

1.1.1 This Section gives the requirements for copper alloy castings for one-piece propellers and separately cast blades and bosses for fixed pitch and controllable pitch propellers (CPP). These include contra-rotating propellers and propulsors fitted to podded drives and azimuth units.

1.1.2 These castings are to be manufactured and tested in accordance with the appropriate requirements of Chapters 1 and 2 and the specific requirements of this Section.

1.1.3 As an alternative to 1.1.2, castings which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Section or alternatively are approved for a specific application.

1.1.4 The appropriate requirements of this Section may also be applied to the repair and inspection of propellers which have been damaged during service.

1.1.5 Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

1.2 Manufacture

1.2.1 All castings are to be manufactured at foundries approved by Lloyd's Register (hereinafter referred to as 'LR').

1.2.2 The pouring is to be carried out into dried moulds using degassed liquid metal. The pouring is to avoid turbulent flow. Special devices and/or procedures are to be used to prevent slag flowing into the mould.

1.3 Quality of castings

1.3.1 All castings are to be free from surface or internal defects which would be prejudicial to their proper application in service.

1.3.2 The removal and repair of defects are dealt with in 1.9 and 1.10.

1.4 Chemical composition

1.4.1 The chemical compositions of samples from each melt are to comply with the manufacturing specification approved by LR and also with the overall limits given in Table 9.1.1. In addition to carrying out chemical analysis for the elements given in the Table, it is expected that manufacturers will ensure that any harmful residual elements are within acceptable limits.

1.4.2 The use of alloys whose chemical compositions are different from those detailed in Table 9.1.1 will be given special consideration by LR.

1.4.3 The manufacturer is to maintain records of all chemical analyses, which are to be made available to the Surveyor so that he can satisfy himself that the chemical composition of each casting is within the specified limits.

Table 9.1.1 Chemical composition of propeller and propeller blade castings

Alloy designation	Chemical composition of ladle samples %							
	Cu	Sn	Zn	Pb	Ni	Fe	Al	Mn
Grade Cu 1 Manganese bronze (high tensile brass)	52–62	0,1–1,5	35–40	0,5 max.	1,0 max.	0,5–2,5	0,5–3,0	0,5–4,0
Grade Cu 2 Ni-manganese bronze (high tensile brass)	50–57	0,1–1,5	33–38	0,5 max.	2,5–8,0	0,5–2,5	0,5–2,0	1,0–4,0
Grade Cu 3 Ni-aluminium bronze	77–82	0,1 max.	1,0 max.	0,03 max.	3,0–6,0 (*see* Note)	2,0–6,0 (*see* Note)	7,0–11,0	0,5–4,0
Grade Cu 4 Mn–aluminium bronze	70–80	1,0 max.	6,0 max.	0,05 max.	1,5–3,0	2,0–5,0	6,5–9,0	8,0–20,0

NOTE
For Naval ships, the nickel content is to be higher than the iron content.

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1.4.4 When a melt is wholly prepared from ingots for which an analysis is already available, and provided that no significant alloy additions are made during melting, the ingot maker's certified analysis can be accepted subject to occasional checks as required by the Surveyor. If any foundry returns are added to the melts, the ingot manufacturer's chemical analyses are to be supplemented by frequent checks as required by the Surveyor.

1.4.5 For alloys Grade Cu 1 and Cu 2, the zinc equivalent shall not exceed 45 per cent, and is to be calculated using the following formula:

$$\text{zinc equivalent \%} = 100 - \frac{100 \times \%Cu}{100 + A}$$

where A is the algebraic sum of the following:

1 x % Sn
5 x % Al
–0,5 x % Mn
–0,1 x % Fe
–2,3 x % Ni

1.4.6 Samples for metallographic examination are to be prepared from the ends of test bars cast from every melt of Grade Cu 1 and Cu 2 alloys. The proportion of alpha-phase determined from the average of at least five counts is to be not less than 25 per cent.

1.5 Heat treatment

1.5.1 At the option of the manufacturer, castings may be supplied in the 'as-cast' or heat treated condition. However, if heat treatment is to be applied, full details are to be included in the manufacturing specification.

1.5.2 If any welds are made in the propeller casting, stress relief heat treatment is required in order to minimise the residual stresses. Requirements concerning such heat treatment are given in 1.10.

1.6 Test material

1.6.1 Test samples are to be cast separately from each melt used for the manufacture of propeller or propeller blade castings.

1.6.2 The test samples are to be of the keel block type, generally in accordance with the dimensions given in Fig. 9.1.1 and are to be cast in moulds made from the same type of material as used for the castings.

1.6.3 The method and procedures for the identification of the test specimens, and the castings they represent, are to be agreed with the Surveyor. The identification marks are to be transferred and maintained during the preparation of test specimens.

1.6.4 Where castings are supplied in the heat treated condition, the test samples are to be heat treated together with the castings which they represent.

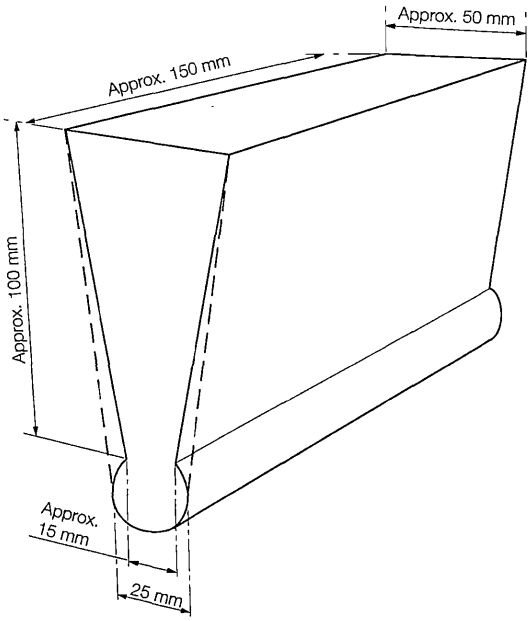

Fig. 9.1.1 Keel block type test sample

1.7 Mechanical tests

1.7.1 At least one tensile test specimen representative of each cast is to be prepared. The dimensions of this test specimen are to be in accordance with Fig. 2.2.1 in Chapter 2.

1.7.2 The results of all tensile tests are to comply with the requirements given in Table 9.1.2.

1.7.3 The mechanical properties of alloys whose chemical compositions do not accord with Table 9.1.1 are to comply with a manufacturing specification approved by LR.

Table 9.1.2 Mechanical properties for acceptance purposes: propeller and propeller blade castings

Alloy designation	0,2% proof stress N/mm^2 minimum	Tensile strength N/mm^2 minimum	Elongation on $5{,}65\sqrt{S_o}$ % minimum
Grade Cu 1 Manganese bronze (high tensile brass)	175	440	20
Grade Cu 2 Ni-manganese bronze (high tensile brass)	175	440	20
Grade Cu 3 Ni-aluminium bronze	245	590	16
Grade Cu 4 Mn-aluminium bronze	275	630	18

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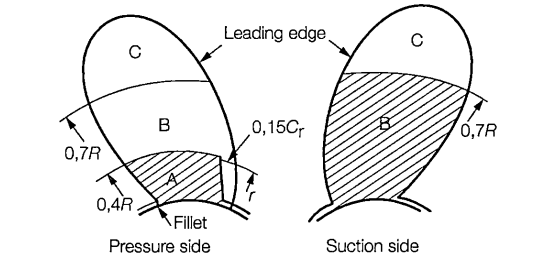
1.8 Inspection and non-destructive examination

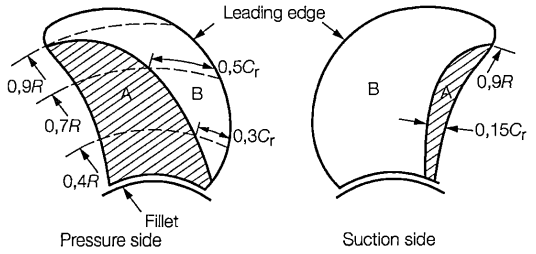
1.8.1 Propeller castings should be visually inspected at all stages of manufacture. The manufacturer is to draw any significant imperfections to the attention of the Surveyor. Such imperfections are to be verified in accordance with 1.9.

1.8.2 All finished castings are to be subjected to a comprehensive visual examination by the Surveyor, including internal surfaces such as the bore and bolt holes.

1.8.3 For the purpose of these requirements, the blades of propellers, including CPP blades, are divided into three severity Zones A, B and C as shown in Fig. 9.1.2 and detailed in 1.8.4 for blades having skew angles of 25° or less and 1.8.5 for blades having skew angles of greater than 25°.



(a) Blades with propeller skew angles of 25° or less



(b) Blades with propeller skew angles of greater than 25°

R = propeller radius
C_r = chord length at radius r

NOTE
For a definition of skew angle, *see* the relevant Rules

Fig. 9.1.2 Severity zones in all propeller blades

1.8.4 **Skew angles of 25° or less:**

- Zone A is the area on the pressure side of the blade from and including the root fillet to 0,4*R* and bounded by the trailing edge and by a line at a distance 0,15 times the chord length from the leading edge.
- Zone B includes the areas inside 0,7*R* on both sides of the blade, excluding Zone A.
- Zone C includes the areas outside 0,7*R* on both sides of the blade.

1.8.5 **Skew angles of greater than 25°:**

- Zone A is the area on the pressure side of the blade bounded by, and including, the root fillet and a line running from the junction of the leading edge with the root fillet to the trailing edge at 0,9*R* and passing through the mid-point of the chord at 0,7*R* and a point situated at 0,3 of the chord length from the leading edge at 0,4*R*.
- Zone A also includes the area along the trailing edge on the suction side of the blade from the root to 0,9*R* and with its inner boundary at 0,15 of the chord length tapering to meet the trailing edge at 0,9*R*.
- Zone B constitutes the whole of the remainder of the blade surfaces.

1.8.6 In propeller blades with continuously loaded tips (CLT), the whole of the tip plate and the adjoining blade to a distance of 100 mm is to be regarded as severity Zone B, *see* Fig. 9.1.3. For propellers with diameters less than 2 m, the width of this zone may be reduced to one tenth of the propeller radius.

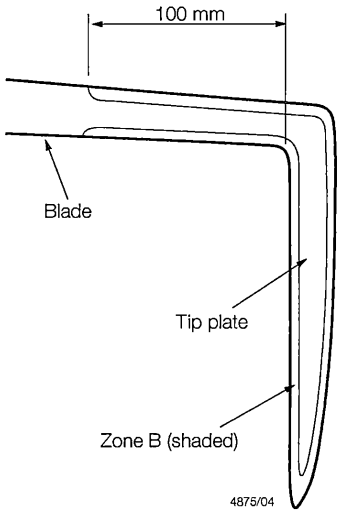


Fig. 9.1.3
Severity Zone B at Continuously loaded blade tip

1.8.7 In addition, the palm of a CPP blade is divided into severity Zones A and B as shown in Fig. 9.1.4.

1.8.8 If a CPP blade has an integrally cast journal, the fillets of the journal and the adjoining material up to a distance of 20 mm from the fillet run-outs are to be regarded as Zone B, as indicated in Fig. 9.1.5. The remainder of the surface of the journal may be regarded as Zone C.

1.8.9 Hubs of controllable pitch propellers are to contain a Zone A region at each blade port as shown in Fig. 9.1.6. The remainder may be regarded as Zone C.

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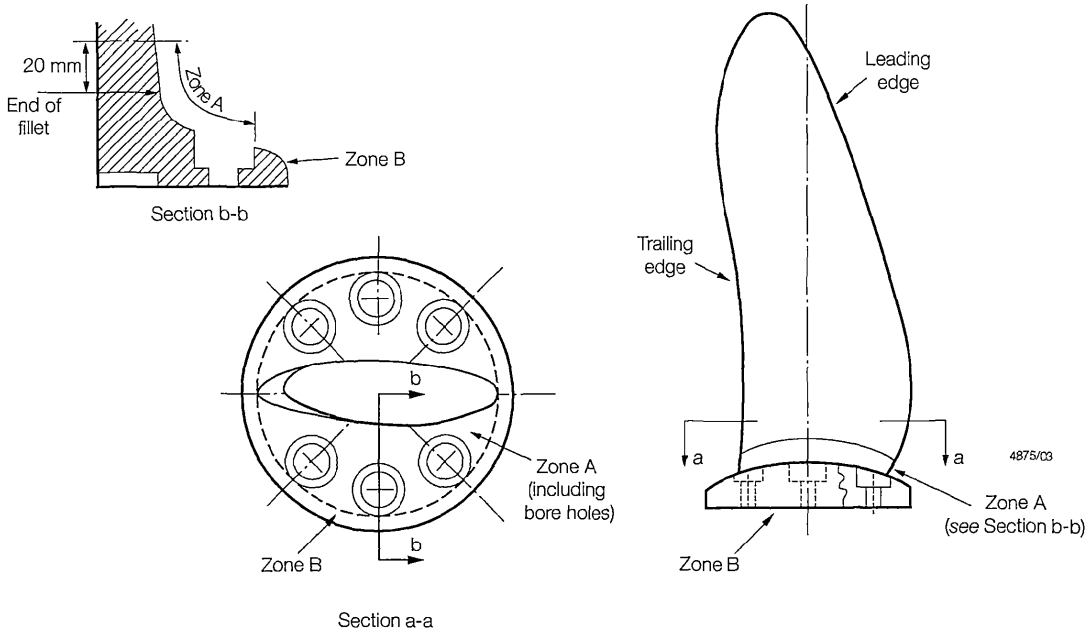
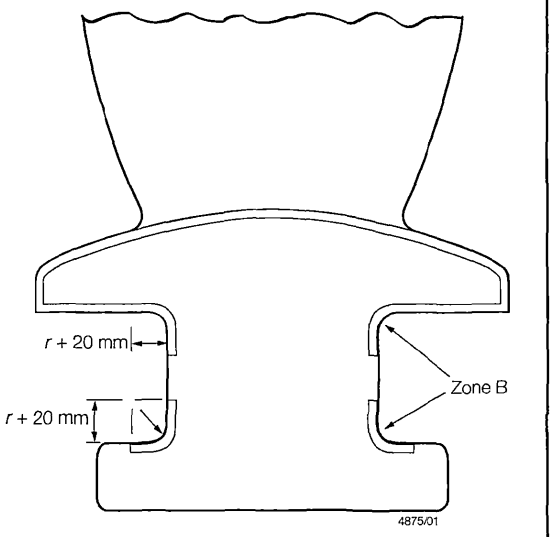


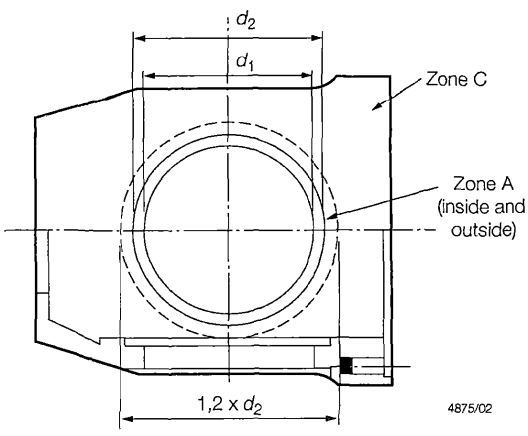
The surfaces of blades are to be divided into severity zones in accordance with Fig. 9.1.2

Fig. 9.1.4 Severity zones for controllable pitch propeller blades



The surfaces of the journal which are not shaded are to be regarded as severity Zone C

Fig. 9.1.5
Severity zones in integrally cast CPP blade journals



(d_1 and d_2 = diameters)

Fig. 9.1.6
Severity zones for controllable pitch propeller hub

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1.8.10 On completion of machining and grinding, the whole surface of each casting is to be subjected to a dye penetrant inspection in accordance with a procedure acceptable to LR.

1.8.11 All dye penetrant inspections on Zone A areas in the finished condition are to be made in the presence of the Surveyor.

1.8.12 Dye penetrant inspections on Zones B and C are to be performed by the manufacturer and may be witnessed at the Surveyor's request.

1.8.13 The surface to be inspected shall be divided into reference areas of 100 cm^2. The indications detected shall, with respect to their size and number, not exceed the values given in Table 9.1.3. The area shall be taken in the most unfavourable location relative to the indication being evaluated.

1.8.14 Indications exceeding the acceptance standard in Table 9.1.3 shall be repaired in accordance with 1.9.

1.8.15 All defects requiring repair by welding in new propeller castings are to be recorded on sketches showing their locations and dimensions. Copies of these sketches are to be presented to the Surveyor prior to repair.

1.8.16 Where repairs have been made either by grinding or welding, the repaired areas are to be subjected to dye penetrant inspection in the presence of the Surveyor, regardless of their location.

1.8.17 Where no welds have to be made on a casting, the manufacturer is to provide the Surveyor with a statement that this is the case.

1.8.18 Where it is suspected that a casting contains internal defects, radiographic and/or ultrasonic examination may be required by the Surveyor. The acceptance criteria are to be agreed between the manufacturer and LR in accordance with a recognised standard. The standard ASTM E272-99 (Severity Level 2) or equivalent is to be the radiographic acceptance standard for copper alloy castings. Ultrasonic testing of Cu 1 and Cu 2 is not considered in these Rules. For Cu 3 and Cu 4, ultrasonic inspection of defects may be possible and is to comply with the requirements for steel castings.

1.8.19 The measurement of dimensional accuracy is the responsibility of the manufacturer but the report on dimensional inspection is to be presented to the Surveyor who may require checks to be made and to witness such checks.

1.8.20 Static balancing is to be carried out on all propellers in accordance with the approved plan. Dynamic balancing is necessary for propellers running above 500 rpm.

1.9 Rectification of defective castings

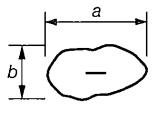
1.9.1 The rectification of defective propeller and propeller blade castings is to be carried out in accordance with the requirements given in 1.9.2 to 1.9.12.

Table 9.1.3 Allowable number and size of dye penetrant indications in a reference area of 100 cm^2 (*see* Note 1)

Severity Zones	Max. total number of indications	Type of indications (*see* Note 2)	Max. number of each type (*see* Notes 3 and 4)	Max. acceptable value for 'a' or '*l*' of indications (mm) (*see* Note 2)
A	7	Non-linear Linear Aligned	5 2 2	4 3 3
B	14	Non-linear Linear Aligned	10 4 4	6 6 6
C	20	Non-linear Linear Aligned	14 6 6	8 6 6

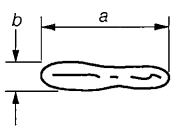
NOTES

1. The reference area is defined as an area of 0,1 m^2, which may be square or rectangular, with the major dimension not exceeding 250 mm. The area shall be taken in the most unfavourable location relative to the indication being evaluated.
2. Non-linear, linear and aligned indications are defined as follows:



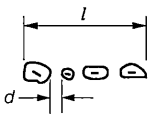
$\frac{a}{b} < 3$

non-linear



$\frac{a}{b} \geq 3$

linear



$d \leq 2$ mm

aligned

3. Only indications that have any dimension greater than 1,5 mm shall be considered relevant.
4. Single non-linear indications less than 2 mm in Zone A and less than 3 mm in other zones may be disregarded.
5. The total number of non-linear indications may be increased to the maximum total number, or part thereof, represented by the absence of linear or aligned indications.

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1.9.2 The rectification of small indications within the acceptance standard of Table 9.1.3 is not generally required except where they occur in closely spaced groups.

1.9.3 Where, in the surface of the end face or bore of a propeller boss, local pores are present which do not themselves adversely affect the strength of the casting, they may be filled with a suitable plastic filler after the appropriate preparation of the defective area. The foundry is to maintain records and details of all castings which have been so rectified.

1.9.4 Where unacceptable defects are found in a casting, they are to be removed by mechanical means, and the surfaces of the resulting depressions are subsequently to be ground smooth. Complete elimination of the defects is to be proved by adequate dye penetrant inspection.

1.9.5 Shallow grooves or depressions resulting from the removal of defects may, at the discretion of the Surveyor, be accepted provided that they will cause no appreciable reduction in the strength of the castings and that they are suitably blended by grinding.

1.9.6 Welded repairs are to be undertaken only when they are considered to be necessary and approved by the Surveyor. In general, welds having an area less than 5 cm^2 are to be avoided.

1.9.7 All weld repairs are to be carried out in accordance with qualified procedures by suitably qualified welders, and are to be completed to the satisfaction of the Surveyor. Records are to be made available to the Surveyor.

1.9.8 Welding is generally not permitted in Zone A and will only be allowed after special consideration.

1.9.9 Prior approval by the Surveyor is required for any welds in Zone B. Complete details of the repair procedure are to be submitted for each case.

1.9.10 Repair by welding is allowed in Zone C provided that there is compliance with 1.9.6 and 1.9.7.

1.9.11 The maximum area of any single repair and the maximum total area of repair in any one zone or region are given in Table 9.1.4.

1.9.12 Where it is proposed to exceed the areas given in Table 9.1.4, the nature and extent of the repair work are to be approved by the Surveyor before commencement of the repair.

1.10 Weld repair procedure

1.10.1 Welding is to be carried out under cover in positions free from draughts and adverse weather conditions.

1.10.2 The manufacturer is to submit a detailed welding procedure specification covering the weld preparation, welding parameters, filler metal, preheating, post-weld heat treatment and inspection procedures.

Table 9.1.4 Permissible rectification of new propellers by welding

Severity zone or region	Maximum individual area of repair	Maximum total area of repairs
Zone A	Weld repairs not generally permitted	
Zone B	60 cm^2 or 0,6% x S whichever is the greater	200 cm^2 or 2% x S, whichever is the greater in combined Zones B and C but not more than 100 cm^2 or 0,8% x S, whichever is the greater, in Zone B on the pressure side
Zone C		
Other regions (*see* Note)	17 cm^2 or 1,5% area of the region whichever is the greater	50 cm^2 or 5% x area of the region whichever is the greater

where S = area of one side of a blade = $0{,}79 \frac{D^2 B}{N}$

D = finished diameter of propeller
B = developed area ratio
N = number of blades

NOTE
Other regions include:
(a) the bore;
(b) the forward and aft faces of the boss;
(c) the outer surface of the boss to the start of the blade root fillets;
(d) the inner face of a CPP blade palm;
(e) all surfaces of CPP nose cones;
(f) the surfaces of integral journals to CPP blades other than the fillets.

1.10.3 Before welding is started, Welding Procedure Qualification tests are to be carried out and witnessed by the Surveyor. Each welder is to be qualified to carry out the proposed welding using the same process, consumable and position which are to be used for the repair.

1.10.4 Defects to be repaired by welding are to be removed completely by mechanical means (e.g. grinding, chipping or milling). Removal of defects in accordance with the requirements for Zone A is to be demonstrated by dye penetrant inspection in the presence of the Surveyor. The excavation is to be prepared in a manner which will allow good fusion and is to be clean and dry.

1.10.5 Metal arc welding with the electrodes or filler wire used in the procedure tests is to be used for all types of repairs. Welds should preferably be made in the downhand (flat) position. Where necessary, suitable preheat is to be applied before welding, and the preheat temperature is to be maintained until welding is completed.

1.10.6 When flux coated electrodes are used they are to be dried immediately before use, in accordance with the manufacturer's instructions.

1.10.7 All slag, undercuts and other defects are to be removed before the subsequent run is deposited.

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1.10.8 With the exception given in 1.10.9, all weld repairs in areas of solid propellers exposed to sea-water, and all repairs to separately cast blades, are to be stress relief heat treated.

1.10.9 Stress relief heat treatment is not mandatory after welding Grade Cu 3 castings in Zone C unless a welding consumable susceptible to stress corrosion (e.g. complying with the composition range of Grade Cu 4) is used. All welds in Zones A and B however, must be stress relieved by heat treatment, regardless of alloy.

1.10.10 Propeller and propeller blades are to be stress relieved within the following temperature ranges:

alloy Grades Cu 1 and Cu 2	350°C to 550°C
alloy Grade Cu 3	450°C to 500°C
alloy Grade Cu 4	450°C to 600°C

Soaking times are to be in accordance with Table 9.1.5, and subsequent cooling from the soaking temperature is to be suitably controlled to minimise residual stresses and is not to exceed 50°C per hour until the temperature is below 200°C. Care should be taken to avoid heating castings in the Grade Cu 3 alloy at temperatures between 300° and 400°C for prolonged periods.

Table 9.1.5 Soaking times for stress relief heat treatment of copper alloy propellers

Stress relief temperature °C (*see* Notes)	Alloy Grade Cu1 and Cu2		Alloy Grade Cu3 and Cu4	
	Hours per 25 mm of thickness	Maximum recommended total time hours	Hours per 25 mm of thickness	Maximum recommended total time hours
350	5	15	—	—
400	1	5	—	—
450	1/2	2	5	15
500	1/4	1	1	5
550	1/4	1/2	1/2	2
600	—	—	1/4	1

NOTES
1. Treatment at 550°C is not applicable to alloy Grade Cu3.
2. Treatment at 600°C is only applicable to alloy Grade Cu4.

1.10.11 Stress relief heat treatment is to be carried out, where possible, in furnaces having suitable atmosphere and temperature control. Sufficient thermocouples are to be attached to the casting to measure the temperature at positions of extremes of thickness.

1.10.12 As an alternative to 1.10.11, local stress relief heat treatment may be accepted, provided that the Surveyor is satisfied that the technique will be effective and that adequate precautions are taken to prevent the introduction of detrimental temperature gradients. Where local stress relief heat treatment is approved, adequate temperature control is to be provided. The area of the propeller or blade adjacent to the repair is to be suitably monitored and insulated to ensure that the required temperature is maintained and that temperature gradients are moderate. Care should be taken to select the shape of an area to be heat treated which will minimise residual stresses.

1.10.13 On completion, welds are to be ground smooth for visual examination and dye penetrant inspection. Where a propeller or propeller blade is to be stress relief heat treated, a visual examination is to be made before heat treatment, and both visual and dye penetrant examinations are to be made after the stress relief heat treatment. Irrespective of location, all weld repairs are to be assessed according to Zone A in Table 9.1.3.

1.10.14 The foundry is to maintain full records detailing the weld procedure, heat treatment and extent and location on drawings of repairs made to each casting. These records are to be available for review by the Surveyor, and copies of individual records are to be supplied to the Surveyor on request.

1.10.15 LR reserves the right to restrict the amount of repair work accepted from a manufacturer when it appears that repetitive defects are the result of improper foundry techniques or practices.

1.11 Identification

1.11.1 Castings are to be clearly marked by the manufacturer in accordance with the requirements of Chapter 1. The following details are to be shown on all castings which have been accepted:

(a) Identification mark which will enable the full history of the item to be traced.
(b) Alloy grade.
(c) LR or Lloyd's Register and the abbreviated name of LR local office.
(d) Personal stamp of Surveyor responsible for the final inspection.
(e) Date of final inspection.
(f) Skew angle, if in excess of 25°. *See* Pt 5, Ch 7,1 of the Rules for Ships for the definition of skew angle.

1.12 Certification of materials

1.12.1 A LR certificate is to be issued for each propeller, *see* Ch 1,3.1

1.12.2 The manufacturer is to provide the Surveyor with the following particulars for each casting:

(a) Purchaser's name and order number.
(b) Description of casting.
(c) Alloy designation and/or trade name.
(d) Identification number of casting.
(e) Cast identification number if different from (d).
(f) Details of heat treatment, where applicable.
(g) Skew angle, if in excess of 25°. *See* the relevant Rules for the definition of skew angle.
(h) Final weight of casting.
(j) Results of non-destructive tests and details of test procedures.
(k) Proportion of alpha-structure for Cu1 and Cu2 alloys.
(l) Results of mechanical tests.
(m) A sketch showing the location and extent of welding repairs (if any).

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■ *Section 2*
Castings for valves, liners and bushes

2.1 Scope

2.1.1 This Section makes provision for copper alloy castings for valves, liners, bushes and other fittings intended for use in the construction of ships, other marine structures, machinery and pressure piping systems.

2.1.2 Castings are to be manufactured and tested in accordance with Chapters 1 and 2, and also with the requirements given in this Section.

2.1.3 As an alternative to 2.1.2, castings which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Section or alternatively are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

2.2 Manufacture

2.2.1 Castings are to be manufactured at foundries approved by LR.

2.3 Quality of castings

2.3.1 All castings are to be free from surface or internal defects which would be prejudicial to their proper application in service.

2.4 Chemical composition

2.4.1 The chemical composition is to comply with the requirements of a National or International Standard and, where appropriate, with the limits for the principal elements of the preferred alloys listed in Tables 9.2.1 and 9.2.2.

2.4.2 With the exception given in 2.4.3, chemical analysis is required on each cast.

2.4.3 Where a cast is wholly prepared from ingots for which an analysis is already available, and provided that no significant alloy additions are made during melting, the ingot maker's certified analysis can be accepted subject to occasional check tests as requested by the Surveyor. The frequency of these check tests should, as a minimum, be one in every ten casts. If one of these check analyses fails to comply with the specification, checks are to be made on the previous and subsequent melts. If one or both of these further analyses is unsatisfactory, chemical analysis is to be carried out on all further melts until the Surveyor is satisfied that a return can be made to the use of occasional check tests.

2.5 Heat treatment

2.5.1 Where required by the specification, castings may be supplied in either the 'as-cast' or heat treated condition.

2.5.2 Where castings are supplied in a heat treated condition, the test samples are to be heat treated with the castings they represent prior to the preparation of the tensile test specimens.

2.6 Test material

2.6.1 Test material sufficient for the tests specified in 2.6.4 and for possible re-test purposes is to be provided for each cast of material.

2.6.2 The test material is to be separately cast into moulds made of the same material as that used for the castings they represent.

2.6.3 For the alloys listed in Table 9.2.1, sand cast test bars are generally to be in accordance with Fig. 9.2.1.

2.6.4 For the alloys listed in Table 9.2.2, keel block type test samples are to be in accordance with Fig. 9.1.1.

Table 9.2.1 Chemical compositions of long freezing range alloys: principal elements only

Alloy type	Designation	Chemical composition						Typical applications
		Cu	Sn	Zn	Pb	Ni	P	
Phosphor bronze	Cu Sn11P Cu Sn12	87,0 – 89,5 85,0 – 88,5	10,0 – 11,5 11,0 – 13,0	0,05 max. 0,50 max.	0,25 max. 0,7 max.	0,10 max. 2,0 max.	0,5 – 1,0 0,60 max.	Liners, bushes, valves and fittings
Gunmetal	Cu Sn10 Zn2	Remainder	9,5 – 10,5	1,75 – 2,75	1,5 max.	1,0 max.	—	Liners, valves and fittings
Leaded gunmetal	Cu Sn5 Zn5 Pb5 Cu Sn7 Zn2 Pb3 Cu Sn7 Zn4 Pb7 Cu Sn6 Zn4 Pb2	83,0 – 87,0 85,0 – 89,0 81,0 – 85,0 86,0 – 90,0	4,0 – 6,0 6,0 – 8,0 6,0 – 8,0 5,5 – 6,5	4,0 – 6,0 1,5 – 3,0 2,0 – 5,0 3,0 – 5,0	4,0 – 6,0 2,5 – 3,5 5,0 – 8,0 1,0 – 2,0	2,0 max. 2,0 max. 2,0 max. 1,0 max.	0,10 max. 0,10 max. 0,10 max. 0,05 max.	Bushes, valves and fittings
Leaded bronze	Cu Sn10 Pb10 Cu Sn5 Pb9 Cu Sn7 Pb15 Cu Sn5 Pb20	78,0 – 82,0 80,0 – 87,0 74,0 – 80,0 70,0 – 78,0	9,0 – 11,0 4,0 – 6,0 6,0 – 8,0 4,0– 6,0	2,0 max. 2,0 max. 2,0 max. 2,0 max.	8,0 – 11,0 8,0 – 10,0 13,0 – 17,0 18,0 – 23,0	2,0 max. 2,0 max. 0,5 – 2,0 0,5 – 2,5	0,10 max. 0,10 max. 0,10 max. 0,10 max.	Bushes

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Table 9.2.2 Chemical compositions of short freezing range alloys: principal elements only

Alloy type	Designation	Chemical composition								Typical applications
		Cu	Ni	Fe	Mn	Cr	Nb	Si	Al	
Copper 30% nickel	Cu Ni30 Fe1 Mn1	64,5 min.	29,0–31,0	0,5–1,5	0,6–1,2	–	–	0,1 max.	–	Flanges, valves and fittings
	Cu Ni30 Fe1 Mn1 Nb Si	Remainder	29,0–31,0	0,5–1,5	0,6–1,2	–	0,5–1,0	0,3–0,7	–	
	Cu Ni30 Cr2 Fe Mn Si (*see* Note 1)	Remainder	29,0–32,0	0,5–1,0	0,5–1,0	1,5–2,0	–	0,15–0,50	–	
Copper 10% nickel	Cu Ni10 Fe1 Mn1	84,5 min.	9,0–11,0	1,0–1,8	1,0–1,5	–	1,0 max.	0,10 max.	–	Flanges, valves and fittings
Aluminium bronze	Cu Al10 Fe5 Ni5	76,0–83,0	4,0–6,0 (*see* Note 2)	4,0–5,5 (*see* Note 2)	3,0 max.	–	–	0,1 max.	8,5–10,5	Bushes, valves and fittings
	Cu Al11 Fe6 Ni6	72,0–78,0	4,0–7,5 (*see* Note 2)	4,0–7,0 (*see* Note 2)	2,5 max.	–	–	0,1 max.	10,0–12,0	

NOTES
1. Normally alloy Cu Ni30 Cr2 Fe Mn Si contains 0,1 to 0,25% titanium and 0,05 to 0,15% zirconium.
2. For Naval ships, the nickel content is to be higher than the iron content.

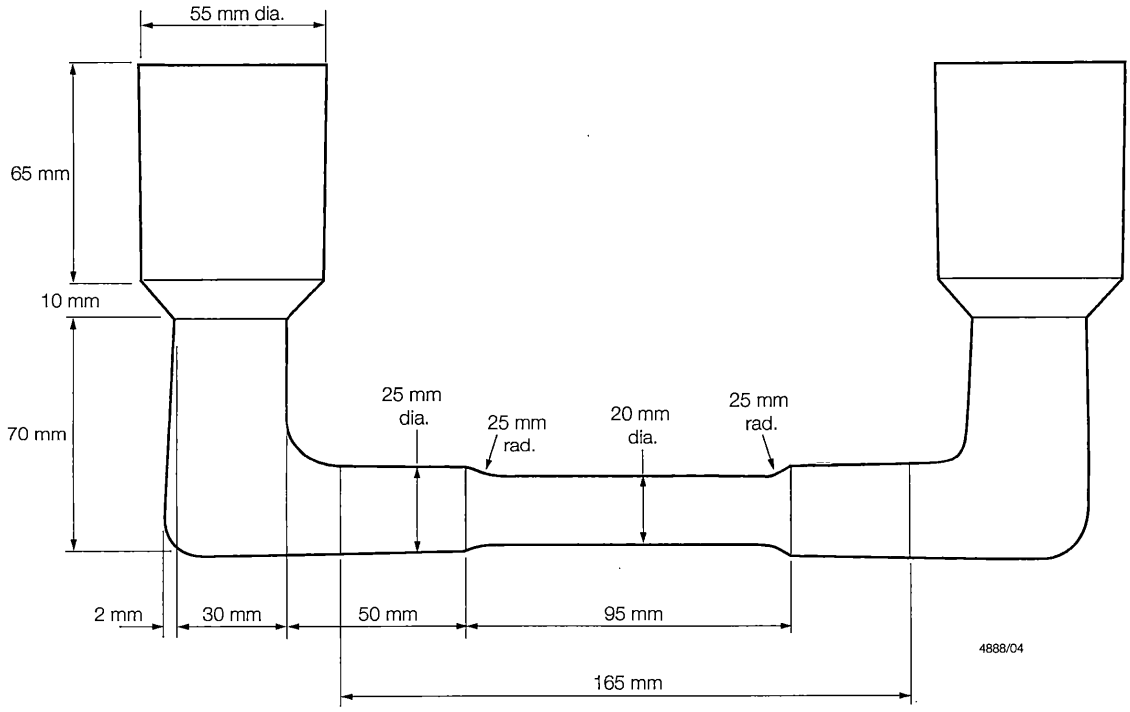

Fig. 9.2.1 Sand cast test bars for long freezing range alloys

2.6.5 If it is proposed to use any other form of test bar, this is to be agreed in advance with the Surveyor.

2.6.6 As an alternative, for liners and bushes, the test material may be taken from the ends of the castings.

2.7 Mechanical tests

2.7.1 A tensile test specimen is to be prepared from each test sample. The dimensions of the specimens are to comply with Fig. 2.2.1 or Fig. 2.2.2 in Chapter 2.

2.7.2 The results of all tests are to comply with the appropriate requirements given in Tables 9.2.3 and 9.2.4.

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Table 9.2.3 Mechanical properties of long freezing range alloys for acceptance purposes

Alloy type	Designation	0,2% proof stress N/mm² minimum (See Note 1)		Tensile strength N/mm² minimum		Elongation on $5{,}65\sqrt{S_o}$ % minimum	
		Sand	Centrifugal	Sand	Centrifugal	Sand	Centrifugal
Phosphor bronze	Cu Sn11 P	130	170	250	330	5	4
	Cu Sn12	140	150	260	280	7	5
Gunmetal	Cu Sn10 Zn2	130	130	270	250	13	5
Leaded gunmetal	Cu Sn5 Zn5 Pb5	90	110	200	250	13	13
	Cu Sn7 Zn2 Pb3	130	130	230	260	14	12
	Cu Sn7 Zn4 Pb7	120	120	230	260	15	12
	Cu Sn6 Zn4 Pb2	110	110	220	240	15	12
Leaded bronze	Cu Sn10 Pb10	80	110	180	220	8	6
	Cu Sn5 Pb9	60	90	160	200	7	6
	Cu Sn7 Pb15	80	90	170	200	8	7
	Cu Sn5 Pb20	70	80	150	170	5	6

NOTES
1. The 0,2% proof stress values are given for information purposes only and, unless otherwise agreed, are not required to be verified by test.
2. Castings may be supplied in the chill cast condition in which case the mechanical properties requirements are to be in accordance with a specification agreed by LR.

Table 9.2.4 Mechanical properties of short freezing range alloys for acceptance purposes

Alloy type	Designation	0,2% proof stress N/mm² minimum (See Note 1)		Tensile strength N/mm² minimum		Elongation on $5{,}65\sqrt{S_o}$ % minimum	
		Sand	Centrifugal	Sand	Centrifugal	Sand	Centrifugal
Copper 30% Nickel	Cu Ni30 Fe1 Mn1	120	120	340	340	18	18
	Cu Ni30 Fe1 Mn1 Nb Si	230	—	440	—	18	—
	Cu Ni30 Cr2 Fe Mn Si	250	—	440	—	18	—
Copper 10% Nickel	Cu Ni10 Fe1 Mn1	120	100	280	280	20	25
Aluminium Bronze	Cu Al10 Fe5 Ni5	250	280	600	650	13	13
	Cu Al11 Fe6 Ni6	320	380	680	750	5	5

2.8 Inspection

2.8.1 All castings are to be cleaned and adequately prepared for inspection. Before acceptance, all castings are to be presented to the Surveyor for visual examination. This is to include the examination of internal surfaces, where applicable.

2.8.2 For valves and other pressure components, dye penetrant inspection is required and the Surveyor is to witness the tests. Unless otherwise agreed, the acceptance criteria to be applied are to meet the requirements of Table 9.2.5, or equivalent.

2.8.3 The accuracy and verification of dimensions are the responsibility of the manufacturer. However, the report on dimensional inspection is to be presented to the Surveyor who may request to witness confirmatory measurements.

Table 9.2.5 Visual and surface NDE acceptance criteria for valves and pressure components

Defect type	Acceptance criteria for visual and surface NDE, *see* Note
Linear indications	Not permitted
Porosity	Individual pores are not to exceed 3 mm diameter bleed out, and the sum of the diameters of all indications in an area of 70 x 70 mm is not to exceed 24 mm²

NOTE
Inspection is to be in accordance with a procedure acceptable to LR.

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2.9 Rectification of defective castings

2.9.1 Subject to the prior approval of the Surveyor, castings containing local porosity may be rectified by impregnation with a suitable plastic filler provided that the extent of the porosity is such that it does not adversely affect the strength of the casting.

2.9.2 Proposals to repair a defective casting by welding are to be submitted to the Surveyor before this work is commenced. The Surveyor is to be satisfied that the number, position and size of the defects are such that the castings can be efficiently repaired.

2.9.3 Where approval is given for the repair by welding, complete elimination of the defects is to be proven by adequate non-destructive testing.

2.9.4 All welding is to be in accordance with an approved and qualified weld procedure and carried out by a qualified welder.

2.9.5 A statement and/or sketch detailing the extent and position of all weld repairs is to be prepared by the manufacturer as a permanent record. These records are to be available for review by the Surveyor, and copies of individual records are to be supplied to the Surveyor on request.

2.9.6 The alloys listed in Table 9.2.1 are not satisfactory for repair by welding which is generally not permitted. Weld repairs may, however, be considered in special circumstances provided that a suitable procedure, with proof of previous satisfactory repairs is submitted to the Surveyor.

2.9.7 The welding during manufacture of liners is not permitted in any alloy containing more than 0,5 per cent lead.

2.10 Pressure testing

2.10.1 Where required by the relevant Rules, castings are to be pressure tested before final acceptance. Unless otherwise agreed, these tests are to be carried out in the presence of the Surveyors and are to be to their satisfaction.

2.11 Identification

2.11.1 The manufacturer is to adopt a system of identification which will enable all finished castings to be traced to the original cast, and the Surveyor is to be given full facilities for tracing the casting when required.

2.11.2 Before acceptance, all castings which have been tested and inspected with satisfactory results are to be clearly marked by the manufacturer with the following details:

(a) Identification number, cast number or other markings which will enable the full history of the casting to be traced.
(b) LR or Lloyd's Register and the abbreviated name of LR's local office.
(c) Personal stamp of the Surveyor responsible for inspection.
(d) Test pressure, where applicable.
(e) Date of final inspection.

2.11.3 Where small castings are manufactured in large numbers, modified arrangements for identification may be specially agreed with the Surveyor.

2.12 Certification of materials

2.12.1 A LR certificate is to be issued, *see* Ch 1,3.1.

2.12.2 The manufacturer is to provide the Surveyor with the following particulars for each casting or batch of castings which has been accepted:

(a) Purchaser's name and order number.
(b) Description of castings and alloy grade.
(c) Identification number.
(d) Ingot or cast analysis.
(e) Full details of heat treatment, where applicable.
(f) Mechanical test results.
(g) Test pressure, where applicable.

2.12.3 In addition to 2.12.2, the manufacturer is to provide, where applicable, a statement and/or sketch detailing the extent and position of all weld repairs made to each casting.

■ *Section 3* Tubes

3.1 Scope

3.1.1 Provision is made in this Section for seamless copper and copper alloy tubes intended for use in condensers, heat exchangers and pressure piping systems.

3.1.2 Tubes for Class I and II pressure systems (as defined in the relevant Rules) are to be manufactured and tested in accordance with the requirements of Chapters 1 and 2 and the requirements of this Section.

3.1.3 As an alternative to 3.1.2, tubes which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Section or alternatively are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

3.1.4 Tubes for Class III pressure systems are to be manufactured and tested in accordance with the requirements of a National or International Standard recognised by LR. The manufacturer's test certificate will be acceptable and is to be provided for each batch of material.

3.2 Manufacture

3.2.1 Tubes for Class I and II pressure systems are to be manufactured at a works approved by LR for the grade of material being supplied.

3.2.2 Tubes for Class III pressure systems are not required to be manufactured at a works approved by LR.

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3.3 Quality

3.3.1 Tubes are to be clean and free from surface and internal defects and residues from manufacturing operations.

3.3.2 The tubes are to be supplied in smooth, round, straight lengths, free from deleterious films in the bore. The ends are to be cut clean and square with the axis of the tube and are to be de-burred.

3.4 Dimensional tolerances

3.4.1 The tolerances on the wall thickness and diameter of the tubes are to be in accordance with a National or International Standard recognised by LR.

3.4.2 The measurement of dimensional accuracy and compliance with the specification are the responsibility of the manufacturer, but the reports are to be made available to the LR Surveyors, who may require checks to be made in their presence.

3.5 Chemical composition

3.5.1 The chemical composition is to comply with the requirements of a National or International Standard recognised by LR and comply with the base limits for the principal elements given in Table 9.3.1.

3.6 Heat treatment

3.6.1 Copper-phosphorus and aluminium brass tubes are to be supplied in the annealed condition. Aluminium brass tubes may additionally be required to be given a suitable stress relieving heat treatment when subjected to a cold straightening operation after annealing.

3.6.2 Tubes in the copper-nickel iron alloys are to be supplied in a solution heat treated condition to ensure that no iron rich phases are present.

3.7 Mechanical tests

3.7.1 Tubes are to be presented for test in batches of 300 lengths. A batch is to consist of tubes of the same size, manufactured from the same material grade.

3.7.2 At least one length is to be selected at random from each batch and subjected to the following tests:
(a) Tensile test.
(b) Flattening test.
(c) Drift expanding test.

3.7.3 The procedures for mechanical tests and the dimensions of the test specimens are to be in accordance with Chapter 2.

3.7.4 The flattening test is to be continued until the interior surfaces of the tube meet.

3.7.5 For the drift expanding test, the mandrel is to have an included angle of 45°.

3.7.6 The results of all mechanical tests are to comply with the appropriate requirements given in Table 9.3.2.

3.7.7 At the discretion of the Surveyor, a modified testing procedure may be adopted for small quantities of materials. In such cases, these may be accepted on the manufacturer's declared chemical composition and hardness tests or other evidence of satisfactory properties.

Table 9.3.1 Chemical composition of principal elements only

Designation	Chemical composition %								
	Cu	As	P	Fe	Pb	Ni	Al	Mn	Zn
Copper-phosphorus deoxidised–non-arsenical	99,85 min.	–	0,013–0,050	—	—	—	—	—	—
Copper-phosphorus deoxidised–arsenical	99,2 min.	0,30–0,50	0,013–0,050		—	—	—	—	—
Aluminium brass	76,0–79,0	0,02–0,06	—	0,06 max.	0,07 max.	—	1,8–2,5	—	Remainder
90/10 Copper-nickel-iron (*see* Note)	Remainder	—	—	1,0-2,0	—	9,0–11,0	—	0,5–1,0	—
70/30 Copper-nickel-iron (*see* Note)	Remainder	—	—	0,40–1,00	—	29,0–33,0	—	0,5–1,5	—

NOTE
Where the purchaser specifies that the product is intended for subsequent welding applications, the following limits will apply:

Zn	0,50% max.	S	0,02% max.
Pb	0,02% max.	C	0,05% max.
P	0,02% max.		

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Table 9.3.2 Mechanical properties for acceptance purposes

Designation	0,2% proof stress N/mm^2 minimum	Tensile strength N/mm^2 minimum	Elongation on 5,65$\sqrt{S_o}$ % minimum	Drift expansion test % minimum	Grain size mm maximum (*see* Note)
Copper-phosphorus deoxidised–non-arsenical	65	220	40	40	—
Copper-phosphorus deoxidised–arsenical	65	220	40	40	—
Aluminium brass	125	320	40	30	0,045
90/10 Copper-nickel-iron	100	270	30	30	0,045
70/30 Copper-nickel-iron	120	360	30	30	0,045

NOTE
When a maximum grain size is specified, the structure is to be completely re-crystallised. The manufacturer is to guarantee the grain size, but testing of each batch will not be required.

3.8 Visual examination

3.8.1 All tubes are to be visually examined. The manufacturer is to provide adequate lighting conditions to enable an internal and external examination of the tubes to be carried out.

3.8.2 The inner and outer surfaces are to be clean and smooth but may have a superficial, dull iridescent film on both the inner and outer surfaces.

3.9 Stress corrosion cracking test

3.9.1 This is an accelerated test for detecting the presence in tubes of internal stresses which might result in failure, in storage or in service, due to stress corrosion cracking.

3.9.2 The test is applicable only to aluminium brass and copper-nickel-iron tubes.

3.9.3 The test specimen is to consist of a 150 mm length cut from the tube selected for mechanical tests in accordance with 3.7.2.

3.9.4 The test is to be carried out in accordance with a National or International Standard recognised by LR or by the test method given in 3.9.5.

3.9.5 The test specimen is to be immersed in a mercurous nitrate solution at room temperature for 30 minutes. Aluminium brass specimens are to be examined for cracks immediately after rinsing, while copper-nickel-iron specimens are to be examined 24 hours after rinsing.

3.9.6 Should any specimen fail to meet the requirements of this test, then all tubes represented by that specimen are to be withdrawn. The tubes may be re-submitted after stress relieving treatments for full testing in accordance with 3.7 and 3.9.

3.10 Hydraulic test

3.10.1 Each tube is to be subjected to a hydraulic test at the manufacturer's works.

3.10.2 The hydraulic test pressure is to be determined from the following formula, except that the maximum test pressure need not exceed 70 bar:

$$P = \frac{20st}{D}$$

where

P = test pressure, in bar
D = nominal outside diameter, in mm
t = nominal wall thickness, in mm
s = 40 for copper-phosphorus
60 for Al-brass and
90/10 copper nickel iron
75 for 70/30 copper nickel iron.

3.10.3 The test pressure is to be maintained for sufficient time to permit proof that the tubes do not weep, leak or undergo a permanent increase in diameter. Unless otherwise agreed, the manufacturer's certificate of satisfactory hydraulic test will be accepted.

3.10.4 Where it is proposed to adopt a test pressure other than that determined in 3.10.2, the proposal will be subject to special consideration.

3.10.5 Subject to special approval, an automated eddy current test can be accepted in lieu of the hydraulic test. Discontinuous irregularities on the external and internal surfaces of the tubes are permitted if they are within the agreed dimensional tolerances, with the exception of cracks, which are not permitted.

3.11 Rectification of defects

3.11.1 The repair of defects by welding is not permitted.

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3.12 Identification

3.12.1 Tubes are to be clearly marked by the manufacturer in accordance with the requirements of Chapter 1. The following details are to be shown on all materials which have been accepted:

(a) LR or Lloyd's Register.
(b) Manufacturer's name or trade mark.
(c) Grade of material or designation code.
(d) Identification number and/or initials which will enable the full history of the item to be traced.

3.12.2 Identification is to be by rubber stamp or stencils. Hard stamping is not permitted.

3.13 Certification of materials

3.13.1 A manufacturer's certificate validated by LR is to be issued (*see* Ch 1,3.1), giving the following particulars for each casting or batch of castings which has been accepted:

(a) Purchaser's name and order number.
(b) Specification or grade of material.
(c) Description and dimensions.
(d) Cast number and chemical composition.
(e) Mechanical test results.
(f) Results of stress corrosion cracking test, where applicable.
(g) Hydraulic test report.

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Equipment for Mooring and Anchoring

Section

1 **Anchors**

2 **Stud link chain cables for ships**

3 **Stud link mooring chain cables**

4 **Studless mooring chain cables**

5 **Short link chain cables**

6 **Steel wire ropes**

7 **Fibre ropes**

Section 1 Anchors

1.1 Scope

1.1.1 This Section makes provision for the manufacture and testing of anchors constructed from cast, forged and fabricated components.

1.1.2 This Section is applicable to the following types of anchor:
(a) Ordinary.
(b) High holding power (HHP).
(c) Super high holding power (SHHP).

1.1.3 In the context of this Section, the reference to swivels refers to those directly attached to the anchor shank in lieu of the conventional 'D' shackle. For other mooring equipment swivels, *see* 2.13.

1.2 Manufacture

1.2.1 All anchors are to be of an approved design.

1.3 Cast steel anchors

1.3.1 Cast steel anchor heads, shanks, shackles and swivels are to be manufactured and tested in accordance with the requirements of Ch 4,1 and Ch 4,2. The Special grade quality is to be used for anchor heads, shanks and shackles.

1.3.2 Special consideration will be given to the use of other grades of steel for the manufacture of swivels.

1.3.3 To confirm the quality of cast anchor components, the Surveyor is to witness drop and hammering tests.

1.3.4 When drop and hammering tests are required, they are to be carried out as follows:
(a) Each anchor, or the components of an anchor made from more than one piece, is to be dropped from a clear height of 4 m onto a steel slab laid on a solid foundation.
(b) Separately cast flukes, shanks and shackles are to be suspended horizontally from a clear height of 4 m before being dropped.
(c) Anchors cast in one piece are to be drop tested twice from a clear height of 4 m. For the first test, the shank and flukes are to be horizontal. For the second test, two steel blocks are to be placed on the slab, arranged so that the middle of each fluke makes contact with the blocks without the crown making contact with the slab, and the orientation of the anchor is to be vertical with the crown nearest the slab.
(d) If the slab is broken by the impact, the test is to be repeated on a new slab.

1.3.5 When hammering tests are required, they are to be carried out after the drop test on each anchor head and shank, which is slung clear of the ground, using a non-metallic sling, and hammered to check the soundness of the component. A hammer of at least 3 kg mass is to be used.

1.3.6 As part of the manufacturer's works approval, consideration may be given to carrying out drop tests in alternative locations to the manufacturer's when the facilities and location are not suitable.

1.3.7 Repair of fractures or unsoundness detected during the drop or hammering tests are not permitted and the component is to be rejected.

1.4 Forged steel anchors

1.4.1 Forged steel anchor pins, swivels, shanks and shackles are to be manufactured and tested in accordance with the requirements of Ch 5,1 and Ch 5,2 carbon and carbon-manganese steel for welded construction. Rolled steel bar may be used provided that the requirements of Ch 5,1.2.9 are met.

1.4.2 Special consideration will be given to other grades of steel for the manufacture of swivels.

1.5 Fabricated steel anchors

1.5.1 Where it is proposed to use plate material for fabricated steel anchors, it is to comply with the requirements of Ch 3,2 or Ch 3,3, and the proposed manufacturing procedure is to be submitted for approval.

1.5.2 Fabricated anchors are to be manufactured in accordance with Chapter 13.

1.5.3 Stress relief is to be carried out as required in the approved welding procedure.

1.6 Rectification

1.6.1 All rectification is to be agreed with the Surveyor.

1.6.2 Rectification of defective castings is to be carried out in accordance with Ch 4,1.9.

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1.6.3 Rectification of defective forgings is to be carried out in accordance with Ch 5,1.9.

1.6.4 Rectification of defective fabricated anchors is to be carried out by suitably qualified welders within the parameters of the approved welding procedure used in construction.

1.6.5 Rectification of defective castings, forgings or fabricated anchors by welding is to be carried out using qualified weld procedures in accordance with Ch 12,1 and Ch 12,2, and in accordance with Ch 13,1 and Ch 13,2.

1.7 Super high holding power (SHHP) anchors

1.7.1 The impact test requirements for SHHP anchor shackles are to be in accordance with the requirements for Grade U3 in Table 10.2.1.

1.8 Assembly

1.8.1 Assembly and fitting is to be carried out in accordance with the approved design.

1.8.2 Securing of anchor pins, shackle pins or swivels by welding is to be carried out by suitably qualified welders in accordance with an approved welding procedure.

1.9 Proof test of anchors

1.9.1 Anchors having a mass of 75 kg or more inclusive of stock (56 kg in the case of high holding power anchors) are to be tested in the presence of the Surveyor at a proving establishment recognised by LR. A list of recognised proving establishments is published separately by LR. In addition to the requirements stated in this Chapter, attention must be given to any relevant statutory requirements of the National Authority of the country in which the ship or mobile offshore unit is to be registered.

1.9.2 The anchor is to be visually examined before application of the proof test load to ensure that it is free from cracks, notches, inclusions and other surface defects that would impair the performance of the product.

1.9.3 As required by 1.9.1, each anchor is to be subjected to a proof loading test in an approved testing machine and is to withstand the load given in Table 10.1.1 for the appropriate mass of the anchor. The proof load is to be applied on the arm or on the palm at a spot which, measured from the extremity of the bill, is one-third of the distance between it and the centre of the crown. For stocked anchors, each arm is to be tested individually. For stockless anchors, both arms are to be tested at the same time, first on one side of the shank, then reversed and tested on the other.

Table 10.1.1 Proof load tests for anchors
(*see* Notes 1 and 2)

Mass of anchor (1.6.5) kg	Proof test load kN	Mass of anchor (1.6.5) kg	Proof test load kN	Mass of anchor (1.6.5) kg	Proof test load kN
50	23,2	2200	376,0	7800	861,0
55	25,2	2300	388,0	8000	877,0
60	27,1	2400	401,0	8200	892,0
65	28,9	2500	414,0	8400	908,0
70	30,7	2600	427,0	8600	922,0
75	32,4	2700	438,0	8800	936,0
80	33,9	2800	450,0	9000	949,0
90	36,3	2900	462,0	9200	961,0
100	39,1	3000	474,0	9400	975,0
120	44,3	3100	484,0	9600	987,0
140	49,0	3200	495,0	9800	998,0
160	53,3	3300	506,0	10 000	1010,0
180	57,4	3400	517,0	10 500	1040,0
200	61,3	3500	528,0	11 000	1070,0
225	65,8	3600	537,0	11 500	1090,0
250	70,4	3700	547,0	12 000	1110,0
275	74,9	3800	557,0	12 500	1130,0
300	79,5	3900	567,0	13 000	1160,0
325	84,1	4000	577,0	13 500	1180,0
350	88,8	4100	586,0	14 000	1210,0
375	93,4	4200	595,0	14 500	1230,0
400	97,9	4300	604,0	15 000	1260,0
425	103,0	4400	613,0	15 500	1280,0
450	107,0	4500	622,0	16 000	1300,0
475	112,0	4600	631,0	16 500	1330,0
500	116,0	4700	638,0	17 000	1360,0
550	125,0	4800	645,0	17 500	1390,0
600	132,0	4900	653,0	18 000	1410,0
650	140,0	5000	661,0	18 500	1440,0
700	149,0	5100	669,0	19 000	1470,0
750	158,0	5200	677,0	19 500	1490,0
800	166,0	5300	685,0	20 000	1520,0
850	175,0	5400	691,0	21 000	1570,0
900	182,0	5500	699,0	22 000	1620,0
950	191,0	5600	706,0	23 000	1670,0
1000	199,0	5700	713,0	24 000	1720,0
1050	208,0	5800	721,0	25 000	1770,0
1100	216,0	5900	728,0	26 000	1800,0
1150	224,0	6000	735,0	27 000	1850,0
1200	231,0	6100	740,0	28 000	1900,0
1250	239,0	6200	747,0	29 000	1940,0
1300	247,0	6300	754,0	30 000	1990,0
1350	255,0	6400	760,0	31 000	2030,0
1400	262,0	6500	767,0	32 000	2070,0
1450	270,0	6600	773,0	34 000	2160,0
1500	278,0	6700	779,0	36 000	2250,0
1600	292,0	6800	786,0	38 000	2330,0
1700	307,0	6900	794,0	40 000	2410,0
1800	321,0	7000	804,0	42 000	2490,0
1900	335,0	7200	818,0	44 000	2570,0
2000	349,0	7400	832,0	46 000	2650,0
2100	362,0	7600	845,0	48 000	2730,0

Proof loads for intermediate mass are to be determined by linear interpolation

NOTES

1. Where ordinary anchors have a mass exceeding 48 000 kg, the proof loads are to be taken as 2,059 (mass of anchor in kg)$^{2/3}$ kN.
2. Where high holding power anchors have a mass exceeding 36 000 kg, the proof loads are to be taken as 2,452 (actual mass of anchor in kg)$^{2/3}$ kN.

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1.9.4 The general arrangements for the test are to be such that the complete anchor, including the shackle, shackle pins and any welded or bolted connections are included in the test. If a replacement shackle is needed which requires welding or heating for fitting, the combined anchor and shackle are to be proof load tested. If welding or heating is not involved in fitting, the shackle may be proof load tested separately from the anchor.

1.9.5 The mass to be used in Table 10.1.1 is:

(a) For stockless anchors, the total mass of the anchor.
(b) For stocked anchors, the mass of the anchor excluding the stock.
(c) For high holding power anchors, a nominal mass equal to 1,33 times the actual total mass of the anchor.
(d) For mooring anchors, including positional mooring anchors, a nominal mass equal to 1,33 times the actual total mass of the anchor, unless specifically agreed otherwise.
(e) For super high holding power anchors, a nominal mass equal to twice the actual total mass of the anchor.

1.9.6 For positional mooring anchors, the proof test loading is to be that required by 1.9.3 or 50 per cent of the minimum break strength of the intended anchor line, whichever is the greater.

1.9.7 The gauge length is to be measured with 10 per cent of the required load applied, before and after proof test. The two measurements shall differ by no more than 1 per cent. The gauge length is the distance between the tip of each fluke and a point on the shank adjacent to the shackle pin, *see* Fig. 10.1.1.

1.9.8 After proof testing, all accessible surfaces are to be visually inspected by the Surveyor.

1.9.9 Following proof testing, NDE is to be conducted as described in Table 10.1.2 for ordinary and HHP anchors and Table 10.1.3 for SHHP anchors.

1.9.10 Each casting is to be subjected to ultrasonic inspection in the region of runners and risers, or where excess material has been removed by thermal methods. This examination is to extend around the whole periphery of the casting and for a distance of $t/3$ beyond the area affected, where t is the maximum thickness. In addition, random areas are to be selected by the Surveyor and examined.

1.9.11 Acceptance criteria for castings are to be in accordance with Chapter 4.

1.9.12 Acceptance criteria for forgings are to be in accordance with Chapter 5.

1.9.13 Paint or anti-corrosive coatings are not to be applied until these inspections are completed to the satisfaction of the Surveyor.

Table 10.1.2 NDE requirements following proof testing for Ordinary and HHP anchors

Location	Method of NDE
Feeder heads, runners and risers of castings	Magnetic particle inspection and ultrasonic test, *see* Note 1
All welds	Magnetic particle inspection
Forged components	Not required
Fabrication welds	Magnetic particle inspection
NOTES 1. *See also* 1.9.10. 2. Penetrant testing is to be used in lieu of magnetic particle testing for stainless steel, aluminium and copper alloy anchors.	

Table 10.1.3 NDE requirements following proof testing for SHHP anchors

Location	Method of NDE
Feeder heads, runners and risers of castings	Magnetic particle inspection and ultrasonic test, *see* Note 1
All surfaces of castings	Magnetic particle inspection
All welds	Magnetic particle inspection
Forged components	Not required
Fabrication welds	Magnetic particle inspection
NOTES 1. *See also* 1.9.10. 2. Additionally, all surfaces of all SHHP anchors are to be surface inspected by the magnetic particle or penetrant method as appropriate. 3. Penetrant is to be used in lieu of magnetic particle testing for stainless steel, aluminium and copper alloy anchors.	

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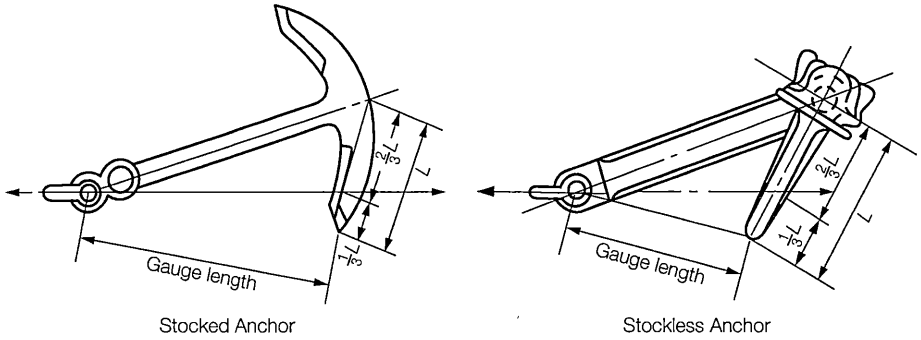

Fig. 10.1.1 Location of gauge length measurement during proof load

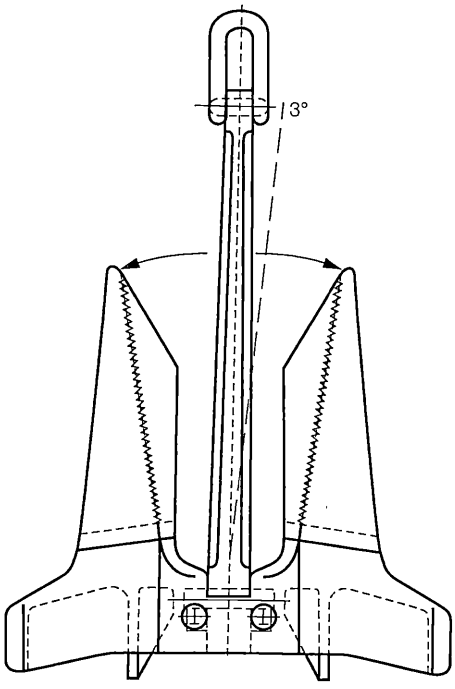

Fig. 10.1.2 Allowable lateral movement of shank

1.9.14 On completion of the proof testing, anchors made in more than one piece are to be examined for free movement of their heads over the complete range of rotation.

1.10 Clearances and tolerances

1.10.1 Where no fitting tolerances are specified on the approved plans the following assembly and fitting tolerance are to be applied.

1.10.2 The clearance either side of the shank within the shackle jaws and the shackle pin in the shank end hole is to be no more than 3 mm for small anchors up to 3 tonnes, 4 mm for anchors up to 5 tonnes, 6 mm for anchors up to 7 tonnes and is not to exceed 12 mm for larger anchors.

1.10.3 The shackle pin is to be a push fit in the eyes of the shackle, which are to be chamfered on the outside to ensure a good tightness when the pin is clenched over on fitting. The shackle pin to hole tolerance is to be no more than 0,5 mm for pins up to 57 mm and 1,0 mm for pins of larger diameter.

1.10.4 The trunnion pin is to be a snug fit within the chamber and be long enough to prevent horizontal movement. The gap is to be no more than 1 per cent of the chamber length.

1.10.5 The lateral movement of the shank is not to exceed 3 degrees from the centreline datum, *see* Fig. 10.1.2.

1.10.6 Unless otherwise agreed, the verification of mass and dimensions is the responsibility of the manufacturer. The Surveyor is only required to monitor this inspection. The mass of the anchor is to exclude the mass of the swivel, unless the swivel is in lieu of the conventional 'D' shackle.

1.11 Identification

1.11.1 Identification marks on the shank are to be approximately level with the fluke tips. On the fluke, these markings are to be approximately at a distance of two thirds from the tip of the bill to the centre line of the crown on the right hand fluke, looking from the crown towards the shank.

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1.11.2 The following details are to be shown on all anchors:
(a) LR or Lloyd's Register and abbreviated name of LR's local office issuing the certificate.
(b) Number of the certificate.
(c) Month and year of test.
(d) Mass (also the letters 'HHP' when approved as high holding power anchors or 'SHHP' when approved as super high holding power anchors).
(e) Mass of stock (in the case of stocked anchors).
(f) National Authority requirements, as applicable.
(g) Manufacturer's mark.

1.11.3 In addition to 1.11.2, each important part of an anchor is to be plainly marked by the maker with the words 'forged steel' or 'cast steel' as appropriate. Fabricated steel anchor heads do not require special marking.

1.12 Certification

1.12.1 The manufacturer is to provide the Surveyor with a written statement that the anchor has been manufactured and tested in accordance with LR Rules together with the following particulars:
(a) Purchaser's name and order number.
(b) Type of anchor and principal dimensions.
(c) Mass of anchor.
(d) Identification mark which will enable the full history of manufacture to be traced.
(e) Chemical composition.
(f) Details of heat treatment.
(g) Mechanical test results.
(h) Proof load.
(j) Results of the non-destructive examination.
(k) Weld location maps (cast steel anchors only).

1.12.2 Shanks, heads, pins, shackles and swivels are to be certified by LR in accordance with the relevant sections of Chapters 3, 4 and 5.

1.12.3 An LR Anchor Certificate is to be issued for the completed anchor which will include the following particulars:
(a) Manufacturer's name.
(b) Type of anchor.
(c) Mass of anchor.
(d) Grade of materials.
(e) Proof test load.
(f) Heat treatment.
(g) Marking applied to anchor.
(h) Dimensions.
(j) General Approval of an Anchor Design Certificate Number.
(k) Fluke and shank identification numbers.

Section 2
Stud link chain cables for ships

2.1 Scope

2.1.1 Provision is made in this Section for a range of grades, U1, U2 and U3, of stud link chain and fittings intended for anchor or mooring cables for ships.

2.1.2 The requirements for offshore mooring chain cables are given in Section 3.

2.2 Manufacture

2.2.1 All grades of chain cable and accessories are to be manufactured by approved procedures at works approved by LR. A list of approved manufacturers of stud link chain cables and fittings is published separately by LR.

2.2.2 The links may be made by the flash-butt or other approved welding process, or in the case of Grades U2 and U3 they may be flash-butt welded or drop forged, designated U2(a) or U3(a), or cast steel designated U2(b) or U3(b), *see* Table 10.2.5.

2.2.3 As far as practicable, consecutive links in all chain cable should originate from a single cast or batch of bar stock (*see* Ch 3,9.6.1), and indicating marks should be stamped on the final link formed from one cast or batch and the first link formed from a separate cast or batch.

2.2.4 A length of chain cable is to measure not more than 27,5 m and is to comprise an odd number of links. In this context, a length is a statutory term and is the basis for the number of test samples.

2.3 Flash butt welded chain cable

2.3.1 Bar material is to comply with the requirements of Ch 3,9 and may be heated either by electrical resistance or in a furnace. For electrical resistance heating, the process is to be controlled by an optical heat sensor. For furnace heating, thermocouples in close proximity to the bars are to be used for control. The temperature is to be continuously recorded. In both cases, the controls are to be checked at least once every eight hours and checks are to be recorded.

2.3.2 Mechanical properties testing of U1 cable is not required. For Grade U2 cable supplied in the as-welded condition, and Grade U3 in all conditions, one tensile and one set of three Charpy V-notch impact test specimens are to be taken at the side of a link opposite the weld from at least every fourth 27,5 m length of cable. A further set of three impact test specimens is to be taken with the notch positioned at the centre of the weld, *see* Table 10.2.3. The test specimens are not to be selected from the same length as that from which the breaking test sample is taken, unless breaking test samples are to be taken from every length of the batch. All test samples are to be correctly identified with the lengths of cable represented.

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2.3.3 The test links from which the mechanical test specimens are prepared are to be made as part of the chain cable and are to be heat treated with it. They may be removed from the cable prior to heat treatment provided that each sample is heat treated with, and in the same manner as, the chain it represents and is subjected to the proof load appropriate to the chain grade and diameter prior to preparation of the mechanical test specimens.

2.3.4 The results of tests on specimens taken from the non-welded areas are to comply with the appropriate requirements of Table 10.2.1. The results of tests on the welds are to comply with the requirements of Table 10.2.6.

2.4 Cast chain cables

2.4.1 The manufacture of cast steel chain cable is generally to be in accordance with the requirements of Ch 4,1, as appropriate.

2.4.2 The chemical composition of ladle samples is to comply with the specification approved by LR.

2.4.3 Separately cast test samples are to be provided from each cast. They are to be of similar dimensions to the links they represent and are to be heat treated together with, and in the same manner as, the completed chain cable, *see* Table 10.2.3.

2.4.4 Tensile and Charpy V-notch impact test specimens are to be taken from each test sample and machined to the dimensions given in Ch 2,3.

2.4.5 The results of all tests are to comply with the requirements given in Table 10.2.1 for the relevant grade.

2.5 Forged chain cables

2.5.1 The procedure for the manufacture and testing of drop forgings for chain cable will be specially considered, but is generally to be in accordance with the appropriate requirements of Ch 5,1.

2.5.2 The chemical composition is to comply with Table 10.2.2.

2.5.3 The completed forgings are to be heat treated in accordance with Table 10.2.3.

2.5.4 Test samples in the form of forgings of similar dimensions to the links they represent and from the same cast and heat treatment charge are to be provided.

2.5.5 One tensile and three Charpy V-notch specimens are to be taken from each test sample.

2.5.6 The results of mechanical tests are to comply with the requirements of Table 10.2.1 for the relevant grade.

2.6 Stud material

2.6.1 Steel studs are to be used for all grades of welded chain cable. In general, the carbon content should not exceed 0,23 per cent but mechanical tests for acceptance purposes are not required.

2.7 Welding of studs

2.7.1 Where studs are welded into the links this is to be completed before the chain cable is heat treated.

2.7.2 The stud ends must be a good fit inside the link, and the weld is to be confined to the stud end opposite the flash-butt weld. The full periphery of the stud end is to be welded. If, however, it can be demonstrated to the Surveyor that the quality of welding is of a high standard then partial peripheral welding may be accepted provided that welds are made only at the sides of the stud and that each run extends continuously for at least 25 per cent of the stud periphery. Weld start/stop positions are not to be located in the plane of the chain cable.

2.7.3 The welds are to be made by qualified welders using an approved procedure and consumables approved to Grade 3 and low hydrogen, in accordance with Chapter 11.

2.7.4 The welds are to be of good quality and free from defects liable to impair the proper use of the chain. Undercuts, end craters and similar stress raising defects shall, where necessary, be ground off.

2.7.5 At least one stud weld within each length of cable is to be inspected using dye penetrant testing in accordance with Ch 1,5 after the chain has been proof loaded. If a crack is found, the stud welds in the adjoining links are to be inspected; if a crack is found in either link, all the stud welds in that length are to be inspected using dye penetrant.

2.7.6 The size of the stud welds is to be in accordance with Fig. 10.3.1.

2.8 Heat treatment of completed chain cables

2.8.1 The completed chain cable is to be heat treated in accordance with Table 10.2.3 for the appropriate grade of cable.

2.8.2 Special consideration will be given to the heat treatment of certain types of drop forged chain cable.

2.8.3 In all cases, heat treatment is to be carried out prior to the proof loading and breaking tests.

2.8.4 All test samples are to be heat treated with, and in the same way as, the chain cables they represent.

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Table 10.2.1 Mechanical properties of finished chain cable and fittings

Grade	Yield stress N/mm² minimum	Tensile strength N/mm²	Elongation on $5{,}65\sqrt{S_o}$ % minimum	Reduction of area % minimum	Charpy V-notch impact tests	
					Test temperature °C	Average energy J minimum
U2	295	490 – 690	22	—	0 (*see* Note 1)	27
U3	410	690 minimum	17	40	0 –20 (*see* Note 2)	60 35

NOTES
1. When required *see* Table 10.2.3.
2. Testing may be carried out at either 0°C or –20°C.
3. Mechanical testing is not required for finished chain cables and fittings in Grade U1.

Table 10.2.2 Chemical composition of butt welded and forged chain cable

Grade	Chemical composition %												
	C max.	Si	Mn	P max.	S max.	Al	N max.	Cr max.	Cu max.	Nb max.	Ni max.	V max.	Mo max.
U1	0,20	0,15 – 0,35	0,40 min.	0,04	0,04	—	—	—	—	—	—	—	—
U2	0,24	0,15 – 0,55	1,60 max.	0,035	0,035	0,02 min. *see* Note 1	—	—	—	—	—	—	—
U3	0,33	0,15 – 0,35	1,90 max.	0,04	0,04	0,065 max. *see* Note 2	0,015	0,25	0,35	0,05 *see* Note 2	0,40	0,10 *see* Note 2	0,08

NOTES
1. Aluminium may be partly replaced by other grain refining elements.
2. To obtain fine grain steel, at least one of these grain refining elements must be present in sufficient amount.

Table 10.2.3 Condition of supply and scope of mechanical tests for finished chain cables and fittings

Grade	Manufacturing method	Condition of supply	Number of test specimens on every four lengths of chain cable of 27,5 m or less, or on each batch of fittings		
			Tensile test on base materials	Charpy V-notch impact test	
				Base material	Weldment
U1 cable	Flash butt welded	As welded Normalised	— —	— —	— —
U2 cable	Flash butt welded	As welded Normalised	1 —	3 —	3 —
U3 cable	Flash butt welded	Normalised Normalised and Tempered Quenched and Tempered	1	3	3
U2 cable	Cast or drop forged	Normalised	1	3	—
U3 cable	Cast or drop forged	Normalised Normalised and Tempered Quenched and Tempered	1	3	—
U2 fittings	Cast or drop forged	Normalised	1	3	—
U3 fittings	Cast or drop forged	Normalised Normalised and Tempered Quenched and Tempered	1	3	—

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2.9 Testing of completed chain cables

2.9.1 All chain cables are to be subjected to a Proof Load test and a Breaking Load test. In addition, mechanical tests should be carried out where required, *see* Table 10.2.3.

2.9.2 All chain cables are to be tested in the presence of a Surveyor, at a proving establishment recognised by LR. A list of recognised proving establishments is published separately by LR. In addition to the requirements stated in this Chapter, attention must be given to any relevant statutory requirements of the National Authority of the country in which the ship is to be registered.

2.10 Proof load tests

2.10.1 Each length of chain cable is to be subjected to a proof loading test in an approved testing machine and is to withstand the load given in Table 10.2.4 for the appropriate grade and size of cable.

2.10.2 On completion of the test, each link is to be visually examined and is to be free from significant defects. Special attention is to be given to welds.

2.10.3 Should any link be found to be defective it is to be replaced by an approved connecting link (joining shackle or substitute link as detailed in 2.14). The chain is then to be subjected to a repeat of the proof load test followed by re-examination.

2.10.4 If a link breaks during proof load testing, a sample consisting of three common links is to be taken from each side of the broken link and subjected to a breaking test as detailed in 2.10. If either of these samples fails, the length of cable is not to be accepted. A thorough examination of all broken links is to be made to determine the cause of failure and, after evaluation, LR will consider the extent of cable which is to be rejected.

2.11 Breaking load tests

2.11.1 Breaking load tests are to be carried out on three-link samples selected by the Surveyor from the completed (including heat treatment) chain. The test links may be removed from the chain prior to heat treatment provided that each sample is heat treated with, and in the same manner as the chain it represents. They are to be properly identified with the lengths of chain they represent.

2.11.2 The number of tests required is to be in accordance with Table 10.2.5 except that for chafing chain for Emergency Towing Arrangements (ETA), *see* Pt 3, Ch 13,10.2, one test is to be carried out on each 110 m of finished chains.

2.11.3 Breaking test specimens are to withstand the load given in Table 10.2.4 for the appropriate grade and size of cable. The specimen is considered to have passed this test if it has shown no sign of fracture after application of the required load for a minimum of 30 seconds.

2.11.4 Where a breaking test specimen fails, a further specimen is to be cut from the same length of cable and subjected to test. If this re-test fails, the length of cable from which it was taken is to be rejected. When this test is also representative of other lengths, each of the remaining lengths is to be individually tested by taking a breaking test specimen from each length of the batch. If one of these further tests fails, the entire set of lengths represented by the original test is to be rejected.

2.11.5 For large diameter cables where the required breaking load is greater than the capacity of the testing machines, special consideration will be given to acceptance of an alternative testing procedure.

2.12 Dimensional inspection

2.12.1 After proof testing, the entire chain is to be checked for length, five links at a time with an overlap of two links, which is to include the first five links, to ensure that the chain meets the tolerances given in 2.15.5. The measurements are to be made while the chain is loaded to about 10 per cent of the proof load.

2.12.2 The links held in the end blocks may be excluded from these measurements.

2.12.3 If a five link length of chain exceeds the tolerance given in 2.15.5, then the oversize links are to be removed and an approved connecting link inserted.

2.12.4 Checks of all other dimensions are to be made on three links, selected by the Surveyor, from every four 27,5 m lengths.

2.12.5 If one of the links detailed in 2.12.4 fails to comply with the required tolerances, measurements are to be made on a further five links in every four 27,5 m lengths.

2.12.6 If more than one link in a 27,5 m length of chain cable fails to meet the tolerance requirements, all the links in that length are to be measured.

2.12.7 All links failing to comply with the maximum dimensional tolerances are to be removed and replaced by connecting links of an approved type. The chain is then to be subjected to a further proof load test and re-examined.

2.12.8 If the length over five links is less than the nominal, then the chain may be stretched by loading above the specified proof test load provided that the applied load is not greater than ten per cent above the proof test load, and only random lengths of the chain need to be stretched.

2.12.9 Loads used for plastic straining to set studs are not to exceed 0,8 per cent of the proof load unless specifically approved for higher loads.

2.12.10 Paint or anti-corrosive coatings are not to be applied until these inspections are completed to the satisfaction of the Surveyor.

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Table 10.2.4 Test loads for stud link anchor chain cables

Chain diameter	Grade U1		Grade U2		Grade U3	
	Proof load kN	Breaking load kN	Proof load kN	Breaking load kN	Proof load kN	Breaking load kN
d mm	$0{,}00686d^2$ $(44-0{,}08d)$	$0{,}00981d^2$ $(44-0{,}08d)$	$0{,}00981d^2$ $(44-0{,}08d)$	$0{,}01373d^2$ $(44-0{,}08d)$	$0{,}01373d^2$ $(44-0{,}08d)$	$0{,}01961d^2$ $(44-0{,}08d)$
12,5	46	66	66	92	–	–
14	58	82	82	115	–	–
16	75	107	107	150	–	–
17,5	89	128	128	179	–	–
19	105	150	150	211	–	–
20,5	122	175	175	244	244	349
22	140	201	201	281	281	401
24	166	238	238	333	333	475
26	194	278	278	389	389	556
28	225	321	321	450	450	642
30	257	367	367	514	514	734
32	291	416	416	583	583	832
34	327	468	468	655	655	936
36	366	523	523	732	732	1045
38	406	580	580	812	812	1160
40	448	640	640	896	896	1280
42	492	703	703	984	984	1406
44	538	769	769	1076	1076	1537
46	585	837	837	1171	1171	1673
48	635	908	908	1270	1270	1814
50	686	981	981	1373	1373	1961
52	739	1057	1057	1479	1479	2113
54	794	1135	1135	1589	1589	2269
56	850	1216	1216	1702	1702	2430
58	908	1299	1299	1818	1818	2597
60	968	1384	1384	1938	1938	2767
62	1029	1472	1472	2060	2060	2943
64	1092	1562	1562	2187	2187	3123
66	1157	1655	1655	2316	2316	3308
68	1223	1749	1749	2448	2448	3496
70	1291	1846	1846	2583	2583	3690
73	1395	1995	1995	2792	2792	3988
76	1503	2149	2149	3007	3007	4295
78	1576	2254	2254	3154	3154	4505
81	1689	2415	2415	3380	3380	4827
84	1805	2580	2580	3612	3612	5158
87	1923	2750	2750	3849	3849	5498
90	2045	2924	2924	4093	4093	5845
92	2127	3042	3042	4258	4258	6081
95	2254	3223	3223	4510	4510	6442
97	2339	3345	3345	4682	4682	6687
100	2470	3532	3532	4943	4943	7060
102	2558	3658	3658	5120	5120	7312
105	2692	3850	3850	5389	5389	7697
107	2783	3980	3980	5571	5571	7957
111	2968	4245	4245	5941	5941	8486
114	3110	4447	4447	6224	6224	8889
117	3253	4652	4652	6511	6511	9299
120	3398	4859	4859	6801	6801	9714
122	3496	4999	4999	6997	6997	9994
124	3595	5141	5141	7195	7195	10276
127	3744	5354	5354	7494	7494	10703
130	3895	5571	5571	7796	7796	11135
132	3997	5716	5716	8000	8000	11426
137	4254	6083	6083	8514	8514	12161
142	4515	6456	6456	9036	9036	12906
147	4779	6834	6834	9565	9565	13662
152	5046	7217	7217	10100	10100	14426
157	5316	7602	7602	10640	10640	15197
162	5588	7991	7991	11185	11185	15975

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Table 10.2.5 Number of breaking tests from completed cables

Designation	Method of manufacture	Number of breaking test specimens
Grade U1	Flash-butt welded and heat treated	One from every four lengths of 27,5 m or less
Grade U2(a) U3(a)	Flash-butt welded, or drop forged and heat treated	One from every four lengths of 27,5 m or less
Grade U1 U2(a)	Flash-butt welded but not heat treated	One from each length of 27,5 m or less
Grade U2(b) U3(b)	Cast and heat treated	One per heat treatment batch with a minimum of one from every four lengths of 27,5 m or less

Table 10.2.6 Mechanical properties of welds in chain cables

Grade	Charpy V-notch impact test	
	Test temperature °C	Average energy J min
U1	—	—
U2	0 (*see* Note 1)	27
U3	0	50
	–20 (*see* Note 2)	27

NOTES
1. Impact tests are only required if the chain cable is not heat treated.
2. Impact testing may be carried out at 0°C or minus 20°C.

2.13 Fittings for chain cables

2.13.1 Cable fittings are to be manufactured at an approved works.

2.13.2 The materials from which the fittings are made are to be manufactured at approved works, in accordance with the appropriate requirements of Ch 4,1 or Ch 5,1 respectively. Alternative arrangements may be agreed provided that full details concerning the manufacturer are submitted to LR.

2.13.3 All fittings are to be manufactured to an approved manufacturing specification, and provision is to be made for tensile specimens and, where applicable, impact test specimens, *see* Table 10.2.3. The test samples are to be prepared in accordance with 2.4.3 or 2.5.4 as applicable. The test specimens are to be subjected to heat treatment with the fittings they represent. The mechanical test requirements are the same as those for the relevant grade of chain cable, *see* Table 10.2.1. A batch of fittings is to be of the same grade, size and heat treatment charge and to have originated from a single cast of steel. Enlarged and end links need not be tested provided that they are manufactured and heat treated together with the chain cable. Mechanical tests of pins are to be taken in accordance with 3.8.15.

2.13.4 Fittings such as shackles, swivels and swivel shackles are to be forged or cast in steel of at least Grade U2. The welded construction of fittings may also be approved providing that full details of the manufacturing process and the heat treatment are submitted.

2.13.5 All chain cable accessories, including spares, are to be subjected to the proof loads appropriate to the grade and size of cable for which they are intended. These include shackles, swivels, swivel shackles, enlarged links and end links. Anchor shackles, however, are to be tested in combination with the anchor, *see* 1.4.

2.13.6 The appropriate breaking load is to be applied for a minimum of 30 seconds to at least one item out of every batch of up to 25 (1 in 50 for lugless (Kenter) shackles), and this item is to be destroyed and not used as part of an outfit. For the purpose of break load testing, a batch of accessories is to be of the same grade, size and heat treatment charge and may consist of items from different casts, provided that the sample tested is from the cast with the lowest tensile properties. Enlarged and end links need not be tested provided that they are manufactured and heat treated together with the chain cable.

2.13.7 If the sample fails to withstand the breaking load without fracture, two more samples from the same batch may be tested. If either of these samples fails, the batch is to be rejected.

2.13.8 Where the items are of increased dimensions, and have been specially approved, or if material of a higher grade than is specified is used, then the breaking load is to be applied to each item, and the items so tested included with the outfit. For the purpose of this paragraph, items of increased dimensions are those so designed that their breaking strength is not less than 1,4 times the Rule minimum breaking load of the chain cable with which they are to be used.

2.13.9 LR may waive the breaking load test provided that:
(a) the breaking load test has been completed satisfactorily during approval testing, and
(b) the tensile and impact properties of each manufacturing batch are proved and
(c) the accessories are subjected to suitable non-destructive testing.

2.13.10 All testing is to be carried out in the presence of the Surveyor and to his satisfaction.

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2.13.11 All fittings are to be stamped in accordance with 2.16.

2.14 Substitute single links

2.14.1 Single links to connect lengths of chain cable or to substitute for defective links, without the necessity for re-heat treatment of the whole cable length, are to be made by the chain manufacturer in accordance with an approved procedure. Separate approvals are required for each grade of chain cable and the tests are to be made on the maximum size of chain for which approval is sought. Re-approval is required annually.

2.14.2 Manufacture and heat treatment of the substitute link are not to affect the strength of the adjoining links. The temperature reached by these links is nowhere to exceed 250°C.

2.14.3 The steel bar used is to conform with the specification for the chain in accordance with Ch 3,9.

2.14.4 Details of the method of manufacture, including heat treatment, are to be submitted for approval, together with the results of a series of tests laid down by LR.

2.14.5 All links involved in the approval tests are to be destroyed and are not to be used as part of a chain cable.

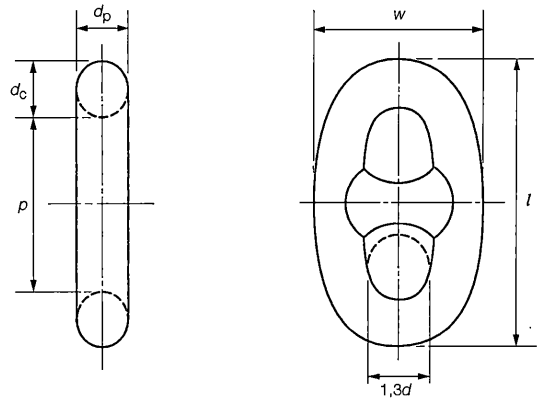
2.14.6 Every substitute link included in a chain cable is to be subjected to the proof load appropriate to the grade and size of chain in which it is incorporated, as detailed in Table 10.2.4.

2.14.7 Each substitute link is to be stamped on the stud with the identification marks listed in 2.16.1 plus a unique number for the link. The adjoining links are also to be stamped on the studs.

2.15 Dimensions and tolerances

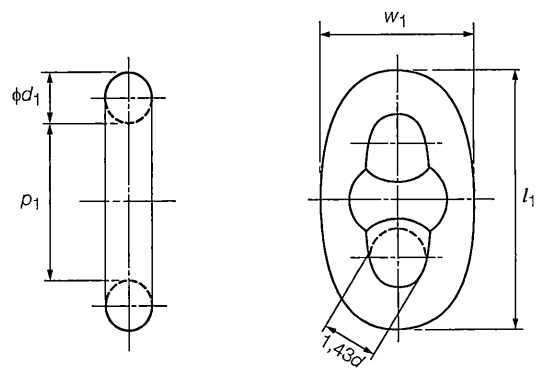
2.15.1 The form and proportion of links and shackles are to be in accordance with ISO/1704-2008, *see* Figs. 10.2.1 to 10.2.8. Design of chain cables must be to a standard recognised by LR, such as ISO 1704; alternatively the design may be specifically approved by LR.

2.15.2 Manufacturing tolerances on stud link chain are to be within ±2,5 per cent (taking into account that all components of the chain are to be a good fit with one another), except for those detailed in 2.15.3.



d_c = nominal diameter at crown measured in plane of link
d_p = nominal diameter at crown measured perpendicular to plane of link
l = 6d
p = 4d
w = 3,6d to the nearest millimetre

Fig. 10.2.1 Common link



d = nominal diameter of common stud link
d_1 = nominal diameter of enlarged stud link = 1,1d
l_1 = $6d_1 \approx 6{,}6d$
p_1 = $4d_1 \approx 4{,}4d$
w_1 = $3{,}6d_1 \approx 3{,}96d$

Fig. 10.2.2 Enlarged link

2.15.3 The nominal diameter, d, is to be the average of the diameters, measured in the plane of the link, d_c, and perpendicular to the plane of the link, d_p, *see* Fig. 10.2.1. The negative tolerance on the nominal diameter is not to exceed the following:

Minus 1 mm when $d \leq 40$ mm
Minus 2 mm when 40 mm $< d \leq 84$ mm
Minus 3 mm when 84 mm $< d \leq 122$ mm
Minus 4 mm when $d > 122$ mm

The plus tolerance on the diameter at the crown measured out of the plane of the link, d_p, is not to exceed 5 per cent.

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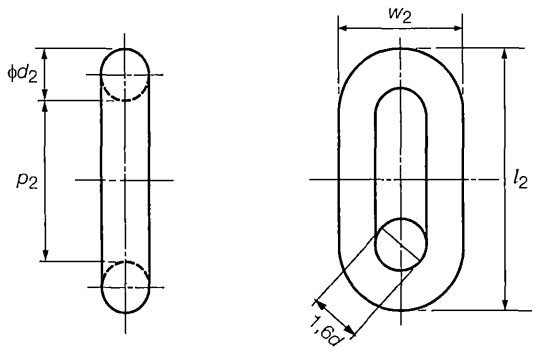

d = nominal diameter of common stud link
d_2 = nominal diameter of end link = 1,2d (d_2 – 1,2d)
l_2 = $p_2 + 2d_2 \approx 6{,}75d$
p_2 = $3{,}65d_2 \approx 4{,}35d$
w_2 = $3{,}3d_2 \approx 4d$

Fig. 10.2.3 End link

2.15.4 The cross-sectional area is to be calculated using the nominal diameter, d. The cross-sectional area at the crown of the link is to have no negative tolerance.

2.15.5 The diameter measured at locations other than the crown is to have no negative tolerance. The plus tolerance is to be in accordance with Table 3.9.3 of Chapter 3 except at the butt weld where it is to be in accordance with the manufacturer's specification, which is to be agreed by LR.

2.15.6 The maximum allowable tolerance on a length of five links measured in accordance with 2.12.1 is plus 2,5 per cent. No under-tolerance is permitted.

2.15.7 All measurements are to be made on links selected by the Surveyor and are to be carried out to the Surveyor's satisfaction.

2.15.8 Studs are to be located in the links centrally, and at right angles to the sides of the link, although the studs of the final link at each end of any length may also be located off-centre to facilitate the insertion of the joining shackle. Tolerances in accordance with Fig. 10.3.1 are acceptable provided that the stud fits snugly and its ends lie flush against the inside of the link.

2.15.9 The following tolerances are applicable to accessories:

Nominal diameter: plus 5 per cent, minus 0 per cent
Other dimensions: ±2,5 per cent.

2.15.10 For lugless shackles of the Kenter type, the radii indicated in Fig. 10.2.8 are to be not less than 0,03 times the chain diameter.

2.15.11 All materials are to be free from internal and surface defects that might impair proper workability, use and strength. Subject to agreement by the Surveyor, surface defects may be removed by grinding provided the acceptable tolerances are not exceeded.

2.16 Identification

2.16.1 All lengths of Grades U1, U2 and U3 cable and all fittings are to be stamped with the following identification marks:

(a) LR or Lloyd's Register and abbreviated name of LR's local office issuing the certificate.
(b) Number of certificate.
(c) Proof load and grade of chain.
(d) Surveyor's personal stamp.
(e) Each length of chain cable is to be stamped on both ends.

2.17 Certification

2.17.1 An LR certificate is to be issued for chain cable only, fittings only or chain cable with associated fittings.

2.17.2 Each test certificate is to include the following particulars for all items included on the certificate:

(a) Purchaser's name and order number.
(b) Description and dimensions.
(c) Grade of chain cable.
(d) Identification mark which will enable the full history of the chain or fitting to be traced.
(e) Chemical composition.
(f) Details of heat treatment.
(g) Mechanical test results.
(h) Breaking test load.
(j) Proof load.

2.17.3 Where appropriate, the certificate is to include a list of all substitute links together with their grade of steel, the name of the steelmaker, the heat number and the purchase order number.

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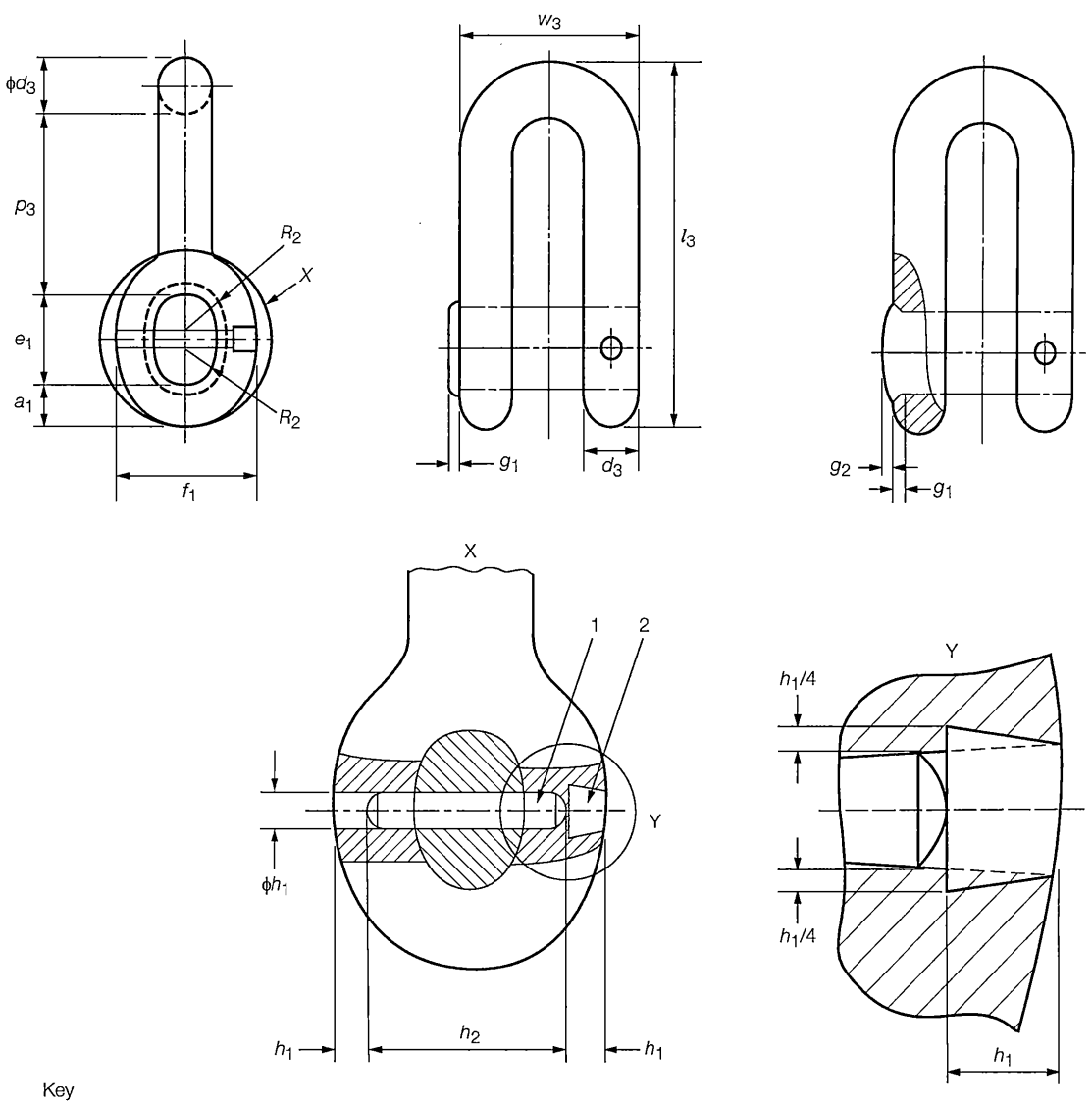

Key
X retaining pin
Y dovetail chamber

d	=	nominal diameter of common stud link	f_1	=	2,8d
d_3	=	nominal diameter of joining shackle = 1,3d	g_1	=	0,2d
l_3	=	7,1d	g_2	=	0,1d
p_3	=	$l_3 - (d_3 + a_1 + e_1) = 3{,}4d$	h_1	=	nominal diameter of taper pin
w_3	=	4d	h_2	=	nominal length of taper pin
a_1	=	0,8d	R_1	=	0,6d
e_1	=	1,6d	R_2	=	0,5d

Fig. 10.2.4 End shackle

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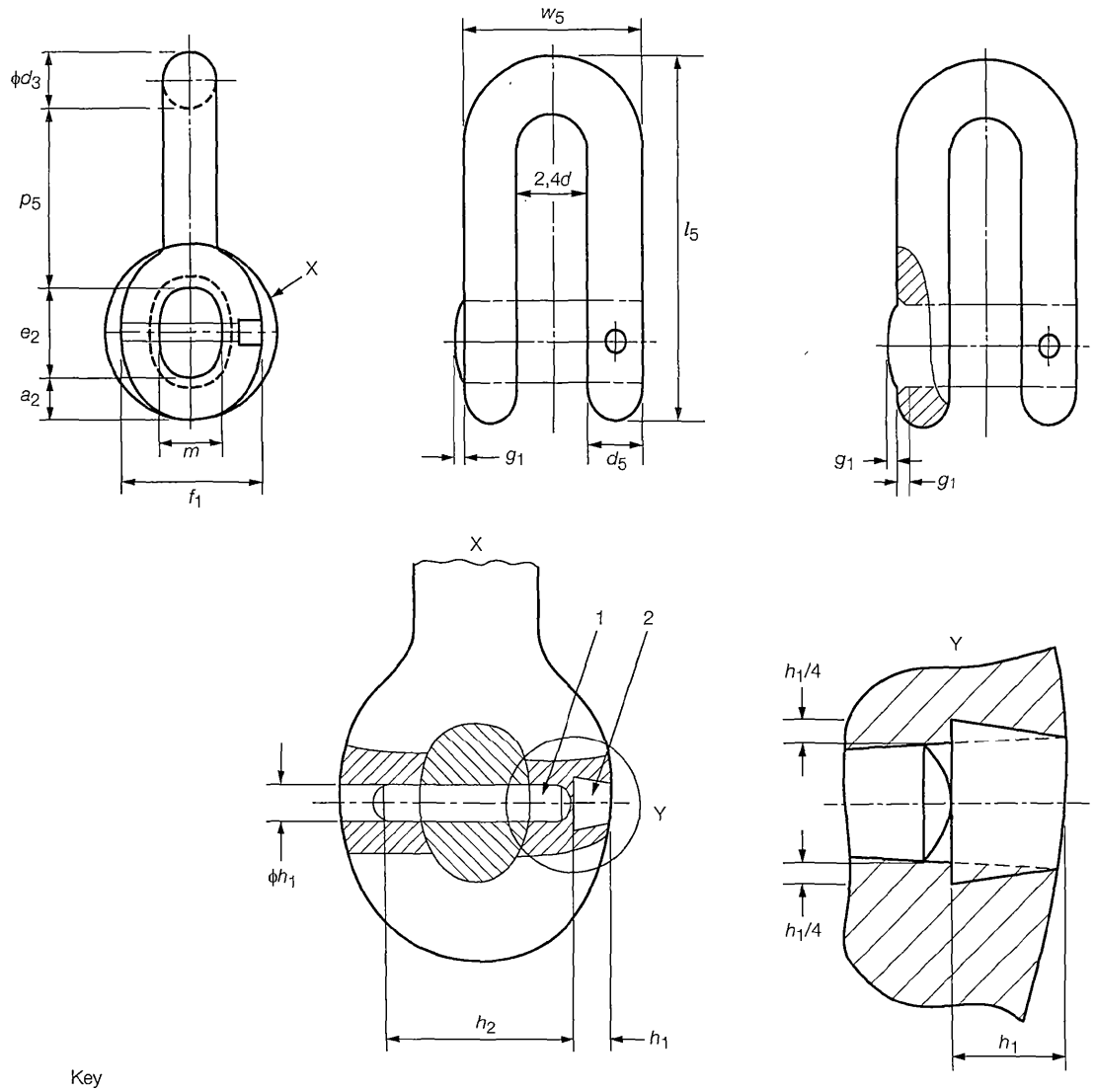

Key
X retaining pin
Y dovetail chamber

d	=	nominal diameter of common stud link	f_2	=	3,1d
d_5	=	nominal diameter of end shackle = 1,4d	g_1	=	0,2d
l_5	=	8,7d	g_2	=	0,1d
p_5	=	$l_5 - (d_3 + a_2 + e_2) = 4{,}5d$	m	=	1,4d
w_5	=	5,2d	h_1	=	nominal diameter of taper pin
a_2	=	0,9d	h_2	=	nominal length of taper pin
e_2	=	1,8d			

Fig. 10.2.5 Dee shackle

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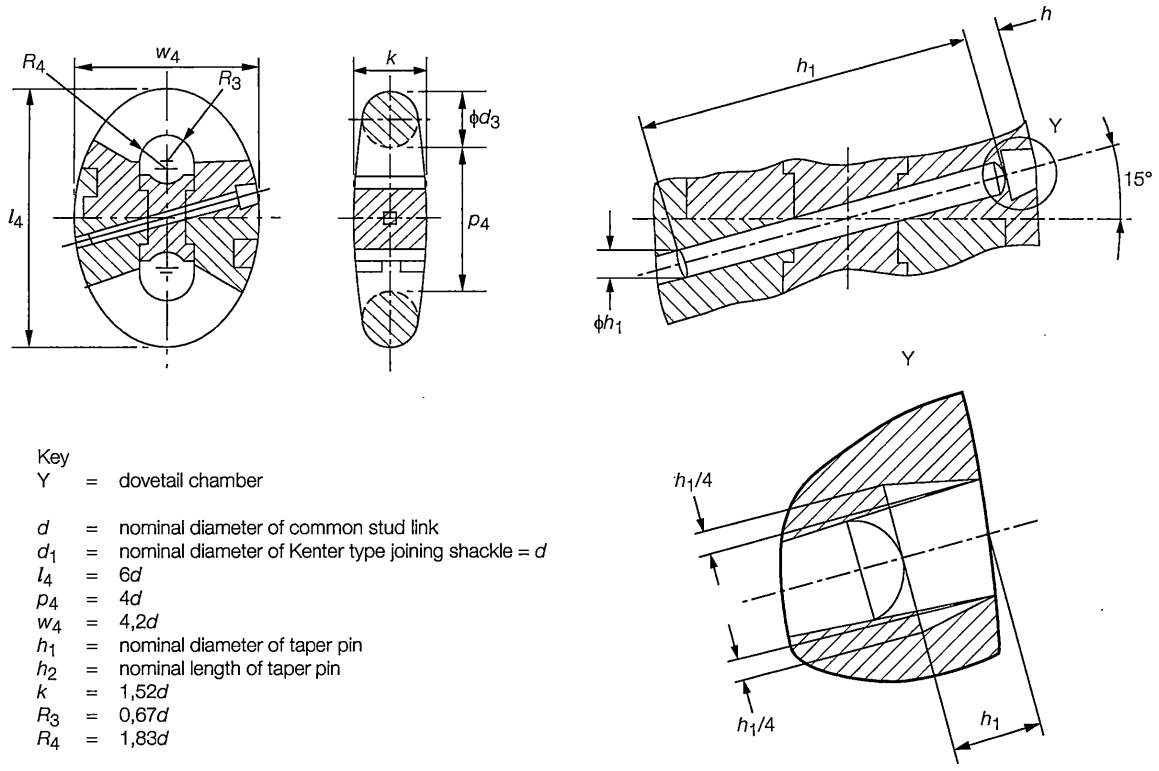
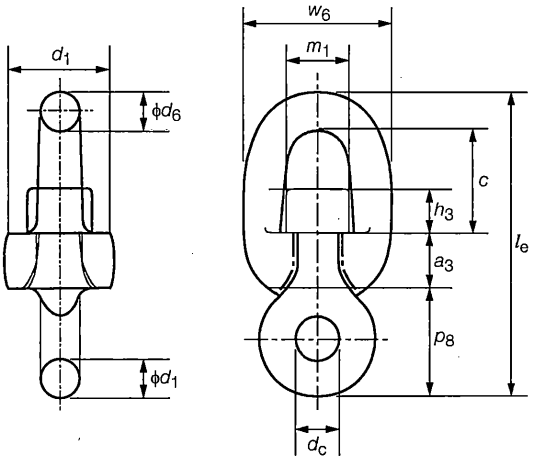


Key
Y = dovetail chamber

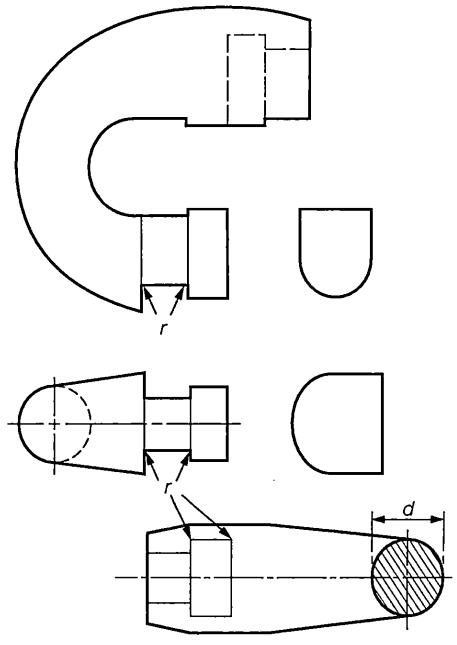
d = nominal diameter of common stud link
d_1 = nominal diameter of Kenter type joining shackle = d
l_4 = $6d$
p_4 = $4d$
w_4 = $4{,}2d$
h_1 = nominal diameter of taper pin
h_2 = nominal length of taper pin
k = $1{,}52d$
R_3 = $0{,}67d$
R_4 = $1{,}83d$

Fig. 10.2.6 Lugless shackle



d = nominal diameter of common stud link
d_6 = nominal diameter of swivel = $1{,}2d$
l_e = $9{,}7d$
p_e = $d_g - 3{,}4d$
w_6 = $4{,}7d$
d_7 = $1{,}1d$
a_3 = $1{,}76d$
m_1 = $2d$
h_3 = $d_g - 1{,}4d$
c = $3{,}35d$

Fig. 10.2.7 Swivel



The radii indicated by r are to be not less than 0,03 x d

Fig. 10.2.8 Lugless shackle of the Kenter type

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■ *Section 3*
Stud link mooring chain cables

3.1 Scope

3.1.1 Provision is made in this Section for five grades, R3, R3S, R4, R4S and R5, of stud link chain intended for offshore mooring applications such as mooring of mobile offshore units, offshore loading systems and gravity based structures during fabrication.

3.1.2 In addition, chain cable conforming to the requirements of the current edition of API specification 2F is acceptable provided that it has been manufactured, inspected and tested under Survey by LR, and that the bar stock has also been certified by LR in accordance with Ch 3,9.

3.2 Manufacture

3.2.1 All grades of chain cable and accessories are to be manufactured by approved procedures at works approved by LR. A list of approved manufacturers for stud link chain cables is published separately by LR.

3.2.2 The works in which the chain is manufactured is to have a quality system approved by LR. The provision of such a quality system is required in addition to and not in lieu of the witnessing of tests by a Surveyor.

3.2.3 Approval is confined to a single works and is limited to one grade of cable made from bar from a nominated and approved supplier. Separate approvals are required if steel bar is supplied from more than one works and for other grades of cable, *see also* Ch 3,9.

3.2.4 Details of the method of manufacture and the specification of the steel, are to be submitted.

3.2.5 Offshore mooring chains are to be made in continuous lengths by flash-butt welding.

3.2.6 Bar material may be heated either by electric resistance or in a furnace. For electrical resistance heating, the process is to be controlled by an optical heat sensor. For furnace heating, thermocouples in close proximity to the bars are to be used for control and the temperature is to be continuously recorded. In both cases, the controls are to be checked at least once every eight hours and records taken.

3.2.7 The following welding parameters (as approved in the weld procedure) are to be controlled during welding of each link:

(a) platen motion;
(b) current as a function of time; and
(c) hydraulic pressure.

The controls are to be checked at least once every four hours.

3.2.8 The records of bar heating, flash-butt welding and heat treatment are to be made available to the Surveyor when required.

3.2.9 As far as practicable, consecutive links in all chain cable should originate from a single batch of bar stock (*see* Ch 3,9.6.1) and indicating marks should be stamped on the final link formed from one batch and the first link formed from a separate batch.

3.3 Dimensions and tolerances

3.3.1 The form and proportions of links and shackles are to be in accordance with ISO/1704-2008, *see* Figs. 10.2.1 to 10.2.8. Design of chain cables must be to a recognised standard, such as ISO 1704; alternatively the design may be specifically approved by LR. Link tolerances are to be in accordance with 3.3.2 to 3.3.6.

3.3.2 Diameter measured at the crown:

Minus 1 mm when $d_c \leq 40$ mm
Minus 2 mm when 40 mm $< d_c \leq 84$ mm
Minus 3 mm when 84 mm $< d_c \leq 122$ mm
Minus 4 mm when 122 mm $< d_c \leq 152$ mm
Minus 6 mm when 152 mm $< d_c \leq 184$ mm
Minus 7,5 mm when 184 mm $< d_c \leq 210$ mm

The plus tolerance must not exceed 5 per cent of the nominal diameter, and the cross-sectional area at the crown is to have no negative tolerance.

3.3.3 The diameter measured at locations other than the crown is to have no negative tolerance. The plus tolerance is to be in accordance with Table 3.9.3 except at the butt weld where it is to be in accordance with the manufacturer's specification, which is to be agreed by LR.

3.3.4 The maximum allowable tolerance on a length of five links measured in accordance with 2.12.1 is +2,5 per cent. No under-tolerance is permitted.

3.3.5 A manufacturing tolerance on all other dimensions of ±2,5 per cent is acceptable subject to all parts fitting properly together.

3.3.6 The tolerances for common links are to be measured in accordance with Fig. 10.3.3.

3.3.7 All measurements are to be made on links selected by the Surveyor and are to be carried out to the Surveyor's satisfaction.

3.3.8 Studs are to be located in the links centrally, and at right angles to the sides of the link, although the studs of the final link at each end of any length may also be located off-centre to facilitate the insertion of the joining shackle. The tolerances in accordance with Fig. 10.3.2 are acceptable provided that the stud fits snugly and its ends lie flush against the inside of the link.

3.4 Studs

3.4.1 The studs are to be made of steel corresponding to that of the chain or in compliance with a specification approved by LR. In general, the carbon content should not exceed 0,23 per cent if the studs are to be welded in place.

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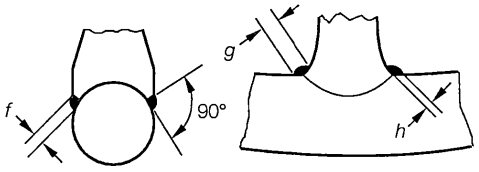
3.4.2 Studs may be welded into grade R3 and R3S chains. The welding of studs into grade R4, R4S and R5 chain is not permitted unless specially approved.

3.4.3 In all cases where studs are welded into links, this is to be carried out in accordance with 2.7.

3.4.4 The size of the stud welds is to be in accordance with Fig. 10.3.1.



Dimension Designation	Nominal Dimension	Minus Tolerance
f	0,10*d*	0,01*d*
g	0,20*d*	0,02*d*
h	0,09*d*	0,01*d*

d = Nominal diameter of barstock

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Fig. 10.3.1
Dimensions and tolerances of stud welds

3.4.5 All stud welds are to be visually inspected. At least 10 per cent of all stud welds within each length of chain are to be examined by magnetic particle inspection after proof load testing. Stress raising defects such as cracks, lack of fusion, gross porosity, and undercuts exceeding 1 mm are not permitted; if any such defects are found, then all stud welds in that length of chain are to be examined by means of magnetic particle inspection.

3.4.6 Where plastic straining is used to set studs, the applied load is not to be greater than that qualified in approval tests. The combined effect of shape and depth of the impression of the stud in the link is not to cause any harmful notch effect or stress concentration.

3.5 Heat treatment of completed chain cables

3.5.1 The chain is to be normalised, normalised and tempered or quenched and tempered in accordance with the specification approved by LR.

3.5.2 The chains are to be heat treated in a continuous furnace; batch heat treatment is not permitted.

3.5.3 The temperature and time, or temperature and chain speed, are to be controlled and continuously recorded.

3.5.4 Heat treatment is to be carried out prior to the proof loading and breaking tests.

3.5.5 Calibration of furnaces is to be verified by measurement and recording of actual link temperature (surface and internal).

3.6 Testing of completed chain cables

3.6.1 All chain cables are to be tested in the presence of a Surveyor, at a proving establishment recognised by LR. A list of recognised proving establishments is published by LR. In addition to the requirements stated in this Chapter, attention must be given to any relevant statutory requirements of the National Authority of the country in which the ship is to be registered.

3.6.2 The entire length of chain cable is to be subjected to a proof loading test in an approved testing machine and is to withstand the load given in Table 10.3.1 for the appropriate grade and size of cable.

3.6.3 Care should be taken to obtain a uniform stress distribution in the links being tested.

3.6.4 The chain is to be shot or sand blasted prior to testing in order to ensure that its surfaces are free from scale, paint or other coating for inspection.

3.6.5 On completion of the proof load test, each link is to be visually examined and is to be free from significant defects such as mill defects, surface cracks, dents and cuts, especially where gripped by clamping dies during flash butt welding. Studs are to be securely fastened and any burrs, irregularities and rough edges are to be removed by careful grinding.

3.6.6 All flash butt welds, including the area gripped by the clamping dies, are to be examined by magnetic particle inspection. The area is to be free from cracks, lack of fusion, gross porosity and any other stress concentrations.

3.6.7 Surface defects in the region of the flash butt welds may be removed by grinding, provided that the depth of grinding does not exceed five per cent of the link diameter and is smoothly contoured into the surrounding material. The final dimensions are still to conform with the agreed standard.

3.6.8 All flash butt welds are also to be examined by ultrasonic inspection and are to be free from defects such as internal cracks or lack of fusion.

3.6.9 All non-destructive examination is to be carried out in accordance with approved procedures, in accordance with Ch 1,5.

3.6.10 All non-destructive examination operators are to be qualified to a minimum Level II, qualified in accordance with a recognised standard.

3.6.11 After proof testing, the entire chain is to be checked for length, five links at a time with an overlap of two links, which is to include the first five links, to ensure that the chain meets the tolerances given in 2.15.5. The measurements are to be made while the chain is loaded to about 10 per cent of the proof load.

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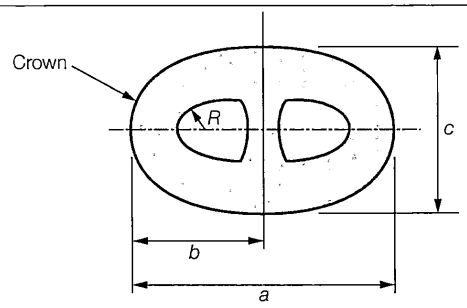
Fig. 10.3.2 Stud link tolerances

The internal link radii (*R*) and external radii should be uniform



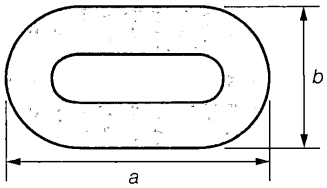
Designation	Description	Nominal dimension of the link	Minus tolerance	Plus tolerance
a	Link length	6*d*	0,15*d*	0,15*d*
b	Link half length	*a**/2	0,10*d*	0,10*d*
c	Link width	3,6*d*	0,09*d*	0,09*d*
e	Stud angular misalignment	0 degrees	4 degrees	4 degrees
R	Inner radius	0,65*d*	0	—

Symbols

d = nominal diameter of chain
*a** = actual link length

Fig. 10.3.3 Studless and common link tolerances

The internal link radii (*R*) and external radii should be uniform



Designation	Description	Nominal dimension of the link	Minus tolerance	Plus tolerance
a	Link length	6*d*	0,15*d*	0,15*d*
b	Link width	3,35*d*	0,09*d*	0,09*d*
R	Inner radius	0,60*d*	0	—

Symbols

d = nominal diameter of chain

NOTE
Other dimensional ratios are subject to special approval.

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Table 10.3.1 Test loads for mooring chain cables *(continued)*

Nominal diameter *d*	Grade R3			Grade R3S			Grade R4			Grade R4S			Grade R5		
	Proof test load		Break test load	Proof test load		Break test load	Proof test load		Break test load	Proof test load		Break test load	Proof test load		Break test load
	Stud link chain	Studless chain		Stud link chain	Studless chain		Stud link chain	Studless chain		Stud link chain	Studless chain		Stud link chain	Studless chain	
mm	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN
50	1480	1480	2230	1800	1740	2490	2160	1920	2740	2400	2130	3040	2510	2230	3200
52	1594	1594	2402	1939	1874	2682	2327	2068	2952	2585	2295	3275	2704	2402	3447
54	1712	1712	2580	2083	2013	2881	2499	2222	3170	2777	2465	3517	2904	2580	3703
56	1834	1834	2764	2231	2156	3086	2677	2380	3396	2974	2640	3768	3111	2764	3966
58	1960	1960	2953	2383	2304	3297	2860	2542	3628	3178	2820	4025	3323	2953	4237
60	2089	2089	3147	2540	2455	3514	3048	2710	3867	3387	3006	4290	3542	3147	4516
62	2221	2221	3347	2701	2611	3737	3242	2881	4112	3602	3196	4562	3767	3347	4802
64	2357	2357	3551	2867	2771	3965	3440	3058	4364	3822	3392	4841	3997	3551	5096
66	2496	2496	3761	3036	2935	4200	3643	3238	4621	4048	3593	5127	4233	3761	5397
68	2639	2639	3976	3209	3102	4440	3851	3423	4885	4279	3798	5420	4475	3976	5706
70	2785	2785	4196	3387	3274	4685	4064	3613	5156	4516	4008	5720	4723	4196	6021
73	3010	3010	4535	3660	3538	5064	4392	3904	5572	4881	4331	6182	5104	4535	6507
76	3242	3242	4884	3942	3811	5454	4731	4205	6001	5257	4665	6658	5498	4884	7009
78	3400	3400	5123	4135	3997	5720	4962	4411	6295	5514	4893	6984	5766	5123	7351
81	3643	3643	5490	4431	4283	6130	5317	4726	6745	5908	5243	7484	6179	5490	7877
84	3893	3893	5866	4735	4577	6550	5682	5051	7208	6313	5603	7997	6602	5866	8418
87	4149	4149	6252	5046	4878	6981	6056	5383	7682	6729	5972	8523	7037	6252	8971
90	4412	4412	6647	5365	5187	7422	6439	5723	8167	7154	6349	9062	7482	6647	9539
92	4590	4590	6916	5582	5396	7722	6699	5954	8497	7443	6606	9428	7784	6916	9924
95	4862	4862	7326	5913	5716	8180	7096	6307	9001	7884	6997	9987	8246	7326	10512
97	5047	5047	7604	6138	5933	8490	7365	6547	9343	8184	7263	10366	8559	7604	10911
100	5328	5328	8028	6480	6264	8964	7776	6912	9864	8640	7668	10944	9036	8028	11520
102	5519	5519	8315	6712	6488	9285	8054	7159	10217	8949	7942	11336	9359	8315	11932
105	5809	5809	8753	7065	6829	9773	8478	7536	10754	9420	8360	11932	9851	8753	12560
107	6005	6005	9048	7304	7060	10103	8764	7790	11118	9738	8643	12335	10184	9048	12984
111	6404	6404	9650	7789	7529	10775	9347	8308	11856	10385	9217	13154	10861	9650	13847
114	6709	6709	10109	8159	7887	11287	9791	8703	12420	10879	9655	13780	11378	10109	14506
117	7018	7018	10574	8535	8251	11807	10242	9104	12993	11380	10100	14415	11902	10574	15174
120	7331	7331	11047	8916	8619	12334	10700	9511	13573	11889	10551	15059	12434	11047	15852
122	7542	7542	11365	9173	8868	12690	11008	9785	13964	12231	10855	15493	12792	11365	16308
124	7755	7755	11686	9432	9118	13048	11319	10061	14358	12576	11161	15930	13153	11686	16768
127	8078	8078	12171	9824	9497	13591	11789	10479	14955	13099	11626	16592	13700	12171	17466
130	8404	8404	12663	10221	9880	14139	12265	10903	15559	13628	12095	17262	14253	12663	18171
132	8623	8623	12993	10488	10138	14508	12585	11187	15965	13984	12411	17713	14625	12993	18645
137	9178	9178	13829	11162	10790	15441	13395	11906	16992	14883	13209	18852	15565	13829	19844

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Table 10.3.1 Test loads for mooring chain cables (*conclusion*)

Nominal diameter *d*	Grade R3			Grade R3S			Grade R4			Grade R4S			Grade R5		
	Proof test load		Break test load	Proof test load		Break test load	Proof test load		Break test load	Proof test load		Break test load	Proof test load		Break test load
	Stud link chain	Studless chain		Stud link chain	Studless chain		Stud link chain	Studless chain		Stud link chain	Studless chain		Stud link chain	Studless chain	
mm	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN
142	9741	9741	14677	11847	11452	16388	14216	12637	18033	15796	14019	20008	16520	14677	21061
147	10311	10311	15536	12540	12122	17347	15048	13376	19089	16720	14839	21179	17487	15536	22294
152	10887	10887	16405	13241	12800	18317	15890	14124	20156	17655	15669	22363	18464	16405	23540
157	11469	11469	17282	13949	13484	19297	16739	14879	21234	18599	16507	23559	19452	17282	24799
162	12056	12056	18166	14663	14174	20284	17596	15641	22320	19551	17351	24764	20447	18166	26068
167	12647	12647	19056	15381	14869	21278	18458	16407	23414	20508	18201	25977	21448	19056	27345
172	13240	13240	19950	16103	15566	22276	19324	17177	24513	21471	19055	27196	22455	19950	28628
177	13836	13836	20847	16827	16267	23278	20193	17949	25615	22437	19912	28420	23465	20847	29915
182	14433	14433	21746	17553	16968	24282	21064	18723	26720	23404	20771	29645	24477	21746	31205
187	15029	15029	22646	18279	17670	25286	21935	19498	27825	24372	21630	30871	25489	22646	32496
192	15626	15626	23544	19004	18371	26289	22805	20271	28929	25339	22488	32096	26500	23544	33785
197	16220	16220	24440	19727	19070	27290	23673	21043	30029	26303	23344	33317	27509	24440	35071
202	16813	16813	25332	20448	19766	28286	24537	21811	31126	27264	24196	34534	28513	25332	36351
207	17401	17401	26220	21164	20459	29277	25397	22575	32216	28219	25044	35744	29512	26220	37625
210	17753	17753	26749	21591	20872	29868	25910	23031	32867	28788	25550	36465	30108	26749	38385

Grade R3		
Proof test load	Stud link chain	$0{,}0148d^2\ (44 - 0{,}08d)$
	Studless chain	$0{,}0148d^2\ (44 - 0{,}08d)$
Break test load		$0{,}0223d^2\ (44 - 0{,}08d)$
Grade R3S		
Proof test load	Stud link chain	$0.0180d^2\ (44 - 0{,}08d)$
	Studless chain	$0{,}0174d^2\ (44 - 0{,}08d)$
Break test load		$0{,}0249d^2\ (44 - 0{,}08d)$
Grade R4		
Proof test load	Stud link chain	$0{,}0216d^2\ (44 - 0{,}08d)$
	Studless chain	$0{,}0192d^2\ (44 - 0{,}08d)$
Break test load		$0{,}0274d^2\ (44 - 0{,}08d)$
Grade R4S		
Proof test load	Stud link chain	$0{,}0240d^2\ (44 - 0{,}08d)$
	Studless chain	$0{,}0213d^2\ (44 - 0{,}08d)$
Break test load		$0{,}0304d^2\ (44 - 0{,}08d)$
Grade R5		
Proof test load	Stud link chain	$0{,}0251d^2\ (44 - 0{,}08d)$
	Studless chain	$0{,}0223d^2\ (44 - 0{,}08d)$
Break test load		$0{,}0320d^2\ (44 - 0{,}08d)$

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3.6.12 The links held in the end blocks may be excluded from these measurements.

3.6.13 If the length over five links is less than the nominal, the chain may be stretched by loading above the specified proof test load provided that the applied load is not greater than ten per cent above the proof test load, and that only random lengths of the chain need to be stretched.

3.6.14 Loads used for plastic straining to set studs are not to exceed those approved in qualification tests.

3.6.15 Checks of all other dimensions are to be made on at least five per cent of the links in the cable.

3.6.16 If any link fails to meet the dimensional tolerance requirements (*see* 3.3), measurements are to be made on 20 more links on each side of the incorrect one. If failure to meet any particular dimensional requirements occurs in more than two of the measured links, then all the links are to be dimensionally checked.

3.6.17 Should any link be found to be defective or fail to meet the dimensional tolerance requirements or if a five link length of chain exceeds the specified tolerance, the unsatisfactory links are to be removed from the chain, and connecting common links complying with the requirements of 3.7 inserted in their places.

3.6.18 The chain is then to be subjected to a further proof load test and re-examined.

3.6.19 The number of connecting common links which may be used to replace defective links is not to exceed three in any 100 m length of chain. The number and type of joining shackles which may be used are to be subject to the written agreement of the end user.

3.6.20 If a link breaks during proof load testing, a sample consisting of three common links is to be taken from each side of the broken link and subjected to a breaking test as detailed in 3.6.21 and 3.6.22. If either of these samples fails, the proof loaded length of cable is not to be accepted. A thorough examination of all broken links is to be made to determine the cause of failure and, after evaluation, LR will consider the extent of cable which is to be rejected and also the possibility that similar factors to those which caused the failure may also be present in other parts of the cable, or other chain cables. The Surveyor is to be advised in advance of all examinations, with reasonable notice being given.

3.6.21 In addition to the requirements of 3.6.2, three link samples are to be selected by the Surveyors from the completed chain for breaking tests. The number of tests required is to be in accordance with Table 10.3.2. Extra links are to be provided for the mechanical tests detailed in 3.6.25. All test links are to be made as part of the chain cable and are to be heat treated with it. These may be removed from the cable prior to heat treatment provided that each sample is heat treated with, and in the same manner as, the chain it represents and is subjected to the proof load appropriate to the chain grade and diameter prior to selection of the mechanical test specimens. They are to be properly identified with the length of chain they represent.

Table 10.3.2 Frequency of break and mechanical tests

Nominal chain diameter mm	Maximum sampling interval m (*See* Note)
Min. — 48	91
49 — 60	110
61 — 73	131
74 — 85	152
86 — 98	175
99 — 111	198
112 — 124	222
125 — 137	250
138 — 149	274
150 — 162	297
163 — 175	322
176 — 186	346
187 — 199	370
199 — 210	395

NOTE
If the sampling interval contains links made from more than one cast, extra break and mechanical tests are required so that tests are made on every cast.

3.6.22 Breaking test specimens are to withstand the load given in Table 10.3.1 for the appropriate grade and size of cable for a period of 30 seconds. The specimen is considered to have passed this test if it has shown no sign of fracture after application of the required load.

3.6.23 If a breaking test specimen fails, two further specimens are to be cut from the same sampling length and both are to be subjected to the breaking test load. If one of the re-test specimens fails the length is to be rejected. All the broken links are to be subjected to an investigation into the cause of failure. LR will then decide which lengths of chain can be accepted and on further action.

3.6.24 For large diameter cables where the required breaking load is greater than the capacity of the testing machines, special consideration will be given to acceptance of an alternative testing procedure.

3.6.25 One tensile and three sets of Charpy V-notch impact test specimens are to be taken from links cut from the heat treated and proof loaded chain at intervals no greater than those indicated in Table 10.3.2 provided that every cast is sampled. The tensile specimen and one set of impact specimens are to be taken from the side of the link opposite the weld. One set of impact test specimens is to have the notches positioned at the centre of the flash butt weld and the third set is to be taken from the bend. All the specimens are to be taken from positions in accordance with Fig. 10.3.4.

3.6.26 The frequency of testing at the link bends may be reduced at the discretion of LR provided it can be verified that the required toughness is achieved consistently.

3.6.27 The results of the mechanical tests are to comply with the requirements of Table 10.3.3.

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Table 10.3.3 Mechanical properties of chain cable materials

Grade	Yield stress N/mm² minimum	Tensile strength N/mm²	Elongation % minimum	Reduction of area % minimum (*See* Note 3)	Charpy V-notch impact tests		
					Test temperature °C	Average energy J minimum	Average energy flash weld J minimum
R3	410 (*See* Note 1)	690 minimum (*See* Note 1)	17	50	0 –20 (*See* Note 2)	60 40	50 30
R3S	490 (*See* Note 1)	770 minimum (*See* Note 1)	15	50	0 –20 (*See* Note 2)	65 45	53 33
R4	580 (*See* Note 1)	860 minimum (*See* Note 1)	12	50	–20	50	36
R4S (*See* Note 4)	700 (*See* Note 1)	960 (*See* Note 1)	12	50	–20	56	40
R5 (*See* Note 4)	760 (*See* Note 1)	1000 (*See* Note 1)	12	50	–20	58	42

NOTES
1. The ratio of yield strength to tensile strength should not exceed 0,92.
2. Testing may be carried out at either 0°C or –20°C.
3. For cast fittings, the minimum values for reduction of area are to be 40% for Grades R3 and R3S and 35% for Grades R4, R4S and R5.
4. The maximum hardness for Grade R4S is to be HB330, and for Grade R5 is to be HB340.

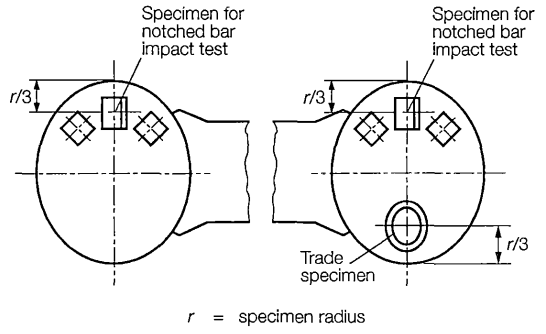

Fig. 10.3.4 Sampling of chain links

3.6.28 If the tensile test requirements are not achieved, two further specimens from the same sample are to be tested. The related length of chain will be considered acceptable if both re-test specimens meet the requirements but failure of either of the re-test specimens will result in rejection of the sampling length of chain represented by the tests.

3.6.29 If the impact test requirements are not achieved, re-tests may be carried out in accordance with Ch 1,2.4. Failure to meet the re-test requirements will result in rejection of the sampling length of chain represented by the tests.

3.6.30 The mass per unit length of stud link mooring cable is to comply with Table 10.3.4.

3.7 Connecting common links or substitute links

3.7.1 Single links to connect lengths of heat treated chain cable or to substitute for test links or defective links without the necessity for re-heat treatment of the whole length of cable are to be made by the chain manufacturer in accordance with an approved procedure. Separate approvals are required for each grade of chain cable and tests are to be made on the maximum size of chain for which approval is sought.

3.7.2 Manufacture and heat treatment of the connecting common link is not to affect the strength of the adjoining links. The temperature reached by these links is nowhere to exceed 250°C.

3.7.3 The steel bar used is to conform with the specification for the chain and approved by LR in accordance with Ch 3,9.

3.7.4 Details of the method of manufacture, including heat treatment, are to be submitted for approval, together with the results of a series of tests laid down by LR.

3.7.5 All links involved in the approval tests are to be destroyed and are not to be used as part of a chain cable.

3.7.6 Every connecting common link included in a chain cable is to be subjected to the proof load appropriate to the grade and size of chain in which it is incorporated as detailed in Table 10.3.1.

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Table 10.3.4 Mass per unit length of chain cable

Nominal chain diameter (mm)	Mass per unit length $0{,}0291d^2$ (kg/m)
50	73
55	88
60	105
65	123
70	143
75	164
80	186
85	210
90	236
95	263
100	291
105	321
110	352
115	385
120	419
125	455
130	492
135	530
140	570
145	612
150	655
155	699
160	745
165	792
170	841
175	891
180	943
185	996
190	1051
195	1107
200	1164
205	1223
210	1283

3.7.7 Every connecting common link is to be inspected in accordance with 3.6.5 to 3.6.10.

3.7.8 A second identical link is to be made for mechanical tests which are to be in accordance with 3.6.25. This test link is also to be inspected in accordance with 3.7.7.

3.7.9 Each connecting common link is to be stamped on the stud with the identification marks listed in 3.9.1 plus a unique number for the link. The adjoining links are also to be stamped on the studs.

3.8 Fittings for offshore mooring chain

3.8.1 Cable fittings are to be manufactured at an approved works. Fittings include, but are not limited to, shackles, triplates, end shackles, swivels, and swivel shackles.

3.8.2 The materials from which the fittings are made are to be manufactured at approved works, in accordance with the appropriate requirements of Ch 4,1 or Ch 5,1, and 3.8.3 to 3.8.6. Alternative arrangements may be agreed provided that full details concerning the manufacturer are submitted to LR.

3.8.3 Steel used for fittings must be manufactured by an approved process, and be killed and fine grain treated.

3.8.4 The austenite grain size of steel used for fittings must be 6 or finer as measured in accordance with ASTM E112.

3.8.5 Steel used for forgings or castings for grades R4S and R5 must be vacuum degassed.

3.8.6 For steel used for forgings or castings for grades R4S and R5 the following tests are to be carried out on each heat:

(a) Assessment and quantification of the level of non-metallic micro inclusions. These must be acceptable for the final product.

(b) Macro etching on representative sample, in accordance with ASTM E381 or equivalent, this must be free from any injurious segregation or porosity.

(c) Jominy hardenability tests in accordance with ASTM A255 or equivalent.

The results of these tests are to be supplied by the steel manufacturer, and the results are to be included in the final accessory documentation.

3.8.7 Fittings for chain are to be heat treated in accordance with procedures that have been approved by LR.

3.8.8 All fittings are to be manufactured to a manufacturing specification approved by LR, and provision is to be made for tensile and impact test specimens. The test samples are to be subjected to heat treatment with the fittings they represent. The mechanical test requirements are the same as those for the relevant grade of chain cable, *see* Table 10.3.3.

3.8.9 A batch is defined as fittings from the same heat of steel that have been part of the same heat treatment charge.

3.8.10 Mechanical tests for fittings are to be taken from full size fittings that have been heat treated with the production batch they represent, and the tests are to be taken after the fitting has been proof load tested. It is not permitted to use separate representative coupons unless approved by LR in accordance with 3.8.14.

3.8.11 Forged shackle bodies and forged Kenter shackles are to have a set of three Charpy impact tests and a tensile test taken from the crown of the shackle. For smaller diameter shackles, where the geometry does not allow for the tensile test to be taken from the crown, this may be taken from the straight portion from the locations specified in Fig. 10.3.5, with the Charpy impact test specimens on the outside radius.

3.8.12 The test pieces for cast shackle bodies and cast Kenter shackles can be taken from the straight portion of the fitting from the locations shown in Fig. 10.3.5.

3.8.13 For fittings with complex geometries the locations of test pieces taken are to be approved by LR.

3.8.14 Where fittings are produced in small batches (less than 5) alternative testing may be approved; a proposal must be submitted in a written procedure for consideration.

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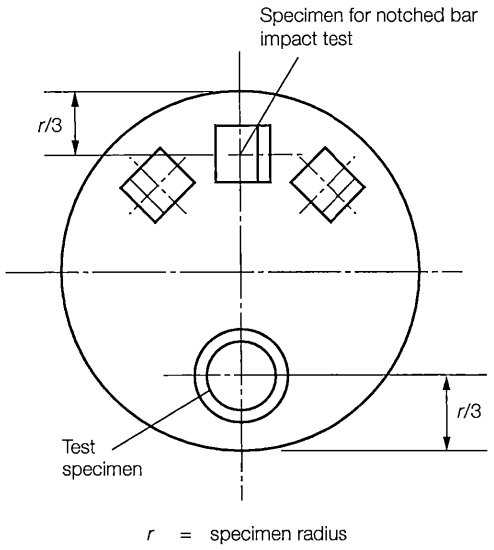

Fig. 10.3.5
Sampling of steel bars, forgings and castings

3.8.15 Mechanical tests of pins are to be taken as shown in Fig. 10.3.6 from the mid length of a sacrificial pin of the same diameter as the final pin. For oval pins, the diameter taken is to represent the smaller dimension. Mechanical tests may be taken from an extended pin of the same diameter as the final pin that incorporates a test prolongation and a heat treatment buffer prolongation, where equivalence with mid length test values have been established. The length of the buffer is to be at least equal to 1 pin diameter which is removed after the heat treatment cycle is finished. The test coupon can then be removed from the pin. The buffer and test are to come from the same end of the pin, as shown in Fig. 10.3.6.

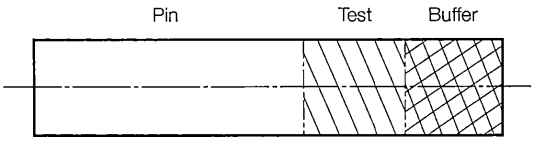

Fig. 10.3.6
Buffer and test piece location for pins

3.8.16 Manufacturers intending to supply accessories in the machined condition (e.g. Kenter type shackles) are to submit detailed drawings for approval by LR.

3.8.17 All chain cable accessories, including spares, are to be subjected to the proof loads appropriate to the grade and size of cable for which they are intended, *see* Table 10.3.1. Prior to this test, the accessories are to be shot or sand blasted to ensure that their surfaces are free from scale, paint or any other coating which could interfere with any subsequent inspection.

3.8.18 The appropriate breaking load as required by Table 10.3.1 is to be applied to at least one item out of every batch of up to 25, and this item is to be destroyed and not used as part of an outfit.

3.8.19 If the sample fails to withstand the breaking load without fracture, or in the event of failure of any other test, then the entire batch is to be rejected unless the cause of failure has been determined and it can be demonstrated that the condition causing failure is not present in any of the other accessories in the batch. If this can be demonstrated then two more samples from the same batch may be tested. If either of these samples fails, the batch is to be rejected.

3.8.20 For very large fittings where the required breaking load is greater than the capacity of the testing machine and for individually produced accessories or accessories produced in small batches, proposals for an alternative method of testing will be given special consideration. All proposals for alternative testing methods are to be detailed in writing and submitted.

3.8.21 At least one accessory from each batch is to be checked dimensionally after proof load testing. The manufacturer is to provide a statement that the dimensions comply with the specified requirements.

3.8.22 The following tolerances apply of the unmachined dimensions of all fittings;

(a) nominal diameter plus 5 per cent, minus 0 per cent; and
(b) other dimensions plus or minus 2,5 per cent.

3.8.23 All accessories are to be subjected to close visual examination after proof load testing, particular attention being paid to machined surfaces and highly stressed regions. All accessories are also to be examined by magnetic particle or dye penetrant inspection and ultrasonic testing. All NDE is to be carried out in accordance with 3.6.9 and 3.6.10. The manufacturer is to provide a statement that the non-destructive examination has been carried out with satisfactory results; this statement is to include reference to the techniques used and the operator's qualifications.

3.8.24 All testing is to be carried out to the satisfaction and in the presence of the Surveyor.

3.8.25 Fittings with increased dimensions, or fittings of a higher material grade, may be specially approved and included in an outfit, provided that;

(a) each item is successfully tested at the required breaking load for the chain cable for which they are intended; and
(b) items of increased dimensions are so designed that their breaking strength is not less than 1,4 times the Rule minimum breaking load for the chain cable for which they are intended, and this has been verified by procedure tests.

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3.9 Identification

3.9.1 Each length of chain is to be permanently marked with the following:

(a) LR and abbreviated name of LR's local office issuing the certificate.
(b) Certificate number (this may be abbreviated provided it is stated in the certificate).
(c) Grade and proof load of chain.

3.9.2 The chain is to be marked as follows:

(a) at each end (the marking should identify the leading and tail end of each chain),
(b) at intervals not exceeding 100m,
(c) on all connecting common links or shackles and the immediately adjacent links,
(d) on the first and last common link of each individual charge used in the continuous length.

3.9.3 All identification marks are to be made on the studs and are to be permanent and legible throughout the expected service life of the chain.

3.10 Documentation

3.10.1 A complete Chain Inspection and Testing Report, in booklet form, is to be provided by the chain manufacturer for each continuous chain length, and for each order for chain and fittings. It is to include all dimensional checks, test and inspection reports, non-destructive test reports, process records, as well as any non-conformity, together with corrective action and repair work.

3.10.2 All documents, including reports and appendices, are to contain a reference to the relevant certificate number.

3.10.3 The chain manufacturer is responsible for storing all the documentation in a safe and retrievable manner for a period of at least 10 years.

3.11 Certification

3.11.1 An LR certificate is to be issued for each continuous single length of chain, and each type of fitting, *see* Ch 1,3.1.

3.11.2 Each test certificate is to include the following particulars:

(a) Purchaser's name and order number.
(b) Description and dimensions.
(c) Grade of chain cable.
(d) Identification mark which will enable the full history of the chain to be traced.
(e) Chemical composition.
(f) Details of heat treatment.
(g) Mechanical test results.
(h) Breaking test load.
(j) Proof load.
(k) The number and locations of all connecting common links and all marked links.

■ *Section 4* Studless mooring chain cables

4.1 Scope

4.1.1 Provision is made in this Section for five grades, R3, R3S, R4, R4S and R5 of studless flash butt welded chain cable intended for long term mooring applications.

4.1.2 The chain is generally expected to be deployed only once for a pre-determined service life.

4.1.3 Each studless chain link design will require to be approved by LR. The plan submitted for this approval is to include the minimum proof and breaking test loads, and the chain mass calculations.

4.2 Manufacture

4.2.1 All the requirements of 3.2, with the exception of that relating to studs, apply to the manufacture of studless mooring chain cables.

4.3 Shape and dimensions of links

4.3.1 The shape and dimensions of the links are to be in accordance with the approved design.

4.4 Dimensional tolerances

4.4.1 The dimensional tolerances of studless links are to be in accordance with the requirements of 3.3.1 to 3.3.7.

4.5 Heat treatment

4.5.1 Heat treatment of the chain is to be in accordance with the requirements of 3.5.

4.6 Testing of completed chain

4.6.1 All chain cables are to be tested in the presence of a Surveyor, at a proving establishment recognised by LR. A list of recognised proving establishments is published by LR. In addition to the requirements stated in this Chapter, attention must be given to any relevant statutory requirements of the National Authority of the country in which the ship is to be registered.

4.6.2 The entire length of chain cable is to be subjected to a proof load test in an approved testing machine and is to withstand the load given in Table 10.3.1 for the appropriate grade and diameter of the chain, *see also* 4.1.3.

4.6.3 Inspection after proof load testing is to be in accordance with the requirements given in 3.6.3 to 3.6.20, excluding that related to checking of studs in 3.6.5.

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4.6.4 In addition to the inspection of the flash butt welded areas as required in 3.6.6, the surfaces of the bends of at least 10 per cent of the links are to be examined by magnetic particle inspection and are to be free from cracks or other defects.

4.6.5 If stretching of links is required in order to maintain dimensional tolerances, the load applied is not to exceed the proof load by more than 10 per cent, and only random lengths of the chain need to be stretched.

4.6.6 Breaking load tests are to be carried out in accordance with 3.6.21 to 3.6.23 and Tables 10.3.1 and 10.3.2.

4.6.7 Alternative procedures to breaking load testing (*see* 3.6.24) are not permissible unless prior agreement is given by LR after special consideration.

4.6.8 Mechanical testing is to be carried out in accordance with 3.6.25 to 3.6.30 and Table 3.3.4.

4.6.9 The weight of the chain cable is to be in accordance with the approved plan.

4.7 Connecting or substitute links

4.7.1 Connecting links and substitute links are to be in accordance with the requirements of 3.7.

4.8 Fittings

4.8.1 Fittings for studless chain are to comply with the requirements of 3.8.

4.9 Identification

4.9.1 All chain and each fitting is to be identified in accordance with 3.9.1 and 3.9.2.

4.9.2 Identification marks are to be made on the outside of the straight part of the link, opposite the flash butt weld.

4.10 Certification

4.10.1 Certificates are to be issued in accordance with 3.11.

4.11 Documentation

4.11.1 Documentation in accordance with 3.11 is to be provided by the manufacturer.

■ *Section 5* Short link chain cables

5.1 Scope

5.1.1 This Section gives the requirements for electrically welded steel short link chain cable for marine use but excluding those applications covered by the *Code for Lifting Appliances in a Marine Environment*.

5.1.2 Provision is made for grade M(4), as defined in ISO 1834:1999. Allowance is also made for the requirements of ISO 4565.

5.2 Manufacture

5.2.1 Short link chain cables are to be manufactured at works approved by LR. A list of approved manufacturers for short link chain cable is published separately by LR.

5.2.2 The chain is to be supplied in either the normalised or quenched and tempered condition. Heat treatment is to be carried out prior to proof and breaking load testing.

5.2.3 The chain may be galvanised using a hot dipping process provided that this is carried out prior to proof and breaking load testing. If galvanised, it is recommended that the thickness of the zinc coating be not less than 70 microns.

5.2.4 Unless otherwise agreed, the finished chain is to be free from coatings other than zinc.

5.3 Bar material

5.3.1 Bars for the manufacture of short link chain cable are to be made and tested in accordance with the appropriate requirements of Ch 3,1 and to the requirements of an International or acceptable National Standard.

5.3.2 The bars are to be made at a works approved by LR.

5.3.3 The steel is to be fully killed and fine grain treated.

5.3.4 The steel is to have mechanical properties which will allow the chain to meet the mechanical test requirements of 5.4.7 and Table 10.5.1.

5.4 Testing and inspection of chain cables

5.4.1 All chain cable of 12,5 mm diameter and above, and all steering chains irrespective of diameter, are to be tested in the presence of a Surveyor at a proving establishment recognised by LR. A list of recognised proving establishments is published by LR. In addition to the requirements stated in this Chapter, attention is to be given to any relevant statutory requirements of the National Authority of the country in which the ship or other marine structure is to be registered.

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Table 10.5.1 Mechanical test requirements for short link chain cables

Chain diameter mm	Grade M(4)	
	Proof load kN	Breaking load minimum kN
5	7,9	15,8
6,3	12,5	25
7,1	15,9	31,8
8	20,2	40,4
9	25,5	51
10	29,5	63
11,2	31,5	79
12,5	49,1	98,2
14	63	126
16	81	162
18	102	204
20	126	252
22,4	158	316
25	197	394
28	247	494
32	322	644
36	408	816
40	503	1006
45	637	1274

5.4.2 For chain of diameter less than 12,5 mm, other than steering chains, the manufacturer's tests will be acceptable.

5.4.3 After completion of all manufacturing processes, including heat treatment and galvanising, the whole of the chain is to be subjected to the appropriate proof load specified in Table 10.5.1.

5.4.4 The whole of the chain is to be inspected after the proof load test and is to be free from significant defects.

5.4.5 At least one sample, consisting of seven or more links, is to be selected by the Surveyor from each 200 m or less of chain for breaking load tests. Two additional links may be required for engagement in the jaws of the testing machine. These extra links are not to be taken into account in determining the total elongation, *see* 5.4.7.

5.4.6 The breaking load is to comply with the appropriate requirements of Table 10.5.1.

5.4.7 The total elongation of the breaking load sample at fracture, expressed as a percentage of the original inside length of the sample after proof loading, is to be not less than 20 per cent.

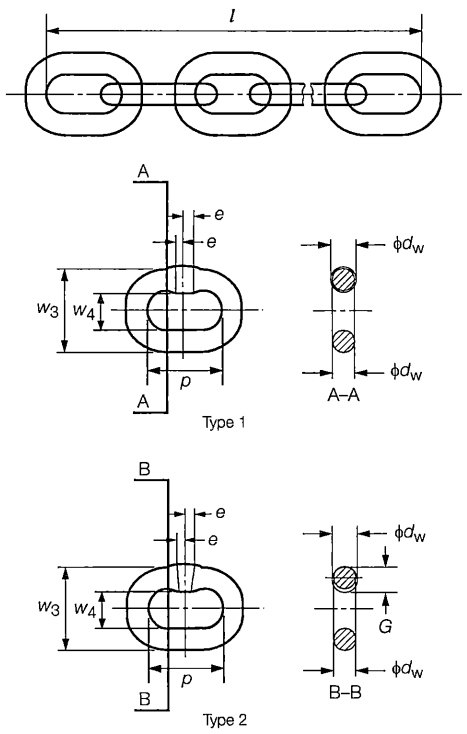
5.5 Dimensions and tolerances

5.5.1 The form and proportions of links are to be in accordance with Fig. 10.5.1.

5.5.2 Manufacturing tolerances are to be within the following limits:

Nominal diameter, d_n	± 5%
Pitch of chain, p_1	± 3%
Length measured over 11 links, l	± 2%
Inside width, w_1	$1{,}35d_n$ minimum
Outside width, w	$3{,}6d_n$ maximum

The tolerances are to apply after galvanising. All measurements are to be taken after proof testing.



l = multiple pitch length
p = pitch (internal link length)
d_n = measured diameter of the material, except at the weld
d_w = measured diameter of the material at the weld (Type 1) or weld dimension perpendicular to the plane of the link (Type 2)
G = dimension in other planes as per individual chain specification (Type 2)
e = length affected by welding, on either side of the centre link
w_1 = internal link width away from the weld
w_2 = external link width away from the weld
w_3 = external link width over the weld
w_4 = internal link width at the weld

Fig. 10.5.1 Form and proportions of links

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5.6 Identification

5.6.1 All lengths of cable are to be stamped with the following identification marks:
(a) Inspector's mark and date.
(b) Reference mark or number of certificate.
(c) Manufacturer's mark or name.
(d) Chain cable quality mark, M, is to be stamped on at least each twentieth link or at intervals of one metre, whichever is the lesser distance.

5.6.2 Where the inspection is performed under LR's supervision, the inspector's mark and date are to be replaced by LR and the abbreviated name of LR's local office issuing the certificate.

5.7 Certification

5.7.1 The manufacturer is to supply the Surveyor with a certificate stating compliance with an appropriate ISO standard, and also, in the event of the requirements of 5.4 being undertaken other than in the presence of the Surveyor, stating that the test and inspection requirements have been complied with at a recognised proving establishment.

5.7.2 Each test certificate is to include the following particulars:
(a) the quality and description of chain,
(b) identification mark,
(c) nominal size of chain,
(d) proof load,
(e) breaking load,
(f) total elongation at fracture,
(g) where appropriate, the name of the proving establishment.

■ *Section 6* Steel wire ropes

6.1 Scope

6.1.1 Provision is made in this Section for the requirements for the manufacture, testing and certification of steel wire ropes intended to be used for general marine purposes, as well as permanent anchoring, mooring and marine lifting applications.

6.2 General requirements

6.2.1 For general marine purposes, such as stream wires, towlines and ship mooring lines, the construction is to be in accordance with Table 10.6.1. The construction, diameter and strength of steel wire ropes for permanent offshore applications, such as mooring, anchoring and lifting, are covered by other LR Rules. Alternative applications of wire ropes may be accepted, subject to special consideration.

6.2.2 The manufacturer's plant and method of production are to be approved by LR. A list of approved manufacturers of steel wire ropes is published annually in the *List of Approved Manufacturers of Materials*.

6.2.3 For shaped wire, for example, for large diameter ropes for permanent mooring, where there are no established Standards, the manufacturer is to provide evidence by way of test reports that specifications have been developed and agreed with the purchaser and LR for the purposes intended.

6.3 Steel wire for ropes

6.3.1 Steel wire is to be of homogeneous quality, uniform strength and free of defects likely to impair the manufacture and performance of the rope.

6.3.2 For all ropes, the specified minimum tensile strength of the wire is to be 1420, 1570, 1770 or 1960 N/mm^2. The specified minimum tensile strength of the wire is the designated grade for the rope, unless otherwise defined by the purchaser's specification. The actual tensile strength of the wire is not to exceed 120 per cent of the specified minimum tensile strength.

Table 10.6.1 Recommended rope construction

Purpose	Construction of rope			Construction of strands
	Strands	Wires	Core	
Stream wires, towlines and mooring lines	6	24	Fibre	15 over 9 over fibre core
	6	37	Fibre	18 over 12 over 6 over 1
	6	26	Fibre	10 over (5 + 5) over 5 over 1
	6	31	Fibre	12 over (6 + 6) over 6 over 1
	6	36	Fibre	14 over (7 + 7) over 7 over 1
	6	41	Fibre	16 over (8 + 8) over 8 over 1
	6	30	Fibre	18 over 12 over fibre core
Towlines and mooring lines used in association with mooring winches	6	31	7 x 7 wire rope	12 over (6 + 6) over 6 over 1
	6	36	7 x 7 wire rope	14 over (7 + 7) over 7 over 1
	6	41	7 x 7 wire rope	16 over (8 + 8) over 8 over 1

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6.3.3 For new rope construction, the manufacturer is to carry out prototype testing suitable for the application of the rope and this is to include tests on wire used for the construction.

6.3.4 Tensile and torsion tests, coating, and adhesion (wrap) tests are to be carried out on wire used for the manufacture of rope.

6.3.5 At least 10 per cent of the spools used for the manufacture of the strand are to be tested. The manufacturer is to demonstrate that tests have been carried out on at least one wire intended for each of the outer and inner strands, and for each diameter and grade used.

6.3.6 The heat number, wire diameter and strength of wire used for a particular construction are to be recorded by the manufacturer.

6.3.7 Torsion tests are to be carried out on the wire by causing one or both of the securing vices to be revolved until fracture occurs (a tensile load not exceeding two per cent of the breaking load of the wire may be applied to keep the wire stretched).

6.3.8 The uncoated wire is to withstand, without fracture, the number of complete twists given for Grades 1 or 3 in Table 10.6.2.

6.3.9 The galvanised wire is to withstand, without fracture, the number of complete twists given in the specification, as agreed with the purchaser and LR. In the absence of a suitable specification, the results are to comply with Table 10.6.2.

6.3.10 Hot dipped galvanised steel wire is to be used for the manufacture of ropes for marine applications. Depending upon the application, the coating may comply with any of the grades in Table 10.6.3. Grades 1 and 2 are heavy coatings. Grade 3 is the minimum coating weight where the galvanising is carried out prior to final wire drawing. Uncoated wire may be considered for approved applications.

6.3.11 The mass per unit area of the zinc coating is to be determined in accordance with a recognised National or International Standard.

6.3.12 Zinc coating tests are to be carried out for each designated grade of wire. The manufacturer is to demonstrate that the coatings are continuous and uniform and suitable for the intended purpose.

6.3.13 Unless otherwise specified by the purchaser, zinc coating tests are to be carried out on the wire prior to stranding.

6.3.14 The adhesion of the coating is to be tested by wrapping the wire round a cylindrical mandrel for 10 complete turns. The ratio between the diameter of the mandrel and that of the wire is to be as in Table 10.6.4. After wrapping on the appropriate mandrel, the zinc coating is to have neither flaked nor cracked to such an extent that any zinc can be removed by rubbing with a cloth.

Table 10.6.2 Torsion test

Diameter coated wire mm	Minimum number of twists					
	Grade 2		Grade 1 or 3			
	Minimum strength N/mm^2		Minimum strength N/mm^2			
	1570	1770	1420	1570	1770	1960
<1,3	19	18	29	26	23	23
≥1,3 <2,3	18	17	26	24	21	21
≥2,3 <3,0	16	14	24	22	—	19
≥3,0 <4,0	12	10	20	18	—	17
≥4,0 <4,6	—	—	18	16	—	—
≥4,6 <5,0	—	—	16	14	—	—
≥5,0 <6,0	—	—	14	11	—	—

NOTE
The minimum test length is 100*d* or 300 mm, where *d* is the wire diameter.

Table 10.6.3 Zinc coating

Diameter of coated wire mm	Zinc coating, minimum g/m^2		
	Grade1	Grade 2	Grade 3
≥0,20 <0,25	—	30	20
≥0,25 <0,33	—	45	30
≥0,33 <0,40	—	60	30
≥0,40 <0,50	60	75	40
≥0,50 <0,60	70	90	50
≥0,60 <0,80	85	110	60
≥0,80 <1,00	95	130	70
≥1,00 <1,20	110	150	80
≥1,20 <1,50	120	165	90
≥1,50 <1,90	130	180	100
≥1,90 <2,50	—	205	110
≥2,50 <3,20	—	230	125
≥3,20 <4,00	—	250	135

Table 10.6.4 Wrap test for adhesion of coating

Coating	Diameter of coated wire mm	Maximum ratio of mandrel to wire diameter
Grade 1 and 2	<1,5	4
	≥1,5	6
Grade 3	<1,5	2
	≥1,5	3

6.4 Tests on completed ropes

6.4.1 Every length of wire rope is to be subjected to a breaking strength test.

6.4.2 A sample of sufficient length is to be provided for the breaking load test. The rope ends are to be enclosed in a suitable socket. Testing is to be carried out in accordance with a recognised National or International Standard.

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6.4.3 The rope may be subject to cyclic loading for bedding purposes prior to testing. The rope is to be tested at a suitable strain rate in accordance with a recognised National or International Standard.

6.4.4 The load is to be applied until one wire break is witnessed or 130 per cent of the minimum breaking load is recorded. The maximum recorded load is to be reported by the manufacturer.

6.4.5 Tests in which a breakage occurs adjacent to and as a result of damage from the grips are to be rejected, if the applied load is less than the specified minimum requirement. The rope is to be retested to withstand the agreed minimum breaking load.

6.4.6 With the exception of offshore mooring ropes, consideration may be given to determining the breaking load by summation or aggregating actual test results on individual wires, if facilities are not available for undertaking a breaking test on a production basis. A suitable spin factor or lay-up deduction allowance in accordance with a recognised National or International Standard for the applicable rope diameter, designated grade and construction is to be applied.

6.4.7 Where spin factors or lay-up deduction allowances are proposed by the manufacturer, a report on suitable cyclic load testing of prototype ropes of the same construction, strength and diameter is to be approved by LR. In addition, the manufacturer is to show that a satisfactory breaking load test has been carried out in the previous two years, and witnessed by LR for the same rope construction, diameter and designated grade.

6.4.8 LR may give special consideration to spin factors or lay deductions based on data extrapolated from smaller diameter ropes of the same construction, provided that these ropes have been tested in accordance with 6.4.7.

6.4.9 All data arising from smaller diameter ropes for the extrapolation in 6.4.8 are to have been derived from tests carried out within two years of the manufacture of the larger diameter rope.

6.4.10 The finished rope is to have no more than one wire connecting weld in any length of 18*d*, where *d* is the diameter of the rope.

6.5 Inspection

6.5.1 A report on dimensional and visual examination is to be presented to the Surveyor by the manufacturer. The dimensions and discard criteria are to comply with an agreed National or International Standard.

6.5.2 Visual and dimensional checks are to be carried out in the presence of the Surveyor.

6.6 Identification

6.6.1 All completed ropes are to be identified with attached labels detailing the rope type, diameter and length.

6.7 Certification

6.7.1 A manufacturer's certificate, in accordance with Ch1,3.1.3(c), is to be issued. The certificate is to be validated by the manufacturer's representative, who is to be independent of the production process and LR.

6.7.2 Each test certificate is to contain the following particulars:

- Purchaser's name and order number.
- Details of the rope construction.
- Core material.
- Grade of zinc coating.
- Mechanical test results.
- Adhesion test results.
- Dimensions.
- Method of breaking load testing.
- Breaking load.

■ *Section 7* Fibre ropes

7.1 Manufacture

7.1.1 Fibre ropes intended as mooring lines may be made of coir, hemp, manila or sisal, or may be composed of synthetic (man-made) fibres. They may be three-strand (hawser laid), four-strand (shroud laid) or nine-strand (cable laid), but other constructions will be specially considered.

7.1.2 Each length of rope is to be manufactured from suitable material of good and consistent quality. Rope materials should, in general, comply with a recognised National Standard.

7.1.3 Synthetic fibre ropes are to be suitable for the purpose intended and should comply with a recognised standard.

7.1.4 Weighting and loading matter is not to be added, and any lubricant is to be kept to a minimum. Any rot-proofing or water repellancy treatment is not to be deleterious to the fibre nor is it to add to the weight or reduce the strength of the rope.

7.2 Tests of completed ropes

7.2.1 The breaking load is to be determined by testing to destruction a sample cut from the completed rope.

7.2.2 The minimum test length and the initial test load are to be as given in Table 10.7.1. After application of the initial load, the diameter and evenness of lay up of the sample are to be checked. The sample is then to be uniformly strained at the rate given in Table 10.7.1 until it breaks.

7.2.3 The actual breaking load is to be not less than that given in an appropriate National Standard.

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Table 10.7.1 Breaking load test

Material	Test length mm minimum	Initial load % (*see* Note)	Rate of straining mm/min
Natural fibre	1800	2	150 ± 50
Synthetic fibre	900	1	100 max.

NOTE
Percentage of specified minimum breaking load.

7.2.4 If the sample is held by grips and the break occurs within 150 mm of the grips, the test may be repeated, but not more than two tests may be made on any one coil.

7.2.5 Where difficulty is experienced in testing a sample of a completed synthetic fibre rope, LR will consider alternative methods of testing.

7.3 Identification

7.3.1 Each coil of rope is to be identified with an attached label detailing the material, construction, diameter and length.

7.4 Certification

7.4.1 A manufacturer's certificate, in accordance with Ch1,3.1.3(c), is to be issued. The certificate is to be validated by the manufacturer's representative, who is to be independent of the production process and LR.

7.4.2 Each test certificate is to include the following particulars:

- Manufacturer's name.
- Purchaser's name and order number.
- Rope type.
- Dimensions.
- Test length.
- Rate of straining.
- Breaking load.

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Approval of Welding Consumables

Chapter 11

Section

1 **General**

2 **Mechanical testing procedures**

3 **Electrodes for manual and gravity welding**

4 **Wire-flux combinations for submerged-arc automatic welding**

5 **Wires and wire-gas combinations for manual, semi-automatic and automatic welding**

6 **Consumables for use in electro-slag and electro-gas welding**

7 **Consumables for use in one-side welding with temporary backing materials**

8 **Consumables for welding austenitic and duplex stainless steels**

9 **Consumables for welding aluminium alloys**

■ *Section 1* General

1.1 Scope

1.1.1 Provision is made in this Chapter for the approval by Lloyd's Register (hereinafter referred to as 'LR') of electrodes, wires, fluxes and other consumables intended for use in the welding of the following types of materials:

(a) Steel of various grades as represented by Grade A through to Grade FH69, *see* Sections 3 to 7.
(b) A wide range of low-temperature service steels, *see* Sections 3 to 7.
(c) Stainless steels including nitrogen strengthened grades and some of the duplex varieties, *see* Section 8.
(d) Aluminium alloys, *see* Section 9.

1.1.2 For this purpose, welding, consumables are categorised and subject to the special requirements of different Sections of this Chapter.

(a) Covered electrodes for manual welding and gravity welding.
(b) Combinations of wire and flux for automatic submerged-arc welding.
(c) Combinations of wire and gas for gas metal-arc welding and wires for self-shielding welding.
(d) Combinations for electro-slag and electro-gas welding.
(e) Combinations with temporary backing materials for one-side welding.
(f) Consumables for welding austenitic and duplex stainless steels.
(g) Combinations for welding aluminium.

1.2 Grading

1.2.1 Consumables for welding structural steels are graded into ten strength levels, and each of these is further subdivided into several levels in respect of notch toughness. The five basic levels of toughness are indicated by a number (1 to 5). Normal tensile strength is indicated by 'N'. Higher tensile strength is indicated by 'Y', and if the yield strength is higher than 375 N/mm^2 the Y is followed by a number (40 to 69), as shown in Table 11.1.1.

1.2.2 In addition to the grade, consumables are also allocated a suffix indicating the welding technique used. These are defined in the context of the following Sections of this Chapter.

1.2.3 Consumables for structural and low temperature service steels may be controlled low hydrogen and approved as such. Grade marking H15, H10 or H5 will be applied, as appropriate.

1.2.4 For joining higher strength steels, approval granted for 1Y consumables will be limited to maximum material thickness of 25 mm.

1.2.5 Test assemblies are not to be subjected to any heat treatment, except in those higher strength grades where it is considered necessary to use the welded joint in the stress relieved (tempered) condition. In those cases, the code 'sr' will be added to the approval grade.

1.2.6 Further details of grading are given in subsequent Sections of this Chapter.

1.3 Manufacture

1.3.1 The manufacturer's plant and method of production of welding consumables are to be such as to ensure reasonable uniformity in manufacture.

1.4 Approval procedures

1.4.1 Welding consumables will be approved subject to a satisfactory inspection of the works by the Surveyor for compliance with the test requirements detailed in subsequent Sections in this Chapter.

1.4.2 The test assemblies are to be prepared under the supervision of the Surveyor, and using samples selected by him. All tests are to be carried out in his presence.

1.4.3 For Charpy V-notch tests, a set of three test specimens is to be prepared and the average energy value is to comply with the requirements of subsequent Sections in this Chapter. One individual value may be less than the required average value provided that it is not less than 70 per cent of this value.

1.4.4 Where chemical analysis is required for approval, the results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

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Approval of Welding Consumables

Table 11.1.1 Welding consumable grades appropriate to structural and low temperature service steel grades

Consumable grade	Suitable for steel grades (*see* Notes)			
1. Ship Grade Steels (Ch 3,2 and Ch 3,3)				
1N	A	***AH27S***	—	—
2N	B, D	***DH27S***	—	—
3N	E	***EH27S***	—	—
1Y	A	***AH27S***	***AH32***	***AH36***
2Y	B, D	***DH27S***	***DH32***	***DH36***
3Y	E	***EH27S***	***EH32***	***EH36***
4Y	—	***FH27S***	***FH32***	***FH36***
2Y40	***AH32***	***AH36***	***AH40***	—
2Y40	***DH32***	***DH36***	***DH40***	—
3Y40	***EH32***	***EH36***	***EH40***	—
4Y40	***FH32***	***FH36***	***FH40***	—
5Y40	***FH32***	***FH36***	***FH40***	—
2Y47	—	—	***AH40***	***AH47***
2Y47	—	—	***DH40***	***DH47***
3Y47	—	—	***EH40***	***EH47***
4Y47	—	—	***FH40***	***FH47***
2. High Strength Steels (Ch 3,10) *see* Note 3				
3Y42	***AH36***	***AH40***	AH42	—
3Y42	***DH36***	***DH40***	DH42	—
4Y42	***EH36***	***EH40***	EH42	—
5Y42	***FH36***	***FH40***	FH42	—
3Y46	***AH40***	AH42	AH46	—
3Y46	***DH40***	DH42	DH46	—
4Y46	***EH40***	EH42	EH46	—
5Y46	***FH40***	FH42	FH46	—
3Y50	AH42	AH46	AH50	—
3Y50	DH42	DH46	DH50	—
4Y50	EH42	EH46	EH50	—
5Y50	FH42	FH46	FH50	—
3Y55	AH50	AH55	—	—
3Y55	DH50	DH55	—	—
4Y55	EH50	EH55	—	—
5Y55	FH50	FH55	—	—
3Y62	AH55	AH62	—	—
3Y62	DH55	DH62	—	—
4Y62	EH55	EH62	—	—
5Y62	FH55	FH62	—	—
3Y69	AH62	AH69	—	—
3Y69	DH62	DH69	—	—
4Y69	EH62	EH69	—	—
5Y69	FH62	FH69	—	—
3. Ferritic Low Temperature Service Steels (Ch 3,6)				
1 1/2 Ni	1 1/2 Ni	—	—	—
3 1/2 Ni	3 1/2 Ni	—	—	—
5 Ni	5 Ni	—	—	—
9 Ni	9 Ni	—	—	—

NOTES
1. Steel grades shown in bold italic type include the equivalent (LT-xxxx) low temperature service grades referenced in Ch 3,6.
2. The Table applies to the multi-run welding techniques (i.e. m, S, M).
3. Approval of consumables intended for welding high strength steels in Ch 3,10 also includes the standard ship steel grades as shown in bold italic type and equivalent low temperature service steel grades referenced in Ch 3,6.

1.4.5 LR may require, in any particular case, such additional tests or requirements as may be necessary.

1.4.6 A *List of Approved Welding Consumables* is published by LR.

1.4.7 LR is to be notified of any alteration proposed to be made in the process of manufacture subsequent to approval. Sufficient detail is to be provided to determine the need for further testing to maintain the approval.

1.4.8 Consideration will be given to alternative procedures for approval in the case of manufacturers producing consumables under the control of another manufacturer or plant already having approval of one or more products.

1.5 Annual inspection and tests

1.5.1 All establishments where approved welding consumables are manufactured, and the associated quality control procedures, are to be subjected to annual inspection. On these occasions, samples of the approved consumables are to be selected by the Surveyor and subjected to the tests detailed in subsequent Sections in this Chapter. These are to be completed and reported before the end of the one year period beginning at the initial approval date, and repeated annually so as to provide at least an average of one annual test per year.

1.6 Changes in grading

1.6.1 Changes in grading of welding consumables will be considered only at the manufacturer's request, preferably at the time of annual testing. For upgrading in connection with impact properties, and uprating in connection with tensile properties, tests from butt weld assemblies will be required in addition to the normal annual approval tests. For upgrading in connection with hydrogen testing, specific tests will be required in accordance with ISO 3690. Downgrading and downrating may be imposed by LR where tests and re-tests fail to meet the requirements of this Chapter.

1.7 Manufacturers' Quality Assurance Systems

1.7.1 As an alternative to 1.5, manufacturers may seek maintenance of approval based on acceptance by LR of their 'in house' quality assurance system, and by regular audit of that system carried out in accordance with procedures approved by LR.

1.8 Certification

1.8.1 Each carton or package of approved consumables is to contain a certificate from the manufacturer, generally in accordance with the following: 'The *<insert name of manufacturer>* company certifies that the composition and quality of these consumables conform with those of the consumables used in making the test pieces submitted to and approved by the approval bodies nominated on the label of this package.'

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Section 2
Mechanical testing procedures

2.1 Dimensions of test specimens

2.1.1 Dimensions of test pieces for deposited metal tensile tests, butt weld tensile tests, bend tests and Charpy V-notch impact test are to machined to the dimensions and tolerances detailed in Chapter 2.

2.2 Testing procedures

2.2.1 The procedures used for all tensile and impact tests are to comply with the requirements of Chapter 2.

2.2.2 Butt weld bend test specimens are to be tested at ambient temperature and are to be bent through an angle of 120° over a former having a diameter which relates to the thickness of the test specimen as detailed in subsequent Sections. For each pair of bend test specimens, one specimen is to be tested with the face of the weld in tension and the other with the root of the weld in tension.

2.2.3 Macro examinations are to be carried out on polished and etched specimens at a maximum magnification not exceeding x10. The examination is to ensure complete fusion, inter-run penetration and freedom of defects.

2.3 Re-testing procedures

2.3.1 Re-testing procedures are to comply with Ch 2,1.4.

Section 3
Electrodes for manual and gravity welding

3.1 General

3.1.1 Dependent on the results of the mechanical and other tests, approval will be allocated as one of the grades from Table 11.1.1.

3.1.2 Approval of an electrode will be given in conjunction with a welding technique indicated by a suffix 'm' for manual welding, 'G' for gravity or contact electróde and 'p' for deep penetration electrode.

3.1.3 If the electrodes are in compliance with the requirements of the hydrogen test given in 3.4, a suffix 'H15' or 'H10' or 'H5' will be added to the grade mark. Table 11.3.1 shows the mandatory levels of low hydrogen approval for the various approval grades.

3.1.4 For each strength level, electrodes which have satisfied the requirements for a higher toughness grade are considered as complying with the requirements for a lower grade.

Table 11.3.1 Minimum low hydrogen approval requirements for manual and gravity electrodes

Approval grades	Low hydrogen grade required
1 (1N), 2 (2N), 3 (3N)	NR
2Y, 3Y, 4Y	H15 (*see* Note 2)
2Y40 to 5Y40	H15
2Y47 to 4Y47	H10
3Y42 to 5Y42	H10
3Y46 to 5Y46	H10
3Y50 to 5Y50	H10
3Y55 to 5Y55	H5
3Y62 to 5Y62	H5
3Y69 to 5Y69	H5
1½ Ni	H15
3½ Ni	H15
5 Ni	NR (*see* Note 3)
9 Ni	NR (*see* Note 3)

NOTES
1. NR – Not required. Approval may be obtained when requested.
2. Optional in this case. If low hydrogen approval is not obtained, there is a limitation on the carbon equivalent of the steel which is permitted to be welded.
3. Assumes use of an austenitic, non-transformable, filler material.

3.1.5 Electrodes approved for normal and higher strength levels up to and including 'Y' are also considered suitable for welding steels in the three strength levels below that for which they have been approved.

3.1.6 Electrodes approved for strength levels Y40 to Y50, but excluding Y47 are also considered suitable for welding steels in two strength levels below that for which they have been approved.

3.1.7 Electrodes approved for strength levels Y47, Y55 and above are also considered suitable for welding steels in only one strength level below that for which they have been approved.

3.1.8 The welding current used is to be within the range recommended by the manufacturer and, where an electrode is stated to be suitable for both a.c. and d.c., a.c. is to be used for the preparation of the test assemblies.

3.1.9 Where an electrode is submitted only for approval for fillet welding and to which the butt weld test provided in 3.3 is not considered applicable, approval tests are to consist of the fillet weld tests as given in 3.5 and deposited metal tests with chemical analyses as given in 3.2.

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3.2 Deposited metal test assemblies

3.2.1 The deposited metal test assemblies are to be prepared in the downhand position as shown in Fig. 11.3.1, one with 4 mm diameter electrodes and the other with 8 mm diameter electrodes, or the largest size manufactured if this is less than 8 mm diameter. If an electrode is available in one diameter only, one test assembly is sufficient. Any of the grades of steel in Table 11.1.1 may be used for the preparation of these assemblies, up to a strength level which is not more than two levels above that for which approval is sought.

3.2.2 For Y47 grades, as an alternative to Fig. 11.3.1, the thickness of the plate used for the test assembly may be taken as 50 mm.

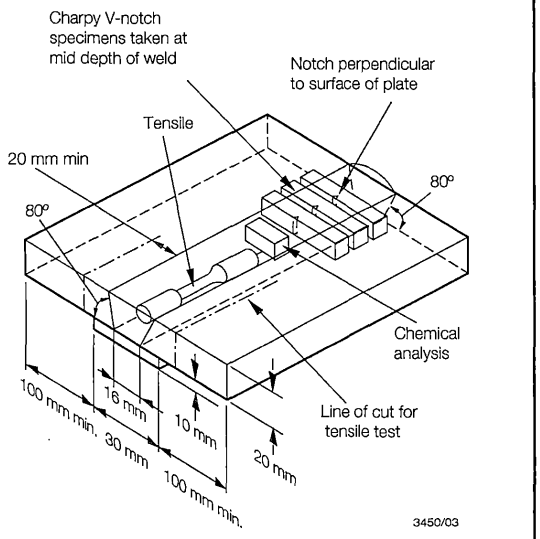

Fig. 11.3.1 Deposited metal test assembly

3.2.3 The weld metal is to be deposited in single- or multi-run layers according to normal practice, and the direction of deposition of each layer is to alternate from each end of the plate, each run of weld metal being not less than 2 mm and not more than 4 mm thick. Between each run, the assembly is to be left in still air until it has cooled to less than 250°C, the temperature being taken in the centre of the weld, on the surface of the seam. After being welded, the test assemblies are not to be subjected to any heat treatment, except in those higher strength grades where it is considered necessary to use the welded joint in the stress-relieved (tempered) condition. In those cases, the code 'sr' will be added to the approval grading.

3.2.4 The chemical analysis of the deposited weld metal in each deposited metal test assembly is to be supplied by the manufacturer and is to include the content of all significant alloying elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

3.2.5 One tensile and three impact test specimens are to be taken from each test assembly as shown in Fig. 11.3.1. Care is to be taken that the axis of the tensile test specimen coincides with the centre of the weld and the mid-thickness of the plates. The impact test specimens are to be cut perpendicular to the weld, with their axes 10 mm from the upper surface. The notch is to be positioned in the centre of the weld and cut in the face of the test specimen perpendicular to the surface of the plate.

3.2.6 The results of all tests are to comply with the requirements of Table 11.3.2 as appropriate.

3.3 Butt weld test assemblies

3.3.1 Butt weld assemblies, as shown in Fig. 11.3.2, are to be prepared for each welding position (downhand, horizontal-vertical, vertical-upward, vertical-downward, and overhead) for which the electrode is recommended by the manufacturer. In the case of electrodes for normal strength and higher strength steels (up to 355 N/mm^2 minimum specified yield strength), electrodes satisfying the requirements for downhand and vertical-upward positions will be considered as also complying with the requirements for the horizontal-vertical position. In all other cases, approval for the horizontal-vertical position will require a butt weld to be made in that position and fully tested.

3.3.2 For Y47 grades, as an alternative to Fig. 11.3.2 the thickness of the plate used for the test assembly may be taken as 50 mm.

3.3.3 Where the electrode is to be approved only in the downhand position, an additional test assembly is to be prepared in that position.

3.3.4 The grades of steel used for the preparation of the test assemblies are to be as follows:

Grade 1 (1N) electrodes	A
Grade 2 (2N) electrodes	A, B or D
Grade 3 (3N) electrodes	A, B, D or E
Grade 2Y electrodes	AH32, AH36, DH32 or DH36
Grade 3Y electrodes	AH32, AH36, DH32, DH36, EH32 or EH36
Grade 4Y electrodes	AH32 AH36, DH32, DH36, EH32, EH36, FH32 or FH36
Grade 2Y40 electrodes	AH40 or DH40
Grade 3Y40 electrodes	AH40, DH40 or EH40
Grade 4Y40 electrodes	AH40, DH40, EH40 or FH40
Grade 5Y40 electrodes	AH40, DH40, EH40 or FH40
Grade 2Y47 electrodes	AH47, DH47
Grade 3Y47 electrodes	AH47, DH47, EH47
Grade 4Y47 electrodes	AH47, DH47, EH47 or FH47

Where Grade 32 higher tensile steel is used, the tensile strength is to be not less than 490 N/mm^2. The chemical composition, including the content of grain refining elements, is to be reported in all cases where higher tensile steel is used.

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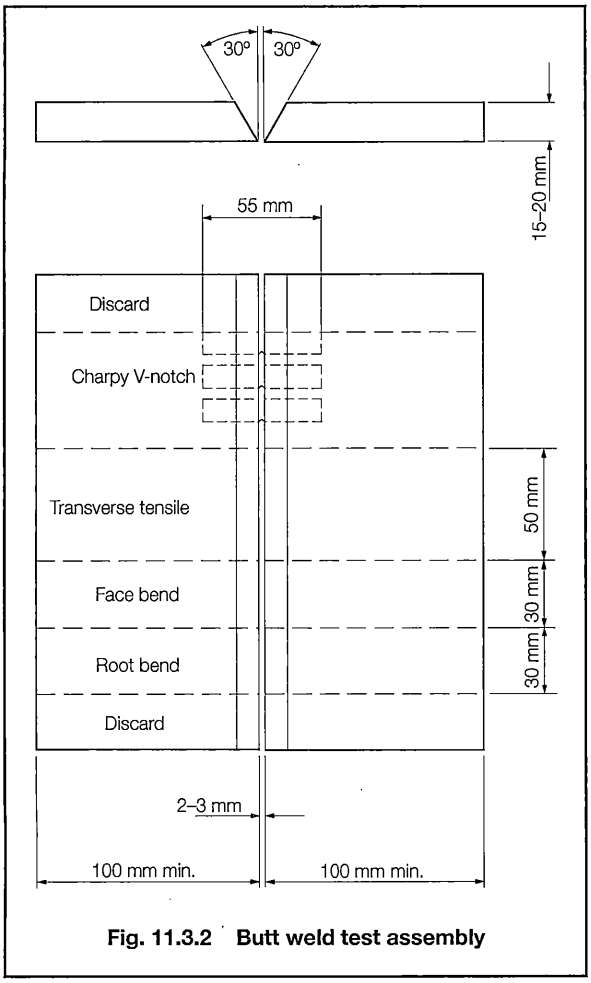

Fig. 11.3.2 Butt weld test assembly

3.3.5 For all other grades, the steel plates used are to be selected by reference to Table 11.1.1, and are to have at least their chemical composition and tensile properties within the limits specified for that grade in Chapter 3. The strength grade used is to be the same as that for which approval is sought, and the toughness grade is to be no higher than that for which approval is also sought.

3.3.6 The test assemblies are to be made by welding together two plates of equal thickness (15 to 20 mm), not less than 100 mm in width and of sufficient length to allow the cutting out of test specimens of the prescribed number and size. The plate edges are to be prepared to form a single V-joint, the included angle between the fusion faces being 60° and the root gap 2 to 3 mm. The root face is to be 0 to 2 mm.

3.3.7 The following welding procedure is to be adopted in making the test assemblies:

Downhand (a). The first run with 4 mm diameter electrode. Remaining runs (except the last two layers) with 5 mm diameter electrodes or above according to the normal welding practice with the electrodes. The runs of the last two layers with the largest diameter of electrode manufactured or 8 mm whichever is the lesser.

Downhand (b) (where a second downhand test is required). First run with 4 mm diameter electrode. Next run with an electrode of intermediate diameter of 5 mm or 6 mm, and the remaining runs with the largest diameter of electrode manufactured or 8 mm whichever is the lesser.

Horizontal-vertical. First run with 4 mm or 5 mm diameter electrode. Subsequent runs with 5 mm diameter electrodes.

Vertical-upward and overhead. First run with 3,25 mm diameter electrode. Remaining runs with 4 mm diameter electrodes or possibly with 5 mm if this is recommended by the manufacturer for the positions concerned.

Vertical-downward. If the electrode being tested is intended for vertical welding in the downward direction, this technique is to be adopted for the preparation of the test assembly using electrode diameters as recommended by the manufacturer.

3.3.8 For all assemblies, the back sealing runs are to be made with 4 mm diameter electrodes in the welding position appropriate to each test sample, after cutting out the root run to clean metal. For electrodes suitable for downhand welding only, the test assemblies may be turned over to carry out the back sealing run.

3.3.9 Normal welding practice is to be used and, between each run, the assembly is to be left in still air until it has cooled to less than 250°C, the temperature being taken in the centre of the weld, on the surface of the seam. After being welded, the test assemblies are not to be subjected to any heat treatment, except in those higher strength grades where it is considered necessary to use the welded joint in the stress-relieved (tempered) condition. In those cases, the code 'sr' will be added to the approval grading.

3.3.10 It is recommended that the welded assemblies be subjected to a radiographic examination to ascertain if there are any defects in the weld prior to the preparation of test specimens.

3.3.11 The test specimens as shown in Figs. 11.3.2 and 11.3.3 are to be prepared from each test assembly.

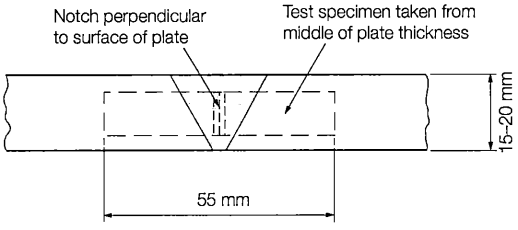

Fig. 11.3.3
Butt weld test assembly position of impact test specimens

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Table 11.3.2 Requirements for deposited metal tests (covered electrodes)

Grade (*see* Note 3)	Yield stress N/mm^2 minimum	Tensile strength N/mm^2 (*see* Note 1)	Elongation on 50 mm % minimum	Charpy V-notch impact tests	
				Test temperature °C	Average energy (*see* Note 2) J minimum
1N, 2N, 3N	305	400 – 560	22	+20, 0, –20	47
1Y, 2Y, 3Y, 4Y	375	490 – 660	22	+20, 0, –20, –40	47
2Y40, 3Y40, 4Y40, 5Y40	400	510 – 690	22	0, –20, –40, –60	47
2Y47, 3Y47, 4Y47	460	570 – 720	19	0, –20, –40	53
3Y40	400	510 – 690	22	–20	47
3Y42	420	530 – 680	20	–20	47
3Y46	460	570 – 720	20	–20	47
3Y50	500	610 – 770	18	–20	50
3Y55	550	670 – 830	18	–20	55
3Y62	620	720 – 890	18	–20	62
3Y69	690	770 – 940	17	–20	69
4Y40	400	510 – 690	22	–40	47
4Y42	420	530 – 680	20	–40	47
4Y46	460	570 – 720	20	–40	47
4Y50	500	610 – 770	18	–40	50
4Y55	550	670 – 830	18	–40	55
4Y62	620	720 – 890	18	–40	62
4Y69	690	770 – 940	17	–40	69
5Y40	400	510 – 690	22	–60	47
5Y42	420	530 – 680	20	–60	47
5Y46	460	570 – 720	20	–60	47
5Y50	500	610 – 770	18	–60	50
5Y55	550	670 – 830	18	–60	55
5Y62	620	720 – 890	18	–60	62
5Y69	690	770 – 940	17	–60	69
$1^1/_2$ Ni	375	460	22	–80	34
$3^1/_2$ Ni	375	420	25	–100	34
5 Ni	375	500	25	–120	34
9 Ni	375	600	25	–196	34

NOTES
1. Single values are the minimum requirements.
2. Energy values from individual impact test specimens are to comply with 1.4.3.
3. Grade 1Y is not applicable to SMAW consumables referenced in Section 3.

3.3.12 The results of all tensile and impact tests are to comply with the requirements of Table 11.3.3 as appropriate. The position of fracture in the transverse tensile test is to be reported.

3.3.13 The bend test specimens can be considered as complying with the requirements if, after bending, no crack or other open defect exceeding 3 mm in dimensions can be seen on the outer surface.

3.4 Hydrogen test

3.4.1 The hydrogen gradings are specified in 3.1.3. The hydrogen grading required determines the method of testing permitted as shown in Table 11.3.4. Where ISO 3690 is used as the testing method, three test specimens are to be prepared and tested, and all three hydrogen test results must be below the maximum value for the hydrogen mark required.

3.5 Fillet weld test assemblies

3.5.1 Fillet weld assemblies as shown in Fig. 11.3.4 are to be prepared for each welding position (horizontal-vertical, vertical-upward, vertical-downward or overhead) for which the electrode is recommended by the manufacturer. The grade of steel used for the test assemblies is to be as detailed in 3.3.4. The length of the test assembly, *L*, is to be sufficient to allow at least the deposition of the entire length of the largest diameter electrode being tested. Where an electrode is submitted for approval of both butt and fillet welding, approval tests are to include the deposited metal tests as given in 3.2, the butt weld tests as given in 3.3, and only one fillet weld test as given in subsequent paragraphs of this sub-Section welded in the horizontal-vertical position.

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Table 11.3.3 Requirements for butt weld tests (covered electrodes)

Grade (*see* Note 3)	Tensile strength N/mm^2	Bend test ratio: $\frac{D}{t}$	Charpy V-notch impact tests	
			Test temperature °C	Average energy (*see* Note 1) J minimum
				All positions (*see* Note 2)
1N, 2N, 3N	400	3	+20, 0, –20	47 (34)
1Y, 2Y, 3Y, 4Y	490	3	+20, 0, –20, –40	47 (34)
2Y40, 3Y40, 4Y40, 5Y40	510	3	0, –20, –40, –60	47 (39)
2Y47, 3Y47, 4Y47	570 – 720	4	0, –20, –40	53
3Y40	510	3	–20	47 (39)
3Y42	530 – 680	4	–20	47
3Y46	570 – 720	4	–20	47
3Y50	610 – 770	4	–20	50
3Y55	670 – 830	5	–20	55
3Y62	720 – 890	5	–20	62
3Y69	770 – 940	5	–20	69
4Y40	510	3	–40	47 (39)
4Y42	530 – 680	4	–40	47
4Y46	570 – 720	4	–40	47
4Y50	610 – 770	4	–40	50
4Y55	670 – 830	5	–40	55
4Y62	720 – 890	5	–40	62
4Y69	770 – 940	5	–40	69
5Y40	510	3	–60	39
5Y42	530 – 680	4	–60	47
5Y46	570 – 720	4	–60	47
5Y50	610 – 770	4	–60	50
5Y55	670 – 830	5	–60	55
5Y62	720 – 890	5	–60	62
5Y69	770 – 940	5	–60	69
1 1/2 Ni	490	3	–80	27
3 1/2 Ni	450	3	–100	27
5 Ni	540	4	–120	27
9 Ni	640	4	–196	27

NOTES
1. Energy values from individual impact test specimens are to comply with 1.4.3.
2. Values in ( ) apply only to welds made in the vertical position with upward progression.
3. Grade 1Y is not applicable to SMAW consumables referenced in Section 3.

Table 11.3.4 Permitted methods for obtaining low hydrogen grading

Hydrogen Grade	Permitted Method
H15	ISO 3690 (or Glycerine) (*See* Note)
H10	ISO 3690
H5	ISO 3690

NOTE
ISO method preferred.

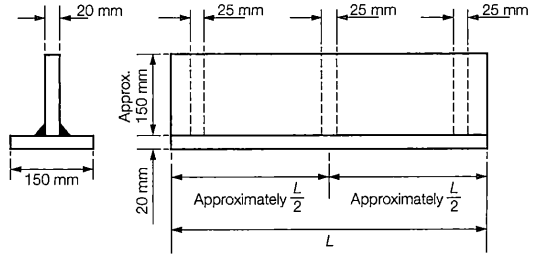

Fig. 11.3.4 Fillet weld test assembly

3.5.2 For Y47 grades, as an alternative to Fig. 11.3.4, the thickness of the plate used for the test assembly may be taken as 50 mm.

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3.5.3 The electrode sizes to be used are the maximum and minimum diameters recommended by the manufacturer for fillet welding. The first side is to be welded using the maximum diameter. The second side is to be welded only after the assembly has been allowed to cool below 50°C using the minimum diameter. The size of these single run fillet welds will, in general, be determined by the electrode size and the welding current employed during testing and should represent the range of fillet weld bead sizes recommended by the manufacturer.

3.5.4 Each test assembly is to be sectioned to form three macro-sections, each about 25 mm thick. These are to be examined for root penetration, satisfactory profile, freedom from cracking and reasonable freedom from porosity and slag inclusions. Any undercut is not to exceed 0,5 mm in depth. Convexity or concavity of the profile is not to exceed one-tenth of the fillet bead throat dimension. All such observations are to be reported.

3.5.5 Hardness measurements are to be made on the central macro-section only, as shown in Fig. 11.3.5. The results are to be reported.

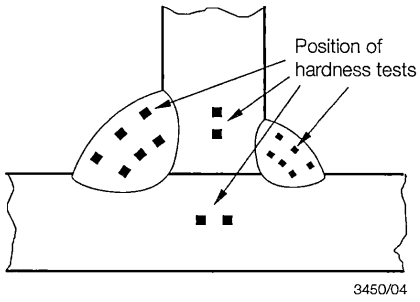

Fig. 11.3.5
Hardness tests for fillet weld test assembly

3.5.6 One of the remaining sections of the assembly is to have the weld on the first side gouged or machined to facilitate breaking the fillet weld on the second side by closing the two plates together, subjecting the root of the weld to tension. On the other remaining section, the weld on the second side is to be gouged or machined and the section fractured using the same procedure. The fractured surfaces are to be examined. They are to show satisfactory penetration, freedom from cracks and reasonable freedom from porosity and this should be reported.

3.6 Electrodes designed for deep penetration welding

3.6.1 Where an electrode is designed solely for the deep penetration welding of downhand butt joints and horizontal-vertical fillets in normal tensile strength steel, only the tests detailed in 3.7 and 3.8 are required for approval purposes.

3.6.2 Electrodes designed solely for the deep penetration welding technique will be approved as complying with Grade 1 requirements only and will be given the suffix 'p'.

3.6.3 Where a manufacturer recommends that an electrode having deep penetrating properties can also be used for downhand butt welding of thicker plates with prepared edges, the electrode will be treated as a normal penetration electrode, and the full series of tests in the downhand position is to be carried out, together with the deep penetration tests given in 3.7 and 3.8.

3.6.4 Where a manufacturer desires to demonstrate that an electrode, in addition to its use as a normal penetration electrode, also has deep penetrating properties when used for downhand butt welding and horizontal fillet welding, the additional tests given in 3.7 and 3.8 are to be carried out.

3.6.5 Electrodes approved for both normal and deep penetration welding will have the suffix 'p' added after the appropriate grade mark for normal penetration welding.

3.6.6 Where the manufacturer prescribes a different welding current and procedure for the electrode when used as a deep penetration electrode and a normal penetration electrode, the recommended current and procedure are to be used when making the test assemblies in each case.

3.7 Deep penetration butt weld test assemblies

3.7.1 Two plates of thickness equal to twice the diameter of the core of the electrode plus 2 mm are to be butt welded together with one downhand run of welding from each side. The plates are to be not less than 100 mm wide and of sufficient length to allow the cutting out of the test specimens of the correct number and size as shown in Fig. 11.3.6. Grade A steel is to be used for these test assemblies. The joint edges are to be prepared square and smooth and, after tacking, the gap is not to exceed 0,25 mm. The test assembly is to be welded using an 8 mm diameter electrode, or the largest diameter manufactured if this is less than 8 mm and the assembly is to be allowed to cool below 50°C between runs.

3.7.2 The test specimens as shown in Figs. 11.3.3 and 11.3.6 are to be prepared from each test assembly.

3.7.3 The results of tensile and impact tests are to comply with the requirements of Table 11.3.3 for Grade 1 electrodes. The position of fracture in the tensile test is to be reported. The bend test specimens are to be in accordance with 3.3.13.

3.7.4 The discards at the end of the welded assemblies are to be not more than 35 mm wide. The joints of these discards are to be polished and etched and must show complete fusion and inter-penetration of the weld beads. At each cut in the test assembly, the joints are also to be examined to ensure that complete fusion has taken place.

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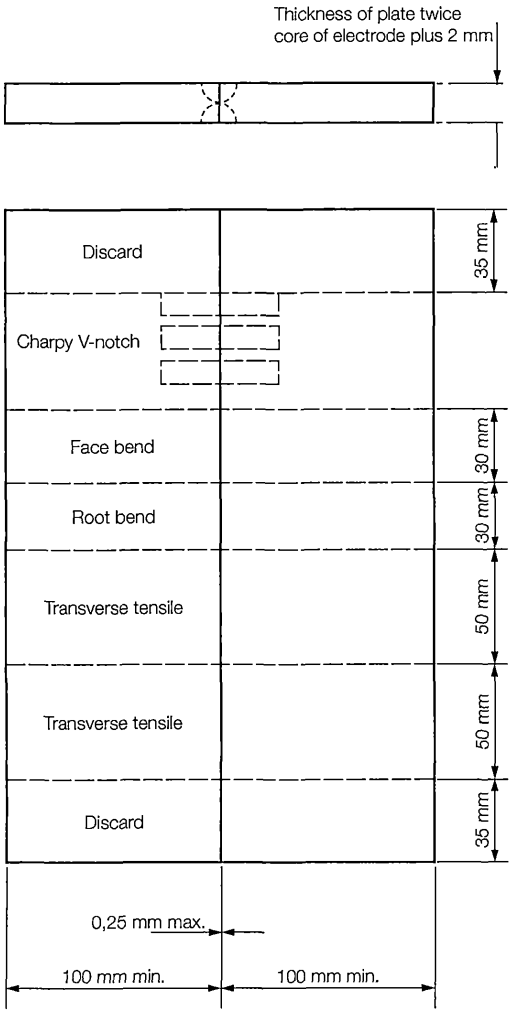

Fig. 11.3.6
Deep penetration butt weld test assembly

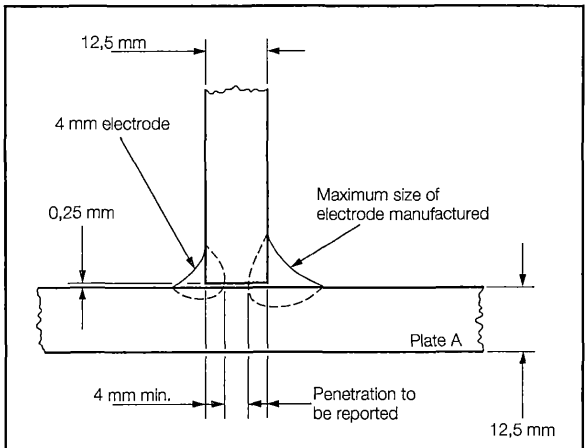

Fig. 11.3.7
Deep penetration fillet weld test assembly

3.8 Deep penetration fillet weld test assemblies

3.8.1 A fillet weld assembly is to be prepared as shown in Fig. 11.3.7 with plates about 12,5 mm in thickness. The welding is to be carried out with one run for each fillet with plate A in the horizontal plane during the welding operations. The length of the fillet is to be 160 mm and the gap between the plates is to be not more than 0,25 mm. Grade A steel is to be used for these test assemblies.

3.8.2 The fillet weld on one side of the assembly is to be carried out with a 4 mm diameter electrode, and that on the other side with the maximum diameter of electrode manufactured. The welding current used is to be within the range recommended by the manufacturer, and the welding is to be carried out using normal welding practice except that the assembly is to be allowed to cool below 50°C between runs.

3.8.3 The welded assembly is to be cut by sawing or machining within 35 mm of the ends of the fillet welds, and the joints are to be polished and etched. The welding of the fillet made with a 4 mm diameter electrode is to show a penetration of 4 mm (*see* Fig. 11.3.7) and the corresponding penetration of the fillet made with the maximum diameter of electrode manufactured is to be reported.

3.9 Electrodes designed for gravity or contact welding

3.9.1 Approval for welding using the gravity, 'G', technique is available for welding only normal strength and higher tensile steels up to and including Grade 36.

3.9.2 Where an electrode is submitted solely for approval for use in contact welding using automatic gravity or similar welding devices, deposited metal tests, butt weld tests and, where appropriate, fillet weld tests similar to those for normal manual electrodes are to be carried out using the process for which the electrode is recommended by the manufacturer.

3.9.3 Where an electrode is submitted for approval for use in contact welding using automatic gravity or similar welding devices in addition to normal manual welding, butt weld and, where appropriate, fillet weld tests, using the gravity or other contact device as recommended by the manufacturer, are to be carried out in addition to the normal approval tests.

3.10 Annual tests

3.10.1 For normal penetration electrodes, the annual tests are to consist of two deposited metal test assemblies. These are to be prepared and tested in accordance with 3.2. If an electrode is available in one diameter only, one test assembly is sufficient.

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3.10.2 Where an electrode is approved solely for deep penetration welding, the annual test is to consist of one butt welded test assembly. This is to be prepared and tested in accordance with 3.7.

3.10.3 Where an electrode is approved for both normal and deep penetration welding, annual tests as detailed in 3.10.1 and 3.10.2 are to be carried out.

3.10.4 Where an electrode is approved solely for gravity or contact welding, the annual test is to consist of one deposited metal test assembly using the gravity or other contact device as recommended by the manufacturer.

3.10.5 Where an electrode is approved for both manual and gravity welding, annual tests as detailed in 3.10.1 and 3.10.4 are to be carried out.

■ *Section 4*
Wire-flux combinations for submerged-arc automatic welding

4.1 General

4.1.1 Wire-flux combinations for single and multiple electrode submerged-arc automatic welding, without the use of temporary backing, are divided into the following two categories:

- For use with the multi-run technique.
- For use with the two-run technique.

Where particular wire-flux combinations are intended for welding with both techniques, tests are to be carried out for each technique.

4.1.2 Dependent on the results of mechanical and other tests, approval will be allocated as one of the grades from Table 11.1.1.

4.1.3 The suffixes T or M will be added after the grade mark to indicate approval for the two-run technique or, multi-run technique respectively.

4.1.4 Wire-flux combinations satisfying the requirements for multi-run or two-run techniques will also be approved for fillet welding in the downhand and horizontal-vertical position, subject to agreement by the manufacturer.

4.1.5 If the consumable combination is in compliance with the requirements of the hydrogen test given in 3.4, a suffix H15, H10 or H5 will be added to the grade. Table 11.4.1 shows the mandatory levels of low hydrogen approval for the various approval grades.

4.1.6 For each strength level, wire-flux combinations which have satisfied the requirements for a higher toughness grade are considered as complying with the requirements for a lower grade.

Table 11.4.1 Minimum low hydrogen approval requirements for wire-flux combinations

Approval grade	'H' grade for Multi-run	'H' grade for Two-run
1 (1N), 2 (2N), 3 (3N)	NR	NR
1Y, 2Y, 3Y, 4Y	NR	NR
2Y40 to 5Y40	H15	NR
2Y47 to 4Y47	H10	H15
3Y42 to 5Y42	H10	H15
3Y46 to 5Y46	H10	H15
3Y50 to 5Y50	H10	H10
3Y55 to 5Y55	H5	H10
3Y62 to 5Y62	H5	H5
3Y69 to 5Y69	H5	H5
$1^1/_2$ Ni	H15	NR
$3^1/_2$ Ni	H15	NR
5 Ni (*see* Note 2)	NR	NR
9 Ni (*see* Note 2)	NR	NR

NOTES
1. NR – Not required. Approval can be obtained when requested.
2. Assumes use of an austenitic, non-transformable, filler material.

4.1.7 Wire-flux combinations approved with multi-run technique for normal and higher strength levels up to and including 'Y' are also considered suitable for welding steels in the three strength levels below that for which they have been approved.

4.1.8 Wire-flux combinations approved with multi-run technique for strength levels Y40 to Y50, but excluding Y47 are also considered suitable for welding steels in two strength levels below that for which they have been approved.

4.1.9 Wire-flux combinations approved with multi-run technique for strength levels Y47, Y55 and above are also considered suitable for welding steels in only one strength level below that for which they have been approved.

4.1.10 Wire-flux combinations with two-run technique approval are not considered suitable for welding steels of any other strength level with that technique, *see* 4.5.1.

4.1.11 The welding current may be either a.c. or d.c. (electrode positive or negative) according to the recommendation of the manufacturer. If both a.c. and d.c. are recommended, a.c. is to be used for the tests.

4.1.12 Wire-flux combinations for multiple electrode submerged-arc welding will be subject to separate approval tests. These are to be carried out generally in accordance with the requirements of this Section.

4.1.13 Wire-flux combinations are not naturally low hydrogen in character, but for the lower strength grades of steel low hydrogen testing is not normally a requirement for approval. With higher strength steels it is more important and Table 11.4.1 shows the mandatory minimum low hydrogen status required for approval of wire-flux combinations.

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4.2 Approval tests for multi-run technique

4.2.1 Where approval for use with the multi-run technique is requested, deposited metal and butt weld tests are to be carried out.

4.3 Deposited metal test assemblies (multi-run technique)

4.3.1 One deposited metal test assembly is to be prepared as shown in Fig. 11.4.1, using any of the grades of steel in Table 11.1.1 up to a strength level which is not more than two levels above that for which approval is sought.

4.3.2 For Y47 grades, as an alternative to Fig. 11.4.1, the thickness of the plate used for the test assembly may be taken as 50 mm.

4.3.3 The bevelling of the plate edges is to be carried out by machining or mechanised gas cutting. In the latter case any remaining scale is to be removed from the bevelled edges.

4.3.4 Welding is to be in the downhand position, and the direction of deposition of each run is to alternate from each end of the plate. After completion of each run, the flux and welding slag are to be removed. Between each run, the assembly is to be left in still air until it has cooled to less than 250°C, the temperature being taken in the centre of the weld, on the surface of the seam. The thickness of the layer is to be not less than the diameter of the wire nor less than 4 mm, unless it is clearly stated as part of the consumable manufacturer's published recommendations.

4.3.5 The welding conditions (amperage, voltage and rate of travel) are to be in accordance with the recommendations of the manufacturer and are to conform with normal good welding practice for multi-run welding.

4.3.6 The chemical analysis of the deposited weld metal in each test assembly is to be supplied by the manufacturer and is to include the content of all significant alloying elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

4.3.7 Two longitudinal tensile and three impact test specimens are to be taken from each test assembly as shown in Fig. 11.4.1. Care is to be taken that the axes of the tensile test specimens coincide with the centre of the weld and the mid-thickness of the plates. The impact test specimens are to be cut perpendicular to the weld with their axes 10 mm from the upper surface. The notch is to be positioned in the centre of the weld and cut in the face of the test specimen perpendicular to the surface of the plate.

4.3.8 In those cases where two-run technique approval is also sought, only one longitudinal tensile specimen need be prepared and tested from this assembly.

4.3.9 The results of all tests are to comply with the requirements of Table 11.4.2, as appropriate.

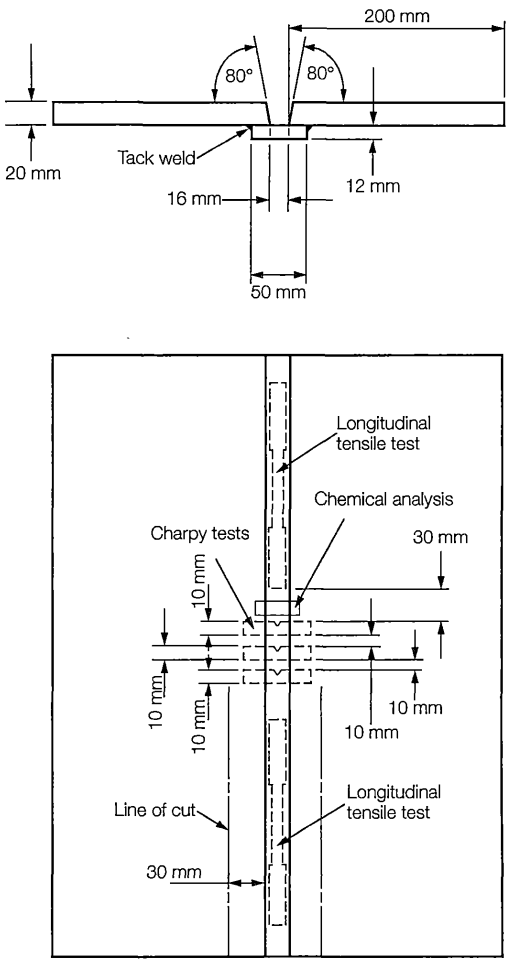

Fig. 11.4.1 Deposited metal test assembly

4.4 Butt weld test assemblies (multi-run technique)

4.4.1 One butt weld test assembly is to be prepared as shown in Fig. 11.4.2.

4.4.2 The grade of steel used for the preparation of the test assembly are to be as follows:

Grade 1 wire-flux combination	A
Grade 2 wire-flux combinations	A, B or D
Grade 3 wire-flux combinations	A, B, D or E
Grade 1Y wire-flux combination	AH32 or AH36
Grade 2Y wire-flux combinations	AH32, AH36, DH32 or DH36
Grade 3Y wire-flux combinations	AH32, AH36, DH32, DH36, EH32 or EH36
Grade 4Y wire-flux combinations	AH32, AH36, DH32, DH36, EH32, EH36, FH32 or FH36
Grade 2Y40 wire-flux combination	AH40 or DH40

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Table 11.4.2 Requirements for deposited metal tests (wire-flux combinations)

Grade	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation on 50 mm % minimum	Charpy V-notch impact tests	
				Test temperature °C	Average energy (*see* Note) J minimum
1N, 2N, 3N	305	400 – 560	22	+20, 0, –20	34
1Y, 2Y, 3Y, 4Y	375	490 – 660	22	+20, 0, –20, –40	34
2Y40, 3Y40, 4Y40, 5Y40	400	510 – 690	22	0, –20, –40, –60	39
2Y47, 3Y47, 4Y47	460	570 – 720	19	0, –20, –40	53
3Y40	400	510 – 690	22	–20	39
3Y42	420	530 – 680	20	–20	47
3Y46	460	570 – 720	20	–20	47
3Y50	500	610 – 770	18	–20	50
3Y55	550	670 – 830	18	–20	55
3Y62	620	720 – 890	18	–20	62
3Y69	690	770 – 940	17	–20	69
4Y40	400	510 – 690	22	–40	39
4Y42	420	530 – 680	20	–40	47
4Y46	460	570 – 720	20	–40	47
4Y50	500	610 – 770	18	–40	50
4Y55	550	670 – 830	18	–40	55
4Y62	620	720 – 890	18	–40	62
4Y69	690	770 – 940	17	–40	69
5Y40	400	510 –690	22	–60	39
5Y42	420	530 – 680	20	–60	47
5Y46	460	570 – 720	20	–60	47
5Y50	500	610 – 770	18	–60	50
5Y55	550	670 – 830	18	–60	55
5Y62	620	720 – 890	18	–60	62
5Y69	690	770 – 940	17	–60	69
1½ Ni	375	460	22	–80	34
3½ Ni	375	420	25	–100	34
5 Ni	375	500	25	–120	34
9 Ni	375	600	25	–196	34

NOTE
Energy values from individual impact test specimens are to comply with 1.4.3.

Grade 3Y40 wire-flux combinations AH40, DH40 or EH40
Grade 4Y40 wire-flux combinations AH40, DH40, EH40 or FH40
Grade 5Y40 wire-flux combinations AH40, DH40 EH40, FH40
Grade 2Y47 wire-flux combinations AH47 or DH47
Grade 3Y47 wire-flux combinations AH47, DH47 or EH47
Grade 4Y47 wire-flux combinations AH47, DH47, EH47 or FH47

Where Grade 32 higher tensile steel is used, the tensile strength is to be not less than 490 N/mm^2. The chemical composition, including the content of grain refining elements, is to be reported in all cases where higher tensile steel is used.

4.4.3 For all other grades, the steel plates used are to be selected by reference to Table 11.1.1, and are to have at least their chemical composition and tensile properties within the limits specified for that grade in Chapter 3. The strength grade used is to be the same as that for which approval is sought, and the toughness grade is to be no higher than that for which approval is also sought.

4.4.4 The plate edges are to be prepared to form a single V-joint, the included angle between the fusion faces being 60° and the root face being 4 mm. The bevelling of the plate edges is to be carried out by machining or mechanised gas cutting. In the latter case, any remaining scale is to be removed from bevelled edges.

4.4.5 Welding is to be carried out in the downhand position by the multi-run technique, and the welding conditions are to be the same as those adopted for the deposited metal test assembly. The back sealing run is to be applied in the downhand position after cutting out the root run to clean metal.

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Table 11.4.3 Requirements for butt weld tests (wire-flux combinations)

Grade	Tensile strength N/mm^2	Bend test ratio: $\frac{D}{t}$	Charpy V-notch impact tests	
			Test temperature °C	Average energy (*see* Notes 1 and 2) J minimum
1N, 2N, 3N	400	3	+20, 0, –20	34
1Y, 2Y, 3Y, 4Y	490	3	+20, 0, –20, –40	34
2Y40, 3Y40, 4Y40, 5Y40	510	3	0, –20, –40, –60	39
2Y47, 3Y47, 4Y47	570 – 720	4	0, –20, –40	53
3Y40	510	3	–20	39
3Y42	530 – 680	4	–20	47 (41)
3Y46	570 – 720	4	–20	47
3Y50	610 – 770	4	–20	50
3Y55	670 – 830	5	–20	55
3Y62	720 – 890	5	–20	62
3Y69	770 – 940	5	–20	69
4Y40	510	3	–40	39
4Y42	530 – 680	4	–40	47 (41)
4Y46	570 – 720	4	–40	47
4Y50	610 – 770	4	–40	50
4Y55	670 – 830	5	–40	55
4Y62	720 – 890	5	–40	62
4Y69	770 – 940	5	–40	69
5Y40	510	3	–60	39
5Y42	530 – 680	4	–60	47 (41)
5Y46	570 – 720	4	–60	47
5Y50	610 – 770	4	–60	50
5Y55	670 – 830	5	–60	55
5Y62	720 – 890	5	–60	62
5Y69	770 – 940	5	–60	69
1½ Ni	490	3	–80	27
3½ Ni	450	3	–100	27
5 Ni	540	4	–120	27
9 Ni	640	4	–196	27

NOTES
1. Energy values from individual impact test specimens are to comply with 1.4.3.
2. Values in ( ) apply only to two-run technique impact test specimens.

4.4.6 It is recommended that the welded assembly be subjected to a radiographic examination to ascertain if there are any defects in the weld prior to the preparation of test specimens.

4.4.7 The test specimens as shown in Fig. 11.3.3 and Fig. 11.4.2 are to be prepared from each test assembly.

4.4.8 The results of all tensile and impact tests are to comply with the requirements of Table 11.4.3, as appropriate. The position of fracture of the transverse tensile test is to be reported.

4.4.9 The bend test specimens can be considered as complying with the requirements if, after bending, no cracks or other open defects exceeding 3 mm in dimension can be seen on the outer surface.

4.5 Approval tests for two-run technique

4.5.1 Where approval for use with the two-run technique is requested, two butt weld test assemblies are to be prepared and tested using plates of the strength level for which approval is required. Each strength level requires separate approval.

4.5.2 Two welded assemblies are to be made from a pair of plates of matching thicknesses. The thickness of the thicker pair of plates will be the maximum for which the approval is valid. The second assembly is to be welded from plates having approximately half of the thickness of the first assembly.

4.6 Butt weld test assemblies (two-run technique)

4.6.1 The grade of steel used for the preparation of the test assemblies is not to be of any higher grade (impact toughness) than that for which approval is required. The chemical composition, including the content of grain refining elements, and the strength properties of the plates used, are to be reported.

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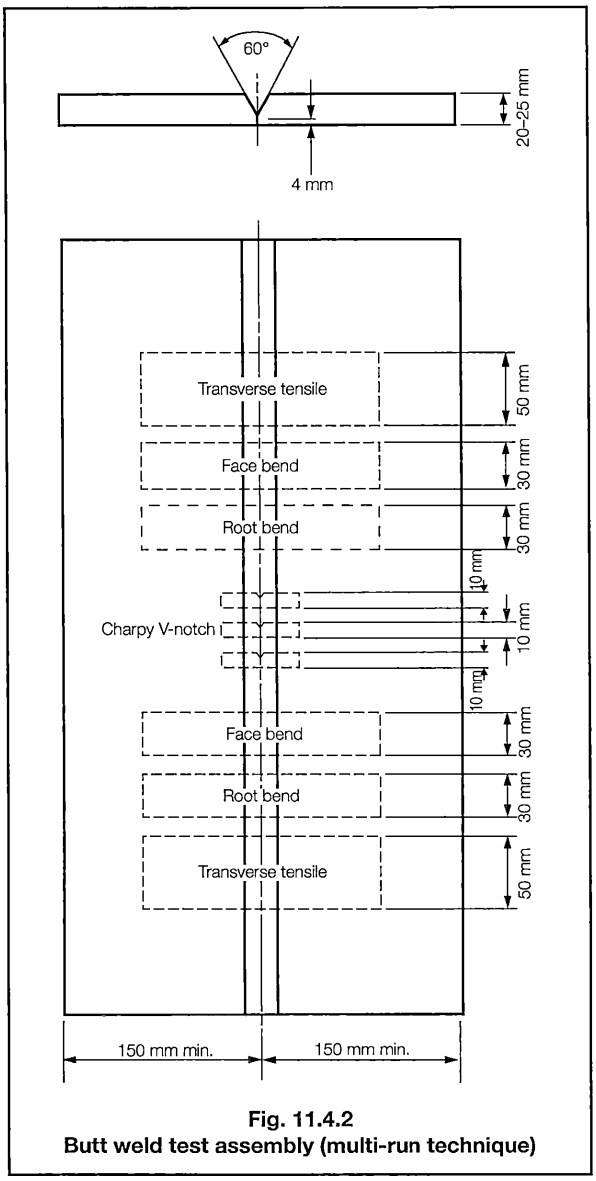

Fig. 11.4.2
Butt weld test assembly (multi-run technique)

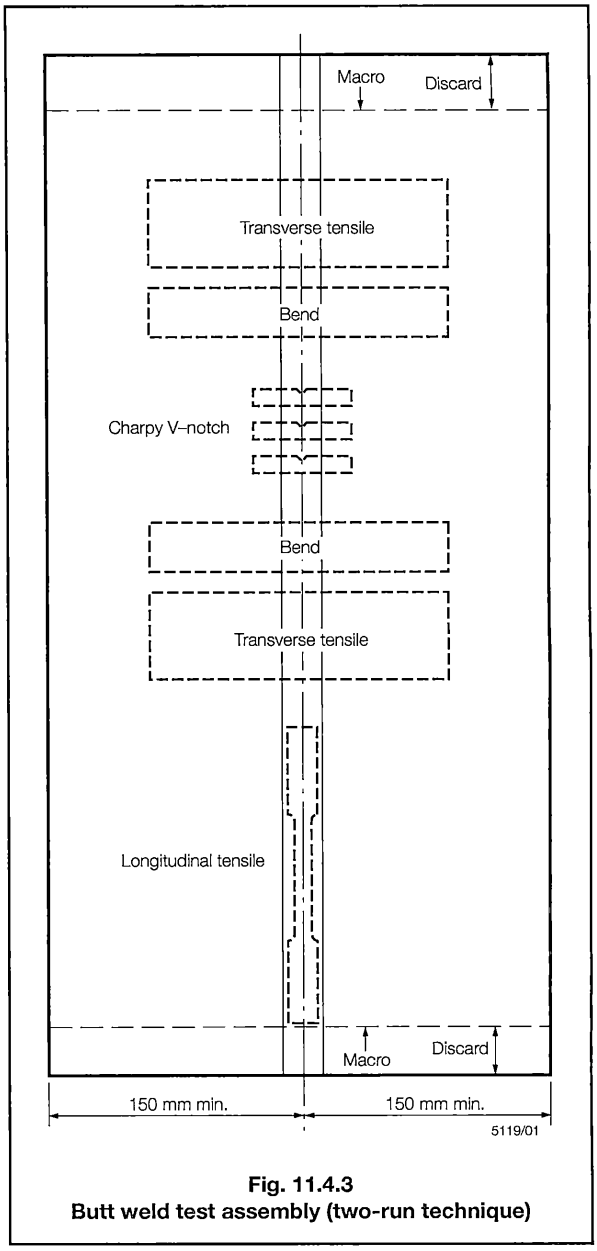

Fig. 11.4.3
Butt weld test assembly (two-run technique)

4.6.2 The maximum diameter of wire and the edge preparation to be used are to be in accordance with Table 11.4.4. Small deviations in the edge preparation may be allowed if requested by the manufacturer. The bevelling of the plate edges is to be performed by machining or mechanised gas cutting. In the latter case, any remaining scale is to be removed from the bevelled edges. The root gap should not exceed 0,7 mm.

4.6.3 Each butt weld is to be welded in two runs, one from each side, using amperages, voltages and travel speeds in accordance with the recommendations of the manufacturer and normal good welding practice. After completion of the first run, the flux and welding slag are to be removed and the assembly is to be left in still air until it has cooled to less than 100°C, the temperature being taken in the centre of the weld, on the surface of the seam.

4.6.4 It is recommended that the butt weld assemblies be subjected to radiographic examination to ascertain if there are any defects in the weld prior to the preparation of test specimens.

4.6.5 The test specimens, as shown in Fig. 11.4.3 and Fig. 11.4.4, are to be prepared from each test assembly, except as detailed in 4.6.8. The edges of two of the discards are to be polished and etched, and must show complete fusion and inter-run penetration of the welds. At each cut in the test assembly, the edges are also to be examined to ensure that complete fusion has taken place.

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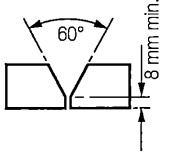
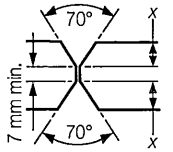
Table 11.4.4 Butt weld assembly preparation

Plate thickness mm	Recommended diameter	Maximum diameter of wire mm
12,5		5
20–25		6
35–40		7

4.6.6 The results of transverse tensile and impact tests are to comply with the requirements of Table 11.4.3 as appropriate. The position of fracture of the transverse tensile tests is to be reported.

4.6.7 The bend test specimens can be considered as complying with the requirements if, after bending, no crack or other open defects exceeding 3 mm in dimensions can be seen on the outer surface. One of the specimens from each assembly is to be tested with the side first welded in tension, and the second specimen with the other side in tension.

4.6.8 The longitudinal tensile specimen shown in Fig. 11.4.3 is to be prepared from the thicker assembly, even in those cases where multi-run technique approval is also sought. This test specimen is to be machined to the dimensions shown in Ch 11,2.1.1, and the longitudinal axis is to coincide with the centre of the weld about 7 mm below the plate surface on the side from which the second run is made. The test specimen may be given a hydrogen release treatment in accordance with 2.1.1. The results of this test are to comply with the requirements of Table 11.4.2.

4.6.9 The chemical analysis of the weld metal of the second run in each assembly is to be determined and reported. This is to include the content of all significant elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

4.7 Annual tests

4.7.1 Annual tests are to consist of at least the following:

(a) For wire-flux combinations approved for the multi-run technique, one deposited metal test assembly.

(b) For wire-flux combinations approved for the two-run technique, one butt weld test assembly using plate material 20 to 25 mm in thickness. For Y47 the thickness of plate material may be taken as 50 mm.

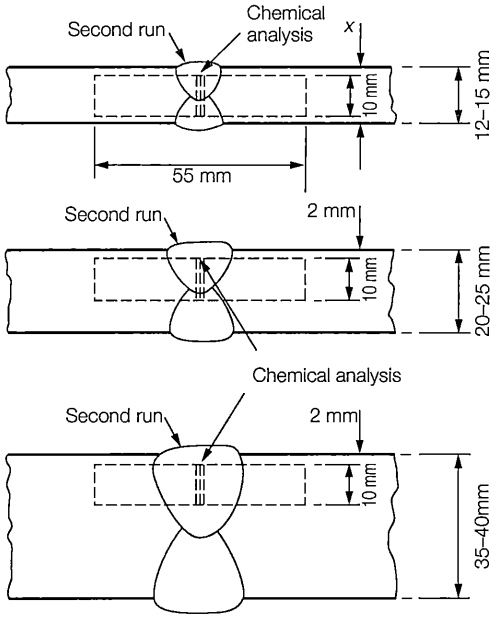


Fig. 11.4.4
Butt weld test assembly (two-run technique): position of impact test specimens

4.7.2 The deposited metal assemblies are to be prepared and tested in accordance with 4.3, except that only one longitudinal tensile, three impact test specimens and a chemical analysis are required.

4.7.3 The butt weld test assemblies are to be prepared and tested in accordance with 4.6, except that only one transverse tensile, two bend, three impact test specimens and a chemical analysis are required. One longitudinal tensile test specimen is also to be prepared where the wire-flux combination is approved solely for the two-run technique.

4.7.4 Where a wire-flux combination is approved for welding a range of steels with different specified minimum strength levels, steel of the highest strength approved is to be used for the preparation of the butt weld assembly required by 4.7.1(b).

■ *Section 5*
Wires and wire-gas combinations for manual, semi-automatic and automatic welding

5.1 General

5.1.1 Wire-gas combinations and flux-cored or flux-coated wires (for use with or without a shielding gas) are divided into the following categories for the purposes of approval testing:

(a) For use in manual multi-run welding with the inert gas tungsten arc welding process (GTAW).

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Table 11.5.1 Minimum low hydrogen approval requirements for wires and wire-gas combinations

Approval grade	'H' grade for m and S techniques	'H' grade for M technique	'H' grade for T technique
1 (1N), 2 (2N), 3 (3N)	NR	NR	NR
1Y, 2Y, 3Y, 4Y	H15 (see Note 2)	NR	NR
2Y40 to 5Y40	H15	H15	NR
2Y47 to 4Y47	H10	H10	H10
3Y42 to 5Y42	H10	H10	H15
3Y46 to 5Y46	H10	H10	H15
3Y50 to 5Y50	H10	H10	H10
3Y55 to 5Y55	H5	H5	H10
3Y62 to 5Y62	H5	H5	H5
3Y69 to 5Y69	H5	H5	H5
$1^1/_2$ Ni	H15	H15	NR
$3^1/_2$ Ni	H15	H15	NR
5 Ni	NR (see Note 3)	NR	NR
9 Ni	NR (see Note 3)	NR	NR

NOTES
1. NR – Not required. Approval may be obtained when requested.
2. Optional in this case. If low hydrogen approval is not obtained, there is a limitation on the carbon equivalent of the steel which is permitted to be welded.
3. Assumes use of an austenitic, non-transformable, filler material.

(b) For use in semi-automatic multi-run metal arc welding.
(c) For use in single electrode multi-run automatic metal arc and GTAW welding.
(d) For use in single electrode two-run automatic metal arc and GTAW welding.

5.1.2 The term 'manual', is used to describe the technique where the gas-shielded tungsten arc torch is held in one hand and the filler is added separately by the other hand.

5.1.3 The term 'semi-automatic' is used to describe processes in which the weld is made manually by a welder holding a gun through which the wire is continuously fed.

5.1.4 In the GTAW process, 'automatic' refers to the fully mechanised control and application of both torch and separate filler wire.

5.1.5 Dependent on the results of mechanical and other tests, approval will be allocated as one of the grades from Table 11.1.1.

5.1.6 A suffix S will be added after the grade mark to indicate approval for semi-automatic multi-run welding.

5.1.7 For wires intended for automatic welding, the suffixes T or M will be added after the grade mark to indicate approval for two-run or multi-run welding techniques, respectively.

5.1.8 For wires intended for both semi-automatic and automatic welding, the suffices will be added in combination.

5.1.9 Solid wire-gas combinations are considered naturally low hydrogen in character and qualify for 'H15' approval without testing. This is not so for cored wires and continuous coated wires which must be tested if there is a need for low hydrogen approval. For the lower strength grades of steel, low hydrogen testing is not normally a requirement for approval. With higher strength steels, it is more important and Table 11.5.1 shows the mandatory minimum low hydrogen status required for approval of wire-gas combinations.

5.1.10 The testing methods to be used for low hydrogen approval are to be in accordance with 3.4, modified to use the manufacturer's recommended welding conditions and adjusting the deposition rate to give a weld deposit weight per sample similar to that deposited when using manual electrodes.

5.1.11 Where applicable, the approved combination will name either the specific gas composition or its trade name, but in either case the composition of the shielding gas is to be reported. Unless otherwise agreed, additional approval tests are required when a shielding gas is used other than that used for the original approval tests. However a wire and gas combination approved with an argon/carbon dioxide shielding gas where the carbon dioxide is between 15-25 per cent is also approved for other combinations of argon/carbon dioxide, provided the carbon dioxide content is within the range 15-25 per cent. The range of approval is limited to ferritic consumables in solid wire, flux cored and coated wire forms and subject to the agreement of the consumable manufacturer and LR.

5.1.12 Wires and wire-gas combinations for multiple electrode automatic welding will be subject to separate approval tests. Any proposals are to be submitted for consideration.

5.1.13 Wires and wire-gas combinations approved with multi-run technique for normal and higher strength levels up to and including 'Y' are also considered suitable for welding steels in the three strength levels below that for which they have been approved.

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5.1.14 Wires and wire-gas combinations approved with multi-run technique for strength levels Y40 to Y50, but excluding Y47 are also considered suitable for welding steels in two strength levels below that for which they have been approved.

5.1.15 Wires and wire-gas combinations approved with multi-run technique for strength levels Y47, Y55 and above are also considered suitable for welding steels in only one strength level below that for which they have been approved.

5.1.16 Wires and wire-gas combinations with two-run technique approval are not considered suitable for welding steels of any other strength level with that technique, *see* 5.4.1.

5.2 Approval tests for manual and semi-automatic multi-run welding

5.2.1 Approval tests for manual (GTAW) and semi-automatic multi-run welding are to be carried out generally in accordance with the requirements of Section 3, except as required by 5.2, using the respective technique for the preparation of all test assemblies.

5.2.2 Two deposited metal test assemblies are to be prepared in the downhand position as shown in Fig. 11.3.1, one using the smallest diameter, and the other using the largest diameter of wire for which approval is required. Where only one diameter is manufactured, only one deposited metal assembly is to be prepared.

5.2.3 For Y47 grades, as an alternative to Figs. 11.3.1 to 11.3.4, the thickness of the plate used for the test assembly may be taken as 50 mm.

5.2.4 The weld metal is to be deposited according to the practice recommended by the manufacturer, and the thickness of each layer of weld metal is to be between 2 mm and 6 mm, unless it is clearly stated as part of the consumable manufacturer's published recommendations.

5.2.5 The chemical analysis of the deposited weld metal in each test assembly is to be supplied by the manufacturer and is to include the content of all significant alloying elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

5.2.6 Butt weld assemblies as shown in Fig. 11.3.2 are to be prepared for each welding position for which the wire is to be approved. In the case of approvals for normal and higher strength steels (up to 355 N/mm^2 minimum specified yield strength), tests satisfying the requirements in both the downhand and vertical-upward positions will be considered as having also satisfied the requirements for the horizontal-vertical position. In all other cases, approval in the horizontal-vertical position will require a butt weld to be made in that position and be fully tested.

5.2.7 The downhand assembly is to be welded using, for the first run, wire of the smallest diameter to be approved and, for the remaining runs, wire of the largest diameter to be approved.

5.2.8 Where approval is requested only in the downhand position, an additional butt weld assembly is to be prepared in that position using, if possible, wires of different diameter from those required by 5.2.7. If only one wire diameter is to be approved, this second downhand butt weld should be made using either larger or smaller beads than the first assembly.

5.2.9 The butt weld assemblies, in positions other than downhand, are to be welded using, for the first run, wire of the smallest diameter to be approved, and for the remaining runs, the largest diameter of wire recommended by the manufacturer for the position concerned.

5.2.10 Fillet weld test assemblies as detailed in 3.5 are to be prepared, examined and tested.

5.2.11 Low hydrogen approval tests are to be carried out if required by 5.1.9.

5.2.12 Test specimens from each assembly are to be prepared and tested in accordance with the requirements of 3.2 and 3.3.

5.3 Approval tests for multi-run automatic welding

5.3.1 Approval tests for multi-run automatic welding are to be carried out generally in accordance with the requirements of Section 4, except as required by 5.3, using the multi-run automatic welding technique for the preparation of all test assemblies.

5.3.2 One deposited metal test assembly is to be prepared as shown in Fig. 11.4.1. Welding is to be as detailed in 4.3.4, except that the thickness of each layer is to be not less than 3 mm, unless it is clearly stated as part of the consumable manufacturer's published recommendations.

5.3.3 For Y47 grades, as an alternative to Figs. 11.4.1 and 11.4.2, the thickness of the plate used for the test assembly may be taken as 50 mm.

5.3.4 One butt weld test assembly is to be prepared as shown in Fig. 11.4.2 for each welding position to be approved for the automatic multi-run technique.

5.3.5 Test specimens from each test assembly are to be prepared and tested in accordance with the requirements of Section 4 for multi-run submerged-arc automatic welding.

5.3.6 Low hydrogen approval tests are to be made if required by 5.1.9.

5.3.7 At the discretion of LR, wires approved for semi-automatic welding in the downhand position may also be approved without additional tests, for use in multi-run automatic welding.

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5.4 Approval tests for two-run automatic welding

5.4.1 Approval tests for two-run automatic welding are to be carried out generally in accordance with the requirements of Section 4, except as required by 5.4, using the two-run automatic welding technique for the preparation of all test assemblies. Two butt weld test assemblies are to be prepared and tested using plates of the strength level for which approval is required. Each strength level requires separate approval.

5.4.2 Two butt weld test assemblies are to be prepared generally as detailed in 4.5 and 4.6 using plates 12 to 15 mm and 20 to 25 mm in thickness.

5.4.3 If approval is requested for welding plate thicker than 25 mm, one assembly is to be prepared using plates approximately 20 mm in thickness and the other using plates of the maximum thickness for which approval is requested.

5.4.4 The edge preparation of the test assemblies is to be as shown in Fig. 11.5.1. Small deviations in edge preparation may be allowed, if these form part of the consumable manufacturer's recommendations. For assemblies using plates over 25 mm in thickness, the edge preparation is to be reported for information.

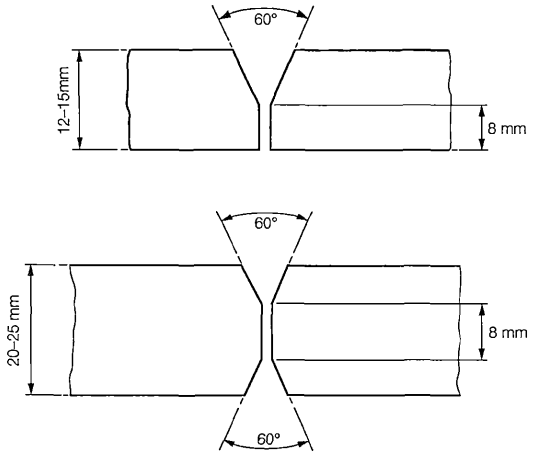

Fig. 11.5.1
Normal edge preparation for two-run butt weld test assemblies

5.4.5 The diameters of wires used are to be in accordance with the recommendations of the manufacturer and are to be reported.

5.4.6 Test specimens from each butt weld assembly are to be prepared and tested in accordance with the requirements of Section 4 for two-run submerged-arc automatic welding.

5.4.7 The weld metal chemical analysis is to be reported as in 4.6.9. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

5.5 Annual tests

5.5.1 Annual tests are to consist of at least the following:

(a) Wires approved for manual welding or semi-automatic welding or either of these combined with approval for automatic multi-run welding:
one deposited metal test assembly prepared in accordance with 5.2 using a wire of diameter within the approved range.

(b) Wire approved for automatic multi-run welding:
one deposited metal test assembly prepared in accordance with 5.3 using a wire of diameter as stated in (a).

(c) Wires approved for two-run automatic welding:
one butt weld test assembly prepared in accordance with 5.4 using plates 20 to 25 mm in thickness or the maximum approved thickness. The diameter of wire used is to be reported.

■ *Section 6* Consumables for use in electro-slag and electro-gas welding

6.1 General

6.1.1 The requirements for the approval of consumables used for electro-slag or electro-gas welding (including consumable nozzles, where applicable) are generally as detailed in Section 4 for two-run submerged-arc welding consumables, except as otherwise detailed in this Section.

6.1.2 For each grade, approval may be restricted for use with specific compositional types of steel. For Grades 1Y, 2Y, 3Y, 4Y, 2Y40, 3Y40 and 4Y40 this will normally be in respect of the grain refining element content, and tests on niobium grain refined steel will normally qualify for use also on steels treated with aluminium or vanadium or combinations of these elements.

6.1.3 Superscript numbers are applied to the 'Y' of higher strength steel consumables, e.g. $2Y^1$, to indicate the type of parent steel for which approval is applicable as follows:

Y^1 approval Grade for higher strength steel is limited to parent steel which has been treated only with aluminium.

Y^2 approval Grade for higher strength steel is appropriate to niobium-treated steels, whether aluminium treated or not. It also covers steels treated only with aluminium.

6.1.4 Each strength level requires separate approval involving the welding and testing of two butt weld assemblies of different thickness. The greater thickness will determine the maximum approved thickness.

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6.2 Butt weld test assemblies

6.2.1 Two butt weld test assemblies are to be prepared, one with plates 20 to 25 mm in thickness and the other with plates 35 to 40 mm in thickness. The steel used is not to be of any higher grade (impact toughness) than that for which approval is required. The limitations of 6.1.2 need to be considered in this Section. The chemical composition of the plate, including the content of grain refining elements, is to be reported.

6.2.2 The welding conditions and the edge preparation adopted are to be in accordance with the recommendations of the manufacturer and are to be reported in detail. The manufacturer's maximum recommended gap between plates is to be used in making the test assemblies.

6.2.3 It is recommended that the assemblies are subjected to radiographic examination to identify any defects before the preparation of any test specimens.

6.2.4 Test specimens as follows, and as shown in Fig. 11.6.1, are to be prepared from each test assembly:

(a) Two longitudinal tensile test specimens.
(b) Two transverse tensile test specimens.
(c) Two bend test specimens.
(d) Two macro-sections.
(e) Two sets of three impact test specimens notched in accordance with Fig. 11.6.2.

6.2.5 The chemical analysis of the weld metal in each assembly is to be determined and reported. This is to be supplied by the manufacturer and is to include the content of all significant elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

6.2.6 The results of all transverse tensile and impact tests are to comply with the requirements given in Table 11.4.3 as appropriate. The position of fracture of the transverse tensile test is to be reported. The Charpy V-notch impact test requirements are as for the two-run technique in Table 11.4.3.

6.2.7 The results of all longitudinal tensile tests are to comply with the requirements of Table 11.4.2.

6.2.8 The bend test specimens are to be in accordance with 4.6.7 and Table 11.4.3. Each surface of the weld is to be tested Fension.

6.3 Annual tests

6.3.1 Annual tests are to consist of at least one butt weld test assembly using plate material 20 to 25 mm in thickness.

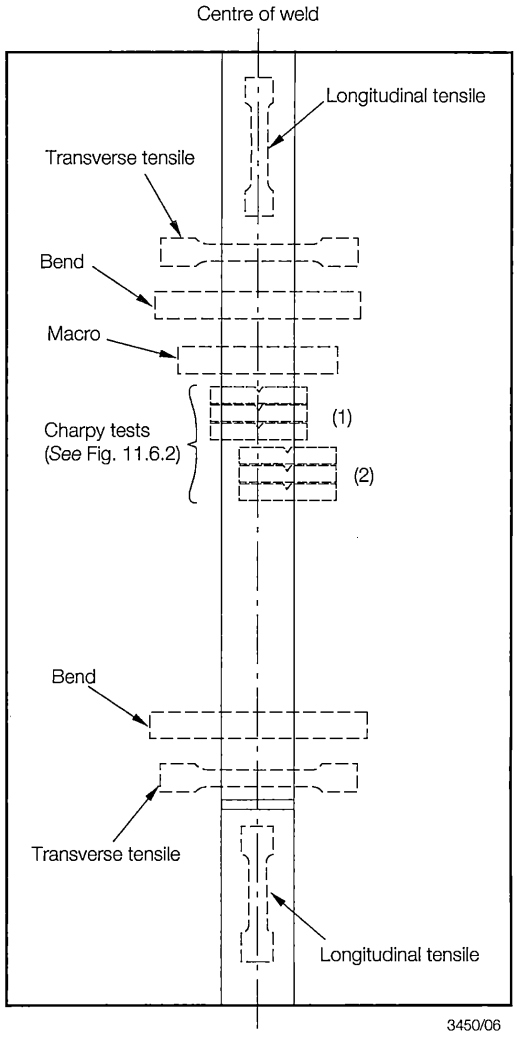

Fig. 11.6.1
Butt weld test assembly for electro-slag or electro-gas welding

6.3.2 The assembly is to be prepared and tested in accordance with 6.2 except that only the following tests are required:

(a) One longitudinal tensile test.
(b) One transverse tensile test.
(c) Two bend tests.
(d) Two sets of three Charpy V-notch impact tests; one set with the notch at the centre of the weld (Position (1) in Fig. 11.6.2), and one set with the notch in the weld metal 2 mm from the fusion line (Position (2) in Fig.11.6.2).
(e) Chemical analysis.
(f) One macro section.

6.3.3 Where a consumable or combination is approved for a range of steels with different specified minimum strength levels, steel of the highest strength level is to be used for the preparation for the assembly required by 6.3.1.

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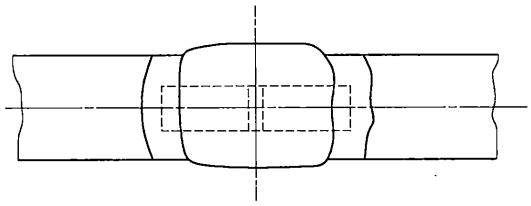
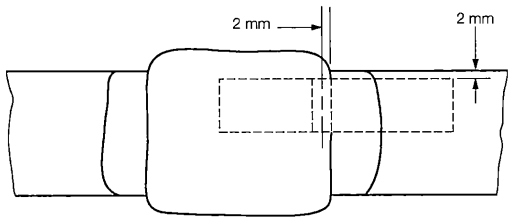


(1) In the centre of the weld metal



(2) In the weld metal, 2 mm from the fusion line

Fig. 11.6.2
Position of Charpy V-notch impact test specimens

Section 7
Consumables for use in one-side welding with temporary backing materials

7.1 General

7.1.1 The requirements for approval of combinations including temporary backing material, for use in one-side welding techniques, are dependent on the technique used and which basic technique it most closely follows. The following are provided for:

(a) Technique m – for manual electrode/backing combinations.
(b) Technique S – for wire-gas/backing combinations used with semi-automatic multi-run technique.
(c) Technique M – for wire-flux or wire-gas in combination with backing material (and maybe supplementary filler materials) used with an automatic multi-run technique.
(d) Technique A – as for M but using a procedure with a high heat input rate (large bead size relative to thickness welded). This would apply to welds made by four or less runs in 20 mm thickness, or eight or less runs in 35 mm.

7.1.2 For technique m, S or M, a single butt weld is to be made in plate of 20–25 mm thickness. For technique A, two butt welds are to be made, one in plate of the maximum thickness recommended by the manufacturer, the other in plate of approximately half the thickness of the first. Usually this will involve thicknesses in the region of 35–40 mm and 20–25 mm respectively.

7.1.3 A wire and gas combination approved with an argon/carbon dioxide shielding gas where the carbon dioxide content is between 15-25 per cent is also approved for other combinations of argon/carbon dioxide, provided the carbon dioxide content is within the range 15-25 per cent. The range of approval is limited to ferritic consumables in solid wire, flux cored and coated wire forms and subject to the agreement of the consumable manufacturer and LR.

7.1.4 Any unrecognised techniques or unusual combinations will be considered for approval subject to a test programme to be agreed based on the details of the technique and combination which are to be submitted in advance.

7.1.5 Where low hydrogen approval is required either by Table 11.7.1 or by the manufacturer, it should be noted that this will generally be achieved through separate testing of:

(a) the backing material, and
(b) the welding electrode or combination of wire-flux or wire-gas.

7.1.6 The hydrogen potential of the backing material is to be determined using the modified Gayley-Wooding method which expresses the total hydrogen content as water by weight per cent. The qualifying levels are:

To qualify as:	H_20 g/100g sample
H15	0,5
H10	0,3
H5	0,2

7.1.7 The sampling and approval of the combinations without the backing are to follow the general requirements of Sections 3, 4 or 5, as appropriate.

7.1.8 Combinations approved with multi-run technique (m, S and M) for normal and higher strength levels up to and including 'Y' are also considered suitable for welding steels in the three strength levels below that for which they have been approved.

7.1.9 Combinations approved with multi-run technique (m, S and M) for strength levels Y40 to Y50, but excluding Y47, are also considered suitable for welding steels in two strength levels below that for which they have been approved.

7.1.10 Combinations approved with multi-run technique (m, S and M) for strength levels Y47, Y55 and above are also considered suitable for welding steels in only one strength level below that for which they have been approved.

7.1.11 Combinations approved for the 'A' multi-run technique are not considered suitable for welding steels of any other strength level with that technique.

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Table 11.7.1 Minimum low hydrogen approval requirements for one-side welding with combinations including temporary backing material

Approval grades	'H' grade for m and S techniques	'H' grade for M technique	'H' grade for A technique
1 (1N), 2 (2N), 3 (3N)	NR	NR	NR
1Y, 2Y, 3Y, 4Y	H15 (*see* Note 2)	NR	NR
2Y40 to 5Y40	H15	H15	NR
2Y47 to 4Y47	H10	H10	H15
3Y42 to 5Y42	H10	H10	H15
3Y46 to 5Y46	H10	H10	H15
3Y50 to 5Y50	H10	H10	H10
3Y55 to 5Y55	H5	H5	H10
3Y62 to 5Y62	H5	H5	H5
3Y69 to 5Y69	H5	H5	H5
$1^1/_2$ Ni	H15	H15	NR
$3^1/_2$ Ni	H15	H15	NR
5 Ni (*see* Note 3)	NR	NR	NR
9 Ni (*see* Note 3)	NR	NR	NR

NOTES
1. NR – Not required. Approval may be obtained when requested.
2. Optional in this case. If low hydrogen approval is not obtained, there is a limitation on the carbon equivalent of the steel which is permitted to be welded.
3. Assumes the use of an austenitic, non-transformable, filler material.

7.2 Approval tests for manual (m), semi-automatic (S) and automatic multi-run (M) techniques

7.2.1 For each position to be approved, one butt weld assembly is to be prepared using plates of 20–25 mm thickness as shown in Fig. 11.7.1. The grade of plate used is to be no higher in toughness than that for which approval is required. The strength is to be appropriate to the grade for which welding approval is requested.

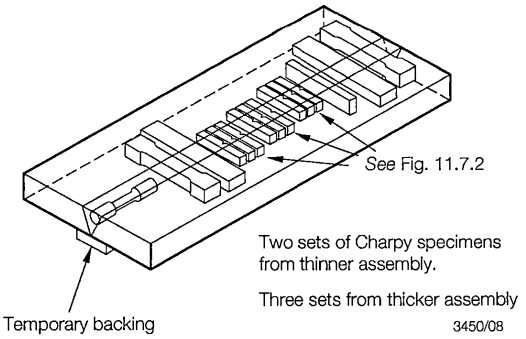

Fig. 11.7.1
Butt weld test assembly and specimens for all techniques

7.2.2 The thickness of test assembly is to be 50 mm for Y47 base material.

7.2.3 The edge preparation and welding conditions are to be in accordance with the recommendations of the manufacturers.

7.2.4 Test specimens are to be prepared as shown in Fig. 11.7.1 and Fig. 11.7.2(a):
(a) One longitudinal tensile test specimen (from the centre of the weld).
(b) Two transverse tensile specimens.
(c) Two bend test specimens, one with the face in tension, the other with the root in tension.
(d) One macrosection.
(e) Two sets of three Charpy impact test specimens positioned and notched in accordance with Fig.11.7.2(a).

7.2.5 The results of all transverse tensile, bend and impact tests are to comply with the requirements in Table 11.3.3 for m and S technique, and Table 11.4.3 for M technique. The position of fracture of the transverse tensile test is to be reported. The appearance of the bend test specimens is to be in accordance with 3.3.13.

7.2.6 The results of all longitudinal tensile tests are to comply with the requirements in Table 11.3.2.

7.2.7 Low hydrogen approval is required in accordance with Table 11.7.1.

7.2.8 Chemical analyses are to be made and reported from positions corresponding to the weld metal in the upper and lower Charpy specimens of the downhand butt weld. These are to be supplied by the manufacturer and are to include the content of all significant elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

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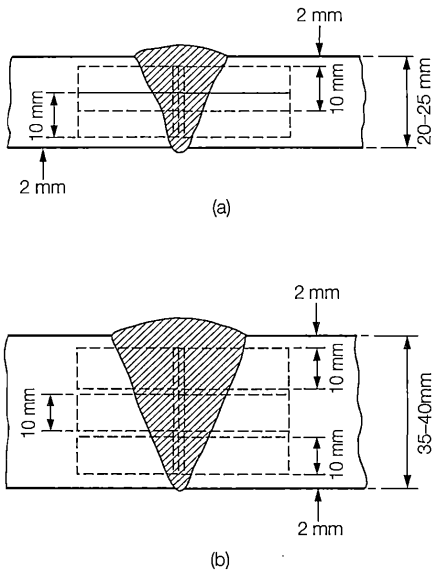

Fig. 11.7.2
Position of Charpy V-notch impact tests for one-side automatic welding

7.3 Approval tests for high heat input automatic (A) techniques

7.3.1 Two butt weld assemblies are to be prepared, usually one of 35–40 mm thickness, the other 20–25 mm, as shown in Fig. 11.7.1, noting that in the thinner assembly only two sets of Charpy specimens are required. The grade of plates used is to be no higher in toughness than that for which approval is required. The strength is to be appropriate to the grade for which welding approval is requested.

7.3.2 For Y47 grade, the thicker assembly is to be prepared from the maximum thickness for which approval is required, and the thinner assembly is to be prepared from 50 mm thickness. Where approval is required for 50 mm thickness, only one assembly from that thickness is required.

7.3.3 The edge preparation and welding conditions are to be in accordance with the manufacturer's recommendations, and are to be reported to LR.

7.3.4 Test specimens as follows are to be prepared as shown in Fig. 11.7.1 and Figs. 11.7.2(a) and (b):

(a) One longitudinal tensile test specimen (from centre of weld).
(b) Two transverse tensile test specimens.
(c) Two bend test specimens.
(d) One macro-section.
(e) From assembly 20 to 25 mm thick, two sets of three impact test specimens positioned and notched in accordance with Fig. 11.7.2(a).
(f) From assembly 35 to 40 mm thick, three sets of three impact test specimens positioned and notched in accordance with Fig. 11.7.2(b).
(g) From assembly of thickness 50 mm or more, three sets of three impact test specimens positioned and notched in accordance with Fig. 11.7.2(b). The second set positioned in the mid-thickness of test assembly.
The bend specimens are to be tested, one with the face in tension, the other with the root in tension.

7.3.5 The results of all transverse tensile, bend and impact tests are to comply with the requirements of Table 11.4.3. The appearance of the bend test specimens is to be in accordance with 3.3.13. The Charpy V-notch impact test requirements are as for the two-run technique in Table 11.4.3.

7.3.6 The results of all longitudinal tensile tests are to comply with the requirements in Table 11.3.2, except that for Grades 1Y, 2Y and 3Y the tensile strength is to be not less than 490 N/mm^2.

7.3.7 Low hydrogen approval is required in accordance with Table 11.7.1.

7.3.8 Chemical analyses are to be made and reported from positions corresponding to the weld metal in the uppermost and lowest Charpy specimens in the thicker plate weld. This is to be supplied by the manufacturer and is to include the content of all significant elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

7.4 Annual tests

7.4.1 Annual tests are to consist of, at least, one butt weld test assembly, for each technique approved, using plates of 20 to 25 mm thickness.

7.4.2 The assembly is to be prepared and tested in accordance with 7.2 or 7.3, as appropriate, except that only the following tests are required:

(a) One longitudinal tensile test (from centre of weld).
(b) One transverse tensile test.
(c) Two bend tests.
(d) One set of three impact tests taken from the root of the weld and the specimens notched in accordance with Fig. 11.7.2.
(e) Chemical analysis (one only).

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Section 8
Consumables for welding austenitic and duplex stainless steels

8.1 General

8.1.1 Tests for the approval of consumables intended for welding the austenitic and duplex stainless steels detailed in Ch 3,7 are to be carried out generally in accordance with the Section (3, 4, 5, 6 or 7) relevant to the type of consumable or combination.

8.1.2 Approval will be indicated by the grade or grades of parent stainless steel for which the consumable or combination is approved.

8.1.3 Where a shielding gas is employed, separate approval will be required for each specific shielding gas composition.

8.1.4 Consumables for welding the austenitic stainless steels and the duplex stainless steels to carbon or carbon-manganese steels will be approved in a similar manner. Parent plate used for the butt and fillet weld test assemblies will be carbon or carbon-manganese steel with either austenitic stainless steel or duplex stainless steel, as appropriate. Approval will be indicated by 'SS/CMn' and 'Dup/CMn' respectively, however, no buttering of test assembly plates is allowed for these two approvals.

8.1.5 Separate approval will be given for welding chemical and cryogenic applications. For chemical use, evidence of relevant corrosion resistance will be required. Charpy impact toughness tests will be required for all uses, but for cryogenic use the Charpy impact toughness requirements are more severe.

8.1.6 The welding technique will be indicated in the approval grading by a letter:

- m – for manual SMAW or GTAW welding.
- S – for wire-gas combinations used with a semi-automatic multi-run technique.
- M – for wire-flux or wire-gas combinations used with an automatic multi-run technique.
- T – for wire-flux or wire-gas combinations used with an automatic two-run technique.
- A – as for M but using a procedure with a high heat input rate (large bead size relative to thickness welded). This would apply to welds made by four or less runs in 20 mm thickness, or eight or less runs in 35 mm.

8.2 Deposited metal test assemblies

8.2.1 Where the relevant Section requires deposited metal assemblies to be made and tested, the plates used must be either of the type for which approval is required or of normal strength carbon, or carbon-manganese steel with the prepared edges built up with stainless steel weld metal and finished with a layer of weld metal from the consumable to be approved.

8.2.2 The chemical analysis of the deposited weld metal is to be reported, including all significant elements. The elements reported will be dependent on the type of stainless steel for which approval of the consumables is requested. Any unusual weld metal compositions will have to be justified in respect of the particular approval requested. This is to be supplied by the manufacturer and is to include the content of all significant elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

8.2.3 The results of all tensile and notch impact tests are to comply with the requirements given in Table 11.8.1 as appropriate.

8.2.4 The ferrite content in the last weld run from each deposited metal assembly is to be determined by physical or metallographic means, and reported, indicating the method of determination.

8.3 Butt weld test assemblies

8.3.1 Where the relevant Section requires butt weld assemblies to be made and tested, the plates used are to be either of the type for which approval is required or of steel having strength and ductility within the range specified for the grade to be approved. In the latter case, provided the consumable is metallurgically compatible with the base material to be used, the prepared edges are to be built up with a layer of weld metal before final machining of the weld preparation.

8.3.2 The results of transverse tensile, notch impact and bend tests are to comply with the requirements of Table 11.8.2 as appropriate. The position of fracture is to be reported to LR.

8.3.3 The ferrite content at the centre of the weld metal in each butt weld assembly is to be determined by physical or metallographic means, and meet the requirements in Table 11.8.2. The method of determination is to be reported.

8.3.4 For austenitic and duplex stainless steel approvals (except for types 304L, 316L, 321 and 347), an appropriate sample from each butt weld assembly is to be submitted to the corrosion testing provided in ASTM G48, Method 'C'. The results are to be reported so as to allow confirmation of the maximum acceptable pitting corrosion resistance temperature. This will be part of the approval grading and will be set at 5°C intervals. The minimum pitting corrosion temperature would not be expected to be less than 20°C.

8.4 Fillet weld test assemblies

8.4.1 Where the relevant Section requires fillet weld assemblies to be made and tested, the plates used must be either of the type for which approval is required or of steel having strength and ductility within the range specified for the grade to be approved. In the latter case, the surfaces on which the fillet weld beads are to be deposited are to be cut back by machining and then built up to original dimensions with weld metal from the consumable to be approved.

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Table 11.8.1 Requirements for deposited metal tests (manual, semi-automatic and automatic multi-run techniques)

Grade	0,2% proof stress N/mm² minimum	1% proof stress N/mm² minimum	Tensile strength N/mm² minimum	Elongation on 50 mm % minimum	Charpy V-notch impact tests		
					Chemical test temperature °C	Cryogenic test temperature °C	Average energy *See* Note 1 J minimum
304L	270	310	500	25	–20	–196	29
304LN	305	345	530	22	–20	–196	29
316L	270	310	500	22	–20	–196	29
316LN	305	345	530	22	–20	–196	29
317L	305	345	530	22	–20	–196	29
317LN	340	380	570	22	–20	–196	29
321	290	330	550	22	–20	–196	29
347	290	330	550	22	–20	–196	29
S 31254	370	410	650	22	–20	–196	29
N 08904	270	310	500	22	–20	–196	29
SS/CMn	270	310	500	22	–20	–60	29
S 31260	485	525	690	20	–20	*see* Note 2	40
S 31803	450	490	620	25	–20		40
S 32550	550	590	760	15	–20		40
S 32750	550	590	800	15	–20		40
S 32760	550	590	750	25	–20		40
Dup/CMn	270	310	500	22	–20	*see* Note 2	40

NOTES
1. Energy values from individual impact test specimens are to comply with 1.4.3.
2. Approval for cryogenic applications is to be obtained at the procedure approval stage.

Table 11.8.2 Requirements for butt weld tests (all techniques)

Grade	Tensile strength N/mm² minimum	Bend test ratio: $\frac{D}{t}$	Weld ferrite content %	Charpy V-notch impact tests		
				Chemical test temperature °C	Cryogenic test temperature °C	Average energy (*see* Note 1) J minimum
304L	500	3	4–12	–20	–196	27
304LN	530	3	4–12	–20	–196	27
316L	500	3	4–12	–20	–196	27
316LN	530	3	4–12	–20	–196	27
317L	530	3	4–12	–20	–196	27
317LN	570	3	4–12	–20	–196	27
321	550	3	4–12	–20	–196	27
347	550	3	4–12	–20	–196	27
S 31254	650	3	(*see* Note 2)	–20	–196	27
N 08904	500	3	(*see* Note 2)	–20	–196	27
SS/CMn	500	3	4–12	–20	–60	27
S 31260	690	4	35–65	–20	(*see* Note 3)	40
S 31803	620	3	35–65	–20		40
S 32550	760	6	35–65	–20		40
S 32750	800	6	35–65	–20		40
S 32760	750	6	35–65	–20		40
Dup/CMn	500	3	(*see* Note 2)	–20	(*see* Note 3)	40

NOTES
1. Energy values from individual impact test specimens are to comply with 1.4.3.
2. To be reported for special consideration.
3. Approval for cryogenic applications is to be obtained at the procedure approval stage.

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8.4.2 The ferrite content at the centre of the weld metal in each fillet weld bead of each assembly is to be determined from the centre macro-section by physical or metallographic means, and reported. The method of determination is also to be reported to LR.

8.4.3 Where approval is sought for fillet welding only, corrosion testing is to be carried out in accordance with 8.3.4 from a sample taken from the deposited metal test assembly.

8.5 Annual tests

8.5.1 Annual tests are to be carried out as required by the relevant Section appropriate to the type of consumable and welding technique. The tests are to include a weld ferrite content in accordance with 8.2.4 or 8.3.3 as appropriate.

8.5.2 The results of all tests are to comply with the requirements given in Table 11.8.1 and Table 11.8.2 as appropriate.

■ *Section 9* Consumables for welding aluminium alloys

9.1 General

9.1.1 Tests for the approval of consumables intended for welding the aluminium alloys detailed in Chapter 8 are to be carried out generally in accordance with the requirements of Sections 1, 2 and 5, except as otherwise detailed in this Section.

9.1.2 Approval will be indicated by the grade shown in Table 11.9.1. Plate of the corresponding type of aluminium alloy and of appropriate thickness is to be used for the preparation of the weld test assemblies, and may be of any temper listed in LR Rules.

9.1.3 The welding technique will be indicated in the approval grading by a letter:

m – manual multi-run welding (GTAW),
S – semi-automatic multi-run welding (GMAW),
M – automatic multi-run welding (GTAW or GMAW),
T – automatic two-run welding (GMAW).

9.1.4 The compositions of the shielding gas and the filler/electrode wire are to be reported.

9.1.5 Approval granted using the multi-run technique for a specific filler/electrode wire with a gas in one of the groups listed in Table 11.9.2 will extend to any other gas compositions within that same group, provided that the gas composition is within the range recommended by the consumable manufacturer, subject to agreement with LR.

9.1.6 Approval granted for the two-run technique will be for a specific shielding gas composition; additional tests may be required if a change in shielding gas composition is sought.

Table 11.9.1 Requirements for butt weld tests

Consumable Approval Grade (*see* Note 1)	Base material used for the test	Tensile strength N/mm^2 minimum	Bend test ratio $\frac{D}{t}$
LR RA/LR WA	5754	190	3
LR RB/LR WB	5086	240	6
LR RC1/LR WC1	5083	275	6
LR RC2/LR WC2 (*see* Note 2)	5383 or 5456	290	6
LR RC3/LR WC3 (*see* Note 2)	5059	330	6
LR RD/LR WD (*see* Note 4)	6005A 6061 6082	170 170 170	6 6 6

NOTES
1. The prefixes 'R' and 'W' indicate 'rod' form (for Gas Tungsten Arc Welding (GTAW)) or 'wire' form (for Gas Metal Arc Welding (GMAW) and GTAW).
2. Approval of grade LR RC2/LR WC2 confers approval of 5383, 5456 and 5083 base material grade.
3. Approval of grade LR RC3/LR WC3 confers approval of 5059, 5383, 5456 and 5083 base material grades.
4. Approval of grade LR RD/LR WD confers approval of 6005A, 6061 and 6082 base material grades.

Table 11.9.2 Shielding gas compositions

Group	Gas composition (Vol. %) (*see* Note)	
	Helium	Argon
I-1	–	100
I-2	100	–
I-3	>0 ≤33	Remainder
I-4	>33 ≤66	Remainder
I-5	>66 ≤95	Remainder
S	Special gas	

NOTE
Gases of other composition (mixed gases) or special purity may be considered as special gases and will require separate approval tests.

9.1.7 On completion of welding, assemblies are to be allowed to cool naturally to ambient temperature. Welded test assemblies and test specimens are not to be subjected to any heat treatment after welding except for the alloy Grades 6005A, 6061 and 6082. These are to be allowed to naturally age at ambient temperature for a period of 72 hours from the completion of welding, before testing is carried out. A second solution heat treatment is not permitted.

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9.1.8 All butt test assemblies are to be subjected to both radiographic and visual examination and imperfections such as lack of fusion, lack of penetration, cavities, inclusions, pores and cracks assessed in accordance with Intermediate Level C of ISO 10042, aided where necessary by dye penetrant and ultrasonic examination.

9.1.9 Fillet weld test assemblies and macro-sections are to be visually examined for imperfections, such as lack of fusion, lack of penetration, cavities, inclusions, pores and cracks, in accordance with Intermediate Level C of ISO 10042, aided where necessary by radiographic and dye penetrant examination.

9.2 Approval tests for manual, semi-automatic and automatic multi-run techniques

9.2.1 Plate of the corresponding type of aluminium alloy and of appropriate thickness is to be used for the preparation of the weld test assemblies.

9.2.2 The welding parameters are to be within the range recommended by the manufacturer and are to be reported.

9.2.3 Welded assemblies are to be prepared and tested in accordance with 9.3, 9.4 and 9.5.

9.3 Deposited metal test assembly

9.3.1 One assembly is to be prepared in the downhand position as shown in Fig. 11.9.1.

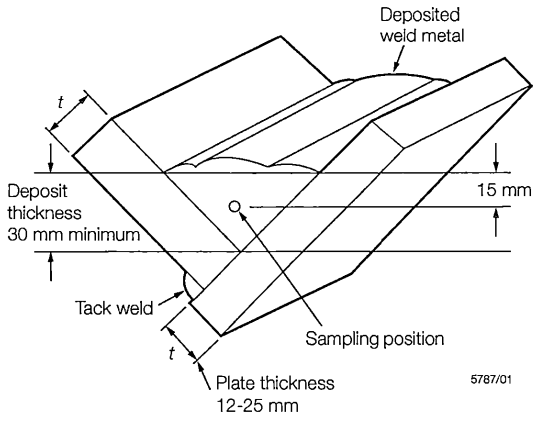

Fig. 11.9.1 Deposited metal test assembly

9.3.2 The chemical composition of the plate used for the assembly is to be compatible with the weld metal.

9.3.3 The thickness of the plate used, and the length of the assembly, are to be appropriate to the welding process. The plate thickness is to be not less than 12 mm.

9.3.4 For the approval of filler wire/gas and electrode wire/gas combinations for manual or semi-automatic welding by GTAW or GMAW, one test assembly is to be welded using any size of wire within the range for which approval is sought.

9.3.5 For automatic multi-run approval, one test assembly is to be welded by the respective process using the recommended diameter of wire.

9.3.6 The weld metal is to be deposited in multi-run layers in accordance with normal practice. The direction of deposition of each layer is to alternate from each end of the plate.

9.3.7 The deposited weld metal in the assembly is to be analysed and reported including the contents of all significant elements. The elements reported will be dependent on the type of aluminium alloy for which approval of the consumables is requested. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

9.4 Butt weld test assemblies

9.4.1 Plate of the corresponding type of aluminium alloy and of an appropriate thickness is to be used for the preparation of the test assemblies.

9.4.2 In order to ensure sound and representative welds, it is essential that test assemblies are cleaned and degreased prior to welding. Assemblies as shown in Fig. 11.9.2 are to be prepared for each welding position (downhand, horizontal-vertical, vertical-upward, vertical-downward, and overhead) for which the consumable is recommended by the manufacturer; except that consumables satisfying the requirements for downhand and vertical-upward positions will be considered as also complying with the requirements for the horizontal-vertical position. Any wire diameter(s) to be approved may be used.

9.4.3 One assembly, as shown in Fig. 11.9.3, is to be prepared for welding in the downhand position. The assembly is to be welded using, for the first run, wire of the smallest diameter recommended by the manufacturer and, for the remaining runs, wire of the largest diameter to be approved.

9.4.4 The welding conditions are to be in accordance with the recommendations of the manufacturer and are to be reported in detail.

9.4.5 The welded assemblies are to be subjected to NDE. Imperfections are to be assessed in accordance with 9.1.8.

9.4.6 The test specimens are to be taken from the welded assemblies as shown in Fig. 11.9.2 and Fig. 11.9.3. For each assembly they are to comprise:

- 2 transverse tensile specimens;
- 2 face bend specimens; and
- 2 root bend specimens.

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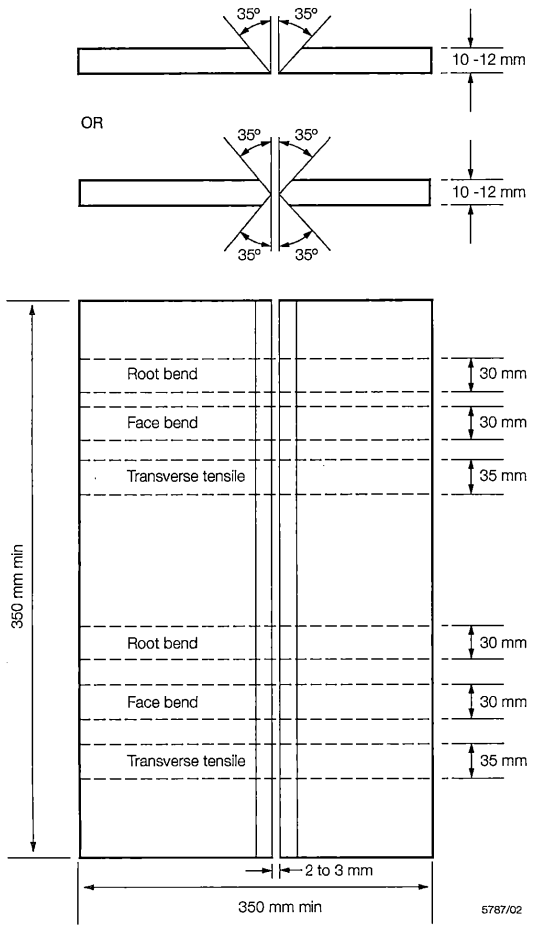

Fig. 11.9.2
Butt weld test assembly
(positional, multi-run technique)

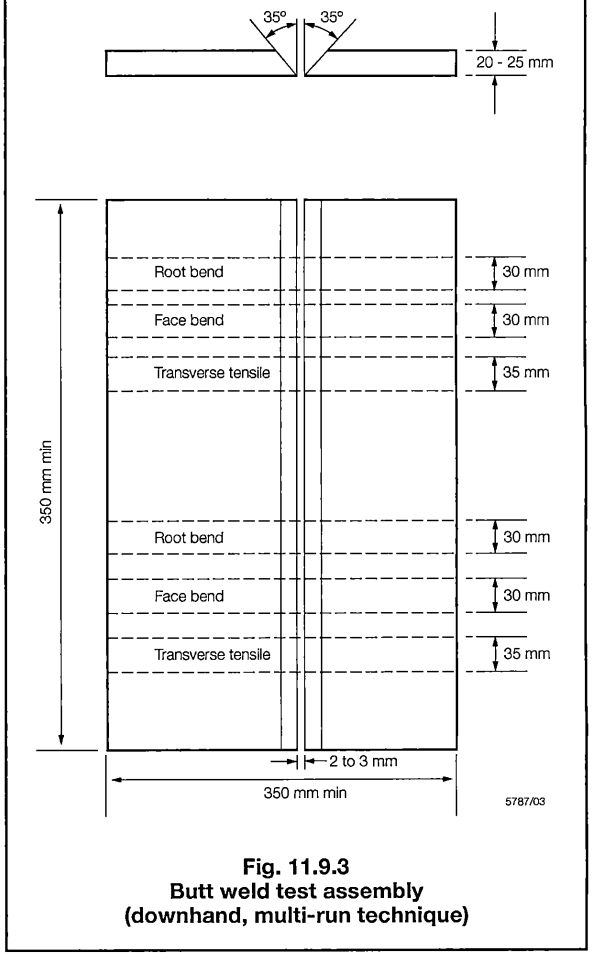

Fig. 11.9.3
Butt weld test assembly
(downhand, multi-run technique)

9.4.7 All tensile test specimens are to have a tensile strength not less than the respective value shown in Table 11.9.1. The position of each fracture is to be reported.

9.4.8 The bend test specimens are to be bent around a former having a diameter not more than the number of times the thickness of the test specimen, as shown in Table 11.9.1, and can be considered as complying with the requirements if, after bending to an angle of not less than 180°, no crack or other open defect exceeding 3 mm in length can be seen on the outer surface. Flaws appearing at the corners of a test specimen may be ignored.

9.4.9 In order to obtain uniform bending of the bend test specimens, it is recommended that the wrap-around or guided bend test using a roller method is employed.

9.5 Fillet weld test assembly

9.5.1 When approval is being sought for both butt and fillet welding, one assembly is to be prepared and welded in the horizontal-vertical position and tested in accordance with the appropriate requirements of 3.5, except that the plates are to be of an aluminium alloy compatible with the weld metal, that no hardness tests are required and that for automatic multi-run approval only one fillet weld bead is to be made using the recommended wire diameter. In this case, the bead size is to be as large as the maximum single bead size recommended by the manufacturer for fillet welding.

9.5.2 When approval is being sought for fillet welding only, one assembly is to be prepared and welded in each position for which approval is sought, and tested as detailed in 9.5.1.

9.5.3 The results of examination of the macro-specimens and the fractured fillet welds are to be reported in accordance with 3.5.4 and 3.5.6. Imperfections are to be assessed in accordance with 9.1.9.

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9.6 Approval tests for two-run technique

9.6.1 Two butt weld test assemblies are to be prepared using the following plate thicknesses:

(a) one with the maximum thickness for which approval is requested; and

(b) one with a thickness approximately one half to two thirds that of the maximum thickness.

9.7 Butt weld test assemblies (two-run technique)

9.7.1 The plates used are to be of the aluminium alloy appropriate to the approval required as shown in Table 11.9.1. The composition of the plate material is to be within the range specified for that alloy in Table 8.1.2 in Chapter 8 and is to be reported including all significant elements.

9.7.2 The wire diameter, edge preparation, welding current, arc voltage and travel speed are to be in accordance with the manufacturer's recommendations and are to be reported.

9.7.3 Each butt weld is to be made in two runs, one from each side. After completion of the first run, the assembly is to be left in still air until it has cooled to less than 50°C.

9.7.4 The welded assemblies are to be subjected to NDE. Imperfections are to be assessed in accordance with 9.1.8.

9.7.5 The test specimens as shown in Fig. 11.9.4 are to be prepared from each test assembly. The edges of the discards are to be polished and etched, and must show complete fusion and inter-run penetration of the welds. Each cut in the assembly is also to be examined to confirm that complete fusion and penetration have been achieved.

9.7.6 The results of the transverse tensile tests are to be as in 9.4.7 and of the bend tests as in 9.4.8. The position of the fracture in each transverse tensile specimen is to be reported.

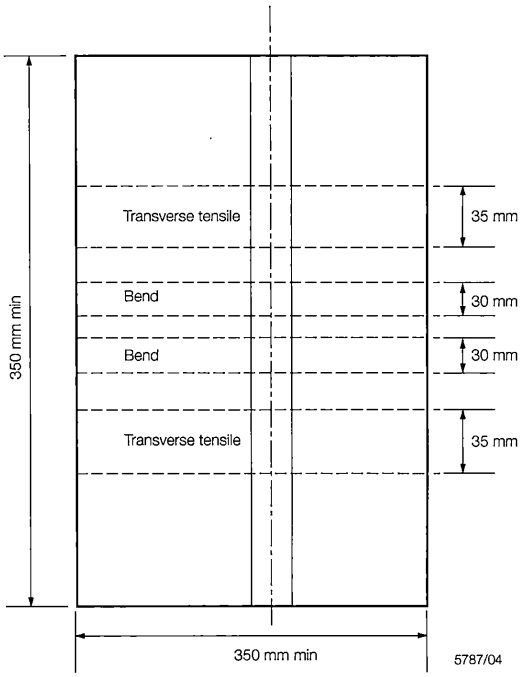

Fig. 11.9.4
Butt weld test assembly (two-run technique)

9.8 Annual tests

9.8.1 Annual tests are to consist of the following:

(a) for combinations approved for the multi-run technique, one deposited metal assembly in 9.3 and one downhand butt assembly in 9.4;

(b) for combinations approved for the two-run technique, one butt weld assembly in plate material of thickness equal to one half to two thirds that of the maximum thickness approved.

9.8.2 For the automatic two-run technique, one butt weld assembly is to be prepared and tested in accordance with 9.7.

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Welding Qualifications

Section

1 **General qualification requirements**

2 **Welding Procedure Qualification Tests for Steels**

3 **Specific requirements for stainless steels**

4 **Welding procedure tests for non-ferrous alloys**

5 **Welder qualification tests**

Section 1
General qualification requirements

1.1 General

1.1.1 This Section applies to all welding qualifications and tests required to be performed in the course of new construction, conversions, modifications or repairs made on ships, other marine structures and their associated pressure vessels, machinery and equipment.

1.1.2 These Rules also apply to all welding work related to other applications for which Lloyd's Register (hereinafter referred to as LR) have issued Rules or have an interest.

1.1.3 It is the responsibility of the manufacturer to ensure compliance with all aspects of these Rules. All deviations are to be recorded as non-compliances and brought to the attention of the Surveyor along with the corrective actions taken. Failure to do this is considered to render the welding tests as not complying with the Rules.

1.1.4 Welding tests are to be performed under survey at the manufacturer's works. Welding procedure qualification tests and welder qualifications tests are to be performed and approved prior to commencement of fabrication or construction.

1.1.5 Weld procedure tests made in accordance with EN, ISO, JIS, ASME or AWS may be considered for acceptance provided that, as a minimum, they are equivalent to and meet the technical intent of these Rules to the satisfaction of the Surveyor.

1.1.6 Welding tests that have previously been carried out may be considered for acceptance, provided that they have been supervised by an independent body acceptable to LR and the Surveyor is satisfied with the authenticity of such tests.

1.1.7 The responsibility for the performance of the weld tests rests with the manufacturer. Aspects of the welding tests, such as mechanical testing, non-destructive testing and heat treatment, may be subcontracted by the manufacturer provided that the subcontractor performs the work under the technical control and direction of the manufacturer, and this is agreed with the Surveyor prior to commencing the work.

1.1.8 In these Rules, the term 'manufacturer' is considered to include any firm or organisation that performs welding and is considered to be the shipbuilder, or construction firm, or fabricator, or material manufacturer.

1.2 Design

1.2.1 Welding procedure qualification tests are required to give assurance that construction welds made in accordance with the approved plans or the approved design have acceptable properties. It is the manufacturer's responsibility to establish and document whether a procedure is suitable for a particular application.

1.2.2 The requirements relate to mechanical properties of the weld and heat affected zone, however, other tests may be required on certain materials, for example, corrosion or fatigue tests, in order to ensure suitability for the proposed application.

1.3 Materials

1.3.1 Materials used for testing are to be of the same grade, type and from the same manufacturing process as those to be used for construction, unless prior agreement is obtained from the Surveyor. Such agreements will only apply on a case-by-case basis.

1.3.2 All materials used for testing are to be suitably marked and identifiable to the original manufacturer's material certificate.

1.4 Performance of welding tests

1.4.1 All welding and subsequent testing is to be performed in accordance with the requirements of this Chapter.

1.4.2 The manufacturer is responsible for monitoring the tests and for recording all the welding variables as specified in 2.2 and for compiling all the non-destructive examination (NDE) reports and mechanical test records for submission to the Surveyor.

1.4.3 The laboratory or testing establishment used to perform the tests is to have the necessary equipment, maintained in good order and suitably calibrated. The Surveyor is to be satisfied that the laboratory personnel have the appropriate skills and are appropriately qualified in accordance with Ch 2,1.2.1.

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Section 2
Welding Procedure Qualification Tests for Steels

2.1 General

2.1.1 The requirements of this Section relate to welding procedure test requirements of carbon, carbon-manganese steels and low alloys steels. Additional requirements for austenitic and austenitic/ferritic duplex stainless steels, aluminium and copper alloys are specified in Sections 3 and 4 respectively.

2.1.2 Prior to performing the welding procedure qualification test, the manufacturer is to present to the Surveyor a preliminary Welding Procedure Specification (pWPS) detailing the welding processes, positions, joint types, materials and heat treatments to be performed during the test. The pWPS is to be presented for information prior to commencing the test.

2.1.3 The type and extent of testing to be applied to each welding procedure test is to be in accordance with subsequent Sections of this Chapter.

2.1.4 For the welding procedure approval, the welding procedure qualification tests given in this Section are to be carried out with satisfactory results. Welding procedure specifications are to refer to the test results achieved during welding procedure qualification testing.

2.2 Welding variables

2.2.1 In order that the conditions of the qualification test may be applied to production welding operations, the appropriate variables are to be recorded by the manufacturer during welding and testing from the following list:

(a) The unique qualification reference number and the date of welding;
(b) The material type, grade, product form, dimensions and identification;
(c) Welding process(es), including tack welds;
(d) Joint type, dimensions and surface condition;
(e) Welding position(s);
(f) Welding technique(s), weaving, multiple electrodes, etc;
(g) Welding consumables including fluxes, shielding gases, etc;
(h) Control of consumables, baking or drying conditions, etc;
(j) Welding parameters, current, voltages, travel speeds, etc;
(k) Number and sequence of weld runs;
(l) Backing materials including any backing gas;
(m) Preheats and interpass temperatures;
(n) Methods used for cleaning and inspection of root deposits;
(o) Post-weld heat treatment, temperature and cycle times;
(p) Special weld profiling requirements.

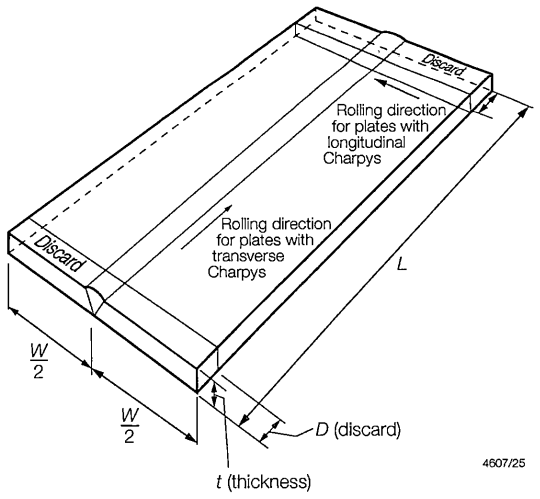
2.2.2 Other variables may need to be recorded depending on the particular welding process or application and are to be agreed with the Surveyor, for example the peak and base current and cycle times for pulse welding, electrode type and nozzle size for GTAW welding, etc.

2.3 Steel test assemblies

2.3.1 Tests are to be performed using the welding process and positions anticipated for actual construction. The weld test assemblies are to be representative of construction conditions and are to be welded in the same manner as intended for the actual production welds. Where pre-fabrication primers are used in the shipyard, these are to be included in the test assemblies.

2.3.2 For plate tests, the direction of plate rolling relative to the weld direction is to be considered. Where the material used for the test requires longitudinal impact tests, the plate rolling direction is to be perpendicular to the weld direction and for material which requires impact testing in the transverse direction, the rolling direction is to be parallel to the weld direction.

2.3.3 Typical test assemblies are shown in Fig. 12.2.1(a) to (c). These are a minimum requirement to permit the removal of all the necessary mechanical test specimens. Where impact tests or other toughness tests are required, the total width is not to be less than 8 times the material thickness of the thicker material being joined.



Welding Processes	*L* (min) mm	*W* (min) mm	*D* (min) mm
Manual/Semi-automatic	350	300	50
Automatic	1000	400	75

Fig. 12.2.1(a) Butt weld test assembly in plate

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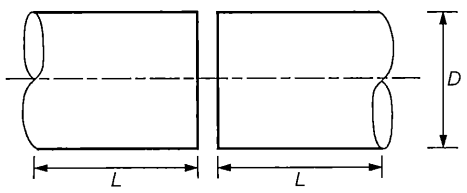
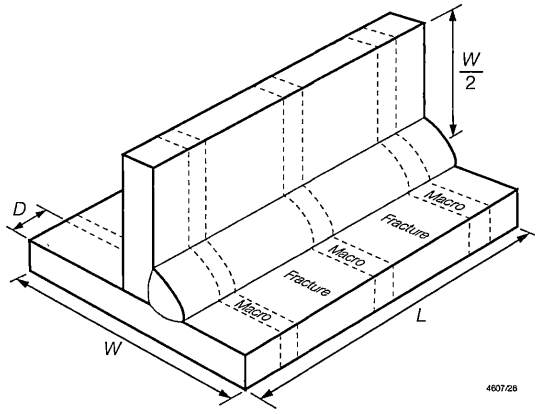


L = 150 mm minimum
D = Outside diameter

Fig. 12.2.1(b) Butt weld test assembly in pipe



Welding Processes	*L* (min) mm	*W* (min) mm	*D* (min) mm
Manual/Semi-automatic	350	300	50
Automatic	1000	300	75

Fig. 12.2.1(c) Fillet weld test assembly in plate

2.3.4 Welding procedure test assemblies are to be welded separately from production welds and are to be marked with the unique test identification number. The individual pieces of the test assembly may be held together to maintain their relative joint conditions by means of suitable tack welds, clamps or strongbacks.

2.3.5 Welding of the test assemblies and testing of test specimens is to be monitored by the Surveyor.

2.3.6 The test assembly is to be placed in one of the welding positions shown in Fig. 12.2.2(a) to (d), as specified in the test Welding Procedure Specification (pWPS) and the specified level of preheat applied prior to the start of welding.

2.3.7 Designations for equivalent welding positions shown by different standards are shown in Table 12.2.1.

Table 12.2.1 Equivalent designations of welding positions

Weld position		Standard	
		ISO 6947	AWS
Plate butt welds			
Flat	D	PA	1G
Horizontal	X	PC	2G
Vertical, weld up	Vu	PF	3G
Vertical, weld down	Vd	PG	3G
Overhead	O	PE	4G
Pipe butt welds			
Pipe horizontal, rotated, weld horizontal	D	PA	1G
Pipe vertical, not rotated, weld horizontal	X	PC	2G
Pipe horizontal, not rotated, weld flat, vertical and overhead	D+Vu+O D+Vd+O	PF PG	5G
Pipe inclination fixed, not rotated	45°	H-L045 J-L045	6G
Plate fillet welds			
Flat	D	PA	1F
Horizontal	X	PB	2F
Vertical up	Vu	PF	3F
Vertical down	Vd	PG	3F
Overhead	O	PD	4F
Pipe fillet welds			
Flat, pipe rotated	D	PA	1FR
Horizontal, pipe fixed	X	PB	2F
Horizontal, pipe rotated	D	PB	2FR
Overhead, pipe fixed	O	PD	4F
Multiple, pipe fixed	D+Vu+O D+Vd+O	PF PG	5F

2.4 Welding of steel test assemblies

2.4.1 Welding of the test assembly is to be carried out in accordance with the agreed pWPS. Where, during the progress of the test, it is found necessary to change the conditions specified on the pWPS, this is to be brought to the attention of the Surveyor. If agreed, the test may be permitted to continue with the new conditions and these are to be recorded.

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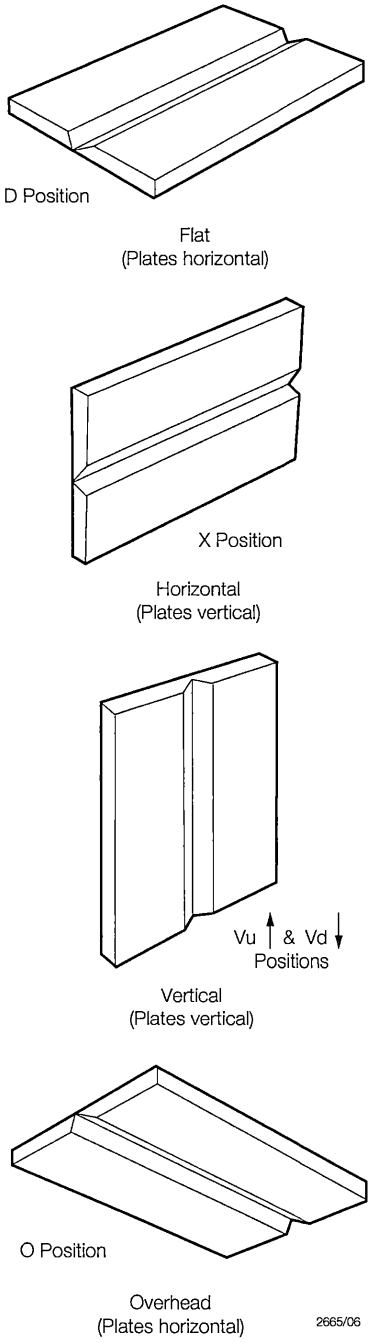
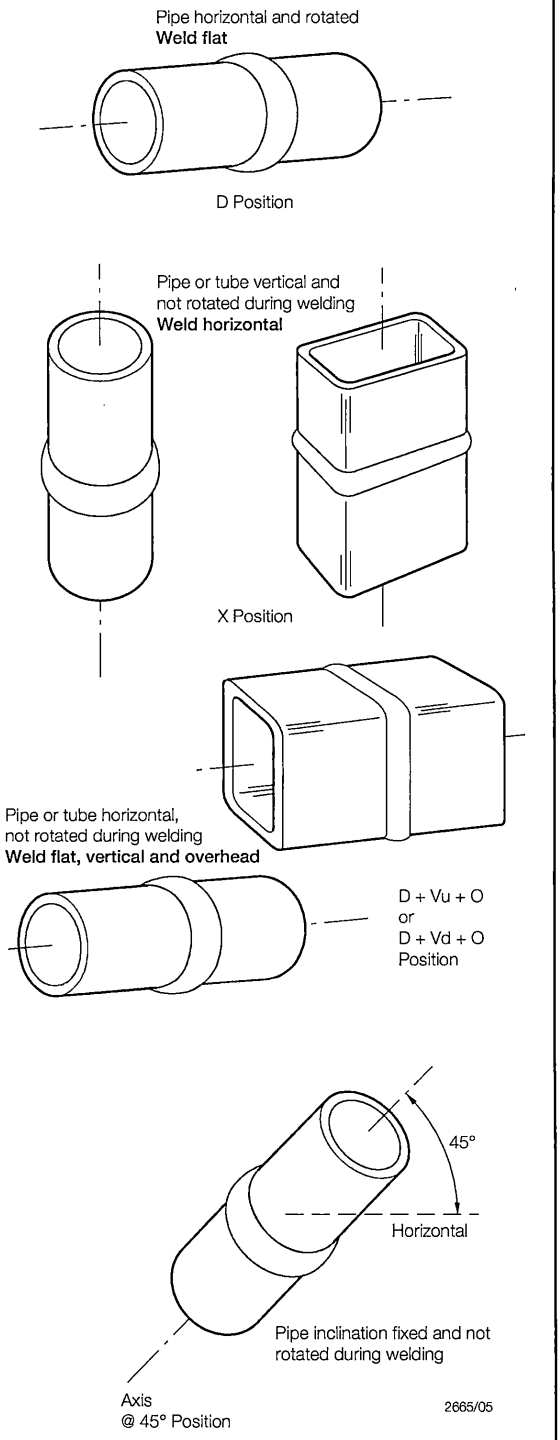


Position of test plates for plate assemblies

Fig. 12.2.2(a) Plate butt weld test positions



Position of pipes and welds for qualification weld test assemblies

Fig. 12.2.2(b) Pipe butt weld test positions

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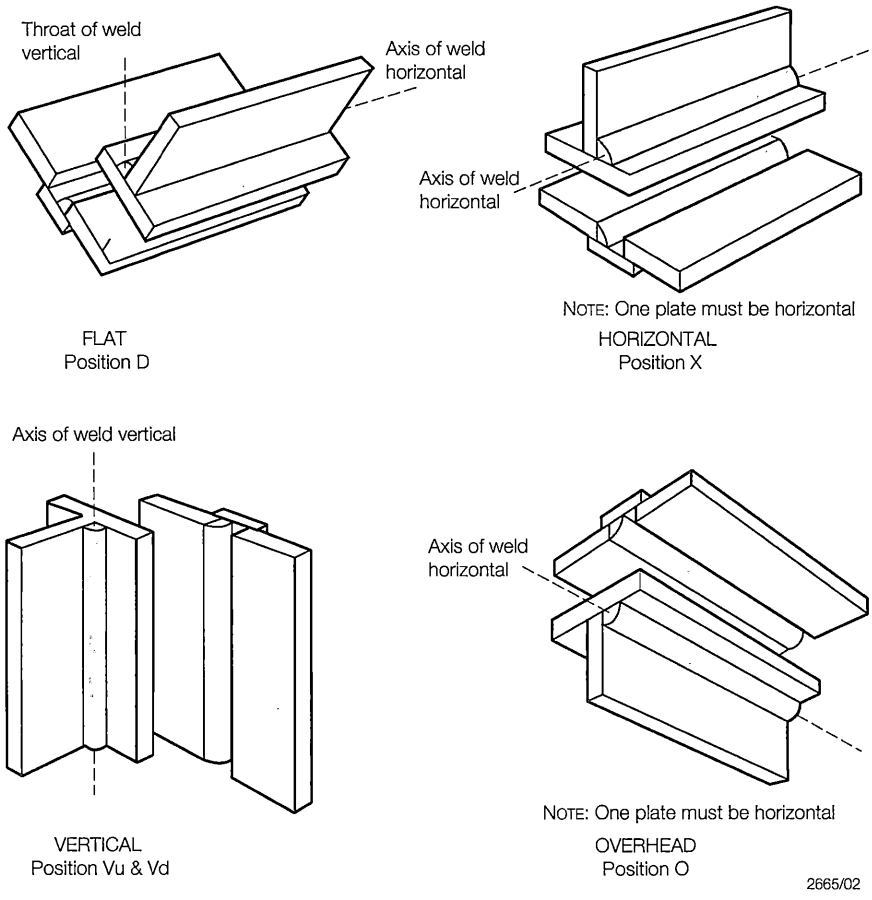

Fig. 12.2.2(c) Plate fillet weld test positions

2.4.2 Where the production work requires welding over tack welds, the test is to simulate this condition and the tack welds are to be included in the inspection length of the test weld and their position recorded.

2.4.3 For manual and semi-automatic welding processes, weld stops and re-starts are to be included in the inspection length of the test weld.

2.4.4 Fillet weld test assemblies are welded on one side only.

2.4.5 Where the construction welding is predominately fillet welding, in addition to the butt weld qualification test, a fillet weld qualification test is to be performed to confirm that acceptable weld quality is achieved.

2.5 Non-destructive examination (NDE)

2.5.1 On completion of welding, prior to sectioning for mechanical tests, the inspection length of the test assembly is to be subjected to both visual examination and surface crack detection.

2.5.2 Butt weld assemblies are also to be subjected to radiographic or ultrasonic examination over the whole inspection length of the weld.

2.5.3 For welds in steels with specified yield strength up to 400 N/mm^2, and with carbon equivalent less than or equal to 0,41 per cent, NDE may be performed as soon as the test assembly has cooled to ambient temperature. For other steels, NDE is to be delayed for a period of at least 48 hours after the test assembly has cooled to ambient temperature.

2.5.4 Where post-weld heat treatment is required, NDE is to be performed after the heat treatment is complete.

2.5.5 All NDEs are to be carried out in accordance with the requirements of Ch 1,5. Assessment of results is to be in accordance with ISO 5817 Level B except for excess convexity and excess throat thickness where Level C will apply. Linear porosity is not permitted.

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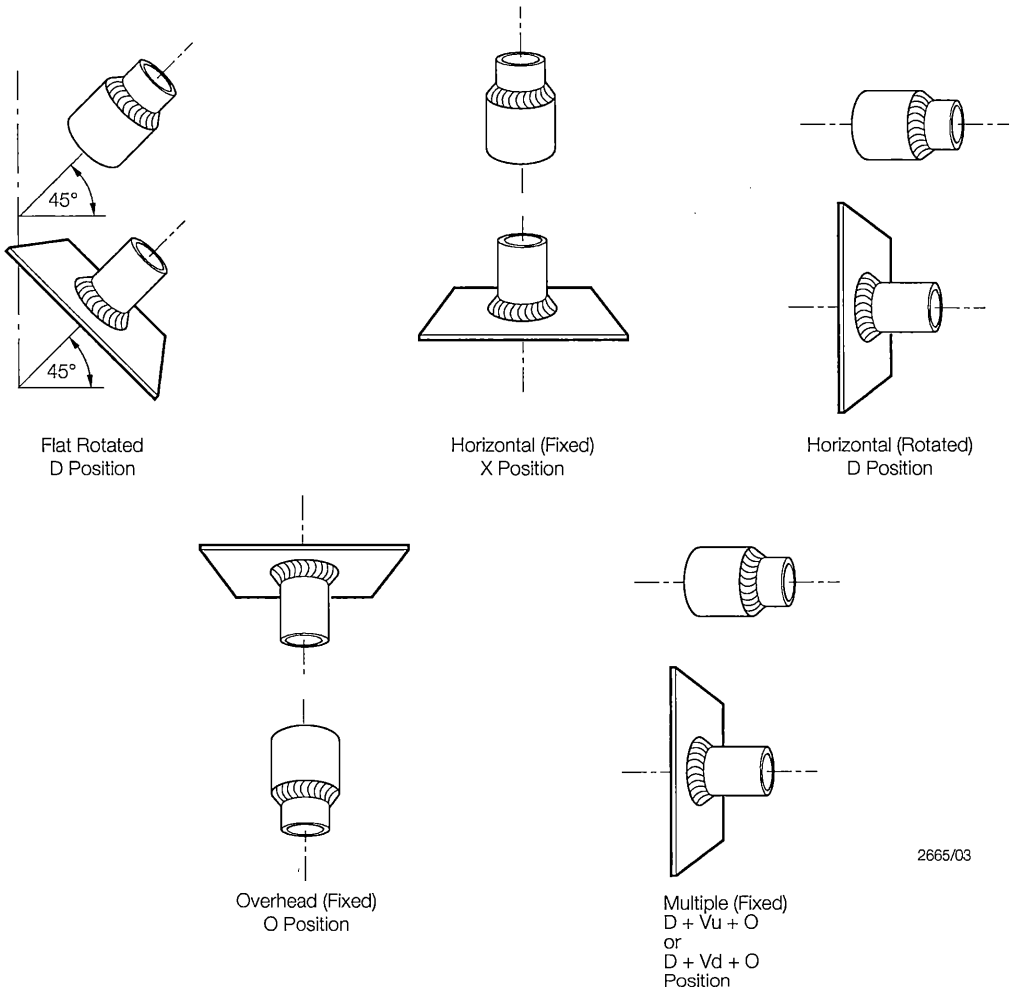

Fig. 12.2.2(d) Pipe fillet weld test positions

2.5.6 As an alternative to radiography, ultrasonic examination may be carried out and acceptance criteria that are considered to result in equivalent weld quality (in accordance with 2.5.5) are to be agreed, with the Surveyor, prior to the tests being carried out. Ultrasonic testing will be subject to the thickness limitation specified in Ch 13,2.12.5.

2.5.7 Where the test assembly does not satisfy the non-destructive examination acceptance criteria, the test is to be rejected. A duplicate test assembly may be welded using the original welding conditions. If this fails NDE, the welding procedure is to be considered as incapable of achieving the requirements without modification.

2.5.8 Subject to prior agreement with the Surveyor, where unacceptable imperfections are of a volumetric nature and are localised in one small area of the test assembly, the test may be permitted to continue and specimens for destructive testing may be removed, avoiding this area.

2.6 Destructive tests – General requirements

2.6.1 The weld test assembly may only be sectioned for destructive testing after any heat treatment and the required non-destructive examinations have been completed successfully.

2.6.2 The dimensions of the test specimens and testing conditions are to be in accordance with the requirements specified in Chapter 2.

2.6.3 The results of destructive tests are to be assessed in accordance with the acceptance criteria specified in 2.12, unless other, more stringent requirements are specified for the application.

2.6.4 Where a weld test is made between materials of different grades, the acceptance criteria that are to be applied are those applicable to the lower grade material.

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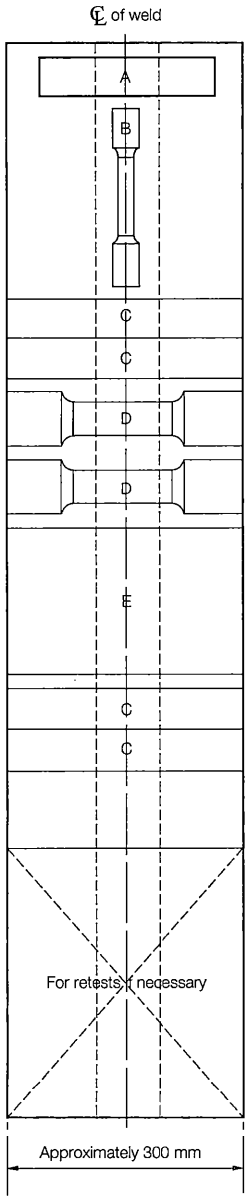

Test requirements
A One macro including hardness survey
B All weld metal tensile test
C Four bend tests.
Two root bends and two face bends for thickness up to 12 mm.
For thickness above 12 mm four side bends
D Two transverse tensiles
E Five sets of Charpy V-notch impact tests, notched at the following positions:
1 set at weld centre
1 set at fusion line (FL)
1 set at FL + 2 mm
1 set at FL + 5 mm (if required by Figs. 12.2.6 and 12.2.7)
1 set at FL + 10 mm (if required)

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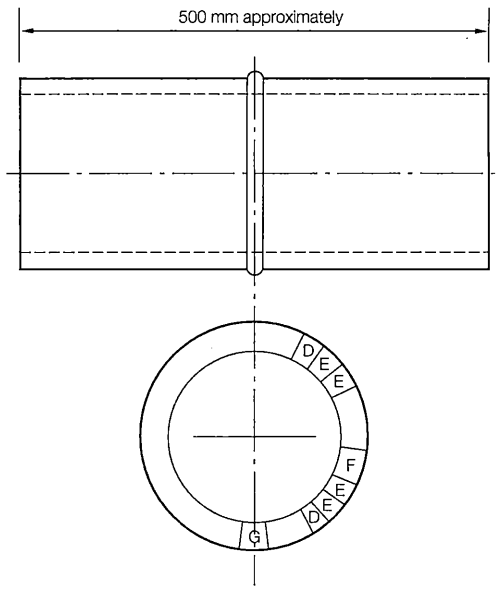
Fig. 12.2.3
Butt welds in plate and pipe over 750 mm diameter



The diameter of the test piece is to be a minimum of *D*/2
where
D is the maximum diameter of the pipe to be welded in construction

Test requirements
A Visual examination
B Surface crack detection
C 100% radiographic examination
D Two transverse tensile tests
E Four bend tests.
Four side bends for thickness greater than 12 mm.
In other cases, two face and two root bends
F Four sets Charpy V-notch impact tests
1 set notched at centre of weld
1 set notched at fusion line (FL)
1 set notched at FL + 2 mm
1 set notched at FL + 5 mm (if required by Figs. 12.2.6 and 12.2.7)
G One macro specimen including hardness survey

Fig. 12.2.4
Butt welds in pipe less than 750 mm diameter

2.7 Destructive tests for steel butt welds

2.7.1 The test assembly is to be sectioned for mechanical testing in accordance with Figs. 12.2.3 or 12.2.4.

2.7.2 The longitudinal all weld metal tensile test specimen is to be of circular cross-section as detailed in Ch 11,2.1.1. Where more than one welding process or type of consumable has been used to make the weld, test specimens are to be removed from each respective area of the weld. This does not apply to the process or consumables used to make the root or first weld run. During the test, the yield or proof stress, ultimate tensile strength, and elongation to failure are to be recorded.

2.7.3 Where approved welding consumables have been used, the longitudinal all weld metal tensile test may be omitted.

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2.7.4 The transverse tensile test specimen is to be of full thickness with the dimensions shown in Ch 11,2.1.1. The tensile strength and fracture locations are to be reported.

2.7.5 Where the maximum load required to fracture the transverse tensile specimen is likely to exceed the capacity of the tensile testing equipment, several tensile specimens may be removed through the thickness and tested. Specimens are to be prepared such that they overlap in the thickness direction so that the full plate thickness is tested.

2.7.6 Transverse bend specimens of rectangular section are to be prepared with the weld centred in the middle of the specimen as shown in Fig. 12.2.5. For material of thickness 12 mm or greater, the face and root bends may be substituted by side bend tests. The weld reinforcement may be removed by grinding or machining prior to testing and the edges rounded to a radius not exceeding 10 per cent of the specimen thickness. Each specimen is to be bent through an angle of at least 180°. The bend test ratio is to be the lesser of the following:

(a) $D_f = (D/t) + 1$

or

(b) $D_f = 100/E_m$ (rounded up to the next whole number)

where

D_f = is the bend test ratio

(D/t) = is the value from Tables 11.3.3, 11.4.3 or 11.8.2 in Chapter 11, as appropriate

E_m = is the minimum specified percentage elongation for the test material (based on a proportional gauge length of $5{,}65\sqrt{S_o}$)

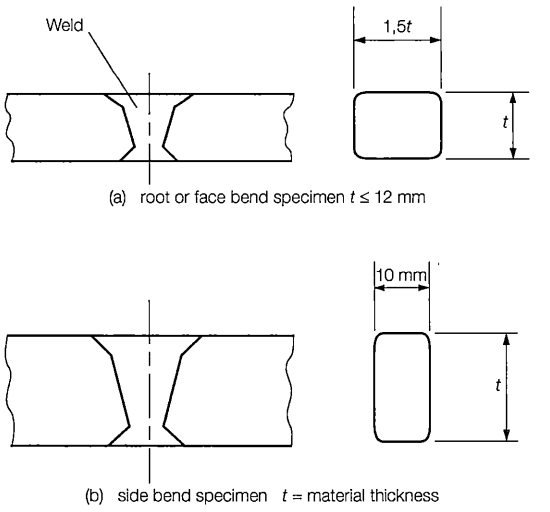

Fig. 12.2.5 Transverse bend test specimens

2.7.7 Where the weld test is made between different material types, the requirements of 2.7.8 are to be applied to the material with the lower toughness specification.

2.7.8 For hull structural steels, impact test specimens are to be prepared from the locations shown in Figs. 12.2.6 or 12.2.7, with the notch perpendicular to the plate surface and have the dimensions and proportions in accordance with Ch 2,3. Where more than one welding process or type of consumable has been used to make the weld, test specimens are also to be removed from these respective parts of the weld. Note that this does not apply to the welding process or consumables used solely to make the root or first weld run. Where the weld thickness exceeds 50 mm, an additional set of impact tests is required from the root area of the weld irrespective or whether different welding process or welding consumables are used as shown in Figs. 12.2.6 and 12.2.7.

2.7.9 For offshore structures and pressure vessels, impact test specimens are not required to be notched at the FL + 10 mm location. Where more than one welding process or type of consumable has been used to make the weld, test specimens are to be removed from the respective areas of the weld. This does not apply to the process or consumables used solely to make the root or first weld run.

2.7.10 At least one macro examination specimen is to be removed from the test plate, near the end where welding started. The specimen is to include the complete cross-section of the weld and the heat affected zone and be prepared and etched to clearly reveal the weld runs and the heat affected zone. Examination is to be performed under a magnification of between x5 and x10.

2.7.11 A chemical analysis of the weld metal is to be performed on the macro specimen where approved welding consumables have not been used. The results are to comply with the limits given in the welding consumable specification.

2.7.12 A Vickers hardness survey is to be performed on the macro specimen taken from the weld start end of the test assembly in accordance with that shown in Fig. 12.2.8, using a test load not in excess of 10 kg. For each row of indents, there are to be a minimum of 3 individual indentations in the weld metal, the heat affected zones (both sides) and the base metal (both sides). The recommended distance between indents is 1,0 mm, but the distance between indents should not be less than the minimum specified in ISO 6507/1.

2.8 Destructive tests for steel fillet welds

2.8.1 Fillet weld test assemblies are to be sectioned for destructive testing in accordance with Fig. 12.2.1(c) and as follows:

(a) two fracture tests;

(b) three macro-sections;

(c) one hardness survey.

2.8.2 Two fracture test specimens are to be removed from the test weld and are to be subjected to testing by bending the upright plate onto the through plate to produce fracture, as shown in Fig. 12.2.1(c).

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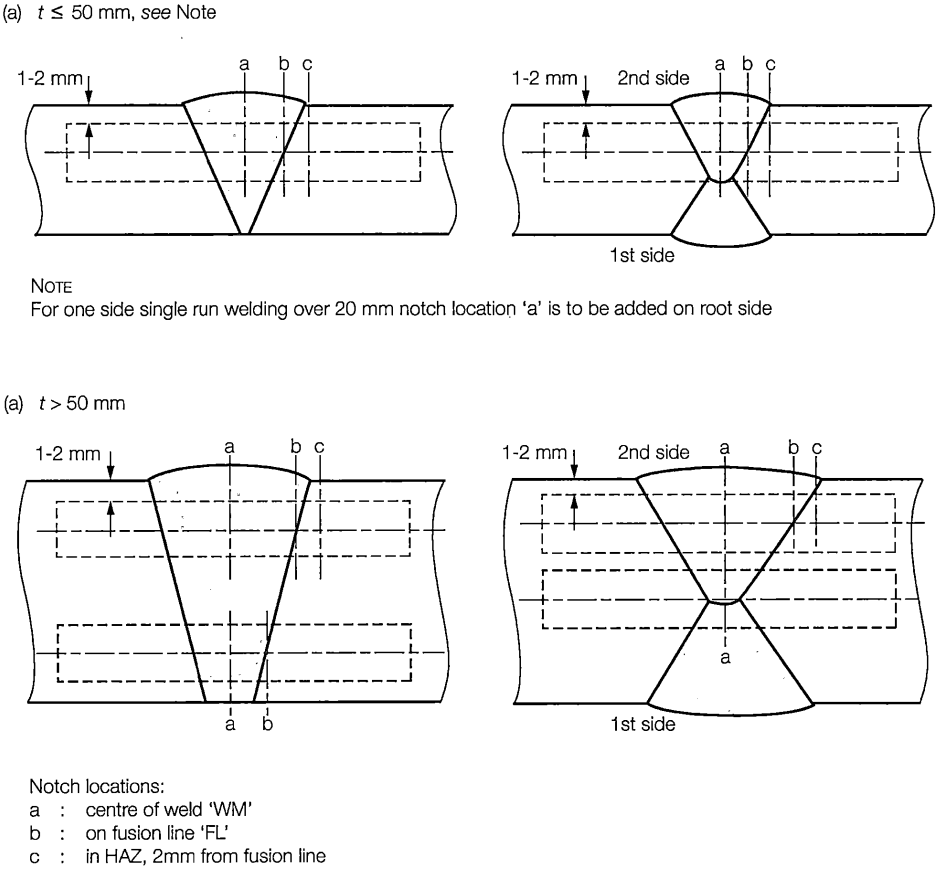

Fig. 12.2.6 Locations of V-notch for butt weld of normal heat input (heat input ≤ 50 kJ/cm)

2.8.3 At least three macro examination specimens are to be removed from the test plate. The specimens are to include the complete cross-section of the weld and the heat affected zone and is to be prepared to clearly reveal the weld runs and the heat affected zone. One of the specimens is to include a weld stop/start position. Examination is to be performed under a magnification of between x5 and x10.

2.8.4 A Vickers hardness survey is to be performed on the macro specimen taken from the weld start end of the test assembly in accordance with that shown in Fig. 12.2.9, using a test load not exceeding 10 kg.

2.9 Destructive tests for T, K, Y steel nozzle welds

2.9.1 Full penetration 'T', 'K' and 'Y' joints for structural applications and nozzle welds for pressure vessels are to be sectioned for testing in accordance with Fig. 12.2.10 and tested as detailed below:

(a) three macro specimens;
(b) impact tests from the weld, fusion line and fusion line + 2 (where the material thickness permits);
(c) one hardness survey.

In addition, butt weld tests are to be performed in accordance with 2.7, using the same welding conditions, in order to verify acceptable weld and heat affected zone properties.

2.9.2 The impact tests are to be removed from the vertical (up) position 'B' in Fig. 12.2.10 and tested in accordance with 2.7.8.

2.9.3 A Vickers hardness survey is to be performed on the macro-section removed from position 'A' or 'C' in accordance with that shown in Fig. 12.2.11 using a test load not exceeding 10 kg.

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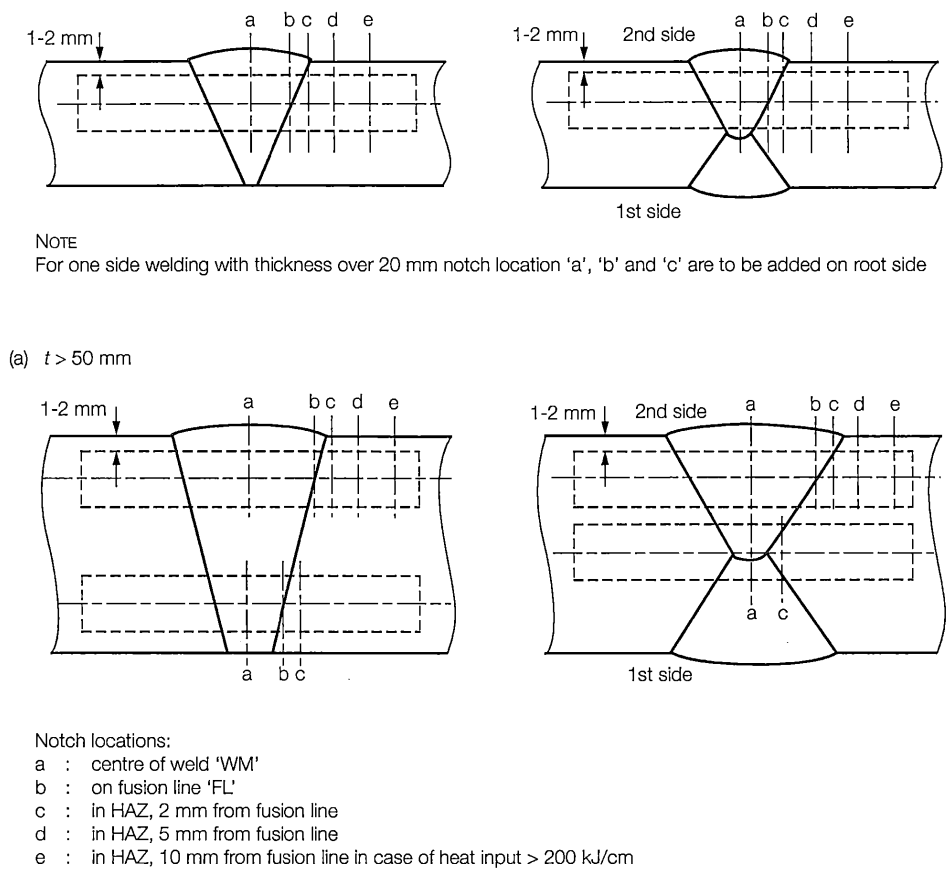

Fig. 12.2.7 Locations of V-notch for butt weld of high heat input (heat input > 50 kJ/cm)

2.10 Destructive tests for steel pipe branch welds

2.10.1 Pipe branch welds may be by either full penetration, partial penetration or fillet welded, depending on the application and the approved plans. Where these types of welded joints are used, tests are to be performed which simulate the construction conditions.

2.10.2 The test weld assembly is to simulate the smallest angle between the branch and main pipe and is to be subjected to macro-examination and hardness testing, as follows:

(a) For a branch weld that is full penetration, testing is to be performed in accordance with the requirements for 'T', 'K' and 'Y' joints in 2.9.

(b) For a branch weld that is either a partial penetration or fillet weld, testing is to be in accordance with the requirements for fillet welds in 2.8.

2.11 Destructive tests for weld cladding of steel

2.11.1 Where weld cladding or overlay is allowed by Chapter 13, and is considered as providing strength to the component to which it is welded, the type and location of test specimens are to be in accordance with Fig. 12.2.12, except that micro-sections are not required. Impact tests may be omitted where the base material does not have specified impact properties. The longitudinal tensile and bend tests are to be tested in a similar manner to transverse specimens specified in 2.7.2 and 2.7.6, respectively.

2.11.2 Where the weld cladding is not considered as contributing to the strength of the component, but is required for corrosion or wear resistance, the type and location of test specimens are to be in accordance with Fig. 12.2.12, except that tensile and impact tests are not required.

2.11.3 Where the weld cladding is applied for corrosion resistance, in addition to the above, weld metal analysis is to be performed on one of the micro-sections, on the final weld surface but 2 mm deep. The analysis is to be within the limits specified for the corrosion resistance required.

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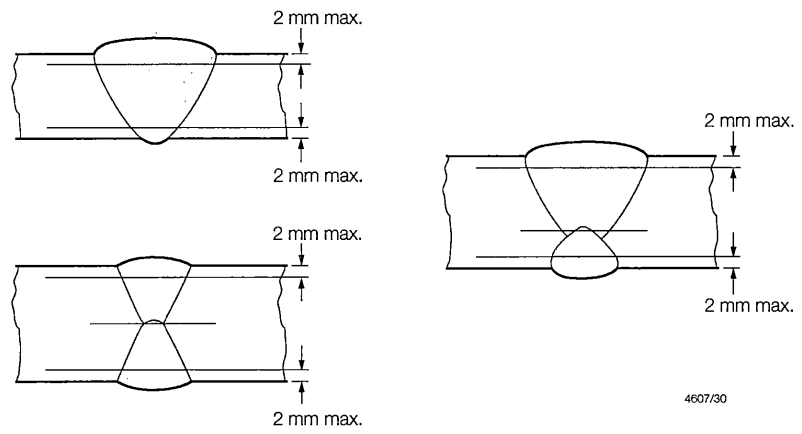

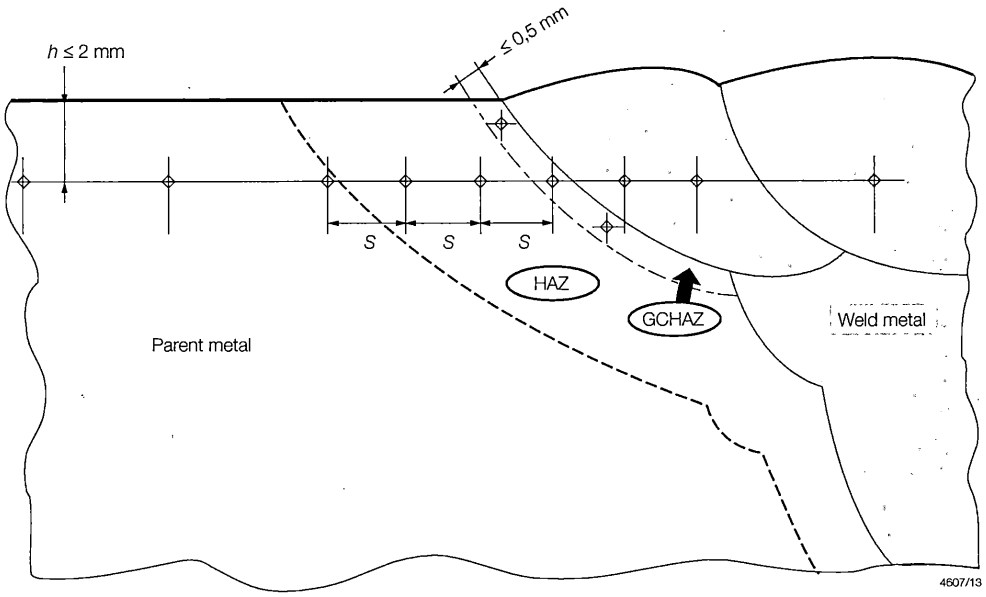

HAZ	Heat affected zone
GCHAZ	Grain coarsened heat affected zone
S	Indentation spacing

Fig. 12.2.8 Hardness testing locations for butt welds

2.12 Mechanical test acceptance criteria for steels

2.12.1 **Longitudinal all weld metal tensile test:**

(a) In general, the longitudinal all weld tensile test is to meet the minimum properties specified in Tables 11.3.2 or 11.4.2 in Chapter 11, as appropriate to the grade of steel and welding process used in the test.

(b) Where the application is such that no consumable approvals are specified in Chapter 11, the longitudinal all weld tensile test tensile is to meet the minimum properties specified for the base materials used in the test.

(c) For pressure vessels manufactured from carbon or carbon/manganese steels, the tensile strength from the longitudinal all weld tensile test is not to be less than the minimum specified for the plate material and is not to be more than 145 N/mm^2 above this value, *see* Ch 13,4.8.3.

2.12.2 **Transverse tensile test**: The tensile strength measured from the transverse tensile test is not to be less than the minimum specified for the base material used in the test.

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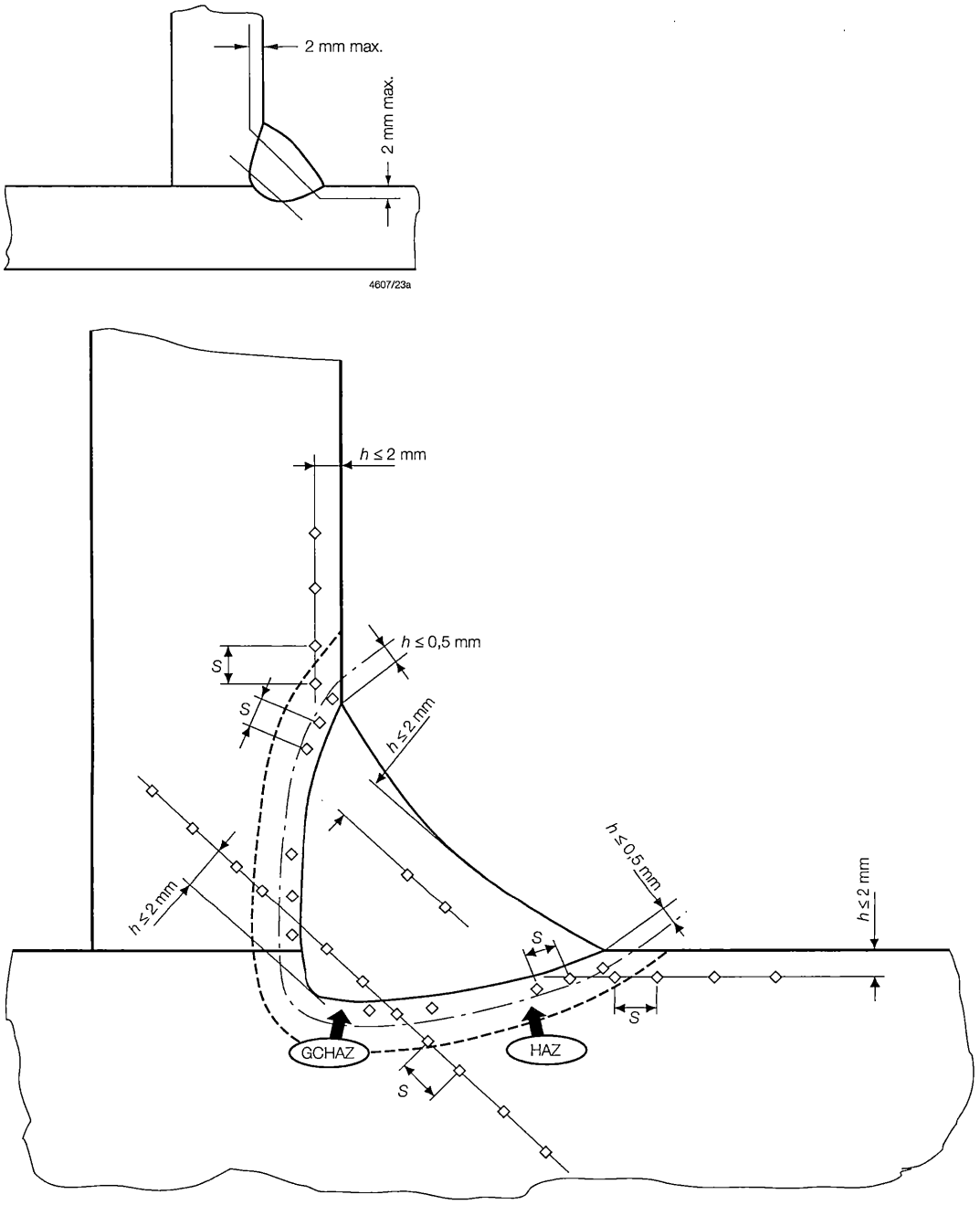

HAZ Heat affected zone
GCHAZ Grain coarsened heat affected zone
S Indentation spacing

Fig. 12.2.9 Hardness test locations for fillet welds

2.12.3 **Bend tests:**

(a) In general, bend tests are to exhibit no defects exceeding 3,0 mm measured in any direction across the tension face of the specimen after being bent over the required diameter of former to the appropriate angle.

(b) Bend tests for pressure vessel applications are to exhibit no defects exceeding 3,0 mm measured along the specimen or 1,5 mm measured transverse to the specimen axis, after bending.

(c) In all cases, premature failure of the bend tests at the edges of the specimen is to not be cause for rejection unless these are associated with a weld defect.

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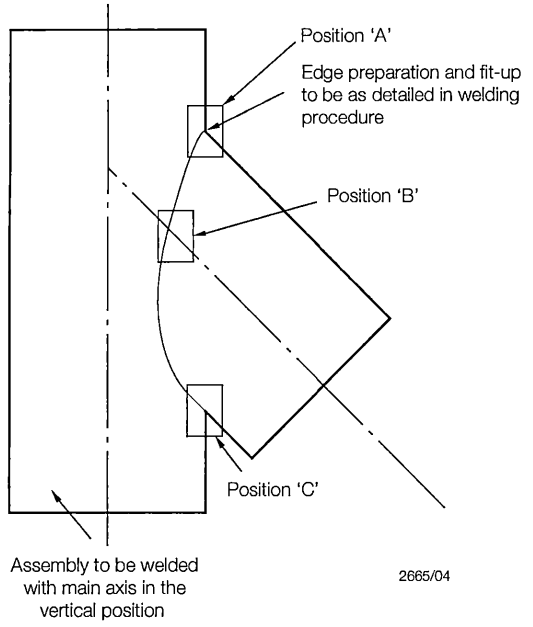


Fig. 12.2.10
Location of macro-examination test specimens for T, K and Y joints

2.12.4 **Impact toughness tests**:

(a) Impact test specimens for hull construction are to be tested at the temperature, and are to achieve the minimum impact energy, as specified in Tables 12.2.2 and 12.2.3.

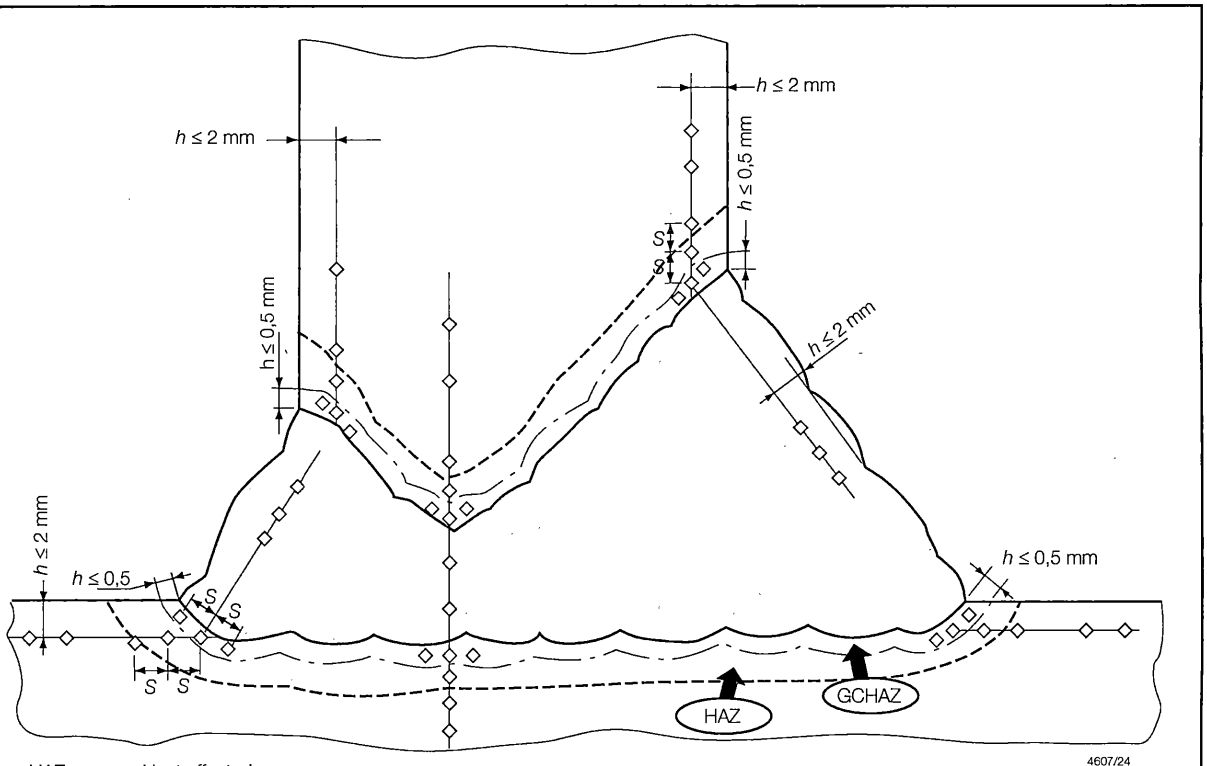
(b) Impact test specimens for applications other than hull construction are to be tested at the same temperature and achieve the same minimum energy values, as specified for the base materials used in the test.

(c) Impact test acceptance criteria are to be in accordance with the above unless the Rules applicable to the particular construction specify more stringent requirements.

(d) For quench and tempered steels, the required test temperature and absorbed energy are to be in accordance with that specified for the parent materials.

2.12.5 **Macro-examination**: The macro-section is to reveal an even weld profile blending smoothly with the base material. The weld dimensions are to be in accordance with the requirements of the pWPS and any defects present are to be assessed against the non-destructive examination acceptance criteria given in 2.5.5.

2.12.6 **Hardness surveys**: The maximum hardness value reported, is not to exceed 350 Hv for steels with a specified minimum yield strength up to ≤420 N/mm^2, nor exceed 420 Hv for steels with a specified minimum yield strength in the range 420 N/mm^2 to 690 N/mm^2.



HAZ Heat affected zone
GCHAZ Grain coarsened heat affected zone
S Indentation spacing

Fig. 12.2.11 Hardness test locations for T, K and Y joints

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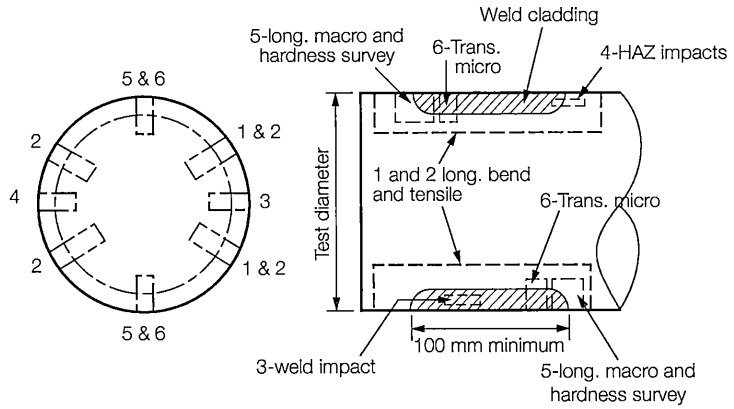

Test specimens
1 Longitudinal tensile test to include the weld metal, heat affected zone (HAZ) and base metal.
2 Longitudinal side bend test to include the weld metal, heat affected zone (HAZ) and base metal.
3 Weld metal Charpy V notch impact test.
4 HAZ Charpy impact test from Fusion Line and Fusion Line + 2 mm.
5 Longitudinal macro-section and hardness survey.
6 Transverse micro-section.

NOTE
In the case of shafts and pipes of circular section, the longitudinal direction is parallel to the centreline of the shaft or pipe axis.

Fig. 12.2.12 Type and location of test specimens for weld cladding

Table 12.2.2 Impact test requirements for butt joints ($t \leq 50$ mm) *see* Notes 1 and 2

Grade of steel	Test temperature (°C) *see* Note 4	Value of minimum energy absorbed (J), *see* Note 4		
		Manual or semi-automatic welded joints		Automatically welded joints
		Downhand, Horizontal, Overhead	Vertical upward, Vertical downward	
A, *see* Note 3 B, *see* Note 3, D E A32, A36 D32, D36 E32, E36 F32, F36	20 0 –20 20 0 –20 –40	47	34	34
A40 D40 E40 F40	20 0 –20 –40		39	39

NOTES
1. Steel with yield strength greater than 390 N/mm^2 is not permitted in thickness less than 50 mm, *see* Table 3.3.1 in Chapter 3.
2. These requirements are to apply to test piece of which butt weld is perpendicular to the rolling direction of the plates.
3. For grade A and B steels average absorbed energy on fusion line and in heat affected zone is to be a minimum of 27 J.
4. For Naval ships both the test temperature and value of minimum energy absorbed are to be those specified for the parent material.

2.12.7 **Weld fracture or break tests (for pressure vessel test welds)**: The faces of the broken fillet weld fracture or weld break test are to be examined for defects and assessed in accordance with the non-destructive acceptance criteria given in ISO 5817 Level B, except for excess convexity and excess throat thickness where Level C will apply.

2.13 Failure to meet requirements (Retests)

2.13.1 Where a tensile, bend or hardness specimen fails to meet requirements, further test specimens may be removed and tested in accordance with the requirements of Ch 2,1.4.1.

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Table 12.2.3 Impact test requirements for butt joints (t > 50 mm), *see* Note 1

Grade of steel	Test temperature (°C) see Note 2	Value of absorbed energy (J, min), *see* Note 2		
		Manual or semi-automatic welded joints		Automatically welded joints
		Downhand, Horizontal, Overhead	Vertical upward, Vertical downward	
A	20	34	34	34
B	0	34	34	34
D	0	47	38	38
E	–20	47	38	38
AH32, AH36	20	47	41	41
DH32, DH36	0	47	41	41
EH32, EH36	–20	47	41	41
FH32, FH36	–40	47	41	41
AH40	20	50	46	46
DH40	0	50	46	46
EH40	–20	50	46	46
FH40	–40	50	46	46
AH47	20	53	53	53
DH47	0	53	53	53
EH47	–20	53	53	53
FH47	–40	53	53	53

NOTES
1. These requirements are to apply to test piece of which butt weld is perpendicular to the rolling direction of the plates.
2. For the Naval ships both the test temperature and value of minimum absorbed energy are to be those specified for the parent material.

2.13.2 Where an impact specimen fails to meet requirements, a further set of three specimens may be removed and tested in accordance with the requirements of Ch 2,1.4.4.

2.13.3 Where a macro specimen reveals a defect that is planar in nature, the welding procedure test is to be considered as not satisfying the requirements and a new test assembly is required.

2.13.4 Where a macro specimen does not meet requirements as a result of a volumetric imperfection exceeding the permitted size, two additional specimens may be removed from the same test weld and examined. If either of these macro-sections also fails to satisfy the requirements, the welding procedure is to be considered as not having met the requirements.

2.13.5 If there is a single hardness value above the maximum values specified, additional hardness tests are to be carried out, either on the reverse of the specimen, or after sufficient grinding of the tested surface. None of the additional hardness values is to exceed the maximum hardness values specified, otherwise the welding procedure is to be considered as not having met the requirements.

2.13.6 Where there is insufficient material available in the welded test assembly to provide re-test specimens, subject to prior agreement with the Surveyor, a second assembly may be welded using the same conditions as the original test weld.

2.14 Test records

2.14.1 The procedure qualification record (PQR) is to be prepared by the manufacturer and is to include details of the welding conditions used in the test specified in 2.2 and the results of all the non-destructive examinations and destructive tests, including re-tests.

2.14.2 Provided that the PQR lists all the relevant variables and there are no inconsistent features and the results satisfy the requirements, the PQR may be endorsed by the Surveyor as satisfying the requirement of the Rules, *see also* 1.1.4.

2.15 Range of approval

2.15.1 A welding procedure qualification test that has successfully met the requirements may be used for a wider range of applications than those used during the test.

2.15.2 Changes outside of the ranges specified are to require a new welding procedure test.

2.15.3 Other ranges of approval from those specified in this Section may be agreed with the Surveyor, provided that they are in accordance with recognised National or International Standards.

2.15.4 **Manufacturer.** A welding procedure qualified by a manufacturer is valid for welding in workshops under the same technical and quality management.

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2.15.5 **Welding process and technique.** The welding process and welding techniques approved are to be those employed during the welding procedure qualification test. Where multiple welding processes are used, these are to be employed in the same order as that used in the welding procedure qualification test. However, it may be acceptable to delete or add a welding process where it has been used solely to make the first weld run in the root of the joint, provided back gouging or grinding of the root weld is specified on the WPS. For multi-process procedures, the welding procedure approval may be carried out with separate welding procedure tests for each welding process.

2.15.6 **Welding positions.** Approval for a test made in any position is restricted to that position. To qualify a range of positions, test assemblies are to be welded for the highest heat input position, and the lowest heat input position, and all applicable tests are to be made on those assemblies. The above excludes welding in the vertical position with travel in the downward direction which will always require separate qualification testing and only be acceptable for that position.

2.15.7 **Joint types.** A qualification test performed on a butt weld may be considered acceptable for fillet and partial penetration welds, provided the same welding conditions are used. The range of approval depending on the type of joint for butt welds is given in Table 12.2.4.

Table 12.2.4 Range of approval for different types of butt joints

Type of welded joint for test assembly				Range of approval
Butt welding	One side	With backing	A	A,C,D
		Without backing	B	A,B,C,D
	Both sides	With gouging	C	C
		Without gouging	D	C,D

2.15.8 **Range of material types:**

(a) A qualification test performed on one strength level of steel may be used to weld all similar materials with the same or lower specified minimum yield stress with the exception of the two-run (T) or high welding heat input (A) techniques where acceptance is limited to the strength level used in the test. Similarly, a qualification test performed on a steel with one toughness level may be considered acceptable for welding all similar materials with the same or three toughness grades lower specified minimum toughness level.

(b) A qualification test performed on H47 strength grade steels may be used to weld the steel of the same strength level or grade H40 and all lower toughness grades to that tested.

(c) For high strength quenched and tempered steels, for each strength level, welding procedures are considered applicable to the same and lower toughness grades as that tested. For each toughness grade, welding procedures are considered applicable to the same and one lower strength level as that tested. The approval of quenched and tempered steels does not qualify thermo-mechanically rolled steels (TMCP steels) and vice versa.

(d) For weldable C and C-Mn steel forgings, welding procedures are applicable to the same and lower strength level as that tested. The approval of quenched and tempered steel forgings does not qualify other delivery conditions and vice versa.

(e) For weldable C and C-Mn steel castings, welding procedures are applicable to the same and lower strength level as that tested. The approval of quenched and tempered steel castings does not qualify other delivery conditions and vice versa.

Dissimilar materials. Where a qualification test has been performed using dissimilar materials, acceptance is to be limited to the materials used in the test.

2.15.9 **Thickness and diameter range:**

(a) For straight butt welds, the material thickness range to be approved is to be based on the thickness of the test piece and the type of weld as shown in Table 12.2.5.

(b) For butt welds between plates of unequal thickness, the lesser thickness is the ruling dimension.

(c) For fillet welds and 'T' butt welds, Table 12.2.5 is to be applicable to both the abutting and through member thicknesses. In addition to the requirements of Table 12.2.5, the range of approval of throat thickness '*a*' for fillet welds is to be as follows:
- single run: 0,75*a* to 1,5*a*
- multi-run: as for butt welds with multi-run (i.e. $a = t$)

(d) Notwithstanding any of the above, the approval of maximum thickness of base metal for any technique is to be restricted to the thickness of the test assembly if three of the hardness values in the heat affected zone are found to be within 25 Hv of the maximum permitted.

(e) The material diameter range to be approved is to be based on the diameter of the test piece and type of weld as shown in Table 12.2.6.

2.15.10 **Welding consumables:**

(a) For manual and semi-automatic welding used for the fill and capping weld runs, it may be acceptable to change the brand or trade name of the welding electrode or wire from that used in the test, provided the proposed alternative has the same or higher approval grading and the same flux type (e.g. basic low hydrogen, rutile, etc.) as used in that test.

(b) For the consumable used to make the root weld of full penetration butt welds made from one side only, no change in the type or trade name of the consumable or backing material is permitted. Alternative backing materials may be used provided they are equivalent to those used for approval. Where the approved backing material is a low hydrogen grade and the steel being welded requires a low hydrogen backing material, testing of the alternative backing material is to confirm compliance with the requirements of Ch 11,7

(c) For processes with heat input over 5 kJ/mm, no change in the type or trade name of the consumable is permitted.

2.15.11 **Shielding gas.** For gas shielded welding processes, a change in shielding gas composition from that used in the test will require a new qualification test.

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Table 12.2.5 Welding procedure thickness approval range – Butt welds

Test thickness, *see* Note 1 (*t* in mm)	Range approved	
	All multi-run butt welds and all fillet welds *see* Notes 3 and 4	All single-run or two-run two-run (T technique) butt welds
$t \leq 3$	*t* to 2*t*	0,7*t* to 1,1*t*
$3 < t \leq 12$	3 to 2*t*	0,7*t* to 1,1*t*
$12 < t \leq 100$	0,5*t* to 2*t*, *see* Note 2	0,7*t* to 1,1*t* *see* Note 5
$t > 100$	0,5*t* to 1,5*t*	0,7*t* to 1,1*t* *see* Note 5

NOTES
1. Where the test plates have dissimilar thickness, the thickness, *t*, is to be based on the minimum thickness for butt welds and the maximum thickness for fillet welds.
2. Subject to a maximum limit of 150 mm.
3. For multi process procedures, the recorded thickness contribution of each process is to be used as a basis for the range of approval of the individual welding process.
4. For vertical down welding, the test piece thickness, *t*, is the upper limit of the range of application.
5. For processes with heat input over 5,0 kJ/mm, the upper limit of the range of approval is to be 1,0 *t*.

Table 12.2.6 Diameter range approved

Diameter used for test, *see* Note 1	Range of diameters approved
$D \leq 25$ mm	0,5*D* to 2*D*
$D > 25$ mm	> 0,5*D*, *see* Note 2

NOTES
1. *D* is the outside diameter of the pipe or the smallest side dimension of rectangular hollow section.
2. Lower diameter range limited to 25 mm minimum.

2.15.12 **Heat Input.** The upper limit of heat input approved is 25 per cent greater than that used in the test, or 5,5 kJ/mm, whichever is the smaller. With heat input over 5,0 KJ/mm, the upper limit is 10 per cent above that used in the test. In all cases, the lower limit of heat input approved is 25 per cent lower than that used in the test.

2.15.13 **Current type.** The current type used during the qualification test is to be the only type approved. Additionally, changes from or to pulsed current require new qualification tests.

2.15.14 **Preheat temperature.** The temperature used during the test is to be the minimum approved. Higher temperatures may be specified for production welds up to the maximum interpass temperature. Where hardness tests have been performed that exhibit results near the maximum permitted, an increase in preheat temperature is required when welding material of greater thickness than that used in the test.

2.15.15 **Interpass temperature.** The maximum interpass temperature recorded during qualification testing is to be the maximum approved. Lower temperatures may be specified for production welding, but no lower than the minimum preheat temperature.

2.15.16 **Post-weld heat treatment.** A qualification test performed with no post weld heat treatment is only acceptable for production welding where no heat treatment is applied. Where the qualification test has included a post weld heat treatment, this is to be applied to all welds made with the welding procedure. The average specified soak temperature may vary by up to 25°C from that tested.

2.15.17 **Shop primers.** Welding procedure qualification with shop primers qualifies welds without primer, but not vice versa.

2.16 Welding procedure specification (WPS)

2.16.1 A welding procedure specification (WPS) is to be prepared by the manufacturer detailing the welding conditions and techniques to be employed for production welding. The WPS is to be based on the conditions and variables used during the qualification test, and is to include all the ranges of the essential variables specified in 2.2.1 and 2.15.

2.16.2 The WPS should reference the procedure qualification record upon which it is based and is to be approved by the Surveyor prior to commencing production welding.

■ *Section 3* Specific requirements for stainless steels

3.1 Scope

3.1.1 The requirements of this Section relate to the group of steel materials classed as stainless steels and include austenitic and duplex grades and martensitic grades.

3.1.2 In all cases, welding procedure tests are to be performed generally in accordance with Section 2 with the specific requirements specified below.

3.2 Austenitic stainless steels

3.2.1 The requirements of this Section relate to the group of stainless steel materials that are austenitic at ambient and sub-zero temperatures, (e.g., 304L, 316L types), *see* Table 3.7.1 in Chapter 3.

3.2.2 Impact tests are to be performed from specimens removed from the weld metal. Tests in the heat affected zone are not required.

3.2.3 Hardness tests are generally not required.

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3.2.4 For cryogenic or corrosion resistant applications, the ferrite content in the weld cap region is to be measured and is to be in the range 2 to 10 per cent, with the exception of grades S 31245 and N 08904 where the content is to be nominally zero.

3.2.5 A qualification test performed on an austenitic grade may be considered acceptable for welding other austenitic steels with the same or lower level of alloying elements and the same or lower tensile strength.

3.2.6 A qualification test performed for cryogenic applications may be considered acceptable for chemical applications, but not vice versa.

3.3 Duplex stainless steels

3.3.1 The requirements of this Section relate to the group of stainless steel materials that have a ferritic-austenitic structure and are usually referred to as duplex or super duplex stainless steels (e.g.,S 31803, S 32760).

3.3.2 Impact test specimens are to be removed from the weld and heat affected zone in accordance with Section 2 with the exception that impact test specimens notched at the FL + 10 mm location are not required. The specimens are to be tested at a temperature of –20°C or the minimum design temperature whichever is the lower and exhibit a minimum average energy of 40 J.

3.3.3 The corrosion resistance is to be maintained in the welded condition and the following tests are to be performed to demonstrate acceptable resistance, unless agreed otherwise.

(a) A sample is to be removed from the weld and heat affected zone for micro-structural examination and is to be suitably prepared and etched so that the micro-structures of the weld and heat affected zones can be examined at a magnification of x200 or higher. The micro-structure of the weld and heat affected zone is to be examined, the percentage grain boundary carbides and intermetallic precipitates is to be reported.

(b) The ferrite content in the un-reheated weld cap and cap HAZ along with the weld root and root HAZ are to be measured and reported. The ferrite content is to be in accordance with Table 12.3.1. Where the intended construction is such that the corrosion medium is only in contact with one surface of the weld (i.e., the weld root), the ferrite determination need only be reported in that surface area.

(c) Corrosion testing is to be performed on samples removed from the weld such that both the weld and HAZ are included in the test. The critical pitting temperature is to be determined in accordance with ASTM G48 Method C and meet the requirements specified in Table 12.3.1. The cap and root surfaces are to be inspected for evidence of pitting and may require probing the surface with a needle. Pitting found on the ends of the specimen in the weld cross-section may be ignored. The use of the weight loss method for corrosion testing may be accepted subject to special consideration.

Table 12.3.1 Requirements for ferrite content and corrosion tests for duplex stainless steel test welds

Duplex Stainless Steel Material Grade	Weld and HAZ Ferrite content	Minimum Critical Pitting Temperature (CPT)
S 31260	30 to 70%	20°C
S 31803	30 to 70%	20°C
S 32550	35 to 65%	25°C
S 32750	35 to 65%	25°C
S 32760	35 to 65%	25°C

3.3.4 Where the test weld is between a grade of carbon steel and duplex stainless steel, the test requirements of 3.3.3(a) and (c) are not required and the ferrite content of the weld and the duplex heat affected zone are to be reported for information.

3.3.5 A qualification test performed on a duplex stainless steel grade may be considered acceptable for welding other duplex grades which have the same or less stringent mechanical or corrosion properties.

3.3.6 The range of heat input is not to vary by more than +10 per cent or –25 per cent from that used during testing.

3.4 Martensitic stainless steels

3.4.1 The requirements of this Section relate to the group of stainless steel materials that have a martensitic structure at ambient temperatures, *see* Table 4.5.1 in Chapter 4.

3.4.2 The results of the hardness survey results are to be reported for information purposes only.

3.4.3 A qualification test is considered acceptable only for the grade of material used in the test.

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Section 4
Welding procedure tests for non-ferrous alloys

4.1 Requirements for aluminium alloys

4.1.1 The requirements for welding procedure qualification tests for aluminium alloys are to be in accordance with the general requirements of Section 2 with the following exceptions and specific requirements.

4.1.2 Non-destructive examination is to be performed in accordance with 2.5 and the assessment of results is to be in accordance with Table 12.4.1 and Table 12.4.2.

4.1.3 Acceptance of the mechanical tests is to be in accordance with Ch 11,9. Welding of the strain hardened and heat treatable aluminium alloys will generally result in a loss of tensile strength in the heat affected zone below that specified for the base materials and the tensile strength acceptance criteria to be applied is that specified for the material in the annealed or 'as fabricated' condition. Minimum values of tensile strength measured on the transverse tensile samples are given in Table 12.4.3.

4.1.4 Impact tests and hardness surveys are not required for aluminium alloys.

4.1.5 Four side bend tests may be used in place of root and face bends where the test thickness exceeds 12 mm, and longitudinal bend tests may be used instead of transverse tests where the test weld is between different grades of alloy. Bend specimens are to be bent round a former in accordance with Table 11.9.1 in Chapter 11, with the exception that the 6000 series alloys may be bent round a former with $D/t = 7$.

4.1.6 The ranges of approval to be applied to the WPS are to be as specified for steel in 2.15 with the following exceptions:

(a) The welding positions approved are as detailed in Table 12.4.4.

(b) The aluminium alloys are grouped into three groups as follows:

- Group A: aluminium-magnesium alloys, with Mg content ≤3,5 per cent (alloy 5754).
- Group B: aluminium-magnesium alloys with 4 per cent ≤Mg ≤5,6 per cent (alloys 5059, 5083, 5086, 5383 and 5456).
- Group C: aluminium-magnesium-silicon alloys (alloys 6005A, 6061 and 6082). For each group, the qualification made on one alloy qualifies the procedure also for the other alloys in the group, with equal or lower tensile strength after welding. The qualification made on group B alloys qualifies the procedure for Group A alloys also. Approval for the range of material grades is summarised in Table 12.4.5.

Table 12.4.1 Acceptance criteria for surface imperfections of aluminium alloys

Surface discontinuity	Classification according to ISO 6520-1	Acceptance criteria
Crack	100	Not permitted
Lack of fusion	401	Not permitted
Incomplete root penetration in butt joints welded from one side	4021	Not permitted
Surface pore	2017	$d \le 0{,}1s$ or $0{,}1a$ max. 1,0 mm
Uniformly distributed porosity (*see* Note 1)	2012	≤ 0,5% of area
Clustered porosity	2013	Not permitted
Continuous undercut	5011	Not permitted
Intermittent undercut	5012	$h \le 0{,}1t$ or 0,5 mm (whichever is the lesser)
Excess weld metal (*see* Note 2)	502	$h \le 1{,}5$ mm + $0{,}1b$ or 6 mm (whichever is the lesser)
Excess penetration	504	$h \le 4$ mm
Root concavity (*see* Note 2)	515	$h \le 0{,}05t$ or 0,5 mm (whichever is the lesser)
Linear misalignment (*see* Notes 3 and 4)	507	$h \le 0{,}2t$ or 2,0 mm (whichever is the lesser)

Symbols

a = nominal throat thickness of a fillet weld
b = width of weld reinforcement
d = diameter of a gas pore
h = height or width of an imperfection
s = nominal butt weld thickness
t = wall or plate thickness (nominal size)

NOTES
1. To be in accordance with EN ISO 10042.
2. A smooth transition is required.
3. The limits for linear misalignment relate to deviations from the correct position. Unless otherwise specified, the correct position is to be taken when the centrelines coincide.
4. Dimensional tolerances not specified in these Rules are to be mutually agreed between the manufacturer and the Surveyor.

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Table 12.4.2 Acceptance criteria for internal imperfections of aluminium alloys

Internal discontinuity	Classification according to ISO 6520-1	Acceptance criteria
Crack	100	Not permitted
Lack of fusion	401	Not permitted
Incomplete penetration	402	Not permitted
Single gas pore	2011	$d \leq 0{,}2s$ or $0{,}2a$ or 4 mm (whichever is the lesser)
Linear porosity (*see* Note 2)	2014	Not permitted
Uniformly distributed porosity (*see* Note 2)	2012	$0{,}5t$ to $3t$ ≤ 1% of area $> 3t$ to $12t$ ≤ 2% of area $> 12t$ to $30t$ ≤ 3% of area $> 30t$ ≤ 4% of area
Clustered porosity (*see* Note 1)	2013	$dA \leq 15$ mm or wp (whichever is the lesser)
Elongated cavity Wormhole	2015 2016	$l \leq 0{,}2s$ or $0{,}2a$ or 3 mm (whichever is the lesser)
Oxide inclusion (*see* Note 2)	303	$l \leq 0{,}2s$ or $0{,}2a$ or 3 mm (whichever is the lesser)
Tungsten inclusion	3041	$l \leq 0{,}2s$ or $0{,}2a$ or 3 mm (whichever is the lesser)
Copper inclusion	3042	Not permitted
Multiple imperfections in any cross-section	—	The sum of the acceptable individual imperfections in any cross-section is not to exceed $0{,}2t$ or $0{,}2a$ (whichever is the lesser)

Symbols

a = nominal throat thickness of a fillet weld
d = diameter of a gas pore
h = height or width of an imperfection
s = nominal butt weld thickness
t = wall or plate thickness (nominal size), in mm
wp = width of weld or width or height of cross-sectional area
dA = diameter of area surrounding gas pores
l = length of imperfection in longitudinal direction of weld

NOTES
1. For this acceptance criterion, linear porosity is to be considered as three aligned gas pores in a length of 25 mm.
2. Porosity is to be determined in accordance with ISO 10042. The requirements for a single gas pore are to be met by all the gas pores within this circle. Systematic clustered porosity is not permitted.

Table 12.4.3 Tensile strength requirements by grade for aluminium alloys

Parent material Grade (alloy designation)	Minimum tensile strength (N/mm^2)
5754	190
5086	240
5083	275
5383	290
5059	330
5456	290
6005A	170
6061	170
6082	170

Table 12.4.4 Welding procedure approval, welding positions for aluminium alloys

Test position		Positions approved
Downhand	D	D
Horizontal-vertical	X	D, X
Vertical up	Vu	D, X, Vu
Overhead	O	D, X, Vu and O

NOTE
Welding in vertical down (Vd) position is not recommended.

(c) The qualification of a procedure carried out on a test assembly of thickness t is valid for the thickness range given in Table 12.4.6. In the case of butt joints between dissimilar thicknesses, t is the thickness of the thinner material. In the case of fillet joints between dissimilar thicknesses, t is the thickness of the thicker material. In addition to the requirements of Table 12.4.6, the range of the qualification of throat thickness of fillet welds, a, is given in Table 12.4.7. Where a fillet weld is qualified by a butt weld test, the throat thickness range qualified is to be based on the thickness of the deposited weld metal.

(d) The range of shielding gas compositions approved is to be in accordance with Table 11.9.2 in Chapter 11.

(e) A change in the brand or trade name of the filler metal from that used in the test is acceptable, provided that the proposed consumable has the same or higher strength grading.

(f) A change in post-weld heat treatment or ageing is not permitted, except that for the heat treatable alloys, artificial ageing may give approval for prolonged natural ageing.

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Table 12.4.5 Welding procedure approval, aluminium material grades approved

Material used in qualification test	Material Grades approved				
5754	5754				
5086	5086	5754			
5083	5083	5086	5754		
5383	5383	5083	5086	5754	
5059	5059	5383	5083	5086	5754
5456	5456	5383	5083	5086	5754
6005A	6005A	6082	6061		
6082	6005A	6082	6061		
6061	6005A	6082	6061		

NOTE
Approval includes all the different strained and tempered conditions in each case.

Table 12.4.6 Range of qualification for parent material thickness

Thickness of test assembly, t (mm)	Range of qualification Multi pass welds	Range of qualification All single-run or two-run (T technique) butt welds
$t \leq 3$	0,5 to 2t	0,5t to 1,1t
$3 < t \leq 20$	3 to 2t	0,5t to 1,1t
$t > 20$	$\geq 0,8t$	0,5t to 1,1t

Table 12.4.7 Range of qualification of throat thickness for fillet welds

Throat thickness of test piece, a (mm)	Range of qualification
$a < 10$	0,75 a to 1,5 a
$a \geq 10$	$\geq 7,5$

Table 12.4.8 Minimum transverse tensile strengths for welded copper alloy propellers

Alloy designation	Minimum tensile strength (N/mm^2)
CU 1	370
CU 2	410
CU 3	500
CU 4	550

4.2 Requirements for copper alloys

4.2.1 The requirements for welding procedure qualification tests for copper alloys are to be in accordance with the requirements for steel as given in Section 2 with the following exceptions and additions.

4.2.2 Impact tests on copper alloys are not required.

4.2.3 Hardness tests are not required for seawater service.

4.2.4 For the welding of cast copper alloys for propellers, the minimum tensile strength from the transverse tensile test is to be in accordance with Table 12.4.8.

4.2.5 Bend tests are to be performed over a diameter of former as detailed in Table 12.4.9.

4.2.6 The range of approval to be applied to the WPS is to be as specified in 2.15 with the exception of the material grades which are detailed in Table 12.4.10.

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Table 12.4.9 Former diameters for bend testing of copper alloy welds

Alloy designation (*see* Chapter 9)	Former diameter (*D/t*)
Cast propellers: CU1 CU2 CU3 CU4	 4 4 6, *see* Note 6, *see* Note
Other short freezing range castings: Copper-Nickel 90/10 Copper-Nickel 70/30 Aluminium bronze	 4 4 6
Wrought alloys (tubes and pipes): Copper-phosphorus Aluminium-brass 90/10 Copper-nickel-iron 70/30 Copper-nickel-iron	 3 3 3 3
NOTE Where the qualification tests for these alloys are subjected to post-weld heat treatment the former diameter may be increased to *D/t* = 10.	

Table 12.4.10 Range of approval for copper alloy material grades

Category	Alloy grade used in the qualification test	Alloy grades approved
Propellers	CU1 CU2 CU3 CU4	CU1 CU1 and CU2 CU1, CU2 and CU3 CU4 *see* Note 1
Tubes/pipes	90/10 Copper-Nickel-Iron 70/30 Copper-Nickel-Iron	90/10 Copper-Nickel-Iron 70/30 Copper-Nickel-Iron and 90/10 Copper-Nickel-Iron
Tubes/pipes *see* Note 2	Copper-Phosphorus deoxidised – arsenical Copper-Phosphorus deoxisised – non arsenical Aluminium-brass	Copper-Phosphorus deoxidised – arsenical Copper-Phosphorus deoxisised – non arsenical Aluminium-brass
NOTES 1. Where a CU3 type welding consumable has been used for the qualification test, the range of approval may also include welding of CU3. 2. These grades have limited weldability and approval to weld is subject to the materials satisfying the requirements of Table 9.3.1 in Chapter 9.		

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Section 5
Welder qualification tests

5.1 Scope

5.1.1 The requirements of this Section relate to qualification of welders involved in welded construction associated with ships, or other marine structures, and products or components intended for use on or in these structures.

5.1.2 The requirements relate to fusion welding processes that are designated as manual, semi-automatic or partly mechanised. Special consideration will be given to other welding processes adapted from these requirements.

5.1.3 Prior to commencing production welding, the welder is to have performed a qualification test that satisfies these requirements. It is the responsibility of the manufacturer to ensure that the welder possesses the required level of skill for the work to be undertaken.

5.1.4 The qualification of welders is to be documented by the manufacturer and the records are to be available for review by the Surveyor.

5.1.5 Welder qualification tests made in accordance with EN, ISO, JIS, ASME or AWS may be considered for acceptance provided that, as a minimum, they are equivalent to, and meet the technical intent of these Rules to the satisfaction of the Surveyor.

5.2 Welder qualification test assemblies

5.2.1 The welding of the welder qualification test assembly is to simulate, as far as practicable, the conditions to be experienced in production and be witnessed by the Surveyor. The test is to be carried out on a test assembly piece and not by way of production welding.

5.2.2 The test is to simulate, as far as practicable, the welding techniques and practices to be encountered during production welding. The test assembly is to be designed to test the skill of the welder and have the shape and dimensions appropriate to the range of approval required.

5.2.3 The inspection length of the test weld is to be such as to permit the removal of all the necessary test specimens and for plate tests, but in no case is to be less than 250 mm. The test assembly is to be set in one of the positions as shown in Fig. 12.2.2 appropriate to the welding positions to be approved.

5.2.4 A welding procedure specification (WPS) is required for the execution of the qualification test and is to include the information specified in 2.2.1, as a minimum.

5.2.5 The test assembly is to be marked with a unique identification and the inspection length is to be identified prior to commencing welding. For pipe welds, the whole circumference is to be considered as the inspection length.

5.2.6 During welding of the test assembly, the welding time is to be similar to that expected under production conditions. For manual or semi-automatic processes, at least one stop and re-start in the root and in the top surface layer is to be included in the inspection length and marked for future inspection.

5.2.7 During welding of the test assembly, minor imperfections may be removed by the welder by any method that is used in production, except on the surface layer.

5.2.8 The Surveyor may stop the test if the welding conditions are not correct or if there is any doubt about the competence of the welder to achieve the required standard.

5.3 Examination and testing

5.3.1 Each completed test weld is to be examined and tested in accordance with the requirements of Table 12.5.1.

5.3.2 Visual examination is to be performed in the as welded state prior to any other assessment.

5.3.3 For plate butt welds, fracture testing may be used in place of radiography.

5.3.4 Where a backing strip has been used, it is to be retained for non-destructive examinations, but is to be removed prior to performing any bend or fracture tests.

5.3.5 Where fracture tests are required, they are to sample as much of the inspection length as practicable and the test assembly may be cut into several test specimens to achieve this. Testing is to be performed as shown in Figs. 12.5.1(a) or 12.5.1(b).

5.3.6 For butt weld tests in aluminium alloys both radiography and bend tests are required.

5.3.7 When bend tests are required, 2 root and 2 face bends are to be tested and where the test thickness exceeds 12 mm, these may be substituted by 4 side bends specimens. The diameter of former to be used is to be in accordance with that specified for welding procedure qualification testing given in 2.7.6(a).

5.3.8 Where macro examination is required, the specimen is to be polished and etched to reveal the weld runs and heat affected zones, and be examined at a magnification between x5 and x10.

5.4 Acceptance criteria

5.4.1 The acceptance criteria are to be in accordance with 2.5.5.

5.4.2 Fracture tests and macro-sections are to be assessed in accordance with the non-destructive examination acceptance criteria.

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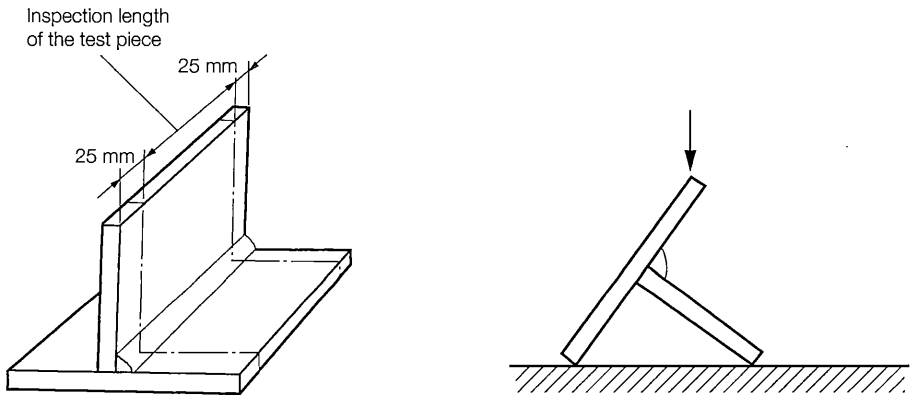
Table 12.5.1 Welder qualification test requirements

Examination type	Butt welds	Fillet welds	Pipe branch welds
Visual	100%	100%	100%
Surface crack detection	*See* Note 1	100%	100%
Radiography	100% *See* Notes 2 and 6	Not required	Not required
Bend tests	4 required *See* Notes 3 and 6	Not required	Not required
Fracture tests	Not required	1 required *See* Note 4	Not required
Macro	Not required	1 required *See* Note 4	4 required *See* Note 5

NOTES
1. Surface crack detection examination may be required by the Surveyor in order to clarify the acceptability of any weld feature.
2. Radiography may be replaced by ultrasonic examination for carbon and low alloy steels where the thickness exceeds 8 mm.
3. Bend tests are required for gas metal arc welding with solid wire (GMAW) and oxy-acetylene welding.
4. The fracture test may be replaced with 4 macro sections equally spaced along the inspection length.
5. Macro-sections are to be separated by 90° measured around the abutting pipe member.
6. Radiography and bend tests are required for tests in aluminium alloys.



(a)
Sectioning into an even-numbered quantity of test specimens

(b)
Fracture testing
(The fillet weld may be notched if necessary)

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Fig. 12.5.1(a) Preparation and fracture testing of test specimens for a fillet weld in plate

5.4.3 Bend tests are considered acceptable if after bending through an angle of at least 180°, there are no defects on the tension side of the specimen greater than 3 mm in any direction.

5.5 Failure to meet requirements

5.5.1 Where a macro-section fails to meet requirements, one additional specimen may be removed from the test assembly and examined.

5.5.2 Where a bend or fracture test specimen fails to meet requirements, two additional specimens may be prepared from the same test assembly. If there is insufficient material, the welder may be permitted to weld an additional assembly to the same WPS, at the discretion of the Surveyor.

5.5.3 Where any of the additional test specimens fails to satisfy the requirements, the test will be considered as not meeting the requirements.

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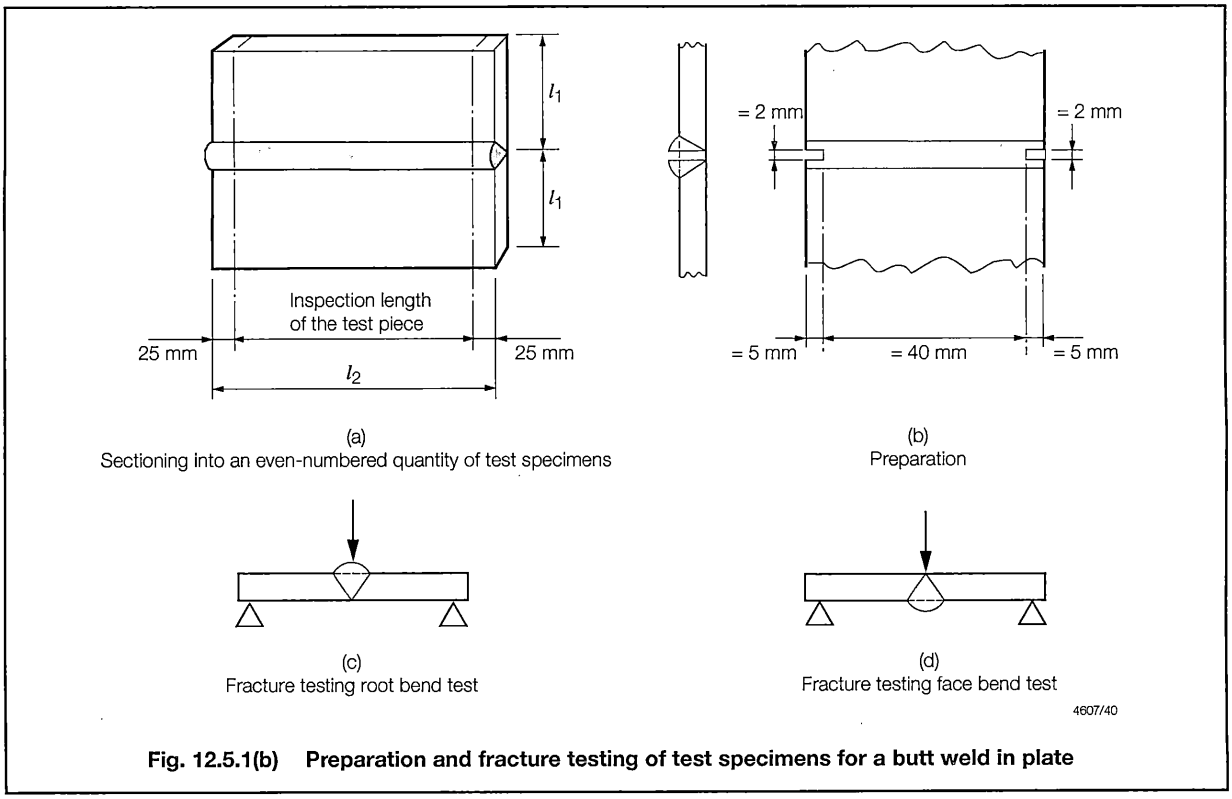

Fig. 12.5.1(b) Preparation and fracture testing of test specimens for a butt weld in plate

5.5.4 Where a test fails to comply with the acceptance criteria, the welder may be permitted to weld a second test piece. If this does not meet requirements, the welder is to be considered as not being capable of achieving the requirements.

5.6 Range of approval

5.6.1 Upon successful completion of all the necessary examinations and tests, the welder is to be considered qualified. The essential variables and the range of welding conditions for which the welder is considered approved are specified in the following paragraphs.

5.6.2 Welding variables such as preheat, interpass temperature, heat input and current type are not considered welder qualification variables. However, if the WPS used for testing specify these, they are to be included in the test and the welder is expected to follow the specific instructions.

5.6.3 Where the WPS used for the welder qualification test specifies post weld heat treatment, this need not be applied to the test weld unless bend tests are required and the material exhibits low ductility in the as welded condition.

5.6.4 The qualification test performed by a manufacturer is only applicable to workshops under the same technical control and quality system as that used for the test.

5.6.5 The welding process used in the qualification test is the process approved. However, it is possible for the welder to use more than one process in the test and the range of approval that may be applied to each will be within the limits of the essential variables appropriate to the part of the test where each welding process was used.

5.6.6 Material types are to be grouped as shown in Table 12.5.2 for welder qualifications. A qualification test performed on one material from a group will permit welding of all other materials within the same group. In addition, qualification on one group of materials may confer approval to weld other groups as shown in Table 12.5.3.

5.6.7 A qualification test performed on one thickness will confer approval to weld other thicknesses as specified in Table 12.5.4. Where welding is required between materials of different thickness, the reference thickness for approval purposes is to be the lesser thickness.

5.6.8 A qualification test performed on plate confers approval to weld on pipes having an outside diameter greater than 500 mm in a fixed position (*see* Table 12.5.5 and Table 12.5.6).

5.6.9 A qualification test performed using a specific diameter of pipe will give approval to weld other diameters as shown in Table 12.5.5. For branch welds, the diameter upon which approval is based is to be the branch member.

5.6.10 A qualification test performed on a butt weld may be considered as giving approval for fillet welds.

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Table 12.5.2 Welder qualification materials groupings

Material group	Material description	Typical LR Grades	Rules for Material references
WQ 01	Low carbon unalloyed, C/Mn, or Low alloyed steels (Re ≤ 360 N/mm^2)	A, B, D and E AH to FH32 and 36 Boiler 510FG and lower LT-AH to FH32 and 36 U1 and U2 Steel castings Steel pipes	Ch 3,2 Ch 3,3 Ch 3,4 Ch 3,6 Ch 3,9 and Ch 10 Ch 4,2, 3, 6 and 7 Ch 6,2, 3, 4 and 6
WQ 02	Cr-Mo, or Cr-Mo-V creep resisting steels	13CrMo45 and 11CrMo910 1Cr½Mo and 2¼Cr1Mo ½Cr½Mo¼V	Ch 3,4 Ch 4,6 and Ch 6,2, 3 and 6 Ch 4,6 and Ch 6,2
WQ 03	High strength fine grained, Normalised or quenched, or Tempered structural steels (2,0 – 5% Ni, with Re > 360 N/mm^2)	AH to FH40 to 69 LT-AH to LT-FH40 1½ , 3½ Ni steels and castings U3, R3, R3S and R4	Ch 3,3 and 10 Ch 3,6 Ch 3,6, Ch 4,7 and Ch 6,4 Ch 3,9 and Ch 10
WQ 04	Ferritic, or martensitic stainless steels (12 to 20% Cr)	13% Cr (martensitic)	Ch 4,5 (martensitic)
WQ 05	Ferritic low temperature steels	5Ni and 9Ni	Ch 3,6
WQ 011	Ferritic-austenitic stainless steels, Austenitic stainless steels, or Cr-Ni steels	304, 316, 317, 321 and 347 S31260, S31803, S32550 and S32750	Ch 3,7 and 8 Ch 4,8 and Ch 6,5
WQ 22a	Aluminium alloy – Non-heat treatable Mg < 3,5%	5754	Chapter 8
WQ 22b	Aluminium alloy – Non-heat treatable 3,5% < Mg < 5,6%	5083 and 5086	Chapter 8
WQ 23	Aluminium alloy – Heat treatable	6005-A, 6061 and 6082	Chapter 8
WQ 30	Copper alloys for propellers – Manganese bronze	Cu1	Ch 9,1
WQ 31	Copper alloys for propellers – Nickel-manganese bronze	Cu2	Ch 9,1
WQ 32	Copper alloys for propellers – Nickel-aluminium bronze	Cu3	Ch 9,1
WQ 33	Copper alloys for propellers – Manganese-aluminium bronze	Cu4	Ch 9,1
WQ 34	Copper alloys for tubes – Copper phosphorus	Deoxidised – non-arsenical and arsenical	Ch 9,3
WQ 35	Copper alloys for tubes – Aluminium brass	Aluminium brass	Ch 9,3
WQ 36	Copper alloys for tubes – Copper-nickel-iron	70/30 Cu/Ni and 90/10 Cu/Ni	Ch 9,3

5.6.11 A butt qualification test welded from one side, with the root unsupported (i.e., no backing), will give approval for welds made from both sides with or without back gouging or grinding, but not vice versa.

5.6.12 A qualification test performed in one position will give approval to weld in other positions as shown in Table 12.5.6.

5.6.13 For manual metal arc welding with covered electrodes, a qualification test performed using an electrode with one type of coating will only be approved for welding with that type of coating. However, a qualification test performed using a basic low hydrogen type coating will confer approval to use electrodes with rutile coatings.

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Table 12.5.3 Welder qualification, range of approval for material groups

Material group used for testing	Material groups approved to weld			
WQ 01	WQ 01			
WQ 02	WQ 01	WQ 02		
WQ 03	WQ 01	WQ 02	WQ 03	
WQ 04	WQ 01	WQ 02	WQ 04	
WQ 05	WQ 05			
WQ 11	WQ 11	WQ 05, *see* Note	WQ 04, *see* Note	
WQ 22a	WQ 22a	WQ 22b		
WQ 22b	WQ 22a	WQ 22b		
WQ 23	WQ 22a	WQ 22b	WQ 23	
WQ 30	WQ 30	WQ 31	WQ 32	WQ 33
WQ 31	WQ 30	WQ 31	WQ 32	WQ 33
WQ 32	WQ 30	WQ 31	WQ 32	WQ 33
WQ 33	WQ 30	WQ 31	WQ 32	WQ 33
WQ 34	WQ 34	WQ 35		
WQ 35	WQ 34	WQ 35		
WQ 36	WQ 36			

NOTE
Provided an austenitic welding consumable compatible with material group WQ 11 is used.

Table 12.5.4 Welder qualification, range of approval for material thickness

Material type	Test piece thickness (mm)	Range approved, *see* Note (mm)
Steel and copper alloys	$t \leq 3$ $3 < t \leq 12$ $t > 12$	t to $2t$ 3,0 to $2t$ ≥ 5,0
Aluminium alloys	$t \leq 6$ $6 < t \leq 15$ $t > 40$ mm	0,7 to 2,5t 6,0 < $t \leq$ 40,0 41 to $2t$

NOTE
For oxy-acetylene welding the maximum thickness is limited to 1,5 t.

Table 12.5.5 Welder qualification, diameter range of approval for pipes and hollow sections

Material type	Test piece diameter (mm)	Range approved (mm)
Steel and copper alloys	$D \leq 25$ $25 < D \leq 150$ $D > 150$ Plate, *see* Note 2	D to $2D$ 0,5D to $2D$, *see* Note 1 ≥ 0,5D ≥ 500
Aluminium alloys	$D \leq 125$ $D > 125$ Plate, *see* Note 2	0,25D to $2D$ ≥ 0,5D ≥ 500

NOTES
1. Subject to 25 mm minimum diameter.
2. Plate qualification will approve welding on pipes greater than 150 mm diameter when the pipe is rotated.

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Table 12.5.6 Welding position ranges for welder qualification

Test weld conditions		Positions qualified			
		Plate		Pipe, *see* Note 1	
Type of weld	Test position	Butt weld	Fillet weld	Butt weld	Fillet weld
Plate butt, *see* Note 5	D	D	D	D	D
	X	D,X	D, X	D	D, X
	Vu	D, Vu	D, X, Vu	D	D, Vu
	Vd	Vd	Vd	—	—
	O	D, X, Vu, O	D, X, Vu, O	D	D, X, Vu, O
Plate Fillet, *see* Note 5	D	—	D	—	D
	X	—	D, X	—	D, X
	Vu	—	D, X, Vu	—	D, X, Vu
	Vd	—	Vd	—	—
	O	—	D, X, Vu, O	—	D, X, Vu, O
Pipe butt	D	D	D, X	D	D, X
	X	D, X	D, X	D, X	D, X
	D+Vu+O, *see* Note 3	D, Vu, O	D, X, Vu, O	D, Vu, O	D, X, Vu, O
	D+Vd+O, *see* Notes 2 and 3	Vd	Vd	Vd	Vd
	Axis at 45°, *see* Note 4, Travel Vu	D, X, Vu, O	D, X, Vu, O	D, X, Vu, O	D, X, Vu, O
	Axis at 45°, *see* Notes 2, 3 and 4, Travel Vd	Vd	Vd	Vd	Vd
Pipe fillet	D	—	D	—	D
	X	—	D, X	—	D, X
	D+Vu+O *see* Note 3	—	D, X, Vu, O	—	D, X, Vu, O
	D+Vd+O *see* Note 3	—	Vd	—	Vd

NOTES
1. Pipe D position means pipe in horizontal position and rotated, *see* Fig. 12.2.2(b) and Fig. 12.2.2(d).
2. Vd position not usually recommended for pipe welds less than 500 mm diameter.
3. Pipe fixed with axis in the horizontal position (e.g. ASME 5G).
4. Pipe fixed with axis at 45° to the horizontal (e.g. ASME 6G).
5. Plate qualification tests confers approval to weld pipes with diameter greater than 500 mm.

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5.6.14 For gas shielded welding processes that use a single component shielding gas, no change to the gas composition is permitted from that tested. Where the test has used a two component shielding gas, a change in the ratio of component gases is permitted, provided that one of the components is not reduced to zero. Where the test has used a three component shielding gas, changes are permitted in the ratio of component gases and the gas with the smallest ratio may be reduced to zero, provided this does not change the shielding gas from an active one to an inert one or vice versa. In addition, where a change in shielding gas composition requires a different welding method or technique to be employed, a new qualification test will be required.

5.6.15 A change of welding flux from that used for the test is permitted.

5.7 Welders qualification certification

5.7.1 All the relevant conditions used during the test are to be entered on the welder's qualification certificate along with the permitted range of approval.

5.7.2 If the Surveyor is satisfied that the welder has demonstrated the appropriate level of skill and all tests are satisfactory, the Surveyor will endorse the certificate verifying that the details contained on it are correct and that the test welds were prepared, welded and tested in accordance with the specified Rules, Codes or Standards.

5.7.3 The welder is considered to be approved for an initial validity period of 2 years. The welder is considered to have retained the qualification subject to the manufacturer confirming every 6 months that the welder has used the welding process with acceptable performance in the preceding 6 months.

5.7.4 After 2 years, the Surveyor may extend the validity of the approval for another period of two years provided that records or documented evidence is made available confirming acceptable welding performance, within the original range of approval, without a break exceeding 6 months. The Surveyor will signify acceptance of the extension to the validity by endorsing the certificate.

5.7.5 Where there is any reason to question the welder's ability, or there is a lack of continuity in the use of the welding process, or insufficient recorded evidence of acceptable weld performance, the welder is to perform a new qualification test.

5.7.6 Where the manufacturer has existing welders that have previously performed qualification tests, these may be considered for acceptance provided they satisfy the above requirements and the tests have been performed in the presence of an independent examiner that is acceptable to the Society.

5.7.7 Not withstanding the above, the Surveyor may at any time request a review of a welder's qualification records. If there is any reason for doubt concerning the skill of the welder, the Surveyor may withdraw the qualification and require a re-qualification test to be performed.

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Requirements for Welded Construction

Chapter 13

Section

1 **General welding requirements**

2 **Specific requirements for ship hull structure and machinery**

3 **Specific requirements for fabricated steel sections**

4 **Specific requirements for fusion welded pressure vessels**

5 **Specific requirements for pressure pipework**

6 **Repair of existing ships by welding**

7 **Austenitic and duplex stainless steel – Specific requirements**

8 **Specific requirements for welded aluminium**

Section 1
General welding requirements

1.1 Scope

1.1.1 This Chapter specifies requirements for fabrication and welding during construction and repair of ships or other marine structures, and their associated pressure vessels, machinery, equipment, components and products intended for use in these structures.

1.1.2 The requirements relate to fusion welding. Special consideration will be given to the use of other welding processes based on these requirements.

1.1.3 It is the responsibility of the manufacturer to ensure compliance with all aspects of these Rules and inform the Surveyor of any deviations that have occurred. All deviations are to be recorded as non-compliances along with the corrective actions taken and failure to do this is considered to render the fabrication to be in non-compliance with the Rules.

1.1.4 Welded constructions that comply with National or International specifications may be accepted to the satisfaction of the surveyor, provided that these specifications give reasonable equivalence to the requirements of this Chapter.

1.1.5 All welded construction is to be to the satisfaction of the Surveyor.

1.2 Design

1.2.1 Prior to commencing any work, the component to be manufactured is to be subjected to design review and approval in accordance with the Rule requirements.

1.2.2 The material characteristics that are affected by welding, particularly the loss of strength (e.g., in precipitation or strain hardened aluminium alloys) are to be considered in the design. The weld joints in such materials are to be arranged such that they are in areas of lower stress.

1.3 Materials

1.3.1 Materials used in welded construction are to be manufactured at works approved by LR. The use of materials from alternative sources will be subject to agreement of the Surveyor and satisfactory verification testing.

1.3.2 Materials are to be supplied and certified in accordance with the requirements of Chapters 1 to 10 of these Rules.

1.3.3 Materials used in welded construction are to be readily weldable and are to have proven weldability, unless requirements are agreed with LR in advance.

1.3.4 Where the construction details are such that materials are subject to through-thickness strains, consideration is to be given to using material with specified through-thickness properties as specified in Ch 3,8.

1.3.5 When ordering materials for construction, consideration is to be taken of the possible degradation of properties during fabrication or post-weld heat treatment. Where these materials are used, consideration is to be given to additional test requirements being specified to the supplier.

1.3.6 The identity of materials is to be established by way of markings etc, during fabrication, so that traceability to the original manufacturer's certificate is maintained.

1.3.7 Pre-fabrication shop primers may be applied prior to welding, provided that they are of an approved type and have been tested to demonstrate that they have no deleterious effects on the completed weld.

1.3.8 Where it is proposed to weld forgings and/or castings, full details of the joint details, welding procedures and post-weld heat treatments are to be submitted for consideration.

1.4 Requirements for manufacture and workmanship

1.4.1 The welding workshops are to be assessed by the Surveyor for their capability to produce work of the required quality in accordance with the requirements specified for the type of construction, *see* Sections 2 to 5.

1.4.2 Where structural components are to be assembled and welded in works sub-contracted by the builder, the Surveyor is to inspect the sub-contractor's works to ensure that compliance with the requirements of this Chapter is achieved.

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1.4.3 The manufacturer is to provide a system of regular supervision of all welding, by suitably qualified and experienced personnel.

1.4.4 Welding is to be performed in covered workshops as far as practicable. Where this is not possible, provision is to be made in the welding area to give adequate protection from wind, rain and cold, etc.

1.4.5 Where required, arrangements are to be such as to permit adequate ventilation and access for preheating, and for the satisfactory completion of all welding operations.

1.4.6 The location of welding connections and sequences of welding are to be arranged to minimise distortion and the build up of residual stresses. Welded joints are to be so arranged as to facilitate the use of downhand welding wherever possible.

1.4.7 In the case of repairs to existing structures or components, care is to be exercised when attaching fit-up aids by welding to ensure that the base materials in way of the attachments are of weldable quality.

1.4.8 In order to prevent cross-contamination of different material types, the welding of carbon steel materials is to be in areas segregated from that used for either austenitic or non-ferrous materials, *see* Section 7.

1.5 Cutting of materials

1.5.1 Materials may be cut to the required dimensions by thermal means, shearing or machining in accordance with the manufacturing drawings or specifications.

1.5.2 Cold shearing is not to be used on materials in excess of 25 mm thick. Where used, the cut edges that are to remain un-welded are to be cut back by machining or grinding for a minimum distance of 3 mm.

1.5.3 Material, which has been thermally cut, is to be free from excessive oxides, scale and notches.

1.5.4 All cut edges are to be examined to ensure freedom from material and/or cutting defects. Visual examination may be supplemented by other techniques.

1.5.5 Thermal cutting of alloy and high carbon steels may require the application of preheat, and special examination of these cut edges will be required to ensure no cracking. In these cases, the cut edge is to be machined or ground back a distance of at least 2 mm, unless it has been demonstrated that the cutting process has not damaged the material.

1.5.6 Any material damaged in the process of cutting is to be removed by machining, grinding or chipping back to sound metal. Weld repair may only be performed with the agreement of the Surveyor.

1.6 Forming and bending

1.6.1 Plates, pipes, etc., may be formed to the required shape by any process which does not impair the quality of the material.

1.6.2 Where hot forming is employed or during cold forming where the material is subjected to a permanent strain exceeding 10 per cent or formed to a diameter to thickness ratio less than 10, tests are required to be performed to demonstrate that the material properties remain acceptable.

1.6.3 As far as practicable, forming is to be performed by the application of steady continuous loading using a machine designed for that purpose. The use of hammering, in either the hot or cold condition is not to be employed.

1.6.4 Material may be welded prior to forming or bending, provided that it can be demonstrated that the weld mechanical properties are not impaired by the forming operation. All welds subjected to bending are to be inspected on completion to ensure freedom from surface breaking defects.

1.7 Assembly and preparation for welding

1.7.1 Excessive force is not to be used in fairing and closing the work. Where excessive root gaps exist between surfaces or edges to be joined, corrective measures are to be adopted.

1.7.2 Provision is to be made for retaining correct alignment during welding operations in accordance with the approved manufacturing specifications and welding procedures.

1.7.3 Tack welds are to be avoided as far as practicable. When used, tack welds are to be of the same quality as the finished welds, made in accordance with approved welding procedures, and where they are to be retained as part of the finished weld, they are to be clean and free from defects.

1.7.4 Generally, tack welds are not to be applied in lengths of less than 30 mm for mild steel grades and aluminium alloys, and 50 mm for higher tensile steel grades. Smaller tack welds may be accepted for steels, provided that the carbon equivalent of the materials being welded is not greater than 0,36 per cent.

1.7.5 Where deep penetration welding is used (*see* 2.4.6), welding procedure tests are to demonstrate that the specified degree of penetration is achieved in way of tack welds left in place.

1.7.6 Where temporary bridge pieces or strong-backs are used, they are to be of similar materials to the base materials and welded in accordance with approved welding procedures.

1.7.7 Any fit-up aids and tack welds, where welded to clad materials, are to be attached to the base material and not to the cladding.

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1.7.8 Surfaces of all parts to be welded, are to be clean, dry and free from rust, grease, debris and other forms of contamination.

1.7.9 When misalignment of structural members either side of bulkheads, decks etc., exceeds the agreed tolerance, the misaligned item is to be released, realigned and re-welded in accordance with an approved procedure.

1.8 Welding equipment and welding consumables

1.8.1 Welding plant and equipment is to be suitable for the purpose intended and properly maintained, taking into account relevant safety precautions.

1.8.2 Suitable means of measuring the welding parameters (i.e. current, voltage and travel speed) are to be available. Electrical meters are to be properly maintained and have current calibrations.

1.8.3 Welding consumables are to be suitable for the type of joint and grade of material to be welded, and in general, are to be LR Approved in accordance with Chapter 11.

1.8.4 Special care is to be taken in the distribution, storage and handling of all welding consumables. They are to be kept in heated dry storage areas with a relatively uniform temperature in accordance with the consumable manufacturer's recommendations. Condensation on the metal surface (e.g., wire electrodes and studs) during storage and use is to be avoided.

1.8.5 Prior to use, welding consumables are to be dried and/or baked in accordance with the consumable manufacturer's recommendations.

1.8.6 Satisfactory storage and handling facilities for consumables are to be provided close to working areas and the condition of welding consumables are to be subject to regular inspections.

1.9 Welding procedure and welder qualifications

1.9.1 Welding procedures are to be developed by the manufacturer for all welding, include weld repairs, and are to be capable of achieving the mechanical property requirements and non-destructive examination quality appropriate to the work being undertaken.

1.9.2 Welding procedures are to be established for the welding of all joints and are to be qualified by testing in accordance with Chapter 12. The welding procedures are to give details of the welding process, type of consumable, joint preparation, welding position and filler metals to be used.

1.9.3 The proposed welding procedures are to be approved by the Surveyor prior to construction.

1.9.4 All welders and welding operators are to be qualified in accordance with the requirements of Chapter 12. Qualification records to demonstrate that welding personnel have the skills to achieve the required standard of workmanship are to be available to the Surveyor.

1.10 Welding during construction

1.10.1 Materials to be assembled for welding are to be retained in position by suitable means such that the root gaps and alignment are in accordance with the approved manufacturing specifications and welding procedures.

1.10.2 Surfaces of all parts to be welded, are to be clean, dry and reasonably free from rust, scale and grease.

1.10.3 Pre-heat is to be applied, as specified in the approved welding procedure, for a distance of at least 75 mm from the joint preparation edges. The method of application and temperature control are to be such as to maintain the required level throughout the welding operation.

1.10.4 When the ambient temperature is 0°C or less, or where moisture resides on the surfaces to be welded, due care is to be taken to pre-heat the joint to a minimum of 20°C, unless a higher pre-heat temperature is specified.

1.10.5 Where tack welds are to be removed from the root of the weld joint, this is to be carried out such that the surrounding material and joint preparation is not damaged.

1.10.6 The welding arc is to be struck on the parent metal which forms part of the weld joint or on previously deposited weld metal.

1.10.7 Where the welding process used is slag forming (e.g., manual metal arc, submerged arc, etc.) each run of deposit is to be cleaned and free from slag before the next run is applied.

1.10.8 Full penetration welds are to be made from both sides of the joint as far as practicable. Prior to welding the second side, the weld root is to be cleaned, in accordance with the requirements of the approved welding procedure, to ensure freedom from defects. When air-arc gouging is used, care is to be taken to ensure that the ensuing groove is slag and oxide free and has a profile suitable for welding.

1.10.9 Where welding from one side only, care is to be exercised to ensure the root gap is in accordance with the approved welding procedure and the root is properly fused.

1.10.10 Particular care is to be exercised in welding in the vertical position with direction of travel downward (Vd) to avoid welding defects. The use of solid wire gas metal arc (GMAW) process in the vertical down position is to be avoided.

1.10.11 Welding is to proceed systematically with each welded joint being completed in correct sequence without undue interruption.

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1.10.12 After welding has been stopped for any reason, care is to be taken in restarting to ensure that the previously deposited weld metal is thoroughly cleaned of slag and debris, and preheat has been re-established.

1.10.13 Care is to be taken to avoid stress concentrations such as sharp corners or abrupt changes of section, and completed welds are to have an even contour, blending smoothly with the base materials. The weld shape and size is to be in accordance with that specified in the approved drawings or specifications.

1.10.14 Welded temporary attachments used to aid construction are to be removed carefully by grinding, cutting or chipping. The surface of the material is to be finished smooth by grinding followed by crack detection.

1.10.15 Where fabricated and welded components require to be machined, all major welding operations are to be completed prior to final machining.

1.10.16 Welding to parts which are subjected to rotating fatigue (e.g., shafts) is not generally permitted.

1.10.17 Welding onto parts that have been hardened for wear resistance or strength (e.g., gear teeth) is not permitted.

1.10.18 Where welding of clad ferritic steel plates is to be undertaken, the clad materials are to be ground back from the prepared edge by at least 10 mm. In general, the ferritic materials are to be welded prior to welding of the cladding material.

1.11 Non-destructive examination of welds

1.11.1 Non-destructive examinations are to be made in accordance with a definitive written procedure prepared and endorsed by a person qualified according to a Nationally Recognised Scheme with a grade equivalent to Level III qualification of ISO 9712, SNT-TC-1A, EN473, or ASNT Central Certification Program (ACCP). As a minimum, the procedure will identify personnel qualification levels, NDE datum and identification system, extent of testing, methods to be applied with technique sheets, acceptance criteria and reporting requirements. These procedures are to be reviewed by the Surveyor. *See* Ch 1,5.

1.11.2 Non-destructive examinations are to be undertaken by personnel qualified according to a Nationally Recognised Scheme with a grade equivalent to Level II qualification of ISO 9712, SNT-TC-1A, EN473 or ASNT Central Certification Program (ACCP). Operators qualified to Level I of the above schemes (or equivalent recognised by LR) may be engaged in testing under the supervision of personnel qualified to Level II or III (or equivalent recognised by LR). Personnel qualifications are to be verified by certification.

1.11.3 Effective arrangements are to be provided by the manufacturer for the inspection of finished welds to ensure that all welding, and where necessary, all post-weld heat treatment, has been satisfactorily completed.

1.11.4 Welds are to be clean and free from paint at the time of visual inspection unless specified otherwise in the following Sections.

1.11.5 The weld surface finish is to ensure accurate and reliable detection of defects. Where the weld surface is irregular or has other features likely to interfere with the interpretation of non-destructive examination, the weld is to be ground or machined.

1.11.6 Prior to inspection, welded temporary attachments and lifting eyes used to aid construction are to be removed carefully by grinding, cutting or chipping or other approved means. The surface of the material is to be finished smooth by grinding followed by crack detection. Any defects caused in the removal process are to be repaired and re-inspected.

1.11.7 For welds in steels with specified yield strength up to 400 N/mm^2, and with carbon equivalent less than or equal to 0,41 per cent, NDE may be performed as soon as the test assembly has cooled to ambient temperature. For other steels, NDE is to be delayed for a period of at least 48 hours after the test assembly has cooled to ambient temperature.

1.11.8 Non-destructive examinations are to be performed in accordance with the requirements of the Rules. Examinations are to be in accordance with agreed written procedures prepared by the manufacturer or ship builder.

1.11.9 The Surveyor may request additional inspections where there is reason to question the quality of workmanship, or where the weld is part of a complicated fabrication where there is high restraint or high residual stresses.

1.11.10 Welds are to be examined after completion of any post-weld heat treatment.

1.11.11 Where weld defects are discovered, the full extent is to be ascertained by applying additional non-destructive examinations where required. Unacceptable defects are to be completely removed and, where necessary, weld repaired in accordance with the relevant Sections of this Chapter. The repairs are to be re-inspected using the same technique as the original inspection.

1.11.12 Results of non-destructive examinations are to be recorded and evaluated by the constructor on a continual basis in order that the quality of welding can be monitored. These records are to be available to the Surveyor.

1.11.13 The constructor is to be responsible for the review, interpretation, evaluation and acceptance of the results of NDE. Reports stating compliance or otherwise with the criteria established in the inspection procedure are to be issued. Reports are to comply, as a minimum, with the requirements of Ch 1,5.

1.11.14 The extent of applied non-destructive examination is to be increased when warranted by the analysis of previous results.

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1.12 Routine weld tests

1.12.1 Routine or production weld tests may be specified as a means of monitoring the quality of the welded joints. This type of quality control test is generally specified for pressure vessel and LNG construction but may be used for other types of welded fabrication.

1.12.2 Routine weld tests may be requested by the Surveyor where there is reason to doubt the quality of workmanship.

1.12.3 Where routine test welds have been agreed, they are to be performed in accordance with the general requirements for the type of construction, *see* Sections 3 and 4.

1.13 Rectification of material defects

1.13.1 Repair of defects found in base materials is not to be carried out without the prior approval of the Surveyor.

1.13.2 In general, surface defects in the material may be removed by grinding, chipping, etc., provided the remaining material thickness is not reduced below the minimum thickness tolerance, and the area is ground to blend in smoothly with the surrounding material.

1.13.3 Confirmation that the defect has been removed is required by performing visual examination, augmented by either magnetic particle or dye penetrant examination techniques.

1.13.4 Surface defects, which cannot be repaired by the above method, may be repaired by welding where permitted by Chapters 3 to 9. Such repairs are to be performed in accordance with the requirements of this Section and those specified in Chapters 3 to 9.

1.13.5 Any defects in the structure resulting from the removal of temporary attachments are to be prepared, efficiently welded and ground smooth so as to achieve a defect free repair.

1.14 Rectification of distortion

1.14.1 Fairing, by linear or spot heating, to correct distortions due to welding, may be carried out. In order to ensure that the properties of the material are not adversely affected, approved procedures are to be utilised. On completion of such processes, visual examination of all heat affected areas in the vicinity is to be carried out to ensure freedom from cracking.

1.14.2 When misalignment of members exceeds the agreed tolerance, the misaligned item is to be cut apart, realigned and re-welded in accordance with an approved procedure.

1.15 Rectification of welds defects

1.15.1 Where repairs are extensive the manufacturer is to investigate the reason for the defects and take the necessary actions to prevent recurrence. In addition, consideration is to be given to the sequence of repairs and to providing temporary supports to prevent misalignment or collapse.

1.15.2 Cracks are to be reported to the Surveyor and the cause established prior to undertaking weld repairs.

1.15.3 Defects may be removed by grinding, chipping or thermal gouging. Where thermal gouging is used, the repair groove is to be subsequently ground clean to remove oxides and debris. The groove is to have a profile suitable for welding.

1.15.4 Prior to commencing repair welding, it is to be confirmed that no defect exists on the prepared surface by performing visual examination, augmented by either magnetic particle or dye penetrant examination techniques.

1.15.5 Repair welding is to be performed using approved welding procedures.

1.15.6 Completed repairs are to be re-examined by the non-destructive examination method(s) that detected the original defect and are to confirm that the original defect has been removed.

1.15.7 Where the component or structure has been subjected to post-weld heat treatment prior to weld repair, this is to be repeated after completion of all repair welding.

1.15.8 Where non-destructive examination reveals that the original defect has not been successfully removed, one more repair attempt may be performed.

1.15.9 The manufacturer is to monitor the quality of welding and maintain records of welding repairs and take the necessary corrective actions where repair rates are outside normal limits.

1.16 Post-weld heat treatment

1.16.1 On completion of welding, post-weld heat treatment may be required depending on the type of welded construction, the material type and thickness as specified by the relevant Parts or Sections of the Rules.

1.16.2 In general, heat treatment after welding is to be a stress relief treatment in order to reduce residual stresses introduced by welding and is generally applicable to ferritic steels. Where other types of heat treatment (e.g., normalising, solution annealing) are proposed, demonstration of acceptable mechanical properties of the weldment are to be confirmed by a welding procedure test which includes a simulated heat treatment.

1.16.3 Parts are to be properly prepared for heat treatment. Machined surfaces (e.g., flange faces, screw threads, etc.) are to be protected against scaling and sufficient temporary supports provided to prevent distortion or collapse of the structure.

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1.16.4 Details of the heat treatment to be applied, soaking time and temperature, heating and cooling rates, etc., are to be submitted for review prior to commencing.

1.16.5 Post-weld heat treatment is to be carried out in a purpose built furnace which is efficiently maintained. In special cases, where the configuration of the component is such that thermal stresses during heating and cooling can be minimised, local post-weld heat treatment may be used. This would not normally apply to the complex geometry of cast materials during manufacture within the foundry environment.

1.16.6 In all cases, the heat treatment facilities and arrangements are to be capable of controlling the temperature throughout the heat treatment cycle and adequate means of measuring and recording the component temperature are to be provided. Thermocouples are to be attached so they are in contact with the component.

1.16.7 Unless specified otherwise, stress relief heat treatment is to be carried out by means of controlled heating from 300°C, to the soak temperature, holding within the prescribed soaking temperature range for the time specified (usually 1 hour per 25 mm of weld thickness) followed by controlled cooling to below 300°C.

1.16.8 Where post-weld stress relief is specified for welded constructions that contain joints between different materials (e.g. ferritic to austenitic steels), the details of the materials, welding procedures and heat treatment cycle to be applied are to be submitted for special consideration and approval.

1.16.9 Non-destructive examination of welds is to be performed after completion of any heat treatment.

1.17 Certification

1.17.1 Products or components are not to be considered complete until all the requirements of the construction specification have been met and all activities have been completed.

1.17.2 Upon completion of the works, the manufacturer is to provide documentation which indicates that:

(a) All welds are complete and there are no outstanding repairs.
(b) The appropriate post-weld heat treatments have been performed.
(c) Appropriate destructive tests have been performed.
(d) Proof testing of welds has been performed.

1.17.3 Before the test certificates or shipping statements are signed by the Surveyor, the manufacturer is required to provide a written declaration stating that the product is in accordance with the requirements of 1.17.2.

Section 2
Specific requirements for ship hull structure and machinery

2.1 Scope

2.1.1 The requirements of this Section apply to the construction of ships, including hull structure, superstructure and deckhouses, components forming part of the ship structure and its machinery (excluding pressure equipment and piping, *see* Section 4). These requirements are in addition to the general welding requirements specified in Section 1.

2.1.2 The shipyard and manufacturer's works are to be assessed to give assurance that they have the facilities, equipment, personnel and quality control procedures to produce work of the required quality.

2.2 Welding consumables

2.2.1 Welding consumables used for hull construction are to be approved in accordance with Chapter 11 and are to be suitable for the type of joint and grade of material to be welded.

2.2.2 Steel welding consumable approvals, up to and including Grade Y40 and Y47, are considered acceptable for hull construction in line with Table 11.1.1 in Chapter 11, Ch 12,2.2.2 and the following:

(a) Consumables up to Grade Y are acceptable for welding steels up to 3 strength levels below that for which the approval applies, e.g., a consumable with approval grading 3Y is acceptable for welding EH36, EH32 and EH27S higher tensile ship steels and grade E normal strength ship steel.
(b) Consumables for Grade Y40 are acceptable for welding steels up to two strength levels below that for which the approval applies. Consumables for Grade Y47 are acceptable for welding steels up to one strength level below that for which the approval applies.
(c) Consumables with an approved impact toughness grading are acceptable for welding steels with lower specified impact properties subject to (a) above, e.g. a consumable with approval grading 3Y is acceptable for welding EH, DH and AH materials.
(d) For welding steels of different grades or different strength levels, the welding consumables may be of a type suitable for the lesser grade or strength being connected. The use of a higher grade of welding consumable may be required at discontinuities or other points of stress concentration.

2.2.3 In general, the use of preheating and hydrogen controlled welding consumables for welding of ship steels up to strength grade H40 is to be in accordance with Table 13.2.1. The carbon equivalent is to be calculated from the ladle analysis using the formula given below:

$$\text{Carbon equivalent} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Nl + Cu}{15}$$

Preheat and the use of low hydrogen controlled consumables will be required for welding of steel grades higher than Grade H40.

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Table 13.2.1 Preheat and consumable requirements for welding of carbon and carbon manganese steels up to strength grade H40

Carbon equivalent C_{eq}	Pre-heat	Hydrogen controlled consumables
C_{eq} equal to or less than 0,41%	Not required	Not required, *see* Note 3
C_{eq} above 0,41 but not exceeding 0,45%	Not required, *see* Notes 1 and 2	Required
C_{eq} greater than 0,45%	Required	Required

NOTES
1. Preheat may need to be applied in order to meet the maximum hardness values specified in Ch 12,2.12.6.
2. Under conditions of high restraint or low ambient temperature preheat may need to be applied.
3. Hydrogen controlled consumables may need to be considered for welding of
   (a) Thicker materials (i.e., > 35 mm).
   (b) Higher strength materials.
   (c) Welds subject to high restraint.

2.2.4 All aluminium alloy welding consumables are to be approved in accordance with Chapter 11 and are suitable for welding the grades of material as shown in Table 13.2.2.

Table 13.2.2 Welding of aluminium alloys – Consumable requirements

Consumable approval grade	Base material alloy grade
RA or WA	5754
RB or WB	5086, 5754
RC or WC	5083, 5086, 5754
RD or WD	6005A, 6061, 6082

2.2.5 All austenitic stainless steel and duplex stainless steel welding consumables are to be approved in accordance with the Chapter 11 and are suitable for welding the grades of material as shown in Table 13.2.3.

2.3 Welding procedure and welder qualifications

2.3.1 Welding procedures and welder qualifications are to be tested and approved in accordance with the requirements of Chapter 12.

2.4 Construction and workmanship

2.4.1 Weld preparations and openings may be formed by thermal cutting, machining or chipping. Chipped surfaces that will not be subsequently covered by weld metal are to be ground smooth.

Table 13.2.3 Welding of austenitic stainless and duplex stainless steels – Consumable requirements

Consumable approval grade	Suitable for welding material alloy grades
Austenitic stainless steels	
321 347	321 347 and 321
Austenitic stainless steel – Low carbon	
304L (*see* Note 3) 304LN (*see* Note 3) 316L 316LN 317L 317LN	304L 304LN and 304L 316L and 304L 316LN, 316L, 304LN and 304L 317L, 316LN, 316L, 304LN and 304L 317LN, 317L, 316LN, 316L, 304LN and 304L
Super austenitic stainless steels, *see* Note 2	
S31254 N08904	S31254 and N08904 N08904
Duplex stainless steels, *see* Note 1	
S31260 S31803 S32550 S32750 S32760	S31260 and S31803 S31803 S32550 S32750 and S32550 S32760, S32550, S31260 and S31803
Stainless steels welded to carbon steels	
SS/CMn Duplex/CMn	Carbon steel to all steels in Sections 1, 2 and 3 Carbon steel to all duplex stainless steel in Section 4

NOTES
1. The use of a different welding consumable grade from that of the base material may require demonstration of acceptable corrosion properties.
2. May be used for welding low carbon austenitic grades provided measures are taken to prevent solidification cracking from occurring.
3. These are LR Grades and do not correspond to any National or International Standards/Grades.

2.4.2 Prior to welding, the alignment of plates and stiffeners forming part of the hull structure is to be in accordance with the tolerances specified in the relevant part of the Rules.

2.4.3 When welding from one side only, care is to be exercised to ensure the root gap and fit up are in accordance with the approved welding procedure and the root is properly fused.

2.4.4 Where it is proposed to use permanent backing strips, the intended locations and welding procedures are to be submitted for consideration.

2.4.5 Temporary backing strips may be used provided they are in accordance with approved welding procedures and are subsequently removed on completion of welding.

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2.4.6 The outer surfaces of completed welds are to blend smoothly with the base materials and provide a smooth transition and gradual change of section.

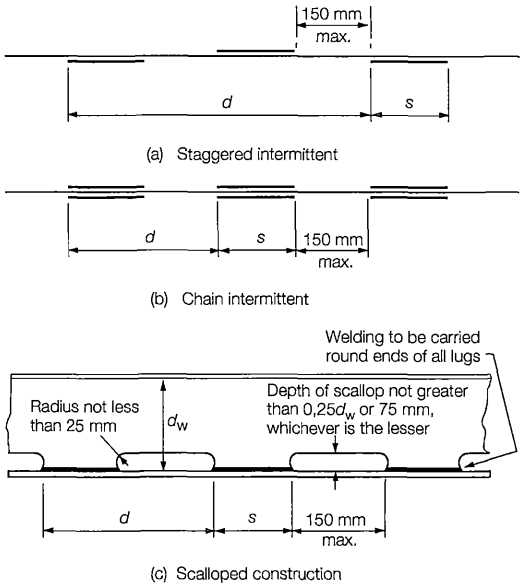
2.4.7 Weld joints in parts of oil engine structures that are stressed by the main gas or inertia loads are to be designed as continuous full penetration welds. They are to be arranged so that welds do not intersect, and that welding can be effected without difficulty.

2.4.8 When modifications or repairs have been made which result in openings having to be closed by welded inserts, particular care is to be given to the fit of the insert and the welding sequence. The welding is also to be subject to non-destructive examination.

2.4.9 Where welding of aluminium alloy is employed, the following additional requirements are to be complied with so far as they are applicable:

(a) Welding is to be performed by fusion welding using inert gas or tungsten inert gas process or by the friction stir welding process. Where it is proposed to use other welding processes, details are to be submitted for approval.

(b) The weld joint surfaces should be scratch brushed, preferably immediately before welding, in order to remove oxide or adhering films of dirt, filings, etc.



NOTE *s* to be not less than 75 mm, in all cases

Fig. 13.2.1 Weld types

2.5 Butt welds

2.5.1 Where the ship hull is constructed of plates of different thicknesses, the thicker plates are to be chamfered in accordance with the approved plans. In all cases the chamfer is not to exceed a slope of 1 in 3 so that the plates are of equal thickness at the weld seam. Alternatively, if so desired, the width of the weld may be included as part of the smooth taper to the thicker plate provided the difference in thickness is not greater than 3 mm.

2.5.2 Where stiffening members are attached by continuous fillet welds and cross completely finished butt or seam welds, these are to be made flush in way of the fillet weld. Similarly for butt welds in webs of stiffening members, the butt weld is to be complete and generally made flush with the stiffening member before the fillet weld is made. Where these conditions cannot be complied with, a scallop is to be arranged in the web of the stiffening member, *see* Fig. 13.2.1. Scallops are to be of such a size and in such a position that a satisfactory weld can be made.

2.6 Lap connections

2.6.1 Overlaps are generally not to be used to connect plates which may be subjected to high tensile or compressive loading and alternative arrangements are to be considered. However, where plate overlaps are adopted, the width of the overlap is not to exceed four times, nor be less than three times the thickness of the thinner plate and the joints are to be positioned to allow adequate access for completion of sound welds. The faying surfaces of lap joints are to be in close contact and both edges of the overlap are to have continuous fillet welds.

2.7 Closing plates

2.7.1 For the connection of plating to internal webs, where access for welding is not practicable, the closing plating is to be attached by continuous full penetration welds or by slot fillet welds to face plates fitted to the webs. Slots are to have a minimum length of 90 mm and a minimum width of twice the plating thickness, with well rounded ends. Slots cut in plating are to be smooth and clean and are to be spaced not more than 230 mm apart, centre to centre. Slots are not to be filled with welding.

2.7.2 For the attachment of rudder shell plating to the internal stiffening of the rudder, slots are to have a minimum length of 75 mm and, in general, a minimum width of twice the side plating thickness. The ends of the slots are to be rounded and the space between them is not to exceed 150 mm.

2.8 Stud welding

2.8.1 Where permanent or temporary studs are to be attached by welding to main structural parts in areas subject to high stress, the proposed location of the studs and the welding procedures adopted are to be approved.

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2.9 Fillet welds

2.9.1 T-connections are generally to be made by fillet welds on both sides of the abutting plate, the dimensions and spacing of which are shown in Fig. 13.2.1. Where the connection is highly stressed, deep penetration or full penetration welding may be required. Where full penetration welding is required, the abutting plate may be required to be bevelled.

2.9.2 Where an approved deep penetration procedure is used, the fillet leg length calculated may be reduced by 15 per cent provided that the manufacturer is able to meet the following requirements:

(a) Use of a welding consumable approved for deep penetration welding in accordance with Chapter 11 for either the 'p' or 'T' techniques.

(b) Demonstrations by way of production weld testing that the minimum required penetration depths (i.e., throat thicknesses) are maintained. This is to be documented on a monthly basis by the manufacturer and be available to the Surveyor.

2.9.3 The calculated fillet leg length may be reduced by 20 per cent, provided that in addition to the requirements of 2.9.2(a) and (b), the manufacturer is able to consistently meet the following additional requirements:

(a) The documentation required in 2.9.2(b) is to be completed and made available to the Surveyor upon request on a weekly basis.

(b) Suitable process selection confirmed by satisfactory welding procedure tests covering both minimum and maximum root gaps.

2.9.4 Where intermittent welding is used, the welding is to be made continuous in way of brackets, lugs and scallops and at orthogonal connections with other members.

2.10 Post-weld heat treatment

2.10.1 Post-weld stress relief heat treatment is applied to improve the fatigue performance or to improve resistance to brittle fracture and is generally required for carbon and carbon-manganese and low alloy steels under any of the following conditions:

(a) Where the material thickness exceeds 65 mm.

(b) For complicated weld joints where there are high stress concentrations.

(c) Where fatigue loads are considered high.

2.10.2 Post-weld heat treatment is to be applied to the following types of welded construction:

(a) Welding of steel castings where the thickness of the casting at the weld exceeds 30 mm, except where castings are directly welded to the hull structure.

(b) Oil engine bedplates except engine types where the bedplate as a whole is not subjected to direct loading from the cylinder pressure. For these types, only the transverse girder assemblies need to be stress relieved.

(c) Welding of gear wheels.

(d) Welding of gear cases associated with main or auxiliary engines, *see* Part 5 of the Rules for Ships.

2.10.3 Where required, heat treatment is to be performed in accordance with the requirements specified in 4.6 for pressure vessel construction.

2.10.4 Special consideration may be given to omit the required post-weld heat treatment. Evaluation is to be based on critical engineering assessment involving fracture mechanics testing and proposals are to be submitted which include full details of the application, materials, welding procedures, inspection procedures, design stresses, fatigue loads and cycles. Evidence will be required to demonstrate that the inspection techniques and procedures to be employed are able to detect flaws down to the sizes determined from the fracture mechanics (and or fatigue) calculations.

2.11 Tolerances

2.11.1 Tolerances after welding are to be in accordance with the relevant Part of the Rules.

2.11.2 Distortion which has resulted from welding may be corrected by spot heating in accordance with 1.14.

2.12 Non-destructive examination of welds

2.12.1 All finished welds are to be sound and free from cracks and substantially free from lack of fusion, incomplete penetration, porosity and slag. The surfaces of welds are to be reasonably smooth and substantially free from undercut and overlap. Care is to be taken to ensure that the specified dimensions of welds have been achieved and that both excessive reinforcement and under-fill of welds is avoided.

2.12.2 Welds forming part of the hull and superstructure may be coated with a thin layer of protective primer prior to inspection provided it does not interfere with inspection and is removed, if required by the Surveyor, for closer interpretation of possible defective areas.

2.12.3 All welds are to be visually inspected by personnel designated by the builder. Visual inspection of all welds may be supplemented by other non-destructive examination techniques in cases of unclear interpretation, as considered necessary. The acceptance criteria for visual testing are given in Table 13.2.4.

2.12.4 In addition to visual inspection, welded joints are to be examined using any one or a combination of ultrasonic, radiographic, magnetic particle, eddy current, dye penetrant or other acceptable methods appropriate to the configuration of the weld.

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Table 13.2.4 Acceptance criteria for visual testing, magnetic particle and liquid penetrant testing

Surface discontinuity	Classification according to ISO 6520-1	Acceptance criteria for visual testing
Crack	100	Not accepted
Lack of fusion	401	Not accepted
Incomplete root penetration in butt joints welded from one side	4021	Not accepted
Surface pore	2017	Single pore diameter $d \leq 0{,}25t$, for butt welds, with maximum diameter 3 mm, *see* Note 1 $d \leq 0{,}25a$, for fillet welds, with maximum diameter 3 mm, *see* Note 1 $2{,}5d$ as minimum distance to adjacent pore
Undercut in butt welds	501	Depth ≤ 0,5 mm, whatever the length Depth ≤ 0,8 mm, with a maximum continuous length of 90 mm, *see* Note 2
Undercut in fillet welds	501	Depth ≤ 0,8 mm, whatever the length

NOTES
1. t is the plate thickness of the thinnest plate, and a is the throat of the fillet weld.
2. Adjacent undercuts separated by a distance shorter than the shortest undercut are to be regarded as a single continuous undercut.

2.12.5 The method to be used for the volumetric examinations of welds is the responsibility of the builder. Radiography is generally preferred for the examination of butt welds of 8 mm thickness or less. Ultrasonic testing is acceptable for welds of 8 mm thickness or greater and is to be used for the examination of full penetration tee butt or cruciform welds or joints of similar configuration. Advanced ultrasonic techniques, such as Phased Array Ultrasonic Testing (PAUT), may be used as a volumetric testing method in lieu of radiography or manual ultrasonic testing. If these methods are used, the thickness limitations for manual ultrasonic testing apply.

2.12.6 The acceptance criteria for radiographic testing are given in Table 13.2.5, and those for ultrasonic testing in Table 13.2.6.

2.12.7 Checkpoints examined at the pre-assembly stage are to include ultrasonic testing on examples of the stop/start points of automatic welding and magnetic particle inspection of weld ends.

2.12.8 Checkpoints examined at the assembly stage are generally to be selected from those welds intended to be examined as part of the agreed quality control programme to be applied by the builder. The locations and number of checkpoints are to be approved by the Surveyor.

2.12.9 Where components of the structure are subcontracted for fabrication, the same inspection regime is to be applied as if the item had been constructed within the main contractor's works. In these cases, particular attention is to be given to highly loaded fabrications (such as stabiliser fin boxes) forming an integral part of the hull envelope.

2.12.10 Particular attention is to be paid to highly stressed items. Magnetic particle inspection is to be used at ends of fillet welds, T-joints, joints or crossings in main structural members and at stern frame connections.

2.12.11 Special attention is to be given to the examination of plating in way of lifting eye plate positions to ensure freedom from cracks. This examination is not restricted to the positions where eye plates have been removed, but includes the positions where lifting eye plates are permanent fixtures.

2.12.12 Checkpoints for volumetric examination are to be selected so that a representative sample of welding is examined.

2.12.13 Typical locations for volumetric examination and number of checkpoints to be taken are given in the relevant Sections of the Rules. A list of the proposed items to be examined is to be submitted for approval.

2.12.14 For the hull structure of refrigerated spaces, and of ships designed to operate in low air temperatures, the extent of non-destructive examination will be specially considered. For non-destructive examination of gas ships *see* the *Rules for the carriage for Liquefied Gases*.

2.12.15 For all ship types, the builder is to carry out random non-destructive examination at the request of the Surveyor.

2.12.16 Results of non-destructive examinations made during construction are to be recorded and evaluated by the builder on a continual basis in order that the quality of welding can be monitored. These records are to be available to the Surveyor.

2.12.17 The extent of applied non-destructive examinations is to be increased when warranted by the analysis of previous results.

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Table 13.2.5 Acceptance criteria for radiographic testing

Discontinuity	Classification according to ISO 6520-1	Acceptance criteria for radiographic testing, *see* Note 1
Crack	100	Not accepted
Lack of fusion	401	Continuous maximum length $t/2$ or 25 mm, whichever is the less, *see* Note 2 Intermittent cumulative length maximum t or 50 mm, whichever is less, *see* Note 3
Lack of root fusion	4013	Not accepted in butt joints welded from one side
Incomplete root penetration	4021	Not accepted in butt joints welded from one side
		Continuous maximum length $t/2$ or 25 mm, whichever is lesser, *see* Note 2 Intermittent cumulative maximum length t or 50 mm, whichever is less, *see* Note 3
Slag inclusion	301	Continuous maximum length t or 50 mm, whichever is less, *see* Note 2 Intermittent cumulative length maximum $2t$ or 100 mm, whichever is less, *see* Notes 3 and 4
Gas pore	2011	Maximum dimension for a single pore: $d \leq 0{,}2t$, max. 4,0 mm *see* Note 5
Uniformly distributed porosity	2012	Maximum dimension of the area of imperfections: For single run welds: ≤ 1,5% For multi-run welds: ≤ 3% *See* Notes 6 and 7
Clustered (localised) porosity	2013	Maximum dimension of the summation of the projected area of the imperfection: ≤ 8% *See* Notes 6 and 7
Elongated cavity	2015	$h \leq 0{,}3t$, max. 3,0 mm $l \leq t$, max. 50 mm *See* Notes 8 and 9
Wormholes	2016	$h \leq 0{,}3t$, max. 3,0 mm $l \leq t$, max. 50 mm *See* Notes 8 and 9
Metallic inclusions other than copper	304	$h \leq 0{,}3t$, max. 3,0 mm *See* Note 8
Copper inclusions	3042	Not permitted

NOTES
1. t is the thickness of the thinnest plate.
2. Two adjacent individual discontinuities of length l_d1 and l_d2 situated on a line and where the distance l_d between them is shorter than the shortest discontinuity are to be regarded as a continuous discontinuity of length $l_d1 + l_d + l_d2$.
3. Sum of the length of individual continuous discontinuities.
4. Parallel inclusions not separated by more than 3 times the width of the largest inclusion are to be regarded as one continuous discontinuity.
5. d is the diameter of the gas pore.
6. The limits for the maximum single gas pore within this group still apply.
7. Further reference to porosity limits may be obtained in ISO 5817:2007.
8. h is the width of the imperfection.
9. l is the length of the imperfection.

2.13 Weld repairs

2.13.1 The full extent of any weld defect is to be ascertained by applying additional non-destructive examination where required. Unacceptable defects are to be completely removed and, where necessary, re-welded and re-examined in accordance with the requirements of 1.15.

2.13.2 During the assembly of large components, root gaps in excess of those specified in the approved welding procedure may be rectified by welding.

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Table 13.2.6 Acceptance criteria for ultrasonic testing

Echo height	Acceptance criteria for ultrasonic testing, *see* Note
Greater than 100% of DAC curve	Maximum length *t*/2 or 25 mm, whichever is less
Greater than 50% of DAC curve, but less than 100% of DAC curve	Maximum length *t* or 50 mm, whichever is less
Indications evaluated to be cracks are unacceptable regardless of echo height; Indications evaluated to be lack of penetration or lack of root fusion in joints welded from one side are unacceptable regardless of echo height.	
NOTE Two adjacent individual discontinuities of length L1 and L2 situated on a line and where the distance L between them is shorter than the shortest discontinuity are to be regarded as a continuous discontinuity of length L1 + L + L2.	

2.13.3 Rectification of wide root gaps in butt welds, up to a maximum gap of 16 mm, may be performed provided that the length of these areas is small in relation to the whole weld length. Repairs may be executed by applying weld buttering layers to one edge of the weld joint, followed by machining or grinding to return the root opening to the required dimensions. The weld buttering and filling of the joint are to be in accordance with welding procedures qualified in accordance with Chapter 12.

2.13.4 For sub-assemblies, rectification of wide root gaps may be performed using a backing strip, provided that it is removed on completion of the welding.

2.13.5 Rectification of wide root gaps in fillet welds may be carried out as follows:

(a) where the root gap, *g*, is in excess of 3 mm, but not greater than 5 mm, the fillet leg length, *z*, may be increased by *g* – 2,0 mm;

(b) where the root gap is in excess of 5 mm, the joint detail may be changed into a full penetration weld.

2.13.6 Where repair welds are made using small weld beads, suitable precautions (including preheat) are to be taken to avoid high hardness and possible cold cracking.

2.14 Welding afloat with water backing

2.14.1 Welding afloat with water backing is not recommended due to the additional precautions required during survey and therefore, is generally not permitted. However consideration may be given to welding afloat with water backing after specific LR approval has been obtained by the yard or fabricator prior to such welding being carried out. Such approval will only be given once all of the following conditions are satisfied:

(a) The welding procedure qualification tests are carried out on steel plates with water backing and the water is maintained at the flow rate and minimum water temperature anticipated during fabrication.

(b) The carbon equivalent of the steel plates used in the welding procedure qualification tests are to be greater than 0,41 per cent based on the IIW formula. Where it can be shown that all hull steel plates and new sections will have a carbon equivalent value below this figure, steel plates with the maximum carbon equivalent value may be used for the welding procedure qualification tests.

(c) Welding procedure qualification tests are carried out without preheat.

(d) The thickness of steel plate used in the welding procedure qualification test is the minimum hull plate thickness to be used during fabrication.

(e) The maximum measured hardness on the completed welding procedure qualification assembly is less than or equal to 350 HV10. Following fabrication welding, 10 per cent of welds are to be hardness tested in way of heat-affected zones at weld starts to confirm compliance with the 350 HV10 limit.

(f) The heat input used in the welding qualification test is the minimum permitted heat input during fabrication.

(g) Only low hydrogen welding consumables (H5) are used.

(h) In addition to normal non-destructive testing for welds, 10 per cent of the welds are additionally subject to magnetic particle inspection 48 hours after welding is complete.

(j) The welding procedure qualification tests for the repair of welds carried out afloat with water backing are to be carried out on test pieces that have previously been welded afloat and also meet the requirements above.

2.14.2 Welding in, or underwater, is not permitted.

■ *Section 3* Specific requirements for fabricated steel sections

3.1 Scope

3.1.1 Fabricated steel sections are items used in place of rolled sections and as such will not be regarded as sub-assemblies. Products regarded as sub-assemblies are subject to requirements of welded construction specified in Section 2.

3.1.2 The requirements for structural steel sections are based on these being manufactured from flat products by automatic welding and intended for use in the construction of ships and other marine structures.

3.1.3 Fabricated steel sections are to be manufactured in accordance with the requirements of this Section and the general requirements of Section 1.

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3.1.4 In all cases, sections are to be manufactured at works, which have been assessed and approved in accordance with *Materials and Qualification Procedures for Ships, Book J, MQPS Procedure 12-1*.

3.2 Dimensions and tolerances

3.2.1 Products are to conform dimensionally to the provisions of an acceptable National or International Standard.

3.2.2 The minimum throat thickness of fillet welds is to be determined from:

Throat thickness = 0,34t but not to be taken as less than 3 mm

where

t = plate thickness of the thinner member to be joined (generally the web).

3.2.3 Where a welding procedure using deep penetration welding is used (*see* Chapter 11, 'p' and 'T' welding techniques) the minimum leg length required will be specially considered provided the requirements of 2.9.2 are complied with.

3.2.4 Unless agreed otherwise, the leg length of the weld is to be not less than 1,4 times the specified throat thickness.

3.3 Identification of products

3.3.1 Every finished item is to be clearly marked by the manufacturer in at least one place with the following particulars:

(a) The manufacturer's name or trade mark.
(b) Identification mark for the grade of steel.
(c) Identification number and/or initials which will enable the full history of the item to be traced.
(d) Where required by the purchaser, the order number or other identification mark.
(e) The letters 'LR'.
(f) The Surveyor's personal stamp.

The above particulars, but excluding the manufacturer's name or trade mark where this is embossed on finished products, are to be encircled with paint or otherwise marked so as to be easily recognisable.

3.3.2 In the event of any material bearing LR's brand failing to comply with the test requirements, the brand is to be removed or unmistakably defaced, *see also* Ch 1,4.7.

3.4 Manufacture and workmanship

3.4.1 For cut edges that are to remain unwelded, it is to be demonstrated that the plate preparation procedures used are able to achieve edges that are free from cracks or other deleterious imperfections.

3.4.2 Where assembly jigs and devices are used to bring the web into contact with the flanges and hold these in place during welding, means are to be provided to ensure that the degree of contact is maintained until welding is complete.

3.4.3 Welding procedures are to be established for the welding of all joints including weld repairs and are to be approved in accordance with Chapter 12. Welders are to be approved in accordance with Chapter 12, and qualification records are to be available to the Surveyor.

3.4.4 The welding consumables used are to be approved in accordance with Chapter 11 and are to be suitable for the type of joint and grade of steel as described in 2.2. For joining steel of different tensile strengths, the consumables are to be suitable for the tensile strength of the component considered in the determination of weld size.

3.4.5 The application of pre-heat and the use of low hydrogen welding consumables are to be in accordance with the requirements of 2.2.

3.4.6 Welding is to be double continuous fillet welding or full penetration welding as specified in the approved plans.

3.4.7 Where deep penetration welding is used, the requirements of 2.9.2 are to be complied with.

3.5 Non-destructive examination

3.5.1 Surface inspection and verification of dimensions are the responsibility of the manufacturer and are to be carried out on all materials prior to despatch. Acceptance by the Surveyor of material later found to be defective does not absolve the manufacturer from this responsibility.

3.5.2 The Surveyor will carry out checks to ensure that the weld size and profile are in accordance with the manufacturing specification and the manufacturer's Quality Control Procedures.

3.5.3 The manufacturer is to examine the welds by magnetic particle or dye penetrant methods. The length examined is to be 200 mm at each end, for each length cut for delivery.

3.5.4 If cracks are revealed, these are to be reported to the Surveyor and the whole of the length is to be examined by magnetic particle or dye penetrant methods. Corrective action in respect of the manufacturing process, and repairs are to be as indicated in the manufacturers' Quality Control Manual.

3.5.5 The weld defect is not to exceed the acceptance levels given in Table 13.2.4.

3.6 Routine weld tests

3.6.1 One production batch test is required for every 500 m of fabricated section manufactured, or fraction thereof. From each batch test, two samples are to be removed, one from near the beginning of the production run and one from near the end. From each of these test samples one macro specimen and one fracture test specimen are to be taken.

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3.6.2 The macro specimens are to be prepared and etched to demonstrate freedom from unacceptable defects and that the weld penetration is in accordance with the manufacturing specification. The fracture specimens are to be broken, one for each side of the fillet weld, and the fractured surfaces examined for compliance with the requirements of Table 13.2.5.

3.6.3 Where the welding procedure used has employed the deep penetration technique, the amount of root penetration is to be measured on the macro specimen and is not to be less than that demonstrated during welding procedure approval testing.

3.6.4 For the purposes of this Section, a batch is to consist of products of only one size and grade of material.

3.7 Certification and records

3.7.1 Each test certificate is to include the following particulars:

(a) Purchaser's name and order number.
(b) Where known, the contract number for which the material is intended.
(c) Address to which material is despatched.
(d) Description and dimensions of the product.
(e) Specification or grade of the steel.
(f) Identification number and/or initials.
(g) Cast number and chemical composition of ladle samples of constituent plates.
(h) Mechanical test results of constituent plates.
(j) Condition of supply when other than as-rolled.
(k) Make and brand of welding consumables.

3.7.2 Test certificates or shipping statements may be signed by the Surveyor, provided the documentation requirements of 1.17 are satisfied. The following form of declaration will be accepted if stamped or printed on each test certificate or shipping statement with the name of the works and signed by an authorised representative of the manufacturer:

'We hereby certify that the material has been made by an approved procedure in accordance with the Lloyd's Register's Rules for Materials'.

3.7.3 The manufacturer is to maintain records by which sources of material can be identified together with the results of all inspections and tests.

■ *Section 4*
Specific requirements for fusion welded pressure vessels

4.1 Scope

4.1.1 The requirements of this Section apply to fusion welded pressure vessels and process equipment, heating and steam raising boilers, and steam or gas turbine rotors and cylinders and are in addition to those requirements referred to in Section 1.

4.1.2 The allocation of pressure vessel Class is determined from the design criteria in Pt 5, Ch 10 and 11 of the Rules for Ships. Prior to commencing construction, the design of the vessel is to be approved. Construction requirements for turbine rotors and cylinders are to be in accordance with Class 2/1, unless a higher Class is specified in the approved plans.

4.1.3 Pressure vessels will be accepted only if manufactured by firms equipped and competent to undertake the quality of welding work required for the Class of vessel proposed. The manufacturer's works are to be approved in accordance with the requirements specified in *Materials and Qualification Procedures for Ships, Book A, Procedure MQPS 0-4*.

4.1.4 The term 'fusion weld', for the purpose of these requirements, is applicable to welded joints made by manual, semi-automatic, or automatic electric arc welding processes. Special consideration will be given to the proposed use of other fusion welding processes.

4.2 Cutting and forming of shells and heads

4.2.1 Cut or chipped surfaces which will not be subsequently covered by weld metal are to be ground smooth.

4.2.2 Shell plates and heads are to be formed to the correct contour up to the extreme edge of the plate.

4.2.3 Vessels manufactured from carbon or carbon manganese steel plates (*see* Table 3.4.1 in Chapter 3, grades 360AR to 510FG), which have been hot formed or locally heated for forming, are to be re-heat treated in accordance with the original supplied condition on completion of this operation. Vessels formed from plates supplied in the as-rolled condition are to be heat treated in accordance with the material manufacturer's recommendations.

4.2.4 Subsequent heat treatment will not be required where steels are supplied in the as-rolled, normalised or normalised and controlled rolled condition, or hot forming is carried out entirely at a temperature within the normalising range.

4.2.5 For alloy steel vessels where hot forming is employed (*see* Table 3.4.1 in Chapter 3, 13Cr Mo 45, etc.), the plates are to be heat treated on completion in accordance with the material manufacturer's recommendations.

4.2.6 Where plates are cold formed, subsequent heat treatment is to be performed where the internal radius is less than 10 times the plate thickness. For carbon and carbon-manganese steels this heat treatment may be a stress relief heat treatment.

4.2.7 In all cases where hot forming is employed, and for cold forming to a radius less than 10 times the thickness, the manufacturer is required to demonstrate that the forming process and subsequent heat treatments result in acceptable properties.

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4.3 Fitting of shell plates and attachments

4.3.1 The location of welded joints is to be such as to avoid intersecting butt welds in the vessel shell plates. The attachment of nozzles and openings in the vessels are to be arranged to avoid main shell weld seams.

4.3.2 The surfaces of the plates at the longitudinal or circumferential seams are not to be out of alignment with each other, at any point, by more than 10 per cent of the plate thickness. In no case is the misalignment to exceed 3 mm for longitudinal seams, or 4 mm for circumferential seams.

4.3.3 Where a vessel is constructed of plates of different thicknesses (tube plate and wrapper plate), the plates are to be so arranged that their centrelines form a continuous circle.

4.3.4 For longitudinal seams, the thicker plate is to be equally chamfered inside and outside by machining over a circumferential distance not less than twice the difference in thickness, so that the plates are of equal thickness at the longitudinal weld seam. For the circumferential seam, the thickest plate is to be similarly prepared over the same distance longitudinally.

4.3.5 For the circumferential seam, where the difference in the thickness is the same throughout the circumference, the thicker plate is to be reduced in thickness by machining to a taper for a distance not less than four times the offset, so that the two plates are of equal thickness at the weld joint. A parallel portion may be provided between the end of the taper and the weld edge preparation; alternatively, if so desired, the width of the weld may be included as part of the smooth taper to the thicker plate.

4.3.6 All attachments (lugs, brackets, reinforcing plates, etc.) are to conform to the shape of the surface to which they are attached.

4.4 Welding

4.4.1 Welding procedures are to be established for all welds joining pressure containing parts and for welds made directly onto pressure containing parts. Welding procedures are to be based on qualification tests performed in accordance with Chapter 12.

4.4.2 In all cases where tack welds, in the root of the weld seam, are used to retain plates or parts in position prior to welding, they are to be removed in the process of welding the seam.

4.4.3 Steel backing strips may be used for the circumferential seams of Class 2/1, Class 2/2 and Class 3 pressure vessels and are to be the same nominal composition as the plates to be welded.

4.4.4 Fillet welds are to be made to ensure proper fusion and penetration at the root of the fillet. At least two layers of weld metal are to be deposited at each weld affixing branch pipes, flanges and seatings.

4.4.5 The outer surface of completed welds is to be at least flush with the surface of the plates joined, and any weld reinforcement is to provide a smooth transition and gradual change of section with the plate surface.

4.4.6 Where attachment of lugs, brackets, branches, manhole frames, reinforcement plates and other members are to be made to the main pressure shell by welding, this is to be to the same standard as required for the main vessel shell construction.

4.4.7 The main weld seams and all welded attachments made to pressure containing parts are to be completed prior to post weld heat treatment.

4.4.8 The finish of welds attaching pressure parts and non-pressure parts to the main pressure shell is to be such as to allow satisfactory examination of the welds. In the case of Class 1 and Class 2/1 pressure vessels, these welds are to be ground smooth, if necessary, to provide a suitable finish for examination.

4.5 General requirements for routine weld production tests

4.5.1 Routine weld production tests are specified as a means of monitoring the quality of the welded joints and are required for pressure vessel Classes 1, 2/1 and 2/2.

4.5.2 Routine production test plates are required during the manufacture of vessels and as part of the initial approval test programme for Class 1 vessel manufacturers, refer to MQPS 0-4.

4.5.3 Routine production weld tests are not required for Class 3 pressure vessels unless there are doubts about the weld quality where check tests may be requested by the Surveyor.

4.5.4 Routine production test plates are not required for circumferential seams of cylindrical pressure vessels. Spherical vessels are to have one test plate prepared having a welded joint which is a simulation of the circumferential seams.

4.5.5 Routine production weld tests may be requested by the Surveyor where there is reason to doubt the quality of workmanship.

4.6 Production test plate assembly requirements

4.6.1 Two test plates and one complete test assembly, of sufficient dimensions to provide all the required mechanical test specimens is to be prepared for each vessel and is to be welded as a continuation and simulation of the longitudinal weld joint.

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4.6.2 For Class 2/2 vessels, where a large number are made concurrently at the same works using the same welding procedure and the plate thicknesses do not vary by more than 5 mm, one test may be performed for each 37 m of longitudinal plus circumferential weld seam. In these cases the thickness of the test plate is to be equal to the thickest shell plate used in the construction.

4.6.3 Where the vessel size or design results in a small number of longitudinal weld seams, one test assembly may be prepared for testing provided that the welding details are the same for each seam.

4.6.4 Test plate materials are to be the same grade, thickness and supply condition and from the same cast as that of the vessel shell. The test assembly is to be welded at the same time as the vessel weld to which it relates and is to be supported so that distortion during welding is minimised.

4.6.5 As far as practicable, welding is to be performed by different welders where there is a requirement for several routine tests to be welded.

4.6.6 The test assembly may be detached from the vessel weld only after the Surveyor has performed a visual examination and has added his mark or stamp. Straightening of test welds prior to mechanical testing is not permitted.

4.6.7 Where the pressure vessel is required to be subjected to post-weld heat treatment, the test weld is to be heat treated, after welding, in accordance with the same requirements. This may be performed separately from the vessel.

4.7 Inspection and testing

4.7.1 The test weld is to be subjected to the same type of non-destructive examination and acceptance criteria as specified for the weld seam to which the test relates. Non-destructive examination is to be performed prior to removing specimens for mechanical testing, but after any post-weld heat treatment.

4.7.2 The test weld is to be sectioned to remove the number and type of test specimens for mechanical testing as given in 4.8.

4.8 Mechanical requirements

4.8.1 The routine production test assembly is to be machined to provide the following test specimens:

(a) Tensile.
(b) Bend.
(c) Hardness.
(d) Impact (*see* Table 13.4.1).
(e) Macrograph and hardness survey of full weld section.

4.8.2 One set of specimens for mechanical testing are to be removed, as shown in Figs. 13.4.1 or 13.4.2 as appropriate for the Class of approval. Impact tests are to be removed and tested where required by Table 13.4.1.

4.8.3 **Longitudinal tensile test for weld metal.** An all-weld metal longitudinal tensile test is required. For thicknesses in excess of 20 mm, where more than one welding process or type of consumable has been used to complete the joint, additional longitudinal tests are required from the respective area of the weld. This does not apply to the welding process or consumables used solely to deposit the root weld. Specimens are to be tested in accordance with the following requirements:

(a) The diameter and gauge length of the test specimen is to be in accordance with Ch 11,2.1.1.
(b) For carbon and carbon-manganese steels the tensile strength of the weld metal is to be not less than the minimum specified for the plate material and not more than 145 N/mm^2 above this value. The percentage elongation, A, is to be not less than that given by:

A = (980-R)/21,6 but not less than 80 per cent of the minimum elongation specified for the plate

where

R is the tensile strength, in N/mm^2, obtained from the all weld metal tensile tests.

(c) For other materials the tensile strength and percentage elongation is not to be less than that specified for the base materials welded.

4.8.4 **Transverse tensile test for joint.** Transverse tensile test specimens are to be removed and tested in accordance with the following requirements:

(a) One reduced section tensile test specimen is to be cut transversely to the weld to the dimensions shown in Ch 11,2.1.1 and the weld reinforcement is to be removed.

Table 13.4.1 Impact test requirements

Pressure vessel Class	Minimum design temperature	Plate material thickness t	Impact test temperature
Class 1 *see* Note	–10°C or above	All	5°C below the minimum design temperature or 20°C, whichever is the lower
All Classes	Below –10°C	$t \leq 20$ mm	5°C below the minimum design temperature
		20 mm $< t \leq 40$ mm	10°C below the minimum design temperature
		Over 40 mm	Subject to special consideration
NOTE Impact testing is not required for Classes 2/1, 2/2 and 3.			

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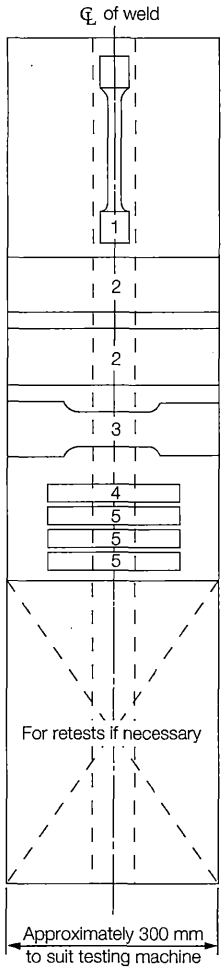
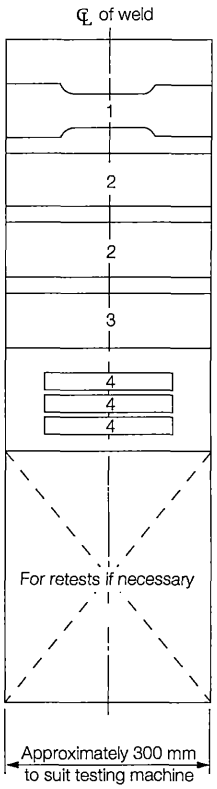


1. All weld metal tensile test specimen.
2. Bend test specimens.
3. Tensile test for joints.
4. Macro-test specimen.
5. Charpy V-notch impact.
(For all Class 1 pressure vessels and other Classes of pressure vessels where the minimum design temperature is below –10°C).

Fig. 13.4.1
Routine weld test – Test specimens for Class 1 and Class 2/1

(b) In general, where the plate thickness exceeds 30 mm, or where the capacity of the tensile test machine prevents full thickness tests, each tensile test may be made up of several reduced section specimens, provided that the whole thickness of the weld is subjected to testing.

(c) The tensile strength obtained is to be not less than the minimum specified tensile strength for the plate material, and the location of the fracture is to be reported.



1. Tensile test for joints.
2. Bend test specimens.
3. Nicked bend test specimen.
4. Charpy V-notch impact test specimens (if required by Table 13.4.1).

Fig. 13.4.2
Routine weld tests – Test specimens for Class 2/2 and Class 3

4.8.5 **Transverse bend test.** The bend test specimens are to be removed and tested in accordance with the following requirements:

(a) Two bend test specimens of rectangular section are to be cut transversely to the weld, one bent with the outer surface of the weld in tension (face bend), and the other with the inner surface in tension (root bend).

(b) The specimen dimensions are to be in accordance with Chapter 2.

(c) Each specimen is to be mounted on roller supports with the centre of the weld midway between the supports. The former is to have a diameter specified in Ch 12,2.7.6 depending on the material being welded.

(d) After bending through an angle of at least 180° there is to be no crack or defect exceeding 1,5 mm measured across the specimen or 3 mm measured along the specimen. Premature failure at the edges of the specimen is not to be cause for rejection, unless this is associated with a weld defect.

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4.8.6 **Macro-specimen and hardness survey**. A macro examination specimen is to be removed from the test assembly near the end where welding started. The specimen is to include the complete cross-section of the weld and the heat affected zone. The specimen is to be prepared and examined in accordance with the following requirements:

(a) The cross-section of the specimen is to be ground, polished and etched to clearly reveal the weld runs, and the heat affected zones.

(b) The specimen is to show an even weld profile that blends smoothly with the base material and have satisfactory penetration and fusion, and an absence of significant inclusions or other defects.

(c) Where there is doubt in the condition of the weld as shown by macro-etching, the area concerned is to be microscopically examined.

(d) For carbon, carbon manganese and low alloy steels, a Vickers hardness survey is to be performed on the macro-specimen using either a 5 kg or 10 kg load. Testing is to include the base material, the weld and the heat affected zone. Hardness scans on the cross-section are to be performed as specified in Fig. 12.2.8 in Chapter 12. The maximum recorded hardness is to not exceed 350 Hv.

4.8.7 **Charpy V-notch impact test**. Charpy V notch impact test specimens are to be prepared and tested as required by Table 13.4.1 and in accordance with the following requirements:

(a) The dimensions and tolerances of the specimens are to be in accordance with Chapter 2.

(b) Charpy V-notch impact specimens and are to be removed with the notch perpendicular to the plate surface.

(c) Specimens are to be removed for testing from the weld centreline and the heat affected zone (fusion line and fusion line + 2 mm locations) detailed in Fig. 12.2.6 or Fig. 12.2.7 in Chapter 12, as appropriate. Heat affected zone impact tests may be omitted where the minimum design temperature is above +20°C.

(d) For thicknesses in excess of 20 mm, where more than one welding process or type of consumable has been used to complete the joint, impact tests are required from the respective areas of the weld. This does not apply to the welding process or consumables used solely to deposit the root weld.

(e) The average energy of a set of three specimens is not to be less than 27 J or the minimum specified for the base material, whichever is the higher. The minimum energy for each individual specimen is to meet the requirements of Ch 1,4.5.2.

4.8.8 **Nick break bend tests**. A nick bend or fracture test specimen is to be a minimum of 100 mm long measured along the weld direction and is to be tested in accordance with and meet the requirements of the following:

(a) The specimen is to have a slot cut into each side along the centreline of the weld and perpendicular to the plate surface.

(b) The specimen is to be bent along the weld centreline until fracture occurs and the fracture faces are to be examined for defects. The weld is to be sound, with no evidence of cracking or lack of fusion or penetration and be substantially free from slag inclusions and porosity.

4.9 Failure to meet requirements

4.9.1 Where any test specimen fails to meet the requirements, additional specimens may be removed and re-tested in accordance with Ch 2,1.4.

4.9.2 Where a routine weld test fails to meet requirements, the welds to which it relates will be considered as not having met the requirements. The reason for the failure is to be established, and the manufacturer is to take such steps as necessary to either

(a) Remove the affected welds and have them re-welded, or

(b) Demonstrate that the affected production welds have acceptable properties.

4.10 Heat treatment

4.10.1 Fusion welded pressure vessels, where indicated in Table 13.4.2, are to be heat treated on completion of the welding of the seams and of all attachments to the shell and ends, and before the hydraulic test is carried out.

4.10.2 Tubes which have been expanded into headers or drums may be seal welded without further post-weld heat treatment.

4.10.3 Steam and gas turbine cylinders and rotors are to be subjected to post-weld heat treatment irrespective of thickness.

4.10.4 Where the weld attaches parts of different thicknesses, the thickness to be used when applying the requirements for post-weld heat treatment is to be either the thinner of the two plates for butt welded connections, or the thickness of the shell for welds to flanges, tubeplates and similar connections.

4.10.5 Care is to be exercised to provide drilled holes in double reinforcing plates and other closed spaces prior to heat treatment.

4.11 Basic requirements for heat treatment of fusion welded pressure vessels

4.11.1 Recommended soaking temperatures and soak durations for post-weld heat treatment are given in Table 13.4.3 for different materials. Where other materials are used for pressure vessel construction, full details of the proposed heat treatment are to be submitted for consideration.

4.11.2 Where pressure vessels are of dimensions that the whole length cannot be accommodated in the furnace at one time, the pressure vessels may be heated in sections, provided that sufficient overlap is allowed to ensure the heat treatment of the entire length of the longitudinal seam.

4.11.3 Where materials other than those detailed in Table 13.4.3 are used or where it is proposed to adopt special methods of heat treatment, full particulars are to be submitted for consideration. In such cases, it may be necessary to carry out tests to show the effect of the proposed heat treatment.

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Table 13.4.2 Post-weld heat treatment requirements

Type of steel	Plate thickness above which post-weld heat treatment (PWHT) is required	
	Steam raising plant	Other pressure vessels
Carbon and carbon/manganese steels without low temperature impact values	20 mm	30 mm
Carbon and carbon/manganese steels with low temperature impact values	20 mm	40 mm
1Cr ½Mo	All thicknesses	All thicknesses
2¼Cr 1Mo	All thicknesses	All thicknesses
½Cr ½Mo ¼V	All thicknesses	All thicknesses
Other alloy steels	Subject to special consideration	

Table 13.4.3 Post-weld soak temperatures and times

Material type	Soak temperature (°C)	Soak period
Carbon and carbon/manganese grades	580–620°	1 hour per 25 mm of thickness, minimum of 1 hour
1Cr ½Mo	620–660°	1 hour per 25 mm of thickness, minimum of 1 hour
2¼Cr 1Mo	650–690°	1 hour per 25 mm of thickness, minimum of 1 hour
½Cr ½Mo ¼V	670–720°	1 hour per 25 mm of thickness, minimum of 1 hour
NOTE For materials supplied in the tempered condition, the post-weld heat treatment temperature is to be lower than the material tempering temperature.		

4.12 Non-Destructive Examination of welds

4.12.1 Non-Destructive Examinations (NDE) of pressure vessel welds are to be carried out in accordance with a nationally recognised code or standard.

4.12.2 NDE is not to be applied until an interval of at least 48 hours has elapsed since the completion of welding.

4.12.3 NDE Personnel are to be qualified to an appropriate level of a nationally recognised certification scheme.

4.12.4 Qualification schemes are to include assessments of practical ability for Levels I and II individuals. These examinations are to be made on representative test pieces containing relevant defects.

4.13 Extent of NDE for Class 1 pressure vessels

4.13.1 All butt welded seams in drums, shells, headers and test plates, together with tubes or nozzles with outside diameter greater than 170 mm, are subject to 100 per cent volumetric and surface crack detection inspections.

4.13.2 For circumferential butt welds in extruded connections, tubes, headers and other tubular parts with an outside diameter of 170 mm or less, at least 10 per cent of the total number of welds is to be subjected to volumetric examination and surface crack detection inspections.

4.13.3 Full penetration tube sheet to shell welds are to be subjected to 10 per cent volumetric examination and 10 per cent surface inspection, prior to the installation of the tubes.

4.13.4 In addition to the acceptance limits stated in Tables 13.2.4 to 13.2.6, no cracks, lack of fusion, or lack of penetration is permitted.

4.13.5 When an unacceptable indication is detected, the full length of the weld is to be subjected to 100 per cent examination by the same method, testing conditions and acceptance criteria.

4.14 Extent of NDE for Class 2/1 pressure vessels

4.14.1 For Class 2/1 pressure vessels, volumetric and surface crack detection inspections are to be applied at selected regions of each main seam. At least 10 per cent of each main seam is to be examined together with the full length of each welded test plate. When an unacceptable indication is detected, at least two additional check points in the seam are to be selected by the surveyor for examination using the same inspection method. Where further unacceptable defects are found either:

(a) the whole length of weld represented is to be cut out and re-welded and re-examined as if it was a new weld with the test plates being similarly treated, or

(b) the whole length of the weld represented is to be re-examined using the same inspection methods.

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4.14.2 Butt welds in furnaces, combustion chambers and other pressure parts for fired pressure vessels under external pressure, are to be subject to spot volumetric examination. The minimum length for each check point is to be 300 mm.

4.14.3 The extent of NDE for turbine cylinders and rotors is to be agreed with the Surveyor.

4.14.4 The requirements of 4.13.3, 4.13.4 and 4.13.5 apply to Class 2/1 pressure vessels.

4.15 NDE Method

4.15.1 Volumetric examinations may be made by radiography. For welds of nominal thickness greater than or equal to 8 mm, the examinations may be by ultrasonic testing. The preferred method for surface crack detection in ferrous metals is magnetic particle inspection. The preferred method for non-magnetic materials is liquid penetrant inspection.

4.16 Evaluation and reports

4.16.1 The manufacturer is to be responsible for the review, interpretation, evaluation and acceptance of the results of NDE. Reports stating compliance, or non-compliance, with the criteria established in the inspection procedure are to be issued. Reports are to comply, as a minimum, with the requirements of Ch 1,5.

4.17 Repair to welds

4.17.1 Where non-destructive examinations reveal unacceptable defects in the welded seams, they are to be repaired in accordance with 1.15 and are to be shown by further non-destructive examinations to have been eliminated.

4.17.2 In the case where spot radiography has revealed unacceptable defects, the requirements of 4.14.1 apply.

4.17.3 Where post-weld heat treatment is required in accordance with 4.10, weld repairs to the vessel or cylindrical shell or parts attaching to the shell are to be subjected to a subsequent heat treatment in accordance with 4.10.

4.17.4 In the event of unsuccessful weld repair of a defect, only one more repair attempt may be made of the same defect. Any subsequent repairs may require the re-repair excavation to be enlarged to remove the original repair heat affected zone.

■ *Section 5* Specific requirements for pressure pipework

5.1 Scope

5.1.1 Fabrication of pipework is to be carried out in accordance with the requirements of this Section and the general requirements given in Section 1, unless more stringent requirements have been specified.

5.1.2 Piping systems are to be constructed in accordance with the approved plans and specifications.

5.1.3 Fabricated pipework will be accepted only if manufactured by firms that have demonstrated that they have the facilities and equipment and are competent to undertake the quality of welding required for the Class of pipework proposed.

5.2 Manufacture and workmanship

5.2.1 Pipe welding may be performed using manual, semi-automatic or fully automatic electric arc processes. The use of oxy-acetylene welding will be limited to Class 3 pipework in carbon steel or carbon/manganese material that is not for carrying flammable fluids and limited to butt joints in pipes not exceeding 100 mm diameter or 9,5 mm thickness.

5.2.2 Welding of pipework, including attachment welds directly to pressure retaining parts is to be performed in accordance with approved welding procedures that have been qualified in accordance with Chapter 12.

5.2.3 Where the work involves a significant number of branch connections, tests will be required to demonstrate that the type of joint(s) and welding techniques employed are capable of achieving the required quality.

5.2.4 Where pressure pipework is assembled and butt welded insitu, the piping is to be arranged well clear of adjacent structures to allow sufficient access for preheating, welding, heat-treatment and non-destructive examination of the joints.

5.2.5 Alignment of pipe butt welds is to be in accordance with Table 13.5.1 unless more stringent requirements have been agreed. Where fusible inserts are used, the alignment is to be within 0,5 mm in all cases.

5.2.6 The number of welds is to be kept to a minimum. The minimum separation between welds, measured toe-to-toe, is to be not be less than 75 mm. Where it is not possible to achieve this, adjacent welds are to be subjected to surface crack detection NDE.

5.2.7 Welding consumables and fusible root inserts, where used, are to be suitable for the materials being joined.

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Table 13.5.1 Pipe butt weld alignment tolerances

Pipe size	Maximum permitted misalignment
$D < 150$ mm and $t \leq 6$ mm	1,0 mm or 25% of t, whichever is the lesser
$D < 300$ mm and $t \leq 9,5$ mm	1,5 mm or 25% of t, whichever is the lesser
$D \geq 300$ and $t > 9,5$ mm	2,0 mm or 25% of t, whichever is the lesser
where D = pipe internal diameter t = pipe wall thickness	

5.2.8 Acceptable methods of flange attachment are to be used, *see* Fig. 12.2.2 in Pt 5, Ch 12 of the Rules for Ships. Where backing rings are used with flange type (a) they are to fit closely to the bore of the pipe and be removed after welding. The rings are to be made of the same material as the pipes. The use of flange types (b) and (c) with alloy steel pipes is limited to pipes up to and including 168,3 mm outside diameter.

5.2.9 Where socket welded fittings are employed, the diametrical clearance between the outside diameter of the pipe and the base of the fitting is not to exceed 0,8 mm, and a gap of approximately 1,5 mm is to be provided between the end of the pipe and the internal step at the bottom of the socket.

5.2.10 For welding of carbon, carbon/manganese and low alloy steels, the preheat to be applied will be dependent on the material grade, thickness and hydrogen grading of the welding consumable in accordance with Table 13.5.2, unless welding procedure testing indicates that a higher level is required.

5.2.11 Welding without filler metal is generally not permitted for welding of duplex stainless steel materials.

5.2.12 All welds in high pressure, high temperature pipelines are to have a smooth surface finish and even contour; and where necessary, made smooth by grinding.

5.2.13 Check tests of the quality of the welding are to be carried out periodically.

5.3 Heat treatment after bending of pipes

5.3.1 After forming or bending of pipes, the heat treatments specified in this Section are to be applied unless the pipe material manufacturer specifies or recommends other requirements.

5.3.2 Generally, hot forming is to be carried out within the normalising temperature range. When carried out within this temperature range, no subsequent heat treatment is required for carbon and carbon/manganese steels. For alloy steels, 1Cr ½Mo, 2¼Cr 1Mo and ½Cr ½Mo ¼V, a subsequent tempering heat treatment in accordance with the temperatures and times specified in Table 13.5.3 is required, irrespective of material thickness.

5.3.3 When hot forming is performed outside the normalising temperature range, a subsequent heat treatment in accordance with Table 13.5.3 is required.

5.3.4 After cold forming to a radius (measured at the centreline of the pipe) of less than four times the outside diameter, heat treatment in accordance with Table 13.5.3 is required.

5.3.5 Heat treatment should be carried out in accordance with 1.16.

Table 13.5.2 Welding preheat levels for pipework

Material Grade	Thickness, t (mm) *see* Note 4	Minimum preheat temperature (°C) *See* Note 1	
		Non-low H_2	Low H_2 *see* Note 2
Carbon and carbon/manganese grades: 320 and 360	$t \leq 15$ $t \geq 15$	50 100	10 50
Carbon and carbon/manganese grades: 410, 460 and 490	$t \leq 15$ $t \geq 15$	75 150	20 100
1Cr ½Mo	$t < 13$ $t \geq 13$	*See* Note 3	100 150
2¼Cr 1Mo	$t < 13$ $t \geq 13$	*See* Note 3	150 200
½Cr ½Mo ¼V	$t < 13$ $t \geq 13$	*See* Note 3	150 200

NOTES
1. Where the ambient temperature is 0°C or below, pre-warming of the weld joint is required in all cases.
2. Low hydrogen process or consumables are those that have been tested and have achieved a grading of H15 or better (*see* Chapter 11).
3. Low hydrogen welding process is required for these materials.
4. t = the thickness of the thinner member for butt welds, and the thicker member for fillet and branch welds.

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Table 13.5.3 Heat treatment after bending of pipes

Type of steel	Heat treatment required
Carbon and carbon/manganese: Grades 320, 360, 410, 460 and 490	Normalise at 880 to 940°C
1Cr ½Mo	Normalise at 900 to 940°C, followed by tempering at 640 to 720°C
2¼Cr 1Mo	Normalise at 900 to 960°C, followed by tempering at 650 to 780°C
½Cr ½Mo ¼V	Normalise at 930 to 980°C, followed by tempering at 670 to 720°C
Other alloy steels	Subject to special consideration

5.3.6 Bending procedures and subsequent heat treatment for other alloy steels will be subject to special consideration.

5.4 Post-weld heat treatment

5.4.1 Post-weld heat treatment is to be carried out in accordance with the general requirements specified in 1.16 and 4.10.

5.4.2 The thickness limits, the recommended soaking temperatures and periods, for application of post-weld heat treatment are given in Table 13.5.4.

5.4.3 Where the use of oxy-acetylene welding is proposed, due consideration is to be given to the need for normalising and tempering after such welding.

5.5 Non-destructive examination

5.5.1 Non-destructive examination of pipe welds is to be carried out in accordance with the general requirements of 1.11 and the following.

5.5.2 Butt welds in Class 1 pipes with an outside diameter greater or equal to 75 mm are to be subject to 100 per cent volumetric and visual inspections. Consideration is to be given to the extent and method of testing applied to butt welds in Class 1 pipes with an outside diameter less than 75 mm.

5.5.3 Butt welds in Class II pipes are to be subjected to at least 10 per cent random volumetric inspections when the outside diameter is greater than 100 mm.

5.5.4 NDE for Class II pipes with a diameter less than 100 mm is to be at the discretion of the Surveyor.

5.5.5 Non-destructive examination procedures, methods and the evaluation of reports are to be in accordance with 4.15 and 4.16.

5.5.6 Fillet welds on flange pipe connections of Class I pipes are to be examined by surface crack detection methods.

5.6 Repairs to pipe welds

5.6.1 Where non-destructive examinations reveal unacceptable defects in a weld, the defects are to be removed and repaired in accordance with 1.15. Completed repairs are to be shown by further non-destructive examination to have eliminated the defects.

5.6.2 For pipes with diameter less than 88 mm and where unacceptable defects have been found during non-destructive examination, consideration is to be given to cutting the weld out completely, re-making the weld preparation and re-welding as a new joint (because of the difficulty of making small repairs).

Table 13.5.4 Post-weld heat treatment requirements for pipework

Material Grade	Thickness for which post-weld heat treatment is required	Soak temperature (°C) *see* Note 2	Soak period
Carbon and carbon/manganese grades: 320, 360, 410, 460, 490	Over 30 mm	580–620°C	1 hour per 25 mm of thickness, minimum of 1 hour
1Cr ½Mo	Over 8 mm	620–660°C	1 hour per 25 mm of thickness, minimum of 1 hour
2¼Cr 1Mo	All	650–690°C	1 hour per 25 mm of thickness, minimum of 1 hour
½Cr ½Mo ¼V	All, *see* Note 1	670–720°C	1 hour per 25 mm of thickness, minimum of 1 hour

NOTES
1. Heat treatment may be omitted for thicknesses up to 8 mm and diameters not exceeding 100 mm provided welding procedure tests have demonstrated acceptable properties in the as welded condition.
2. For materials supplied in the tempered condition, the post weld heat treatment temperature is to be at least 20°C less than the material tempering temperature.

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5.6.3 Where repeated weld repairs have to be made to a weld, only two such attempts are to be permitted, thereafter the weld is to be cut apart and removed, and re-welded as a new joint.

5.6.4 Where pipework requires post-weld heat treatment weld, repairs to the pressure retaining parts are to be subjected to a subsequent heat treatment. Similarly, where welding is conducted after pressure testing, a further pressure test is to be required unless specific exemption has been agreed.

■ *Section 6* Repair of existing ships by welding

6.1 Scope

6.1.1 This Section specifies requirements for repairs made by welding after introduction into service. This Section includes defects to hull structures, machinery, equipment and components. It also includes replacement of structure due to damage or corrosion. These requirements are in addition to those specified in the preceding Sections of this Chapter.

6.1.2 These requirements apply unless the original builder or manufacturer has specified alternative requirements.

6.2 Materials used for repairs

6.2.1 Permanent materials used in the repair are to be in accordance with 1.3.

6.2.2 Prior to commencing any welding, the material grades present in the original structure in way of the repair are to be determined. Where the materials cannot be identified from the ship records, test samples may be removed for chemical analysis and mechanical testing in order to determine the material grades.

6.2.3 Temporary materials that are to be welded to the main structure to assist in executing the repairs, but removed on completion, are to be of weldable quality.

6.3 Workmanship

6.3.1 A repair method is to be established by the shipyard or repair yard and is to be agreed by the Surveyor prior to commencing any repair work.

6.3.2 The removal of crack-like defects is to be confirmed by visual examination and surface crack detection NDE. This may be augmented by ultrasonic examination where several defects are reported at different depths at the same location.

6.3.3 The weld joint or groove shape used for the repair is to have a profile suitable for welding.

6.3.4 The weld area is to be carefully cleaned, in particular, where the material surface has been painted or has been subjected to an oily or greasy environment.

6.4 Non-destructive examination

6.4.1 On completion of welding and any post-weld heat treatment, repair welds are to be subjected to the type and extent of NDE and assessed in accordance with the acceptance criteria specified for the original construction.

6.4.2 Where the original construction specification did not specify NDE, the completed welds are to be, as a minimum, subject to visual examination. Consideration of other NDE techniques is to take due cognisance of the location or the repair within the vessel.

6.4.3 Where spot NDE is applied and defects are found, the extent of NDE is to be increased to include an equal amount of weld length. Where this reveals unacceptable defects, either the whole weld will be rejected or the extent of inspection increased to 100 per cent examination.

6.4.4 The acceptance criteria to be applied are to generally be in accordance with the original build specification. Where conflict of requirements exist, the NDE acceptance limits for welding procedure tests specified in Ch 12,2.5.5 may be used as a minimum requirement.

6.5 Repairs to welds defects

6.5.1 Where NDE reveals unacceptable defects, these are to be repaired in accordance with 1.15.

■ *Section 7* Austenitic and duplex stainless steel – Specific requirements

7.1 Scope

7.1.1 This Section specifies requirements for the fabrication and welding of austenitic and duplex stainless steels, and is in addition to those detailed above.

7.1.2 Fabrication and welding of these materials is to be in designated areas which are separated from those used for other materials, such as carbon steels and copper alloys. Where work is performed in the same workshop as other materials, adequate barriers or screening are to be provided to prevent cross-contamination of different material types.

7.1.3 All tools and equipment used are to be suitable for use on stainless steel materials. The use of tools or equipment made of carbon steel materials is to be avoided. It is permissible to use carbon steel tools provided that the surfaces that come into contact with the austenitic and duplex stainless materials are protected with an austenitic or nickel base alloy.

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7.2 Design

7.2.1 Care is to be exercised in the weld design to prevent crevice corrosion from occurring, particularly where austenitic materials are used. In this respect fillet welds and partial penetration welds are to be continuous and welded on both sides of the joint.

7.3 Forming and bending

7.3.1 Materials that are cold formed, such that the total strain exceeds 15 per cent (i.e. where the formed diameter to thickness ratio is less than 6:1) are to be subjected to a subsequent softening heat treatment in accordance with the material manufacturers recommendations, unless it is demonstrated by testing that the material properties are acceptable in the 'as formed' condition.

7.3.2 Materials may be hot formed provided that a subsequent softening heat treatment is carried out. The forming process and the subsequent heat treatment are to be in accordance with the material manufacturer's recommendations.

7.4 Fabrication and welding

7.4.1 Welding may be performed using shielded manual arc welding (SMAW), gas tungsten arc welding (GTAW), MIG/MAG welding (GMAW), flux cored arc welding (FCAW), plasma arc welding (PAW) and submerged arc welding (SAW). The use of other welding processes will be subject to special consideration and will require submission of the process details, consumables and the weld properties achieved.

7.4.2 Misalignment may be corrected by the application of steady even force (e.g., using hydraulic or screw-type clamps). Hammering or heating is not permitted.

7.4.3 For full penetration welds, a backing or shielding gas is to be provided to prevent oxidation of the root weld. The backing gas is to be maintained until completion of, at least, the root and first fill layer. The backing gas may be omitted where the weld is back gouged or ground to remove the root weld.

7.4.4 Shielding and backing gases are to be an inert type of high purity and oxygen free.

7.4.5 For welding of Duplex stainless, the use of backing gases that contain up to 2 per cent nitrogen is permitted.

7.4.6 Welding of duplex stainless steels without filler metal is generally not permitted.

7.4.7 Degreasing agents, acid solutions, washing water etc. used for cleaning and any marking crayons and paints used are to be free of chlorides.

7.5 Repairs

7.5.1 Correction of distortion by the application of heat is not permitted.

■ *Section 8*
Specific requirements for welded aluminium

8.1 Scope

8.1.1 This Section specifies requirements for the fabrication and welding of aluminium alloys, and is in addition to those detailed in this Chapter.

8.1.2 Fabrication and welding of these materials is to be in designated areas which are separated from those used for other materials, such as carbon steels, stainless steels and copper alloys. Where work is performed in the same workshop as other materials, adequate barriers or screening are to be provided to prevent cross-contamination of different material types.

8.1.3 All tools and equipment used are to be suitable for use on aluminium alloy materials. The use of tools made of carbon steel materials is to be avoided where possible.

8.2 Forming and bending

8.2.1 Aluminium alloys are to be subject to cold forming and cold bending only.

8.3 Fabrication and welding

8.3.1 Welding may be performed using gas tungsten arc welding (GTAW) or metal inert gas welding (GMAW), MIG/MAG welding (GMAW), or variants thereof. The use of other welding processes such as friction stir welding (FSW) will be subject to special consideration and will require submission of the process details, consumables and the weld properties achieved.

8.3.2 A comparison of the mechanical properties for selected welded and unwelded alloys is given in Table 13.8.1.

8.3.3 Misalignment may be corrected by the application of steady even force (e.g., using hydraulic or screw-type clamps). Hammering or heating is not permitted.

8.3.4 Correction of distortion by the application of heat is not permitted.

8.4 Non-destructive examination

8.4.1 The requirements of Ch 13,1.11 and Ch 13,2.12 apply; however, acceptance criteria applicable to aluminium are to be in accordance with Table 13.8.2 and Table 13.8.3.

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Table 13.8.1 Minimum mechanical properties for aluminium alloys

Alloy	Condition	0,2% proof stress, N/mm^2		Ultimate tensile strength, N/mm^2	
		Unwelded	Welded (*see* Note 4)	Unwelded	Welded (*see* Note 4)
5083	O/H111	125	125	275	275
5083	H112	125	125	275	275
5083	H116/H321	215	125	305	275
5383	O/H111	145	145	290	290
5383	H116/H321	220	145	305	290
5086	O/H111	100	95	240	240
5086	H112	125 (*see* Note 2)	95	250 (*see* Note 2)	240
5086	H116/H321	195	95	275	240
5059	O/H111	160	160	330	330
5059	H116/H321	260	160	360	300
5456	O	125	125	285	285
5456	H116	200 (*see* Note 5)	125	290 (*see* Note 5)	285
5456	H321	215 (*see* Note 5)	125	305 (*see* Note 5)	285
5754	O/H111	80	80	190	190
6005A (see Note 1)	T5/T6 Extruded: Open Profile Extruded: Closed Profile	215 215	100 100	260 250	160 160
6061 (see Note 1)	T5/T6 Rolled Extruded: Open Profile Extruded: Closed Profile	240 240 205	125 125 125	290 260 245	160 160 160
6082	T5/T6 Rolled Extruded: Open Profile Extruded: Closed Profile	240 260 240	125 125 125	280 310 290	190 190 190

NOTES
1. These alloys are not normally acceptable for application in direct contact with sea-water.
2. See also Table 8.1.3 or Table 8.1.4 in Chapter 8.
3. The mechanical properties to be used to determine scantlings in other types and grades of aluminium alloy manufactured to National or proprietary standards and specifications are to be individually agreed with LR, *see also* Ch 8,1.1.5.
4. Where detail structural analysis is carried out, 'unwelded' stress values may be used away from heat affected zones and weld lines, *see also* Pt 3, Ch 2, 1.1.3 of the Rules for Ships.
5. For thickness less than 12,5 mm, the minimum unwelded 0,2% proof stress is to be taken as 230 N/mm^2 and the minimum tensile strength is to be taken as 315 N/mm^2.

8.4.2 Alternative NDE acceptance criteria will be subject to special consideration provided that they are equivalent to these requirements.

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Table 13.8.2 Acceptance criteria for surface imperfections of aluminium

Surface discontinuity	Classification according to ISO 6520-1	Acceptance criteria
Crack	100	Not permitted
Lack of fusion	401	Not permitted
Incomplete root penetration in butt joints welded from one side	4021	Not permitted
Surface pore	2017	$d \leq 0{,}3s$ or $0{,}3a$ or 1,5 mm (whichever is the lesser)
Linear porosity (*see* Note 1)	2014	Not permitted
Uniformly distributed porosity (*see* Note 2)	2012	≤ 1% of area
Clustered porosity	2013	Not permitted
Continuous undercut	5011	$h \leq 0{,}1t$ or 0,5 mm (whichever is the lesser)
Intermittent undercut	5012	$h \leq 0{,}1t$ or 1,0 mm (whichever is the lesser)
Excess weld metal (*see* Note 3)	502	$h \leq 1{,}5$ mm + $0{,}15b$ or 8 mm (whichever is the lesser)
Excess penetration	504	$h \leq 4$ mm
Root concavity (*see* Note 3)	515	$h \leq 0{,}1t$ or 1 mm (whichever is the lesser)
Linear misalignment (*see* Notes 4 and 5)	507	$h \leq 0{,}1t$ or 1,0 mm (whichever is the lesser)
Angular misalignment	508	(*see* Note 6)

Symbols

a = nominal throat thickness of a fillet weld
b = width of weld reinforcement
d = diameter of a gas pore
h = height or width of an imperfection
s = nominal butt weld thickness
t = wall or plate thickness (nominal size)

NOTES
1. For these acceptance criteria, linear porosity is to be considered as three aligned gas pores in a length of 25 mm.
2. To be in accordance with EN ISO 10042.
3. A smooth transition is required.
4. Linear misalignment is to be a maximum of 0,5 mm in highly stressed areas. For other areas, the linear misalignment is to be a maximum of 1,0 mm locally, where the sum of the length of imperfection is not more than 10% of the weld length.
5. The limits for linear misalignment relate to deviations from the correct position. Unless otherwise specified, the correct position is that when the centrelines coincide.
6. Angular misalignment shall be mutually agreed between the designer and the fabricator.

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Table 13.8.3 Acceptance criteria for internal imperfections of aluminium

Internal discontinuity	Classification according to ISO 6520-1	Acceptance criteria (*see* Note 1)
Crack	100	Not permitted
Lack of fusion	401	Not permitted
Incomplete penetration	402	Not permitted
Single gas pore	2017	$d \leq 0{,}3s$ or $0{,}3a$ or 5 mm (whichever is the lesser)
Linear porosity	2014	Assess as lack of fusion
Uniformly distributed porosity (*see* Note 1)	2012	$0{,}5 < t < 3$ mm ≤ 2% of area $3 < t < 12$ mm ≤ 4% of area $12 < t < 30$ mm ≤ 6% of area $t > 30$ mm ≤ 8% of area
Clustered porosity (*see* Note 1)	2013	$dA \leq 20$ mm or wp (whichever is the lesser)
Elongated cavity Wormhole	2015 2016	$l \leq 0{,}3s$ or $0{,}3a$ or 4 mm (whichever is the lesser)
Oxide inclusion (*see* Note 2)	303	$l \leq 0{,}5s$ or $0{,}5a$ or 5 mm (whichever is the lesser)
Tungsten inclusion	3041	$l \leq 0{,}3s$ or $0{,}3a$ or 4 mm (whichever is the lesser)
Copper inclusion	3042	Not permitted
Multiple imperfections in any cross-section	—	The sum of the acceptable individual imperfections in any cross-section is not to exceed $0{,}3t$ or $0{,}3a$ (whichever is the lesser)

Symbols

a = nominal throat thickness of a fillet weld
b = width of weld reinforcement
d = diameter of a gas pore
h = height or width of an imperfection
s = nominal butt weld thickness
t = wall or plate thickness (nominal size)
wp = width of weld or width or height of cross-sectional area
dA = diameter of area surrounding gas pores
l = length of imperfection in longitudinal direction of weld

NOTES
1. Porosity is to be determined in accordance with ISO 10042. The requirements for a single gas pore are to be met by all the gas pores within this circle. Systematic clustered porosity is not permitted.
2. If several oxide inclusions l_1, l_2, l_3, ... exist in one cross-section, then they are summed: $l = l_1 + l_2 + l_3 + ...+ l_n$.

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Plastics Materials and other Non-Metallic Materials

Chapter 14

Section

1 **General requirements**

2 **Tests on polymers, resins, reinforcements and associated materials**

3 **Testing procedures**

4 **Plastics pipes and fittings**

5 **Control of material quality for composite construction**

■ *Section 1* General requirements

1.1 Scope

1.1.1 Provision is made in this Chapter for the manufacture and testing of plastics pipes, together with approval requirements for base materials used in the construction or repair of composite vessels, other marine structures, piping and any associated machinery components and fittings which are to be certified or are intended for classification.

1.1.2 These materials and products are to be manufactured and surveyed in accordance with the general requirements of Sections 1, 2 and 3 of this Chapter; and LR's *Materials and Qualification Procedures for Ships (MQPS) Book K*, see Ch 1,2.2.2, which, in addition to the test programme, also details the procedures for application for approval of manufacturers and products and details of the information to be supplied by the manufacturer.

1.1.3 For base materials, the manufacturer's works do not require approval by Lloyd's Register (hereinafter referred to as 'LR'), however the Quality Control procedures must be acceptable in accordance with the appropriate Section of this Chapter.

1.1.4 Where a requirement exists for the material to be approved, the test requirements and information to be submitted for approval of polymers, resins, reinforcements and associated materials are defined in Sections 2 and 3.

1.1.5 Specific material requirements relating to the design and manufacture of plastics pipes and fittings are indicated in Section 4, with the material requirements for hull structures contained in Section 5.

1.1.6 For Builders constructing composite vessels, Section 5 provides the minimum material control requirements for acceptance of the works by LR.

1.1.7 For the purposes of these Rules a 'plastics material' is regarded as an organic substance which may be thermosetting or thermoplastic and which, in its finished state, may contain reinforcements or additives.

1.1.8 Materials not listed in 2.1.1 may be considered for approval on a case-by-case basis. The approved test results will be listed on the issued certificate. Subject to satisfactory service experience and validation of approval, the material may be entered in 2.1.1 of the Rules.

1.2 Information on material quality and application

1.2.1 Where plastics products are to be classed or certified, the manufacturer is to provide the material producer with such information as is essential to ensure that the base materials to be used are in accordance with the approval requirements and the product specification. This information is to include any survey requirements for the materials.

1.3 Manufacture

1.3.1 Plastics products are to be made at works which have been approved (or accepted) for the type of product being supplied using base materials that have been approved.

1.3.2 Base materials are to be approved in accordance with the requirements of Sections 2 and 3.

1.3.3 In order that a works can be approved (or accepted), the manufacturer is required to demonstrate to the satisfaction of LR that the necessary manufacturing and testing facilities are available and are supervised by qualified personnel. A specified programme of tests is to be carried out under the supervision of the Surveyors, and the results are to be to the satisfaction of LR. When a manufacturer has more than one works, the approval (or acceptance) is only valid for the individual works which carried out the test programme.

1.3.4 In order to maintain approval, the manufacturer is required to confirm in writing that there have been no changes in the formulation or production process for the material in question and that the site of manufacture remains unchanged.

1.4 Survey procedure

1.4.1 The Surveyors are to be allowed access to all relevant parts of the works and are to be provided with the necessary facilities and information to enable them to verify that manufacture is being carried out in accordance with the approved procedure. Facilities are also to be provided for the selection of test material, the witnessing of specified tests and the examination of materials, as required by the Rules.

1.4.2 Prior to the provision of test material for acceptance, manufacturers are to provide the Surveyors with details of the order, specification and any special conditions additional to the Rule requirements.

1.4.3 Before final acceptance, all test materials are to be confirmed as typical of the manufactured product and be submitted to the specified tests and examinations under conditions acceptable to the Surveyors. The results are to comply with the specification and any Rule requirements and are to be to the satisfaction of the Surveyors.

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1.4.4 These specified tests and examinations are to be carried out prior to the despatch of finished products from the manufacturer's works.

1.4.5 In the event of any material proving unsatisfactory, during subsequent working, machining or fabrication, it is to be rejected, notwithstanding any previous certification.

1.5 Alternative survey procedure

1.5.1 Where materials are manufactured in quantity by semi-continuous or continuous processes under closely controlled conditions, an alternative system for testing and inspection may be adopted, subject to the agreement of the Surveyors.

1.5.2 In order to be considered for approval, manufacturers are to comply with the requirements of Ch 1,2.

1.6 Post-cure heating

1.6.1 Post-cure heating is to be carried out in properly constructed ovens which are efficiently maintained and have adequate means for control and recording of temperature. The oven is to be such as to allow the whole item to be uniformly heated to the necessary temperature. In the case of very large components which require post-cure heating, alternative methods will be specially considered.

1.7 Test material

1.7.1 Sufficient material is to be provided for the preparation of the test specimens detailed in the specific requirements. It is, however, in the interests of manufacturers to provide additional material for any re-tests which may be necessary, as insufficient or unacceptable test material may be a cause for rejection.

1.7.2 Where test materials, (either base materials or product sample materials) are selected by the Surveyor or a person nominated by LR, these are to be suitably identified by markings which are to be maintained during the preparation of the test specimens.

1.7.3 All base material samples for testing are to be prepared under conditions that are as close as possible to those under which the product is to be manufactured. Where this is not possible, a suitable procedure is to be agreed with the Surveyor.

1.7.4 During production, check test samples are to be provided as requested by the Surveyor.

1.7.5 Should the taking of these samples prove impossible, model samples are to be prepared concurrently with production. The procedure for the preparation of these samples is to be agreed with the Surveyor.

1.7.6 The dimensions, number and orientation of test specimens are to be in accordance with the requirements of a National or International Standard acceptable to LR.

1.8 Re-test procedure

1.8.1 Where test material fails to meet the specified requirement, two additional tests of the same type may be made at the discretion of the Surveyor.

1.8.2 Where an individual test result in a group, (minimum five) deviates from the mean by more than two standard deviations in either the higher or lower direction, the result is to be excluded and a re-test made. Excluded results of tests are to be reported with confirmation that they have been excluded. Only one exclusion is acceptable in any group of tests.

1.9 Visual and non-destructive examination

1.9.1 Prior to the final acceptance, surface inspection, verification of dimensions and non-destructive examination are to be carried out in accordance with the requirements detailed in Sections 3, 4 and 5 of this Chapter.

1.9.2 When there is visible evidence to doubt the soundness of any material or component, such as flaws or suspicious surface marks, it is to be the responsibility of the manufacturer to prove the quality of the material by any suitable method.

1.10 Rectification of defective material

1.10.1 Small surface blemishes may be removed by mechanical means provided that, after such treatment, the dimensions are acceptable, the area is proved free from structural defects and the rectification has been completed to the satisfaction of the Surveyor.

1.10.2 Repair procedures for larger defects are to be agreed with LR prior to implementation.

1.11 Identification of products and base materials

1.11.1 The manufacturer of approved materials is to identify each batch with a unique number.

1.11.2 The manufacturer of plastics products is to adopt a system of identification which will enable all finished products to be traced to the original batches of base materials. Surveyors are to be given full facilities for tracing any component or material when required.

1.11.3 When any item has been identified by the personal mark of a Surveyor, or deputy, this is not to be removed until an acceptable new identification mark has been made by a Surveyor. Failure to comply with this condition will render the item liable to rejection.

1.11.4 Before any pipe or fitting is finally accepted it is to be clearly marked by the manufacturer in at least one place with the particulars detailed in the appropriate specific requirements as given in Section 4.

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1.11.5 Where a number of identical items are securely fastened together in bundles, the manufacturer need only brand the top item of each bundle. Alternatively, a durable label giving the required particulars may be attached to each bundle.

1.12 Certification

1.12.1 Certification of the finished product is to be in accordance with the requirements of the appropriate Sections.

■ *Section 2*
Tests on polymers, resins, reinforcements and associated materials

2.1 Scope

2.1.1 This Section gives the tests and data required by LR for materials approval and/or inspection purposes on the following:

(a) Thermoplastic polymers.
(b) Thermosetting resins.
(c) Reinforcements.
(d) Reinforced thermoplastic polymers.
(e) Reinforced thermosetting resins.
(f) Core materials.
  (i) End-grain balsa.
  (ii) Rigid foams.
  (iii) Synthetic felt type materials.
(g) Machinery chocking compounds.
(h) Rudder and pintle bearings.
(j) Stern tube bearings.
(k) Plywoods.
(l) Adhesive and sealant materials.
(m) Repair compounds.

2.2 Thermoplastic polymers

2.2.1 The following data is to be provided by the manufacturer for each thermoplastic polymer:

(a) Melting point.
(b) Melt flow index.
(c) Density.
(d) Bulk density.
(e) Filler content, where applicable.
(f) Pigment content, where applicable.
(g) Colour.

2.2.2 Samples for testing are to be prepared by moulding or extrusion under the polymer manufacturer's recommended conditions.

2.2.3 The following tests are to be carried out on these samples:

(a) Tensile stress at yield and break.
(b) Modulus of elasticity in tension.
(c) Tensile strain at yield and break.
(d) Compressive stress at yield and break.
(e) Compressive modulus.
(f) Temperature of deflection under load.
(g) Determination of water absorption.

2.3 Thermosetting resins

2.3.1 The data listed in Table 14.2.1 is to be provided by the manufacturer for each thermosetting resin.

Table 14.2.1 Data requirements for thermosetting resins

Data	Type of resin		
	Polyester (*see* Note 3 for vinylester)	Epoxide	Phenolic
Specific gravity of liquid resin	required	required	required
Viscosity	required	required	required
Gel time	required	required	not applicable
Appearance	required	required	required
Mineral content (*see* Note 1)	required	required	not applicable (*see* Note 2)
Volatile content	required	not applicable	not applicable
Acid value	required	not applicable	not applicable
Epoxide content	not applicable	required	not applicable
Free phenol	not applicable	not applicable	required
Free formaldehyde	not applicable	not applicable	required

NOTES
1. This is to be the total filler in the system, including thixotrope, filler, pigments, etc., and is to be expressed in parts by weight per hundred parts of pure resin.
2. If the resin is pre-filled, the mineral content is required.
3. Vinylesters are to be treated as equivalent to polyesters.

2.3.2 Cast samples are to be prepared in accordance with the manufacturer's recommendations and are to be cured and post-cured in a manner consistent with the intended use. The curing system used and the ratio of curing agent (or catalyst) to resin are to be recorded. Where post-cure conditions equivalent to ambient-cure conditions apply, *see* 3.2.2 and 3.2.3.

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2.3.3 The following are to be determined using these samples:
(a) Tensile strength (stress at maximum load) and stress at break.
(b) Tensile strain at maximum load.
(c) Tensile secant modulus at 0,5 per cent and 0,25 per cent strain respectively.
(d) Temperature of deflection under load.
(e) Barcol hardness.
(f) Determination of water absorption.
(g) Volume shrinkage after cure.
(h) Specific gravity of cast resin.

2.3.4 In addition, for gel coat resins the stress at break and modulus of elasticity in flexure are to be determined.

2.3.5 Where resins which have been modified by the addition of waxes or polymers, for example 'low styrene emission or air inhibited' materials, it is to be confirmed that the use of such resins will not result in poor interlaminar adhesion when interruptions to the laminating process occur. The test procedure is to be as follows:
(a) A conventional room temperature curing catalyst/accelerator system is to be used with the resin for laminate preparation.
(b) A laminate of 25 to 35 per cent glass content in mass is to be prepared using two plies of 450 g/m^2 chopped strand mat. The laminate is to be prepared at ambient temperature (18° to 21°C). The laminate is to be allowed to stand for a minimum of four days but no longer than 6 days at ambient temperature.
(c) A further two plies of 450 g/m^2 chopped strand mat are to be laminated onto the exposed surface and cured at ambient temperature for 24 hours. The finished laminate is then to be post-cured at 40°C for 16 hours. The finished laminate is to have a glass content of 25 to 35 per cent.
(d) After cooling, the apparent interlaminar shear strength of the laminate is to be determined in accordance with ISO 14130; the minimum value is given in Table 14.5.5. Before testing the samples shall be conditioned at 23°C and relative humidity of 50 per cent for a period of 88 hours before testing.
(e) If the tests are undertaken at the resin manufacturer's own laboratory, the individual test values are to be reported and the broken test specimens retained for examination by LR.

Alternative test procedures will be considered with prior agreement.

2.4 Reinforcements

2.4.1 The following data is to be provided, where applicable, for each type of reinforcement:
(a) Reinforcement type.
(b) Fibre type for each direction.
(c) Fibre tex value.
(d) Fibre finish and/or treatment.
(e) Yarn count in each direction.
(f) Width of manufactured reinforcement.
(g) Weight per unit area of manufactured reinforcement.
(h) Weight per linear metre of manufactured reinforcement.
(j) Compatibility (e.g. suitable for polyesters, epoxides, etc.).
(k) Constructional stitching – details of yarn, specific gravity, type, frequency and direction.
(l) Weave type.
(m) Binder type and content.
(n) Density of the fibre material.

2.4.2 Tests of the mechanical properties are to be made on laminate samples containing the reinforcement and prepared as follows:
(a) an approved resin of suitable type is to be used;
(b) a minimum of three layers of the reinforcement is to be laid with parallel ply to give a laminate not less than 4 mm thick;
(c) the weights of resin and reinforcement used are to be recorded together with the measured thickness of the laminate, including the measured weight per unit area of the reinforcement used;
(d) for glass reinforcements, the glass/resin ratios, by weight, as shown in Table 14.2.2 are to be used;
(e) for reinforcement type other than glass, a fibre volume fraction, as shown in Table 14.2.3, is to be used.

2.4.3 Rovings intended for filament winding are to be tested as unidirectional rovings.

2.4.4 The following tests as defined in Section 3 are to be made on the samples:
(a) Tensile strength (stress at maximum load).
(b) Tensile strain at break.
(c) Tensile secant modulus at 0,5 per cent and 0,25 per cent strain respectively.
(d) Compressive strength (stress at maximum load).
(e) Compressive modulus.
(f) Flexural strength (stress at maximum load).
(g) Modulus of elasticity in flexure.
(h) Apparent interlaminar shear.
(j) Fibre content.
(k) Determination of water absorption.

Table 14.2.2 Glass fraction by weight for different reinforcement types

Reinforcement type	Glass fraction nominal values
Unidirectional	0,60
Chopped strand mat	0,30
Woven roving	0,50
Woven cloth	0,50
Composite roving (*see* Note)	0,45
Gun rovings	0,33
±45° stitched parallel plied roving	0,50
Triaxial parallel plied roving	0,50
Quadriaxial parallel plied roving	0,50

NOTE
Continuous fibre reinforcement with attached chopped strand mat.

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Table 14.2.3 Content by volume for different reinforcement types

Reinforcement type	Content by volume nominal values
Unidirectional	0,41
Chopped strand mat	0,17
Woven roving	0,32
Woven cloth	0,32
Composite roving (*see* Note)	0,28
Gun rovings	0,19
±45° stitched parallel plied roving	0,32
Triaxial parallel plied roving	0,32
Quadriaxial parallel plied roving	0,32

NOTE
The volume content may be converted to weight fractions by use of the formula:

$W_F = V_F D_F/(D_F V_F + D_R V_R)$

where

W_F = fibre fraction by weight
D_F = density of fibre
D_R = density of cured resin
V_F = fibre fraction by volume
V_R = resin fraction by volume

2.4.5 The laminate is to be tested in air in the directions indicated by Table 14.2.4.

2.4.6 Additionally, tests in 2.4.4(c) and (f) are to be repeated, in one direction only, after immersion in fresh water at 35°C for 28 days with the exception of 2.4.4(k).

Table 14.2.4 Fibre orientations in reinforced test specimens

Type of reinforcement	Test orientations
Unidirectional	0°
Chopped strand mat Gun roving	any direction
Woven roving Woven cloth Composite roving	0° and 90°
± 45° parallel plied roving Triaxial plied roving Quadriaxial plied roving	0°, 45°, 90° and –45°

2.5 Reinforced thermoplastic polymers

2.5.1 Thermoplastic polymers intended for use with reinforcements are to be tested in accordance with 2.2.1 to 2.2.3.

2.5.2 A laminate is to be prepared using the polymer and an approved reinforcement in accordance with a manufacturing specification. The laminate is to be tested in accordance with the appropriate requirements of 2.4.4. Testing may be confined to one direction only.

2.6 Reinforced thermosetting resins

2.6.1 Thermosetting resins intended for use with reinforcements are to be tested in accordance with 2.3.1 to 2.3.4.

2.6.2 No further tests are required for gel coat resins.

2.6.3 For laminating resins, a laminate is to be prepared using the resin and an approved reinforcement as follows:
(a) For polyester resins, chopped strand mat.
(b) For epoxide resins, a balanced woven roving.
(c) For phenolic resins, a balanced woven material.

2.6.4 The laminate is to be tested in accordance with procedures outlined in MQPS Book K procedure 14-1 and 2.4.4 in one fibre direction only.

2.7 Core materials

2.7.1 **General requirements**. The following data is to be provided for each type of core material:
(a) Type of material.
(b) Density.
(c) Description (block, scrim mounted, grooved).
(d) Thickness and tolerance.
(e) Sheet/block dimensions.
(f) Surface treatment.

2.7.2 Manufacturers are required to provide a full application procedure for use of the product.

2.8 Specific requirements for end-grain balsa

2.8.1 The supplier is to provide a signed statement that the balsa (ochroma lozopus) is cut to end-grain, is of good quality, being free from unsound or loose knots, holes, splits, rot, pith and corcho, and that it has been treated against fungal and insect attack, shortly after felling, followed by homogenisation, sterilisation and kiln drying to an average moisture content of no more than 12 per cent.

2.8.2 The following tests are to be carried out on the virgin material, both parallel to and perpendicular to the grain:
(a) Compressive strength (stress at maximum load).
(b) Compressive modulus of elasticity.
(c) Tensile strength (stress at maximum load).
The density of the virgin material is also to be tested.

2.8.3 Where the balsa is mounted on a carrier material (e.g. scrim), any adhesive used is to be of a type compatible with the proposed resin system.

2.8.4 Core shear properties are to be determined according to the requirements of 3.8.1.

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2.9 Specific requirements for rigid foams (PVC, Polyurethane and other types)

2.9.1 The foam is to be of the closed cell type and compatible with the proposed resin system (e.g., polyester, epoxide, etc.).

2.9.2 Foams are to be of uniform cell structure.

2.9.3 Data is to be provided on the dimensional stability of the foam by measurement of the shrinkage.

2.9.4 The following test data is to be submitted for each type of foam:
(a) Density.
(b) Tensile strength (stress at maximum load).
(c) Tensile modulus of elasticity.
(d) Compressive strength (stress at maximum load).
(e) Compressive modulus of elasticity.

2.9.5 Core shear properties are to be determined according to the requirements of 3.8.1.

2.9.6 Additionally, the compressive properties (*see* 2.9.4(d) and (e)) are to be determined at a minimum of five points over the temperature range ambient to maximum recommended service or 70°C, whichever is the greater.

2.10 Synthetic felt type materials with or without microspheres

2.10.1 For materials of this type, the following data is required in addition to the requirements of 2.7.1:
(a) Fibre type.
(b) Width.
(c) Width of finished material.
(d) Weight per unit area of the manufactured material.
(e) Weight per linear metre of the manufactured material.
(f) Compatibility.
(g) Details of the method of combining.

2.10.2 A laminate of the material is to be prepared using a suitable approved resin under conditions recommended by the manufacturer.

2.10.3 The following properties are to be determined:
(a) Tensile strength (stress at maximum load).
(b) Tensile strain at break.
(c) Modulus of elasticity in tension or secant modulus at 0,25 per cent and 0,5 per cent strain.
(d) Compressive strength (stress at maximum load).
(e) Compressive modulus.
(f) Flexural strength (stress at maximum load).
(g) Modulus of elasticity in flexure.
(h) Fibre content.
(j) Water absorption.

2.10.4 In the case of anisotropic materials (e.g., where combined with other reinforcements) the tests listed in 2.10.3 are to be conducted in the 0°, 90° directions and in any other reinforcement direction.

2.10.5 Additionally, the tests listed in 2.10.3 are to be repeated after immersion in fresh water at 35°C for 28 days. For anisotropic materials, the requirement is for this test to be carried out in one direction only.

2.10.6 The shear properties (of the resin filled system) are to be determined according to 3.8.1.

2.11 Machinery chocking compounds (resin chocks)

2.11.1 Thermosetting materials for filling the space between the base of machinery and its foundation where the maintenance of accurate alignment is necessary are to be approved by LR before use.

2.11.2 Approval will be considered by LR for use under the following service conditions:
- Loading of 3,5 N/mm^2 (max) for a temperature not exceeding 60°C.
- Loading of 2,5 N/mm^2 (max) for a temperature not exceeding 80°C.
- Other loading conditions.

2.11.3 The exotherm temperature, defined as the maximum temperature achieved by the reacting resin under conditions equivalent to those of intended use, is to be determined according to a procedure approved by LR.

2.11.4 The following properties are to be determined on chock material cured at the measured exotherm temperature:
(a) The impact resistance (Izod).
(b) Hardness.
(c) Compressive strength (stress at maximum load) and modulus of elasticity.
(d) Water absorption.
(e) Oil absorption.
(f) Heat deflection temperature.
(g) Compressive creep is to be measured according to 3.9.4.
(h) Curing linear shrinkage.
(j) Flammability.

2.11.5 The chocking compound approval is contingent on the material achieving the minimum exotherm value as specified when used on an installation under practical conditions.

2.11.6 Where the resin chock is to be used for installation of sterntubes and sternbushes in addition to the requirements of 2.11.4, the tensile strength and modulus of elasticity in tension are to be measured.

2.11.7 The manufacturer's installation procedure is required to be documented and is to be to the satisfaction of LR.

2.12 Rudder and pintle bearings

2.12.1 Materials used for rudder and pintle bearings are to be approved by LR before use.

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2.12.2 Initial approval is to be based on a review of the following physical properties of the material:

(a) Compressive strength (stress at maximum load) and modulus of elasticity.
(b) Tensile strength (stress at maximum load) and modulus of elasticity.
(c) Shear strength (stress at maximum load).
(d) Impact strength.
(e) Swelling in oil and in water.
(f) Hardness.

2.12.3 Additionally, friction data is to be provided under both wet and dry conditions.

2.12.4 Furthermore, the installation instructions (especially recommended clearances) are to be reviewed by LR prior to provisional approval being given.

2.12.5 If the above data is satisfactory, the material will be provisionally approved until sufficient service experience has been gained.

2.13 Sterntube bearings

2.13.1 Materials used for sterntube bearings are to be approved by LR before use.

2.13.2 Approval is to be based on a review of the physical properties as given by 2.12.2.

2.13.3 Friction data is to be provided under the lubrication system(s) proposed for the material(s).

2.14 Plywoods

2.14.1 All plywoods are to be approved to BS 1088 or equivalent National or International Standard in accordance with LR's Type Approval Procedure.

2.14.2 For structural applications in the marine environment, a minimum timber rating of moderate durability according to BS 1088 is required.

2.14.3 Enhancement of durability by use of preservatives is permitted, subject to each veneer layer being treated with a recognised preservative.

2.14.4 Where Okoume, as specified by BS 1088 is involved, (i.e. non-durable timber classification) this may only be used for marine structures subject to the specific application being acceptable to LR.

2.15 Adhesive and sealant materials

2.15.1 Materials of these types are to be accepted by LR before use.

2.15.2 The requirements for acceptance are dependent on the nature of the application.

2.15.3 In the first instance, the manufacturer is to submit full details of the product, procedure for method of use (including surface preparation) and the intended application. After review of these details, LR will provide a specific test schedule for confirmation of the material's properties.

2.15.4 Any acceptance granted will be limited to specific applications and will be contingent on the instructions for use being adhered to.

2.16 Repair compounds

2.16.1 Materials used for repairs are to be accepted by LR before use.

2.16.2 For acceptance purposes, the manufacturer is to submit full product details, and user instructions, listing the types of repair for which the system is to be used together with details of any installer accreditation schemes.

2.16.3 Dependent on the proposed uses, LR may require testing in accordance with a specified test programme.

2.16.4 Materials will not be accepted for the following uses unless specific evidence of their suitability is provided:

(a) Any component in rubbing contact.
(b) Any component subject to dynamic cyclic loading.
(c) Any pressure part in contact with gas or vapour.
(d) Any pressure part in contact with liquid above 3,5 bar.
(e) Any component where operating temperature exceeds 90°C.

All uses of materials of these types are subject to the discretion of the Surveyor.

■ *Section 3* Testing procedures

3.1 General

3.1.1 This Section gives details of the test methods to be used for base materials and on finished plastics products such as fibre reinforced plastics (FRP) piping and any testing required in the construction of composite vessels.

3.1.2 In general, testing is to be carried out by a competent independent test house which, at the discretion of LR, may or may not require witnessing by the Surveyor.

3.1.3 Alternatively, testing may be carried out by the manufacturer subject to these tests being witnessed by the Surveyor.

3.1.4 All testing is to be carried out by competent personnel.

3.1.5 Unless specified otherwise, testing is to be carried out in accordance with a recognised ISO Standard, where one exists, and all test programmes are to have written procedures.

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3.1.6 Alternatively, testing may be carried out in accordance with a National Standard provided that it conforms closely to an appropriate ISO standard and subject to prior agreement with the Surveyor.

3.1.7 Mechanical properties are to be established using suitable testing machines of approved types. The machines and other test equipment are to be maintained in a satisfactory and accurate condition and are to be recalibrated at approximately annual intervals. Calibration is to be undertaken by a nationally recognised authority or other organisation of standing and is to be to the satisfaction of the Surveyor. A record of all calibrations is to be kept available in the test house. The accuracy of test machines is to be within ±one per cent.

3.2 Preparation of test samples

3.2.1 Thermoplastic samples are to be prepared in accordance with the manufacturer's recommendations for moulding. For finished products, samples are to be taken from the product during production in accordance with the manufacturer's quality plan, but where this is impractical, separate test samples are to be prepared in a manner identical with that of the product.

3.2.2 Samples of thermosetting resins are to be prepared using the curing system recommended by the manufacturer and identical with that used for the finished product.

3.2.3 The post curing conditions for samples of thermosetting resins are to be as recommended by the manufacturer and identical with those used for the finished product. Where the samples are made for the general approval of a resin, the post curing conditions are to be those in which the resin is intended to be used.

3.2.4 Where curing of the product is intended to take place at room temperature, the sample is to be allowed to cure at room temperature (18 to 21°C) for 24 hours followed by a post-cure at 40°C for 16 hours.

3.2.5 Where a reinforcement is to be used, the ratio of reinforcement to resin or polymer is to be nominally the same as that of the finished product or in accordance with Table 14.2.2 or 14.2.3.

3.2.6 Where laminates are prepared specifically for approval test purposes, the reinforcement is to be laid parallel plied.

3.3 Preparation of test specimens

3.3.1 The test specimen is to be prepared in accordance with the appropriate ISO standard and the requirements of this Section.

3.3.2 Precautions are to be taken during machining to ensure that the temperature rise in the specimen is kept to a minimum.

3.4 Testing

3.4.1 Strain measurement is to be made by the use of a suitable extensometer or strain gauge.

3.4.2 The rate of strain is to be in accordance with the appropriate ISO standard.

3.4.3 The number of test specimens from each sample to be tested is to be in accordance with the ISO standard. For mechanical testing this is five.

3.5 Discarding of test specimens

3.5.1 If a test specimen fails because of faulty preparation or incorrect operation of the testing machine, it is to be discarded and replaced by a new specimen.

3.5.2 In addition, if the deviation of one result in a group of five exceeds the mean by more than two standard deviations, that result is to be discarded and one further specimen tested, *see* 1.8.1 and 1.8.2.

3.6 Reporting of results

3.6.1 All load/displacement graphs and tabulated results are to be reported, including mean values and the calculated standard deviation.

3.6.2 Additionally, full details of the sample and specimen preparation are to be provided including (where applicable):
(a) Catalyst/accelerator or curing agent types and mix ratio.
(b) Weights of resins, and/or reinforcements used.
(c) Casting/laminate dimensions.
(d) Number of layers of reinforcement used.
(e) Curing/post-curing conditions.

3.7 Tests for specific materials

3.7.1 The data requirements in 2.2 and 2.3 for thermoplastic or thermosetting resins or polymers are to be determined in accordance with suitable National or International Standards.

3.7.2 Recognised Standards to which specimens of unreinforced thermoplastic resins are to be tested are listed in Table 14.3.1.

3.7.3 Test standards for unreinforced cast thermosetting resins are given in Table 14.3.2.

3.7.4 The Standards to which laminate specimens of any type are to be tested are listed in Table 14.3.3.

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Table 14.3.1 Tests for unreinforced thermoplastic resins

Test	Standard	
Tensile properties	ISO 527-2:1993	Test speed = 5 mm/min Specimen 1A or 1B
Flexural properties	ISO 178:2001	Test speed = $\frac{\text{Thickness}}{2}$ mm/min
Water absorption	ISO 62:2008	Method 1
Temperature of deflection under load	ISO 75-2:2004	Method A
Compressive properties	ISO 604:2002	Test speed – as for ductile materials

NOTES
1. Water absorption – result to be expressed as milligrams.
2. Tensile modulus values are to be determined using an extensometer which may be removed for strain to failure.

Table 14.3.2 Tests on unreinforced cast thermoset resin specimens

Test	Standard	
Tensile properties	ISO 527-2:1993	Test speed = 5 mm/min Specimen 1A or 1B
Flexural properties	ISO 178:2001	Test speed = $\frac{\text{Thickness}}{2}$ mm/min
Water absorption	ISO 62:2008	Method 1
Temperature of deflection under load	ISO 75-2:2004	Method A
Compressive properties	ISO 604:2002	Test speed = 1 mm/min

NOTES
1. ISO 62:2008 – where resins are intended for use under ambient conditions to avoid additional post-curing, the requirement in ISO 62:2008 for pre-drying the test specimen at 50°C is to be omitted. The test result is to be expressed as mg of water.
2. ISO 527-2:1993 – tensile properties are to be measured using extensometry.

Table 14.3.3 Tests on laminate specimens

Test	Standard	
Tensile properties	ISO 527-4:1997	Test speed = 2 mm/min Specimens Types II or III
Flexural properties	ISO 14125:1998	Test speed = $\frac{\text{Thickness}}{2}$ mm/min Method A
Compressive properties	ISO 604:2002	Test speed = 1 mm/min
Interlaminar shear	ISO 14130:1997	
Water absorption	ISO 62:2008	Method 1
Glass content	ISO 1172:1996	

NOTES
1. ISO 62:2008 – where resins are intended for use under ambient conditions to avoid additional post-curing, the requirement in ISO 62:2008 for pre-drying the test specimen at 50°C is to be omitted. The test result is to be expressed as mg of water.
2. ISO 527-4:1997 – tensile properties are to be measured using extensometry.
3. Tensile modulus values are to be determined using an extensometer which may be removed for strain to failure.

3.8 Structural core materials

3.8.1 Initially, the core shear strength and modulus are to be determined by ISO 1922:2001 or ASTM C273/C273M. Test sandwich panels are then to be prepared and subjected to four-point flexural tests to determine the apparent shear properties according to ASTM C393/C393M:06 (short beam) at two representative thicknesses (i.e., 15 mm and 30 mm). Testing is to be carried out at ambient temperature and at 70°C. The following requirements are to be observed:

(a) Each skin is to be identical and have a thickness not greater than 21 per cent of the nominal core thickness. For hand laid constructions, each skin is to comprise a lightweight chopped strand mat reinforcement (300 g/m^2) consolidated at a glass content, by weight, of 0,3 against the core, plus the required number of woven reinforcements consolidated, using an isophthalic polyester resin, to give a minimum glass content, by weight, of 0,5.

(b) The method of construction of the sandwich laminate is to reflect the core material manufacturer's instructions for use, i.e., application of bonding paste, surface primer or any other recommended system.

(c) Where vacuum bagging techniques or equivalent systems are used, these will be subject to individual consideration.

(d) All resins and reinforcements are to hold current LR approval.

(e) Curing conditions are to be in accordance with 3.2.3 and 3.2.4.

(f) The dimensions of the test samples should be based on the requirements of ASTM C393 Paragraph 5.1, and the ratio parameters as indicated in ASTM C393 Paragraph 5.2, using a proportional limit stress (F) for the woven roving skins of 130 N/mm^2 and a span (a_2) of not less than 400 mm.

3.8.2 For each type of test sample, the following data are to be reported, together with the submission of a representative test sample showing the mode of failure for each density of core material:

(a) Skin and core thickness, and core type and density.

(b) Resin/catalyst/accelerator ratio.

(c) Skin construction, including types and weight of reinforcements, resin(s), etc.

(d) Details of production method and curing conditions (temperature and times).

(e) Where additional preparation of the foam is involved, for example the use of primers or bonding pastes, full details are to be provided.

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(f) Actual span between base supports for each type of test sample.

3.8.3 The following requirements apply to end-grain balsa:

(a) The data requirements of 2.7.1 are to be provided, where applicable, according to suitable National or International Standards.

(b) The balsa is to be tested according to the requirements of 3.8.1.

(c) The test methods for balsa are given in Table 14.3.4.

Table 14.3.4 Tests on end-grain balsa

Test	Standard
Density	ISO 845:2006
Tensile properties	ASTM C297/C297M:04 Test speed = $\frac{\text{Thickness}}{10}$ mm/min
Compressive properties	ISO 844:2007 Test speed = $\frac{\text{Thickness}}{10}$ mm/min
Shear properties	ISO 1922:2001 Test speed = 1mm/min

3.8.4 The following requirements apply to rigid foams:

(a) The data requirements of 2.7.1 are to be provided in accordance with a suitable National or International Standard.

(b) The foam is to be tested according to the requirements of 3.8.1.

(c) The test methods for rigid foams are to be in accordance with Table 14.3.4.

3.8.5 The following requirements apply to synthetic felt type materials:

(a) The data requirements of 2.10.1 are to be provided according to suitable National or International Standards.

(b) The material is to be tested according to the requirements of 3.8.1, with the following modifications:

(i) The core of the laminate test sandwich panel is to be prepared with a fibre content as recommended by the manufacturer.

(ii) The felt fibre/resin ratio is to be stated.

(iii) The required test thicknesses of the cores are to be changed from 30 mm and 15 mm to 12 mm and 6 mm respectively.

(c) The prepared laminate of the base material is to be of minimum thickness 3,5 mm with a minimum of three layers.

(d) The specified tests on the laminate (*see* 2.10.3) are to be conducted according to the requirements of Table 14.3.3.

3.9 Machinery chocking compounds

3.9.1 Test samples of the cured chock resin are to be prepared under ambient conditions and then post-cured at the exotherm temperature as determined in 2.11.3.

3.9.2 The specified properties are to be determined as required by Table 14.3.5.

Table 14.3.5 Tests for machinery chocking compounds

Test	Standard
Izod Impact Resistance	ISO 180-2000 Unnotched
Barcol hardness	ASTM D2583-07 or BS 2782 part 10 Method 1001
Compressive strength	ISO 604:2002 Test speed = 1 mm/min
Water absorption	ISO 62:2008 Method 1 25 mm x 20 mm cylinder (to constant weight)
Oil absorption (light machine)	ISO 175:1999 25 mm x 20 mm cylinder (to constant weight)
Temperature of deflection under load	ISO 75-2 Method A

3.9.3 The percentage linear shrinkage of cured material is to be measured.

3.9.4 Creep is to be measured according to the following method:

(a) A 25 mm x 20 mm diameter parallel faced cylinder is to be pre-loaded against a steel base at 2,5 N/mm^2 or 3,5 N/mm^2, or at the specified higher loading condition, at ambient temperature for 16 hours.

(b) The temperature is to be increased at the rate of 8°C per hour until the service temperature (60°C or 80°C) is reached.

(c) During this time, the creep of the cylinder is to be measured at 15 minute intervals.

(d) The temperature and loading are to be maintained for a minimum of 100 days measuring the creep at intervals of 24 hours.

(e) A plot of creep in mm (linear scale) against time (log scale), together with full experimental details, is to be provided for review by LR.

3.10 Rudder and pintle bearings

3.10.1 All mechanical properties as required by 2.12 are to be measured according to suitable National or International Standards.

3.10.2 Frictional properties are to be determined according to a method agreed with LR.

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3.11 Sterntube bearings

3.11.1 The requirements for sterntube bearings are as defined in 2.13.

■ *Section 4*
Plastics pipes and fittings

4.1 Scope

4.1.1 This Section gives the general requirements for plastics pipes and fittings, with or without reinforcement, intended for use in the services listed in the relevant Rules dealing with design and construction. Hoses and mechanical couplings are not covered by these requirements.

4.1.2 Pipes and fittings intended for application in Class I, Class II and Class III systems for which there are Rule requirements, are to be manufactured in accordance with the requirements of Section 1 and this Section.

4.1.3 As an alternative to 4.1.2, plastics pipes and fittings which comply with National or proprietary specifications may be accepted, provided that the specifications give reasonable equivalence to the requirements of this Section or, alternatively, are approved for a specific application. The survey and certification are however to be carried out in accordance with the requirements of this Section.

4.2 Design requirements

4.2.1 The requirements for design approval are detailed in the relevant Rules.

4.2.2 The design submission is to include a materials list with confirmation that the materials listed have properties and characteristics conforming with those values used in the design submission. As a minimum, the details given should include the following:

(a) Resin.
(b) Accelerator (type and concentration).
(c) Catalyst or curing agent (type and concentration).
(d) Reinforcement.
(e) Cure/post-cure conditions.
(f) Resin/reinforcement ratio.
(g) Wind angle (or lay-up sequence) and orientation.
(h) Dimensions and tolerances.

This submission is to include similar details for the fittings together with a description of the method of attachment of the fittings to the pipes.

4.2.3 Any alteration of the component materials or manufacturing operations from those used in the design submission will necessitate a completely new submission.

4.2.4 If the piping manufacturer anticipates the possible use of alternative materials, these should be listed in the design submission. Proof that the modified product will meet the specified requirements will be needed prior to its use.

4.3 Manufacture

4.3.1 Plastics pipes and fittings intended for use in Class I, Class II and Class III systems are to be manufactured at facilities approved by LR, using materials approved by LR.

4.3.2 A Manufacturing Specification is to be submitted. This is to contain details of the following:

(a) All constituent materials.
(b) Manufacturing procedures such as lay-up sequence or wind angle, the ratios of curing agent to resin and reinforcement to resin, the laminate thickness, the mandrel dwell time (initial cure) and the cure and post-cure conditions.
(c) Quality control procedures including details and frequency of tests on the incoming materials, tests made during production and on the finished piping.
(d) Acceptance standards and tolerances, including all dimensions.
(e) Procedures for cosmetic repair.
(f) System for traceability of the finished piping to the batches of raw materials.
(g) Method of bonding pipes and fittings.

4.3.3 Details of all raw materials are to be submitted for approval and are to be in accordance with the Manufacturing Specification and the design submission.

4.3.4 All batches of raw materials are to be provided with unique identifications by their manufacturers.

4.3.5 No batch of material is to be used later than its date of expiry.

4.3.6 The piping manufacturer is to ensure that all batches of materials are used sequentially.

4.3.7 The piping manufacturer is to maintain records of the amounts of resin and reinforcement used, in order to ensure that the proportions remain within the limits set in the Manufacturing Specification.

4.3.8 Records are to be kept of the wind angle and/or the orientation of the reinforcement.

4.3.9 The piping manufacturer is to ensure that each item of piping is traceable to the batch or batches of material used in its manufacture. The unique identifications referred to in 4.3.4 are to be included on all documents.

4.3.10 The curing oven is to be suitable for the intended purpose and all pyrometric equipment is to be calibrated at least annually and adequate records maintained.

4.3.11 The temperature of the pipe or fitting is to be controlled and recorded by the attachment of suitably placed thermocouples.

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4.4 Quality assurance

4.4.1 The piping manufacturer is to have a quality assurance system approved to ISO 9001 or equivalent. This system should ensure that the pipes and fittings are produced with uniform and consistent mechanical and physical properties in accordance with acceptable standards.

4.5 Dimensional tolerances

4.5.1 Dimensions and tolerances are to conform to the Manufacturing Specification.

4.5.2 The wall thicknesses of the pipes are to be measured at intervals around the circumference and along the length in accordance with an appropriate National Standard. The thicknesses are to accord with the Manufacturing Specification.

4.5.3 The responsibility for maintaining the required tolerances and making the necessary measurements rests with the manufacturer. Occasional checking by the Surveyor does not absolve the manufacturer from this responsibility.

4.6 Composition

4.6.1 The composition of the pipes and fittings is to be in accordance with the Manufacturing Specification.

4.6.2 Where alternative materials are used (*see* 4.2.4), the manufacturer is to demonstrate to the Surveyor's satisfaction, and prior to their introduction, their suitability with respect to the performance of the piping. Otherwise, full testing as specified in 4.7 will be required.

4.7 Testing

4.7.1 For thermoplastic pipes, the polymer manufacturer is to make the following measurements on samples taken from each batch:

(a) Melting point.
(b) Melt flow index.
(c) Density.
(d) Filler/pigment content, where applicable.
(e) Tensile stress at yield and break.
(f) Tensile strain at yield and break.

4.7.2 The values obtained are to be certified by the polymer manufacturer.

4.7.3 For reinforced thermoset pipes,the resin manufacturer is to determine, on samples taken from each batch, at least the following:

(a) All resins:
  (i) Viscosity.
  (ii) Gel time.
  (iii) Filler content, where applicable.
(b) Polyester resins:
  (i) Type (orthophthalic, isophthalic, etc.).
  (ii) Volatiles content.
  (iii) Acid value.
(c) Epoxide resins:
  (i) Free epoxide content.
(d) Phenolic resins:
  (i) Free phenol content.
  (ii) Free formaldehyde content.

4.7.4 The values obtained are to comply with the requirements of the Manufacturing Specification.

4.7.5 Where the resin manufacturer mixes batches, both the original batches and the mixed batch are to be tested in accordance with 4.7.1 to 4.7.3 as appropriate. The mixed batch is then to be given a unique batch number.

4.7.6 The polymer or resin manufacturer is to demonstrate that each batch of polymer or resin satisfies the requirement for temperature of deflection under load and this is not to be less than 80°C.

4.7.7 These measurements should be repeated on each batch by the piping manufacturer. Where this is not done, LR may require that the tests be made on a random basis by an independent laboratory.

4.7.8 The piping manufacturer is to confirm, by means of tests on at least one batch in twenty, that the temperature of deflection under load exceeds the specified minimum under manufacturing conditions.

4.7.9 Where reinforcements are used, at least the following are to be recorded, where applicable:

(a) Tex of yarn(s) or roving(s).
(b) Ends per 100 mm in all reinforcement orientations.
(c) Weight per square metre.
(d) Binder/size content.
(e) Stitch type and count.
(f) Type of fibre used.
(g) Surface treatment and/or finish.

4.7.10 All items in 4.7.9 are to comply with the Manufacturing Specification.

4.7.11 The piping manufacturer is to maintain accurate records of resin and glass usage and is to calculate the resin/glass ratio on an ongoing basis.

4.7.12 During manufacture of the piping, apart from the requirements of 4.7.5, 4.7.6 and 4.7.8, tests are to be carried out on the constituents and final product in accordance with Table 14.4.1.

4.7.13 The standards of acceptance are those listed in the Manufacturing Specification approved by LR.

4.7.14 At the Surveyor's discretion, sections of pipe are to be subjected to hydraulic bursting tests and/or measurements of axial strength.

4.7.15 If the batch of resin or polymer, or the curing agent, or their ratio is changed during manufacture of a batch of pipes, at least two additional measurements of the gel time are to be carried out during each shift.

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Table 14.4.1 Testing during manufacture of pipes

Component/ operation	Characteristic	Rate of testing
Resin/curing agent/catalyst	Gel time Rate of consumption	Two per shift Continuous
Reinforcement	Quality Wind angle Rate of consumption	Continuous Continuous Continuous
Resin/ reinforcement	Ratio	Continuous
Pipe	Post-cure: temperature of the pipe in oven	Continuous
	Cure level	At least eight per length
	Dimensions	Each length
	Hydraulic pressure test	Each length
	Electrical resistance	Each length (*see* Note)
	Hydraulic bursting test	At Surveyor's discretion
	Axial strength	At Surveyor's discretion

NOTE
Measurements of electrical resistance are only required on piping where the operating conditions given in Pt 5, Ch 12,5.2.4 of the *Rules and Regulations of the Classification of Ships* apply.

4.8 Visual examination

4.8.1 All pipes and fittings are to be visually examined and are to be free from surface defects and blemishes.

4.8.2 The pipes are to be reasonably straight and the cut ends are to be square to the axis of the pipe.

4.9 Hydraulic test

4.9.1 Each length of pipe is to be tested at a hydrostatic pressure not less than 1,5 times the rated pressure of the pipe.

4.9.2 The test pressure is to be maintained for sufficient time to permit proof and inspection. Unless otherwise agreed, the manufacturer's certificate of satisfactory hydraulic test, endorsed by the Surveyor, will be accepted.

4.10 Repair procedure

4.10.1 Repairs are not allowed, with the exception of minor cosmetic blemishes as detailed in 1.10.1.

4.10.2 A repair procedure for these minor blemishes is to be included in the Manufacturing Specification.

4.11 Identification

4.11.1 All piping is to be identified in such a manner that traceability to all the component materials used in its manufacture is ensured. The Surveyor is to be given full facilities for tracing the material when required.

4.11.2 Pipes and fittings are to be permanently marked by the manufacturer by moulding, hot stamping or by any other suitable method, such as printing, in accordance with 1.11. The markings are to include:
(a) Identification number, *see* 4.11.1.
(b) LR or Lloyd's Register, and the abbreviated name of LR's local office.
(c) Manufacturer's name or trademark.
(d) Pressure rating.
(e) Design standard.
(f) Material system with which the piping is made.
(g) Maximum service temperature.

4.12 Certification

4.12.1 The manufacturer is to provide the Surveyor with copies of the test certificates or shipping statements for all material which has been accepted.

4.12.2 Each test certificate is to contain the following particulars:
(a) Purchaser's name and order number.
(b) If known, the contract number for which the piping is intended.
(c) Address to which piping is despatched.
(d) Type and specification of material.
(e) Description and dimensions.
(f) Identification number, *see* 4.11.1.
(g) Test results.

■ *Section 5*
Control of material quality for composite construction

5.1 Scope

5.1.1 This Section gives the general requirements for control of material quality when used in the construction of composite craft.

5.1.2 For composite craft built under the Rules, the survey of materials is to be conducted in accordance with the requirements of Sections 1 to 3 and this Section.

5.2 Design submission

5.2.1 The requirements for design submission are detailed in the appropriate Part of the Rules which includes full information on composite materials.

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5.3 Construction

5.3.1 All constructions are to be carried out using materials approved or accepted by LR.

5.3.2 All materials are to be in accordance with the approved construction documentation.

5.3.3 All batches of materials are to be provided with unique identifications by their manufacturers. Components are to be similarly identified.

5.3.4 No batch of material is to be used later than its date of expiry.

5.3.5 The Builder is to ensure that all batches of materials are used systematically and sequentially.

5.3.6 The Builder is to maintain, on a continuous basis, records of the amounts of resin and reinforcement used, in order to ensure that the proportions remain within the limits set in the construction documentation.

5.3.7 Records are to be kept of the sequence and orientation of the reinforcements.

5.3.8 The Builder is to ensure that each section of the construction is traceable to the batch or batches of material used. The unique identifications required under 1.11.1 are to be included on all relevant quality control documentation.

5.3.9 Any curing system used is to be demonstrated as suitable for the intended purpose and all pyrometric equipment is to be calibrated at least annually and adequate records maintained.

5.3.10 The post-curing temperature is to be controlled and recorded by the attachment of suitably placed thermocouples.

5.4 Quality assurance

5.4.1 Where the Builder has a quality assurance system, this is to include the requirements of this Section.

5.5 Dimensional tolerances

5.5.1 Dimensions and tolerances are to conform to the approved construction documentation.

5.5.2 The thicknesses of the laminates are, in general, to be measured at not less than ten points, evenly distributed across the surface. In the case of large sections, at least ten evenly distributed measurements are to be taken in bands across the width at maximum spacing of two metres along the length.

5.5.3 The responsibility for maintaining the required tolerances and making the necessary measurements rests with the Builder. Monitoring and random checking by the Surveyor does not absolve the Builder from this responsibility.

5.5.4 Where ultrasonic thickness gauges are used, these are to be calibrated against an identical laminate (of measured thickness) to that on which the thickness measurement is to be carried out. If suitable pieces are not available from the construction, then a small sample of identical lay-up is to be prepared.

5.6 Material composition

5.6.1 The materials, prefabricated sections or components used are to be in accordance with the approved construction documentation.

5.6.2 Where alternative materials are used, these are to be of approved or accepted types and the manufacturer is to demonstrate to the Surveyor's satisfaction, prior to their introduction, their suitability with respect to performance, otherwise full testing as appropriate will be required.

5.7 Material testing

5.7.1 Where so required, the material manufacturer is to provide the purchaser with certificates of conformity for each batch of material supplied, indicating the relevant values specified in 5.7.4 to 5.7.8. These values are to comply with those specified by the approved construction documentation.

5.7.2 Where the Builders do not conduct verification testing of the information indicated in 5.7.4 to 5.7.8, they are to ensure that copies of all certificates of conformity (which must indicate the actual tested values) are obtained for all batches of materials received, and maintain accurate records. The Surveyor may at any time select a sample of a material for testing by an independent, where applicable, source and should such tests result in the material failing to meet the specification, then that batch will be rejected.

5.7.3 The following tests are to be carried out, where applicable, on receipt of any material:

(a) The consignment is to be divided into its respective batches and each batch is to be labelled accordingly.
(b) Each batch is to be visually examined for conformity with the batch number, visual quality and date of expiry.
(c) Each batch is to be separately labelled and stored separately.
(d) Each unit, within the batch, is to be labelled with the batch number.
(e) Records are to be maintained of the above and these are to be cross-referenced with the certificate of conformity for the material and/or the Builder's own test results.

5.7.4 For thermosetting resins, reinforced or otherwise, the resin manufacturer is to have determined, on samples taken from each batch, at least the following:

(a) All resins:
  (i) Viscosity.
  (ii) Gel time.
  (iii) Filler content, where applicable.
(b) Polyester and vinylester resins:
  (i) Type (orthophthalic, isophthalic, etc.).
  (ii) Volatiles content.
  (iii) Acid value.

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(c) Epoxide resins:
  (i) Free epoxide content.
(d) Phenolic resins:
  (i) Free phenol content.
  (ii) Free formaldehyde content.

5.7.5 For thermoplastics, the polymer manufacturer is to have made the following measurements on samples taken from each batch:
(a) Melting point.
(b) Melt flow index.
(c) Density.
(d) Filler/pigment content, where applicable.
(e) Tensile stress at yield and break.
(f) Tensile strain at yield and break.

5.7.6 Where the resin or polymer manufacturer mixes batches, both the original batches and the mixed batch are to be tested in accordance with 5.7.4 or 5.7.5 as appropriate. The mixed batch is then to be given a unique batch number.

5.7.7 For reinforcements, the material manufacturer is to have recorded, where applicable, the following for each batch of material:
(a) Tex of yarn(s) or roving(s).
(b) Ends per 100 mm in all reinforcement orientations.
(c) Weight per square metre.
(d) Binder/size content.
(e) Stitch type and count.
(f) Type of fibre used.
(g) Surface treatment and/or finish.

5.7.8 For core materials, the following properties are to be recorded by the manufacturer for each batch:
(a) Type of material.
(b) Density.
(c) Description (block, scrim mounted, grooved).
(d) Thickness and tolerance.
(e) Sheet/block dimensions.
(f) Surface treatment.
Together with the following mechanical properties:
In the case of rigid foams:
(g) Compressive strength (stress at maximum load) and modulus of elasticity.
(h) Core shear strength.In the case of end-grain balsa:
(j) Tensile strength (stress at maximum load).
(k) Compressive strength (stress at maximum load) and modulus of elasticity.

5.7.9 During construction, tests are to be carried out on the constituents and final product in accordance with Table 14.5.1.

5.7.10 The standards of acceptance for testing are those listed in the material manufacturer's specification, approved construction documentation or agreed quality control procedures as applicable.

5.7.11 Laminate fibre content is to be determined at the request of the Surveyor, in particular where the thickness measured does not correlate with the specified fibre content, by weight. This will, in general, result in additional reinforcement being required.

5.7.12 If the batch of resin or polymer, or the curing agent, or their ratio is changed, at least two additional measurements of the gel time are to be carried out during each shift.

5.8 Visual examination

5.8.1 All constructional mouldings and any components are to be visually examined and are to be free from surface defects and blemishes.

Table 14.5.1 Testing during construction

Component/operation	Characteristic	Rate of testing
Resin/curing agent/catalyst	Gel time	Two per shift
	Rate of consumption	Continuous
Reinforcement	Quality	Continuous
	Orientation	Continuous
	Rate of consumption	Continuous
Resin/reinforcement	Ratio	Continuous
Construction	Temperature during cure/post cure	Continuous
	Dimensions	Continuous against approved construction documentation
	Cure level (Barcol) against resin manufacturer's specification	At least one per square metre
	Laminate thickness	Continuous against material usage and approved construction documentation (*see also* 5.5.2 to 5.5.4)
	Laminate fibre content	At the Surveyor's request (*see* 5.7.11)

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5.9 Repair procedure

5.9.1 Repairs of minor cosmetic blemishes are permitted providing that these are brought to the attention of the Surveyor.

5.9.2 A repair procedure for these minor blemishes is to be included in the agreed quality control procedures.

5.9.3 Structural repairs are subject to individual consideration and full written details must be approved by the plan approval office prior to introduction.

5.10 Material identification

5.10.1 Records of the construction are to be kept in such a manner that traceability of all the component materials used is ensured. The Surveyor is to be given full facilities for tracing the material's origin when required.

5.10.2 Small representative samples of each batch of material are to be retained, these being suitably labelled to ensure traceability.

5.10.3 When so requested by the Surveyor, the Builder is to provide copies of all test data and/or manufacturers' certificates of conformity appertaining to any material used.

5.11 Minimum tested requirements for material approval

5.11.1 This Section provides the minimum property values required of a material for approval or acceptance by LR and are applicable to materials cured under ambient conditions.

5.11.2 **Gel coat resins**. When the cast resin is tested according to the requirements of 2.3, Table 14.5.2 gives the minimum values for the respective properties.

5.11.3 **Laminating resins**. When tested according to the requirements of 2.3 and 2.4, Tables 14.5.3 and 14.5.4 give the minimum properties for the cast resin and chopped strand mat laminate respectively.

5.11.4 When tested to the requirements of 2.4 for reinforcements, Table 14.5.5 gives the minimum properties for laminates.

5.11.5 Alternatively, materials may be approved by use of the actual tested values whereby the approval value shall equal the mean of the tested values minus twice the standard deviation of a minimum of five tested values.

5.12 Closed cell foams for core construction based on PVC or polyurethane

5.12.1 Table 14.5.6 gives minimum values for closed cell forms for core construction based on PVC or polyurethane.

5.12.2 Other types of foam will be subjected to individual consideration. A minimum core shear strength of 0,5 N/mm^2 is to be achieved.

Table 14.5.2 Gel coat resins, minimum property values

Properties	Minimum value
Tensile strength (stress at maximum load)	40 N/mm^2
Tensile stress at break	40 N/mm^2
Tensile strain at maximum load	2,5%
Modulus of elasticity in tension	As measured
Flexural strength (stress at maximum load)	80 N/mm^2
Modulus of elasticity in flexure	As measured
Barcol hardness	As measured at full cure
Water absorption	70 mg (max)

Table 14.5.3 Laminating resins, minimum property values

Properties	Minimum value
Tensile strength (stress at maximum load)	40 N/mm^2
Tensile stress at break	40 N/mm^2
Tensile strain at maximum load	2,0%
Modulus of elasticity in tension	As measured
Barcol hardness	As measured at full cure
Temperature of deflection under load	55°C
NOTE These minimum values are for the recommended glass content by weight of 0,3.	

5.13 End-grain balsa

5.13.1 Table 14.5.7 gives the minimum property requirement for end-grain balsa.

5.14 Synthetic chocking compounds

5.14.1 Table 14.5.8 gives the minimum property requirements for synthetic chocking compounds.

5.15 Other materials

5.15.1 All other materials will be subject to special consideration.

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Table 14.5.4 Laminating resins, minimum values for properties for CSM laminate at 0,3 glass fraction by weight

Properties	Minimum value
Tensile strength (stress at maximum load)	90 N/mm^2
Secant modulus at 0,25% and 0,5% strain respectively	6,9 kN/mm^2
Compressive strength (stress at maximum load)	125 N/mm^2
Compressive modulus	6,4 kN/mm^2
Flexural strength (stress at maximum load)	160 N/mm^2
Modulus of elasticity in flexure	5,7 kN/mm^2
Apparent interlaminar shear strength (*see* Note)	18 N/mm^2
Fibre content	As measured (0,3)
Water absorption	70 mg (max)

NOTE
Applicable only to the special test for environmental control resins.

Table 14.5.5 Laminates, minimum property requirements

Material type	Property	Value
Chopped strand mat	Tensile strength (stress at maximum load) (N/mm^2)	$200G_c + 30$
	Modulus of elasticity in tension (kN/mm^2)	$15G_c + 2,4$
Bi-directional reinforcement	Tensile strength (stress at maximum load) (N/mm^2)	$400G_c - 10$
	Modulus of elasticity in tension (kN/mm^2)	$30G_c - 0,5$
Uni-directional reinforcement	Tensile strength (stress at maximum load) (N/mm^2)	$1800G_c^2 - 1400G_c + 510$
	Modulus of elasticity in tension (kN/mm^2)	$130G_c^2 - 114G_c + 39$
Chopped strand mat	Flexural (stress at maximum load) (N/mm^2)	$502G_c^2 + 114,6$
	Modulus of elasticity in flexure (kN/mm^2)	$33,4G_c^2 + 2,7$
All	Flexural strength (stress at maximum load) (N/mm^2)	$502G_c^2 + 106,8$
	Modulus of elasticity in flexure (kN/mm^2)	$33,4G_c^2 + 2,2$
	Compressive strength (stress at maximum load) (N/mm^2)	$150G_c + 72$
	Compressive modulus (kN/mm^2)	$40G_c - 6$
	Interlaminar shear strength (N/mm^2)	$22 - 13,5G_c$ (min 15)
	Water absorption (mg)	70 (maximum)
	Glass content (% by weight)	As measured

NOTES
1. After water immersion, the values shall be a minimum of 75% of the above.
2. Where materials have reinforcement in more than two directions, the requirement will be subject to individual consideration dependent on the construction.
3. G_c = glass fraction by weight.

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Table 14.5.6 Minimum characteristics and mechanical properties of rigid expanded foams at 20°C

Material	Apparent density kg/m^3	Strength (stress at maximum load) (N/mm^2)			Modulus of elasticity (N/mm^2)	
		Tensile	Compressive	Shear	Compressive	Shear
Polyurethane	96	0,85	0,60	0,50	17,20	8,50
Polyvinylchloride	60					

Table 14.5.7 Minimum characteristics and mechanical properties of end-grain balsa

Apparent density (kg/m^3)	Strength (stress at maximum load) (N/mm^2)					Compressive modulus of elasticity (N/mm^2)		Shear modulus of elasticity (N/mm^2)
	Compressive		Tensile		Shear	Direction of stress		
	Direction of stress							
	Parallel to grain	Perpendicular to grain	Parallel to grain	Perpendicular to grain		Parallel to grain	Perpendicular to grain	
96	5,0	0,35	9,00	0,44	1,10	2300	35,2	105
144	10,6	0,57	14,6	0,70	1,64	3900	67,8	129
176	12,8	0,68	20,5	0,80	2,00	5300	89,6	145

Table 14.5.8 Minimum characteristics and mechanical properties of synthetic chocking compound

Properties	Minimum value
Izod Impact Resistance	0,8 J
Barcol hardness	40
Compression	100 MPa
Water absorption	0,05%
Oil absorption (light machine)	0,05%
Creep	< 0,2%

NOTES
1. Izod, barcol, compression, and water and oil absorption tests to be performed on samples cured/post-cured to the same condition as the samples for the final creep tests.
2. Minimum creep value to be attained for a stabilised sample after 1000 hours.

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General Requirements and Constructional Arrangements
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■ *Section 1* Rules application

1.1 General

1.1.1 The Rules apply to sea-going motor, sailing and auxiliary craft of normal form, proportions and speed, generally not exceeding a Rule length, L_R of 150 m.

1.2 Exceptions

1.2.1 Craft of unusual form, proportions or speed, or intended for the carriage of special cargoes, or for special or restricted service, not covered specifically by the Rules, will receive individual consideration based on the general standards of the Rules.

1.3 Loading

1.3.1 The Rules are framed on the understanding that craft will be properly loaded and handled; they do not, unless it is stated or implied in the class notation, provide for special distributions or concentrations of loading other than those included in the approved Loading Manual. The Committee may require additional strengthening to be fitted in any craft which, in their opinion, would otherwise be subjected to severe stresses due to particular features of the design, or where it is desired to make provision for exceptional load or ballast conditions.

1.4 Advisory services

1.4.1 The Rules do not cover certain technical characteristics, such as stability except as mentioned in Pt 1, Ch 2,1.1.11, 1.1.13 and 1.1.14, trim, vibration, docking arrangements, etc. The Committee cannot assume responsibility for these matters but is willing to advise upon them on request.

■ *Section 2* Direct calculations

2.1 General

2.1.1 Direct calculations may be specifically required by the Rules or may be required for craft having novel design features, as defined in 1.2, or may be submitted in support of alternative arrangements and scantlings. Lloyd's Register (hereinafter referred to as 'LR') may, when requested, undertake calculations on behalf of designers and make recommendations in regard to suitability of any required model tests.

2.1.2 Where model testing is undertaken to complement direct calculations the following details would normally be required to be submitted: Schedule of tests, details of test equipment, input data, analysis and calibration procedure together with tabulated and plotted output.

2.2 Submission of direct calculations

2.2.1 In cases where direct calculations have been carried out, the following supporting information should be submitted as applicable:

(a) Reference to the direct calculation procedure and technical program used.
(b) A description of the structural modelling.
(c) A summary of analysis parameters including properties and boundary conditions.
(d) Details of the loading conditions and the means of applying loads.
(e) A comprehensive summary of calculation results. Sample calculations should be submitted where appropriate.

2.2.2 In general, submission of large volumes of input and output data associated with such programs as finite element analysis will not be necessary.

2.2.3 The responsibility for error free specification and input of program data and the subsequent correct transposal of output rests with the Builder.

2.3 Global hull strength

2.3.1 Longitudinal strength calculations are to be submitted for all craft with a Rule length, L_R, exceeding that specified in Chapter 6, of Parts 6, 7 and 8, for steel, aluminium alloy and composite respectively, covering the range of load and ballast conditions proposed, in order to determine the required hull girder strength. Still water bending moments and shear forces are to be calculated for both departure and arrival conditions and for any special mid-voyage conditions caused by changes in ballast distribution.

2.3.2 Where the Rule length, L_R, does not exceed that indicated in 2.3.1, longitudinal strength calculations may be required at LR's discretion, dependent upon craft proportions, the proposed loading, structural configuration and material of construction.

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■ *Section 3* Equivalents

3.1 Alternative arrangements and scantlings

3.1.1 In addition to cases where direct calculations are specifically required by the Rules, LR will consider alternative arrangements and scantlings which have been derived by direct calculations in lieu of specific Rule requirements. All direct calculations are to be submitted for examination.

3.1.2 Where calculation procedures other than those available within the LR *Software Guide* are employed, supporting documentation is to be submitted for appraisal and this is to include details of the following:

- calculation methods;
- assumptions and references;
- loading;
- structural modelling;
- design criteria and their derivation, e.g. permissible stresses;
- factors of safety against plate panel instability, etc.

3.1.3 LR will be ready to consider the use of Builder's programs for direct calculations in the following cases:

(a) Where it can be established that the program has previously been satisfactorily used to perform a direct calculation similar to that now submitted.

(b) Where sufficient information and evidence of satisfactory performance is submitted to substantiate the validity of the computation performed by the program.

3.1.4 Alternative arrangements or fittings which are considered to be equivalent to the Rule requirements will be accepted.

3.1.5 Where no special reference is made in this Part to specific requirements, the construction is to be efficient for the intended purpose and to conform to good practice.

3.1.6 Where items are of a novel or unconventional design or manufacture, it is the responsibility of the Builder to demonstrate their suitability and equivalence to the Rule requirements.

3.1.7 Alternative arrangements which are in accordance with the requirements of a National Authority may be accepted as equivalent to the requirements of this Part of the Rules.

■ *Section 4* National and International Regulations

4.1 International Conventions

4.1.1 The Committee, when authorised, will act on behalf of Governments and, if requested, LR will certify compliance in respect of National and International statutory safety and other requirements for passenger and cargo craft.

4.1.2 In satisfying the Load Line Convention, the general structural strength of the craft is required to be sufficient for the draught corresponding to the freeboards to be assigned. Craft built and maintained in accordance with LR's Rules and Regulations possess adequate strength to satisfy the Load Line Convention. However, some National Authorities may, in addition, require to be supplied with calculations of bending moments and shear forces for certain conditions of loading.

4.2 International Association of Classification Societies (IACS)

4.2.1 Where applicable, the Rules take into account unified requirements and interpretations established by IACS.

4.3 International Maritime Organization (IMO)

4.3.1 Attention is drawn to the fact that Codes of Practice issued by IMO contain requirements which are outside the scope of classification as defined in these Rules and Regulations.

■ *Section 5* Information required

5.1 General

5.1.1 The categories and lists of information required are given in 5.2.

5.1.2 Plans are generally to be submitted in triplicate, but one copy only is necessary for supporting documents and calculations.

5.1.3 Plans are to contain all necessary information to fully define the structure, including construction details, equipment and systems as appropriate.

5.1.4 Additional requirements for individual craft types are given in subsequent Chapters.

5.2 Submission of plans and data

5.2.1 Plans and data required to be submitted are indicated in Parts 6, 7 and 8 for steel, aluminium alloy and composite construction respectively, as appropriate.

5.2.2 Where an ***IWS** (In-water Survey) notation is to be assigned, *see* Pt 1, Ch 2,3.8.2, plans and information covering the following items are to be submitted:

- Details showing how rudder pintle and bush clearances are to be measured and how the security of the pintles in their sockets are to be verified with the craft afloat.
- Details showing how stern bush clearances are to be measured with the craft afloat.
- Details of high resistant paint, for information only.

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5.3 Standard designs

5.3.1 Where a craft is a standard design produced in several versions, the plans and data are to clearly define the differences between each version.

5.3.2 Where the craft is a Builder's standard design to be built from previously approved plans and data, a schedule of applicable plans, etc., is to accompany the Request for Survey. Plans of any proposed modifications and changes to the previously approved plans are to be submitted for approval prior to the commencement of any work.

5.3.3 Plan approval of standard designs is only valid so long as no applicable Rule changes take place. When the Rules are amended, the plans for standard types are to be submitted for re-approval.

5.4 Plans and data to be supplied to the craft

5.4.1 To facilitate the ordering of materials for repairs, plans are to be carried in the craft indicating the disposition and grades (other than Grade A) of hull structural steel, the extent and location of higher tensile steel together with details of specification and mechanical properties, and any recommendations for welding, working and treatment of these steels.

5.4.2 Similar information is to be provided when aluminium alloy, fibre composite or other materials are used in the hull construction.

5.4.3 A copy of the final Loading Manual, (where applicable) when approved, and details of the loadings applicable to approved decks, hatch covers and inner bottom are to be placed on board the craft.

5.4.4 Details of any corrosion control system fitted are to be placed on board the craft.

5.4.5 Copies of main scantling plans are to be placed on board.

5.4.6 Where an ***IWS** (In-water Survey) notation is to be assigned, approved plans and information covering the items detailed in 5.2.2 are to be placed on board.

5.5 Fire protection, detection and extinction

5.5.1 For information and plans required, *see* Part 17.

■ *Section 6* Definitions

6.1 General

6.1.1 The following definitions apply except where they are inappropriate or where specifically defined otherwise.

6.2 Principal particulars

6.2.1 **Rule length**, L_R, is the distance, in metres, on the summer load waterline from the forward side of the stem to the after side of the rudder post or to the centre of the rudder stock if there is no rudder post. L_R is to be not less than 96 per cent, and need not be greater than 97 per cent, of the extreme length on the summer load waterline. In craft without rudders, the Rule length, L_R, is to be taken as 97 per cent of the extreme length on the summer load waterline. In craft with unusual stem or stern arrangements the Rule length, L_R, will be specially considered.

6.2.2 **Length between perpendiculars**, L_{pp}, is the distance, in metres, on the summer load waterline from the fore side of the stem to the after side of the rudder post, or to the centre of the rudder stock if there is no rudder post. In craft with unusual stern arrangements the length, L_{pp}, will be specially considered. The forward perpendicular, F.P., is the perpendicular at the intersection of the summer load waterline with the fore side of the stem. The after perpendicular, A.P., is the perpendicular at the intersection of the summer load waterline with the after side of the rudder post or to the centre of the rudder stock for craft without a rudder post.

6.2.3 **Load line length**, L_L, is to be taken as 96 per cent of the total length on a waterline at 85 per cent of the least moulded depth measured from the top of the keel, or as the length from the fore side of the stem to the axis of the rudder stock on that waterline, if that is greater. In craft designed with a rake of keel, the waterline on which this length is measured is to be parallel to the designed waterline. The length L_L is to be measured in metres.

6.2.4 **Length overall**, L_{OA}, is the distance, in metres, measured parallel to the static load waterline from the foreside of the stem to the after side of the stern or transom, excluding rubbing strakes and other projections.

6.2.5 **Length waterline**, L_{WL}, is the distance, in metres, measured on the static load waterline from the foreside of the stem to the after side of the stern or transom.

6.2.6 **Amidships** is to be taken as the middle of the Rule length, L_R, measuring from the forward side of the stem.

6.2.7 **Breadth**, B, is the greatest moulded breadth, in metres, or, for craft of composite construction, the extreme breadth excluding rubbing strakes or other projections. For multi-hull craft it is to be taken as the sum of the breadths of the individual hulls.

6.2.8 **Depth**, D, is measured, in metres, at the middle of the Rule length, L_R, from top of keel to top of the deck beam at side on the uppermost continuous deck, or as defined in appropriate Chapters. When a rounded gunwale is arranged, the depth D is to be measured to the continuation of the moulded deck line at side.

6.2.9 **Draught**, T, is the summer draught, in metres, measured from top of keel.

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6.2.10 **Block coefficient,** C_b, is the moulded block coefficient at draught T corresponding to summer load waterline, based on Rule length L_R and moulded breadth B, as follows:

$$C_b = \frac{\text{moulded displacement (m}^3\text{) at draught } T}{L_R B T}$$

6.3 Freeboard deck

6.3.1 The freeboard deck is normally the uppermost complete deck exposed to weather and sea, which has permanent means of closing all openings in the weather part thereof, and below which all openings in the sides of the craft are fitted with permanent means of watertight closing. It is the deck from which the freeboard is measured.

6.4 Bulkhead deck

6.4.1 Bulkhead deck is the uppermost deck up to which the transverse watertight bulkheads are carried.

6.5 Strength deck

6.5.1 Strength deck is normally the uppermost continuous deck. Other decks may be considered as the strength deck provided that such decks are structurally effective.

6.6 Weather deck

6.6.1 A weather deck is a deck which is exposed to sea and weather loads.

6.6.2 The weather deck is the lowest continuous deck exposed to sea and weather loads, and is not to be taken lower than the bulkhead deck for the determination of the requirements for closing appliances from Chapter 4.

6.7 Wet deck

6.7.1 A wet deck is the lower most exposed surface of the cross-deck structure, connecting the hulls of a multi-hull craft.

6.8 Weathertight

6.8.1 A closing appliance is considered weathertight if it is designed to prevent the passage of water into the craft in any sea conditions.

6.8.2 Generally, all openings in the freeboard deck and in enclosed superstructures are to be provided with weathertight closing appliances.

6.9 Watertight

6.9.1 A closing appliance is considered watertight if it is designed to prevent the passage of water in either direction under a head of water for which the surrounding structure is designed.

6.9.2 Generally, all openings below the freeboard deck in the outer shell/envelope (and in main bulkheads) are to be fitted with permanent means of watertight closing.

6.10 Position 1 and Position 2

6.10.1 For the purpose of Load Line Conditions of Assignment, there are two basic positions of hatchways, doorways and ventilators defined as follows:

Position 1 — Upon exposed freeboard and raised quarterdecks, and exposed superstructure decks within the forward 0,25 of the Load Line length, L_L.

Position 2 — Upon exposed superstructure decks abaft the forward 0,25 of the load line length, L_L and located at least one standard height of superstructure above the freeboard deck.

Upon exposed superstructure decks within the forward 0,25 of the Load Line length, L_L and located at least two standard heights of superstructure above the freeboard deck.

6.11 Reference system

6.11.1 For hull reference purposes, the craft is divided into 21 equally spaced stations where Station 0 is the after perpendicular, Station 20 is the forward perpendicular, and Station 10 is mid-L_{pp}.

6.12 Co-ordinate system

6.12.1 Unless otherwise stated, the co-ordinate system is as shown in Fig. 1.6.1, that is, a right-hand co-ordinate system with the X axis positive forward, the Y axis positive to port and the Z axis positive upwards. Angular motions are considered positive in a clockwise direction about the X, Y or Z axes.

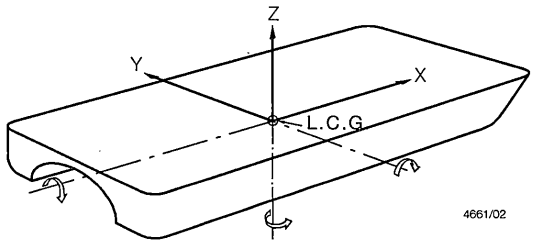

Fig. 1.6.1 Co-ordinate system

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6.13 Superstructure

6.13.1 A superstructure is defined as a decked structure on the freeboard deck, extending from side to side of the craft, or with the side plating being less than four per cent of the breadth, *B*, inboard of the shell plating.

6.13.2 An enclosed superstructure is a superstructure with:

(a) Enclosing bulkheads of efficient construction;
(b) Access openings, if any, in these bulkheads fitted with doors complying with the requirements of Ch 4,6.5;
(c) All other openings in sides or ends of the superstructure fitted with efficient weathertight means of closing.

6.13.3 The standard height of superstructure for L_L of 75 m or less is to be taken as 1,8 m, and for L_L of 125 m or greater is to be taken as 2,3 m. Intermediate values are to be determined by linear interpolation.

6.14 Deckhouse

6.14.1 A deckhouse is in general defined as a decked structure on or above the freeboard deck with side plating being four per cent or more of the breadth, *B*, inboard of the shell plating.

■ *Section 7*
Inspection, workmanship and testing procedures

7.1 General

7.1.1 The minimum requirements in respect of inspection, workmanship and testing are contained within Chapter 2, of Parts 6, 7 and 8, of the Rules for craft constructed in steel, aluminium alloy and composite respectively.

7.2 Construction standards

7.2.1 Construction standards for all materials are to be in accordance with National Standards or these Rules whichever are the higher.

7.2.2 The design requirements for welding and structural detail are to be found in Parts 6 and 7 of the Rules for craft constructed in steel and aluminium alloy respectively.

7.2.3 The design requirements for the bonding of all structural detail of composite materials are contained in Part 8.

7.3 Testing procedures

7.3.1 **Definitions.** For the purpose of these procedures the following definitions apply:

(a) **Protective coating** is the coating system applied to protect the structure from corrosion. This excludes the prefabrication primer.
(b) **Structural testing** is a hydrostatic test carried out to demonstrate the tightness of the tanks and the structural adequacy of the design. Where practical limitations prevail and hydrostatic testing is not feasible, hydro-pneumatic testing, *see* (e), may be carried out instead.
(c) **Leak testing** is an air or other medium test carried out to demonstrate the tightness of the structure.
(d) **Hose testing** is carried out to demonstrate the tightness of structural items not subjected to hydrostatic or leak testing, and other components which contribute to the watertight or weathertight integrity of the hull.
(e) **Hydropneumatic testing** is a combination of hydrostatic and air testing, consisting of filling the tank with water and applying an additional air pressure. The conditions are to simulate, as far as practicable, the actual loading of the tank and in no case is the air pressure to be less than given in 7.3.4.

7.3.2 **Application**. The testing requirements for tanks, including independent tanks, watertight and weathertight compartments, are listed in Table 1.7.1. Tests are to be carried out in the presence of the Surveyor at a stage sufficiently close to completion such that the strength and tightness are not subsequently impaired.

7.3.3 **Structural testing.** The attachment of fittings to oiltight surfaces is to be completed before tanks are structurally tested. Where it is intended to carry out structural tests after the protective coating has been applied welds are generally to be leak tested prior to the coating application.

For welds other than manual and automatic erection welds, manual fillet welds on tank boundaries and manual penetration welds, the leak test may be waived provided that careful visual inspection is carried out, to the satisfaction of the Surveyor, before the coating is applied. The cause of any discolouration or disturbance of the coating is to be ascertained, and any deficiencies repaired.

7.3.4 **Leak testing.** This is carried out by applying an efficient indicating liquid (e.g. soapy water solution) to the weld or outfitting penetration being tested, while the tank or compartment is subject to an air pressure of at least 0,15 bar (0,15 kgf/cm^2).

It is recommended that the air pressure be raised to 0,2 bar (0,2 kgf/cm^2) and kept at this level for about one hour to reach a stabilised state, with a minimum number of personnel in the vicinity, and then lowered to the test pressure prior to inspection. A U-tube filled with water to a height corresponding to the test pressure is to be fitted for verification and to avoid overpressure. The U-tube is to have a cross-section larger than that of the air supply pipe. In addition, the test pressure is to be verified by means of a pressure gauge, or alternative equivalent system.

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Table 1.7.1 Testing requirements

Item to be tested	Testing procedure	Testing requirement
Double bottom tanks	Structural (1)	The greater of: – head of water up to the top of the overflow – head of water up to the margin line – head of water representing the maximum pressure experienced in service
Cofferdams	Structural (1)	The greater of: – head of water up to the top of the overflow – 1,8 m head of water above highest point of tank (4)
Forepeak and aft peak used as tank(3)	Structural	
Tank bulkheads	Structural (1)	The greater of: – head of water up to the top of the overflow – 1,8 m head of water above the highest point of tank (4) – setting pressure of the safety valves, where relevant
Deep tanks	Structural (1)	
Scupper and discharge pipes in way of tanks	Structural (1)	
Double plate rudders	Structural (1), (5)	2,4 m head of water, and rudder should normally be tested while laid on its side
Watertight bulkheads, shaft tunnels, flats and recesses, etc.	Hose (2)	*See* 7.3.5
Watertight doors (below freeboard or bulkhead deck) when fitted in place	Hose (6)	
Weathertight hatch covers and closing appliances	Hose	
Forepeak not used as tank	Hose (2)	
Shell doors when fitted in place	Hose (7)	
Chain locker	Structural	The greater of: • head of water up to the top of the spurling pipe • head of water up to the exposed weather deck
Separate oil fuel tanks	Structural	Head of water representing the maximum pressure which could be experienced in service, but not less than 3,5 m
After peak not used as tank	Leak	*See* 7.3.4

NOTES
1. Leak or hydropneumatic testing may be accepted, provided that at least one tank of each type is structurally tested, to be selected in connection with the approval of the design. (*See also* 7.3.9 and 7.3.10).
2. When hose testing cannot be performed without damaging possible outfittings already installed, it may be replaced by a careful visual inspection of all the crossings and welded joints. Where necessary, dye penetrant test or ultrasonic leak test may be required.
3. Testing of the aft peak is to be carried out after the sterntube has been fitted.
4. The highest point of the tank is generally to exclude hatchways. In holds for liquid cargo or ballast with large hatch openings, the highest point of the tank is to be taken to the top of the hatch.
5. If leak or hydropneumatic testing is carried out, arrangements are to be made to ensure that no pressure in excess of 0,30 bar (0,30 kgf/cm^2) can be applied.
6. *See also* SOLAS Reg. II-1/16. Where the door has been subject to the full hydrostatic test before installation, the hose test may be replaced by careful visual examination.
7. For shell doors providing watertight closure, watertightness is to be demonstrated through prototype testing before installation. The testing procedure is to be agreed with LR.

For tanks constructed of steel or aluminium, leak testing is to be carried out, prior to the application of a protective coating, on all fillet welds and erection welds on tank boundaries, excepting welds made by automatic processes and on all outfitting penetrations.

Selected locations of automatic erection welds and pre-erection manual or automatic welds may also be required to be tested before coating, at the discretion of the Surveyor, taking account of the quality control procedures of the shipyard. Where exempt from this requirement, leak testing may be carried out after the protective coating has been applied, provided that the welds have been carefully inspected to the satisfaction of the Surveyor.

7.3.5 **Hose testing.** This is to be carried out at a maximum distance of 1,5 m with a hose pressure not less than 2,0 bar (2,0 kgf /cm^2). The nozzle diameter is not to be less than 12 mm. The jet is to be targeted directly onto the weld or seal being tested.

7.3.6 **Hydropneumatic testing.** When this is performed, the safety precautions identified in 7.3.4 are to be followed.

7.3.7 For tanks of composite construction, leak testing is to be carried out to air pressures as indicated in 7.3.4.

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7.3.8 Structural testing may be carried out afloat where testing using water is undesirable in dry-dock or on the building berth. The testing afloat is to be carried out by separately filling each tank and cofferdam to the test head given in Table 1.7.1. Alternate tanks and cofferdams may be filled to the test head and the bottom and lower side shell in the intermediate empty tanks and cofferdams and all boundaries are to be examined and the remainder of the bottom and lower side shell and boundaries examined when the water is transferred to the remaining tanks.

7.3.9 Where permitted by Table 1.7.1, complete structural testing may be replaced by a combination of leak and structural testing, as follows. The leak test is generally to be carried out on each tank while the craft is in dry-dock or on the building berth.

(a) Double bottom tanks and cofferdams may be leak tested on the berth, and structural tests carried out afloat.
(b) All deep tanks are to be structurally tested. However, where a number of similar tanks is involved, one typical tank is to be structurally tested and for the remaining tanks the Surveyor may, at his discretion, permit leak testing in lieu of structural testing.
(c) Interconnecting deep and double bottom tanks and 'flume' type stabilisation tanks are to be structurally tested to the test head given in Table 1.7.1.

7.3.10 Equivalent proposals for testing will be considered.

7.3.11 **Trial trip and operational tests**. The items listed in Table 1.7.2 are to be tested on completion of the installation or at sea trials.

Table 1.7.2 Trial trip and operational tests

Item	Requirement
Sliding watertight doors	To be operated under working conditions.
Windlass	An anchoring test is to be carried out in the presence of the Surveyor. The test is to demonstrate that the windlass with brakes, etc., functions satisfactorily and that the power to raise the anchor can be developed and satisfies the Rule requirements. For Rule requirements, *see* Ch 5,8.
Steering gear, main and auxiliary	To be tested under working conditions, to the satisfaction of the Surveyors, to demonstrate that the Rule requirements are met. For Rule requirements, *see* Pt 14, Ch 1.
Davits and deck cranes	To be tested under working conditions to proof load to the satisfaction of the Surveyors.
Fire flaps	To be operated under working conditions to the satisfaction of the Surveyors.
Means of escape	Alternative means of escape from machinery and accommodation spaces is to be proven to the satisfaction of the Surveyors. For Rule requirements, *see* Ch 2,4.10.

■ *Section 8* Building tolerances and associated repairs

8.1 Tolerances – General

8.1.1 Tolerances to be used regarding the acceptability of defects affecting raw materials are to be in accordance with 8.2.

8.1.2 Tolerances to be used for constructional misalignment for all materials are to be discussed between Owners/ Builders and the Surveyor and acceptable Standards agreed subject to the requirements of this Chapter or National Authority requirements where applicable. The permitted degree of inaccuracy/misalignment will vary according to whether the defect is:

(a) In primary structure.
(b) In secondary structure.
(c) Aesthetically pleasing.

8.1.3 The requirements in respect of constructional misalignment of steel/aluminium craft are to be found in 8.6. The requirements for construction using composite materials are contained in Pt 8, Ch 2.

8.2 Raw material surface tolerances

8.2.1 The surface cleanliness of steel/aluminium alloy materials in preparation for painting is to be in accordance with National or paint Manufacturer's Standards.

8.2.2 Where approved corrosion control coatings are to be used the quality of the surface treatment is to be in accordance with the grade specified in the approval documents.

8.3 Surface defects

8.3.1 The limits of depth and extent of surface defects on plate, cast or forged materials in relation to the material plate thickness are shown in Table 1.8.1.

8.3.2 Defects are to be made good by grinding only subject to the plate thickness not being reduced by more than seven per cent of the nominal thickness or 3 mm whichever is the lower, and the area involved not exceeding two per cent of the surface area.

8.3.3 When the limits in 8.3.1 are exceeded, plates may be made good by weld repair in accordance with the requirements specified in Chapter 13 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

8.3.4 Where the depth of the deepest imperfection exceeds 20 per cent of the nominal thickness, or the defective area exceeds two per cent of the total surface area, such areas are to be cropped and replaced. See 8.5.

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Table 1.8.1 Limits of surface defects

Normal thickness of material (mm)	Maximum permissible depth of defect (mm)	
	Area affected – Unlimited	Area affected ≤ 5% of Surface
< 8	0,2	0,4
8 to 25	0,3	0,5
25 to 40	0,4	0,6
≥ 40	0,5	0,8

NOTES
1. Defects are to be measured after shot blasting or plate cleaning.
2. The depth of the deepest imperfection is to be considered.
3. Defects not exceeding the limits shown need not be repaired.
4. Where the depth of the defect reduces the material thickness to below the rolling/forging/casting tolerance (stated in the Rules for Materials) the values in column 2 and 3 will be accepted provided the areas involved do not exceed 15% and 2% respectively, of the plate/forging/casting surface.
5. Defects exceeding the above limits are to be repaired.
6. Crack-like defects are always to be repaired irrespective of their depth.

8.3.5 Complete removal of the defects is to be verified by suitable non-destructive examination techniques and after welding the repair is to be proved free from further defects. The complete removal of defects is to be verified by non-destructive examination in accordance with the requirements specified in Chapter 13 of the Rules for Materials.

8.3.6 Care is to be taken in the repair of defects in higher tensile steel, and aluminium alloy materials. Low hydrogen electrodes with similar properties to the higher tensile steel is to be used with preheating as necessary. Aluminium alloys are to be heat treated after repair, *see* Pt 7, Ch 2,3.

8.4 Plate laminations

8.4.1 Plates in which laminations are suspected or detected are to be ultrasonically tested to determine the full extent of such laminations.

8.4.2 Where laminations are confined to the plate edge, are less than 300 mm long and whose penetration is not more than half the plate thickness, then the defect may be chipped or ground out and rebuilt with weld material.

8.4.3 Where laminations are isolated, located near to the plate surface, and where the total area of the defect does not exceed two per cent of the surface area of the plate, the defect may be repaired as in 8.4.2.

8.4.4 Defective plate, with defects in excess of those stated in 8.4.2 and 8.4.3, is to be cropped back and replaced. See 8.5.

8.4.5 Complete removal of the defect is to be verified by non-destructive examination, and after welding, the repair is to be proved free from further defects.

8.5 Part replacement of plates

8.5.1 When defects exceed the limits laid down in 8.3.4 and 8.4.4 above, the portion of the plate affected is to be cropped and replaced, *see* Table 1.8.2.

8.6 Structural misalignment and fit (steel and aluminium)

8.6.1 For the requirements for the alignment and structural continuity of joints, *see* Chapter 2 of Parts 6 and 7.

8.6.2 Tables 1.8.3, 1.8.4 and 1.8.5 define the minimum limits of accuracy required to be achieved in the various welded joint designs. When these values are not achieved, the defects are to be discussed and agreed by the Builder and the Surveyor before remedial action is taken.

8.6.3 Welding defects are generally to be dealt with in accordance with Chapter 13 of the Rules for Materials. Limits for weld undercut and remedial action to be taken depends on plate thickness and are to be discussed and agreed by the Builder and the Surveyor prior to commencement of repairs.

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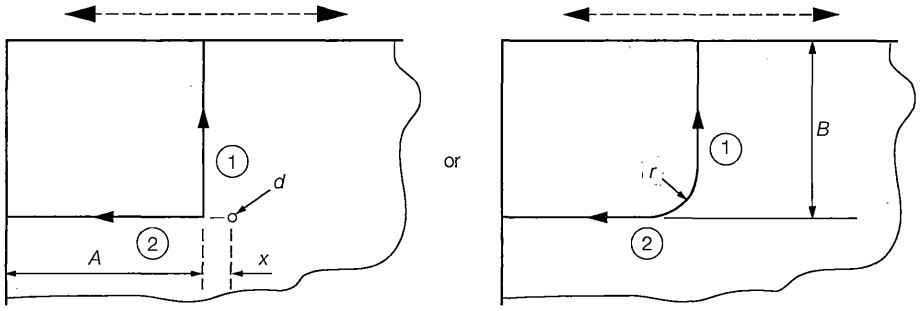
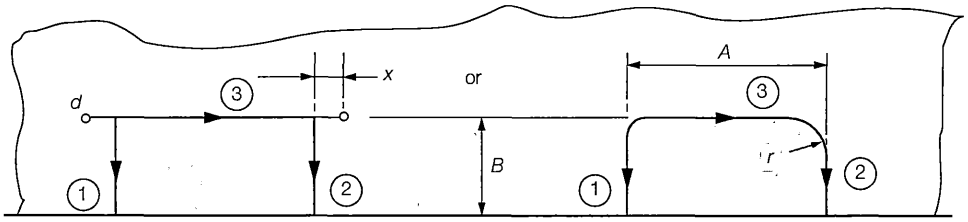
Table 1.8.2 Part replacement of plates

	Parts to be replaced	Shell, strength deck, tank top, top and bottom strakes of longitudinal bulkheads	Elsewhere
A x B	End and corner of plate	1000 x 1000	1000 x 300
	Side of plate	1000 x 300	1000 x 300
	Insert	1000 x 300	1000 x 300

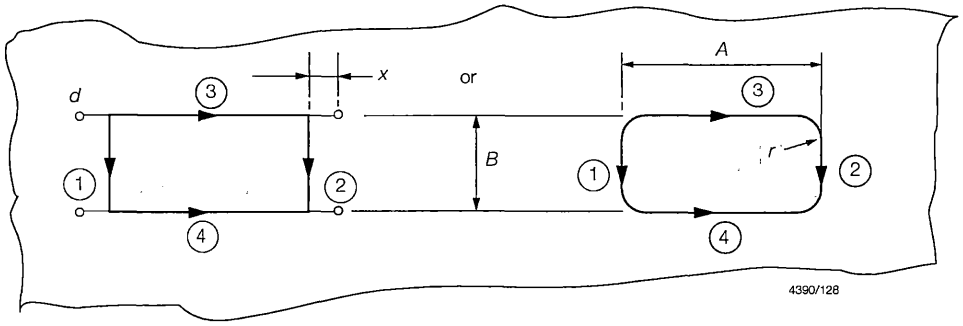
Line of plate replacement to be not less than 100 from extreme edge of defect.
All dimensions are in mm.



(a) Corner or end replacement



(b) Side replacement



(c) Internal replacement

(1) Weld sequence

Weld direction

Direction of principal stress

NOTES
1. All dimensions are minimum.
2. Rolling direction of replaced plate to be the same as that of the parent plate.
3. Minimum distance from outermost defect to line of weld – 100 mm.
4. Dimensions in millimetres:
   x = 50
   d = 1,5 x plate thickness with minimum 6 and maximum 20
   r = 75 minimum

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Table 1.8.3 Structural misalignment and fit (steel and aluminium)

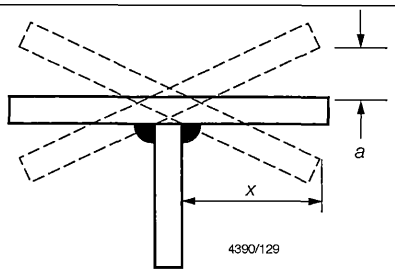
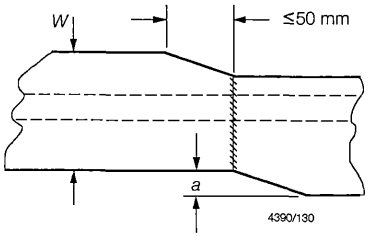
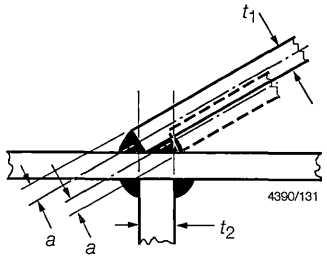
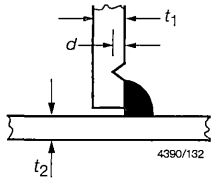
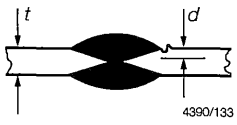
Joint	Location	Acceptable dimensions (mm)	Remedial action	
	Fabricated frames Beams, girders and longitudinals	$a \leq \pm 0{,}03$ x	$a > \pm 0{,}03$ x	Reject
	Butt welded face flats primary structure	$a \leq 0{,}03W$ (max 6 mm)	$a > 0{,}03W$	Reject
	Secondary structure	$a \leq 0{,}04W$ (max 8 mm)	$a > 0{,}04W$	Reject
	Obtuse angle fillet weld	$a \leq t_1/2$	$a > t_1/2$	Reject
	All areas	$d \leq 0{,}1t_1$ (max 0,8 mm)	$d > 0{,}1t_1$	Repair by welding or grinding depends on thickness 't_1' in accordance with 8.3
	All areas	$d \leq 0{,}1t$ (max 0,8 mm)	$d > 0{,}1t$	As above

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Table 1.8.4 Structural misalignment and fit (steel and aluminium)

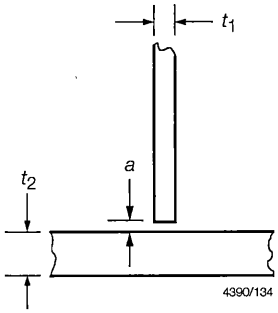
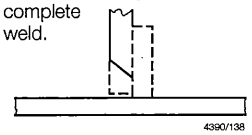
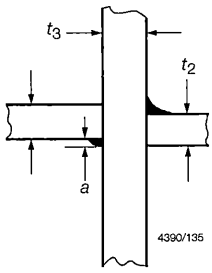
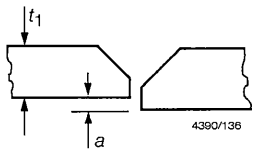
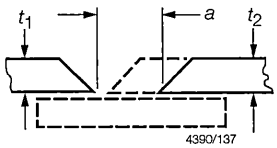
Joint	Location	Permitted misalignment	Remedial action	
	All areas (Continuous fillet weld)	a (mm) $a < 0{,}25t_1$ (max = 1 mm)	a (mm) $0{,}25t_1$ to $0{,}5t_1$ (t_1 max = 5 mm)	Increase weld leg length by 'a'
			$0{,}5t_1$ to t_1 (t_1 max = 15 mm)	Vee material to +/–45°. Fit backing strip and weld. Remove backing strip and complete weld. 
			$a > t_1$	Realign and replace
	All areas (intermittent weld)	$< 0{,}25t_1$	0,25 to $0{,}5t_1$ (t_1 max = 3 mm)	Increase weld lengths by 50%
			$0{,}25t_1$ to $0{,}5t_1$ (t_1 max = 5 mm)	Continuous weld
			$a > t_1$	As for continuous weld above
	Strength members	$a \le t_2/3$	$t_2/3 \le a \le t_1/2$	Increase weld leg length of welds by 10%
	Others	$a \le t_2/2$	$a > t_2/2$	Realign
	Higher tensile steel joint in designated critical areas	$a \le t_3/3$	$a > t_3/3$	Realign
	Strength members	$a \le 0{,}15t_1$ (max 3,0 mm)	$a > 0{,}15t_1$	Realign
	Others	$a \le 0{,}2t_1$ (max 3,0 mm)	$a > 0{,}2t_1$	Realign
	All areas	a in accordance with weld procedure	$a \le t_1$	Build one side of butt until a in accordance with weld procedure
			$a > t_1$ (max 10 mm)	Cut back 150 mm and fit insert plate

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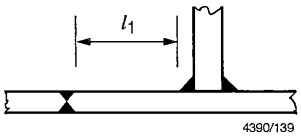
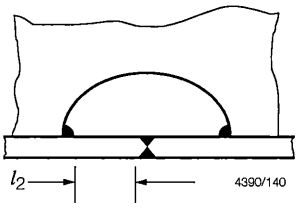
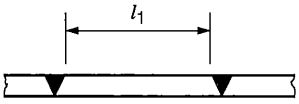
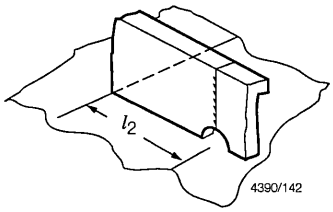
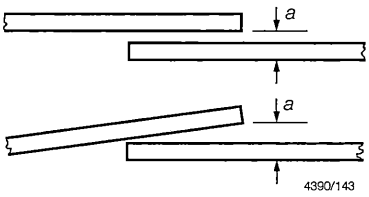
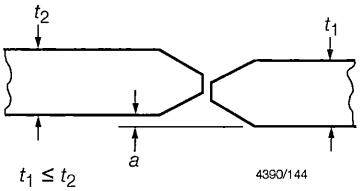
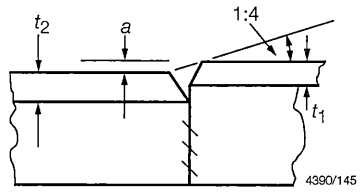
Table 1.8.5 Structural misalignment and fit (steel and aluminium)

Joint	Location	Acceptable dimensions (mm)	Remedial action	
	All	$l_1 \geq 40$ mm	—	Adjust to suit
	All	$l_2 \geq 20$ mm	—	Adjust to suit
	All	$l_1 > 50$ mm	$l_1 < 30$ mm	Treat as an insert
	All	$l_2 \geq 20$ mm	$l_2 < 15$ mm	Adjust to suit
	All All	$a \leq 1,0$ $a \leq 1,0$	$a < 5$ $a \leq 5$	Increase weld leg length by actual 'a' Adjust to suit
	Strength members Other	$a \leq 0,15t_1$ (max 3,0 mm) $a \leq 0,2t_1$ (max 3,0 mm)	$a > 0,15t_1$ $a > 0,2t_1$	Reject Reject
	All	For angle or tee longitudinal $a \leq 0,2t_1$ For offset bulb longitudinal $a \leq 0,2t_2$	$a > 0,2t_1$ $a > 0,2t_2$	Reject Reject

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8.7 Post welding plate deformation

8.7.1 Post welding plate deformation for steel and aluminium alloy construction is to be limited, *see* Table 1.8.6 and Fig. 1.8.1.

Table 1.8.6 Plate deformation limits

Position	*s/t*	δ_p/s
in 0,6*L* amidship	≤ 80 > 80	1/100 1/75
Remainder	all	1/50

Where
s = stiffener spacing, in mm
t = plating thickness, in mm
δ_p = panel deflection, in mm

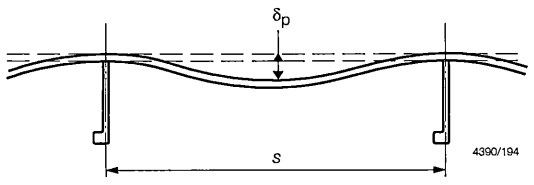

Fig. 1.8.1 Measurement of plate deformation

8.7.2 Deformation outside the limits of Fig. 1.8.1 is to be faired by local heating or the plating renewed.

8.7.3 Local heating of steel is not to exceed 900°C (red heat) when flame straightening is employed.

8.7.4 Local heating of aluminium alloys is not to be carried out. All repairs are to be by renewal of plating.

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Section

1 **General**

2 **Rule structural concept**

3 **Structural idealisation**

4 **Bulkhead arrangements**

5 **Fore and aft end arrangements**

6 **Machinery space arrangements**

7 **Superstructures, deckhouses and bulwarks**

8 **Particular requirements for multi-hulls**

9 **Navigation in ice**

Section 1 General

1.1 Application

1.1.1 This Chapter illustrates the general principles to be adopted in applying the structural requirements given in Parts 4, 6, 7 and 8. In particular, consideration has been given to the layout of the Rules as regards the different regions of the craft, principles for taper of hull scantlings, definition of span point, derivation of section moduli and basic design loading for deck structures. Principles for subdivision are also covered.

1.1.2 Where additional requirements relating to particular craft types apply, these requirements are indicated in the appropriate Parts and are to be complied with as necessary.

Section 2 Rule structural concept

2.1 General

2.1.1 The Rules are based on the concept that the structural and watertight integrity and general safe operation of the craft will not be compromised by static and dynamic loads experienced during normal operating conditions.

2.2 Scantlings

2.2.1 Scantlings are generally based on the strength required to withstand loads imposed by the sea, cargo, passengers, ballast, bunkers and other operational loads. However, the Rules assume that the nature and stowage of the cargo, ballast, etc., are such as to avoid excessive structural stress.

2.2.2 Design loads and pressures as given in Part 5, are to be used with scantling formulae or direct calculation methods to derive scantlings based on maximum allowable stress or other suitable strength criteria.

2.2.3 Hull structural vibration resulting from cyclic loadings arising from the sea and other sources are to be such that the normal operation and structural integrity of the craft are not impaired. However these aspects are outwith the scope of classification, *see* Pt 1, Ch 2,1.4.

2.3 Definition of requirements

2.3.1 Static loads are based on standard conditions defined in Part 5, or determined from loading conditions submitted by the Builder.

2.3.2 Dynamic loadings are examined for both the local and global structures. These loadings are based upon the designer's stated operational and environmental conditions or the Rule minimum criteria, whichever is the greater.

2.3.3 Wave induced loads are considered both in the static condition, i.e. hydrostatic and pitching pressures, and in the dynamic mode, i.e. impact, slamming and hogging and sagging wave landing conditions.

2.3.4 Hull girder strength will in general require to be investigated dependent upon the length, configuration, proportions, proposed loadings, etc., of the craft.

2.3.5 Scantling requirements in respect of miscellaneous items of structure such as local foundations, base plates, insert plates, etc., are not specifically indicated within these Rules. However the acceptance of such items will be specially considered on the basis of experience, good practice and direct calculation where appropriate.

2.4 Definitions and structural terms

2.4.1 The various definitions and structural terms for use throughout this Chapter are as indicated within the appropriate Section.

2.5 Symbols

2.5.1 The various symbols for use throughout this Chapter are as indicated within the appropriate Section.

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Section 3
Structural idealisation

3.1 General

3.1.1 The scantling formulae in the Rules are normally based on elastic or plastic theory using simple beam models supported at one or more points and with varying degrees of fixity at the ends, in association with an appropriate concentrated or distributed load for steel and aluminium craft.

3.1.2 Apart from a local requirement for web or flange thicknesses, the stiffener, beam or girder strength is defined by a section modulus and moment of inertia requirement.

3.1.3 For the derivation of scantlings for fibre composite structures, the formulae are based on equivalent load carrying capability, with limitations on both allowable stress and strain, in addition to deflection controls.

3.2 Geometric properties of sections

3.2.1 The symbols used in this sub-Section are defined as follows:

b = the actual width, in metres, of the load-bearing plating, i.e. one-half of the sum of spacings between parallel adjacent members or equivalent supports

$f = 0{,}3\left(\frac{l}{b}\right)^{2/3}$

but is not to exceed 1,0. Values of this factor are given in Table 2.3.1

l = the overall length, in metres, of the primary support member, as indicated in Fig. 3.1.2 in Pt 6, Ch 3 and Pt 7, Ch 3, respectively, for steel and aluminium alloy construction and Fig. 3.1.3 of Pt 8, Ch 3 for composite construction

t_p = the thickness, in mm, of the attached plating. Where this varies, the mean thickness over the appropriate span is to be used.

3.2.2 The effective geometric properties of rolled or built sections may be calculated directly from the dimensions of the section and associated effective area of attached plating. Where the web of the section is not normal to the attached plating, and the angle exceeds 20°, the properties of the section are to be determined about an axis parallel to the attached plating.

3.2.3 The geometric properties of rolled or built stiffener sections and of swedges are to be calculated in association with effective area of attached load bearing plating of thickness, t_p, mm and of width as given by Pt 6, Ch 3,1.10 or Pt 7, Ch 3,1.11 for steel and aluminium alloy construction respectively. In no case, however, is the width of plating to be taken as greater than either the spacing of the stiffeners or the width of the flat plating between swedges, whichever is appropriate. The thickness, t_p, is the actual thickness of the attached plating. Where this varies, the mean thickness over the appropriate span is to be used.

3.2.4 The effective section modulus of a corrugation over a spacing, s_c, is to be calculated from the dimensions and, for symmetrical corrugations, may be taken as:

$$z = \frac{d_w\,(3b\,t_p + c\,t_w)}{6000}\ \text{cm}^3$$

where

d_w, b, t_p, c and t_w are measured, in mm, and are as shown in Fig. 2.3.1. The value of b is to be taken not greater than:

$50t_p\sqrt{\frac{235}{\sigma_0}}$ for welded corrugations

$60t_p\sqrt{\frac{235}{\sigma_0}}$ for cold formed corrugations

where

σ_0 is defined in Ch 3,1.2.

The value of θ is not to be taken less than 40°. The moment of inertia is to be calculated from:

$$I = 0{,}05 d_w Z\ \text{cm}^4$$

Table 2.3.1 Values of factor *f*

$\frac{l}{b}$	f	$\frac{l}{b}$	f
0,5	0,19	3,5	0,69
1,0	0,30	4,0	0,76
1,5	0,39	4,5	0,82
2,0	0,48	5,0	0,88
2,5	0,55	5,5	0,94
3,0	0,62	6,0 and above	1,00

NOTE
Intermediate values to be obtained by linear interpolation.

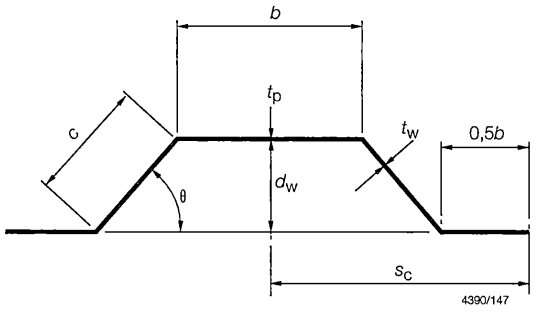

Fig. 2.3.1 Corrugation

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3.2.5 The section modulus of a double plate bulkhead over a spacing, b, may be calculated as:

$$Z = \frac{d_w (6f\, b\, t_p + d_w\, t_w)}{6000} \text{ cm}^3$$

where

d_w, b, t_p and t_w are measured, in mm, and are as shown in Fig. 2.3.2.

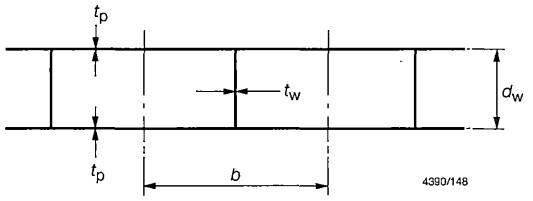

Fig. 2.3.2 Double plate bulkhead

3.2.6 The effective section modulus of a fabricated section may be taken as:

$$Z = \frac{a\, d_w}{10} + \frac{t_w\, d_w^2}{6000}\left(1 + \frac{200\,(A - a)}{200A + t_w\, d_w}\right) \text{ cm}^3$$

where

a = the area of the face plate of the member, in cm^2

d_w = the depth, in mm, of the web between the inside of the face plate and the attached plating. Where the member is at right angles to a line of corrugations, the minimum depth is to be taken

t_w = the thickness of the web of the section, in mm

A = the area, in cm^2, of the attached plating, *see* 3.2.7 If the calculated value of A is less than the face area, a, then A is to be taken as equal to a.

3.2.7 The geometric properties of primary support members (i.e. girders, transverses, webs, stringers, etc.) are to be calculated in association with an effective area of attached load bearing plating, A, determined as follows:

(a) For a member attached to plane plating:

$A = 10f\, b\, t_p$ cm^2

where

f is as defined in 3.2.1.

(b) For a member attached to corrugated plating and parallel to the corrugations:

$A = 10b\, t_p$ cm^2

(*See* Fig. 2.3.1)

(c) For a member attached to corrugated plating and at right angles to the corrugations:

A is to be taken as equivalent to the area of the face plate of the member.

3.3 Determination of span point

3.3.1 The effective span, l_e, of a stiffening member is to be as defined in Parts 6, 7 and 8, for steel, aluminium alloy and composite construction respectively.

3.4 Calculation of hull section properties

3.4.1 The particular requirements for the calculation of the hull section modulus for craft of steel and aluminium alloy construction are defined in Pt 6, Ch 6 and Pt 7, Ch 6 respectively. The particular requirements for the hull section stiffness for craft of composite construction are defined in Pt 8, Ch 6.

■ *Section 4* Bulkhead arrangements

4.1 General

4.1.1 Watertight bulkheads are, in general, to extend to the uppermost continuous watertight deck, hereinafter referred to as the bulkhead deck, and their construction is to be in accordance with Parts 6, 7 and 8 as appropriate.

4.1.2 Where openings are permitted in bulkheads they are to be provided with suitable closing devices in accordance with Ch 4,2.

4.2 Number and disposition of bulkheads

4.2.1 All craft with a Rule length, L_R, greater than 15 m are to have a collision bulkhead.

4.2.2 In motor craft with a Rule length, L_R, less than or equal to 15 m, the machinery is to be enclosed by gastight bulkheads to protect accommodation spaces from gas and vapour fumes from machinery, exhaust and fuel systems.

4.2.3 In all craft with a Rule length, L_R, less than or equal to 25 m, the sterntube is to be enclosed in a watertight compartment, wherever practicable.

4.2.4 All craft with a Rule length, L_R, greater than 25 m are to have an aft peak bulkhead, generally enclosing the sterntubes in a watertight compartment.

4.2.5 All craft with a Rule length, L_R, greater than 15 m are to have a watertight bulkhead at each end of the machinery space, where the machinery is amidships or a watertight bulkhead at the forward end of the machinery space, where the machinery is aft.

4.2.6 All craft with a Rule length, L_R, greater than 25 m are to have a watertight bulkhead at each end of the machinery space, with the aft peak bulkhead forming the aft bulkhead of the machinery space, where the machinery is aft.

4.2.7 Additional watertight bulkheads are to be fitted so that the total number of bulkheads is at least in accordance with Table 2.4.1.

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Table 2.4.1 Total number of bulkheads

Length, L_R, in metres	Total number of bulkheads	
	Machinery amidships	Machinery aft
> 15 ≤ 25	3	2
> 25 ≤ 65	4	3*
> 65 ≤ 85	4	4*
> 85 ≤ 90	5	5*
> 90 ≤ 105	5	5*
> 105 ≤ 115	6	5*
> 115 ≤ 125	6	6*
> 125 ≤ 145	7	6*
> 145	To be individually considered	

*With afterpeak bulkhead forming after boundary of machinery space

4.2.8 Bulkheads are to be spaced at reasonably uniform intervals. Where non-uniform spacing is unavoidable and the length of a compartment is unusually great, the transverse strength of the craft is to be maintained by fitting of web frames, increased framing, etc., and details are to be submitted.

4.2.9 Proposals to dispense with one or more of these bulkheads will be considered, subject to suitable structural compensation, if they interfere with the requirements of a special trade.

4.2.10 Where applicable, the number and disposition of bulkheads are to be arranged to suit the requirements for subdivision, floodability and damage stability, and are to be in accordance with the requirements of the National Authority.

4.3 Collision bulkhead

4.3.1 The collision bulkhead in all craft other than passenger craft, patrol craft and yachts is to be positioned as detailed in Table 2.4.2. Consideration will, however, be given to proposals for the collision bulkhead to be positioned slightly further aft on Arrangement (b) craft, but not more than $0{,}08L_L$ from the fore end of L_L, provided that the application is accompanied by calculations showing that flooding of the space forward of the collision bulkhead will not result in any part of the freeboard deck becoming submerged, or any unacceptable loss of stability. Special consideration may be given to the extent of the collision bulkhead above the bulkhead deck for multi-hull craft.

4.3.2 The collision bulkhead in passenger craft, patrol craft and yachts is to be in accordance with the following:

(a) A craft shall have a forepeak or collision bulkhead, which shall be watertight up to the bulkhead deck. (The bulkhead deck is the uppermost deck up to which the transverse watertight bulkheads are carried, *see* 4.2.10). This bulkhead is to be positioned as detailed in Table 2.4.3.

Table 2.4.2 Collision bulkhead position (excluding passenger craft, patrol craft and yachts)

Arrangement	Length, L_L	Distance of collision bulkhead aft of the fore end of L_L, in metres	
		Minimum	Maximum
(a)	≤ 150	$0{,}05L_L$	$0{,}08L_L$
(b)	≤ 150	$0{,}05L_L - f_1$	$0{,}08L_L - f_1$

Symbols and definitions

$f_1 = \frac{G}{2}$ or $0{,}015L_L$, whichever is the lesser

G = projection of bulbous bow forward of fore end of L_L, in metres

L_L is as defined in Ch 1,6.2

Arrangement (a) A craft that has no part of its underwater body extending forward of the fore end of L_L

Arrangement (b) A craft with part of its underwater body extending forward of the fore end of L_L (e.g. bulbous bow)

(b) If the craft has a long forward superstructure, the forepeak or collision bulkhead is to be extended weathertight to the deck next above the bulkhead deck. The extension need not be fitted directly over the bulkhead below, provided it is located within the limits specified in Table 2.4.3 with the exemption permitted by 4.6.3 and the part of the bulkhead deck which forms the step is made effectively weathertight.

4.3.3 Alternative arrangements may be submitted for consideration in the case of sailing and auxiliary craft.

4.3.4 For craft with pronounced rake of stem, the position of the collision bulkhead will be specially considered.

4.3.5 Accesses are not to be fitted in collision bulkheads. In particular designs where it would be impracticable to arrange access to the fore peak other than through the collision bulkhead, access may be permitted subject to special consideration. Where accesses are provided, the openings are to be as small as practicable and positioned as far above the design waterline as possible. The closing appliances are to be watertight, to open into the fore peak compartment and consideration will be given to operation from one side only.

4.4 Aft peak bulkhead

4.4.1 An aft peak bulkhead, where required to be fitted (in each half of a multi-hull craft) is, in general, to enclose the sterntube, water jet unit, etc., in a watertight compartment. In twin screw craft the sterntubes are to be enclosed in suitable watertight spaces. *See also* Table 2.4.1.

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Table 2.4.3 Collision bulkhead for passenger craft, patrol craft and yachts

Arrangement	Distance of collision bulkhead aft of fore perpendicular, in metres	
	Minimum	Maximum
(a)	$0{,}05L_{pp}$	$3 + 0{,}05L_{pp}$
(b)	$0{,}05L_{pp} - f$	$3 + 0{,}05L_{pp} - f$
Symbols and definitions		
$f = \frac{G}{2}$ or $0{,}015L_{pp}$, whichever is the lesser G = projection of bulbous bow forward of fore perpendicular, in metres L_{pp} is as defined in Ch 1, 6.2 Arrangement (a) A craft that has no part of its underwater body extending forward of the fore perpendicular. Arrangement (b) A craft with part of its underwater body extending forward of the fore perpendicular, e.g. bulbous bow.		

4.5 Height of bulkhead

4.5.1 The collision bulkhead is normally to extend to the uppermost continuous deck or, in the case of craft with combined bridge and forecastle or a long superstructure which includes a forecastle, to the superstructure deck. However, if a craft is fitted with more than one complete superstructure deck, the collision bulkhead may be terminated at the deck next above the freeboard deck. Where the collision bulkhead extends above the freeboard deck, the extension need only be to weathertight standards.

4.5.2 The aft peak bulkhead may terminate at the first deck above the load waterline, provided that this deck is made watertight to the stern or to a watertight transom floor. In passenger craft the aft peak bulkhead is to extend watertight to the bulkhead deck. However, it may be stepped below the bulkhead deck provided the degree of safety of the craft as regards watertight subdivision is not thereby diminished.

4.5.3 The remaining watertight bulkheads are to extend to the bulkhead deck. In passenger craft of restricted draught and all craft of unusual design, the height of the bulkheads will be specially considered.

4.6 Watertight recesses, flats and loading ramps

4.6.1 Watertight recesses in bulkheads are generally to be so framed and stiffened as to provide strength and stiffness equivalent to the requirements for watertight bulkheads.

4.6.2 In collision bulkheads, any recesses or steps in the bulkhead are to fall within the limits of bulkhead positions given in 4.3.1 or 4.3.3 as applicable. Where the bulkhead is extended above the freeboard deck, or bulkhead deck in passenger craft, the extension need only be to weathertight standards. If a step occurs at that deck, the deck need also only be to weathertight standards in way of the step, unless the step forms the crown of a tank, in which case the requirements for deep tank structures are to be complied with.

4.6.3 In craft fitted with bow doors, in which a sloping loading ramp forms part of the collision bulkhead above the freeboard or bulkhead deck, that part of the ramp which is more than 2,30 m above the freeboard or bulkhead deck may extend forward of the minimum limit specified in Table 2.4.2 or Table 2.4.3 as appropriate. Such a ramp is to be weathertight over its complete length.

4.7 Gastight bulkheads

4.7.1 Where bulkheads are required to be gastight in accordance with 4.2.2, and where it is proposed to pierce such bulkheads for the passage of cables, pipes, vent trunking, etc., gastight glands are to be provided to maintain the gastight integrity.

4.8 Tank bulkheads

4.8.1 The scantlings of deep tank bulkheads are to be in accordance with Ch 3,7 of Parts 6, 7 and 8, for steel, aluminium alloy and composite structures respectively.

4.8.2 A centreline bulkhead is, generally, to be fitted in deep tanks which extend from side to side of the craft. The bulkhead may be intact or perforated as desired. If intact, the scantlings are to be as required for boundary bulkheads. If perforated, the modulus of stiffeners may be 50 per cent of that required for boundary bulkheads, using a head measured to the crown of the tank.

4.8.3 The arm length of brackets at the ends of the stiffeners is to be 2,5 times the depth of stiffener. The thickness of the brackets is to be not less than the web thickness of the stiffener.

4.8.4 Air and sounding pipes are to comply with the requirements of Pt 15, Ch 2,11.

4.9 Cofferdams

4.9.1 Tanks carrying oil fuel or lubricating oil are to be separated by cofferdams from those carrying feed water, fresh water, edible oil or similar oils. Similarly tanks carrying vegetable or similar oils are to be separated by cofferdams from those carrying fresh or feed water. Cofferdams are to be fitted between freshwater tanks and black or grey water tanks.

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4.9.2 Lubricating oil tanks are also to be separated by cofferdams from those carrying oil fuel. However such cofferdams need not be fitted provided that:

(a) Common boundaries of lubricating oil and oil fuel tanks have full penetration welds.

(b) The tanks are arranged such that the oil fuel tanks are not generally subjected to a head of oil in excess of that in the adjacent lubricating oil tanks.

4.9.3 Cofferdams are not required between oil fuel double bottom tanks and deep tanks above, provided that the inner bottom plating is not subjected to a head of oil fuel.

4.9.4 Where fitted, cofferdams are to be suitably ventilated.

4.9.5 If oil fuel tanks are necessarily located within or adjacent to the machinery spaces, their arrangement is to be such as to avoid direct exposure of the bottom from rising heat resulting from an engine room fire. *See* Part 17 as applicable.

4.9.6 In passenger craft, water ballast is, in general, not to be carried in tanks intended for oil fuel. Attention is drawn to the Statutory Regulations issued by National Authorities in connection with the *International Convention for the Prevention of Pollution of the Sea by Oil, 1973/78.*

4.10 Means of escape

4.10.1 For the requirements for means of escape on service craft and yachts over 24 m in length, *see* Pt 17, Ch 2 and Pt 17, Ch 3 respectively.

4.10.2 The arrangement of the hull is to be such that all underdeck compartments are as accessible as practicable and provided with a satisfactory means of escape. Access and escape hatches to the machinery and tanks are not to be obstructed by deck coverings or furniture.

4.11 Carriage of low flash point fuels

4.11.1 Special provision is to be made for the carriage of low flash point fuel in accordance with Pt 15, Ch 3,5.

■ *Section 5* Fore and aft end arrangements

5.1 General

5.1.1 The requirements in respect of the general constructional arrangements for mono-hull craft covered by the Rules are contained within this Section.

5.2 Structural configuration

5.2.1 The Rules provide for both longitudinal and transverse framing systems.

5.3 Structural continuity

5.3.1 Suitable scarfing arrangements are to be made to ensure continuity of strength and the avoidance of abrupt structural changes.

5.3.2 Where longitudinal framing terminates and is replaced by a transverse system, adequate arrangements are to be made to avoid an abrupt changeover. Where a forecastle is fitted extending aft of 0,15L from the F.P., longitudinal framing at the upper deck and topsides is generally to be continued forward of the end bulkhead of this superstructure.

5.4 Minimum bow height and reserve buoyancy

5.4.1 All sea-going craft are to be fitted with forecastles, or increased sheer on the upper deck or equivalent, such that the distance from the summer load waterline to the top of the exposed deck at side at the F.P. is not less than:

$$H_b = \left(6075\left(\frac{L_L}{100}\right) - 1875\left(\frac{L_L}{100}\right)^2 + 200\left(\frac{L_L}{100}\right)^3\right) \times \left(2{,}08 + 0{,}609C_b - 1{,}603C_{wf} - 0{,}0129\left(\frac{L_L}{d_1}\right)\right)$$

where

d_1 = draught at 85 per cent of the depth D, in metres

A_{wf} = waterplane area forward of $\frac{L_L}{2}$ at draught d_1, in m^2

B = moulded breadth, in metres

C_b = block coefficient as defined in the Load Lines Convention

C_{wf} = the waterplane area coefficient forward of

$$C_{wf} = \frac{A_{wf}}{\left(\frac{L_L}{2}\right) \times B}$$

H_b = minimum bow height

L_L = Load Line length, in metres.

5.4.2 Craft which are designed to suit exceptional operational requirements, restricted in their service to Group G1, or of novel configuration will be specially considered on the basis of the Rules.

5.4.3 Where the bow height required in 5.4.1 is obtained by sheer, the sheer shall extend for at least 15 per cent of the length of the craft measured abaft the forward end of L_L. Where it is obtained by fitting a forecastle, the forecastle shall extend from the stem to a point at least 0,07L_L abaft the forward end of L_L, and shall be enclosed.

5.4.4 Craft shall have additional reserve buoyancy in the fore end in accordance with the Load Lines Convention.

5.5 Bow crumple zone

5.5.1 In general, the bow crumple zone is that space forward of the collision bulkhead. Passenger and crew accommodation and the carriage of fuel and other oils is not permitted in the bow crumple zone.

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5.6 Strengthening of bottom forward

5.6.1 Except for craft with **G1** and **G2** service notations, additional strengthening of bottom forward is required for craft with the rule length, L_R, greater than 65 m. Details are to be submitted for consideration.

5.7 Bulbous bows

5.7.1 Where a bulbous bow is fitted, the structural arrangements are to be such that the bulb is adequately supported and integrated into the fore peak structure.

5.7.2 At the fore end of the bulb the structure is generally to be supported by horizontal diaphragm plates spaced generally 1,0 m apart in conjunction with a deep centreline web.

5.7.3 In general, vertical transverse diaphragm plates are to be arranged in way of the transition from the peak framing to the bulb framing.

5.7.4 In way of a wide bulb, additional strengthening in the form of a centreline wash bulkhead is generally to be fitted.

5.7.5 In way of a long bulb, additional strengthening in the form of transverse wash bulkheads or substantial web frames spaced about five frame spaces apart are generally to be fitted.

5.7.6 The shell plating is to be increased in thickness at the fore end of the bulb and in other areas likely to be damaged by the anchors and chain cables. The increased plate thickness is to be the same as that required for plated stems.

5.8 Strengthening against bow flare slamming

5.8.1 Where a craft has pronounced flare or rake of bow, the structure in the forward region will be subject to special consideration, and the scantlings and arrangements may require additional strengthening.

■ *Section 6*
Machinery space arrangements

6.1 General

6.1.1 This Section applies to all craft types. Only requirements particular to machinery spaces, including protected machinery casings and engine seatings, are given. For other scantlings and arrangement requirements, *see* the relevant Chapter in Parts 6, 7 and 8.

6.2 Structural configuration

6.2.1 Requirements are given for craft constructed using either a transverse or longitudinal framing system, or a combination of the two.

6.2.2 For machinery spaces situated aft, where the longitudinal framing terminates and is replaced by transverse framing, a suitable scarfing arrangement of the longitudinal framing is to be arranged. *See also* 5.3.

6.2.3 The maximum spacing, S_{max}, of web frames in longitudinally framed machinery spaces is not to exceed 3,8 m. Additionally for transversely framed craft, in way of a machinery space situated adjacent to the aft peak, the spacing of web frames is not to exceed six transverse frame spaces.

6.2.4 Where the machinery space is situated in the midship region, it is recommended that web frames be fitted in the engineroom, spaced not more than six frame spaces apart and extending from the tank top to the level of the lowest deck above the load waterline. The scantlings of these webs are to be such that the combined section modulus of the web frame and the main or 'tween deck frames is 50 per cent greater than that required for normal transverse framing. These webs may be omitted if the section modulus of the transverse frames is increased by 50 per cent.

6.3 Structural continuity

6.3.1 Suitable scarfing arrangements are to be made to ensure continuity of strength and the avoidance of abrupt discontinuities where structure which contributes to the main longitudinal strength of the craft is omitted in way of a machinery space.

6.4 Deck structure

6.4.1 The corners of machinery space openings are to be of suitable shape and design to minimise stress concentrations.

6.4.2 In motor craft having a Rule length, L_R, less than 15 m, the machinery is to be enclosed by gastight decks to protect accommodation spaces from gas and vapour fumes from machinery, exhaust and fuel systems.

6.5 Side shell structure

6.5.1 Side shell structure is to be constructed in accordance with the scantlings indicated in Parts 6, 7 and 8, for steel, aluminium alloy and composite structures respectively.

6.5.2 General requirements for web frames are given in this Section for both longitudinal and transverse framing systems. Where longitudinal framing is adopted in the midship region it is to be carried as far forward and aft as practicable.

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6.5.3 A transverse framing system is to be additionally reinforced by web frames fitted six frame spaces apart. Where a longitudinal framing system is adopted, the spacing of the transverses is not to exceed 2,5 m.

6.6 Double and single bottom structure

6.6.1 Where the Rule length, L_R, of the craft exceeds 50 m, a double bottom is to be fitted in the hull (or hulls in multi-hull craft), extending from the collision bulkhead to the forward watertight bulkhead for the machinery space.

6.6.2 Where the Rule length, L_R, of the craft exceeds 61 m, a double bottom is to be fitted outside the machinery space and is to extend to the collision bulkhead and the aft peak bulkhead. Where no aft peak bulkhead is fitted, the extent of the double bottom will be specially considered.

6.6.3 Where the Rule length, L_R, of the craft exceeds 76 m, the double bottom is to extend throughout the length of the craft.

6.6.4 For multi-hull craft and other craft which are to be assigned an **HSC** notation or which are to operate within **Restricted Service Groups G1, G2, G2A** and **G3**, the extent of the double bottom will be specially considered depending on the number of transverse watertight bulkheads and the requirements of the National Authority concerning stability after damage.

6.6.5 Margin plates and drainage wells are to be provided as necessary and subject to special consideration.

6.6.6 The scantlings of bottom stiffening, floors, centre girders and side girders are to be in accordance with the appropriate Sections of Parts 6, 7 and 8 of the Rules, for craft built in steel, aluminium alloy and composite respectively.

6.6.7 In motor craft the thickness of the floors in machinery spaces is to be 1mm greater than that required by the appropriate Sections of Parts 6 and 7 of the Rules, for craft built in steel and aluminium alloy respectively.

6.6.8 In craft having considerable rise of floor, the depth of the floor plate, or its height at side, may require to be increased. The transverse extent of double bottom will be specially considered.

6.6.9 Suitable arrangements are to be made to provide free passage of water from all parts of the bilge to the pump suctions.

6.6.10 A centreline girder is to be fitted in association with transverse frames, transverses supporting longitudinals or where the breadth of floors at the upper edge is greater than 1,5 m. Where the breadth of the floors at the upper edge exceeds 6,0 m a side girder is also to be fitted each side of the centre girder.

6.6.11 All girders are to extend as far forward and aft as practicable and care is to be taken to avoid any abrupt discontinuity.

6.6.12 Centreline girders fitted in association with flat plate keels are to be formed of intercostal or continuous plates with a continuous face flat welded on the upper edge.

6.6.13 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with 6.8.

6.7 Machinery casings

6.7.1 The scantlings and arrangements of exposed casings protecting machinery openings are to be in accordance with Ch 3,9.8, of Parts 6 and 7, for craft built in steel and aluminium alloy respectively.

6.7.2 Where casing stiffeners carry loads from deck transverses, girders, etc., or where they are in line with pillars below, they are to be suitably increased. *See also* Ch 3,10, Parts 6, 7 and 8, for craft built in steel, aluminium alloy and composite respectively.

6.7.3 Where casing sides act as girders supporting decks over, care is to be taken that access openings do not seriously weaken the structure. Openings are to be effectively framed and reinforced if found necessary. Particular care is to be paid to stiffening where the casing supports the funnel or exhaust uptakes.

6.7.4 Casing bulkheads are to be made gastight and the access doors are to be of a gastight self-closing type.

6.8 Integral fuel tanks

6.8.1 The scantlings of deep tank bulkheads are to be in accordance with Ch 3,7, of Parts 6, 7 and 8, for craft built in steel, aluminium alloy and composite respectively.

6.9 Machinery seatings

6.9.1 Main and auxiliary engines in motor and auxiliary sailing craft are to be effectively secured to the hull structure by seatings of adequate scantlings to resist the gravitational, thrust, torque and vibrating forces which may be imposed upon them.

6.9.2 The longitudinal girders forming the engine seatings are to extend as far forward and aft as practicable and be adequately supported by transverse floors or brackets.

6.9.3 In determining the scantlings of seats for oil engines, consideration is to be given to the general rigidity of the engine itself and to its design characteristics with regard to out of balance forces.

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6.9.4 The seats are to be so designed that they distribute the forces from the engine(s) as uniformly as possible into the supporting structure. Longitudinal girders supporting the seatings are to be arranged in single or double bottoms, and are, in general to extend over the full length of the machinery space. The ends of the girders are to be scarfed into the bottom structure for at least two frame spaces. Adequate transverse brackets are to be arranged in line with floors. Small brackets may be required under the top plate in way of holding down bolts.

6.9.5 For gas turbine installations, seats are to be so designed as to provide effective support and ensure their proper alignment with the gearing, and where applicable allow for thermal expansion of the casings. In general, the seats are not to be arranged in way of breaks or recesses in the double bottom.

6.9.6 Auxiliary machinery is to be secured on seatings, of adequate scantlings, so arranged as to distribute the loadings evenly into the supporting structure.

6.10 Thrust blocks

6.10.1 Main engines and thrust bearings are to be effectively secured to the hull structure by seatings of adequate scantlings to resist the various gravitational, thrust, torque, dynamic and vibratory forces which may be imposed on them.

6.10.2 For initial guidance, it is recommended that the scantlings for oil engine seatings be as indicated in 6.9.3.

■ *Section 7*
Superstructures, deckhouses and bulwarks

7.1 General

7.1.1 Superstructures, deckhouses and bulwarks are to be constructed in accordance with the scantlings indicated in Ch 3,9 of Parts 6, 7 and 8, for steel, aluminium alloy and composite structures respectively.

7.2 Definition of tiers

7.2.1 The lowest, or first tier, is normally that which is directly situated on the deck to which *D* is measured. The second tier is the next tier above the lowest tier and so on. *See* Fig. 2.7.1.

7.2.2 Where the vertical distance between the weatherdeck and the summer load waterline is equal to or greater than the sum of the minimum freeboard and one standard superstructure height, then proposals to treat the first tier erection as a second tier, and so on, will be specially considered. The standard height of superstructure is the height defined in Ch 1,6.13.3. *See* Fig. 2.7.1.

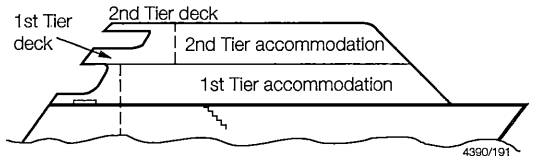

Fig. 2.7.1 Definition of tiers

7.2.3 Suitable scarfing arrangements are to be made to ensure continuity of strength and the avoidance of abrupt structural changes.

7.3 Unusual designs

7.3.1 Craft or structural arrangements which are of unusual design, form or proportions will be individually considered. Special features will be considered in each separate case.

■ *Section 8*
Particular requirements for multi-hulls

8.1 General

8.1.1 The requirements indicated in this Section are particular to multi-hull craft and are to be applied in addition to the general requirements of this Chapter.

8.1.2 The craft is to be considered as one complete structure when determining the minimum geometric summer freeboard. The block coefficient is to be calculated using the actual displacement determined from the hydrostatic data and using the total breadth of the structure and not just a single hull.

8.1.3 If, by using normal procedures, the minimum geometric summer freeboard determined is unreasonable for the operation of the craft, special consideration may be given, on a case by case basis, based on the proposed design configuration.

8.2 Structural configuration

8.2.1 The scantlings and arrangements indicated are for twin hulled craft. Craft with a greater number of hulls will be specially considered on the basis of the Rules.

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8.3 Structural continuity

8.3.1 Structural members which contribute to the overall hull girder strength are to be carefully aligned so as to avoid discontinuities resulting in abrupt variations of stresses and are to be kept clear of any form of openings which may affect their structural performances.

8.3.2 Particular care is to be given to the continuity and alignment in way of the end connections of transverse bridging structures.

8.4 Cross-deck structure

8.4.1 For craft with multi-hulls linked by cross-deck structures, sufficient clearance is to be provided between the cross-deck structure and water surface to limit impact loads.

8.4.2 Where part or all of the cross-deck is intended to provide additional buoyancy to limit craft motion, the loading will be specially considered.

8.4.3 In the determination of the clearance, the following factors should be considered:
(a) Relative motion in waves.
(b) The wave generated between the hulls when running.
(c) The bow sinkage.

8.4.4 The submitted clearances must be validated either by calculations according to accepted theories, model test, full scale measurements or by documentary evidence if similar structures have proved to be satisfactory in service.

8.4.5 Where it is not possible to provide sufficient clearance to reduce the likelihood of slamming of the cross-deck structure, direct calculations or other appropriate means are to be used to assess the loads, assuming the most severe conditions for which the craft is to be approved.

8.5 Bulkheads

8.5.1 Longitudinal watertight bulkheads are to be arranged within the bridging structures of multi-hull craft to prevent cross flooding and the spread of smoke and flames in the event of fire. The number and distribution of bulkheads will be specially considered dependent upon the structural configuration and size of the craft but in no case is the number to be less than:

- one for catamarans of Rule length, L_R, less than or equal to 24 m;
- two for catamarans of Rule length, L_R, greater than 24 m; and
- four for trimarans.

8.6 Fore and aft ends

8.6.1 The forefoot and bow regions of fast craft that may be subjected to frequent impacts from flotsam are to be easily accessible for inspection. Access to the forepeak compartments may be provided through the forepeak bulkhead where access would otherwise be impracticable.

8.6.2 The aft end regions of all craft are to be easily accessible for inspections. Access may be provided through the aft peak bulkhead or by means of deck hatches or manholes.

8.7 Machinery spaces

8.7.1 Where an engine is fitted within a narrow hull, where engineroom temperatures may rise quickly, the ventilation requirements may require to be increased.

8.7.2 Within machinery spaces where space is limited access is to be provided for inspection.

8.8 Superstructures, deckhouses and bulwarks

8.8.1 Superstructures and deckhouses which enclose large flat open areas, that are subjected to racking loads and which may be of several tiers, are to be additionally stiffened with large web frames, partial bulkheads and pillars.

■ *Section 9* Navigation in ice

9.1 General

9.1.1 Where an ice class notation is to be included in the class of a craft, the scantlings will require to be specially considered. The additional requirements for operation in ice will, in general, be in accordance with LR's *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships), Part 8, where appropriate, and also Pt 6, Ch 5,7, Pt 7, Ch 5,7 and Pt 8, Ch 5,6 for steel, aluminium and composite construction respectively.

9.1.2 It is the responsibility of the Owner to determine which ice class notation is most suitable for their requirements.

9.1.3 The strengthening requirements detailed in this Section are applicable to craft, other than those assigned the notation **HSC** and/or **LDC** (*see* Pt 1, Ch 2), intended for operation in first-year ice conditions.

9.1.4 For a multi-hull craft, special consideration is to be given to the interaction of the ice between the hulls.

9.1.5 The requirements of this Section assume that, when approaching ice-infested waters, the craft's speed will be reduced appropriately. The vertical extent of ice strengthening for craft intended to operate in ice conditions at speeds exceeding 15 knots will be specially considered.

9.2 Ice belt

9.2.1 Side scuttles are not to be situated in the ice belt.

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9.2.2 If the weather deck in any part of the craft is situated below the upper limit of the ice belt, the bulwark is to be reinforced to the same degree as the shell plating in the main ice belt.

9.3 Stern construction

9.3.1 A transom stern is not normally to extend below the ice load waterline. Where this cannot be avoided, the transom is to be kept as narrow as possible and the scantlings of plating and stiffeners are to be as required for the midcraft region.

9.4 Bossings and shaft struts

9.4.1 For craft with two or more propellers, shafting and sterntubes are generally to be enclosed within plated bossings. If detached supporting struts are necessary, their design, strengthening and attachment to the hull will be specially considered.

9.5 Powering of ice strengthened craft

9.5.1 For water jets, special consideration is to be given to the potential intake of ice pieces into the impeller causing additional loads and strengthening of steering buckets.

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Section

1 **General**

2 **Rudders**

3 **Sternframes and appendages**

4 **Fixed and steering nozzles, bow and stern thrust units**

5 **Stabiliser arrangements**

6 **Particular requirements for multi-hull craft**

■ *Section 1* General

1.1 Application

1.1.1 This Chapter applies to all the craft types detailed in the Rules, and requirements are given for rudders, nozzles, steering gear, bow and stern thrust unit structure and stabiliser structure.

1.2 General

1.2.1 The following symbols and definitions are applicable to this Chapter, unless otherwise stated:

σ_o = minimum yield stress or 0,5 per cent proof stress of the material, in N/mm^2 and is not to be taken greater than $0{,}7\sigma_T$

where

σ_T = ultimate tensile strength of the material, in N/mm^2.

1.2.2 The scantlings in aluminium alloy are to be obtained by multiplying the scantlings in mild steel, determined from this Chapter, by the following factors:

(a) Plating thickness factor = k_{ta}
where $k_{ta} = \sqrt{k_{aa}}$

(b) Section modulus and cross sectional area factor, k_{aa}
where

k_{aa} = $235/\sigma_{ya}$ or 1,36, whichever is the greater

σ_{ya} = specified minimum yield stress or 0;2 per cent proof stress of aluminium alloy in the welded condition, in N/mm^2.

1.3 Navigation in ice

1.3.1 Where an ice class notation is to be included in the class of a craft, the scantlings will require special consideration, *see* Ch 2,9.

1.4 Materials

1.4.1 The requirements for materials are contained in the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

■ *Section 2* Rudders

2.1 General

2.1.1 The scantlings of the rudder stock are to be not less than those required by Table 3.2.7.

2.1.2 For rudders having an increased diameter of rudder stock, *see* Fig. 3.2.1, the increased diameter is to be maintained to a point as far as practicable above the top of the lowest bearing. This diameter may then be tapered to the diameter required in way of the tiller. The length of the taper is to be at least three times the reduction in diameter. Particular care is to be taken to avoid the formation of a notch at the upper end of the taper.

2.1.3 Sudden changes of section or sharp corners in way of the rudder coupling, jumping collars and shoulders for rudder carriers, are to be avoided.

2.2 Definition and symbols

2.2.1 Definitions and symbols for use throughout this Section are indicated in the appropriate tables.

2.3 Direct calculations

2.3.1 Where the rudder is of a novel design, high aspect ratio or the speed of the craft exceeds 45 knots the scantlings of the rudder and rudder stock are to be determined by direct calculation methods incorporating model test results and structural analysis, where considered necessary by LR.

2.4 Equivalents

2.4.1 Alternative methods of determining the loads will be specially considered, provided that they are based on model tests, full scale measurements or generally accepted theories. In such cases, full details of the methods used are to be provided when plans are submitted for approval.

2.5 Rudder arrangements

2.5.1 Rudders considered are the types shown in Fig. 3.2.1, of double plate or single plate construction, constructed from steel, stainless steel or aluminium alloy. Other rudder types and materials will be subject to special consideration.

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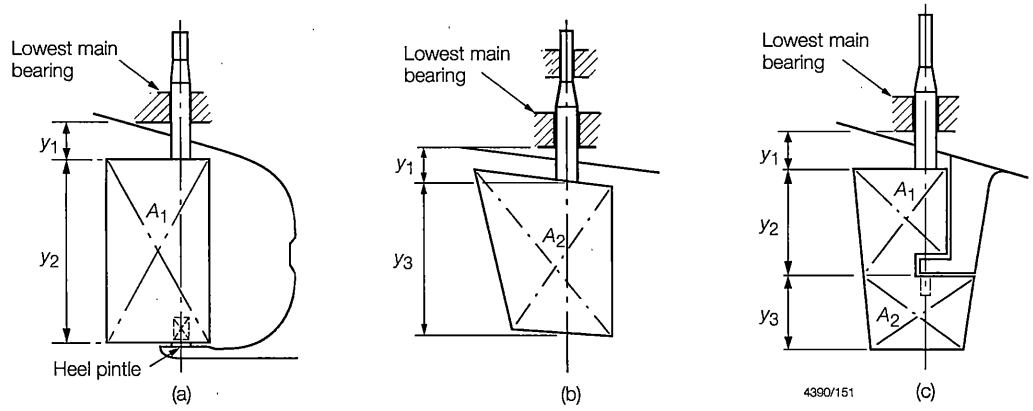

Fig. 3.2.1 Rudder types

2.6 Rudder profile coefficient f_R

2.6.1 The rudder profile coefficient f_R for use in Table 3.2.7 is to be as indicated in Table 3.2.1.

Table 3.2.1 Rudder profile coefficient f_R

Design criteria (*see* Fig. 3.2.2)	f_R ahead condition	f_R astern condition
Normal profile	1,0	0,97
Hollow profile	1,25	1,12
High lift profile	1,7	To be specially considered
Symbols		
f_R = rudder profile coefficient for use in Table 3.2.7		
NOTE Where a rudder is behind a fixed nozzle, the value of f_R given above, is to be multiplied by 1,3.		

2.7 Rudder angle coefficient f_θ

2.7.1 The rudder angle coefficient, f_θ, for use in Table 3.2.7 is to be as indicated in Table 3.2.2.

Table 3.2.2 Rudder angle coefficient f_θ

Rudder angle	2 x 35°	2 x 45°
f_θ	1,0	1,23
Symbols		
f_θ = rudder coefficient for use in Table 3.2.7. Intermediate values may be obtained by interpolation		

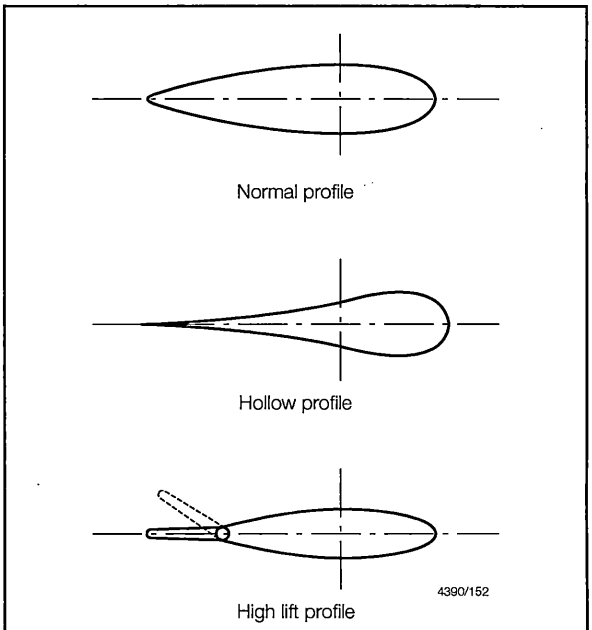

Fig. 3.2.2 Rudder profiles

2.8 Rudder position coefficient f_p

2.8.1 The rudder position coefficient, f_p, for use in Table 3.2.7 is to be as indicated in Table 3.2.3.

2.9 Rudder speed coefficient f_v

2.9.1 The rudder speed coefficient, f_v, for use in Table 3.2.7 is to be as indicated in Table 3.2.4.

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Table 3.2.3 Rudder position coefficient f_p

Design criteria		f_p
Ahead condition	Rudder in propeller slipstream	0,248
	Rudder out of propeller slipstream	0,235
Astern condition		0,185
Bow rudder		0,226
Symbols		
f_p = rudder coefficient for use in Table 3.2.7		

Table 3.2.4 Rudder speed coefficient f_v

Design criteria	f_v
Craft with $\frac{V}{\sqrt{L_{WL}}} < 3,0$	1,00
Craft with $\frac{V}{\sqrt{L_{WL}}} \geq 3,0$	1,12 – 0,005V
Symbols	
L_{WL} as defined in Ch 1,6.2.5 V as defined in Table 3.2.7 f_v = rudder speed coefficient for use in Table 3.2.7	

2.10 Pintle arrangement coefficient *N*

2.10.1 The pintle arrangement coefficient, N, for use in Table 3.2.7 is to be as indicated in Table 3.2.5.

Table 3.2.5 Pintle arrangement coefficient *N*

Support arrangement	Value of N
Two or more pintles Upper stock	$N = 0$
One or no pintle	$N = A_1(0,67y_1 + 0,17y_2) - A_2(y_1 + 0,5y_3)$
Symbols	
N = coefficient for use in Table 3.2.7 A_1, A_2 = part rudder areas, in m^2, *see* Fig. 3.2.1 y_1, y_2, y_3 = vertical dimensions, in metres, *see* Fig. 3.2.1 Any values of y and A not indicated in Fig. 3.2.1 are to be taken as zero.	
NOTE If, in semi-spade (Mariner) type rudders, the pintle is housed above the rudder horn gudgeon and not as shown in Fig. 3.2.1(c), y_2 and y_3 are to be measured to the top of the gudgeon.	

2.11 Centre of pressure

2.11.1 The position of centre of pressure for use in Table 3.2.7 is to be as indicated in Table 3.2.6.

Table 3.2.6 Position of centre of pressure

Design criteria	Value of x_{PF} and x_{PA} to be used in Table 3.2.7
Rectangular rudders; (a) Ahead condition	x_{PF} = $(0,33ex_B - x_L)$, but not less than $0,12x_B$
(b) Astern condition	x_{PA} = $(x_A - 0,25x_B)$, but not less than $0,12x_B$
Non-rectangular rudders; (a) Ahead condition	x_{PF} as calculated from geometric form
(b) Astern condition	x_{PA} (*see* Note) but not less than: $\frac{0,12A_R}{y_R}$
Symbols	
x_{PF} = horizontal distance from the centreline of the rudder pintles, or axle, to the centre of pressure in the ahead condition, in metres x_{PA} = horizontal distance from the centreline of the rudder pintles, or axle, to the centre of pressure in the astern condition, in metres x_B = breadth of rudder, in metres y_R = depth of rudder at centreline of stock, in metres A_R = rudder area, in m^2 x_L and x_A = horizontal distances from leading and after edges, respectively, of the rudder to the centreline of the rudder pintles, or axle, in metres x_S = horizontal length of any rectangular strip of rudder geometric form, in metres e = hull form factor at ahead condition for $L < 65$ m, $e = 1,0$ for $L \geq 65$ m, $e = 2\left(C_b + 10\frac{B}{L_R} - 2\right)\frac{V}{\sqrt{L_R}}$ or $e = 1 + \left(\frac{L_R - 65}{70}\right)$ whichever is the lesser, but not less than 1,0 and need not be taken greater than 1,5 L_R, B and C_b are as defined Ch 1,6.2 V is as defined in Table 3.2.7	
NOTE For rectangular strips the centre of pressure is to be assumed to be located as follows: (a) $0,33ex_S$ abaft leading edge of strip for ahead condition. (b) $0,25x_S$ from aft edge of strip for astern condition.	

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Table 3.2.7 Rudder stock diameter

Requirement
1. Basic stock diameter, d_s, at and below lowest bearing: $d_s = f_c f_p f_v \sqrt[3]{\left(\frac{235}{\sigma_0}\right)^m} f_R f_\theta (V+3)^2 \sqrt{A_R^2 x_p^2 + N^2}$ mm 2. Diameter in way of tiller, d_{SU}: $d_{SU} = d_s$ calculated from (1) with $N = 0$ 3. Lateral force on rudder acting at centre of pressure of blade, P_L: $P_L = \left(\frac{f_p}{0{,}248}\right)^3 \frac{(V+3)^2 A_R f_R f_\theta}{10}$ kN
Symbols
f_c = 79 for craft of Rule length, L_R, 50 m and below varying up to 83,3 at a Rule length, L_R, of 70 m. Intermediate values to be obtained by interpolation 83,3 for craft of Rule length, L_R, 70 m and above f_p = rudder position coefficient, *see* Table 3.2.3 f_v = rudder speed coefficient, *see* Table 3.2.4 f_R = rudder profile coefficient, *see* Table 3.2.1 f_θ = rudder angle coefficient, *see* Table 3.2.2 m = 0,75 for $\sigma_0 > 235$ = 1,0 for $\sigma_0 \leq 235$ σ_0 = minimum yield stress, in N/mm^2, of material used, and is not to be taken greater than $0{,}7\sigma_T$ σ_T = ultimate tensile strength of the material used, in N/mm^2 V = the maximum speed for the astern and ahead condition, in knots. In no case to be less than 5 knots A_R = rudder area, in m^2 x_P = x_{Pa} or x_{Pf}, for the astern and ahead condition respectively, *see* Table 3.2.6 N = coefficient dependent on rudder support arrangement, *see* Table 3.2.5
NOTE Where higher tensile steel is used for the rudder stock, σ_0 is not to be taken as greater than 450 N/mm^2.

2.12 Rudder stock (tubular)

2.12.1 Tubular rudder stock scantlings are to be not less than that necessary to provide the equivalent strength of a solid stock as required by Table 3.2.7, and can be calculated from the following formula:

$$d_E = \sqrt[3]{\frac{d_1^4 - d_2^4}{d_1}} \text{ mm}$$

where

d_E = the diameter of the equivalent solid rudder stock, in mm

d_1, d_2 = external and internal diameters, respectively of the tubular stock, in mm.

2.13 Single plate rudders

2.13.1 The scantlings of a single plate rudder are to be not less than required by Table 3.2.8, *see also* 2.5.1.

2.13.2 Rudder arms are to be efficiently attached to the mainpiece.

Table 3.2.8 Single plate rudder construction

Item	Requirement
Blade thickness	$t_B = 0{,}0015V y_W + 2{,}5$ mm with a minimum of 10 mm
Arms	Spacing ≤ 1000 mm $Z_A = 0{,}0005V^2 x_a^2 y_W$ cm^3
Mainpiece	Diameter = d_s mm For spade rudders, the lower third may taper down to $0{,}75d_s$ mm
Symbols	
t_B = blade thickness, in mm y_W = vertical spacing of rudder arms, in mm V = maximum speed, in knots, as defined in Table 3.2.7 x_a = horizontal distance from the aft edge of the rudder to the centre of the rudder stock, in metres Z_A = section modulus of arm, in cm^3	

2.14 Double plate rudders

2.14.1 The scantlings of a double plated rudder are to be not less than required by Table 3.2.9.

2.14.2 In way of rudder couplings and heel pintles the plating thickness is to be suitably increased.

2.14.3 On semi-spade (Mariner) type rudders a notch effect in the corners in the bottom pintle region is to be avoided (*see* AA, Fig. 3.2.3). An insert plate, 1,6 times the Rule thickness of the side plating, is to be fitted at this position, extending aft of the main vertical web and having well rounded corners. The main vertical web is to be continuous over the full depth of the rudder and have a thickness not less than three times the thickness required by Table 3.2.9, Item (5). Where an additional continuous main vertical web is arranged to form an efficient box structure, the webs are to have a thickness not less than required by Table 3.2.9, Item (5).

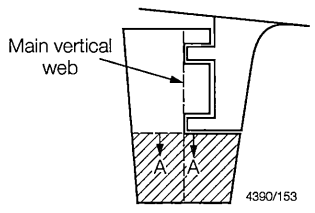

Fig. 3.2.3 Semi-spade (mariner) type rudder

2.14.4 Adequate hand or access holes are to be arranged in the rudder plating in way of pintles as required, and the rudder plating is to be reinforced locally in way of these openings. Continuity of the modulus of the rudder mainpiece is to be maintained in way of the openings.

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Table 3.2.9 Double plated rudder construction

Item	Requirement
(1) Side plating	$t = \beta F_a (0{,}003 y_w + 2{,}03)(1{,}45 + 0{,}1 \sqrt{d_s})$ mm
(2) Webs - vertical and horizontal	As (1) above
(3) Top and bottom plates	As (1) above using y_w = maximum rudder width, in mm, at top or bottom, but not less than 900 mm
(4) Nose plates	$t_N \geq 1{,}25t$ from (1) above
(5) Mainpiece – fabricated rectangular	Breadth and width $\geq d_s$ $t_M = F_a (8{,}5 + 0{,}56 \sqrt{d_s})$ mm Minimum fore and aft extent of side plating = $0{,}2x_B$ Stress due to bending $\leq$ 78,0 N/mm^2
(6) Mainpiece – tubular	Inside diameter $\geq d_s$ t_M as for (5) above Side plating as for (1) above Bending stress as for (5) above
Symbols	
β = $A_a (1 - 0{,}25A_a)$ A_a = panel aspect ratio, but is not to be taken as greater than 2,0 F_a = 1,0 for mild steel, 0,95 for aluminium alloy and 0,9 for stainless steel. Other materials will be specially considered t = thickness, in mm y_w = vertical spacing, in mm, of the horizontal webs or arms, but is not to exceed 900 mm d_s = basic stock diameter, given by Table 3.2.7, in mm t_N = thickness, in mm, of nose plate t_M = thickness, in mm, of side plating and vertical webs forming mainpiece x_B = breadth of rudder, in metres, on centreline of stock	

2.14.5 Connection of rudder side plating to vertical and horizontal webs, where internal access for welding is not practicable, is to be by means of slot welds onto flat bars on the webs. The slots are to have a minimum length of 75 mm and in general, a minimum width of twice the side plating thickness. The ends of the slots are to be rounded. The space between the slots is not to exceed 150 mm and welding is to be based on a weld factor of 0,44.

2.14.6 For testing of rudders, *see* Table 1.7.1 in Chapter 1.

2.14.7 Where the fabricated mainpiece of a spade rudder is connected to the horizontal coupling flange by welding, a full penetration weld is required.

2.15 Cast metal rudders

2.15.1 Where rudders are cast, the mechanical and chemical properties of the metal are to be submitted for approval. If the rudder stock is cast integral with the rudder blade, abrupt changes of section and sharp corners are to be avoided.

2.16 Lowest main bearing requirement

2.16.1 The design of the lowest bearing is to comply with the requirements of Table 3.2.10.

2.17 Bearings

2.17.1 Bearings are to be of approved materials and effectively secured to prevent rotational and axial movement.

2.17.2 Where it is proposed to use stainless steel for liners or bearings for rudder stocks and/or pintles, the chemical composition is to be submitted for approval. Where the two surfaces are stainless steel materials, they should have suitable resistance to galling. When stainless steel material is used, arrangements to ensure an adequate supply of sea-water to the bearing are to be provided to protect against stagnant sea-water initiated corrosion.

2.17.3 Synthetic rudder bearing materials are to be of a type approved by LR.

2.18 Liners

2.18.1 Where liners are fitted to rudder stocks or pintles, they are to be shrunk on or otherwise efficiently secured.

2.18.2 Where it is proposed to use stainless steel liners, the requirements in 2.17.2 are to be complied with.

2.18.3 When stainless steel liners are used, arrangements to ensure an adequate supply of sea-water to the liner are to be provided.

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Table 3.2.10 Lowest main bearing requirements

Item	Requirement	
Lowest main bearing	Depth Z_B, in mm $1{,}5d_s \geq Z_B \geq 1{,}0d_s$	Minimum thickness of wall, in mm lesser of $0{,}2d_s$ or 100
Bearing pressure (on the projected area of the lowest main bearing), where the projected area is to be taken as the length x diameter	Bearing material	Maximum pressure, in N/mm^2 *see* Note 4
	Metal Synthetic	7,0 5,5
Clearance in lowest main bearing on the diameter (note should be taken of the manufacturer's recommended clearances, particularly where bush material requires pre-soaking)	Bearing material	Minimum clearance, in mm *see* Note 3
	Metal, *see* Note 2 Synthetic	$0{,}001d_s + 1{,}0$ $0{,}002d_s + 1{,}0$ but not less than 1,5
Symbols		
d_s = stock diameter, given by Table 3.2.7, in mm		
NOTES 1. Where web stiffening is fitted on the bearing, a reduction in wall thickness will be considered. 2. For bearings which are pressure lubricated the clearance must be restricted to enable the pressure to be maintained. 3. Value of proposed minimum clearance is to be indicated on plans submitted for approval. 4. Proposals for higher pressures or other materials will be specially considered on the basis of satisfactory test results.		

2.19 Pintles

2.19.1 Rudder pintles and their bearings are to comply with the requirements of Table 3.2.11.

2.19.2 Where the lower pintle is housed above the rudder gudgeon, *see* Fig. 3.2.4, and not below as shown in Fig. 3.2.5, C_{PL} is to be measured to the top of the gudgeon.

2.19.3 Special attention is to be paid to the fit of the pintle taper into its socket. To facilitate removal of the pintles, it is recommended that the taper is to be not less than half the maximum value given in Table 3.2.11.

2.19.4 The distance between the lowest rudder stock bearing and the upper pintle is to be as short as possible.

2.19.5 Where liners are fitted to pintles, they are to be shrunk on or otherwise efficiently secured. If liners are to be shrunk on, the shrinkage allowance is to be indicated on the plans. Where liners are formed by stainless steel weld deposit, the pintles are to be of weldable quality steel and details of the procedure are to be submitted.

2.19.6 The bottom pintle on semi-spade (Mariner) type rudders are:

(a) If inserted into their sockets from below, to be keyed to the rudder or sternframe as appropriate or to be hydraulically assembled, with the nut adequately locked, or

(b) If inserted into their sockets from above, to be provided with an appropriate locking device, the nut being adequately secured.

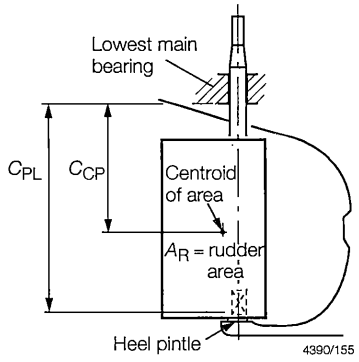

Fig. 3.2.4
Lower pintle housed above rudder gudgeon

2.19.7 Where an ***IWS** (In-water Survey) notation is to be assigned, *see* 2.37.

2.19.8 Where it is proposed to use stainless steel liners, the requirements in 2.17.2 are to be complied with.

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Table 3.2.11 Pintle requirements

Item	Requirement	
(1) Pintle diameter (measured outside liner if fitted)	$\delta_{PL} = \sqrt{\left(\frac{235}{\sigma_o}\right)^m}\,(31 + 4{,}17V\sqrt{A_{PL}})$ mm For single pintle rudders and lower pintle of semi-spade rudders: $A_{PL} = \frac{A_R C_{CP}}{C_{PL}}$ m^2 but for semi-spade rudders need not be taken greater than A_R Upper pintle on semi-spade rudders; $A_{PL} = A_R\left(1 - \frac{C_{CP}}{C_{PL}}\right)$ m^2 or $0{,}35A_R$ m^2, whichever is the greater For rudders with two or more pintles (except semi-spade rudders): $A_{PL} = \frac{A_R}{N_{PL}}$ m^2	
(2) Maximum pintle taper	Method of assembly	Taper (on diameter)
	Manual assembly, key fitted (pintle ≤ 200mm diameter)	1 in 6
	Manual assembly, key fitted (pintle ≥ 400mm diameter)	1 in 9
	For keyed and other manually assembled pintles with diameters between 200 mm and 400 mm, the taper is to be obtained by interpolation	
	Hydraulic assembly, dry fit Hydraulic assembly, oil injection	1 in 12 1 in 15
(3) Bearing length	$Z_{PB} \geq 1{,}2\delta_{PL}$ mm May be less for very large pintles if bearing pressure is not greater than that given in (4), but Z_{PB} must not be less than $1{,}0\delta_{PL}$ mm	
(4) Bearing pressure (on projected area)	Bearing material	Pressure
	Metal Synthetic	7,0 N/mm^2 5,5 N/mm^2
	Using force acting on bearing: $P_{PL} = \frac{A_{PL}(V+3)^2 f_R}{10}$ kN A_{PL} as for item (1)	
(5) Gudgeon thickness in way of pintle (measured outside bush if fitted)	$b_G \geq 0{,}5\delta_{PL}$ but need not normally exceed 125mm	
(6) Pintle clearance (note should be taken of the manufacturer's recommended clearances particularly where bush material requires pre-soaking). Value of proposed minimum clearance is to be indicated on plans submitted for approval	Bearing material	Minimum clearance, mm
	Metal Synthetic	$0{,}001\delta_{PL} + 1{,}0$ $0{,}002\delta_{PL} + 1{,}0$ but not less than 1,5

Symbols

δ_{PL} = pintle diameter, in mm
V = as defined in Table 3.2.7 but not less than 10 knots
A_{PL} = rudder area supported by the pintle, in m^2
C_{CP}, C_{PL} = dimensions in metres, as indicated in Figs. 3.2.4 and 3.2.5
A_R = rudder area, in m^2
σ_o = as defined in Table 3.2.7
N_{PL} = number of pintles on the rudder
Z_{PB} = pintle bearing length, in mm
P_{PL} = force acting on bearing, in kN
b_G = thickness of gudgeon material in way of pintle, in mm
f_R = rudder profile coefficient, *see* Table 3.2.1
m = as defined in Table 3.2.7

NOTE
Proposals for higher pressures or other materials will be specially considered on the basis of satisfactory test results.

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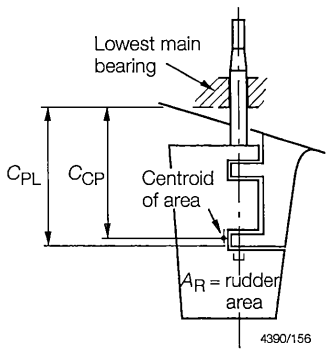

Fig. 3.2.5
Lower pintle housed below rudder gudgeon

2.20 Bolted couplings

2.20.1 Rudder coupling design is to be in accordance with Table 3.2.12.

2.20.2 Where coupling bolts are required they are to be fitted bolts. Suitable arrangements are to be made to lock the nuts.

2.20.3 For rudders with horizontal coupling arrangements, where the upper flange is welded to the rudder stock, a full penetration weld is required and its integrity is to be confirmed by non-destructive examination. Such rudder stocks are to be subjected to a furnace post-weld heat treatment (PWHT) after completion of all welding operations. For carbon or carbon manganese steels, the PWHT temperature is not to be less than 600°C.

Table 3.2.12 Rudder couplings to stock (*see continuation*)

Arrangement	Parameter	Requirement	
		Horizontal coupling	Vertical coupling
(1) Bolted couplings (*see* Notes)	n	≥ 6	≥ 8
	δ_b	$\frac{0{,}65 d_s}{\sqrt{n}}$	$\frac{0{,}81 d_s}{\sqrt{n}}$
	m	$0{,}00071 n\, d_s\, \delta_b^2$	$0{,}00043 d_s^3$
	t_f	$\geq \delta_b$, *see* Note 1	δ_b
	α_{max} *see* Note 2	$(53{,}82 - 35{,}29 k_1)\frac{d_s^3}{P_L h 10^6} - \left(1{,}8 - 6{,}3\frac{R}{d_s}\right)\frac{t_f - t_{fa}}{t_{fa}}$	—
	$\alpha_{as\ built}$ *see* Note 2	$\leq \alpha_{max}$	—
	w_f	$0{,}67\delta_b$	$0{,}67\delta_b$
(2) Conical couplings	θ_t	$\leq \frac{1}{K_1}$	
	l_t	$\geq 1{,}5 d_s$	
	$\overline{p}$	$\frac{P_R \theta_t \overline{\delta}_{ST} + 4M_T \sqrt{K_2\left(\left(\frac{P_R \overline{\delta}_{ST}}{2M_T}\right)^2 + 1\right) - \left(\frac{\theta_t}{2}\right)^2}}{5{,}66 \overline{\delta}_{ST}^2 l_t \left(K_2 - \left(\frac{\theta_t}{2}\right)^2\right)}$	
	w	$\frac{9{,}6 \times 10^{-6} \overline{p}\, \overline{\delta}_{ST}}{\theta_t (1 - \overline{f}^2)}$	
	P_u	Approximately equal to $2{,}83 \overline{p}\, l_t \overline{\delta}_{ST} \left(K_3 + \frac{\theta_t}{2}\right)$	
	P_o	Approximately equal to $2{,}83 \overline{p}\, l_t \overline{\delta}_{ST} \left(K_3 - \frac{\theta_t}{2}\right)$	
	σ_o	$\geq \frac{12{,}35 \times 10^4 w \theta_t \sqrt{3 + f^4}}{\delta_{ST}}$	

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Table 3.2.12 Rudder couplings to stock (*see continuation*)

Arrangement	Parameter	Requirement	
		Horizontal coupling	Vertical coupling
(1) Bolted couplings (*see* Notes)	n	≥ 6	≥ 8
	δ_b	$\frac{0{,}65 d_s}{\sqrt{n}}$	$\frac{0{,}81 d_s}{\sqrt{n}}$
	m	$0{,}00071 n\, d_s\, \delta_b^2$	$0{,}00043 d_s^3$
	t_f	$\geq \delta_b$, *see* Note 1	δ_b
	α_{max} *see* Note 2	$(53{,}82 - 35{,}29k_1)\frac{d_s^3}{P_L h 10^6} - \left(1{,}8 - 6{,}3\frac{R}{d_s}\right)\frac{t_f - t_{fa}}{t_{fa}}$	—
	$\alpha_{as\ built}$ *see* Note 2	$\leq \alpha_{max}$	—
	w_f	$0{,}67\delta_b$	$0{,}67\delta_b$
(2) Conical couplings	θ_t	$\leq \frac{1}{K_1}$	
	l_t	$\geq 1{,}5 d_s$	
	$\overline{p}$	$\frac{P_R \theta_t \overline{\delta}_{ST} + 4M_T \sqrt{K_2\left(\left(\frac{P_R \overline{\delta}_{ST}}{2M_T}\right)^2 + 1\right) - \left(\frac{\theta_t}{2}\right)^2}}{5{,}66 \overline{\delta}_{ST}^2 l_t \left(K_2 - \left(\frac{\theta_t}{2}\right)^2\right)}$	
	w	$\frac{9{,}6 \times 10^{-6} \overline{p}\, \overline{\delta}_{ST}}{\theta_t (1 - \overline{f}^2)}$	
	P_u	Approximately equal to $2{,}83 \overline{p}\, l_t \overline{\delta}_{ST} \left(K_3 + \frac{\theta_t}{2}\right)$	
	P_o	Approximately equal to $2{,}83 \overline{p}\, l_t \overline{\delta}_{ST} \left(K_3 - \frac{\theta_t}{2}\right)$	
	σ_o	$\geq \frac{12{,}35 \times 10^4\, w\, \theta_t \sqrt{3 + f^4}}{\delta_{ST}}$	

2.20.4 The connecting bolts for coupling the rudder to the rudder stock are to be positioned with sufficient clearance to allow the fitting and removal of the bolts and nuts without contacting the palm radius, *R*, *see* Fig. 3.2.6(a). The surface forming the palm radius is to be free of hard and sharp corners and is to be machined smooth to the Surveyor's satisfaction. The surface in way of bolts and nuts is to be machined smooth to the Surveyor's satisfaction.

2.20.5 For spade rudders fitted with a fabricated rectangular mainpiece, the mainpiece is to be designed with its forward and aft transverse sections at equal distances forward and aft of the rudder stock transverse axis, *see* Fig. 3.2.6(b).

2.21 Conical couplings

2.21.1 Where a rudder stock is connected to a rudder by a keyless fitting, the rudder is to be a good fit on the rudder stock cone. During the fit-up, and before the push-up load is applied, an area of contact of at least 90 per cent of the theoretical area of contact is to be achieved, and this is to be evenly distributed. The relationship of the rudder to stock at which this occurs is to be marked, and the push-up then measured from that point. The upper edge of the upper mainpiece bore is to have a slight radius. After the final fitting of the stock to the rudder, positive means are to be used for locking the securing nut to the stock.

2.21.2 Where a keyed tapered fitting of a rudder stock to a rudder is proposed, a securing nut of adequate proportions is to be provided. After the final fitting of the stock to the rudder, positive means are to be used for locking this nut.

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Table 3.2.12 Rudder couplings to stock (*conclusion*)

Symbols

n = number of bolts in coupling

δ_b = diameter of coupling bolts, in mm

d_s, d_{su} = rudder stock diameter as defined in Table 3.2.7

m = first moment of area of bolts about centre of coupling, in cm^3

k_1 = the greater of k_s and k_f

$k_s = \left(\frac{235}{\sigma_o}\right)^m$ where σ_o is the specified minimum yield stress at the rudder stock and m is as defined in Table 3.2.7

$k_f = \left(\frac{235}{\sigma_o}\right)^m$ where σ_o is the specified minimum yield stress at the upper coupling flange and m is as defined in Table 3.2.7

h = vertical distance between the centre of pressure and the centre point of the palm radius, R, in metres, *see* Fig. 3.2.6(a)

R = palm radius between rudder stock and connected flange, not smaller than $\frac{d_s}{10}$, in mm

t_f = minimum thickness of coupling flange, in mm

t_{fa} = as built flange thickness, in mm

α_{max} = maximum allowable stress concentration factor

$\alpha_{as\ built}$ = stress concentration factor for as built scantlings

$= \frac{0,73}{\sqrt{\left(\frac{R}{d_s}\right)}}$

w_f = width of flange material outside the bolt holes, in mm

θ_t = taper of conical coupling, on the diameter, e.g.:

$\theta_t = \frac{1}{15} = 0,067$

l_t = length of taper, in mm

$\bar{p}$ = required mean grip stress, in N/mm^2

w = corresponding push-up of rudder stock, in mm

P_u, P_o = corresponding push-up, pull-off loads respectively, in N

σ_o = minimum yield stress of stock and gudgeon material, in N/mm^2. σ_o is not to be taken greater than 70 per cent of the ultimate tensile strength

P_R = effective weight of rudder, in N

$\overline{\delta_{ST}}$ = mean diameter of coupling taper, in mm

δ_{ST} = diameter of coupling taper at any position, in mm

$\overline{\delta_{GH}}$ = mean external diameter of gudgeon housing, in mm

δ_{GH} = external diameter of gudgeon housing at any position, in mm

$\overline{f}$ $\frac{\overline{\delta_{ST}}}{\overline{\delta_{GH}}}$

f $\frac{\delta_{ST}}{\delta_{GH}}$

M_T = maximum torque applied to stock, and is to be taken as the greater of M_F, M_A or M_W

M_F = $P_L X_{PF} \times 10^6$ Nmm in the ahead condition

M_A = $P_L X_{PA} \times 10^6$ Nmm in the astern condition

M_W = the torque generated by the steering gear at the maximum working pressure supplied by the manufacturer, in Nmm. M_W is not to exceed the greater of $3,0M_F$ or $3,0M_A$

P_L = lateral force on rudder acting at centre of pressure in ahead and astern conditions, as defined in Table 3.2.7, in kN

X_{PF}, X_{PA} = the horizontal distances, in metres, *see* Table 3.2.6

K_1, K_2, K_3 = constants depending on the type of assembly adopted as follows:

		K_1	K_2	K_3
Oil injection method	with key	15	0,0064	0,025
	without key	15	0,0036	0,025
Dry fit method	with key	12	0,0128	0,170
	without key	12	0,0072	0,170

NOTES
1. For spade rudders with horizontal coupling, t_f is not to be less than $0,25d_s$.
2. This requirement is applicable only for spade rudders with horizontal couplings, *see* Fig. 3.2.6.
3. Where materials vary for individual components, scantling calculations for such components are to be based on d_s for the relevant material.

2.22 Rudder carrier arrangements

2.22.1 The weight of the rudder is to be supported at the heel pintle or by a carrier attached to the rudder head. The hull structure supporting the carrier bearing is to be adequately strengthened. The plating under all rudder-head bearings or rudder carriers is to be increased in thickness.

2.23 Anti-jump collars

2.23.1 Suitable arrangements are to be provided to prevent the rudder from lifting.

2.23.2 Jumping collars are not to be welded to the rudder stock.

2.24 Drain plugs

2.24.1 Where rudders are of plated construction, drain plugs are to be provided to ensure that all compartments can be adequately drained. These plugs are to be locked and details of their scantlings, arrangements and position clearly indicated on the rudder plan.

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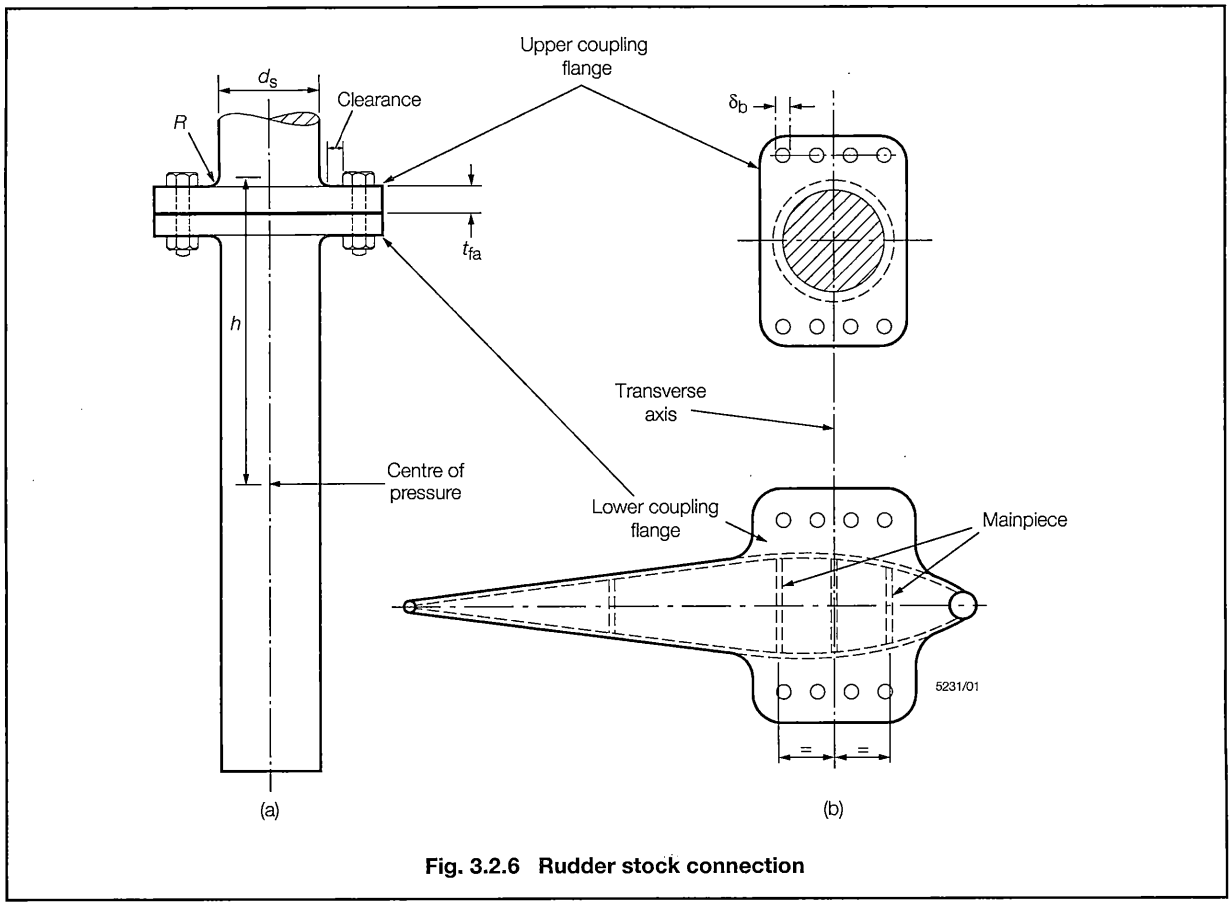

Fig. 3.2.6 Rudder stock connection

2.25 Corrosion protection

2.25.1 All metalwork, is to be suitably protected against corrosion. This may be by coating or, where applicable, by a system of cathodic protection.

2.25.2 Metalwork is to be suitably cleaned before the application of any coating. Where appropriate, blast cleaning or other equally effective means are to be employed for this purpose.

2.26 Dissimilar materials

2.26.1 Where materials vary for individual components, they are to be compatible to avoid galvanic corrosion. Scantling calculations for the components are to be based on d_s for the relevant material, *see* Table 3.2.7.

2.27 Internal coatings

2.27.1 Internal surfaces of the rudder are to be efficiently coated or the rudder is to be filled with foam plastics. Where it is intended to fill the rudder with plastic foam, details of the foam are to be submitted.

2.28 Pressure testing

2.28.1 For testing of rudders, *see* Table 1.7.1 in Chapter 1.

2.29 Tiller arms, quadrants

2.29.1 Tillers and quadrants are to comply with the requirements of Table 1.4.1 in Pt 14, Ch 1.

2.29.2 The steering gear is to be mounted on a seat and adequately secured.

2.30 Connecting bars

2.30.1 Connecting bars are to comply with the requirements of Pt 14, Ch 1,4.3.3.

2.31 Keys and keyways

2.31.1 Where the tiller or quadrant is bolted, a key having an effective cross-sectional area in shear of not less than $0{,}25d_{SU}^2$ mm^2 is to be fitted. The thickness of the key is to be not less than $d_{SU}/6$ mm. Alternatively, the rudder stock may be machined to a square section in lieu of fitting a key. d_{SU} is as defined in Table 3.2.7.

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2.31.2 Keyways are to extend over the full depth of the tiller boss.

2.31.3 Keyways in the rudder stock are to have rounded ends and the corners at the base of the keyway are to be radiused.

2.32 Stopping arrangements

2.32.1 Suitable rudder stops are to be provided to limit the rudder angle to the desired level port and starboard. These stops are to be of substantial construction and efficiently connected to the supporting structure.

2.33 Novel designs

2.33.1 Where rudders are of a novel design they may be specially considered on the basis of the Rules. Alternatively the Builder's/designer's calculations are to be submitted for consideration.

2.34 FRP double plated rudders

2.34.1 Fibre reinforced plastic rudders are to incorporate a metallic framework, consisting of a mainpiece fitted with arms, within the blade, or an equivalent arrangement. Where rudder blades are moulded in halves they are to be effectively joined together by means of external overbonding of the joint or suitable mechanical fastening or equivalent. Both halves of the rudder blade moulding are to be effectively connected to the metallic framework and mainpiece by either mechanical means or suitable bonded connection.

2.34.2 Rudders are to be filled with a suitable material upon completion of the join up, details of the filler material are to be submitted.

2.34.3 The diameter of the top of the rudder mainpiece must not be less than that of the rudder stock. For spade rudders this diameter may be gradually reduced for the lower third to not less than 75 per cent of the rudder stock diameter.

2.34.4 The rudder arms are to be efficiently attached to the mainpiece.

2.34.5 The laminate weight of moulded fibre reinforced plastics double plate rudders is to be determined by direct calculation, subject to a minimum laminate thickness of 5 mm.

2.35 Rudder tube arrangements

2.35.1 The rudder tube construction may be of aluminium alloy, steel, bronze or fibre reinforced plastic.

2.35.2 The scantlings of rudder tubes will be individually considered.

2.35.3 For steel and aluminium hulls, the bottom shell in way of the rudder tubes is to be additionally reinforced by means of an insert plate to increase the bottom shell thickness by 50 per cent.

2.35.4 For F.R.P. hulls, the bottom shell laminate in way of the rudder tubes is to be locally increased by 50 per cent. The increased thickness in way of the rudder tube need not exceed the rule keel thickness requirement.

2.35.5 For F.R.P. sandwich hulls the shell in way of the rudder tube connection is to be either:

(a) Reduced from the sandwich hull construction to single skin laminate for a distance of a least three times the rudder tube diameter about the rudder stock axis. The single skin region is to be additionally reinforced by a minimum of 50 per cent of the sum of the inner and outer sandwich laminate subject to this being at least equivalent to a 50 per cent increase in thickness of the Rule minimum bottom shell laminate for a single skin F.R.P. craft of the equivalent Rule length, L_R. The reinforced laminate need not be greater than the Rule keel laminate thickness.

(b) Reduced from the sandwich hull construction to a single skin laminate for a distance of three times the rudder tube diameter about the rudder stock axis. After bonding in the rudder tube to the single skin laminate the foam core and inner skin are then reinstated.

(c) Proposals to replace the sandwich core with a core having higher core shear strength and compressive strength than that of the adjacent structure prior to bonding the tube to the inner and outer skins will be the subject of special consideration.

2.35.6 The rudder tube may be connected to the shell by bonding, bolting or welding as applicable depending upon the construction material of the shell.

2.35.7 When bonding in rudder tubes the bonding angle is to be not less than the Rule minimum bottom shell weight. F.R.P. tubes are to be thoroughly abraded and degreased prior to installation and laminating. Bonded in metallic tubes are to be knurled in way of the bonding material and thoroughly degreased prior to installation.

2.35.8 Where rudder tubes are to be retained by bolting they are to be provided with a substantial flange securely attached to the hull structure. Where bolts are used, the nuts are to be suitably locked.

2.35.9 Where rudder tubes are to be welded to hull insert plates full penetration welding is required.

2.35.10 Rudder tubes are to be supported by suitable brackets and deep floors to avoid hard spots on the shell and to ensure continuity of the main hull structure.

2.35.11 Rudder bearings are to be secured against rotation within the rudder tubes by suitable pinch bolting or keys. Details are to be submitted for approval.

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2.36 Watertight gland

2.36.1 In rudder trunks which are open to the sea, a seal or stuffing box is to be fitted above the deepest load waterline, to prevent water from entering the steering gear compartment and the lubricant from being washed away from the rudder carrier. If the top of the rudder trunk is below the deepest waterline two separate stuffing boxes are to be provided. Rudder trunk boundaries where exposed to the sea are to have a corrosion protection coating applied in accordance with the manufacturer's instructions.

2.36.2 Where the top of the rudder tube is significantly higher than the deepest load waterline a lesser arrangement of watertightness, such as 'O' rings may be accepted.

2.36.3 The watertight gland body may be formed by the top of the fabricated or cast rudder tube. The gland packing being retained against the top bearing or a check in the wall of the rudder tube and is compressed by a gland packet which may be of the flange type, screwed cap or other suitable arrangement.

2.36.4 Alternative arrangements utilising lip seals or 'O' rings, either in isolation or in combination with one or other of the alternative seal arrangements, will be the subject of special consideration.

2.37 In-water Survey requirements

2.37.1 Where an ***IWS** (In-water Survey) notation is to be assigned, *see* Pt 1, Ch 2,3.8, means are to be provided for ascertaining the rudder pintle and bush clearances and for verifying the security of the pintles in their sockets with the craft afloat.

■ *Section 3* Sternframes and appendages

3.1 General

3.1.1 Stern frames, rudder horns and boss end brackets may be constructed of cast or forged steel, cast or forged aluminium alloy, fabricated from aluminium or steel plate or moulded from fibre reinforced plastic dependent upon the material of construction of the craft. Where shaft brackets are fitted these may be either fabricated, cast or forged from steel or aluminium alloy as applicable to the material of construction of the main hull.

3.1.2 In castings, sudden changes of section or possible constrictions to the flow of metal during casting are to be avoided. All fillets are to have adequate radii, which, in general, are to be not less than 50 to 75 mm, depending on the size of the casting.

3.1.3 Castings and forgings are to comply with the requirements of Chapters 4 and 5 of the Rules for Materials.

3.1.4 Sternframes, rudder horns, shaft brackets, etc., are to be effectively integrated into the craft structure, and their design is to be such as to facilitate this.

3.2 Sternframes

3.2.1 The scantlings of sternframes are to be determined from Table 3.3.1. In the case of very large craft, the scantlings and arrangements may be required to be verified by direct calculations.

3.2.2 Fabricated and cast propeller posts and rudder posts of twin screw craft are to be strengthened at intervals by webs. In way of the upper part of the sternframe arch, these webs are to line up with the floors.

3.2.3 Rudder posts and propeller posts are to be connected to floors of increased thickness. *See* Ch 3,5.10 of Parts 6 and 7 for steel and aluminium alloy construction respectively.

3.2.4 The requirements for sternframes of composite craft are to be in accordance with Pt 8, Ch 3,5.9.

3.3 Rudder horns

3.3.1 The requirements for the scantlings and arrangements of rudder horns are given in Ch 3,5.9 of Parts 6 and 7 for steel and aluminium alloy construction and Pt 8, Ch 3,5.8 for composite construction respectively.

3.4 Shaft bossing

3.4.1 Where the propeller shafting is enclosed in bossings extending back to the bearings supporting the propellers, the aft end of the bossings and the bearings are to be supported by substantially constructed boss end castings or fabrications. These are to be designed to transmit the loading from the shafting efficiently into the craft's internal structure.

3.4.2 For shaft bossings attached to shaft brackets, the length of the boss is to be adequate to accommodate the aftermost bearing and to allow for proper connection of the shaft brackets.

3.4.3 Cast steel supports are to be suitably radiused where they enter the main hull to line up with the boss plating radius. Where the hull sections are narrow, the two arms are generally to be connected to each other within the craft. The arms are to be strengthened at intervals by webs.

3.4.4 Fabricated supports are to be carefully designed to avoid or reduce the effect of hard spots. Continuity of the arms into the craft is to be maintained, and they are to be attached to substantial floor plates or other structure. The connection of the arms to the bearing boss is to be by full penetration welding.

3.4.5 The scantlings of supports will be specially considered. In the case of certain high powered craft, direct calculations may be required.

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Table 3.3.1 Sternframes (*see continuation*)

Item	Parameter	Requirement		
(1) Propeller posts		Cast steel (*see* Fig. 3.3.1(a))	Forged Steel (*see* Fig. 3.3.1(b))	Fabricated mild steel (*see* Fig. 3.3.1(c))
	l	$165\sqrt{T}$ mm	–	$200\sqrt{T}$ mm
	r	$20\sqrt{T}$ mm	–	$18\sqrt{T}$ mm
	t_W	$8\sqrt{T}$ mm (need not exceed 38 mm) (*see* Notes 1 and 2)	–	$6\sqrt{T}$ mm (need not exceed 30 mm) (*see* Notes 1 and 2)
	t_1	$12\sqrt{T}$ mm (min 19 mm)	–	$12\sqrt{T}$ mm
	t_2	$16\sqrt{T}$ mm (min 25 mm)	–	–
	W	$115\sqrt{T}$ mm	$40\sqrt{T}$ mm	$140\sqrt{T}$ mm
	A	–	$(10 + 0{,}5L_R)T$ cm^2 where $L_R \leq 60$ m $40T$ cm^2 where $L_R > 60$m	–
(2) Propeller boss (*see* Note 3 and Fig. 3.3.2)	t_b	$(0{,}1\delta_{TS} + 56)$ mm, but need not exceed $0{,}3\delta_{TS}$		
(3) Rudder posts or axles		Single screw with integral solepiece, *see* Fig. 3.3.5 (a)	Single screw with bolted rudder axle, with hull, *see* Fig. 3.3.3	Twin screw, integral *see* Fig. 3.3.4
	n	–	6 (*see* Note 4)	–
	r	–	–	$20\sqrt{T}$ mm
	r_b	–	δ_A mm	–
	t_F	–	δ_b mm	–
	t_1	–	–	$12\sqrt{T}$ mm
	t_2	–	–	$15\sqrt{T}$ mm
	t_3	–	–	$18\sqrt{T}$ mm
	w	–	–	$120\sqrt{T}$ mm
	z_{PB1}, z_{PB2}	–	$1{,}2\delta_{PL2}$ mm	–
	Z_T	$0{,}147A_R\,b(V + 3)^2$ cm^3	–	–
	δ_A	–	$(25T + 76)$ mm but need not exceed $0{,}9\delta_{PL2}$ mm	–
	δ_b	–	$6{,}25T + 19$ mm or $0{,}225\delta_{PL2}$ mm whichever is the greater	–
	δ_{PL1}, δ_{PL2} bearing pressure and pintle clearance	–	As for rudder pintles (*see* Table 3.2.11)	–
(4) Solepieces (*see* Notes 5,6 and 7)		With integral rudder post, *see* Fig. 3.3.5(a)	With bolted axle, *see* Fig. 3.3.5(b)	Open type (no rudder post), *see* Fig. 3.3.5(c)
(a) Cast steel	Z_T	$0{,}50W$ cm^3	$0{,}95W$ cm^3	$1{,}00W$ cm^3
	Z_V	$0{,}35W$ cm^3	$0{,}40W$ cm^3	$0{,}50W$ cm^3
(b) Fabricated mild steel	Z_T	$0{,}42W$ cm^3	$0{,}81W$ cm^3	$0{,}85W$ cm^3

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Table 3.3.1 Sternframes (*conclusion*)

Symbols	
L_R, T as defined in Ch1,6.2	$L_1 = L_R$, but is to be taken not less than 90 m
a,b,c = distances, in metres, as shown in Fig. 3.3.5	V = maximum service speed, in knots, with the craft in the loaded condition
n = number of bolts in palm coupling	$W = \dfrac{400 A_R C (V+3)^2 (3x+a)}{b (L_1 + 640)}$
r_b = mean distance of bolt centres from centre of palm, in mm	Z_T = section modulus against transverse bending, in cm^3
t_b = finished thickness of boss, in mm	Z_V = section modulus against vertical bending, in cm^3
x = distance, in metres, from centre of rudder stock to section under consideration	δ_b = diameter of coupling bolts, in mm
A = cross-sectional area of forged steel propeller post, in cm^2	δ_{TS} = diameter of tail shaft, in mm
A_R = total rudder area, in m^2	

NOTES

1. Where scantlings and proportions of the propeller post differ from those shown in Item 1, the section modulus about the longitudinal axis of the proposed section normal to the post is to be equivalent to that with Rule scantlings. t_1 is to be not less than $8\sqrt{T}$ (minimum of 19 mm for cast steel sternframes)
2. On sternframes without solepieces, the modulus of the post below the propeller boss, about the longitudinal axis may be gradually reduced to not less than 85% of that required by Note 1, subject to the same thickness limitations.
3. In fabricated sternframes the connection of the propeller post to the boss is to be by full penetration welds.
4. If more than six bolts are fitted, the arrangements are to provide equivalent strength.
5. In fabricated solepieces, transverse webs are to be fitted spaced not more than 760 mm apart. Where the breadth of the solepiece exceeds 900 mm, a centreline vertical web is also to be fitted.
6. Solepieces supporting fixed or movable nozzles will be specially considered (*see* 4.2).
7. For dredging and reclamation craft in restricted service Groups G1, G2 or G3, the scantlings of an 'open' type solepiece are to be such that:
   (a) $Z_T = 0{,}625W$ cm^3.
   (b) The cross-sectional area is not less than 18 cm^2.
   (c) The depth is not less than two-thirds of the width at any point.

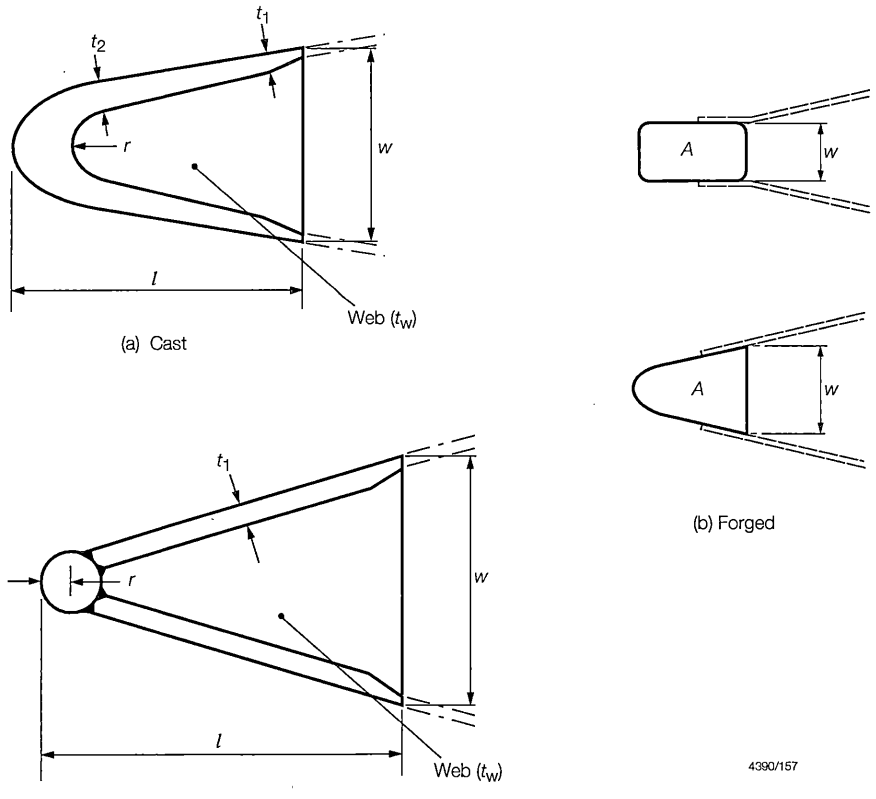

Fig. 3.3.1 Propeller posts

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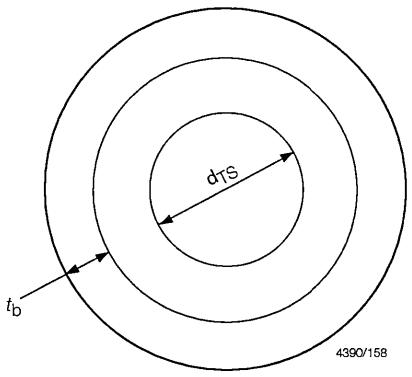

Fig. 3.3.2 Propeller boss

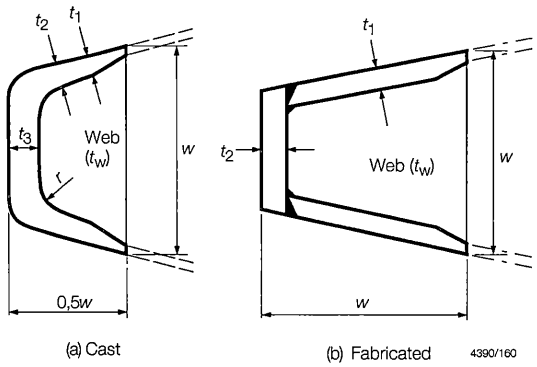

Fig. 3.3.4 Rudder post for twin screw craft

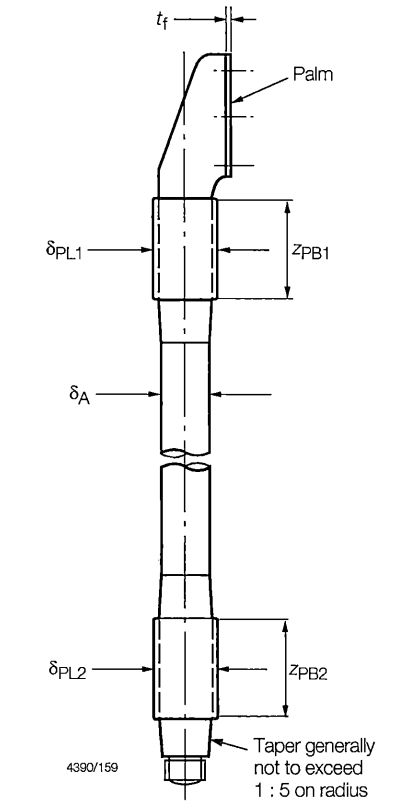

Fig. 3.3.3 Rudder axle

3.4.6 The boss plating is generally to be radiused into the shell plating and supported at the aft end by diaphragms at every frame. These diaphragms are to be suitably stiffened and connected to floors or a suitable arrangement of main and deep web frames. At the forward end, the main frames may be shaped to fit the bossing, but deep webs are generally to be fitted not more than four frame spaces apart.

3.5 Shaft brackets

3.5.1 The scantlings of the arms of shaft brackets, based on a breadth to thickness ratio of about five, are to be determined from 3.6.1 and 3.7.2.

3.5.2 Where the propeller shafting is exposed to the sea for some distance clear of the main hull, it is generally to be supported adjacent to the propeller by independent brackets having two arms. In very small craft the use of single arm brackets will be considered.

3.5.3 Fabricated brackets are to be designed to avoid or reduce the effect of hard spots and ensure a satisfactory connection to the hull structure. The connection of the arms to the bearing boss is to be by full penetration welding.

3.5.4 Where bracket arms are carried through the shell plating, they are to be attached to floors or girders of increased thickness. The shell plating is to be increased in thickness and connected to the arms by full penetration welding.

3.5.5 In the case of certain high powered craft direct calculations may be required.

3.5.6 For shaft brackets having hollow section arms, the cross-sectional areas at the root and the boss should be not less than that required for a solid arm which satisfies the Rule section modulus having the proportions stated in 3.5.1.

3.5.7 The length of the shaft bracket boss, l_b, is to be sufficient to support the length of the required bearing. In general l_b is not to be less than $4d_t$, where d_t is the Rule diameter of the screwshaft, in mm, *see* Pt 11, Ch 2,4.4. Proposals for a reduction in the required shaft bracket boss length will be considered in conjunction with details of the bearing material, allowable bearing operating pressure and installation arrangements, *see* Pt 11, Ch 2,4.16.2. However in no case is l_b to be less than the greater of:

(a) $2d_t$; or
(b) that recommended by the bearing manufacturer; or
(c) as required by 3.4.2.

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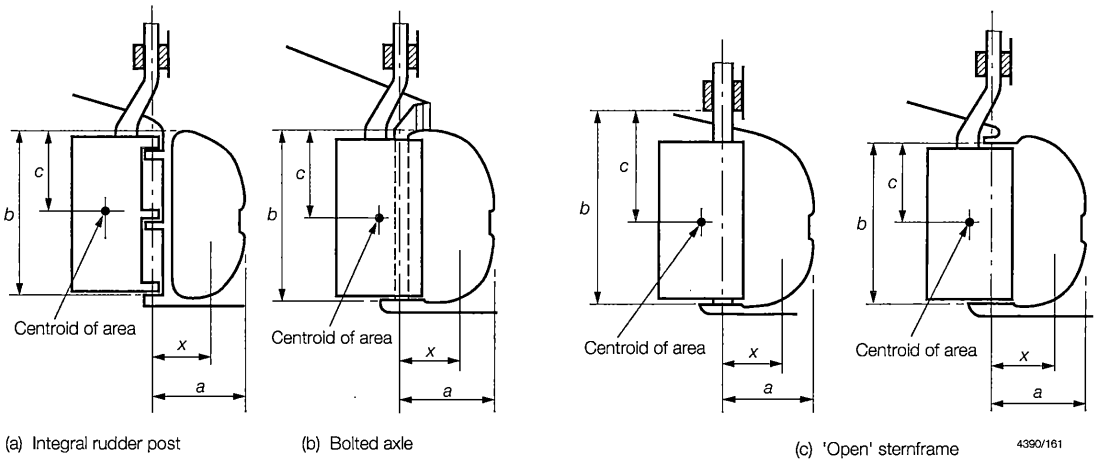

Fig. 3.3.5 Solepiece

3.5.8 Where the shaft and the shaft bracket boss are of the same material, the thickness of the shaft bracket boss is not to be less than $d_t/4$. Where the shaft and the shaft bracket boss are of dissimilar materials, the thickness of the boss, t_b, is to be not less than:

$$t_b = 0{,}75 d_t \left(\sqrt[3]{f_1} - 0{,}667 \right) \text{ mm}$$

NOTE:
In no case is t_b to be taken as less than 12 mm.

where

d_t = Rule diameter of the screwshaft, in the appropriate screwshaft material, in mm, *see* Pt 11, Ch 2,4

f_1 = σ_S/σ_B but not less than 0,825

σ_S = ultimate tensile strength of the shaft material, in N/mm^2

σ_B = ultimate tensile strength of the boss material, in N/mm^2.

3.5.9 The design of the shaft brackets with regard to disturbance of the hydrodynamic flow into the propeller and rudders is outwith the scope of classification.

3.6 Single arm shaft brackets ('P' – brackets)

3.6.1 Single arm shaft brackets are to have a section modulus, Z_{xx}, at the palm of not less than that determined from the formula:

$$Z_{xx} = \frac{a_s d_t^2 f}{45000} \text{ cm}^3$$

where

a_s = the length of the arm to be measured from the centre of the section at the palm to the centreline of the shaft boss, in mm, *see* Fig. 3.3.6

d_t = the Rule diameter for an unprotected screwshaft, in mm, as given in Pt 11, Ch 2,4, using $A = 1{,}0$

f = $400/\sigma_u$

σ_u = ultimate tensile strength of arm material, in N/mm^2

The cross-sectional area of the bracket at the boss is to be not less than 60 per cent of the area of the bracket at the palm.

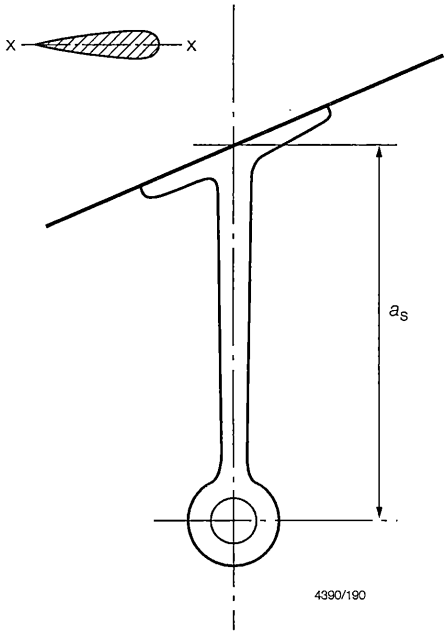

Fig. 3.3.6 Single arm shaft bracket

3.6.2 For single arm shaft brackets a vibration analysis may be required if deemed necessary by LR.

3.7 Double arm shaft brackets ('A' – brackets)

3.7.1 The angle between the arms for double arm shaft brackets is to be generally not less than 50°. Proposals for the angle between the arms to be less than 50° will be specially considered with supporting calculations to be submitted by the designers.

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3.7.2 The arms of double arm shaft brackets are to have a section modulus, Z_{xx}, of not less than that determined from the formula:

$$Z_{xx} = 0{,}45\, n^3 \quad cm^3$$

where

n = the minimum thickness, in cm, of a hydrofoil section obtained from:

$$n = d_t \sqrt{\left(\frac{f}{2000}\right)\left(1 + \sqrt{\left(1 + \left(\frac{0{,}0112}{f}\right)\left(\frac{a_d}{d_t}\right)^2\right)}\right)} \quad cm$$

a_d = the length of the longer strut, in mm, *see* Fig. 3.3.7

d_t and f are as given in 3.6.1.

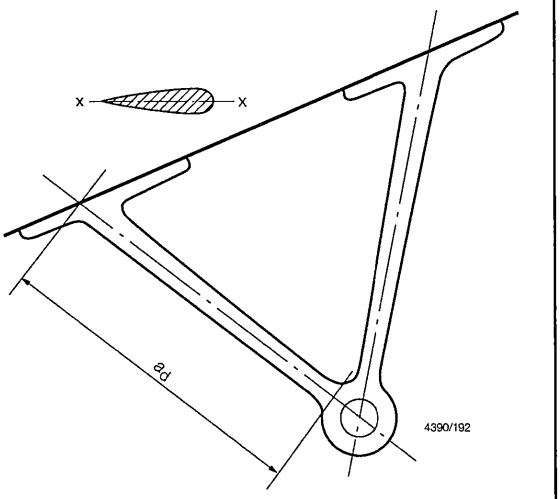

Fig. 3.3.7 Double arm shaft bracket

3.8 Intermediate shaft brackets

3.8.1 The length and thickness of the shaft bracket boss are to be as required by 3.5.7 or 3.5.8 as appropriate. The scantlings of the arms will be specially considered on the basis of the Rules.

3.9 Attachment of shaft brackets by welding

3.9.1 Fabricated supports are to be carefully designed to avoid or reduce the effect of hard spots. Continuity of the arms into the craft is to be maintained, and they are to be attached to substantial floor plates or other structure. The connection of the arms to the bearing boss is to be by full penetration welding.

3.10 Attachment of shaft brackets by bolting

3.10.1 The bottom shell thickness in way of the double arm propeller bracket palms is to be increased by 50 per cent. The bottom shell thickness in way of single arm propeller brackets palms is to be doubled in thickness. The insert plates, or reinforced shell laminate in FRP craft, are to be additionally supported by substantial floor plates or other structure.

3.10.2 Where shaft brackets are attached by bolts, they are to be provided with substantial palms securely attached to the hull structure which is to be adequately stiffened in way. Where bolts are used, the nuts are to be suitably locked.

3.10.3 The bracket palms may be bolted directly onto the shell using a suitable bedding compound. The palms may be bolted onto suitable shims or chocking compound, of an approved type, to facilitate alignment.

3.10.4 Where brackets are bolted onto resin chocks, plans indicating the following information are to be submitted for approval:

(a) The thrust and torque loads, where applicable, that will be applied to the chocked item.
(b) The torque load to be applied to the bracket mounting bolts.
(c) The material of the bracket mounting bolts.
(d) The number, thread size, shank diameter and length of the mounting bolts.

3.10.5 The minimum thickness of a resin chock is to be 12 mm.

3.10.6 The bracket palms are to have well radiused corners, and the faying surface to be dressed smooth. The palm thickness in way of the bolts is to be not less than the propeller bracket boss thickness from 3.5.7 or 3.5.8 as appropriate.

3.10.7 The diameter of the propeller bracket mounting bolts is to be not less than:

$$d_b = \sqrt{\frac{Z_{xx}}{8{,}75\,\pi\, n\, h \times 10^{-5}}} \quad mm$$

and not less than the shell plate thickness in way of the palm or 12 mm, whichever is greater

where

Z_{xx} = the section modulus of the bracket arm determined from 3.6.1 or 3.7.2, in cm^3, as appropriate
n = the number of bolts in each row
h = the distance between rows of bolts, in mm
d_b = the bolt diameter in the same material as the propeller bracket, in mm.

3.10.8 Where the shaft bracket and the shaft bracket mounting bolts are of dissimilar materials (which are galvanically compatible), the diameter of the propeller bracket mounting bolts, as determined from 3.10.7, is to be modified in proportion to the square root of the yield strengths of the particular materials. The corrected bolt diameter of the dissimilar material is to be not less than the propeller bracket boss thickness.

3.10.9 The propeller bracket palms are to have fitted bolts, and suitable arrangements provided to lock the nuts.

3.10.10 A washer plate is to be provided, generally of equal dimensions to the bracket palm with thickness $t_b/6$ mm, subject to a minimum of 3 mm.

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3.11 Attachment of shaft brackets by bonding

3.11.1 Proposals to connect shaft brackets to FRP hulls by bonding will be the subject of special consideration. Details of the following are to be submitted:

(a) Preparation of the hull penetration and internal bonding surface.

(b) Details of transverse through pinning of the shaft bracket strut.

(c) Details of over bonding of strut and pin arrangement and subsequent integration of strut into primary hull structure.

3.12 Alignment of shaft brackets

3.12.1 Particular care is to be paid to the alignment of shaft brackets to minimise vibration and cyclic loadings being transmitted from the propulsion shafting and propellers into the hull structure.

3.12.2 Alignment of bolted shaft brackets may be by means of suitable metallic shims or chocking resin of an approved type. *See* 3.10.2 and 3.10.3.

3.12.3 The alignment of shaft brackets connected by welding or bonding may be facilitated by boring of the bracket boss after attachment of the shaft bracket and stern tube.

3.13 Sterntubes

3.13.1 The sterntube construction may be of aluminium alloy, steel, bronze or fibre reinforced plastic.

3.13.2 The sterntube scantlings are to be individually considered.

3.13.3 For steel and aluminium hulls, the bottom shell, in way of the sterntube, is to be additionally reinforced by means of an insert plate to increase the bottom shell thickness by 50 per cent.

3.13.4 For FRP hulls, the bottom shell laminate, in way of the sterntube, is to be locally increased by 50 per cent by gradual tapering of the laminate. The increased thickness in way of the sterntube need not exceed the Rule keel thickness requirement.

3.13.5 For FRP sandwich hulls, the shell in way of the stern tube connection is to be either:

(a) Reduced from sandwich hull construction to single skin laminate by removal of the core and by combining the inner and outer skins. The single skin region is then to be additionally reinforced by a minimum of 50 per cent of the sum of the inner and outer sandwich laminate. The increased thickness in way of the sterntube need not be greater than the Rule keel thickness requirement.

(b) Reduced from the sandwich hull construction to a single skin laminate by removal of the core and combining the inner and outer skins. After bonding in the stern tube to the single skin laminate the foam core and the inner skin is to be reinstated.

(c) Proposals to replace the sandwich core with a core having higher core shear strength and compressive strength than that of the adjacent structure prior to bonding the tube to the inner and outer skins will be the subject of special consideration.

3.13.6 The sterntube may be connected to the shell by bonding, bolting or welding as applicable depending upon the construction material of the shell.

3.13.7 When bonding in sterntubes the bonding angle laminate weight is to be not less than the Rule minimum bottom weight. FRP tubes are to be thoroughly abraded and degreased prior to installation and laminating. Bonded in metallic tubes are to be knurled in way of the bonding material and thoroughly degreased prior to installation. During the bonding operation particular care is to be given to maintaining the sterntube alignment.

3.13.8 Where sterntubes are to be retained by bolting, they are to be provided with a substantial flange securely attached to the hull structure. Where bolts are used, the nuts are to be suitably locked.

3.13.9 Where sterntubes are to be welded to hull insert plates full penetration welding is required.

3.13.10 Where sterntubes are to be installed using a resin system, of an approved type, the requirements of Pt 11, Ch 2,4.16 are to be complied with.

3.13.11 The region where the shafting enters the craft, and the bearing in way, is to be adequately supported by floors or deep webs.

3.13.12 The shaft bearings are to be secured against rotation within the sterntube.

3.13.13 A suitable gland arrangement is to be provided at the inboard end of sterntubes in accordance with Pt 11, Ch 2,4.15.

3.14 Solepieces

3.14.1 The requirements for solepieces are as indicated in Table 3.3.1.

3.15 Propeller hull clearances

3.15.1 Recommended minimum clearances between the propeller and the sternframe, rudder or hull are given in Table 3.3.2. These are the minimum distances considered desirable in order to expect reasonable levels of propeller excited vibration. Attention is drawn to the importance of the local hull form characteristics, shaft power, water flow characteristics into the propeller disc and cavitation when considering the recommended clearances.

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Table 3.3.2 Recommended propeller hull clearances

Number of Blades	Hull clearances for single screw, in metres, *see* Fig. 3.3.8(a)				Hull clearances for twin screw, in metres, *see* Fig. 3.3.8(b)	
	a	b	c	d	e	f
3	$1{,}20K\delta$	$1{,}80K\delta$	$0{,}12\delta$	$0{,}03\delta$	$1{,}20K\delta$	$1{,}20K\delta$
4	$1{,}00K\delta$	$1{,}50K\delta$	$0{,}12\delta$	$0{,}03\delta$	$1{,}00K\delta$	$1{,}20K\delta$
5	$0{,}85K\delta$	$1{,}275K\delta$	$0{,}12\delta$	$0{,}03\delta$	$0{,}85K\delta$	$0{,}85K\delta$
6	$0{,}75K\delta$	$1{,}125K\delta$	$0{,}12\delta$	$0{,}03\delta$	$0{,}75K\delta$	$0{,}75K\delta$
Minimum value	$0{,}10\delta$	$0{,}15\delta$	t_R	—	3 and 4 blades, $0{,}20\delta$ 5 and 6 blades, $0{,}16\delta$	$0{,}15\delta$

Symbols

L_R and C_b as defined in Ch 1,6.1

$$K = \left(0{,}1 + \frac{L_R}{3050}\right)\left(\frac{3{,}48C_b P_s}{L_R^2} + 0{,}3\right)$$

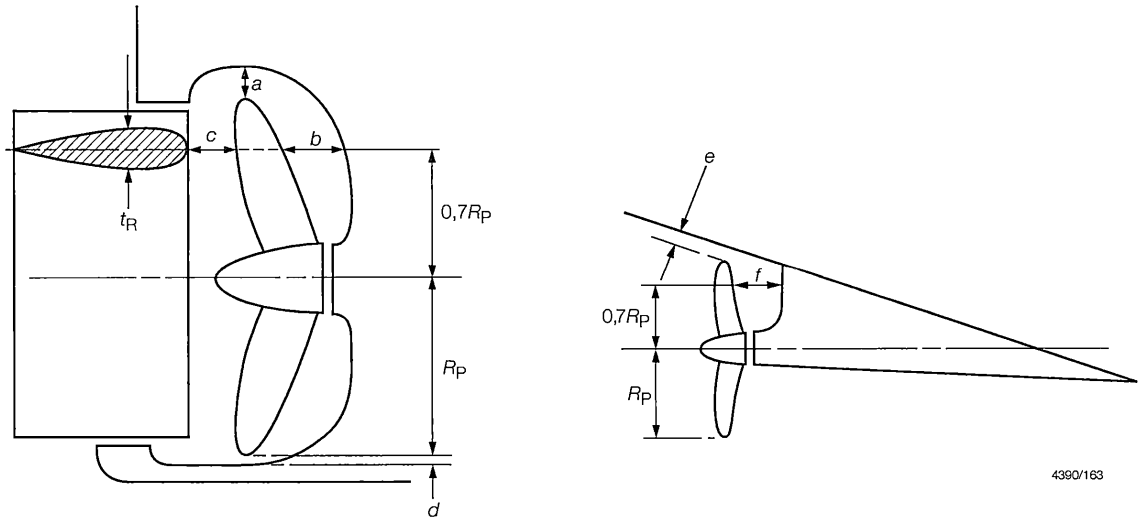
t_R = thickness of rudder, in metres measured at $0{,}7R_p$ above the shaft centreline

P_s = designed power on one shaft, in kW

R_p = propeller radius, in metres

δ = propeller diameter, in metres

NOTE
The above recommended minimum clearances also apply to semi-spade type rudders.



(a) Single screw (b) Twin screw

Fig. 3.3.8 Propeller clearance

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■ *Section 4*
Fixed and steering nozzles, bow and stern thrust units

4.1 General

4.1.1 The requirements for scantlings for fixed and steering nozzles are given, for guidance only, in 4.2 to 4.4 and Table 3.4.1.

4.1.2 The requirements, in general, apply to nozzles with a numeral not greater than 200, *see* Table 3.4.1. Nozzles exceeding this value will be specially considered.

4.2 Nozzle structure

4.2.1 For basic scantlings of the structure, *see* Table 3.4.1, in association with Fig. 3.4.1.

4.2.2 The shroud plating in way of the propeller tips is to be carried well forward and aft of this position, due allowance being made on steering nozzles for the rotation of the nozzle in relation to the propeller.

4.2.3 Fore and aft webs are to be fitted between the inner and outer skins of the nozzle. Both sides of the headbox and pintle support structure are to be connected to fore and aft webs of increased thickness. For thicknesses, *see* Table 3.4.1.

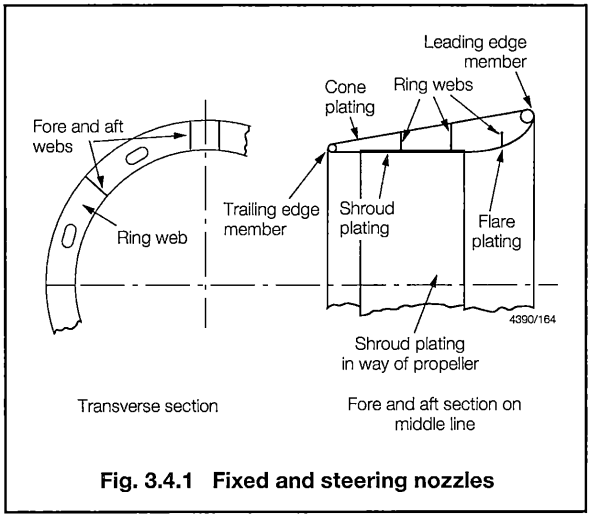

Fig. 3.4.1 Fixed and steering nozzles

4.2.4 The transverse strength of the nozzle is to be maintained by the fitting of ring webs. Two ring webs are to be fitted in nozzles not exceeding 2,5 m diameter. Nozzles between 2,5 and 3,0 m in diameter are generally to have two full ring webs and a half-depth web supporting the flare plating. The number of ring webs is to be increased as necessary on nozzles exceeding 3,0 m in diameter. Where ring webs are increased in thickness in way of the headbox and pintle support structure in accordance with Table 3.4.1, the increased thickness is to be maintained to the adjacent fore and aft web.

Table 3.4.1 Nozzle construction requirements

Item	Requirement
(1) Nozzle Numeral	$N_N = 0{,}01P\delta_P$
(2) Shroud plating in way of propeller blade tips	For $N_N \leq 63$ $t_s = (11 + 0{,}1N_N)$ mm For $N_N > 63$ $t_s = (14 + 0{,}052N_N)$ mm
(3) Shroud plating clear of blade tips, flare and cone plating, wall thickness of leading and trailing edge members	$t_p = (t_s - 7)$ mm but not less than 8mm
(4) Webs and ring webs	As item (3) except in way of headbox and pintle support where $t_W = (t_s + 4)$ mm
(5) Nozzle stock	Combined stresses in stock at lower bearing $\leq 92{,}7$ N/mm^2 Torsional stress in upper stock $\leq 62{,}0$ N/mm^2
(6) Solepiece and strut	Bending stresses not to exceed 70,0 N/mm^2
Symbols	
N_N = a numeral dependent on the nozzle requirements P_s = power transmitted to the propellers, in kW δ_P = diameter of the propeller, in metres t_S = thickness of shroud plating in way of propeller tips, in mm t_p = thickness of plating, in mm t_W = thickness of webs and ring webs in way of headbox and pintle support, in mm	
NOTE Thicknesses given are for mild steel. Reductions in thickness will be considered for certain stainless steels.	

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4.2.5 Local stiffening is to be fitted in way of the top and bottom supports which are to be integrated with the webs and ring webs. Continuity of bending strength is to be maintained in these regions.

4.2.6 Fin plating thickness is to be not less than the cone plating, and the fin is to be adequately reinforced. Solid fins are to be not less than 25 mm thick.

4.2.7 Care is to be taken in the manufacture of the nozzle to ensure its internal preservation and watertightness. The preservation and testing are to be as required for rudders, *see* 2.25 and 2.27, and Table 1.7.2 in Chapter 1.

4.3 Nozzle stock and solepiece

4.3.1 Stresses, derived using the maximum side load on the nozzle and fin acting at the assumed centre of pressure, are not to exceed the values given in Table 3.4.1, in both the ahead and astern conditions.

4.4 Ancillary items

4.4.1 The diameter and first moment of area about the stock axis of coupling bolts and the diameter of pintles, are to be derived from 2.20 and 2.19 respectively.

4.4.2 Suitable arrangements are to be provided to prevent the steering nozzle from lifting.

4.5 Steering gear and allied systems

4.5.1 For the requirements of steering gear, *see* Pt 12, Ch 1.

4.6 Thruster unit wall thickness

4.6.1 The wall thickness of the unit is, in general, to be in accordance with the manufacturer's practice, but is to be not less than:

(a) For steel hulls, the thickness of the adjacent shell plating plus 10 per cent or 2 mm whichever is the greater, subject to a minimum of 7 mm.
(b) For aluminium hulls, the thickness of the adjacent shell plating plus 10 per cent or 1 mm whichever is the greater, subject to a minimum of 8 mm.
(c) For FRP hulls, generally the thickness of the adjacent shell laminate plus 25 per cent subject to a minimum of 8 mm. Full details of the proposed laminate and resin system are to be submitted for approval.

4.7 Thruster unit installation details

4.7.1 The method of attachment of the tube is dependent upon the tube and the craft's construction materials which may be steel, aluminium alloy or FRP.

4.7.2 The tunnel tube is to be fitted either between a pair of deep floors or bulkheads extending to above the design waterline or in a separate watertight compartment.

4.7.3 The shell plating thickness is to be locally increased by 50 per cent in way of tunnel thruster connections.

4.7.4 For welded tube connections the welding is to be by full penetration welding.

4.7.5 For FRP tubes attached by bonding the total bonding reinforcement weight is to be at least that of the hull bottom laminate with the tube bonded internally and externally to the shell laminate. Prior to bonding *in situ* the areas to be bonded are to be thoroughly abraded and degreased and all cut FRP laminate edges resin sealed.

4.7.6 The tunnel tube is to be framed to the same standard as the surrounding shell plating.

4.7.7 The unit is to be adequately supported and stiffened.

4.8 Novel features

4.8.1 Where the Rules do not specifically define the requirements for novel features then the scantlings and arrangements are to be determined by direct calculations. Such calculations are be carried out on the basis of the Rules, recognised standards and good practice, and are to be submitted for consideration.

■ *Section 5* Stabiliser arrangements

5.1 General

5.1.1 The scantlings, arrangements and effectiveness of the stabilisers are outwith the scope of classification; however their foundations, supporting structure and watertight integrity are to be examined.

5.2 Fin stabilisers

5.2.1 Detailed plans are to be submitted clearly indicating the position, supporting structure and design loads for all fins.

5.2.2 The design, construction, operational performance and control systems of the fin stabiliser unit are outside the scope of classification.

5.2.3 Fin stabilisers are to be contained within a watertight enclosure. The purpose of the watertight enclosure is to ensure that any impact to the stabiliser will not affect the survivability or safe operation of the craft. In addition to the requirements of 5.2.4, when determining the location and extent of the watertight enclosure the following should be considered:

(a) Stabiliser blade construction material
(b) Designed failure mode of stabiliser shaft
(c) Damage stability requirements of craft
(d) Survivability of craft after impact to the stabiliser
(e) Function of space containing stabiliser.

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5.2.4 For non-retractable type stabilisers, the watertight divisions forming the forward and aft boundaries of the watertight enclosure are to be arranged not less than one third of the root chord length, C, from the fore and aft extents of the stabiliser, *see* Fig. 3.5.1. Main watertight subdivision bulkheads may be considered as watertight divisions where appropriate.

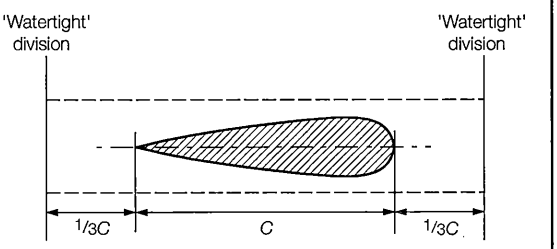

Fig. 3.5.1 Stabiliser positioning

5.2.5 For craft constructed of mild steel the watertight enclosure into which the stabilisers retract is to have a perimeter plating of the same thickness as the surrounding Rule shell plating plus 2 mm, and is to be stiffened to the same standard as the shell. For craft constructed from aluminium alloys the corrections in Ch 3,1.2.2 apply.

5.2.6 For craft constructed from composite materials the laminate thickness of the watertight enclosure into which the stabilisers retract is to be specially considered. Generally the thickness should not be less than that of the bottom shell.

5.2.7 Insert plates are to be fitted or laminate thickness increased in way of stabilisers. The thickness of the insert plate or increased laminate is to be at least 50 per cent greater than the bottom shell thickness in way, and is to extend over an area formed by 1,25 times the stabiliser root chord length and covering all operational angles. In addition, for retractable stabilisers the insert is to extend beyond the shell opening for a distance of not less than 25 per cent the length of the root chord.

5.2.8 Fin stabiliser systems are, in general, not to extend beyond the extreme moulded beam of the hull or below the horizontal line of keel. However, for retractable fins, alternative arrangements may be specially considered. Where the stabiliser fin extends beyond the extreme moulded beam of the hull in the active mode, the side shell is to be permanently marked indicating the forward and aft extent of the stabiliser when deployed. It is recommended that an appropriate symbol be placed on the hull side between the marks.

5.2.9 The stabiliser machinery and surrounding structure is to be adequately supported and stiffened. Where bending stresses are induced in the structure under fatigue conditions the maximum stress is not to exceed 39,0 N/mm^2 in mild steel. Where other materials are used for the supporting structure the limiting stress values will be specially considered on the basis of the Rules.

5.2.10 The scantlings of internal watertight bulkheads and stiffening for fixed installations are to be as specified by the designer/Builder and/or fin unit manufacturer but in no case are to be less than the scantlings for double bottoms as defined in Pt 6, Ch 3,6 for steel structures and Pt 7, Ch 3,6 for aluminium structures. Suitable access is to be provided to allow for maintenance and inspection purposes.

5.2.11 The scantlings and sealing arrangements for the pedestal and bearings will be specially considered, subject to the designer/Builder submitting the following:

(a) Detailed structural calculations for the proposed foundation and adjacent supporting structure.
(b) A detailed finite element model, if carried out, *see* Pt 3, Ch 1,2.
(c) Calculations demonstrating that the effect of damage to the stabiliser arrangement arising from high speed impact, grounding, fouling, etc will not compromise the structural and watertight integrity of the craft.
(d) Maximum torque, bending moments and bearing loads expected for the proposed design.
(e) The stabiliser fin stock material, together with its ultimate tensile and shear strength values (N/mm^2).

5.2.12 Fin bearing materials and seals are to be of an approved type.

5.2.13 Where retractable stabilisers are fitted, position indicators are to be provided on the bridge and adjacent to the stabiliser installation.

5.3 Stabiliser tanks

5.3.1 The general structure of the tank is to comply with the Rule requirements for deep tanks. Sloshing forces in the tank structure are to be taken into account. Where such forces are likely to be significant, the scantlings will be required to be verified by additional calculations.

5.4 Ride control systems

5.4.1 The scantlings, arrangements and effectiveness of ride control systems are currently outwith the scope of classification; however their foundations, supporting structure and watertight integrity together with the associated reaction forces on the hull structure are to be examined. Details of the loadings and supporting calculations are to be submitted with the relevant construction plans for consideration.

5.5 Motion damping arrangements and devices

5.5.1 Motion damping devices are generally outwith the scope of the Rules. Where motion damping devices are fitted the designers/Builders are to submit details of the anticipated loadings and supporting calculations for appraisal of the adjacent hull structure.

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5.6 Novel features

5.6.1 Where the Rules do not specifically define the requirements for novel features then the scantlings and arrangements are to be determined by direct calculations. Such calculations are to be carried out on the basis of the Rules, Recognised Standards and good practice, and are to be submitted for consideration.

Section 6
Particular requirements for multi-hull craft

6.1 General

6.1.1 The requirements for control systems of multi-hull craft are generally in accordance with the requirements of Sections 1 to 5 for mono-hulls.

6.2 Rudders

6.2.1 The scantlings for rudders are to be generally in accordance with Ch 3,2. Where the proposed rudder is of a novel design or the speed of the craft exceeds 45 knots the scantlings of the rudder and rudder stock are to be determined from direct calculation methods incorporating model test results and structural analysis, as considered necessary by LR.

6.3 Sternframes and appendages

6.3.1 Sternframes and appendages are to be considered on the basis of the Rules. Reference is also to be made to Chapter 5, (Special Features) of Parts 6, 7 and 8 for steel, aluminium alloy and composite construction respectively.

6.4 Fixed and steering nozzles, bow and stern thrust units

6.4.1 In general, the requirements are to be in accordance with Ch 3,4.

6.5 Stabiliser arrangements

6.5.1 In general, the requirements for multi-hulls are to be in accordance with the requirements of Ch 3,5 and Ch 5,2.4 of Parts 6, 7 and 8, dependent upon the material of construction.

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Section

1 **General**

2 **Bulkhead openings**

3 **Double bottom openings**

4 **Side and stern doors and other shell openings**

5 **Hatches on exposed decks**

6 **Miscellaneous openings**

7 **Portlights, windows and viewing ports, skylights and glass walls**

8 **Bulwarks, guard rails and other means for the protection of crew**

9 **Deck drainage**

10 **Cabin sole and lining**

11 **Ventilators**

12 **Air and sounding pipes**

13 **Particular requirements for multi-hull craft**

■ *Section 1* General

1.1 Application

1.1.1 The contents of this Chapter are applicable to mono-hull and multi-hull craft constructed in steel, aluminium alloy or composite materials.

1.1.2 Where the requirements of Pt 1, Ch 2,1.1.11 and 1.1.14 require the craft to be subdivided for damage stability aspects these will be considered in addition to the requirements of this Part.

1.1.3 Attention is, however, to be given to any other additional statutory requirements of the National Authority in which the craft is registered.

1.2 Downflooding

1.2.1 Yachts and craft to which the *International Convention on Load Lines*, 1966 is applicable, *see* Pt 1, Ch 2,1.1.11, are to comply with the requirements of this sub-Section.

1.2.2 Doors, hatches, ventilators, windows, portlights, etc. provided with closing appliances which can be secured weathertight, and small openings through which progressive flooding cannot take place are not considered as down flooding points.

1.2.3 Air pipes are to be fitted with automatic closing appliances unless it can be shown that, with the craft at its summer load waterline, the openings will not be immersed at an angle of heel of 40°, or the angle of downflooding if this is less than 40°.

1.3 Definitions and symbols

1.3.1 The **down flooding angle** is the least angle of heel at which openings in the hull, superstructure or deckhouses, which cannot be closed weathertight, immerse and allow flooding to occur.

1.3.2 L_L is the loadline length as defined in Ch 1,6.2.3.

1.3.3 Position 1 and Position 2 are as defined in Ch 1,6.10.

1.4 Bolted connections

1.4.1 Bolted connections are generally to be in accordance with Table 4.1.1. Further requirements are contained throughout this Chapter.

Table 4.1.1 Bolt pitch requirements for structural connections

Location	Pitch
Manhole covers to fuel tanks	$6d_b$
Manhole covers to water tanks	$8d_b$
Covers over void tanks/cofferdams	$10d_b$
Unstiffened portable plates in decks	$5d_b$
Bolted watertight door frames	$8d_b$
Window frames to superstructure	$20d_b$

NOTE
d_b is the diameter of the bolt.

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Section 2
Bulkhead openings

2.1 General

2.1.1 In addition to the requirements of this Section, where compliance with Pt 4, Ch 2,9 and Chapter X of SOLAS 1974, as amended *(High Speed Craft Code)*, is required, the number and construction of the watertight doors in bulkheads will be considered in accordance with these requirements. Each watertight door is to be subjected to a pressure test, *see* Table 1.7.1 in Chapter 1. The test may be carried out either before or after the door is fitted. Regulations regarding openings in watertight bulkheads relevant to passenger or cargo craft, as appropriate, contained in the *International Convention for the Safety of Life at Sea, 1974* and applicable amendments, and Pt 4, Ch 2,9 are also to be complied with.

2.2 Openings in bulkheads below the freeboard deck

2.2.1 Certain openings below the freeboard deck are permitted, but these must be kept to a minimum and provided with means of closing to watertight standards. All such openings are to be to the satisfaction of the Surveyor.

2.3 Watertight doors

2.3.1 Watertight doors are to be efficiently constructed and fitted, and are to be capable of being operated when the craft is listed up to 15° either way. They are to be operated under working conditions and hose tested in place. *See* Ch 1,7.3.

2.3.2 Where the doors are fitted in watertight bulkheads they are to be of equivalent strength to the unpierced bulkhead and capable of being closed watertight. Watertight doors are to be of a type, approved and pressure tested, *see* Table 1.7.1 in Chapter 1, from both sides for the maximum head of water indicated by any required damage stability calculations or up to the bulkhead deck whichever is the greater.

2.3.3 Indicators are to be provided on the bridge showing whether the doors are open or closed.

2.3.4 Doors are to be capable of being operated from both sides of the bulkhead. Power operated sliding doors are to be capable of being opened and closed locally by both power and efficient hand operated mechanisms.

2.3.5 Doors not required to be used at sea may be of the hinged or sliding type. A notice is to be fixed on the closing appliance saying it should be kept closed at all times while the craft is at sea.

2.3.6 Watertight doors which are intended to be used while at sea are to be of the sliding type capable of being remotely closed from the bridge. An audible alarm is to be provided at the door closure. The power, control and indicators are to be operable in the event of main power failure. Particular care is to be paid to minimising the effect of control system failure.

2.3.7 As an alternative to the sliding doors required by 2.3.6, special consideration will be given to the fitting of hinged watertight doors where it can be shown that they are as effective as the sliding type. A suitable log-book system is to be operated to ensure that such doors remain closed except when in use for access.

2.3.8 Subject to the requirements of 2.3.6 and 2.3.7, hinged watertight doors of approved pattern may be fitted in 'tween decks in approved positions. The hinges of these doors are to be fitted with a pin or bush of a suitable copper alloy in accordance with the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials), or of an equivalent material acceptable to Lloyd's Register (hereinafter referred to as 'LR').

2.3.9 No accesses are to be fitted in collision bulkheads. In particular designs where it would be impracticable to arrange access to the fore peak other than through the collision bulkhead, access may be permitted subject to special consideration. Where accesses are provided, the openings are to be as small as practicable and positioned as far above the design waterline as possible. The closing appliances are to be watertight, open into the fore peak compartment and consideration will be given to operation from one side only.

2.4 Pipe and cable ducts, ventilation trunks and other penetrations

2.4.1 Where subdivision and damage stability requirements apply and where penetration of watertight divisions by pipes, ducts, trunks or other penetrations is necessary, arrangements are to be made to maintain the watertight integrity.

2.4.2 Ventilators from deep tanks and tunnels passing through 'tween decks are to have scantlings suitable for withstanding pressures to which they may be subjected, and are to be made watertight.

Section 3
Double bottom openings

3.1 General

3.1.1 Provision is to be made for the free passage of air and water from all parts of the tanks to the air pipes and suctions, account being taken of the pumping rates required.

3.1.2 Adequate access is also to be provided to all parts of the double bottom for future maintenance, surveys and repairs. The edges of all openings are to be smooth.

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3.2 Requirements

3.2.1 A plan showing the location of manholes and access openings within the double bottom is to be submitted. Attention is to be given to any relevant Statutory Requirements of the National Authority of the country in which the craft is to be registered.

3.2.2 The number and positioning of manholes are to be such that access under service conditions is neither difficult nor dangerous. Attention is to be given to any relevant international regulations regarding the minimum size of access openings.

3.2.3 Manholes and their covers are to be of an approved design or in accordance with a recognised National or International Standard.

3.2.4 The size of opening is not, in general, to exceed 50 per cent of the double bottom depth, unless edge reinforcement is provided. In way of outboard ends of floors and fore and aft girders at transverse bulkheads, the number and size of holes are to be kept to a minimum, and the openings are to be circular or elliptical. Edge stiffening may be required in these positions.

3.2.5 Manholes, lightening holes and other cut-outs are to be avoided in way of concentrated loads and areas of high shear. In particular, manholes and similar openings are not to be cut in vertical or horizontal diaphragm plates in narrow cofferdams or double plate bulkheads within one-third of their length from either end, nor in floors or double bottom girders close to their span ends, below the heels of pillars, nor in way of mast steps, unless the stresses in the plating and the panel buckling characteristics have been calculated and found satisfactory.

3.2.6 Manholes, lightening holes and other openings are to be suitably framed and stiffened where necessary.

3.2.7 Air and drain holes, notches and scallops are to be in accordance with Ch 2,4 of Parts 6 and 7 for steel and aluminium alloy construction respectively.

3.3 Alternative arrangements

3.3.1 The Rules are formed on the basis that access to double bottoms will be by means of manholes with bolted covers. However, alternative arrangements will be specially considered.

■ *Section 4* Side and stern doors and other shell openings

4.1 General

4.1.1 These requirements cover cargo and service doors in the craft side (abaft the collision bulkhead) and stern area, below the freeboard deck and in enclosed superstructures.

4.1.2 For the requirements of bow doors, *see* Ch 5,4 of Parts 6 and 7 for steel and aluminium alloy construction respectively.

4.1.3 Side and stern doors are to be so fitted as to ensure tightness and structural integrity commensurate with their location and the surrounding structure. *See also* Ch 1,6.8.2 and 6.9.2.

4.1.4 In general, and for passenger craft in particular, the lower edge of door openings are not to be below a line drawn parallel to the freeboard deck at side, which is at its lowest point at least 230 mm above the upper edge of the uppermost Load Line.

4.1.5 When the lower edge is below the uppermost Load Line, the arrangement will be specially considered. Special consideration is to be given to preventing the spread of leakage water over the deck. The reference to the uppermost Load Line is to be taken as the tropical fresh water line.

4.1.6 Doors are generally to be arranged to open outwards, however inward opening doors will be considered provided strongbacks are fitted when the doors are situated in the first two 'tween decks above the waterline.

4.1.7 For passenger craft the following is also applicable:

(a) Gangway, cargo and service ports fitted below the margin line, *see* 1.2.2, are to satisfy the strength requirements given for side doors in this Section. They are to be effectively closed and secured watertight before the craft leaves port, and are to be kept closed during navigation. Such ports are not to have their lowest point below the deepest subdivision Load Line.

(b) Where the inboard end of a rubbish chute is below the margin line in a passenger craft, the inboard end cover is to be watertight and, in addition to the discharge flap interlock, a screwdown automatic non-return valve is to be fitted in an easily accessible position above the deepest subdivision. The valve is to be controlled from a position above the bulkhead deck and provided with an open/shut indicator, and kept closed when not in use. A suitable notice is to be displayed at the valve position.

4.1.8 Where doors and platforms are fitted in the shell, the structural and watertight integrity of the hull is to be maintained. Such doors and platforms are not to lead directly into the craft and an internal watertight compartment is to be provided in way of the shell openings. The doors and platforms are to be arranged to open outwards. The sill height of the access hull opening is not to be less than 300 mm above the waterline and the sill height of the internal access is to be not less than 300 mm higher than the hull sill. Alternative arrangements will be considered.

4.1.9 Doors may be of steel, aluminium alloy or FRP construction and are to be efficiently connected to the adjoining structure and of equivalent strength and are to have adequate securing and sealing arrangements. It is recommended that doors are hinged about their forward edges and open outwards. Details are to be submitted for approval. Other materials will be specially considered.

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4.1.10 For craft complying with the requirements of this Section, the securing, supporting and locking devices are defined as follows:

(a) A securing device is used to keep the door closed by preventing it from rotating about its hinges or other pivoted attachments to the craft.

(b) A supporting device is used to transmit external and internal loads from the door to a securing device and from the securing device to the craft's structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, that transmits loads from the door to the craft's structure.

(c) A locking device locks a securing device in the closed position.

4.2 Symbols

4.2.1 The symbols used in this Section are defined as follows:

σ = bending stress, in N/mm^2

σ_e = equivalent stress, in N/mm^2

$= \sqrt{\sigma^2 + 3\tau^2}$

τ = shear stress, in N/mm^2

σ_o is defined in Ch 3,1.2.

4.3 Scantlings

4.3.1 In general the strength of side and stern doors is to be equivalent to the strength of the surrounding structure.

4.3.2 Door openings in the side shell are to have well rounded corners and adequate compensation is to be arranged with web frames at sides and stringers or equivalent above and below. *See* Ch 3,3 of Parts 6, 7 and 8 for steel, aluminium alloy and composite construction respectively.

4.3.3 Doors are to be adequately stiffened, and means are to be provided to prevent movement of the doors when closed. Adequate strength is to be provided in the connections of the lifting/manoeuvring arms and hinges to the door structure and to the craft structure.

4.3.4 The thickness of the door plating is to be not less than the shell plating calculated with the door stiffener spacing, and in no case to be less than the minimum adjacent shell thickness.

4.3.5 Where stern doors are protected against direct wave impact by a permanent external ramp, the thickness of the stern door plating may be reduced by 20 per cent relative to the requirements of 4.3.4. Those parts of the stern door which are not protected by the ramp are to have the thickness of plating in full compliance with 4.3.4.

4.3.6 The section modulus of horizontal or vertical stiffeners is to be not less than required for the adjacent shell framing using the actual stiffener spacing. Consideration is to be given, where necessary, to differences in fixity between shell frames and door stiffeners.

4.3.7 Where necessary, door secondary stiffeners are to be supported by primary members constituting the main stiffening elements of the door.

4.3.8 The webs of primary members are to be adequately stiffened, preferably in a direction perpendicular to the shell plating.

4.3.9 The buckling strength of primary members is to be specially considered.

4.3.10 All load transmitting elements in the design load path from door through securing and supporting devices into the craft structure, including welded connections, are to be to the same strength standard as required for the securing and supporting devices.

4.4 Doors serving as ramps

4.4.1 Where doors also serve as vehicle ramps, the plating and stiffeners are to be not less than required for vehicle decks. *See* Ch 5,3 of Parts 6, 7 and 8 for steel, aluminium alloy and composite construction respectively.

4.4.2 The design of the hinges for these doors is to take into account the craft angle of trim or heel which may result in uneven loading of the hinges.

4.5 Closing, securing and supporting of doors

4.5.1 Doors are to be fitted with adequate means of closing, securing and supporting so as to be commensurate with the strength and stiffness of the surrounding structure. The hull supporting structure in way of the doors is to be suitable for the same design loads and design stresses as the securing and supporting devices. Where packing is required, the packing material is to be of comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be considered. Maximum design clearance between securing and supporting devices is not generally to exceed 3 mm.

4.5.2 Securing devices are to be simple to operate and easily accessible. They are to be of an approved type.

4.5.3 Securing devices are to be equipped with mechanical locking arrangements (self locking or separate arrangements), or are to be of gravity type. The opening and closing systems as well as securing and locking devices are to be interlocked in such a way that they can only operate in the proper sequence.

4.5.4 Means are to be provided to enable the doors to be mechanically fixed in the open position taking into account the self weight of the door and a minimum wind pressure of 1,5 kN/m^2 (0,153 tonne-f/m^2) acting on the maximum projected area in the open position.

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4.5.5 The spacing for cleats or closing devices is not to exceed 2,5 m and cleats or closing devices are to be positioned as close to the corners as practicable. Alternative arrangements for ensuring weathertight sealing will be specially considered.

4.5.6 Doors with a clear opening area of 12 m^2 or greater are to be provided with closing devices operable from a remote control position. Doors which are located partly or totally below the freeboard deck with a clear opening area greater than 6 m^2 are to be provided with an arrangement for remote control from a position above the freeboard deck. This remote control is provided for the:

(a) Closing and opening of the doors.

(b) Associated securing and locking devices.

4.5.7 The location of the remote control panel is to be such that the opening/closing operation can be easily observed by the operator or by other suitable means such as closed circuit television.

4.5.8 A notice is to be displayed at the operating panel stating that the door is to be fully closed and secured preferably before, or immediately prior to the craft leaving the berth and that this operation is to be entered in the craft's log. This notice is to be supplemented by warning indicator lights indicating if any door is not fully closed, secured and locked.

4.5.9 Means are to be provided to prevent unauthorised operation of the doors.

4.5.10 Where hydraulic securing devices are applied, the system is to be mechanically lockable in the closed position so that in the event of hydraulic system failure, the securing devices will remain locked. The hydraulic system for securing and locking devices is to be isolated from other hydraulic circuits when in the closed position.

4.5.11 The design force considered for the scantlings of primary members, securing and supporting devices of side shell doors and stern doors are to be taken not less than:

(a) Design forces for securing or supporting devices of doors opening inwards:
External force:
$F_e = Ap_e + F_p$ kN
Internal force:
$P_i = P_o + 10W$ kN

(b) Design forces for securing or supporting devices of doors opening outwards:
External force:
$F_e = Ap_e$ kN
Internal force:
$P_i = P_o + 10W + F_p$ kN

(c) Design forces for primary members:
External force:
$F_e = Ap_e$ kN
Internal force:
$P_i = P_o + 10W$ kN

whichever is the greater.

The symbols used are defined as follows:

p_e = external sea pressure, not to be taken less than 25 kN/m^2

A = total area of door opening, in m^2, to be determined on the basis of the load area taking account of the direction of pressure

F_p = total packing force, kN. When packing is fitted, the packing force per unit length is to be specified, normally not to be taken less than: 5 kN/m

P_c = accidental force, in kN, due to loose cargo, etc., to be uniformly distributed over the area A and not to be taken less than 300 kN. For small doors such as bunker doors and pilot doors, the value of P_c may be taken as zero, provided an additional structure such as an inner ramp is fitted, which is capable of protecting the door from accidental force due to loose cargoes

P_o = the greater of P_c and $5A$ kN

W = weight of the door, in tonnes.

4.6 Systems for indication and monitoring

4.6.1 The following requirements apply to doors in the boundaries of special category spaces or ro-ro spaces, as defined in the SOLAS Convention, through which such spaces may be flooded. For cargo craft, where no part of the door is below the uppermost waterline and the area of the door opening is not greater than 6 m^2, then the requirements of this Section need not be applied.

4.6.2 Separate indicator lights and audible alarms are to be provided on the navigation bridge and on each operating panel to indicate that the doors are closed and that their securing and locking devices are properly positioned. The indication panel is to be provided with a lamp test function. It is not to be possible to turn off the indicator light.

4.6.3 The indicator system is to be designed on the fail safe principle and is to indicate by visual alarms if the door is not fully closed and not fully locked, and by audible alarms if securing devices become open or locking devices become unsecured. The power supply for the indicator system is to be independent of the power supply for operating and closing the doors and is to be provided with a back-up power supply. The sensors of the indicator system are to be protected from water, ice formation and mechanical damages.

4.6.4 The indication panel on the navigation bridge is to be equipped with a mode selection function 'harbour/sea voyage', so arranged that audible alarm is given if the craft leaves harbour with side shell or stern doors not closed or with any of the securing devices not in the correct position.

4.6.5 For passenger craft, a water leakage detection system with audible alarm and television surveillance are to be arranged to provide an indication to the navigation bridge and to the engine control room of any leakage through the doors. For cargo craft, a water leakage detection system with audible alarm is to be arranged to provide an indication to the navigation bridge.

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Table 4.4.1 Permissible stress for bolts, closing and supporting devices

Material	Closing and supporting devices			Thread of bolts
	Direct stress N/mm^2	Shear stress N/mm^2	Equivalent stress N/mm^2	Direct stress N/mm^2
Steel	$\frac{120}{k_s}$	$\frac{80}{k_s}$	$\frac{150}{k_s}$	$\frac{120}{k_s}$
Aluminium	$\frac{64}{k_a}$	$\frac{43}{k_a}$	$\frac{80}{k_a}$	$\frac{64}{k_a}$

NOTES

1. $k_s = \frac{235}{\sigma_o}$, σ_o as defined in Ch 3,1.2.1

2. $k_a = \frac{120}{\sigma_{ya}}$, σ_{ya} as defined in Ch 3,1.2.2

4.7 Design of securing and supporting devices

4.7.1 Securing devices and supporting devices are to be designed to withstand the forces given in 4.5.11 using the permissible stresses given in Table 4.4.1. The terms 'securing device' and 'supporting device' are defined in Pt 6, Ch 5,4.3.

4.7.2 The nominal tensile stress in way of threads of bolts is not to exceed the permissible stress given in Table 4.4.1. The arrangement of securing and supporting devices is to be such that threaded bolts are not to carry support forces.

4.7.3 For steel to steel bearings in securing and supporting devices, the normal bearing pressure is not to exceed $0,8\sigma_o$. For other bearing materials, the permissible bearing pressure is to be determined according to the manufacturer's specification. The normal bearing pressure is to be calculated by dividing the design force by the projected bearing area.

4.7.4 The distribution of the reaction forces acting on the securing and supporting devices may require to be supported by direct calculations taking into account the flexibility of the hull structure and the actual position and stiffness of the supports. Small and/or flexible devices, such as cleats, intended to provide load compression of the packing material are not generally to be included in these calculations.

4.7.5 Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be considered in the calculation of the reaction forces acting on the devices.

4.7.6 The number of securing and supporting devices is generally to be the minimum practicable whilst complying with 4.5.3 and taking account of the available space in the hull for adequate support.

4.7.7 The arrangement of securing devices and supporting devices in way of these securing devices is to be designed with redundancy so that in the event of failure of any single securing or supporting device the remaining devices are capable of withstanding the reaction forces, without exceeding, by more than 20 per cent, the permissible stresses referred to in 4.7.1.

4.8 Operating and Maintenance Manual

4.8.1 An Operating and Maintenance Manual for the doors is to be provided on board and is to contain necessary information on:

(a) main particulars and design drawings;
(b) service conditions (e.g. service area restrictions, acceptable clearances for supports);
(c) maintenance and function testing;
(d) register of inspections and repairs.

This Manual is to be submitted for approval, and is to contain a note recommending that recorded inspections of the door supporting and securing devices be carried out by the craft's staff at monthly intervals or following incidents that could result in damage, including heavy weather or contact in the region of the doors. Any damages recorded during such inspections are to be reported to LR.

4.8.2 Documented operating procedures for closing and securing the doors are to be kept on board and posted at an appropriate place.

4.9 Engine removal arrangements

4.9.1 Where portable plates are required for unshipping machinery or for other similar reasons, they may be accepted provided they are of equivalent strength to the unpierced structure and are secured by gaskets and closely spaced bolts. The pitch spacing of the bolts will be specially considered depending on the hatch stiffening and support arrangements but should not exceed ten diameters.

4.10 Testing on completion

4.10.1 The items listed in Table 1.7.1 in Chapter 1, are to be hose tested to the satisfaction of the Surveyor.

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■ *Section 5* Hatches on exposed decks

5.1 General

5.1.1 This Section applies to small hatchways or access openings in the positions indicated in Fig. 4.5.1.

5.1.2 The number and size of hatchways and other access openings are to be kept to the minimum consistent with the satisfactory operation of the craft.

5.1.3 Hatch covers are to be weathertight when closed, of substantial construction and generally hinged. The means of securing are to be such that weathertightness can be maintained in any sea condition. Details are to be submitted for approval.

5.1.4 Hatch covers may be of steel, aluminium alloy or FRP construction. Where toggles are fitted, their diameter and spacing are to be in accordance with an ISO Standard or equivalent.

5.1.5 Hatches on the weatherdeck in the forward $0{,}25L_R$ or to machinery spaces are to be hinged on the forward side.

5.2 Coaming heights

5.2.1 Hatch coamings are to have a height above the deck surface in accordance with Table 4.5.1. Lower heights may be considered in relation to operational requirements and the nature of the spaces to which access is given.

5.2.2 Flush hatches will be specially considered.

5.2.3 Rope hatches may be accepted with reduced coamings, but generally not less than 380 mm, provided they are well secured and opened only at the Master's discretion. A suitable notice is to be displayed at the hatch.

5.3 Scantlings

5.3.1 Hatch covers are to be of equivalent strength to the deck on which they are fitted.

Table 4.5.1 Height of hatch coamings

Location/Access	Height (mm) (*see* Note 2)
(a) Weather deck/machinery compartment	460
(b) Weather deck/lower deck accommodation	230
(c) Weather deck/cargo hold	460

NOTES
1. For locations (a) and (b), *see* Fig. 4.5.1.
2. Reduced coaming heights will be specially considered based on a craft's service area restriction notation.

5.3.2 The thickness of the coamings is to be not less than the Rule thickness for the deck in the positions in which they are fitted. Stiffening of the coaming is to be appropriate to its length and height.

5.3.3 The covers are to be adequately stiffened.

5.4 Closing devices

5.4.1 Hinges are not to be used as securing devices unless specially considered.

5.4.2 Escape hatches are to be capable of being opened from either side.

5.5 Engine removal hatches

5.5.1 Where portable plates are required in decks for unshipping machinery or for other similar reasons, they may be accepted provided they are of equivalent strength to the unpierced deck and are secured by gaskets and closely spaced bolts. The pitch spacing of the bolts will be specially considered depending on the hatch stiffening and support arrangements but should not exceed ten diameters.

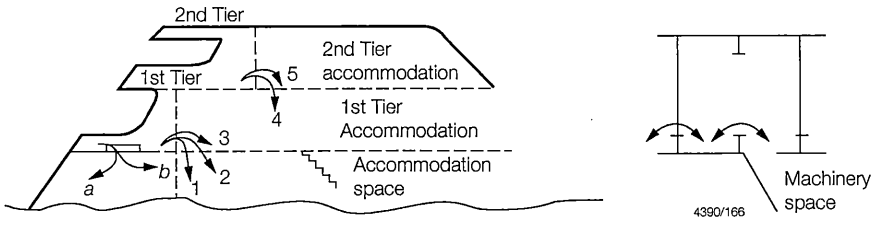

Fig. 4.5.1 Arrangement of doors, sills and hatch coamings

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5.6 Structural details

5.6.1 Various structural details for hatchways and access openings are given in the LR *Guidance Notes for Structural Details.*

5.7 Effective support for large hatch covers

5.7.1 The weight of hatch covers and any loads carried thereon, together with inertial forces generated by craft motions, are to be effectively transmitted to the craft structure. This may be achieved by continuous structural contact of the hatch cover with the craft structure or by means of defined bearing pads. The bearing pressure will be specially considered depending on the construction material.

5.8 National Authority requirements

5.8.1 The height of the hatch coaming may be subject to additional requirements of the National Authority.

5.9 Exceptions

5.9.1 Subject to the agreement of LR exceptions may be given to the requirements of this Section where they interfere with the operation of the craft. Such exceptions will be specially considered.

5.10 Testing upon completion

5.10.1 The items listed in Table 1.7.1 in Chapter 1, are to be hose tested to the satisfaction of the Surveyor.

5.11 Standard designs

5.11.1 Standard designs of hatches may be accepted, provided they are designed and manufactured in accordance with the requirements of a recognised National or International Standard which gives reasonable equivalence to the requirements of this Section.

5.11.2 Standard proprietary flush hatches, not exceeding 650 mm x 650 mm clear opening, which are of a type holding a valid Type Approval by LR, may be accepted for under deck access in non-working areas of craft below 24 m in length, L_R, dependent upon the Service Group Notation. Where the hatch type is not type approved, full details, including the material specification, are to be submitted for approval in each case.

5.12 Novel features

5.12.1 Hatchways of novel or unusual design will be specially considered.

■ *Section 6* Miscellaneous openings

6.1 General

6.1.1 This Section gives requirements for external doors, manholes and flush scuttles, hatchways within enclosed superstructures or 'tween decks and companionways, doors and accesses on weather decks.

6.1.2 Those items listed in Table 1.7.1 in Chapter 1, are to be hose tested to the satisfaction of the Surveyor.

6.2 External doors

6.2.1 Door sills are to have a height above the deck surface in accordance with Table 4.6.1.

Table 4.6.1 Height of door sills

Position/access	Height (mm)
(1) Weather deck/machinery compartment, *see* Note 2	460
(2) Weather deck/lower accommodation	230
(3) Weather deck/1st tier accommodation	150
(4) 1st tier/1st tier accommodation	100
(5) 1st tier/2nd tier accommodation	50

NOTES
1. For positions (1), (2), etc., *see* Fig. 4.5.1
2. Where the access to the machinery space is protected by an outer weathertight door, the inner door sill or hatch coaming may be 230 mm high in association with an outer sill height of 230 mm.

6.2.2 Reduced sill heights for doors will be considered as follows:
(a) dependent upon the service group notation,
(b) for doors which will only be used when the craft is in harbour, or calm water,
(c) where the sill height interferes with the operation of the craft,
(d) where doors do not give access to spaces below the freeboard deck.

6.2.3 The height of the door sill may be subject to additional requirements of the National Authorities.

6.2.4 Where the sill heights do not comply with the requirements of Table 4.6.1, interior deck openings are to be treated as if they were exposed on the weather deck.

6.3 Manholes and flush scuttles

6.3.1 Manholes and flush scuttles fitted in Positions 1 and 2, or within superstructures other than enclosed superstructures, are to be closed by substantial covers capable of being made watertight. Unless secured by closely spaced bolts, the covers are to be permanently attached.

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6.4 Hatchways within enclosed superstructures or 'tween decks

6.4.1 The requirements of Section 5 are to be complied with where applicable.

6.4.2 Access hatches within a superstructure or deckhouse in Position 1 or 2 need not be provided with means for closing if all openings in the surrounding bulkheads have weathertight closing appliances.

6.5 Companionways, doors and accesses on weather decks

6.5.1 Companionways on exposed decks are to be of equivalent construction, weathertightness and strength to a deckhouse in the same position and effectively secured to the deck.

6.5.2 Access openings in:

(a) Bulkheads at ends of enclosed superstructures,

(b) Deckhouses or companionways protecting openings leading into enclosed superstructures or to spaces below the freeboard deck, and

(c) Deckhouses on a deckhouse protecting an opening leading to a space below the freeboard deck,

may be fitted with doors of steel, aluminium alloy, FRP or other equivalent material, permanently and strongly attached to the bulkhead and framed, stiffened and fitted so that the whole structure is of equivalent strength to the unpierced bulkhead, and weathertight when closed. The doors are to be gasketed and secured weathertight by means of clamping devices or equivalent arrangements, permanently attached to the bulkhead or to the door. Doors are generally to open outwards and are to be capable of being operated and secured from both sides. The sill heights are to be as required by 6.2. Double doors are to be equivalent in strength to the unpierced bulkhead, and in Position 1, a centre pillar is to be provided which may be portable.

6.5.3 Elsewhere doors may be of hardwood or equivalent material and are to be of equivalent strength to the unpierced bulkhead.

6.5.4 Portlights or windows in doors are to comply with the requirements given in Section 7. Deadlights or storm covers may be external.

6.5.5 When the closing appliances of openings in superstructures and deckhouses do not comply with 6.5.2, interior deck openings are to be treated as if exposed on the weather deck.

6.5.6 Doors on the weather deck (first tier) protecting direct access to machinery spaces are to be of substantial construction in accordance with approved plans or a recognised National or International Standard. They are to be permanently attached to the casing, outward opening and gasketed weathertight with a minimum of six clips and have a sill height in accordance with 6.2.

6.5.7 Doors on the weather deck to accommodation or spaces protecting access below are to be as required by 6.5.6 with a minimum of four clips.

6.5.8 Where wood doors are proposed on the weather deck in lieu of doors as per 6.5.7, they are to be strongly constructed of hardwood not less than 45 mm thick and double gasketed. For doors in exposed locations, additional securing arrangements by slip bolts, clamps or equivalent will be required. These doors are not to be the sole means of entry or exit from the space. Where these doors may be required to be used as a means of escape in an emergency situation, the additional security arrangements are to be operable from both sides.

6.5.9 FRP doors are not to be fitted in access openings where 'A', 'B' or 'C' class fire integrity is required, or in engine room casings.

6.5.10 Doors in the second tier are to be as required by 6.5.6 with a minimum of four clips.

■ *Section 7*
Portlights, windows and viewing ports, skylights and glass walls

7.1 General

7.1.1 This Section gives the requirements for portlights, windows, viewing ports, sliding glass doors, glass walls, skylights, glazing materials, deadlights and storm covers.

7.1.2 Side scuttles and portholes are considered to be portlights.

7.1.3 A plan showing the location of portlights, windows, viewing ports, skylights and glass walls is to be submitted.

7.1.4 Portlights and windows, together with their glazing and deadlights if required, are to be of an approved design or in accordance with a recognised National or International Standard.

7.1.5 Glass in portlights, windows and skylights is to be thermally toughened safety glass with a thickness in accordance with approved plans or a recognised National or International Standard relative to their location.

7.1.6 Where consideration is given to the use of glazing materials other than thermally toughened glass, the thickness and arrangements are to take account of any different material properties and be approved.

7.1.7 The acceptance of 'glued-in' glazing material, when proposed, will be subject to Type Approval or individual approval and tests as appropriate.

7.1.8 The use of rubber frames is not generally acceptable.

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7.1.9 In position 2, cabin bulkheads and doors are considered effective between portlights or windows and access below.

7.1.10 Side scuttles are defined as being round or oval openings with an area not exceeding 0,16 m^2. Round or oval openings having areas exceeding 0,16 m^2 shall be treated as windows.

7.1.11 Windows are defined as being rectangular openings generally, having a radius at each corner relative to the window size and round or oval openings with an area exceeding 0,16 m^2.

7.2 Applications

7.2.1 As indicated in 1.1. *See also* Part 4 for additional requirements for yachts.

7.3 National Authority requirements

7.3.1 In addition to the requirements of this Section, where relevant, care is to be given to the statutory requirements of the National Authority.

7.4 Portlights

7.4.1 Portlights are to be in accordance with a recognised National or International Standard or of a type accepted for the respective position and having a valid LR Type Approval certificate. Where the portlight is not type approved, full details are to be sumitted for approval in each case.

7.4.2 Portlights may be round, elliptical or elongated and are to be of substantial construction

7.4.3 Portlights are not to be fitted in machinery spaces.

7.4.4 No portlight is to be fitted in such a position that its still is below a line drawn parallel to the freeboard deck at side and having its lowest point 2,5 per cent of the breadth, *B*, above the load waterline corresponding to the summer freeboard (as defined in Ch 1,6.2.7), or 500 mm, whichever is the greater distance, *see* Fig. 4.7.1.

7.4.5 Deadlights or storm covers for portlights are to be provided in accordance with 7.12.

7.5 Windows

7.5.1 Windows are to be in accordance with a recognised National or International Standard or of a type accepted for the respective position and having a valid LR Type Approval certificate.

7.5.2 Where the window is not type approved, full details are to be submitted for approval in each case and the prototype tested in accordance with the requirements of 7.5.3 to 7.5.5.

7.5.3 A hydrostatic test is to be carried out in order to examine watertightness. A design pressure p, where p is given in 7.8.1, is to be applied to the external face of the window and maintained for at least 15 minutes.

7.5.4 A hydrostatic test is to be carried out in order to examine the capability of the frame, and glass retaining arrangements. A design pressure $4p$, where p is given in 7.8.1, is to be applied to the external face of the window. Alternatively, this test may be carried out using a steel plate in place of the glass. Ideally the steel plate should be of a suitable reduced thickness to simulate the flexural performance of the glass.

7.5.5 Equivalent proposals for testing will be considered. Where alternative testing procedures are proposed, these are to be agreed with LR before commencement.

7.5.6 Window glazing is, in general, to be toughened safety glass, fitted in substantial frames supporting both faces of the glass and effectively secured to the structure. Metal to glass contact is to be avoided.

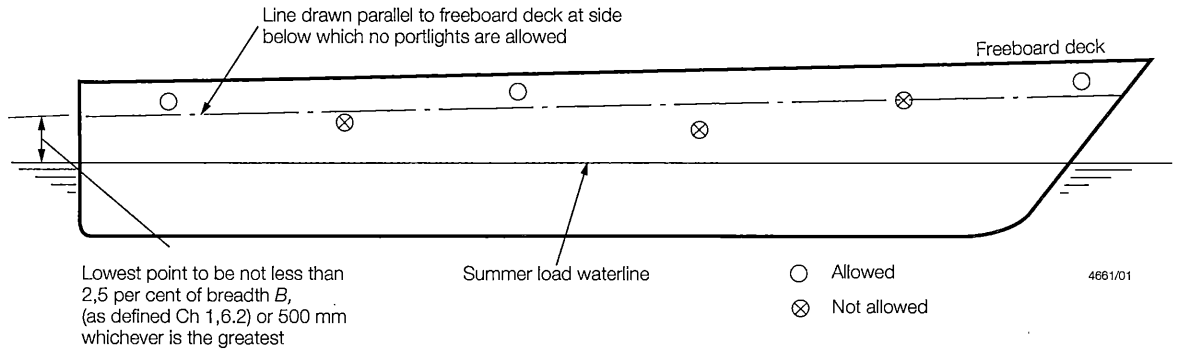

Fig. 4.7.1 Position of portlights

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7.5.7 In general, no windows are to be fitted in the following locations:

(a) below the freeboard deck;

(b) in the first tier end bulkheads or sides of enclosed superstructures; or

(c) in first tier deckhouses that are considered buoyant in the stability calculations.

7.5.8 Wheelhouse window glazing is to be toughened safety glass, or where it is of laminated or sandwich construction, the surface layers are to be of toughened safety glass.

7.5.9 Large windows in the aft end of superstructure or deckhouses will be specially considered.

7.5.10 Openings in the shell for windows are to have well rounded corners.

7.5.11 Storm covers or deadlights for windows are to be provided in accordance with 7.12.

7.6 Viewing ports

7.6.1 In general, viewing ports are not to be fitted in the bottom shell of high speed craft.

7.6.2 Viewing ports are to be watertight and of substantial construction in accordance with approved plans.

7.6.3 Glazing is to be fitted in substantial frames supporting both faces of the glazing and effectively secured to the hull structure.

7.6.4 Where practicable, viewing ports are to be fitted with efficient, hinged, deadlights which are capable of being effectively closed and secured watertight, with or without the glazing in place.

7.6.5 Hydrostatic pressure tests are to be carried out to confirm that the proposed construction, when fitted in the hull, is able to withstand a pressure of four times the design pressure and remain watertight. Where a deadlight is fitted, this test is also to be carried out with the glazing removed and the deadlight closed.

7.7 Sliding glass doors or 'glass walls'

7.7.1 Large glass doors or windows in the aft end of superstructures and deckhouses and other large glass structures forming the sides, ends or roofs of deckhouses will be specially considered.

7.7.2 When sliding glass doors are provided, or a 'glass wall' which includes an access, an alternative access or exit from the space is to be provided and the arrangements are to be in accordance with approved plans and weathertight commensurate with their position. Sill heights are, in general, to be in accordance with 6.2.

7.7.3 The glazing is to be toughened safety glass, or equivalent, and of substantial thickness in accordance with 7.8, 7.9 or 7.10 as appropriate.

7.7.4 Storm covers or roller shutters are to be provided in accordance with 7.12.11.

7.8 Toughened safety glass thickness

7.8.1 The thickness, t, of toughened safety glass is to be not less than 6 mm or that given by the following expression, whichever is the greater:

for glazing of rectangular form

$$t = 0{,}005b\sqrt{\beta p} \text{ mm}$$

for glazing of circular form

$$t = 0{,}00559r\sqrt{p} \text{ mm}$$

where

a = length of longer side of window, in mm

b = length of shorter side of glazing, in mm

p = design pressure in kN/m^2, as defined in Pt 5, Ch 3,3.1 and Ch 4,3.1

r = radius of the glazing, in mm

A_R = aspect ratio of window
$= a/b$

$\beta = -0{,}17 + 0{,}54A_R - 0{,}078A_R^2$ for $A_R \leq 3$
$= 0{,}75$ for $A_R > 3$.

7.8.2 For windows of trapezoidal form, the length of window, a, is to be taken as the mean of the length of the longer sides. The value of b, the length of the shorter side, may be similarly determined.

7.9 Laminated glass thickness

7.9.1 Laminated toughened safety glass may be used having a thickness greater than the single plate toughened safety glass for the same size window, as given by:

$$t_s^2 = t_{i1}^2 + t_{i2}^2 + \ldots\ldots + t_{in}^2 \text{ mm}$$

where

n = number of laminates

t_i = thickness of laminate, in mm

t_s = thickness of equivalent single plate, in mm.

Alternative arrangements that do not meet the above thickness requirement will be specially considered, provided that equivalent strength and bending stiffness to that of a single, thermally toughened pane of thickness, t_s, can be demonstrated in a four-point bending test in accordance with EN-ISO 1288-3 or an equivalent recognised National or International Standard, using no fewer than ten samples. The lower limit of the 90 per cent confidence level interval for the laminated pane shall not be less than the same for monolithic toughened safety glass. Small scale punch test or ring-in-ring test methods shall not be used.

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7.10 Other glazing materials

7.10.1 Materials other than glass may be used for windows, except for those in the wheelhouse, with the thickness obtained by multiplying the thickness for toughened safety glass by a factor of 1,3 for polycarbonate and 1,5 for acrylic. Consideration will be given to composite and multi-layer constructions where documented results of a pressure test confirm that the proposed construction, when fitted in its appropriate frame, is able to withstand a test pressure of four times the design pressure and remain watertight.

7.11 Openings and framing requirements

7.11.1 The strength and dimensions of the frame section are to be appropriate to the size of the window, the type of glazing being used and its method of bedding. The glazing is to be secured to its frame in accordance with the Manufacturer's instructions and recommendations; metal to glass contact is to be avoided.

7.11.2 Rubber frames are not acceptable for windows in Positions 1 and 2, and are not generally acceptable in any other position in external casings. Any proposals to fit rubber frames are to be submitted for consideration. The proposed locations, frame dimensions, glass thicknesses and the results of any tests carried out, are to be forwarded.

7.12 Deadlights and storm covers

7.12.1 Portlights fitted to spaces below the weather deck, or to spaces within enclosed superstructures, are to be fitted with efficient, hinged, inside deadlights which are capable of being effectively closed and secured watertight below the weather deck and weathertight above the weather deck.

7.12.2 In service craft less than 24 m Rule length, L_R, and yachts, portlights in the hull in way of accommodation may have portable deadlights, provided that they are stored adjacent to the portlight and can be readily fitted. Also, in the case of these craft, portlights in superstructures or deckhouses do not require to have deadlights, unless on the weather deck in exposed positions or protecting direct access below, in which case, they are to be provided with deadlights or storm covers.

7.12.3 For craft in **Service Group G1**, storm covers or deadlights are generally not required for windows or portlights in superstructures or deckhouses.

7.12.4 For craft in **Service Group G2**, storm covers or deadlights are required for:

(a) 50 per cent of the windows and portlights in the front of the superstructure or deckhouse on the weather deck.

(b) The windows and portlights in the forward half of the superstructure or deckhouse side on the weather deck, except where these are interchangeable port and starboard, in which case a sufficient number to fit the forward half of one side is to be provided.

(c) Each different size of window and portlight.

7.12.5 For craft in **Service Groups G2A and G3**, storm covers or deadlights are required for:

(a) All windows and portlights in the front of the superstructure or deckhouse on the weather deck.

(b) All windows and portlights in the sides of the superstructure or deckhouse on the weather deck, except where they are interchangeable port and starboard, in which case a sufficient number to fit any one side are to be provided.

(c) Each different size of window and portlight.

7.12.6 For craft in **Service Groups G4** and **G5**, storm covers or deadlights are required as follows:

(a) If fitted in a deckhouse in Position 1, windows are to be provided with strong, hinged, weathertight storm covers. However, if there is an opening leading below deck in this deckhouse, this opening is to be treated as being on an exposed deck and is to have weathertight protection.

(b) Portlights and windows at the shell in Position 2, protecting direct access below, are to be provided with strong permanently attached deadlights.

(c) Portlights and windows at the shell in Position 2, not protecting direct access below, are to be provided with strong portable steel covers for 50 per cent of each size, with means for securing at each window.

(d) Portlights and windows set inboard from the shell in Position 2, protecting direct access below, are either to be provided with strong permanently attached deadlights or, where they are accessible, strong permanently attached external storm covers instead or internal deadlights.

(e) Portlights and windows set inboard from the shell in Position 2, not protecting direct access below, do not require deadlights or storm covers.

(f) Windows in the shell above Position 2 are to be provided with strong portable internal storm covers for 25 per cent of each window, with means of securing being provided at each window.

(g) Where windows are permitted in an exposed bulkhead on the weather deck in the forward $0{,}25L_L$, strong external storm covers are to be provided, which may be portable and stored adjacent.

7.12.7 Deadlights and storm covers are not required for second tier portlights or windows in deckhouses without direct access below.

7.12.8 Where the wheelhouse is in Position 2, in lieu of storm covers being provided for the wheelhouse windows, a weathertight cover, fitted to a coaming of not less than 230 mm in height around the internal stairway opening within the wheelhouse, may be accepted. If this arrangement is accepted, adequate means of draining the wheelhouse are to be provided.

7.12.9 If necessary, for practical considerations, the storm covers may be in two parts.

7.12.10 Deckhouses situated on a raised quarter deck may be treated as being in Position 2 as far as the provision of deadlights is concerned, provided the height of the raised quarter deck is equal to, or greater than the standard height.

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7.12.11 Sliding glass doors are to be provided with storm covers of strong construction, or, in the case of a 'glass wall', this may be protected by a strongly constructed roller shutter or equivalent, which can be readily lowered and secured to provide adequate protection. When necessary, additional portable supports are to be provided for the cover. The arrangements are to be in accordance with approved plans. Alternative arrangements will be specially considered. In lieu of a weathertight coaming for the cover, adequate drainage is to be provided between the cover and the glass which may be in the form of a sump drained overboard, with a grating over.

7.12.12 Deadlights and storm covers are to be weathertight and of equivalent strength to the surrounding structure.

7.12.13 Portable deadlights and storm covers are to be clearly marked to indicate which portlights or windows they fit and stowed in such a way as to be readily fitted.

7.13 Emergency exits

7.13.1 Portlights or windows intended as emergency escapes are to be capable of being opened from both sides and have a minimum clear opening of 600 mm x 600 mm.

7.14 Skylights

7.14.1 Skylights, where fitted, are to be of substantial construction and securely attached to their coamings. The height of the lower edge of opening is to be as required by 5.2.1. The scantlings of the coaming are to be as required by 5.3.2. The thickness of glasses in fixed or opening skylights is to be appropriate to their size and position as required for portlights or windows. Glasses in any position are to be protected from mechanical damage, and where fitted in Positions 1 or 2 (as defined in Ch 1,6.10) are to be provided with robust deadlights or storm covers permanently attached.

7.15 Testing on completion and installation

7.15.1 In order to demonstrate that the requirements of this Section are met the closing arrangements are to be operated under working conditions to the satisfaction of the Surveyor.

7.15.2 The items listed in Table 1.7.1, in Chapter 1, are to be hose tested to the satisfaction of the Surveyor.

7.16 Bonded windows and side scuttles

7.16.1 A 'bonded window or bonded side scuttle' is one in which the glazing material is secured in its frame from the outside of the ship by glue or other adhesive material. No mechanical fixing is provided for the glazing. Bonded windows and bonded side scuttles are to comply with the requirements of 7.5 and 7.4 respectively, in addition to the requirements in this Section. Proposals to secure glazing from the inside of the ship are to be specially considered using the requirements in this Section as a basis. It should be noted that bonding from the inside is not recommended and where it is proposed, further testing will be required. Non-load-bearing secondary bonded glazing, e.g., glazing to improve thermal insulation, is not required to comply with the requirements of this sub-Section.

7.16.2 The adhesive is to be flexible enough to support the glazing without holding it firm. The glue strip is to be elastic, with width and thickness designed to allow the glazing to move in both directions in the plane of the glazing without undue forces on the bonding or the substrate. The glass is to be free to settle under load and not be forced to follow deflections in the supporting structure. If substantial racking of the glazing opening under load is expected, the bonding is to be designed to accommodate such deflections.

7.16.3 Bonded windows and side scuttles may be considered as acceptable, in general, on yachts, depending on their position, size of yacht and applicable statutory requirements, noting the distinction between glazing and the frame, which may have different requirements.

7.16.4 Bonded windows and side scuttles are not permitted in galley areas, including glazing in galley doors (internal or external). They are not permitted on escape routes and evacuation routes where a fire rating is required. The fire integrity of bulkheads is not to be impaired.

7.16.5 The failure of laminated glass is considered to pose a lower risk to safety than that of single pane glass. In the event of breaking, laminated glass more readily holds together and tends not to break up into large sharp pieces. Therefore, in general, laminated glazing is preferred. When laminated glass is used, the sealant is to be compatible with the interlayer. Lamination thickness is to be in accordance with 7.9.1. Special consideration will be given to single pane toughened safety glass.

7.16.6 The durability of the adhesive and the sealant in the long-term marine environment is to be considered in the approval process. Adhesive is to be approved in accordance with Vol 2, Pt 2, Ch 14,2.15. The adhesive bead is to be resistant to or protected from UV radiation, either by an optically dense area at the edges of the glazing or by overlapping trim or UV shielding tape. The adhesive bead is to be resistant to or protected from fungal attack. Arrangements are to be in accordance with the adhesive manufacturer's published guidelines and relevant LR Rules.

7.16.7 The edges of the bonding recess are to be rounded to facilitate the application of the sealant without air entrapment. The width of the gap between the flange and the glazing is to be large enough to accommodate the movement of the glazing as a result of hull deflection and thermal expansion, *see* Fig. 4.7.2. Recommended gap widths for bonded windows are to be taken as:

Gap width	Length of longest side of window
10–15 mm	< 1,5 m
15–20 mm	1,5–3,0 m

7.16.8 The minimum adhesive width and thickness are to be in accordance with the adhesive manufacturer's published guidelines.

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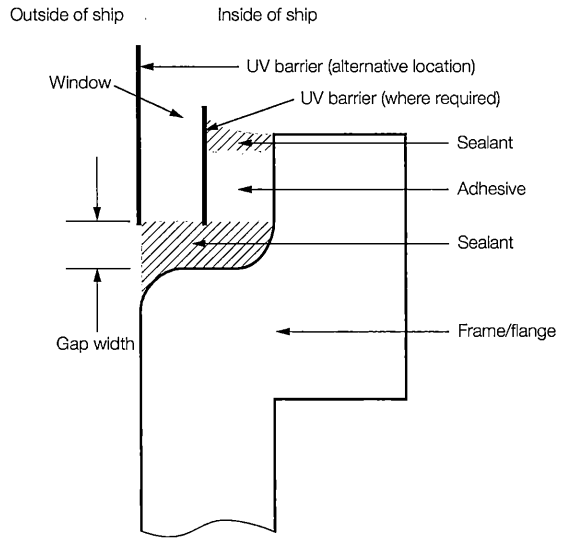

Fig. 4.7.2
Gap width between flange and window, bonded from the outside of the ship

■ *Section 8*
Bulwarks, guard rails and other means for the protection of crew

8.1 General

8.1.1 Bulwarks or guard rails are to be provided at the boundaries of exposed freeboard and superstructure decks and first tier deckhouses. Bulwarks or guard rails are to be not less than 1,0 m in height measured above sheathing, and are to be constructed as required by 8.2 and 8.4 respectively. Special consideration will be given to cases where this height would interfere with the normal operation of the craft.

8.1.2 The freeing arrangements in bulwarks are to be in accordance with Section 9.

8.1.3 Where appropriate, special consideration will be given to the provision of guard-wires in lieu of bulwarks or guard rails.

8.1.4 Where wire ropes are fitted, adequate devices are to be provided to ensure their tautness.

8.1.5 Where stanchions are fitted, every third stanchion is to be supported by a bracket or stay.

8.1.6 A proper step arrangement is to be provided in way of obstructions such as pipe lines, etc.

8.2 Bulwark construction

8.2.1 Plate bulwarks are to be stiffened by a strong rail section and supported by stays from the deck. The spacing of these bulwark stays is not to be greater than 1,83 m. Where bulwarks are cut to form a gangway or other opening, stays of increased strength are to be fitted at the ends of the openings. Bulwarks are to be adequately strengthened in way of eyeplates for cargo gear, and in way of mooring pipes the plating is to be doubled or increased in thickness and adequately stiffened.

8.2.2 In the calculation of the section modulus, only the material connected to the deck is to be included. The bulb or flange of the stay may be taken into account where connected to the deck, and where, at the ends of the craft, the bulwark plating is connected to the sheerstrake, a width of plating not exceeding that considered effective (*see* Pt 6, Ch 3,1.10, Pt 7, Ch 3,1.11 and Pt 8, Ch 3,1.7 for steel, aluminium alloy and composite construction respectively) may also be included. The free edge of the stay is to be stiffened.

8.2.3 Bulwark stays are to be supported by, or to be in line with, suitable underdeck stiffening, which is to be connected by double continuous fillet welds in way of the bulwark stay connection.

8.2.4 The foregoing requirements do not allow for any loading from deck cargoes.

8.3 Openings in bulwarks

8.3.1 Bulwarks are not to be cut for gangway or other openings near the breaks of superstructures, and are also to be arranged to ensure their freedom from main structural stresses. *See* shell plating in appropriate Chapters.

8.4 Guard rails

8.4.1 The opening below the lowest course of guardrails is not to exceed 230 mm. The other courses are to be spaced not more than 380 mm apart. In the case of craft with rounded gunwales, the guard rail supports are to be placed on the flat of the deck.

8.4.2 Satisfactory means, in the form of guard rails, life-lines, handrails, gangways, underdeck passageways or other equivalent arrangements, are to be provided for the protection of the crew in getting to and from their quarters, the machinery space and all other parts used in the necessary work of the craft.

8.4.3 Chains are only permitted in short lengths in way of access openings.

8.4.4 Where permitted by the National Authority, gangways or walkways may be omitted on craft operating within **Service Groups G1** or **G2**. However, lifelines are to be provided on flush deck craft, or where the cargo hatch coamings are less than 600 mm high.

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Section 9
Deck drainage

9.1 General

9.1.1 Where bulwarks on the weather portions of freeboard or superstructure decks form wells, ample provision is to be made for rapidly freeing the decks of large quantities of water by means of freeing ports, and also for draining them.

9.2 Freeing port area

9.2.1 The minimum freeing area on each side of the craft for each well on the freeboard deck or raised quarter deck, where the sheer in the well is not less than the standard sheer required by the *International Convention on Load Lines*, 1966, is to be derived from the following formulae:

(a) where the length, l, of the bulwark in the well is 20 m or less:
area required = $0,7 + 0,035l$ m^2

(b) where the length, l, exceeds 20 m
area required = $0,07l$ m^2
l need not be taken greater than $0,7L_L$, where L_L is the length of the craft as defined in Ch 1,6.2.

9.2.2 If the average height of the bulwark exceeds 1,2 m or is less than 0,9 m, the freeing area is to be increased or decreased, respectively, by 0,004 m^2 per metre of length of well for each 0,1 m increase or decrease in height respectively.

9.2.3 The minimum freeing area for each well on a first tier superstructure is to be half the area calculated from 9.2.1.

9.2.4 Two-thirds of the freeing port area required is to be provided in the half of the well nearest to the lowest point of the sheer curve.

9.2.5 When the deck has no sheer, the minimum freeing area for each well calculated from 9.2.1 is to be increased by 50 per cent. Where the sheer is less than the standard the percentage shall be obtained by linear interpolation. The freeing area is to be spread along the length of the well.

9.2.6 Where the length of the well is less than 10 m, or where a deckhouse occupies most of the length, the freeing port area will be specially considered but in general need not exceed ten per cent of the bulwark area.

9.2.7 Where it is not practical to provide sufficient freeing port area in the bulwark, particularly in small craft, credit can be given for bollard and fairlead openings where these extend to the deck.

9.2.8 Where a craft fitted with bulwarks has a continuous trunk, or hatch side coamings that are continuous, or substantially continuous, the minimum freeing area is to be not less than 20 per cent of the total bulwark area where the width of trunk or hatchway is $0,4B$ or less, and not less than 10 per cent of the total bulwark area when the width of the trunk or hatch is $0,75B$ or greater. The freeing area required for an intermediate width of trunk or hatch is to be obtained by linear interpolation.

9.2.9 Where the trunk referred to in 9.2.8 or its equivalent is included in the calculation of freeboard, open rails are to be fitted for at least 50 per cent of the length of the exposed part of the weather deck. Alternatively, if a continuous bulwark is fitted, the minimum freeing area is to be at least 33 per cent of the bulwark area. The freeing area is to be placed in the lower part of the bulwark.

9.2.10 Where a deckhouse has a breadth less than 80 per cent of the beam of the craft, or the width of the side passageways exceed 1,5 m, the arrangement is considered as one well. Where a deckhouse has a breadth equal to or greater than 80 per cent of the beam of the craft, or the width of the side passageways does not exceed 1,5 m, or when a screen bulkhead is fitted across the full breadth of the craft, this arrangement is considered as two wells, before and abaft the deckhouse.

9.2.11 Adequate provision is to be made for freeing water from superstructures which are open at either or both ends and from all other decks within open or partially open spaces in which water may be shipped and contained.

9.2.12 Suitable provision is also to be made for the rapid freeing of water from recesses formed by superstructures, deckhouses and deck cargo arrangements, etc., in which water may be shipped and trapped. Deck gear, particularly on fishing craft, is not to be stowed in such a manner as to obstruct unduly the flow of water to freeing ports.

9.2.13 The lower edges of freeing ports are to be as near to the deck as practicable, and should not be more than 100 mm above the deck.

9.3 Free flow area

9.3.1 The effectiveness of the freeing port area in bulwarks of craft not fitted with a continuous deck obstruction, depends on the free flow across the deck.

9.3.2 The free flow area is the net total longitudinal area of the transverse passageways or gaps between hatchways and superstructures or deckhouses, due account being made for any obstructions such as equipment or other fittings. The height of passageways or gaps used in the calculation of the area is the height of the bulwark.

9.3.3 The provision of freeing area in bulwarks is to be related to the net free flow area as follows:

(a) If the free flow area is equal to, or greater than the freeing port area calculated from 9.2.8 when the hatchway coamings are continuous, then the minimum freeing area calculated from 9.2.1 is sufficient.

(b) If the free flow area is less than the freeing port area calculated from 9.2.1, then the minimum freeing area is to be that calculated from 9.2.8.

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(c) If the free flow area is less than the freeing port area derived from (a) but greater than that derived from (b), the minimum freeing area, F, in the bulwark is to be obtained from the following formula:

$$F = F_1 + F_2 - f_p \quad m^2$$

where

F_1 = minimum area from 9.2.1
F_2 = minimum area from 9.2.8
f_p = total net area of passages and gaps between hatchways, superstructures and deckhouses (the free flow area).

9.4 Scupper arrangements

9.4.1 Scuppers, sufficient in number and size to provide effective drainage, are to be fitted in all decks.

9.4.2 Scuppers draining weather decks and spaces within superstructures or deckhouses not fitted with efficient weathertight doors are to be led overboard.

9.4.3 Scuppers and discharges which drain spaces below the freeboard deck, or spaces within intact superstructures or deckhouses on the freeboard deck fitted with efficient weathertight doors, may be led to the bilges in the case of scuppers, or to suitable sanitary tanks in the case of sanitary discharges. Alternatively, they may be led overboard provided that:

(a) the freeboard is such that the deck edge is not immersed when the craft heels to 5°, and
(b) the scuppers are fitted with a positive control valve or automatic non-return valve at the shell preventing water from passing inboard.

9.4.4 In craft where an approved fixed pressure water spray fire-extinguishing system is fitted in vehicle or cargo spaces, deck scuppers of not less than 150 mm diameter are to be provided port and starboard, spaced about 9,0 m apart. The scupper area will require to be increased if the design capacity of the drencher system exceeds the Rule required capacity by 10 per cent or more. After installation, the two adjacent sections with the greatest aggregate drencher capacity are to be tested in operation to ensure that there is no build up of water on the deck. The scuppers are to be led inboard to tanks or, alternatively they may be led overboard providing they comply with 9.4.3(a) and (b). Inboard draining scuppers do not require valves but are to be led to suitable drain tanks (water contaminated with petrol or other flammable substance is not to be drained to machinery spaces or any other space where a source of ignition may be present) and the capacity of the tanks is to be sufficient to hold approximately 10 minutes of drenching water. The arrangements for emptying these tanks are to be approved and suitable high level alarms provided. The mouth of the scupper is to be protected by bars.

9.4.5 Scupper pipes from the weather decks discharging overboard below or near the waterline are to be provided with a non-return valve or positive control valve. Where the scupper pipes are of substantial construction, having a wall thickness of not less than that of the side shell plus 2 mm, the non-return valve or positive control valve may be omitted.

9.4.6 For the use of non-metallic pipe, *see* Pt 15, Ch 1,8.

9.5 Large freeing port openings

9.5.1 Where the height of freeing ports is greater than 230 mm, vertical bars spaced approximately 230 mm apart may be accepted, as an alternative to a horizontal rail, to limit the height of the freeing port. Other equivalent arrangements will be specially considered.

■ *Section 10* Cabin sole and lining

10.1 General

10.1.1 Cabin soles are to be fitted and secured in such a manner as to provide access to the structure and fittings below.

10.1.2 The cabin fittings and linings against the side of the craft are to be so fitted as to be capable of being removed when necessary. The method of attachment is not to impair the strength of the structural members.

10.1.3 For fire protection requirements for cabin fittings and linings, *see* Part 17.

10.2 Removal for access

10.2.1 It is recommended that the cabin fittings and linings against the side of the craft be so fitted as to be capable of being removed when necessary. The method of attachment is not to impair the strength of the structural members.

10.3 Fire aspects

10.3.1 For information and plans required, *see* Part 17.

■ *Section 11* Ventilators

11.1 General

11.1.1 This Section provides requirements for ventilators and the ventilation of all craft.

11.1.2 The requirements conform, where relevant, with those of the *International Convention on Load Lines, 1966*. Reference is also to be made to any additional requirements of the National Authority of the country in which the craft is to be registered and to the relevant regulations of the *International Convention for the Safety of Life at Sea, 1974* and applicable amendments.

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11.1.3 Special care is to be taken in the design and positioning of ventilator openings and coamings, particularly in the region of the forward end of superstructures and other points of high stress. The deck plating in way of the coamings is to be efficiently stiffened.

11.1.4 The scantlings of ventilators exposed to the weather are to be equivalent to those of the adjacent deck or bulkhead. Where the height of the ventilator exceeds that required by 11.5.1, the thickness may be gradually reduced above that height to a minimum which will be specially considered dependent on the material of construction. Ventilators are to be adequately stayed.

11.1.5 Ventilators from deep tanks and tunnels passing through 'tween decks are to have scantlings suitable for withstanding the pressures to which they may be subjected, and are to be made watertight.

11.1.6 For the requirements for fire precautions on cargo and passenger craft, *see* Part 17.

11.1.7 Adequate ventilation is to be provided throughout the craft.

11.1.8 For the requirements for yachts, *see also* Part 4.

11.2 Accommodation spaces

11.2.1 Accommodation spaces are to be protected from gas or vapour fumes from machinery, exhaust and fuel systems in accordance with Ch 2,4.7, *see also* Part 17.

11.3 Machinery spaces

11.3.1 In addition to the requirements of this Section, a filter coalescer is to be fitted to the machinery space air intakes to remove fine spray where:

- Intakes are fitted in exposed positions on the weather deck; or
- intakes are large; or
- coaming height is reduced; or
- as required by the engine manufacturer.

Special consideration will be given to alternative arrangements for craft operating within service groups G1–G3, *see also* Part 9.

11.3.2 In general, ventilators necessary to continuously supply the machinery space or the emergency generator room shall have coamings of sufficient height to comply with 11.4.1, without having to fit weathertight closing appliances.

11.3.3 Where it is not practical to comply with 11.3.2 due to ship size and arrangement, lesser heights for machinery space and emergency generator room ventilator coamings, fitted with weathertight closing may be permitted by the Administration in combination with other suitable arrangements to ensure an uninterrupted, adequate supply of ventilation to these spaces.

11.4 Closing appliances

11.4.1 All ventilator openings are to be provided with efficient weathertight closing appliances unless:

(a) The height of the coaming is greater than 4,5 m above the deck at Position 1.

(b) The height of the coaming is greater than 2,3 m above the deck at Position 2.

11.4.2 In order to limit the fire growth potential in every space of the ship, the main inlets and outlets of all ventilation systems shall be capable of being closed from outside the spaces being ventilated. The means of closing shall be easily accessible as well as be prominently and permanently marked and shall indicate whether the inlet or outlet is open or closed. Battery room ventilators are to be fitted with a means of closing only when:

(a) the battery room does not open directly onto an exposed deck; or

(b) the ventilation opening for the battery room is required to be fitted with a closing device according to the Load Line Convention; or

(c) the battery room is fitted with a fixed gas fire-extinguishing system.

11.4.3 Closing appliances are to be permanently attached to the ventilator coaming.

11.4.4 Where, in ferries, ventilators are proposed to be led overboard in an enclosed 'tween deck, the closing arrangements are to be submitted for approval. If such ventilators are led overboard more than 4,5 m above the main vehicle deck, closing appliances may be omitted, provided that satisfactory baffles and drainage arrangements are provided, as in the case of air intakes or exhaust openings for machinery spaces, which may be arranged in the sides of the craft.

11.4.5 Mushroom ventilators closed by a head revolving on a centre spindle (screw down head) are acceptable in Position 2, and also in sheltered positions in Position 1, but the diameter is not to exceed 300 mm if situated within the forward $0{,}25L_L$.

11.4.6 Mushroom ventilators with a fixed head and closed by a screw down plate (screw down cover) may be accepted in exposed positions within the forward $0{,}25L_L$ up to a diameter of 750 mm.

11.4.7 Wall ventilators (jalousies) may be accepted provided they are capable of being closed weathertight by hinged gasketed covers secured by bolts or toggles. They are preferably to face aft or athwartships and are to be fitted with a suitable means of preventing ingress of water and spray when open in the form of louvres, baffles, screens or an equivalent arrangement.

11.4.8 Reference is to be made to Section 1 concerning down flooding through ventilators which do not require closing appliances due to their coaming height being in accordance with 11.4.1.

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11.5 Effective coaming heights

11.5.1 The height of ventilator coamings exposed to the weather is to be as high as practicable, with a minimum height of 600 mm in Position 1 and 450 mm in Position 2. In particularly exposed positions, the height of coamings may be required to be increased or self closing devices may be required.

11.5.2 Reduced coaming heights may be considered for ventilators which are not required for the operation of the craft at sea, provided that operational procedures are in place and a notice is fitted to the ventilator to ensure that the closing device is closed whilst the craft is at sea.

11.5.3 For gooseneck ventilators, the coaming height is to be measured to the underside of the bend, this being the lowest point through which water on deck could pass freely to spaces below.

11.5.4 Where wall ventilators are fitted with an internal baffle which rises above the lower edge of the exterior opening, the coaming height is measured to the top of the baffle.

11.6 Drainage arrangements

11.6.1 Ventilators are to be provided with suitable drainage arrangements, particularly where an internal baffle is fitted, *see* 11.5.4.

■ *Section 12* Air and sounding pipes

12.1 General

12.1.1 Air and sounding pipes are to comply with the requirements of Pt 15, Ch 2,11.

12.1.2 The minimum wall thickness of steel and aluminium alloy air pipes in positions indicated in 12.2.1 is to be taken as:

t_p = 0,03d_p + 3,6 mm with a maximum of 8,5 mm

where

t_p = wall thickness of air pipe, in mm

d_p = external diameter of air pipe, in mm.

12.1.3 The pipe material is to be compatible with the craft construction material.

12.1.4 Composite pipes may be acceptable for use on composite craft and will be specially considered.

12.1.5 Striking plates of suitable thickness, or their equivalent, are to be fitted under all sounding pipes.

12.1.6 For the requirements for yachts, *see also* Part 4.

12.2 Height of air pipes

12.2.1 The height of air pipes from the upper surface of decks exposed to the weather, to the point where water may have access below is normally to be not less than:

- 450 mm on the freeboard deck;
- 300 mm on the superstructure deck;

these heights being measured above deck sheathing, where fitted.

12.2.2 Lower heights may be approved in cases where these are essential for the working of the craft, provided that the design and arrangements are otherwise satisfactory.

12.2.3 An increase in the height of air pipes may be required or recommended by individual Administrations when air pipes to fuel oil and settling tanks are situated in positions where sea water could be temporarily entrapped, e.g. in recesses in the sides and ends of superstructures or deckhouses, between hatch ends, behind high sections of bulwark, etc. This may entail an increase in tank scantlings and will be specially considered.

12.2.4 Air pipes are generally to be led to an exposed deck. Alternatively, air pipes from cofferdams or void spaces may terminate in the enclosed 'tween deck space on main vehicle decks, provided the space is adequately ventilated and the air pipes are provided with weathertight closing appliances.

12.2.5 Where air pipes are led through the side of superstructures, the opening is to be at least 2,3 m above the summer load waterline.

12.3 Closing appliances

12.3.1 All openings of air and sounding pipes are to be provided with permanently attached, satisfactory means of closing to prevent the free entry of water.

12.3.2 Exposed air pipes in positions 1 and 2 are to be provided with approved automatic closing appliances.

■ *Section 13* Particular requirements for multi-hull craft

13.1 General

13.1.1 In addition to the general requirements given in this Chapter, this Section gives particular requirements for multi-hull craft.

13.2 Multi-hull craft escape hatches

13.2.1 Multi-hull craft are to be provided with a suitable means of escape from each accommodation compartment between watertight bulkheads in the event of inversion of the craft.

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13.2.2 Where the requirement given in 13.2.1 is achieved by means of escape hatches in the hull, these are to be fitted in the inboard side of each hull, or in the transom, with the lowest side of the opening at a minimum of 600 mm above the waterline in both the upright and inverted conditions of the craft. Hatch openings are to be a minimum of 450 mm x 450 mm and a maximum of 600 mm x 600 mm.

13.2.3 Escape hatch frames and covers may be of steel, aluminium alloy or FRP construction and are to be of equivalent strength to the unpierced hull side or transom in which they are fitted.

13.2.4 Hatch covers are to be weathertight when closed and the means of securing the hatch cover are to be such that weathertightness can be maintained in any sea condition.

13.2.5 Hydrostatic pressure tests are to be carried out to confirm that the proposed construction, when fitted in the hull, is able to withstand a pressure of four times the design pressure and remain watertight.

13.2.6 Hatch covers are to be flush with the hull and substantially hinged. Where fitted in the inboard side of the hull, the hinges are to be on the forward side.

13.2.7 Escape hatches are to be capable of being opened from both sides. Handles on the outside are to be suitably protected from damage or inadvertent opening.

13.3 Portlights

13.3.1 Where it is proposed to fit portlights in the hulls of wave-piercing and other non-conventional multi-hull craft, the arrangements will be specially considered.

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Section

1 **General**

2 **Equipment Number**

3 **Service group factors**

4 **Craft type factors**

5 **Anchors**

6 **Anchor cable**

7 **Mooring ropes and towlines**

8 **Windlass design and testing**

9 **Structural details**

■ *Section 1* General

1.1 Application

1.1.1 The anchoring equipment specified in this Section is suitable only for use in reasonably sheltered conditions or in emergencies. If the equipment is intended to be used during operations in the open sea, or if the sea or weather conditions in the service area are subject to unusual hazards, e.g. typhoons, etc., the equipment will be specially considered in each case.

1.1.2 Where the Equipment Number exceeds 1140 the equipment is to be in accordance with Pt 3, Ch 13 of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships).

1.2 Definitions

1.2.1 The definitions for use throughout this Chapter are as indicated in the appropriate Section.

1.3 Symbols

1.3.1 The following symbols are used in this Chapter, unless otherwise stated:

b_i = mean breadth of deckhouse or superstructure tier, in metres

h_i = mean height of deckhouse or superstructure tier, in metres

A = area, in m^2, in profile view of the hull, superstructure and deckhouses above the design waterline. Deckhouses with breadth less than B/4 are to be ignored

B_o = the greatest moulded breadth, in metres, or for craft of composite construction, the extreme breadth excluding rubbing strakes or other projections

B_1 = the greatest breadth of the outer hulls of a multi-hull craft, in metres. It is to be measured between the points of intersection of the extension of the hull sides to the normal line of the wet deck

B_2 = the greatest breadth of the centre hull in trimaran type craft, in metres. It is to be measured between the points of intersection of the extension of the hull sides to the normal line of the wet deck

D_h = the sum of bi hi cos qi for all deckhouses and superstructures tiers

G_A = air gap, as defined in Pt 5, Ch 1

α_1 = for multi-hull craft is the distance in metres, from the underside of the cross-deck structure to the underside of the first tier of deckhouse or superstructure for mono-hull craft is the distance in metres, from the waterline to the underside of the first tier of deckhouse or superstructure

θ_i = angle of inclination aft, of tier of deckhouse front, with a line perpendicular to the static load waterline

Δ = loaded displacement, in tonnes.

1.4 Character of classification

1.4.1 To entitle a craft to the figure **1** in its character of classification, equipment in accordance with the requirements of this Chapter is to be provided. The regulations governing assignment of the character figure **1** for equipment are given in Pt 1, Ch 2,3.

1.4.2 For craft intended to be operated only in suitable areas or conditions which have been agreed by the Committee, as defined in Pt 1, Ch 2,3.5, equipment differing from these requirements may be approved if considered suitable for the particular service on which the craft is to be engaged.

1.4.3 Where the Committee has agreed that anchoring and mooring equipment need not be fitted in view of the particular service of the ship, the character letter **N** will be assigned, *see also* Pt 1, Ch 2,3.2.2.

1.4.4 Where the ship is intended to perform its primary designed service function only while it is anchored, moored, towed or linked, the character letter **T** will be assigned, *see also* Pt 1, Ch 2,3.2.2.

1.4.5 For classification purposes the character figure **1**, or either of the character letters **N** or **T**, are to be assigned.

■ *Section 2* Equipment Number

2.1 Equipment Number

2.1.1 The anchoring and mooring equipment is based on an Equipment Number, *EN*, which is to be calculated as given in 2.1.2 to 2.1.4.

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2.1.2 **Mono-hull craft**

$EN = \Delta^{2/3} + 2\,(D_h + B_o\,\alpha_1) + 0{,}1A$

2.1.3 **Catamaran, Swath, SES and other twin hull craft**

$EN = \Delta^{2/3} + 2\,(D_h + B_o\,\alpha_1 + 2G_a\,B_1) + 0{,}1A$

2.1.4 **Trimarans**

$EN = \Delta^{2/3} + 2\,(D_h + B_o\,\alpha_1 + G_a\,(2B_1 + B_2)) + 0{,}1A$

2.2 Novel craft

2.2.1 Where a craft is of unusual form and proportions the requirement for equipment will be individually considered on the basis of the Rules.

■ *Section 3* Service group factors

3.1 General

3.1.1 The masses of anchors and the diameters and lengths of chain cable required by Table 5.5.1 and Table 5.6.1 respectively are for craft in **Service Group G4**.

3.2 G1 craft

3.2.1 For craft in **Service Group G1**, the equipment is generally to be that required for craft in **Service Group G2**; proposals for further reductions will be specially considered.

3.3 G2, G2A, G3 and G4 craft

3.3.1 For craft in **Service Groups G2, G2A, G3**, and **G4**, the mass of the anchor required by Table 5.5.1 may be multiplied by the following factors:

Service Group G2	0,60
Service Group G2A	0,65
Service Group G3	0,73
Service Group G4	1,00

3.3.2 The length and diameter of chain cable are to be those required by Table 5.6.1 corresponding to the reduced anchor mass given in Table 5.5.1.

3.3.3 Towlines and mooring lines are to be those required by Table 5.7.1 corresponding to the equipment number as determined from Section 2.

3.3.4 For service craft on particular duties, a further reduction in the mass of the anchor may be given in accordance with Section 4.

3.4 G5 craft

3.4.1 Craft in **Service Group G5** are considered for the purposes of this Chapter to be unrestricted in their service, and the equipment is to be in accordance with Pt 3, Ch 13 of the Rules for Ships.

3.5 G6 craft

3.5.1 **Service Group G6** covers yachts and patrol craft having unrestricted service.

3.5.2 For yachts, the mass of the anchors required by Table 5.5.1 may be multiplied by the craft type factor indicated in Section 4. The length and diameter of chain cable are to be those required by Table 5.6.1 corresponding to the reduced anchor mass given in Section 4.

3.5.3 For patrol craft, the equipment is to be in accordance with Pt 3, Ch 13 of the Rules for Ships for unrestricted service.

■ *Section 4* Craft type factors

4.1 General

4.1.1 The mass of the anchors required by Table 5.5.1 and corrected for service group factors in accordance with Section 3 (where applicable), are to be corrected by the craft type factors indicated in this Section.

4.2 Craft type factors

4.2.1 **Yachts** with an Equipment Numeral, *EN*, of less than or equal to 220 as determined in 2.1, may have the mass of the anchors as required by Table 5.5.1 reduced by the craft type factor, k_y, in accordance with the following:

$$k_y = \frac{EN}{500} + 0{,}56$$

4.2.2 For yachts with an Equipment Numeral, *EN*, in excess of 220, the craft type factor, k_y, is to be taken as unity.

4.2.3 **Pilot and Patrol** craft operating within **Service Group G1**, and which do not normally anchor in the course of their duties, with an Equipment Numeral *EN* of less than or equal to 220 as determined in 2.1, may have the mass of the anchor as required by Section 3 reduced by the craft type factor, k_{p1}, in accordance with the following:

$$k_{p1} = \frac{EN}{980} + 0{,}28$$

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4.2.4 **Pilot and patrol** craft operating within **Service Group G2**, and which do not normally anchor in the course of their duties, with an Equipment Numeral *EN* of less than or equal to 100 as determined in 2.1.2, may have the mass of the anchor as required by Section 3 reduced by the craft type factor, k_{p2}, in accordance with Table 5.4.1.

Table 5.4.1 Craft type factor

Equipment Numeral, *EN*	Craft type factor, k_{p2}
$\geq 5 \leq 40$	0,8
$> 40 \leq 100$	0,9
> 100	1,0

■ *Section 5* Anchors

5.1 General

5.1.1 The Rules are based on the use of high holding power (HHP) type anchors.

5.1.2 When ordinary holding power anchors are used as bower anchors, the mass given in Table 5.5.1 is to be increased by 33 per cent.

5.1.3 Where it is proposed to fit other types of anchor, the mass will be specially considered.

5.1.4 Craft other than yachts are to be provided with a single anchor on board which must be ready for immediate use.

5.1.5 In addition, the craft is to be supplied with one spare anchor located at each of the ports on its regular scheduled service, or alternatively the spare anchor may be carried on board.

5.1.6 **Yachts** are to be provided with two anchors on board. Each anchor must have the rule length of chain cable attached. Only one anchor is required to be ready for immediate deployment, i.e. around the capstan. The masses of anchors may be of the following combinations:

(a) The mass of the first anchor is to be not less than 100 per cent of the Rule value for the type of anchor concerned. The mass of the second anchor is to be not less than 70 per cent of the Rule value for the type concerned.

(b) The mass of each anchor is to be not less than 90 per cent of the Rule value for the type of anchor concerned.

5.1.7 The fitting of a single anchor on board yachts will be specially considered. The mass of the single anchor is to be not less than 100 per cent of the Rule value for the type of anchor concerned.

Table 5.5.1 Anchors

Equipment number		High holding power bower anchors	
Exceeding	Not exceeding	Number of anchors	Mass of anchor, in kg
—	5	1	11
5	10	1	13
10	15	1	17
15	20	1	22
20	25	1	27
25	30	1	32
30	35	1	37
35	40	1	44
40	45	1	52
45	50	1	59
50	70	1	80
70	90	1	117
90	110	1	154
110	130	1	197
130	150	1	240
150	175	1	292
175	205	1	360
205	240	1	428
240	280	1	495
280	320	1	585
320	360	1	675
360	400	1	765
400	450	1	855
450	500	1	968
500	550	1	1080
550	600	1	1193
600	660	1	1305
660	720	1	1440
720	780	1	1575
780	840	1	1710
840	910	1	1845
910	980	1	1980
980	1060	1	2138
1060	1140	1	2295

5.1.8 Anchors which must be specially laid the right way up, or which require the fluke angle or profile to be adjusted for varying types of sea bed, will not generally be approved for normal craft use. In such cases suitable tests may be required.

5.1.9 Anchors are to be of an approved design. The design of all anchor heads is to be such as to minimise stress concentrations, and in particular, the radii on all parts of cast anchor heads are to be as large as possible, especially where there is considerable change of section.

5.2 Materials

5.2.1 The requirements for anchor materials are contained in the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

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5.2.2 Anchors made of stainless steels or aluminium alloy may be acceptable subject to special consideration.

5.2.3 Where aluminium alloy anchors are proposed, due consideration is to be given to the compatibility of such anchors with the materials of the chain cable, anchor shackle, etc., in order to avoid galvanic corrosion.

5.3 Testing

5.3.1 Testing of anchors is to be carried out in accordance with Chapter 10 of the Rules for Materials.

5.3.2 For holding power testing requirements relating to high holding power anchors, *see* Ch 10,1.7 of the Rules for Materials.

5.4 Anchor shackle

5.4.1 Steel anchor shackles are to be forged or cast steel of approved manufacturer.

5.5 Anchor stowage

5.5.1 Anchors are generally to be housed in suitable hawse pipes, or stowed in dedicated chocks on deck.

5.5.2 Hawse pipes and anchor pockets are to be in accordance with 9.3. Alternatively, roller fairleads of suitable design may be fitted. Where hawse pipes are not fitted, alternative arrangements will be specially considered.

5.6 Super high holding power (SHHP) type anchors

5.6.1 Proposals to use anchors of the SHHP type will be subject to special consideration.

5.6.2 Final acceptance will be dependent upon satisfactory strength and performance tests.

5.6.3 Anchors of designs for which approval is sought as super high holding power anchors are to be tested at sea to show that they have holding powers of at least four times those of approved standard stockless anchors of the same mass.

5.7 Tolerances

5.7.1 The mass of each high holding power anchor given in Table 5.5.1 is for anchors of equal mass. The masses of individual anchors may vary by ±7 per cent of the masses given in the Table, provided that the total mass of the anchors is not less than would have been required for anchors of equal mass.

5.8 Identification

5.8.1 Identification of anchors which have been tested is to be in accordance with Ch 10,1.4 of the Rules for Materials.

■ *Section 6* Anchor cable

6.1 General

6.1.1 Anchor cable may be of stud link chain, short link chain, wire rope or fibre rope, subject to the requirements of this Section.

6.1.2 For each anchor required to be carried on board, *see* 5.1.6, a length of anchor cable, as indicated in Table 5.6.1, is to be provided.

6.2 Chain cable

6.2.1 The diameter of stud link chain cable is to be as indicated in Table 5.6.1.

6.2.2 Short link chain cable may be accepted provided that the breaking load is not less than that of stud link chain cable of the diameter required by Table 5.6.1.

6.2.3 Chain cables may be of mild steel, special quality steel or extra quality steel in accordance with the requirements of Ch 10 of the the Rules for Materials, and are to be graded in accordance with Table 5.6.2.

6.2.4 Grade U1 material having a tensile strength of less than 400 N/mm^2 is not to be used in association with high holding power anchors. Grade U3 material is to be used only for chain 20,5 mm or more in diameter.

6.2.5 In addition to 6.2.3 special consideration will be given to the use of chain cable of stainless steel. Stainless steel is to be of a suitable type, details of which are to be submitted for consideration.

6.2.6 The form and proportion of links and shackles are to be in accordance with Chapter 10 of the Rules for Materials.

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Table 5.6.1 Chain cable

Mass of HHP bower anchor, in kg	Length of chain cable, in metres	Stud link chain cable diameter, in mm		
		Mild steel (Grade:1 or U1)	Special quality steel (Grade:U2)	Extra special quality steel (Grade:U3)
11	55	8	–	–
13	55	8	–	–
17	55	8	–	–
22	55	9	–	–
			–	–
27	55	9	–	–
32	82,5	9	–	–
37	82,5	11,2	–	–
			–	–
44	82,5	11,2	–	–
52	110	11,2	–	–
59	110	12,5	–	–
			–	–
80	110	12,5	–	–
117	110	14	12,5	–
154	110	16	14	–
				–
197	137,5	17,5	16	–
240	137,5	19	17,5	–
292	137,5	20,5	17,5	–
				–
360	137,5	22	19	–
428	165	24	20,5	–
495	165	26	22	20,5
585	165	28	24	22
675	192,5	30	26	24
765	192,5	32	28	24
855	192,5	34	30	26
968	192,5	36	32	28
1080	220	38	34	30
1193	220	40	34	30
1305	220	42	36	32
1440	220	44	38	34
1575	220	46	40	36
1710	247,5	48	42	36
1845	247,5	50	44	38
1980	247,5	52	46	40
2138	247,5	54	48	42
2295	247,5	56	50	44

Table 5.6.2 Grades of steel for use as chain cable

Grade	Material	Tensile strength (N/mm^2)
U1	Mild steel	300 – 490
U2 (a)	Special quality steel (wrought)	490 – 690
U2 (b)	Special quality steel (cast)	490 – 690
U3	Extra special quality steel	690 min

6.3 Testing

6.3.1 Chain cable with a diameter of 12,5 mm or above is to be certified by Lloyd's Register (hereinafter referred to as 'LR'). Chain cable with a diameter below 12,5 mm is to be certified by a recognised testing establishment.

6.3.2 All chain cables are to be tested at establishments and on machines recognised by the Committee and under the supervision of LR's Surveyors or other Officers recognised by the Committee, and in accordance with Chapter 10 of the Rules for Materials.

6.3.3 Test certificates showing particulars of size and weight of cable and of the test loads applied are to be furnished. These certificates are to be examined by the Surveyors when the cables are placed on board the craft.

6.4 Wire rope

6.4.1 When the Equipment Number does not exceed 500 for craft in **Service Groups G1**, **G2**, **G2A** and **G3**, steel wire rope may be accepted in lieu of chain cable under the following conditions:

(a) A length of chain of the diameter specified in Table 5.6.1 is to be fitted to the anchor. The total length of chain is to be not less than 10 per cent of the total required by Table 5.6.1. In no case is the length of chain attached to an anchor to be less than 9 metres.

(b) The wire rope used in lieu of chain cable is to have a breaking load of not less than that of the chain cable it replaces.

(c) The combined length of the chain cable specified in (a) and the wire is to be not less than the length of chain cable required by Table 5.6.1.

(d) Thimbles are to be fitted at both ends of the wire rope, as appropriate.

(e) Suitable precautions are to be taken to reduce the wear on the wire rope at fairleads, etc.

6.4.2 Steel wire ropes are to be manufactured, tested and certified as required by Chapter 10 of the Rules for Materials.

6.5 Fibre rope

6.5.1 When the Equipment Number does not exceed 100, polyamide (or other equivalent synthetic fibre) rope may be accepted in lieu of wire rope, subject to compliance with 6.4.1(a) to (d).

6.5.2 Fibre ropes are to be manufactured, tested and certified as required by Chapter 10 of the Rules for Materials.

6.5.3 Synthetic fibre ropes are to be ultra-violet inhibited as necessary, dependent upon their type.

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6.6 Cable clench

6.6.1 Provision is to be made for securing the inboard ends of the cables to the structure. This attachment is to have a working strength of not less than 10 per cent of the breaking strength of the chain cable, and the structure to which it is attached is to be adequate for this load. Attention is drawn to the advantages of arranging that the cable may be slipped from an accessible position outside the chain cable locker. The proposed arrangement for slipping the chain cable, if constructed outside the chain locker, must be made watertight.

6.7 Cable stopping and release arrangements

6.7.1 It is recommended that suitable bow chain stoppers be provided. The scantlings of these chain stoppers are outwith the scope of the Rules, however the structure in way is to be designed with due regard to the applied loading. Support under chain stopping arrangements is to be to the satisfaction of the Surveyor.

6.8 Cable locker

6.8.1 Adequate storage is to be provided to accommodate the full length of anchor cable.

6.8.2 The chain locker is to be of a capacity and depth adequate to provide an easy direct lead for the cable into the chain pipes, when the cable is fully stowed. Chain or spurling pipes are to be of suitable size and provided with chafing lips. The port and starboard cables are to be separated by a division in the locker.

6.8.3 Chain lockers and spurling pipes are to be watertight up to the exposed weather deck and the space is to be efficiently drained. However, bulkheads between separate chain lockers, or which form a common boundary of chain lockers, need not be watertight.

6.8.4 Where means of access is provided to the chain locker, it is to be closed by a substantial cover and secured by closely spaced bolts.

6.8.5 Where a means of access to spurling pipes or cable lockers is located below the weather deck, the access cover and its securing arrangements are to be in accordance with ISO 5894-1999, or an equivalent National Standard acceptable to LR, recognised standards or equivalent for watertight manhole covers. Butterfly nuts and/or hinged bolts are prohibited as the securing mechanism for the access cover.

■ *Section 7* Mooring ropes and towlines

7.1 Mooring ropes

7.1.1 Craft under 90 m in length are to be equipped with mooring ropes in accordance with Table 5.7.1.

7.1.2 The lengths of individual mooring lines in Table 5.7.1 may be reduced by up to seven per cent of the Table length, provided that the total length of mooring lines is not less than would have resulted had all lines been of equal length. Proposals to fit individual mooring lines of reduced length to suit the particular service will be specially considered.

7.2 Materials

7.2.1 Mooring lines may be of steel wire rope, natural fibre or synthetic fibre. The diameter, construction and specification of wire or natural fibre mooring lines are to comply with the requirements of Chapter 10 of the Rules for Materials. Where it is proposed to use synthetic fibre ropes, the size and construction will be specially considered.

7.3 Testing and certification

7.3.1 Mooring ropes are to be tested and certified in accordance with Chapter 10 of the Rules for Materials.

7.4 Towlines

7.4.1 Towlines are not required for classification other than for craft which are required to comply with the *IMO Code of Safety for High Speed Craft*. The details given in Table 5.7.1 are for guidance purposes only.

7.5 Bollards, fairleads and bull rings

7.5.1 Means are to provided to enable mooring lines to be adequately secured on board the craft. It is recommended that the total number of suitably placed bollards on either side of the craft and/or the total brake holding power of mooring winches should be capable of holding not less than 1,5 times the sum of the maximum breaking strengths of the mooring lines required or recommended. Attention is drawn to the existence of a number of National Standards for bollards and fairleads, and to the importance of ensuring that their seating arrangements, including the supporting hull structure, are efficiently constructed and adequate for the intended loads.

7.6 Towing requirements

7.6.1 Craft which are to comply with the *IMO Code of Safety for High Speed Craft* are to be provided with adequate arrangements to enable the craft to be towed in the worst intended environmental conditions. It is recommended that other craft comply with this requirement.

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Table 5.7.1 Towlines and mooring lines

Equipment Number		Towline, *see* Notes		Mooring lines		
Exceeding	Not exceeding	Minimum length, in metres	Minimum breaking strength, in kN	Number of lines	Minimum length of each line, in metres	Minimum breaking strength, in kN
–	5	90	19,9	2	55	13,9
5	10	90	22,5	2	55	17,6
10	15	90	27,7	2	55	21,5
15	20	90	32,9	2	55	24,5
20	25	110	38,1	2	55	26,6
25	30	110	43,3	2	55	28,2
30	35	110	48,5	2	55	29,6
35	40	135	53,7	2	55	30,8
40	45	135	58,9	2	70	31,8
45	50	135	64,1	2	85	32,7
50	70	180	71,0	2	100	35,5
70	90	180	82,1	2	100	39,3
90	110	180	93,2	2	110	43,1
110	130	180	104,3	2	110	46,6
130	150	180	115,3	2	120	50,2
150	175	180	127,8	2	120	54,4
175	205	180	143,0	2	120	58,8
205	240	180	161,1	2	120	64,2
240	280	180	181,8	3	120	71,1
280	320	180	204,0	3	140	78,5
320	360	180	226,1	3	140	85,8
360	400	180	248,3	3	140	93,2
400	450	180	273,2	3	140	100,5
450	500	180	300,9	3	140	107,9
500	550	180	328,6	4	160	112,8
550	600	180	356,3	4	160	117,7
600	660	180	386,8	4	160	122,6
660	720	180	420,1	4	160	127,5
720	780	180	453,3	4	170	132,4
780	840	180	486,5	4	170	137,3
840	910	180	522,5	4	170	142,2
910	980	180	561,3	4	170	147,1
980	1060	180	602,9	4	180	156,9
1060	1140	180	647,2	4	180	166,7

NOTES
1. Towline specified for guidance only, *see* 7.4.1.
2. Wire ropes used for towlines and mooring lines are generally to be of a flexible construction with not less than:
   144 wires in six strands with seven fibre cores for strengths up to 490 kN
   222 wires in six strands with one fibre core for strengths exceeding 490 kN
   The wires to be laid around the fibre centre of each strand are to be up in not less than two layers.
3. Wire ropes for towlines and mooring lines used in association with mooring winches (on which the rope is stored on the winch drum) are to be of suitable construction.
4. Irrespective of strength of requirements, no fibre rope is to be less than 12 mm diameter.

7.7 Towing bitts

7.7.1 Where towage is to be from more than one point a suitable bridle is to be provided.

7.7.2 Details of the structural scantlings, arrangements, loadings and design assumptions for the towing bitts are to be submitted for consideration.

7.7.3 The towing arrangements should be such that damage to the towline or bridle from abrasion is minimised.

7.8 Mooring winches

7.8.1 Mooring winches where provided are to be suitable for the intended purpose. Supports under the winches are to be to the Surveyor's satisfaction.

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7.8.2 Mooring winches are to be fitted with drum brakes, the strength of which is sufficient to prevent unreeling of the mooring line when the rope tension is equal to 80 per cent of the breaking strength of the rope as fitted on the first layer on the winch drum, *see also* 7.5.1.

Section 8
Windlass design and testing

8.1 General

8.1.1 A windlass, capstan or winch of sufficient power and suitable for the size of anchor cable is to be fitted to the craft. Where Owners require equipment significantly in excess of Rule requirements, it is their responsibility to specify increased windlass power.

8.1.2 Windlasses may be hand or power operated, subject to the requirements of 8.2.3.

8.1.3 Where steel wire rope is used in lieu of chain cable, a suitable winch with sufficient drum capacity to store the length of wire rope fitted is to be provided.

8.1.4 The windlass, anchoring capstans and winches are to be of types approved by LR.

8.1.5 On craft equipped with anchors having a mass of over 50 kg windlass(es) of sufficient power and suitable for the type and size of chain cable are to be fitted. Arrangements with anchor davits will be specially considered.

8.2 Windlass design

8.2.1 The following performance criteria are to be used as a design basis for the windlass:

(a) The windlass is to have sufficient power to exert a continuous duty pull of:
$28,5\ d_c^2$ N – for Grade U1 chain, with $d_c < 14$ mm
$37,5\ d_c^2$ N – for Grade U1 chain, with $d_c \geq 14$ mm
$42,5\ d_c^2$ N – for Grade U2 chain
$47,5\ d_c^2$ N – for Grade U3 chain
over a period of $0,12L_c$ minutes. The test period need not be taken longer than 30 minutes
where
d_c is the chain diameter, in mm
L_c is the total length of chain cable on board, in metres, as given by Table 5.6.1.

(b) The windlass is to have sufficient power to exert, over a period of at least two minutes, a pull equal to the greater of:
(i) short-term pull:
1,5 times the continuous duty pull as defined in 8.2.1(a).
(ii) anchor breakout pull:
$12,18W_a + 7,0L_c\ d_c^2/100$ N
where
W_a is the mass of bower anchor(kg) as given in Table 5.5.1.

(c) In the absence of a chain stopper, the windlass, with its braking system in action and in conditions simulating those likely to occur in service, is to be able to withstand, without permanent deformation or brake slip, a load, applied to the cable, given by:
$K_b\ d_c^2\ (44 - 0,08d_c)$ N
where
K_b = 7,85 for Cable Grade U1
= 11,00 for Cable Grade U2
= 15,70 for Cable Grade U3.

(d) Where a chain stopper is fitted, the windlass braking system is to have sufficient brake capacity to ensure safe stopping when paying out the anchor and chain. It is the Master's responsibility to ensure that the chain stopper is in use when riding at anchor. At clearly visible locations on the bridge and adjacent to the windlass control position, the following notice is to be displayed adjacent to the windlass control position, and at clearly visible locations on the bridge if the windlass can be operated remotely:
'The brake is rated to permit controlled descent of the anchor and chain only. The chain stopper is to be used at all times whilst riding at anchor.'
The performance criteria are to be verified by means of shop tests in the case of windlasses manufactured on an individual basis. Windlasses manufactured under LR's Type Approval Scheme for Marine Engineering Equipment will not require shop testing on an individual basis.

8.2.2 Windlass performance characteristics specified in 8.2.1 and 8.3.2 are based on the following assumptions:
(a) one cable lifter only is connected to the drive shaft,
(b) continuous duty and short term pulls are measured at the cable lifter,
(c) brake tests are carried out with the brakes fully applied and the cable lifter declutched,
(d) the probability of declutching a cable lifter from the motor with its brake in the off position is minimised,
(e) hawse pipe efficiency assumed to be 70 per cent.

8.2.3 Calculations for torque transmitting components are to be based on 1500 hours of operation with a nominal load spectrum factor of 1,0. Alternatively, unlimited hours with a nominal load spectrum factor of 0,8 can be applied.

8.2.4 Where the available input torque exceeds the torque required for anchor breakout, torque overload protection is to be fitted.

8.2.5 An arrangement to release the anchor and chain in the event of windlass power failure is to be provided.

8.2.6 The maximum calculated stress from the load cases stated in Table 5.8.1 are not to exceed the permissible stress limits stated in Table 5.8.2.

8.2.7 The following criteria are to be used for gearing design:
(a) Torque is to be based on the performance criteria specified in 8.2.1.
(b) The use of an equivalent torque, T_{eq}, for dynamic strength calculations is acceptable but the derivation is to be submitted to LR for consideration.

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(c) The application factor for dynamic strength calculation, K_A, is to be 1,15.
(d) Calculations are to be based on 1500 hours of operation.
(e) The static torque is to be 1,5 x T_n, where T_n is the nominal torque.
(f) The minimum factors of safety for load capacity of spur and helical gears, as derived using ISO 6336 or a relevant National or International Standard acceptable to LR, are to be 1,5 for bending stress and 0,6 for contact stress.

8.2.8 Keyways are to be designed to a relevant National or International Standard acceptable to LR.

8.2.9 The maximum stress in brake components is not to exceed the permissible stress stated in Table 5.8.2.

8.2.10 Hand-operated winches are only acceptable if the effort required at the handle does not exceed 15 kgf for raising one anchor at a speed of not less than 2 m/min and making about thirty turns of the handle per minute.

8.2.11 Winches suitable for operation by hand as well as by external power are to be so constructed that the power drive cannot activate the hand drive.

8.3 Control arrangements

8.3.1 All control devices are to be capable of being controlled from readily accessible positions and protected against unintentional operation.

8.3.2 The maximum travel of the levers is not to exceed 600 mm if movable in one direction only, or 300 mm to either side from a central position if movable in both directions.

Table 5.8.1 Design load cases for windlass and chainstopper

Load case	Condition	Note
1	Continuous pull	*See* 8.2.1 (a)
2	Overload pull	*See* 8.2.1 (b)
3	Brake holding load	*See* 8.2.1 (c)

Table 5.8.2 Permissible stress for design load cases

Stress	Load case	
	1 and 2	3
	Permissible stress	
Tension	0,8 *Y*	0,9*Y*
Compression or bending	0,8 *Y*	0,9*Y*
Shear	0,7 *Y*	0,7*Y*
Combined	0,85 *Y*	0,9*Y*

NOTES
1. Where a component is subjected to axial tensile, axial compressive, bending or shear stress, F_c is to be calculated in the normal manner.
2. Where a component is subjected to a combination of co-existent stresses, F_c is the combined stress which is to be calculated as follows:
   Combined bending and tension
   $F_c = 1{,}25f_c + f_{bt}$
   Combined bending and compression
   $F_c = f_c + f_{bc}$
   Combined bending, tension and shear

$$F_c = \sqrt{(1{,}25\, f_t + f_{bt})^2 + 3\, f_q^2}$$

   Combined bending, compression and shear

$$F_c = \sqrt{(f_c + f_{bc})^2 + 3\, f_q^2}$$

where
F_c is the calculated stress
f_t is the calculated axial tensile stress
f_c is the calculated axial compressive stress
f_{bt} is the calculated maximum tensile stress due to bending about both principal axes
f_{bc} is the calculated maximum compressive stress due to bending about both principal axes
f_q is the calculated shear stress
Y is the specified 0,2 per cent proof stress for the material

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8.3.3 Wherever practical, the lever is to move in the direction of the intended movement. If this cannot be achieved, then it is to move towards the right when hauling and towards the left when paying out.

8.3.4 For lever-operated brakes, the brake is to engage when the lever is pulled and disengage when the lever is pushed. The physical effort on the brake for the operator is not to exceed 160 N.

8.3.5 For pedal-operated brakes, the maximum travel is not to exceed 250 mm and the physical effort for the operator is not to exceed 320 N.

8.3.6 The handwheel or crankhandle is to actuate the brake when turned clockwise and release it when turned counterclockwise. The physical effort for the operator is not to exceed 250 N for speed regulation and 500 N at any moment.

8.3.7 When not provided with automatic sequential control, separate push-buttons are to be provided for each direction of operation.

8.3.8 The push-buttons are to actuate the machinery when depressed, and stop and effectively brake the machinery when released.

8.3.9 The above-mentioned individual push-buttons may be replaced by two 'start' and 'stop' push-buttons.

8.3.10 Control systems, whether electric, pneumatic or hydraulic, are to comply with the general requirements of Pt 6, Ch 1,2.

8.4 Maintenance arrangements

8.4.1 Access is to be provided for inspection of reduction gears, bearings, brakes, etc.

8.4.2 Accessible manual lubrication points, including nipples, are to be provided for both oil and grease, as applicable.

8.4.3 Gear-boxes are to be provided with adequate access arrangements for monitoring and replacing oil.

8.5 Protection arrangements

8.5.1 Where applicable, moving parts of windlass machinery are to be provided with suitable railings and/or guards to prevent injury to personnel.

8.5.2 Protection is to be provided for preventing persons from coming into contact with surfaces having temperatures over 50°C.

8.5.3 Steel surfaces not protected by lubricant are to be protected by a coating in accordance with the requirements of a relevant National or International Standard acceptable to LR.

8.5.4 For arrangements of power transmission systems and relief requirements, *see* Pt 5, Ch 14,9.1 of the Rules for Ships.

8.6 Marking and identification

8.6.1 Controls are to be permanently marked for identification, unless their functions are readily apparent. If required, instructions are to be permanently marked and readily visible.

8.7 Tests and trials

8.7.1 Where shop testing is not possible and Type Approval has not been obtained, calculations demonstrating compliance with 8.2.1 are to be submitted together with detailed plans and an arrangement plan showing the following components:

- Shafting.
- Gearing.
- Brakes.
- Clutches.

8.7.2 During trials on board the craft the windlass should be shown to be capable of raising the anchor from a depth of 82,5 m to a depth of 27,5 m at a mean speed of 9 m/min. Where the depth of water in the trial area is inadequate, or the anchor cable is less than 82,5 m, suitable equivalent simulating conditions will be considered as an alternative.

8.8 Seatings

8.8.1 The windlass is to be efficiently bedded and secured to the deck. The thickness of the deck in way of the windlass is to be increased, and adequate stiffening is to be provided, to the Surveyor's satisfaction. The structural design integrity of the bedplate is the responsibility of the Builder and windlass manufacturer.

■ *Section 9* Structural details

9.1 General

9.1.1 An easy lead of the cables from the windlass to the anchors and chain lockers is to be arranged. Where cables pass over or through stoppers, these stoppers are to be manufactured from ductile material and be designed to minimise the probability of damage to, or snagging of, the cable. They are to be capable of withstanding without permanent deformation a load equal to 80 per cent of the Rule breaking load of the cable passing over them.

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9.2 Bulbous bow and wave piercing bow arrangements

9.2.1 The shell plating is to be increased in thickness at the fore end of the bulb and in other areas likely to be damaged by the anchors and chain cables. The increased plate thickness is to be the same as that required for plated stems by Parts 6, 7 and 8 of the Rules for steel, aluminium alloy and composite materials respectively.

9.3 Hawse pipes and anchor recesses

9.3.1 Hawse pipes, bow rollers and other deck gear, of adequate size and construction, are to be provided for handling and securing the anchors and are to be efficiently attached to the structure and arranged to give an easy lead to the cable.

9.3.2 The hawse pipes are to be of sufficient size and thickness, and arranged to give an easy lead for the cable to the windlass.

9.3.3 Hawse pipes and anchor pockets are to be of ample thickness and of a suitable size and form to house the anchors efficiently, preventing, as much as practicable, slackening of the cable or movements of the anchor being caused by wave action. The shell plating and framing in way of the hawse pipes are to be reinforced as necessary, *see* 9.5.1. Substantial chafing lips are to be provided at shell and deck. These are to have sufficiently large, radiused faces to minimise the probability of cable links being subjected to high bending stresses. Alternatively, roller fairleads of suitable design may be fitted. Where unpocketed rollers are used, it is recommended that the roller diameter be not less than eleven times the chain diameter. Where hawse pipes are not fitted, alternative arrangements will be specially considered.

9.4 Spurling pipes

9.4.1 Satisfactory means are to be provided to prevent inadvertent flooding of chain lockers, *see* 6.8. Spurling pipes are to be provided with permanently attached closing appliances to minimise water ingress.

Examples of acceptable arrangements are:

(a) steel plates with cutouts to accommodate chain links, or

(b) canvas hoods with a lashing arrangement that maintains the cover in the secured position.

9.5 Local reinforcement

9.5.1 The thickness of shell plating determined in accordance with the Rule requirements is to be increased locally by not less than 50 per cent in way of hawse pipes.

9.5.2 Supports under windlasses and winches are to be suitably reinforced.

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Section

1 **General requirements**

2 **Noise**

3 **Vibration**

4 **Testing**

5 **Noise and vibration survey reporting**

6 **Non periodical survey requirements**

7 **Referenced standards**

Section 1 General requirements

1.1 Scope

1.1.1 These Rules set down the criteria for the assessment of the noise and vibration on special service craft and are applied in addition to the other relevant requirements of these Rules.

1.1.2 For the purpose of these Rules, the term 'ship', unless otherwise stated, applies to Special Service Craft and Yachts.

1.1.3 Compliance with these Rules is optional.

1.1.4 These Rules provide for two alternatives:

(a) **Class Notations** which indicate that the ship has been assessed and complies with noise and vibration criteria of these Rules and that a periodic survey regime has been established for the lifetime of the ship.

(b) **Certificate of Compliance** which provides evidence that the ship has been assessed and found to comply with the noise and vibration criteria of these Rules.

1.1.5 These Rules recognise existing National and International Standards and specify levels of noise and vibration currently achievable using good engineering practice. Compliance with these requirements will be assessed by review of procedures, inspection and measurement of the relevant parameters and pre-survey reviews. Inspections and measurements are to be conducted, witnessed or assessed by Lloyd's Register's Surveyors unless otherwise agreed by Lloyd's Register (hereinafter referred to as 'LR').

1.1.6 Accommodation comfort is a function of ship type and layout. These Rules address two types of ship:

(a) High-speed (e.g. surface effect ships, wave piercing catamarans, hydrofoils).

(b) Yacht (e.g. sailing yachts, motorised pleasure craft).

1.1.7 These Rules include levels of noise and vibration which should be verified by measurements following completion of the ship. It is recommended that the Builders undertake calculations of noise and vibration characteristics so that any potential problem areas can be identified and control measures implemented.

1.1.8 The sound pressure levels for audible alarms and public address systems fitted in accordance with other Sections of the Rules are to satisfy IMO Resolution A.830(19), Code on Alarms and Indicators.

1.2 Definitions

1.2.1 **Passenger spaces** are defined as all areas intended for passenger use, and include the following:

(a) Passenger cabins.

(b) Public spaces (e.g. restaurants, hospitals, lounges, reading and games rooms, gymnasiums, corridors and/or shops).

(c) Open deck recreation areas.

1.2.2 **Crew spaces** are defined as all areas intended for crew use only, and include the following:

(a) Accommodation spaces (e.g. cabins, offices, mess rooms, recreation rooms).

(b) Work spaces.

(c) Navigation spaces.

1.2.3 **Noise level** is defined as the A-weighted sound pressure level measured in accordance with ISO 2923.

1.2.4 **Vibration level** is defined by the application of either of the two versions of the ISO 6954 Standard:

(a) Where ISO 6954:1984 is applied, the vibration level is defined as the single amplitude peak value of deck structure vibration during a period of steady state vibration, representative of maximum repetitive behaviour, in mm/s, over the frequency range 5 to 100 Hz. For frequencies below 5 Hz, the requirements for vibration levels follow constant acceleration curves corresponding to the acceleration at 5 Hz.

(b) Where ISO 6954:2000 is applied, the vibration level is defined as the overall frequency weighted r.m.s. value of vibration during a period of steady-state operation over the frequency range 1 to 80 Hz.

In general, ISO 6954-2000 is the preferred standard to be applied, however ISO 6954-1984 may be applied where there are practical difficulties in the application of ISO 6954-2000 and this has been agreed between the Owner and Builder.

1.3 Class notations

1.3.1 The class notations described in 1.3.2 to 1.3.6 provide standards for noise and vibration levels in different spaces at the time of delivery and during the ship's life if substantial changes to the machinery installation or interior arrangements are made.

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1.3.2 The **PAC** (Passenger Accommodation Comfort), **CAC** (Crew Accommodation Comfort) and **PCAC** (Passenger and Crew Accommodation Comfort) notations are optional and are primarily intended to apply to passenger ships. If requested, however, any ship can be assessed for compliance, using these requirements as the basis for the assessment and a LR Certificate of Compliance issued (*see* 1.1.4(b) and 1.4).

1.3.3 The **PAC** notation indicates that the passenger accommodation meets the acceptance criteria whilst the **CAC** notation indicates that the crew accommodation and work areas meet the acceptance criteria. The **PCAC** notation indicates that the passenger and crew spaces both meet the acceptance criteria.

1.3.4 For ships which achieve the noise and vibration comfort standards specified in these Rules, the notation **PAC**, **CAC** or **PCAC** will be assigned.

1.3.5 Following the **PAC** or **CAC** notation, numerals **1**, **2** or **3** will indicate the acceptance criteria to which the noise and vibration levels have been assessed. In the case of the **PCAC** notation, two numerals will be assigned. The first will indicate the acceptance criteria for passenger accommodation, whilst the second will indicate the crew comfort criteria.

1.3.6 For particular vessels, impact insulation and transient noise in accordance with 2.5 and 2.6 together with any additional or more stringent noise and vibration criteria may be assessed within the scope of the notations where agreed between the Owner, Builder and LR.

1.4 Certificate of Compliance

1.4.1 A Certificate of Compliance records that a ship has been designed and constructed to satisfy the noise and vibration criteria contained in these Rules. This is to be confirmed by measurements and reporting in accordance with Sections 4 and 5.

1.4.2 A Certificate of Compliance is optional and if requested, any ship can be assessed for compliance using the Rule requirements.

1.4.3 Where noise and vibration levels are at variance with those prescribed by these Rules, they will be added to the certificate for information purposes.

1.4.4 A Certificate of Compliance will be issued after the initial survey required by Section 6.

■ *Section 2* Noise

2.1 Assessment criteria

2.1.1 Where a space is occupied by both passengers and crew, the more stringent of the relevant requirements apply unless agreed between the Builder and Owner and advised to LR.

2.2 Passenger accommodation and public spaces

2.2.1 Under test conditions specified in 4.2, the applicable noise levels specified in Tables 6.2.1 and 6.2.2 should not generally be exceeded. *See* 2.2.3.

Table 6.2.1 High speed craft – Maximum noise levels in dB(A)

Location		Acceptance Numeral		
		1	2	3
Public spaces:	Excluding shops	60	65	70
	Shops	65	68	72

Table 6.2.2 Yachts – Maximum noise levels in dB(A)

Location		Acceptance Numeral		
		1	2	3
Passenger cabins:	Standard	53	55	58
	Superior	50	53	55
Lounges		55	58	60
Open deck recreation areas:	2nd deck from WL	72	75	79
	3rd deck from WL	63	66	70
Wheelhouse		60	62	75

NOTES
1. The levels may be exceeded by 5dB(A) within 3 m of a ventilation inlet/outlet or machinery intake/uptake on open decks.
2. The levels may be exceeded by 3dB(A) in accommodation above the propellers for three decks above the mooring deck.
3. The levels for open deck recreation areas refer to ship generated noise only. On open deck spaces the noise generated from the effects of wind and waves can be considered separately to limits agreed between the Builder and Owner and advised to LR for the trial conditions.

2.2.2 For cabins bordering discotheques and similar entertainment areas, the deck and bulkhead sound insulation is to be sufficient to ensure that the maximum cabin noise levels are not exceeded even when high external noise levels prevail.

2.2.3 Acceptance of noise levels greater than those specified in Tables 6.2.1 and 6.2.2 may be considered where agreed between the Owner and Builder. Not more than 20 per cent of the passenger cabins, 30 per cent of the public spaces and 20 per cent of the crew cabins should exceed the relevant noise criteria by more than 3 dB(A).

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2.2.4 Acoustic insulation of bulkheads and decks between passenger spaces is to be generally in accordance with the values of the weighted apparent sound reduction index, R_W, as given in Table 6.2.3, calculated using ISO 717/1. *See also* 2.2.6.

Table 6.2.3 Minimum air-borne sound insulation indices, R_W

Location		Acceptance Numeral		
		1	2	3
Passenger cabins:	Standard	40	38	37
	Superior	45	42	40
Cabin to corridor:	Standard	38	36	34
	Superior	42	40	37
Cabin to stairway:	Standard	47	45	43
	Superior	50	47	45
Cabin to public space (excluding corridoors/ stairwells and discotheques):	Standard	52	48	48
	Superior	55	50	50
Discotheques to cabins		60	60	60
Discotheques to stairwells and public spaces		52	52	52
Cabin to machinery rooms and engine casing		55	53	50

2.2.5 For the purpose of selecting acoustic sound insulation, the following sound noise levels may be used with the agreement of the Owner and Builder:

(a) Cabins – 80 dB(A).
(b) Dining Rooms – 85 dB(A).
(c) Corridors – 90 dB(A).
(d) Discotheques, Theatres, Entertainment Areas – 105 dB(A).

2.2.6 Acceptance of bulkhead and deck acoustic insulation values less than those specified in Table 6.2.3 may be considered where agreed between the Owner and Builder. Not more than 20 per cent of the interfaces tested should have airborne sound insulation indices, R_W, more than 3 dB(A) lower than the minimum specified values.

2.3 Crew accommodation and work areas

2.3.1 Under the applicable test conditions specified in 4.2, the noise levels specified in Tables 6.2.4 and 6.2.5 are not to be exceeded.

2.3.2 Crew space insulation is to comply with the requirements of IMO Resolution A.468(XII).

Table 6.2.4 Crew accommodation – Maximum noise levels in dB(A)

Location		Acceptance Numeral		
		1	2	3
Sleeping cabins, hospitals		52	55	60
Day cabins		55	60	60
Office conference rooms		55	60	65
Mess rooms, lounges, reception areas:	Within accommodation	57	60	65
	On open decks	65	70	75
Alleyways, changing rooms, bathrooms, lockers		70	75	75
NOTE The levels may be exceeded by 5dB(A) within 3 m of a ventilation inlet/outlet or machinery intake/uptake on open decks.				

Table 6.2.5 Crew work areas – maximum noise levels in dB(A)

Location	dB(A) level
Machinery space(continuously manned) e.g. stores	90
Machinery space(not continuously manned) e.g. pump, refrigeration, thrusters or fan rooms	110
Workshops	85
Machinery control rooms	75
Wheelhouse	65
Bridge wing, additional limits: • 250 Hz band • 500 Hz band	 68 63
Radio room	60
Galleys and pantries: • Equipment not working • Individual items at 1 metre	 75 80
Normally unoccupied spaces (e.g. holds, decks)	90
Ship's whistle, on bridge or forecastle	110

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2.4 Maximum noise levels

2.4.1 Where the measured noise level exceeds the specified criterion by 3 dB(A), or contains subjectively annoying low frequency or tonal components, the noise rating (NR) number is to be established in accordance with the graph shown in Fig. 6.2.1. This is achieved by plotting the linear octave band levels on the graph; the NR number is that NR curve to which the highest plotted octave band level is anywhere tangent. The specified criterion may be considered satisfied if the NR number does not exceed the specified A-weighted value minus 5 dB(A).

2.4.2 Guidance on maximum acceptable sound pressure levels and noise exposure limits for crew spaces is given in IMO Resolution A.468(XII).

2.5 Impact insulation

2.5.1 Where agreed between the Owner, Builder and LR, enhanced criteria for noise levels recognising the effects of impact sound pressures may be applied in accordance with 2.5.2 to 2.5.5.

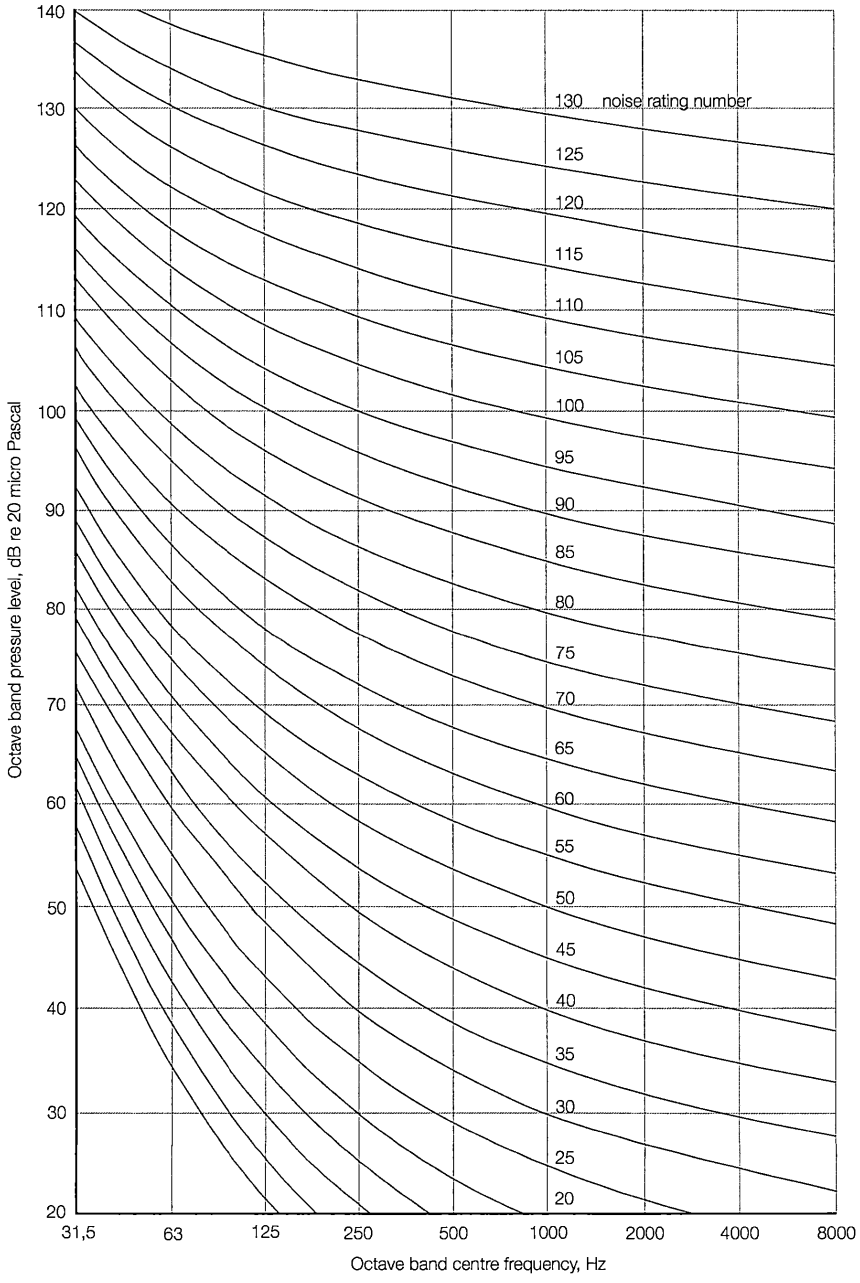

Fig. 6.2.1 Noise rating curves

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2.5.2 For passenger and crew cabins located below or adjacent to dance floors, stages, aerobics and gymnasium areas, jogging tracks or other areas where impact noise is generated, the normalised impact sound pressure level measured within the cabins is not to exceed 45 dB.

2.5.3 For public rooms under dance floors, stages, aerobics and gymnasium areas, jogging tracks or other areas where impact noise is generated, the normalised impact sound pressure level within the space is not to exceed 55 dB.

2.5.4 For passenger cabins, the normalised impact sound pressure level, $L_{n,w}$, calculated using ISO 717/2, is to be generally in accordance with the values stated in Table 6.2.6. *See also 2.5.5.*

Table 6.2.6 Passenger cabins normalised impact maximum sound pressure level $L_{n,w}$

Location	dB
Below decks covered with carpet and soft materials	50
Below decks covered with hard materials (such as wood, marble or similar	60
Below dance floors, theatre or sports rooms	47

2.5.5 Acceptance of normalised impact sound pressure levels greater than those specified in Table 6.2.6 may be considered for assignment of the applicable class notation where agreed between the Owner, Builder and LR. No more than 20 per cent of the passenger cabins tested should exceed the levels specified by more than 3 dB.

2.6 Transient noise

2.6.1 Where agreed between the Owner, Builder and LR, enhanced criteria for transient noise levels may be applied in accordance with 2.6.2.

2.6.2 The maximum sound pressure level (L_{max}) emanating from any machinery or system caused by a single event that produces a noise 'spike' compared to the reference condition sound level (such as vacuum systems or valve operations) is not to cause an increase in noise in comparison with the reference condition as below:

(a) Passenger cabins and public areas: +2 dB(A)
(b) Officer cabins: +2 dB(A)
(c) Crew cabins and public areas: +3 dB(A)

A tolerance of +1 dB(A) may be applied to 5 per cent of cabins and public areas in each fire zone on each deck. This criterion is generally applicable to the specified maximum noise levels for the space concerned.

■ *Section 3* Vibration

3.1 Assessment criteria

3.1.1 Where a space is occupied by both passengers and crew, the more stringent of the relevant requirements apply unless agreed between the Builder and Owner and this agreement advised to LR.

3.1.2 The limits apply to vertical, fore and aft and athwartship vibrations which are to be assessed separately.

3.1.3 Under test conditions specified in 4.2, the applicable vibration levels specified in Tables 6.3.1 to 6.3.3 should not be exceeded.

Table 6.3.1 High speed craft – Maximum vibration levels

Standard:	ISO 6954:1984			ISO 6954:2000		
Units:	Peak velocity (5 –100 Hz)			Frequency weighted (1–80 Hz) velocity mm/s rms		
	Acceptance Numeral					
Location	1	2	3	1	2	3
Public spaces	2,5	4,0	5,0	2,5	3,2	3,6

Table 6.3.2 Yacht – Maximum vibration levels

Standard:	ISO 6954:1984			ISO 6954:2000		
Units:	Peak velocity (5 –100 Hz)			Frequency weighted (1–80 Hz) velocity mm/s rms		
	Acceptance Numeral					
Location	1	2	3	1	2	3
Cabins and lounges	1,0	2,0	3,0	1,8	2,0	2,5
Public spaces	1,5	3,0	4,0	2,5	2,9	3,3
Open recreation decks	2,0	3,5	4,0	2,5	3,2	3,8
NOTE The vibration level may be exceeded by 0,3 mm/s in the yacht's aft body directly above the propellers.						

3.1.4 Acceptance of vibration levels greater than those specified in Tables 6.3.1 to 6.3.3 may be considered for assignment of the applicable class notation where agreed between the Owner, Builder and LR.

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Table 6.3.3 Crew spaces – Maximum vibration levels

Standard	ISO 6954:1984	ISO 6954:2000
Units	Peak velocity (5–100 Hz)	Frequency weighted (1–80 Hz) velocity mm/s rms
Location		
Accommodation and navigation spaces	5,0	3,5
Work spaces	6,0	5,0

3.1.5 The vibration levels for ISO 6954:1984 are stated as peak vibration velocity amplitude. If root mean square levels are measured, each frequency component may be converted to peak vibration velocity amplitude by application of a 1,41 multiplication factor where the ISO 6954:1984 is used for assessment against Tables 6.3.1 to 6.3.3. An approximation of maximum repetitive values may be obtained for direct comparison with the graph in ISO 6954-1984 by further application of the 1,8 conversion factor as stated in the 'Interim guidelines' note of the standard.

3.2 Passenger accommodation and public spaces

3.2.1 Passenger spaces are to comply with the overall vibration levels specified in Tables 6.3.1 and 6.3.2.

3.2.2 No more than 20 per cent of all passenger spaces/areas and public spaces should exceed the relevant vibration criteria specified in Tables 6.3.1 and 6.3.2 by more than 0,3 mm/s whether using ISO 6954:2000 or ISO 6954:1984.

3.3 Crew accommodation and work spaces

3.3.1 Crew spaces are to comply with the overall vibration levels specified in Table 6.3.3.

■ *Section 4* Testing

4.1 Measurement procedures

4.1.1 These requirements take precedence where quoted standards may differ.

4.1.2 The trial measurements may be undertaken by an approved technical organisation as defined in 4.7 or by LR. In the former case, the measurements are to be witnessed by an LR Surveyor.

4.1.3 Subject to agreement by LR and the Owner/Operator, the measurements may be undertaken by the Builder. In this case, the measurements are to be witnessed by an LR Surveyor.

4.2 Test conditions

4.2.1 Test conditions for the surveys are to be in accordance with those detailed in ISO 2923 and ISO 6954:1984 or ISO 6954:2000, as applicable.

4.2.2 The intended operating and loading conditions of the ship during assessment surveys are to be submitted to LR for agreement, prior to commencement of surveys.

4.2.3 Surveys are to be conducted when the ship is fully outfitted and all systems contributing to noise and vibration levels are operational.

4.2.4 The test conditions required for the vibration and noise measurements are to be in accordance with the following conditions:

(a) For high speed craft and yachts, prior to measurement surveys being carried out, the ship operating condition where the worst conditions are experienced between 0 and 85 per cent maximum continuous rating of the propulsion machinery is to be determined. To establish this condition, four measurement positions are to be defined with the agreement of LR and measurements taken of the parameters of interest at ship speeds corresponding to percentages of the maximum continuous rating of the propulsion machinery increasing up to 40 per cent MCR in 10 per cent intervals and from 40 per cent in 5 per cent intervals up to the 85 per cent maximum continuous rating of the propulsion machinery. If the 85 per cent maximum continuous rating condition is found to be the worst condition, then this will form the trial operating conditions. However, if a lower speed condition is found to be worse than the 85 per cent maximum continuous rating condition then both that condition and the 85 per cent maximum continuous rating condition will form the trial operating conditions. Where unavoidable, any barred range within the values required for the trial operating condition may be excluded on agreement between Owner and Builder subject to approval by LR.

(b) The power absorbed by the propeller(s) is to be that defined in 4.2.4(a). Alternatively, by special agreement, some lesser power could be accepted if it can be demonstrated by the Owner that this would correspond to a more representative normal service condition.

(c) Auxiliary machinery essential for the ship's operating conditions together with HVAC systems are to be running at their normal rated capacity during the noise and vibration trials. Combinations of auxiliary machinery operation may be necessary. In addition, the following equipment is to be running if appropriate: stabilisers, waste treatment equipment, swimming pool and jacuzzi equipment.

(d) For sea-going ships, measurements are to be taken with the ship proceeding ahead, at a constant speed and course, in a depth of water not less than five times the draught of the ship. For other ships, an appropriate water depth is to be agreed with LR prior to the trials.

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(e) Trials are to be conducted in sea conditions not greater than sea state 3 on the WMO sea state code. In addition, noise measurements should not be taken when the wind force exceeds 4 on the Beaufort scale.
(f) The ship is to be at a displacement and trim representative of an operating condition.
(g) Rudder angle variations are to be limited to ±2° of the midship position and rudder movements are to be kept to a minimum throughout the measurement periods.
(h) In addition, for ships which are designed to spend a considerable period of time in harbour, the noise and vibration, are to be measured for this condition, with the auxiliary machinery and HVAC systems running at their normal rated capacity.
(j) For passenger ships, intermittently run equipment such as transverse propulsion units are to be operated at 60 per cent of their rated power for additional measurements in surrounding ship areas.

4.2.5 Prior to survey, a test programme is to be submitted for approval by LR. This programme is to contain details of the following:
(a) Measurement locations indicated on a general arrangement of the ship.
(b) The ship's loading condition during survey.
(c) The machinery operating condition, including HVAC system, during survey.
(d) Noise and vibration measuring equipment.

4.3 Noise measurements

4.3.1 Noise measurements are to be conducted in accordance with ISO 2923 and IMO Resolution A.468(XII). Measurements of noise levels are to be carried out using precision grade sound level meters conforming to IEC 60651, Type 1 or 2. Subject to demonstration, equivalent Standards are acceptable.

4.3.2 Where the measured noise level exceeds the relevant criterion by 3 dB(A), or contains subjectively annoying low frequency noise or obvious tonal components, octave band readings are to be taken, with centre frequencies from 31,5 Hz to 8 kHz.

4.3.3 When outfitting is complete, and all soft furnishings are in place, sound insulation indices for passenger spaces are to be determined in accordance with ISO 140. Cabin to cabin indices are to be determined from a minimum of three locations within the passenger accommodation, the number of test locations being agreed with LR.

4.3.4 If required, impact sound measurements are to be carried out in accordance with ISO 140/7 and presented in accordance with ISO 717/2. *See* 4.4.4.

4.4 Noise measurement locations

4.4.1 Measurement locations are to be chosen so that the assessment represents the overall noise environment on board the ship. In addition to the requirements of IMO Resolution A.468(XII) for crew spaces, all public spaces and all passenger spaces are to be measured.

4.4.2 During measurement trials, recognised noise sources are to be operated at their normal level of noise output (e.g. machinery at design rating).

4.4.3 In larger sized spaces, where noise levels may vary considerably, such as restaurants, lounges, atria and open deck recreation areas, measurements are to be taken at locations not greater than 7 m apart.

4.4.4 For high speed craft having large passenger saloons, measurements are to be taken along the centreline and along both sides of the saloons at locations not greater than 7 m apart.

4.4.5 The number of and locations for impact noise measurements are to be agreed between the Builder, Owner and LR. The measurements are to be carried out when the ship is in harbour. The number and location of measurements are to take account of all different combinations of construction, areas of application, types of cabin and spaces below.

4.5 Vibration measurements

4.5.1 Vibration measurements are to be conducted in accordance with ISO 6954:1984 or ISO 6954:2000.

4.5.2 Measurements are to be made with instrumentation meeting the requirements of ISO 8041.

4.5.3 Vibration levels are to be given in terms of the velocity measurement appropriate to the version of the standard being used and should be measured over a period of not less than one minute.

4.6 Vibration measurement locations

4.6.1 Measurement locations are to be chosen so that the assessment represents the overall vibration environment onboard the ship. To minimise survey times, readings may be taken at the locations previously defined for the noise assessment part of the survey.

4.6.2 In cabins, vibration readings are to be taken in the centre of the floor area. The measurements are to indicate the vibration of the deck structure. In large spaces, such as restaurants, sufficient measurements are required to define the vibration profile.

4.6.3 Where deck coverings make transducer attachment impracticable, use of a small steel plate having a mass of at least 1 kg, with spikes as appropriate, is permissible.

4.6.4 At all locations, vibrations in the vertical direction are to be assessed. Sufficient measurements in the athwartships and fore and aft directions are to be taken to define global deck vibrations.

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4.7 Approved technical organisation

4.7.1 An approved technical organisation for the purposes of these Rules is one that is acceptable to the Owner and LR with proven capability in noise and vibration measurement and satisfies all the criteria set out below:

(a) Have instrumentation whose calibration, both before and after the measurements, can be traced back to National Standards and, hence, back to International Standards.

(b) Have analysis procedures capable of data reduction to the requirements and standards set out in these Rules.

(c) Be able to provide a written report in English with contents as defined by Section 5.

■ *Section 5* Noise and vibration survey reporting

5.1 General

5.1.1 Prior to survey, a noise and vibration measurement plan is to be agreed by the Owner, Builder and LR.

5.1.2 The survey report is to comprise the data and analysis for both noise and vibration and is to be submitted to LR for consideration.

5.1.3 The survey report is to be prepared by the organisation undertaking the trial measurements, which may be an approved technical organisation or LR.

5.1.4 The survey report is to be submitted to LR's London Office for evaluation and confirmation that the results are in accordance with the noise and vibration levels specified in these Rules and/or agreed between the Owner and Builder. The assignment of a Class Notation or the issue of a Statement of Compliance will be subject to confirmation by LR.

5.2 Noise

5.2.1 The reporting of results is to comply with ISO 2923, and is to include:

(a) Measurement locations indicated on a general arrangement plan including, where possible, the measured dB(A) level.

(b) Tabulated dB(A) noise levels, together with octave band analysis for positions where the level exceeds the specified criterion by 3 dB(A), or where subjectively annoying low frequency or tonal components were present. The Noise Rating number is also to be given where octave band analyses have been conducted.

(c) Ship and machinery details.

(d) Trial details:
- Loading condition.
- Machinery operating condition.
- Speed.
- Average water depth under keel.
- Weather conditions.
- Sea state.

(e) Details of measuring and analysis equipment (e.g. manufacturer, type and serial numbers), including frequency analysis parameters (e.g. resolution, averaging time, window function).

(f) Copies of the relevant instrument calibration certificates, together with the results of field calibration checks.

5.3 Vibration

5.3.1 The report is to contain the following information:

(a) Measurement positions indicated on a general arrangement plan.

(b) Where ISO 6964:2000 is used, the frequency-weighted overall r.m.s. vibration levels tabulated for all measurement locations calculated using the weighting functions and methodology stated in the standard.

(c) Where ISO 6954:1984 is used, the maximum peak vibration levels and their corresponding frequencies taken from the frequency spectra, tabulated for all measurement locations.

(d) Ship and machinery details.

(e) Trial details:
- Loading condition.
- Machinery operating condition.
- Speed.
- Average water depth under keel.
- Weather conditions.
- Sea state.

(f) Frequency analysis parameters (e.g. resolution, averaging time and window function), if the analysis is done in the frequency domain.

(g) Copies of the relevant instrument calibration certificates, together with the results of field calibration checks.

■ *Section 6* Non periodical survey requirements

6.1 Class notation assignment

6.1.1 Where the assignment of a Class Notation or a Statement of Compliance is requested, an Initial Survey is to comprise sea trial or initial in-service testing, reporting and assessment against the criteria set out in these Rules.

6.1.2 The sea trial or initial in-service testing requirements are set out in Section 4, and are to be reported in accordance with Section 5 and evaluated against the requirements of Sections 2 and 3.

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6.2 Maintenance of class notation through-life and following modifications

6.2.1 Where an Owner has requested assignment of a Class Notation, arrangements are to be agreed between LR and the Owner to record observations/ complaints of excessive noise and vibration that have been such as to disturb the comfort of passengers and crew. The records of the observations are to be made available to the attending LR Surveyor at each Annual Survey.

6.2.2 Where the observations indicate that the noise and/or vibration levels may exceed the criteria relating to the Class Notation requirements and those measured at the Initial Survey, a measurement programme is to be agreed between the Owner and LR and measurements taken in accordance with these Rules.

6.2.3 A Renewal Survey may be required following modifications, alterations or repairs including replacement of major machinery items. It is the responsibility of the Owner to advise LR of such modifications.

■ *Section 7* Referenced standards

7.1 Noise

7.1.1 The following National and International Standards for noise are referred to in these Rules:

- ISO 2923, *Acoustics – Measurement of noise on board vessels.*
- ISO 717/1, *Acoustics – Rating of sound insulation in buildings and of building elements; Part 1: Airborne sound insulation.*
- ISO 717/2, *Acoustics – Rating of sound insulation in buildings and of building elements: Part 2: Impact sound insulation.*
- IMO Resolution A.468(XII), *Code on noise levels on board ships.*
- *IEC Publication 651, Sound level meters.*
- ISO 140/4, *Acoustics – Measurement of sound insulation in buildings and of building elements; Part 4: Field measurements of airborne sound insulation between rooms.*
- ISO 140/7, *Acoustics – Measurement of sound insulation in buildings and of building elements; Part 7: Field measurements of impact sound insulation of floors.*

7.2 Vibration

7.2.1 The following National and International Standards for vibration are referred to in these Rules:

- ISO 6954:1984, *Mechanical vibration and shock – Guidelines for the overall evaluation of vibration in merchant ships.*
- ISO 6954:2000, *Mechanical vibration and shock – Guidelines for the measurement, reporting and evaluation of vibration with regard to habitability on passenger and merchant ships.*
- ISO 8041, *Human response to vibration. Measuring instrumentation.*

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Rules and Regulations for the Classification of Special Service Craft

Volume 3
Part 4
Additional Requirements for Yachts
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Lloyd's Register
LIFE MATTERS

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Section

1 **Introduction**

2 **International Rating Class (IRC) Yachts**

Section 1 Introduction

1.1 General

1.1.1 This Part of the Rules contains the particular requirements for the construction and classification of yachts with an overall length, L_{OA} (as defined in Pt 3, Ch 1,6.2.4), of 24 m or greater, where these differ from the general Rule requirements indicated in Parts 1 to 17.

1.1.2 The regulations for the construction, classification and Periodical Survey of yachts are given in Part 1.

1.1.3 The minimum requirements in respect of intact stability for yachts are indicated in Pt 1, Ch 2,1.1.

1.1.4 Where a Load Line is to be assigned the yacht is to comply with the appropriate requirements of the National Authority or, in the absence of these, in accordance with the requirements of Chapter 2 and Pt 1, Ch 2,1.1.

1.1.5 The requirements for fire protection detection and extinction are to be in accordance with Part 17.

1.1.6 Yachts over 24 m overall length, L_{OA} (as defined in Pt 3, Ch 1,6.2.4), may be the subject of National or International regulations concerning construction, safety and manning and compliance with these regulations is the responsibility of the Owners and Builders. Lloyd's Register is able to advise on such matters and to issue applicable certificates where so authorised by the National Authority with which the yacht is registered.

1.1.7 A yacht may take any hull form and method of propulsion described in Parts 1 to 17 of these Rules. Other hull forms or methods of propulsion will be specially considered.

1.1.8 The scantling requirements for yachts constructed from steel, aluminium alloy and composite materials are given in Parts 6, 7 and 8 respectively. Where it is proposed to construct a yacht in wood or other material not specifically covered by the Rules, such proposals will be subject to special consideration on the basis of the Rules.

1.2 Definitions

1.2.1 **Freeboard deck** is as defined in Pt 3, Ch 1,6.3.1. When a lower continuous deck is designated as the freeboard deck, that part of the hull which extends above the freeboard deck is treated as superstructure so far as concerns the application of the conditions of assignment and the calculation of freeboard. It is from this lower continuous deck that the assigned freeboard is calculated.

1.2.2 **Virtual freeboard deck** is an imaginary continuous deck which, if fitted, would enable a freeboard, calculated in accordance with the Load Line requirements, and measured from the virtual freeboard deck, that would result in a draught not less than that corresponding to the assigned freeboard. That part of the enclosed hull which extends above the virtual freeboard deck may be treated as superstructure so far as concerns the application of the conditions of assignment provided it is not less than one standard superstructure height. (*See also* Pt 3, Ch 2,7.2).

Section 2 International Rating Class (IRC) Yachts

2.1 General

2.1.1 The classification of International Rating Class Yachts will be specially considered on the basis of these Rules.

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1 **General**

2 **Ship side valves**

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■ *Section 1* General

1.1 Plans and data

1.1.1 Plans and data additional to those required by Pt 3, Ch 1,5 may be required to be submitted for appraisal, subject to the form of the yacht.

1.1.2 All plans are to be presented in a clear and unambiguous manner with sufficient details to avoid misinterpretation.

■ *Section 2* Ship side valves

2.1 General

2.1.1 Ship side valves are generally to be in accordance with Pt 15, Ch 2,3, but other materials may be considered.

2.1.2 Valves and sea chests are to be easily accessible and permanently marked. Valves not easily accessible are in addition to be fitted with remote control.

■ *Section 3* Anchor stowage

3.1 General

3.1.1 Where anchors are mounted on stemhead fittings, suitable local sheathing or protection is to be provided in areas where the anchor can make contact with the hull or deck, further precautions are to be taken to minimise hull damage in the event of a collision. The fittings are to be of substantial construction and well secured to the hull and deck.

3.1.2 Details of stemhead fittings incorporating forestay attachments are to be submitted for approval.

■ *Section 4* Bathing and watersport platforms and shell openings

4.1 General

4.1.1 Shell doors including bathing and watersport platforms, are generally to be fitted with a sill not less than 600 mm above the design waterline. All openings are to open into a watertight space with access into the yacht by watertight doors capable of being operated from both sides. The outer shell doors may be of a single or double leaf type with either hand or hand and hydraulic operated door clips to ensure watertightness when at sea. Any locking devices fitted are to 'fail safe' in the event of hydraulic failure. Provision is to be made for doors to be closed and locked by hand in the event of hydraulic failure, *see* Pt 3, Ch 4.

4.1.2 Shell openings with a sill height below, or less than 600 mm above, the design waterline are to be of equivalent structural integrity to the surrounding hull structure. Doors from this space providing internal access are to have a sill height at least 600 mm above the design waterline.

4.1.3 Drainage systems for the above shell openings are to be fitted with non-return valves.

4.1.4 Transom platforms are to be integral with the hull or be separate mechanically secured components.

4.1.5 Integral components are to have scantlings equivalent to the adjacent structure with care taken to ensure continuity of strength with no hard spots.

4.1.6 Separate mechanically secured components are to be of substantial construction and securely fastened to the main structure ensuring bolting and sealing arrangements are satisfactory with no hard spots.

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4.1.7 Recesses for passerelles, windlasses, platforms, cockpits, etc., are to be watertight and of equivalent strength to that of the surrounding hull and deck structure with care being taken to ensure continuity of strength. Electrical and hydraulic penetrations (where fitted) are to be through watertight glands. Direct overboard discharges are to be fitted to prevent any accumulation of water in the recess.

■ *Section 5* Deck safety equipment

5.1 General

5.1.1 Sailing yachts are, in general, to be fitted with a pulpit, pushpit and guard wires with hand rails inboard to assist personnel movement around the upper deck. Motor yachts are, in general, to be fitted with bulwarks and/or guard rails.

5.1.2 The size, height and position of bulwarks, pulpit, pushpit and guard rails or wires and the securing points for handrails and lifelines are to be in accordance with National or International Standards, *see also* 6.9. The scantlings and securing arrangements are to be designed to withstand the maximum load that could be exerted upon them in service, details of which are to be indicated in the relevant plans.

5.1.3 Doors fitted in bulwarks are to be of equal strength to the adjacent bulwarks and be capable of being secured closed at sea.

■ *Section 6* Protection of openings

6.1 General

6.1.1 Closing appliances for yachts are, in general, to provide weathertight integrity and safety equivalent to the requirements of Pt 3, Ch 4 taking into consideration reductions depending on the height of the lowest weatherdeck, relative to the design waterline.

6.1.2 The vertical distance between the freeboard deck and the weatherdeck may be used to reduce the Load Line requirements for closing appliances, coaming heights and openings in the hull, superstructure and deckhouses.

6.1.3 The vertical distance between the virtual freeboard deck and the weatherdeck may be used to reduce the Load Line requirements for closing appliances, coaming heights and openings in the hull, superstructure and deckhouses.

6.1.4 Where this vertical distance (as defined in 6.1.2 and 6.1.3) is at least one standard superstructure height then Load Line requirements for closing appliances, coaming heights and openings apply as if an additional tier of superstructure existed. *See also* Pt 3, Ch 2,7.2.2.

6.1.5 Where this vertical distance (defined in 6.1.2 and 6.1.3) is less than one standard superstructure height the coaming heights of doors, hatches, ventilators, air pipes, etc., may be reduced in proportion to the ratio of the actual distance and one standard superstructure height.

6.2 Hinged weathertight doors

6.2.1 Doors on the weather deck (first tier accommodation) protecting direct access to machinery spaces are to be of substantial construction in accordance with or equivalent to recognised National or International Standards. They are to be permanently attached to the casing, outward opening and gasketed weathertight with a minimum of six clips and have a coaming height of 460 mm with a minimum of 230 mm depending on the excess freeboard.

6.2.2 Doors on the weather deck to first tier accommodation or other spaces protecting access below are to be as required by 6.2.1 with a minimum of four clips. Provided access to the space(s) may be obtained from the deck above, the coaming height may be 230 mm with a minimum of 150 mm depending on the excess freeboard.

6.2.3 Where wood doors are proposed on the weather deck in lieu of doors in 6.2.2 above they are to be strongly constructed of hardwood not less than 50 mm thick, double gasketed with coamings as required by 6.2.2. For doors in exposed locations additional securing arrangements by slip bolts, clamps or equivalent are required. These doors are not to be the sole means of entry or exit from the space. Where these doors may be required to be used as a means of escape in an emergency situation, the additional securing arrangements are to be operable from both sides.

6.2.4 The use of FRP for doors on the weather deck other than to machinery spaces may be accepted, providing the doors are of substantial construction in accordance with 6.2.2.

6.2.5 Proposals to use FRP doors for access to machinery spaces are to comply with 6.2.4 in addition to Part 17, in respect of fire requirements and compliance with any National Authority requirements which may be applicable.

6.2.6 Doors in the second tier accommodation are to be as indicated in 6.2.1 with a minimum of four clips, or wood doors per 6.2.3 and have a coaming height of 100 mm with a minimum of 50 mm depending on the excess freeboard. Sliding doors with equivalent securing arrangements may be accepted.

6.3 Hatches (coamings and covers)

6.3.1 Hatches on the weather deck and deck above are to have a structural integrity of not less than the structure to which they are fitted and are to be weathertight when closed.

6.3.2 Hatches on the weather deck in the forward $0{,}25L_L$ or to machinery spaces are to be hinged on the forward side and have 460 mm coamings with a minimum of 230 mm depending on the excess freeboard.

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6.3.3 Elsewhere on the weather deck, hatches which are proposed to be open at sea and provide access to lower accommodation spaces are to have a coaming height of 230 mm with a minimum of 150 mm depending on the excess freeboard.

6.3.4 Hatches on the deck above the weather deck which are proposed to be open at sea, are to have a coaming height of 150 mm with a minimum of 50 mm depending on the excess freeboard.

6.3.5 Flush hatches that are not closed by gasketed covers and secured by close space bolts will be specially considered but should not, in general, be fitted on the weather deck. However, flush hatches fitted with double gasketed covers with drains led overboard that do not require to be opened at sea and that are in protection locations, will be considered.

6.3.6 Escape hatches are to be operable from both sides.

6.4 Ventilators and air pipes

6.4.1 Ventilators and air pipes are to have coamings complying with Pt 3, Ch 4,11 and Pt 15, Ch 2,11 respectively.

6.4.2 Where necessary for operational reasons, coamings on the weather deck protected by the bulwark, may be reduced to the bulwark height subject to a minimum coaming height of 450 mm for ventilators and 300 mm for air pipes.

6.5 Portlights and windows

6.5.1 The requirements for side scuttles and windows are indicated in Pt 3, Ch 4. Proposals to fit windows below freeboard deck will be specially considered.

6.5.2 Round, elliptical or elongated portlights are to have a structural integrity of not less than the structure to which they are fitted. If fitted below the weatherdeck they are to be provided with permanently attached deadlights. *See also* Pt 3, Ch 4,7.12.2.

6.5.3 Where internal covers are provided, they are to be gasketed and capable of being secured weathertight (with additional backing bars if necessary). Provision is to be made for the storm covers to be stored on board and their stowage location noted in the document 'For the information of the Master'. Internal storm blinds may be accepted subject to satisfactory tests being carried out.

6.5.4 Chemically toughened glass may be used in lieu of thermally toughened glass provided it can be demonstrated the strength of the arrangement is at least equivalent in strength to that of thermally toughened glass. The glazing system is to be of laminated construction and the method of testing will be specially considered.

6.5.5 Wheelhouse windows are to be of toughened safety glass, or where they are of laminated or sandwich construction, the surface layers are to be of toughened safety glass.

6.5.6 Details of the attachment of windows in their frames and of frames to the yacht structure are to be submitted for approval.

6.5.7 Storm covers or deadlights are required for all windows and portlights in the front of the deckhouse on the weather deck and also the sides, except where these are interchangeable port and starboard; in this case a sufficient number to fit any one side are to be provided. Additionally a storm cover or deadlight is to be provided for each different size of window or portlight respectively.

6.5.8 A glazing equivalent may be fitted in lieu of deadlights or stormcovers on the weather deck and above. The thicknesses and arrangements are to be acceptable to the National Authority with whom the craft is registered and/or by the Administration within whose jurisdiction the ship is intended to operate. For arrangements of glazing acceptable to Lloyd's Register (hereinafter referred to as LR), *see* Table 2.6.1. Alternative arrangements of glazing in lieu of deadlights or storm covers may be accepted provided details are submitted for consideration.

6.6 Sliding glass doors or glass walls

6.6.1 When sliding glass doors are provided, or a glass wall which includes an access, an alternative access, or exit from the space, is to be provided, and the arrangements are to be in accordance with approved plans and weathertight commensurate with their position. Coaming heights are, in general, to be in accordance with 6.2 and the use of portable coamings will be considered. Details are to be submitted.

6.6.2 The glass used in the above is to be toughened safety glass or equivalent in accordance with 6.5.

6.6.3 Storm covers of strong construction are to be provided and stored on board. Aft facing glass doors or walls in the second tier and above, are not required to be fitted with storm protection. The use of a virtual freeboard deck to determine storm cover requirements is not permitted. Additional portable supports are to be provided as necessary and full details are to be submitted for approval. Roller shutters or other alternatives will be specially considered.

6.6.4 In lieu of a weathertight coaming for the cover, adequate drainage is to be provided between the cover and the glass which may be in the form of a sump drained overboard, with a grating over, details of such proposals should be submitted for individual consideration.

6.7 Scuppers and sanitary discharges

6.7.1 Piping and valves are, in general, to comply with the requirements indicated in Pt 15, Ch 2,3.

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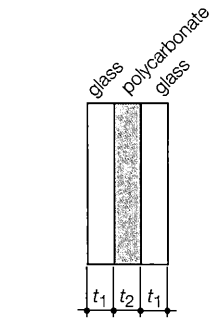
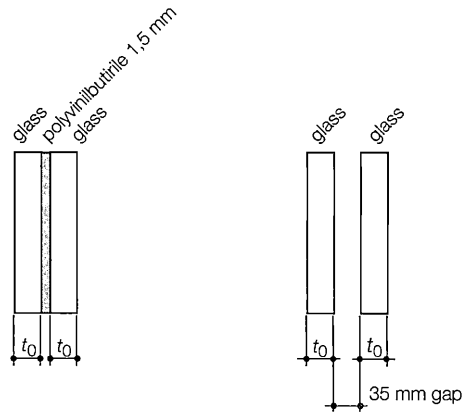
Table 2.6.1 Acceptable arrangements of glazing in lieu of portable storm covers/deadlights

In lieu of portable storm covers	In lieu of deadlights or storm covers
 $t_1^2 + (0{,}77t_2)^2 + t_1^2 = (1{,}2t_0)^2$	
Symbols	
t_0 = minimum thickness of toughened glass as calculated in Pt 3, Ch 4,7.8.1.	

6.8 Freeing ports

6.8.1 In general, freeing ports are to be in accordance with the requirements indicated in Pt 3, Ch 4, taking into consideration the position of the virtual freeboard deck indicated in 6.1.

6.9 Bulwarks, guard rails and wires

6.9.1 Bulwarks, guard rails and wires are in general, to comply with the requirements indicated in Pt 3, Ch 4,8.

6.9.2 Where a bulwark of reduced height is fitted, guard rails or wires are to be provided above the bulwark to a height of 1000 mm above the deck.

6.9.3 Where the proper working of a yacht may otherwise be impeded bulwarks, guard rails of wires of a reduced height may be considered. Details are to be submitted for approval.

6.9.4 Protection is to be provided in way of boats, liferafts, etc.

■ *Section 7* Corrosion protection

7.1 General

7.1.1 The design of the structure and methods of attachment of fittings are to take into consideration procedures to minimise corrosion of metal structures and fittings due to electro-chemical action. All exposed steel and aluminium alloy surfaces are to be protected by the application of a suitable paint and anti-fouling system and the fitting of a cathodic or impressed current protection system.

7.1.2 Sacrificial anodes are to be mounted equidistant between metals being protected, and their location and attachment is to be such as to obviate hard spots.

7.1.3 Anodes with cast-in galvanised steel straps are to be secured to the steel hull by welded studs or direct welding.

7.1.4 The design and performance characteristics of the cathodic protection system is the Builder's responsibility. Particular attention is to be given to the earth bonding system, to provide good electrical continuity.

7.1.5 Yachts fitted with a negatively grounded electrical system or fitted with a negatively grounded independent battery system may use the impressed current cathodic protection scheme.

7.2 Protection – Aluminium alloy yachts

7.2.1 Anti-fouling paints containing copper are not to be used.

7.2.2 Bilges and internal surfaces subject to salt laden air are to be coated with a waterproof mastic or equivalent.

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7.2.3 Particular attention is to be given to the design and selection of materials used for underwater fittings and the associated piping systems to limit the effect of bimetallic corrosion. Where materials other than aluminium are used they are, in general, to be electrically insulated from the hull and internal metal piping or cathodically protected separately by anodes attached directly to such fittings.

7.3 Protection – Composite yachts

7.3.1 Aluminium alloy or steel sterndrives, waterjet units and trim tabs are to be cathodically protected by anodes mounted on the hull, direct to the unit being protected or through the bonding system.

■ *Section 8*
Navigation in first-year ice conditions

8.1 General

8.1.1 Where an ice class notation is to be included in the class of a craft, the scantlings will require special consideration, *see* Pt 3, Ch 2,9.

8.1.2 Yachts in Service Group G6, which have their own propulsion machinery, and which are built of steel but are not strengthened for navigation in ice, may be eligible for assignment of Finnish-Swedish Ice-Due Class II under the Finnish and Swedish Boards of Navigation *Finnish-Swedish Ice Class Rules*. Yachts in Service Groups G1–G4 inclusive, constructed in any material, together with Yachts in Service Group G6 constructed in aluminium or composites are not eligible for this notation.

■ *Section 9*
Support yacht craft

9.1 General

9.1.1 A **support yacht craft** provides support to a 'primary' yacht and may often also be referred to as a 'shadow yacht'. The support yacht may be provided with an extensive range of equipment and facilities to perform these duties, such as small craft, seaplanes, large galleys and waste management systems.

9.1.2 For support yachts, the following are also to be considered according to the load line requirements:
(a) Sill heights of door openings;
(b) Windows and portlights;
(c) Freeing port areas; and
(d) Sill heights of ventilators.

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Section

1 **Hull design and construction parameters**

2 **Hull construction**

3 **Chain plates**

4 **Deck planking**

5 **Deck fittings**

6 **Ballast keels**

7 **Rudder skegs and rudders**

8 **Open cockpits and companionways**

9 **Anchoring and mooring equipment**

■ *Section 1* Hull design and construction parameters

1.1 Plans and data

1.1.1 In addition to the general plans and data required by Pt 3, Ch 1,5 the following details of additional structural components, particular to sailing yachts, are to be submitted for appraisal:

- Sail plan.
- Mast loadings.
- Bowsprit loadings.
- Rigging loadings.
- Mast step.
- Mast partners.
- Ballast keel lines plan.
- Ballast keel securing arrangements.
- Rudder skeg construction and support details.
- Chainplates.
- Through deck fittings.

1.1.2 All plans are to be presented in a clear and unambiguous manner with sufficient details to avoid misinterpretation.

1.2 Mast and rigging support arrangements

1.2.1 Sailing yacht mast and standing rigging loadings and their support structure require special consideration as follows:

(a) Adequate hull and deck longitudinal structure to resist hull bending.

(b) Provision of adequate transverse structure in way of masts, chainplates, keels, skegs, etc.

(c) Provision of adequate bottom structure to support the mast and dissipate the mast loadings.

(d) Local reinforcement as given in Pt 8, Ch 3,3.14 in way of chainplates, forestay and backstay fittings, etc.

(e) The deck and beams are to be suitably strengthened in way of masts, coachroof/deckhouse ends, windlass, cleats, sheet winches, sheet tracks, etc. Where a mast is stepped on the deck or coachroof/deckhouse the structural arrangements will be specially considered.

1.2.2 Details of the designer's/Builder's calculated maximum loads on the mast heel and the breaking loads of all standing rigging are to be submitted with the main structural plans for appraisal.

1.3 Bowsprits

1.3.1 The hull structure in way of the bowsprit is to be suitably reinforced with due account taken of the compressive loads along the bowsprit and bending moments due to rigging loads.

1.3.2 Details of the designer's/Builder's calculated maximum loads on the bowsprit and the breaking loads of all associated standing rigging are to be submitted with the structural plans for appraisal.

■ *Section 2* Hull construction

2.1 Hull scantlings (composite materials)

2.1.1 The basic structural scantlings are, unless specified within this Section, to be as indicated in Part 8.

2.1.2 The shell weight/thickness determined from Part 8, is to be maintained throughout the length of the craft, with the bottom shell weight extending to the chine line or 150 mm above the static load waterline, whichever is the greater.

2.1.3 The keel plate thickness for sailing yachts is to be 1,1 times the keel thickness for motor craft as determined in Part 8. In no case is the thickness of keel to be taken less than the thickness of the adjacent bottom shell or fin and tuck as appropriate.

2.1.4 The fin and tuck thickness is not to be less than 0,9 times the keel thickness for motor craft as determined in Part 8. In no case is the thickness of the fin and tuck to be taken less than the thickness of the adjacent bottom shell.

2.1.5 The construction of hull to deck connections is to be in accordance with Pt 8, Ch 2,5.

2.1.6 The hull laminate is to be strengthened in way of the attachment of chainplates, etc., *see* Pt 8, Ch 2,5.

2.1.7 The stern or transom is to be the same weight as the side shell and is to be adequately stiffened with special consideration being given to the transmission of backstay loadings.

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2.1.8 Where twin bilge keels are fitted, the bottom laminate in way of the bilge keels is to be formed by extending the keel reinforcement to a distance not less than 25 per cent the width of the keel, as required by Part 8, outside the line of the outboard edge of the bilge keels or to the supporting structure whichever is the greater, prior to being tapered in accordance with the Rules to the adjacent bottom shell laminate. *See also* 2.1.10.

2.1.9 The hull and deck are to be locally increased in thickness in way of fittings for rudder tubes, propeller brackets etc. The increase is not to be less than 50 per cent of the adjacent plate laminate. Details of such reinforced areas are to be submitted for consideration.

2.1.10 Local reinforcement is, in general, to extend under the adjacent supporting structure and then be tapered gradually to the base laminate thickness in accordance with Pt 8, Ch 3,3.14.

2.2 Transversely framed yachts

2.2.1 Sailing yachts with a conventional rig, are to be provided with suitably increased scantlings in floors, frames, beams and brackets adjacent to each mast.

2.2.2 In general, beams at the heads of web frames and four beams in way of each mast in sailing and auxiliary yachts are to have their scantlings increased by a factor of two. Where practicable, masts are to be located in way of transverse bulkheads or other primary stiffening.

2.2.3 Keel mounted masts are to be mounted on a suitable mast step secured to three floors at a height sufficient to provide the necessary structural integrity and to keep the heel of the mast clear of any bilge water.

2.2.4 Keel mounted masts are to be fitted with mast partners running fore and aft on either side of the mast to join the transverse beams. The strength of the mast partners are to be the same as for the beams.

2.2.5 Deck mounted masts are to be housed in a mast step positioned directly over a bulkhead or a web frame/deep beams with a pillar fitted under the mast.

2.3 Longitudinally framed yachts

2.3.1 Conventional masts mounted on mast steps as in 2.2.3 are to be fitted with heavy transverse web frames as required by 2.2.2.

2.4 Yachts fitted with non-conventional rigs

2.4.1 The structure in way of non-conventional mast configurations will be specially considered.

■ *Section 3* Chain plates

3.1 General

3.1.1 Chain plates and other securing arrangements to take the loads of all standing rigging for masts and bowsprits, are to be of substantial construction and well integrated with the hull and/or deck supporting structure. They are to be of sufficient strength that, in the event of failure of the standing rigging, the watertight integrity of the hull is not impaired.

3.1.2 The breaking loads of all mast and bowsprit standing rigging together with the actual loads imposed by the rigging are to be submitted.

3.2 Calculations

3.2.1 The strength of any part of chainplates or structure to which it is attached is not to be less than the breaking load of the rigging to which it is attached and subject to the following factors of safety (FOS).

Items:	Minimum FOS:
Rigging	1,0
Lug, eyebolt eye	1,2
Lug to baseplate	1,2
Eyebolt/base plate to foundation	2,0
Chainplate to foundation (below decks)	2,0
Chainplate foundation to hull structure	2,0

■ *Section 4* Deck planking

4.1 General

4.1.1 The construction of decks of steel, aluminium alloy or composite materials is to be in accordance with Pt 6, Ch 3,8, Pt 7, Ch 3,8 and Pt 8, Ch 3,8 respectively. Wood deck sheathing is in general to be treated as cosmetic and is outside the scope of these Rules. However, any wood sheathing fitted is not to be detrimental to the integrity of the main deck structure. Details of the means of attachment of such wood sheathing are to be submitted for consideration.

4.1.2 Decks constructed of wood will be specially considered on the basis of the Rules.

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Section 5
Deck fittings

5.1 General

5.1.1 Due consideration is to be given at the design stage to ensure that additional structural support, by way of pads, brackets etc., is provided in way of deck fittings such as mainsheet and genoa tracks, winches, eyebolts, sail-lead tracks, fairleads, anchor and chain cable handling and securing arrangements, grab rails, guard wires, hatch hinges, etc., which are subject to substantial loadings and or use.

5.1.2 Fittings which are subject to significant loads are, in general, to be through bolted, in single skin areas. The laminate is to be locally increased in thickness as necessary with due account taken of such loadings.

5.1.3 Details of inserts, local reinforcement and through bolting arrangements for yachts of composite construction are to be in accordance with Pt 8, Ch 2 and Ch 3.

Section 6
Ballast keels

6.1 External ballast keel

6.1.1 The ballast keel may be of lead, cast iron or other suitable material. Cast iron or other ferrous metals are not to be used in wood or composite craft sheathed with copper or other non ferrous metal.

6.1.2 Prior to installation the ballast keel is to be 'Dry fitted' to the hull and the top is to be smooth, or slightly concave in all directions, and well coated with a suitable bedding compound.

6.1.3 In composite yachts care is to be taken to prevent crushing of GRP laminates through overtightening of keel bolts.

6.1.4 A substantial plate washer is to be fitted under the head of the keel bolt. The diameter and thickness are to be not less than 4,0 and 0,25 times the bolt diameter, respectively, but the thickness need not in general exceed 8 mm. The top of the bolt is to have sufficient thread to take double nuts or other suitable locking arrangement. *See also* 6.3.6.

6.1.5 The structure in way of the ballast keel is to be in accordance with the requirements of Parts 6, 7 and 8 for the respective material.

6.1.6 In steel/aluminium alloy yachts all bottom structure in way of the ballast keel(s) is to be welded by means of double continuous welding.

6.1.7 Ballast keels are to be fully supported by floors to distribute the keel loadings to the bottom structure, *see* Pt 8, Ch 3. The scantlings of the floors and frames will be specially considered in conjunction with the keel mass together with the size, material and position of the keel bolts.

6.1.8 Canards and lifting keels are outside the scope of the Rules but the structure in way will be specially considered with regard to maintenance of structural and watertight integrity. Full details are to be submitted for appraisal.

6.2 Internal ballast keel

6.2.1 Where ballast is to be incorporated in the keel, the internal surface is to be suitably coated prior to filling, and on completion the top surface is to be sealed.

6.2.2 For steel and aluminium alloy yachts the method of installing the internal ballast is not to be detrimental to the plating or internal structure. Details of the installation procedure are to be submitted for consideration prior to implementation.

6.2.3 Internal ballast is to be suitably supported and secured against movement. The supporting structure in way of internal ballast is to be suitably increased in strength.

6.2.4 In steel/aluminium yachts, the ballast is to be totally encapsulated by fully welded plating with a minimum thickness of 6 mm. Alternative arrangements will be specially considered.

6.2.5 In composite yachts, the internal ballast is to be encapsulated by a laminate equivalent in thickness to half the rule bottom shell laminate or 2400 g/m^2 CSM (or equivalent), whichever is the greater.

6.3 Keel bolts

6.3.1 The keel bolts are to be of a corrosion resistant material. The nuts, washers, etc., are to be of a material the same as, or compatible with, that of the keel bolts. The specifications of these materials are to be submitted for appraisal.

6.3.2 The diameter of keel bolts, d_k, is to be that determined from the following formula, or 14 mm, whichever is the greater:

$$d_k = 14{,}2 \sqrt{\frac{w\, d_{cg}}{\sigma_u\, b_k}} \text{ mm}$$

where

b_k = breadth of top of ballast keel in way of bolt, in mm

d_{cg} = vertical distance of the centre of gravity of weight, w, below top of ballast keel, in mm

w = the portion of the weight of ballast keel supported by the bolt, in kg

σ_u = ultimate tensile strength of the bolt material, in N/mm^2

When determining w for the bolt at the ends of the keel, the weight of any overhang is to be included.

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6.3.3 Where double bolts are to be fitted, the total cross-sectional area of the bolts is to be not less than 1,2 times the cross-sectional area of the bolt determined in accordance with 6.3.2.

6.3.4 Keel bolts are to be fitted alternately on opposite sides of the middle line, and as close as is practicable to the bottom floor structure.

6.3.5 The ballast keel is to be secured by through bolting, but where this is not practicable, short keel bolts or studs may be fitted.

6.3.6 A substantial plate washer is to be fitted under the head of the keel bolt. The diameter and thickness are to be not less than 4,0 and 0,25 times the bolt diameter, respectively, but the thickness need not exceed 8 mm. Washer plates, where square or rectangular, are to have suitably radiused corners. In composite and wood craft the washer plates are to have all edges dressed smooth in addition to being suitably radiused.

6.3.7 The bottoms of short keel bolts are to be secured by nuts and washers fitted in pockets in the keel, or by square plate nuts cast in with the keel. Where cast in, the square plate nuts are to have a breadth and depth not less than 3,0 and 1,0 times the bolt diameter, respectively.

6.3.8 Where studs are fitted, the length of the threaded portion into the cast iron or steel keel is to be not less than 1,5 or 2,5 times the stud diameter where through tapped or blind tapped respectively.

6.3.9 It is recommended that the design of the keel bolt is such that it can be withdrawn for survey and is not cast permanently into the ballast keel.

6.3.10 Details of the proposed torque to be applied to the keel bolts is to be indicated on the relevant plans and submitted.

■ *Section 7* Rudder skegs and rudders

7.1 Skegs

7.1.1 Skegs are to be effectively integrated into the adjacent structure and their design is to be such as to facilitate this.

7.1.2 The scantlings of skegs are to be sufficient to withstand any docking forces that they may be subjected to.

7.1.3 The thickness of the skeg plating is in no case to be taken as less than 1,5 times the thickness of the adjacent bottom shell or the fin and tuck laminate whichever is the greater.

7.1.4 Where metallic sub-frames are laminated into skegs, providing transverse stiffening to the skeg and support for the rudder pintle, such stiffening members are to be fully integrated with hull framing to ensure continuity of strength.

7.1.5 The scantlings of skegs of composite construction will be specially considered on the basis of the Rules, and in this respect are to be of equivalent strength and load carrying capability to that required for skegs of steel construction from Pt 3, Ch 3,3. Due account is to be taken of the differing material properties.

7.1.6 Direct calculations may be used as an alternative to the requirements of 7.1.5 to determine the scantlings of composite skegs. Such calculations are to be submitted for appraisal.

7.2 Rudder construction arrangements

7.2.1 Rudder construction for sailing yachts is generally to be in accordance with Pt 3, Ch 3.2.

7.2.2 For use in the determination of the rudder stock diameter, within Table 3.2.7 in Pt 3, Ch 3, the factor f_c may be taken as 70 for yachts with an overall length, L_{OA}, of 24 m varying up to 79 at a length of 50 m. Intermediate values are to be determined by linear interpolation. Yachts with a length, L_R, in excess of 50 m are to comply with Table 3.2.7.

7.2.3 The rudder stock diameter is to be based upon the maximum stated operational speed of the yacht, but in no case is this to be taken less than $2{,}536\sqrt{L_{WL}}$ knots. L_{WL} is as defined in Pt 3, Ch 1,6.2.5.

■ *Section 8* Open cockpits and companionways

8.1 Cockpit construction

8.1.1 Cockpits are to be of watertight construction with scantlings equivalent to that of the upper deck.

8.1.2 Cockpit lockers and hatches where fitted, are to be of substantial construction and are to be tested weathertight.

8.1.3 Where engine removal or other hatches are fitted in the cockpit sole they are to be watertight and bolted down. Detailed plans are to be submitted for approval.

8.1.4 The height of the cockpit sole above the waterline is to be such that the water will effectively drain overboard under all normal conditions of heel and trim.

8.2 Companionways

8.2.1 Companionway openings, are to be sited on, or as close as possible to, the centreline. Sill heights are to be not less than as required by Pt 3, Ch 4.

8.2.2 Companionway hatches are to be of substantial construction capable of being opened from both sides and be tested weathertight.

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Section 9
Anchoring and mooring equipment

9.1 General

9.1.1 The requirements of Pt 3, Ch 5 apply to fore and aft rigged sailing yachts of all sizes.

9.1.2 Sailing yachts with three or more masts and fitted with a square rig are to be fitted with anchors 25 per cent heavier than those calculated in accordance with Pt 3, Ch 5. Chain cable, hawsers and warps are to be increased accordingly.

9.1.3 Square rigged yachts are to have a full length of chain cable on the main anchor but may have rope with a chain tail fitted to the second anchor. Kedge anchors may be fitted using the rule length and size of warp without a chain tail.

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Section

1 **Rule application**

2 **Direct calculations**

3 **Model experiments**

■ *Section 1* Rule application

1.1 General

1.1.1 The global and local load and design criteria detailed in this Part are to be used in conjunction with the formulae given in Parts 6, 7 and 8 to determine the scantlings of steel, aluminium alloy and composite craft respectively as defined in Part 1.

1.1.2 The global load and design criteria given in this Part are provided to enable the designer/Builder to check global hull strength against ductile failure modes involving gross deformation. The strength calculations are, in general, to be conducted using finite element analysis techniques with a three dimensional model.

1.1.3 Load and design criteria detailed in this Part are to be supplemented by direct calculation methods incorporating model test results and numerical analysis for novel designs. Full scale measurements may be required where considered necessary by Lloyd's Register (hereinafter referred to as LR).

1.1.4 Craft built and classed in accordance with the Rules will, in general, be assigned an operational envelope. This will be based on the allowable speeds, significant wave heights and corresponding displacements. It will form an appendix to the Classification Certificate and is to be incorporated in the craft's Operational Manual. The assigned operational envelope is to be clearly displayed in the wheelhouse. Installation of an accelerometer at LCG connected via a visual display in the wheelhouse may be required.

1.1.5 The operational envelope assigned is based on the assumption that the wave height can be visually observed. Where this is not the case, the speed of the craft is to be suitably reduced.

1.1.6 The design assessment is to include a range of speeds covering all modes of operation for which the craft is designed, i.e. speeds corresponding to displacement, semi planing and fully planing. A craft which is designed to operate in the planing mode will need to be assessed using the requirements of Chapter 3 at its design speed and required significant wave height, as well as the requirements of Chapter 4 when operating at reduced speed and a more severe wave height.

1.1.7 The load design criteria given in this Part are dependent on the operating mode of the craft as follows:

- Craft operating in the **non-displacement** mode:
  - Applies to craft operating in full planing or semi-planing modes.
  - Applies to HSC at design speed. HSC is defined in Pt 1, Ch 2,2.2.8.
  - Applies to LDC at design speed. LDC is defined in Pt 1, Ch 2,2.2.10.
  - Applies to craft in foil borne mode.
  - Applies to craft where other lifting devices are actively supporting some or all of the craft's weight.
  - Typically this applies to craft with a Taylor Quotient, Γ, greater than 3. Γ is defined in Ch 2,2.1.18. However, the following is to be noted:
    - Some craft are not designed to plane, but have Γ greater than 3, e.g. SWATHs and fast displacement yachts and, unless they are classified as HSC, then these craft are to be considered as only operating in the displacement mode.
    - Some craft are designed to plane with Γ less than 3 and these should be considered as operating in the non-displacement mode.
- Craft operating in the **displacement** mode:
  - Applies to craft designed to operate in the displacement mode.
  - Applies to all other craft where they are not operating in the non-displacement mode, e.g. at lower speed in severe weather.

■ *Section 2* Direct calculations

2.1 General

2.1.1 Direct calculations using hydrodynamic computer programs may be specifically required by the Rules. Also they may be required for craft having novel design features, or may be submitted in support of alternative load and design criteria. LR may, when requested, undertake calculations on behalf of designers and make recommendations in regard to suitability of any required model tests.

2.2 Special Service Craft Software

2.2.1 LR's direct calculation procedures and facilities are summarised in a publication entitled the LR *Software Guide*.

2.3 Submission of direct calculations

2.3.1 In cases where direct calculations have been carried out using procedures available in the LR *Software Guide* the following supporting information is to be submitted as applicable:

(a) Reference to the direct calculation procedure and technical program used.
(b) Input data.
(c) A description of the model.

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(d) A summary of analysis parameters including environmental conditions, speeds and headings.
(e) Details of the weight distributions.
(f) A comprehensive summary of calculation results. Sample calculations are to be submitted where appropriate.

2.3.2 In general, all input data and output results are required to be submitted. In such cases, magnetic media with agreed format may be used for submission.

2.3.3 The responsibility for error free specification and input of program data and the subsequent correct transposal of output rests with the designer/Builder.

■ *Section 3* Model experiments

3.1 General

3.1.1 Model experiments and theoretical calculations may be required to be carried out for new design concepts and the results are to be provided when plans are submitted for approval.

3.1.2 Where model testing is undertaken, the following details are to be submitted:
(a) A summary of the model construction and its instrumentation, including calibration of instruments.
(b) A summary of the testing arrangements and procedures.
(c) A summary of the tank facilities and test equipment.
(d) Details of the wave generation, response measurements, definitions and notations.
(e) Details of data recording, reduction and data analysis procedures.
(f) Details of calibration procedures with theoretical computations.
(g) Tabulated and plotted output.

3.2 Model test matrix

3.2.1 Where model testing is undertaken, the minimum test matrix shown in Table 1.3.1 is required to be carried out.

Table 1.3.1 Minimum test matrix

Item	Test matrix
Sea state	Regular and irregular seas
Heading	Beam, head, stern and quartering seas
Speed	Three speeds including zero and maximum service speeds
Wave frequency	Six frequencies

3.2.2 In addition to those quantities which are normally measured in a model experiment, the following data are to be obtained where practicable:
(a) Vertical accelerations at the LCG, bow and stern.
(b) Acceleration loads due to heave and pitch.
(c) Vertical bending moment.
(d) Bow impact pressures at full forward speed.
(e) Oblique sea loads inducing dynamic torque on the cross structure for multi-hull craft.
(f) Splitting loads due to beam seas and roll motion for multi-hull craft.
(g) Impact pressures in tunnel side and top for multi-hull craft.

3.2.3 The basis on which the parameters are chosen for investigation is to be submitted for approval.

3.2.4 Results from open water model experiments and full scale measurements may be accepted and full details are to be submitted for appraisal.

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1 **Environmental conditions**

2 **Definitions and symbols**

3 **Motion response**

4 **Loads on shell envelope**

5 **Impact loads**

6 **Cross-deck structure for multi-hull craft**

7 **Component design loads**

■ *Section 1* Environmental conditions

1.1 General

1.1.1 This Chapter contains information regarding the derivation of load criteria which are to be used for the computation of local design criteria in Chapters 3 and 4.

1.1.2 Environmental conditions include natural phenomena such as wind, wave and currents from which design data are to be derived.

1.1.3 These environmental conditions are usually described by physical variables of statistical nature.

1.1.4 The load criteria used for design are to be based on environmental data for the specific area and operation of the craft.

1.1.5 The loads imposed by the environment are to be based on extreme conditions. These arise as the craft advances in a seaway and is loaded and stressed in a random manner by dynamic forces and moments.

1.1.6 The load criteria given here are derived from experimental and theoretical studies complemented with service experience.

1.1.7 Alternative methods of establishing the load criteria will be specially considered, provided that they are based on model tests, full scale measurements or generally accepted theories. In such cases, full details of the methods used are to be provided when plans are submitted for approval.

■ *Section 2* Definitions and symbols

2.1 Parameters to be used for the determination of load and design criteria

2.1.1 **Air gap.** The air gap, G_A, is the minimum vertical distance, in metres, from the static waterline to the point considered in an operational condition. In no case is G_A to be taken greater then $G_{A(max)}$ as indicated in Fig. 2.2.1.

2.1.2 **Allowable speed *V*.** The allowable speed used in the computation of environmental loads is the design speed, in knots, associated with a nominated operational environment in which the craft is certified at corresponding operational displacement.

2.1.3 **Beaufort Number.** Beaufort Number is a measure of wind strength.

2.1.4 **Bilge tangential point.** For craft with partially submerged hull(s), the bilge tangential point is defined as the tangential point of the bilge with an oblique line sloped at 50° to the horizontal at the LCG, *see* Fig. 2.2.2. For craft with fully submerged hull(s), the bilge tangential point is defined as the intersection points between the hull and the design waterline.

2.1.5 **Deadrise angle.** For craft with no clearly defined deadrise angle at the LCG, the angle, in degrees, to the horizontal of the line at the LCG formed by joining the lowest point of the hull or underside of keel and the bilge tangential point is to be taken as the deadrise angle θ_D, *see* Fig. 2.2.2. For craft with hulls of asymmetric section, where the inner and outer deadrise angles differ, the smaller of the two angles is to be used. For craft with fully submerged hull with circular sections, the deadrise angle is to be taken as 30°.

2.1.6 **Displacement mode.** Displacement mode means the regime, whether at rest or in motion, where the weight of the craft is fully or predominantly supported by hydrostatic forces.

2.1.7 **Froude Number F_n.** The Froude Number is a non-dimensional speed parameter and is defined as:

$$F_n = \frac{0{,}515V_m}{\sqrt{g\,L_{WL}}}$$

where
g is the acceleration due to gravity and is taken to be 9,81 m/s^2.
L_{WL} is defined in 2.1.19.
V_m is the appropriate speed in knots.

2.1.8 **LCG.** The LCG is the longitudinal centre of gravity of the craft in the loading condition under consideration.

2.1.9 **Maximum wave height.** In general the maximum wave height, in metres, will be taken as 1,667 times the significant wave height. Where, for design purposes, a wave length is required this will be taken as the waterline length subject to any restriction resulting from limiting height to length ratio and wave profile angle.

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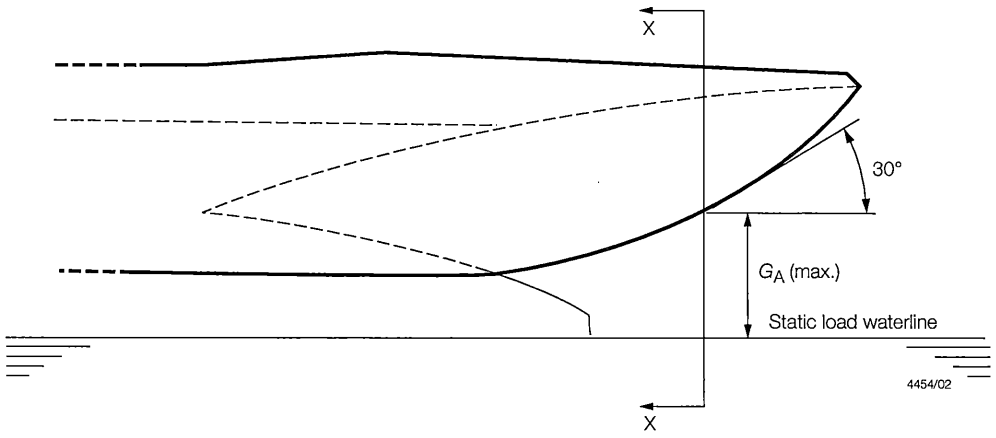
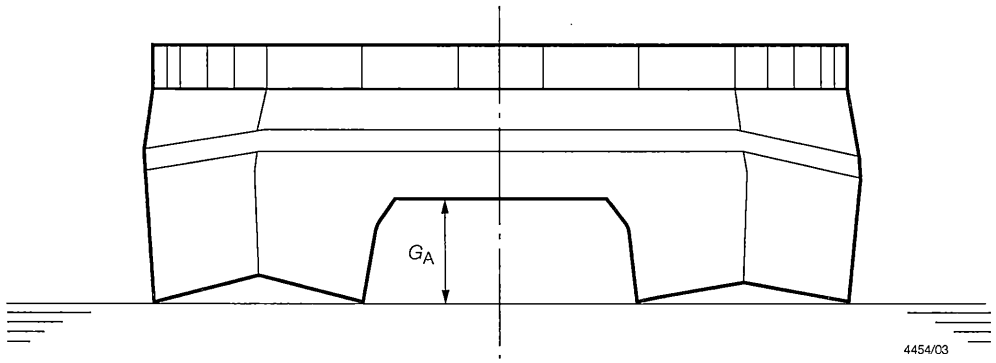
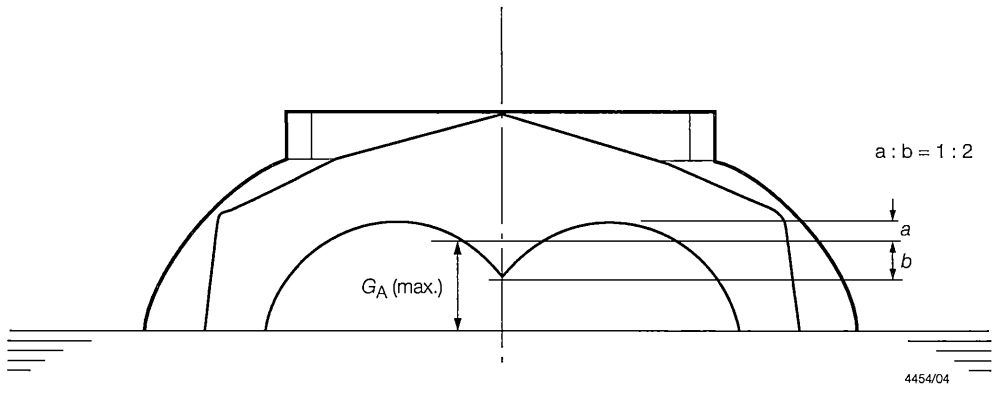


Elevation on Centreline



Section at X – X : Conventional Catamaran



Section at X – X : Wave Piercing Catamaran

Fig. 2.2.1 Definition of air gap

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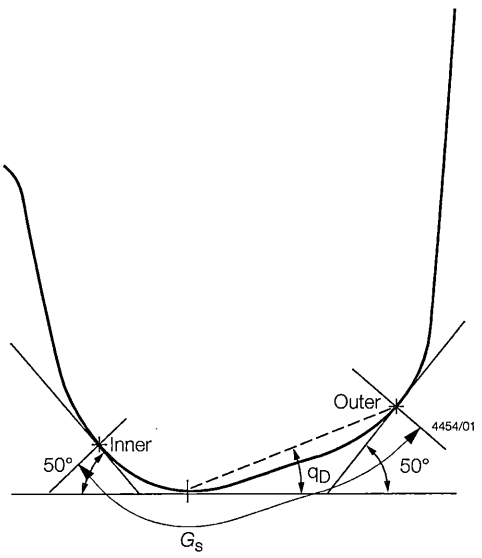


Fig. 2.2.2
Definition of bilge tangential point and G_S for craft with partially submerged hulls

2.1.10 **Non-displacement mode.** Non-displacement mode means the normal operational regime of a craft when non-hydrostatic forces substantially or predominantly support the weight of the craft.

2.1.11 **Operating waterline** is the waterline for the operating condition under consideration.

2.1.12 **Period.** The period is defined as the average time interval between upward crossings of the mean value.

2.1.13 **Sea state.** Sea state is an expression used to categorise wave conditions and is normally defined by sea spectrum, significant wave height and period distribution.

2.1.14 **Significant wave height $H_{1/3}$.** The wave height, in metres, used in the determination of craft motions and loads is a significant wave height, $H_{1/3}$, defined as the average of the one third highest waves in a short term wave measurement record.

2.1.15 **Support girth.** The support girth, G_s, is the girth distance, in metres, measured around the circumference of the shell plate between the tangential points or chines, as appropriate, of the hull for a mono-hull craft. For multi-hull craft it is to be taken between the inner and outer bilge tangential points or chines of the individual hulls. *See* 2.1.4 and Fig. 2.2.2.

2.1.16 **Surviving wave height H_{03}.** The wave height, in metres, used in the determination of the structural integrity of a craft and is defined as the wave height with three per cent probability of exceedance. If this value is unknown, the following equation is to be used to determine H_{03}:

$$H_{03} = 1{,}29H_{1/3}$$

2.1.17 **Taylor Quotient Γ.** The Taylor Quotient is defined as:

$$\Gamma = \frac{V}{\sqrt{L_{WL}}}$$

where V is defined in 2.1.2 and L_{WL} is defined in 2.1.19.

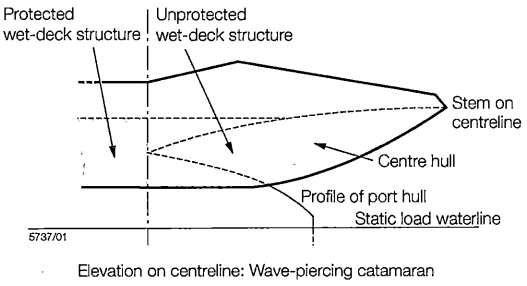
2.1.18 **Volumetric speed number F_v.** The Volumetric speed number is defined as:

$$F_v = 7{,}19\,\nabla^{1/6}$$

where ∇ is the moulded displacement, in m^3, of the craft corresponding to the design waterline.

2.1.19 **Waterline length.** Waterline length, L_{WL}, is as defined in Pt 3, Ch 1,6.2.

2.1.20 **Protected structure,** *see* Fig. 2.2.3. A protected structure is one in which the wet-deck component under consideration is enclosed by port and starboard side inboard structure, where 'side inboard' is as defined in Ch 4,1.5.6 of Parts 6, 7 and 8 for craft of steel, aluminium alloy and composite construction respectively.



Elevation on centreline: Wave-piercing catamaran

Fig. 2.2.3
Definition of wet-deck protected and unprotected structure

2.1.21 **Unprotected structure,** *see* Fig. 2.2.3. An unprotected structure is one in which the wet-deck component under consideration is not enclosed by port and starboard side inboard structure, where 'side inboard' is as defined in Ch 4,1.5.6 of Parts 6, 7 and 8 for craft of steel, aluminium alloy and composite construction respectively.

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2.2 Symbols

2.2.1 L_R, B, D, C_b, L_{WL} and T are as defined in Pt 3, Ch 1,6.2:

x_{wl} = longitudinal distance, in metres, measured forwards from the aft end of the L_{WL} to the position or centre of gravity of the item being considered

z = vertical distance, in metres, from the baseline to the position of centre of gravity of the item being considered. z is positive above the baseline

Normally the following definitions are to be applied:

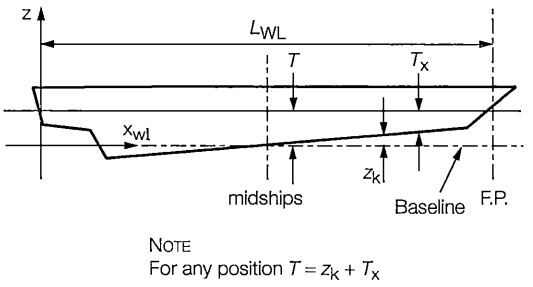
z is to be taken at one third of the panel or strake height

For short stiffener members: z is to be taken at the stiffener mid position

For long stiffener members: z is generally to be taken at the stiffener mid position, but may need to be specially considered, especially when there is a significant pressure variation along its length

z_k = vertical distance of the underside of the keel above the baseline, in metres, *see* Fig. 2.2.4

T_x = local draught to operating waterline at longitudinal position under consideration measured above the baseline is to be taken as the horizontal plane passing through the bottom of the moulded hull at midships, *see* Fig. 2.2.4.



NOTE
For any position $T = z_k + T_x$

Fig. 2.2.4 Definition of Symbols

2.2.2 The displacement, Δ, in tonnes, used in this Part is the mass of the craft in the loading condition under consideration.

2.3 Minimum significant wave height

2.3.1 The minimum value of significant wave height, $H_{1/3}$, *see* 2.1.14, in metres, used in the determination of accelerations and loads is, in general, not to be taken less than that given in Table 2.2.1 for the appropriate Service Groups defined in Pt 1, Ch 2,3.5.

2.3.2 The designer/Builder is to provide the value of significant wave height for use in the determination of the Rule loadings and, further, is to ensure that such a wave height is appropriate to the intended area of operation and/or service. In this respect the statistical wave data may be required to be submitted in support of the wave height nominated.

Table 2.2.1 Minimum significant wave height, $H_{1/3}$

Service Group	Minimum significant wave height, in metres
1	0,6
2	1,0
2A	1,5
3	2,0
4	4,0
5	4,0
6	4,0

2.3.3 A reduction in the minimum value of significant wave height for a particular Service Group will be specially considered, provided that satisfactory statistical wave data for the intended service area are submitted for approval. *See also* 2.1.14.

■ *Section 3* Motion response

3.1 Relative vertical motion

3.1.1 The relative vertical motion is to be taken as:

$$H_{rm} = C_{w,min}\left(1 + \frac{k_r}{(C_b + 0{,}2)}\left(\frac{x_{wl}}{L_{WL}} - x_m\right)^2\right)$$

where

k_r = *see* Table 2.3.1

$$C_{w,min} = \frac{C_w}{k_m}$$

$$k_m = 1 + \frac{k_r\,(0{,}5 - x_m)^2}{(C_b + 0{,}2)}$$

x_m = $0{,}45 - 0{,}6F_n$ but not less than 0,2

C_w = wave head, in metres

= $0{,}0771 L_{WL}\,(C_b + 0{,}2)^{0,3}\ e^{(-0{,}0044 L_{WL})}$

x_{wl} = distance from aft end of L_{WL}, in metres, *see* 2.2.1

L_{WL} = waterline length, in metres, *see* 2.1.19

C_b = block coefficient, *see* 2.2

F_n = Froude Number, *see* 2.1.7, where $V_m = {}^2/_3 V$

V as defined in 2.1.2.

Table 2.3.1 Hull form wave pressure factor

Craft type	k_r
Mono-hull craft in the non-displacement mode	2,25
Mono-hull craft in the displacement mode	1,95
Catamarans and multi-hull craft with partially submerged hulls	2,55
Swaths and multi-hull craft with fully submerged hulls	2,10
Craft supported by hydrodynamic lift provided by foils or other lifting devices	1,50

NOTE
Where multiple craft types apply, the higher value of k_r is to be used.

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3.2 Vertical acceleration

3.2.1 The instantaneous accelerations determined in accordance with the formulae in this Section are to be used to estimate the relationship between allowable speed, V, in knots, wave height, $H_{1/3}$, in metres, and displacement, Δ, in tonnes, and they will form the operational envelope which will be issued as an appendix to the Classification Certificate and be incorporated in the Operational Manual of the craft where such a manual is required by the Rules.

3.2.2 Where the Taylor Quotient, Γ, is greater than 10,8, the motion response criteria are to be specially considered.

3.2.3 The vertical acceleration at the LCG (longitudinal centre of gravity), a_v, is defined as the average of the 1/100 highest accelerations at the LCG.

3.2.4 The vertical acceleration in the non-displacement mode for mono-hull craft is to be taken as:

$$a_v = 1{,}5\theta_B L_1 (H_1 + 0{,}084)(5 - 0{,}1\theta_D)\Gamma^2 \times 10^{-3}$$

where

a_v is the vertical acceleration at the LCG in terms of g

g = acceleration due to gravity (9,81 m/sec^2)

$H_1 = \dfrac{H_{1/3}}{B_W}$, but is not to be taken as less than 0,2

$H_{1/3}$ = design significant wave height in metres

B_c = breadth of hull between the chines or bilge tangential points at LCG, as appropriate, in metres

B_W = breadth of hull at the LCG measured at the waterline, in metres

$L_1 = \dfrac{L_{WL} B_c^3}{B_W \Delta}$, but $\dfrac{L_{WL}}{B_W}$ is not to be taken as less than 3

L_{WL} = waterline length, in metres, *see* 2.1.19

θ_D = deadrise angle at the LCG, in degrees, but is not to be taken as greater than 30°

θ_B = running trim angle in degrees, but is not to be taken as less than 3°

Γ = Taylor Quotient, *see* 2.1.17

Δ = displacement, in tonnes, as defined in 2.2.2.

3.2.5 The vertical acceleration in the non-displacement mode for multi-hull craft is to be taken as:

$$a_v = \frac{f_a L_{WL}}{\Delta}(B_M H_{1/3} + 0{,}084 B_M^2)(5 - 0{,}1\theta_D)\Gamma^2 \times 10^{-3}$$

where

a_v is the vertical acceleration at the LCG in terms of g

f_a = hull form acceleration factor

= 2,7 for craft supported mainly by hydrodynamic lift provided by foils or other lifting devices

= 3,6 for Swaths and multi-hull craft with fully submerged hulls

= 4,5 for catamarans and multi-hull craft with partially submerged hulls

B_M = total breadth of hulls or struts at LCG at the waterline, in metres, excluding tunnels

$H_{1/3}$ = design significant wave height, in metres

L_{WL} = waterline length, in metres, *see* 2.1.19

θ_D = deadrise angle at the LCG, in degrees, but is not to be taken as greater than 30°, *see* 2.1.5

Γ = Taylor Quotient, *see* 2.1.17

Δ = displacement, in tonnes.

3.2.6 The vertical acceleration in the displacement mode for all craft is to be taken as:

$$a_v = 0{,}2\Gamma + \frac{34}{L_{WL}}$$

where

a_v is the vertical acceleration at the LCG in terms of g

L_{WL} = waterline length, in metres, *see* 2.1.19

Γ = Taylor Quotient, *see* 2.1.17.

3.2.7 The vertical acceleration, a_x, at any given location distance x_a from the AP along the hull may be taken as:

$$a_x = a_v \left(0{,}86 - 0{,}32 \frac{x_a}{L_{WL}} + 1{,}76 \left(\frac{x_a}{L_{WL}}\right)^2 + \xi_a\right)$$

where

a_v = vertical acceleration at LCG in terms of g, as appropriate

a_x = is the vertical acceleration at a distance x_a from AP on the static load waterline, in terms of g

x_a = distance from aft end of the static load waterline, in metres, to the point at which the vertical acceleration is calculated

x_{LCG} = distance from aft end of the static load waterline, in metres, to the LCG

L_{WL} = waterline length, in metres, *see* 2.1.19

$\xi_a = 0{,}14 + 0{,}32 \dfrac{x_{LCG}}{L_{WL}} - 1{,}76 \left(\dfrac{x_{LCG}}{L_{WL}}\right)^2$

■ *Section 4*
Loads on shell envelope

4.1 Pressures on the shell envelope

4.1.1 The design pressures for the shell envelope including exposed decks are to include the effects of combined static and dynamic load components. In addition, the effects of impact or slamming loads are also to be considered, but these are to be treated separately, *see* Section 5.

4.1.2 The individual pressure components are given in 4.3 to 4.5 and the combined pressure to be applied to the shell envelope is given in 4.2. The pressure to be applied to exposed and weather decks is given in 4.5.

4.2 Combined hydrostatic and hydrodynamic pressure on the shell plating

4.2.1 The total pressure distribution, P_s, in kN/m^2 acting on the shell plating envelope due to hydrostatic and hydrodynamic pressures is illustrated in Fig. 2.4.1 and is to be taken as specified in Table 2.4.1.

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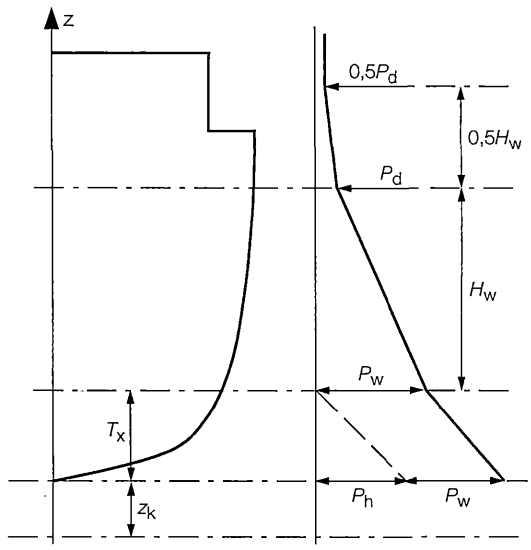

Fig. 2.4.1 Combined pressure distribution, P_s

Table 2.4.1 Combined pressure distribution, P_s

Vertical location i.e. z value	Shell envelope pressure, P_s kN/m^2
For $z \le T_x + z_k$ i.e. up to the operating waterline	$P_h + P_w$
At $z = T_x + z_k + H_w$	P_d
At $z \ge T_x + z_k + 1{,}5H_w$	$0{,}5P_d$
Symbols	
H_w is the nominal wave limit height, *see* 4.4.4 P_d is the weather deck pressure, *see* 4.5.1 P_h is the hydrostatic pressure, *see* 4.3 P_w is the hydrodynamic wave pressure, *see* 4.4 P_h and P_w are to be derived at the appropriate vertical position, z T_x, z and z_k are defined in 2.2	
NOTE Pressure values at other z values are to be derived by interpolation.	

4.3 Hydrostatic pressure on the shell plating

4.3.1 The pressure, P_h, acting on the shell plating up to the operating waterline due to hydrostatic pressure is to be taken as:

$$P_h = 10\,(T_x - (z - z_k))\ \text{kN/m}^2$$

where
T_x, z and z_k are defined in 2.2.

4.4 Hydrodynamic wave pressure

4.4.1 The hydrodynamic wave pressure distribution due to relative motion, P_w, around the shell envelope up to the operating waterline, i.e. $z \le T$, is to be taken as the greater of the following:

P_m kN/m^2 as defined in 4.4.2

P_p kN/m^2 as defined in 4.4.3.

4.4.2 The distribution of hydrodynamic pressure up to the operating waterline, P_m, is to be taken as:

$$P_m = 10 f_z H_{rm}\ \text{kN/m}^2$$

where

$$f_z = \text{the vertical distribution factor} = k_z + (1 - k_z)\left(\frac{z - z_k}{T_x}\right)$$

$$k_z = e^{-u}$$

$$u = \left(\frac{2\pi T_x}{L_{WL}}\right)$$

H_{rm} is defined in 3.1.1
z, z_k, T_x and L_{WL} are defined in 2.2.

4.4.3 The distribution of hydrodynamic pressure up to the operating waterline, P_p, is to be taken as:

$$P_p = 10 H_{pm}\ \text{kN/m}^2$$

where

$$H_{pm} = 1{,}1\left(\frac{2x_{wl}}{L_{WL}} - 1\right)\sqrt{L_{WL}}$$

but not less than $f_L\sqrt{L_{WL}}$

f_L = 0,6 for $L_{WL} < 60$
= 1,5 - 0,015L_{WL} for $60 \le L_{WL} \le 80$
= 0,3 for $L_{WL} > 80$

L_{WL} = as defined in 2.1.19, but not greater than 150 m
x_{wl} is defined in 3.1.

4.4.4 The nominal wave limit height, H_w, above the design draft, T_x, is to be taken as:

$$H_w = 2H_{rm}\ \text{m}$$

where
H_{rm} is given in 3.1.1.

4.5 Pressure on weather and interior decks

4.5.1 The pressure acting on weather decks, P_d, is to be taken as specified in 4.5.2 or 4.5.3 as applicable.

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4.5.2 The pressure acting on weather and interior decks, P_{wh}, in the displacement mode is to be taken as:

$$P_{wh} = f_L (6 + 0{,}01L_{WL})(1 + 0{,}05\Gamma) + E \quad kN/m^2$$

where

f_L = the location factor for weather decks
= 1,0 from aft end to $0{,}88L_R$
= 1,25 from $0{,}88L_R$ to $0{,}925L_R$
= 1,50 from $0{,}925L_R$ to forward end

f_L = 1,0 for interior decks

$E = \dfrac{0{,}7 + 0{,}08L_{WL}}{D - T}$ kN/m² for exposed decks but need not be taken greater than 3 kN/m²

E = 0,0 for sheltered decks

Γ = Taylor Quotient as defined in 2.1.17

Δ = the displacement as defined in 2.2

L_{WL} is as defined in 2.1.19.

4.5.3 The pressure acting on weather and interior decks, P_{wl}, in the non-displacement mode is to be taken as:

$$P_{wl} = f_L (5 + 0{,}01L_{WL})(1 + 0{,}5a_v) + E \quad kN/m^2$$

where f_L and E are as defined in 4.5.2, and a_v is as defined in Section 3.

- a_v is not to be taken less than 1,0, but need not be taken greater than 4,0, for weather decks.
- a_v need not be taken greater than 1,0 for interior decks.

L_{WL} is as defined in 2.1.19.

Section 5
Impact loads

5.1 Impact pressure for displacement mode

5.1.1 The impact pressure, P_{dh}, for mono-hull and multi-hull craft is to be taken as specified in 5.1.2 and 5.1.3 as applicable.

5.1.2 The bottom shell impact pressure due to bottom slamming is given by the following expression:

$$P_{dh} = \Phi_{dh}\left(19 - 2720\left(\frac{T_x}{L_{WL}}\right)^2\right)\sqrt{L_{WL}V} \quad kN/m^2$$

$P_{dh} \geq P_m$

Φ_{dh} = 0,09 at L_{WL} from aft end of L_{WL}
= 0,18 at $0{,}9L_{WL}$ from aft end of L_{WL}
= 0,18 at $0{,}8L_{WL}$ from aft end of L_{WL}
= 0,0 between aft end of L_{WL} and $0{,}5L_{WL}$ from aft end of L_{WL}

L_{WL} = waterline length, in metres, *see* 2.1.19

V = allowable speed in knots, *see* 2.1.2.

Intermediate values to be determined by linear interpolation.

T_x is taken to be the draught T, as defined in Pt 3, Ch 1,6, but need not be taken greater than $0{,}08L_{WL}$.

P_{dh} at $0{,}9L_{WL}$ and $0{,}8L_{WL}$ from aft end of L_{WL} need not be taken greater than P_f at L_{WL} from aft end of L_{WL} as defined in 5.4.1.

5.1.3 The side shell impact pressure shall be taken as P_{dh} at the operating waterline, reducing to $0{,}4P_{dh}$ at the weather deck. Intermediate values between the weather deck at side and operating waterline, are to be determined by linear interpolation.

5.2 Impact pressure for non-displacement mode

5.2.1 The impact pressure, P_{dl}, for mono-hull and multi-hull craft is to be taken as specified in 5.2.2 and 5.2.3 as applicable.

5.2.2 The bottom impact pressure due to slamming, P_{dlb}, is given by the following expression:

$$P_{dlb} = \frac{f_d \Delta \Phi (1 + a_v)}{L_{WL} G_o} \quad kN/m^2$$

where

G_o = support girth or girth distance, in metres, as defined in Table 2.5.1

L_{WL} = waterline length, in metres, *see* 2.1.19

a_v = vertical acceleration as defined in 3.2

Δ = displacement, in tonnes, *see* 2.2.2

f_d = hull form pressure factor
= 54 for mono-hull craft
= $\dfrac{81}{N_H}$ for catamarans and multi-hull craft, where

N_H is the number of hulls, but it is not to be taken as greater than four

For craft in continuous contact with water:

Φ = 0,5 at L_{WL} from aft end of L_{WL}
= 1,0 at $0{,}75L_{WL}$ from aft end of L_{WL}
= 1,0 at $0{,}5L_{WL}$ from aft end of L_{WL}
= 0,5 at aft end of L_{WL}

Intermediate values to be determined by linear interpolation. Otherwise, Φ = 1,0.

Table 2.5.1 Definition of G_o for the determination of bottom impact pressure, P_{dl}, for different regions of the hull

Bottom shell region	G_o	
	Craft with chines	Craft without chines
Between tangential points or chines	G_S	G_S
Between tangential points and design waterline	—	G_{WL}

NOTES
1. G_S = support girth, in metres, as defined in 2.1.15 at LCG.
2. G_{WL} = girth distance, in metres, measured between the waterlines on either side of a hull at the LCG.

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5.2.3 The side shell impact pressure due to slamming is to be taken as:

$$P_{dls} = P_{dlb} \frac{\tan(40 - \theta_B)}{\tan(\theta_S - 40)} \text{ kN/m}^2, \text{ but is not to be taken as greater than } P_{dlb}$$

where

θ_B = mean deadrise angle of bottom plating, in degrees at local section

θ_S = mean deadrise angle of side plating, in degrees at local section

$(40 - \theta_B)$ is not to be taken as less than 10 degrees

$(\theta_S - 40)$ is not to be taken as less than 10 degrees

P_{dls} is to be taken as constant from the chine or operating waterline to a point half G_o from this point, or the weather deck if this is reached first. Multiple chines will be subject to special consideration based on the above principle. *See* Fig. 2.5.1.

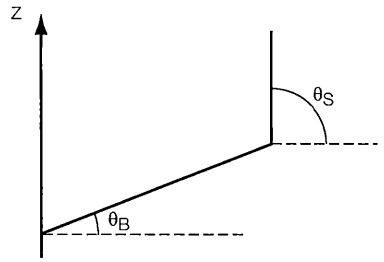

Fig. 2.5.1
Angles used in determination of side shell pressure for planing craft, P_{dls}

5.3 Impact pressure for craft with foils and lifting devices

5.3.1 The impact pressure, P_{fb}, for craft supported by hydrodynamic lift provided by foils or other lifting devices is to be taken as specified in 5.3.2 and 5.3.3, as applicable.

5.3.2 The bottom impact pressure is given by the greater of P_{fba} or P_{fbb}, where:

$$P_{fba} = \frac{16}{L_{WL}} \left(H_{03} + \sqrt{H_0 L_{WL}} \right)^2 \text{ kN/m}^2$$

$$P_{fbb} = \frac{1}{3} K_{po} V_R V \left(1 - \frac{H_0}{H_{03}} \right) \text{ kN/m}^2$$

where

K_{po} = longitudinal distribution factor
= 1,0 between the aft end of the L_{WL} and $0{,}75L_{WL}$
= 2,0 at L_{WL} from the aft end of L_{WL}, intermediate values to be determined by linear interpolation

H_0 = operational height of craft, in metres, measured from the waterline to the top of the keel at LCG

L_{WL} = waterline length, in metres, *see* 2.1.19

H_{03} = surviving waveheight as defined in 2.1.15 but is not taken as less than 1,0

V = allowable speed, in knots, *see* 2.1.2

P_{fbb} is not taken as less than zero.

V_R is the relative vertical speed of the craft at impact, in knots. If this value is unknown, then the following equation is to be used:

$$V_R = \frac{8H_{1/3}}{\sqrt{L_{WL}}} + 2 \text{ knots.}$$

5.3.3 The side shell impact pressure shall be taken as P_{fb} at the chine or at the operating waterline for round bilge hull-forms, as appropriate, reducing to $0{,}3P_{fb}$ at the weather deck. Intermediate values between the weather deck at side and the chine or operating waterline, as appropriate, are to be determined by linear interpolation.

5.4 Forebody impact pressure for displacement mode

5.4.1 Forebody and bow slamming pressure, P_f, at the load waterline due to relative motion is to be taken as:

$P_f = f_f L_{WL} (0{,}8 + 0{,}15\Gamma)^2$ kN/m^2 at FP

$P_f = P_{dh}$ at $0{,}9L_{WL}$ from aft end of L_{WL}

$= P_m$ at $0{,}75L_{WL}$ from aft end of L_{WL}

= 0,0 between aft end of L_{WL} and $0{,}75L_{WL}$ from aft end of L_{WL}

Intermediate values to be determined by linear interpolation

where

f_f = forebody impact pressure factor as defined in Table 2.5.2

L_{WL} = waterline length, in metres, *see* 2.1.19

Γ = Taylor Quotient, *see* 2.1.17.

Table 2.5.2 Forebody impact pressure factor

Craft type	f_f
Mono-hull craft in non-displacement mode	0,94
Mono-hull craft in displacement mode	0,89
Catamarans and multi-hull craft with partially submerged hulls	1,0
Swaths and multi-hull craft with fully submerged hulls	0,91
Craft supported by hydrodynamic lift provided by foils or other lifting devices	0,81

NOTE
Where multiple craft types apply, the higher value of f_f is to be used.

5.4.2 The side shell impact pressure shall be taken as P_f at the chine or at the operating waterline for round bilge hull-forms, as appropriate, reducing to $0{,}4P_f$ at the weather deck. Intermediate values between the weather deck at side and the chine or operating waterline, as appropriate, are to be determined by linear interpolation.

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5.5 Forebody impact pressure for non-displacement mode

5.5.1 Forebody and bow slamming pressure, P_f, at the load waterline due to relative motion is to be taken as:

P_f = the greater of P_{dls} or $f_f L_{WL} (0,8 + 0,15\Gamma)^2$ kN/m^2 at FP
= P_{dls} at $0,75L_{WL}$ from aft end of L_{WL}
= P_m at $0,5L_{WL}$ from aft end of L_{WL}
= 0,0 between aft end of L_{WL} and $0,5L_{WL}$ from aft end of L_{WL}

Intermediate values to be determined by linear interpolation.

where

f_f = forebody impact pressure factor as defined in Table 2.5.2
L_{WL} = waterline length, in metres, *see* 2.1.19
Γ = Taylor Quotient, *see* 2.1.17.

5.5.2 The side shell impact pressure shall be taken as P_f at the chine or at the operating waterline for round bilge hull-forms, as appropriate, reducing to $0,3P_f$ at the weather deck. Intermediate values between the weather deck at side and the chine or operating waterline, as appropriate, are to be determined by linear interpretation.

6.2 Impact pressure

6.2.1 The impact pressure, P_{pc}, acting on the underside of the cross deck ('wet deck') is to be taken as:

$$P_{pc} = \nabla_{pc} K_{pc} V_R V \left(1 - \frac{G_A}{H_{03}}\right) \text{ kN/m}^2$$

where

K_{pc} = longitudinal distribution factor
= 1,0 between the aft end of the L_{WL} and $0,75L_{WL}$
= 2,0 at the L_{WL} from the aft end of L_{WL}, intermediate values to be determined by linear interpolation
G_A = air gap, as defined in 2.1.1
H_{03} = surviving waveheight, as defined in 2.1.16
V = allowable speed, as defined in 2.1.2
∇_{pc} = cross-deck Impact Factor
= 1/6 for protected structures, as defined in 2.1.20
= 1/3 for unprotected structures, as defined in 2.1.21

V_R is the relative vertical speed of the craft at impact, in knots. If this value is unknown, then the following equation is to be used:

$$V_R = \frac{8H_{1/3}}{\sqrt{L_{WL}}} + 2 \text{ knots.}$$

■ *Section 6* Cross-deck structure for multi-hull craft

6.1 Cross-deck structure clearance

6.1.1 For craft with multi-hulls linked by cross-deck structure, sufficient clearance is to be provided between the cross-deck structure and water surface to limit impact loads.

6.1.2 Where part or all of the cross-deck is intended to provide additional buoyancy to limit craft motion, the loading will be specially considered.

6.1.3 In the determination of the clearance, the following factors are to be considered:

(a) Relative motion in waves.
(b) The wave generated between the hulls when running.
(c) The bow sinkage.

6.1.4 The submitted clearance must be validated either by calculations according to accepted theories, model tests, full scale measurements or by documentary evidence if similar structures have proved to be satisfactory in service.

6.1.5 Where it is not possible to provide sufficient clearance to avoid slamming of the cross-deck structure, the equation given in 6.2 is to be used for the assessment of the impact pressures.

■ *Section 7* Component design loads

7.1 Deckhouses, bulwarks and superstructures

7.1.1 The design pressure, P_{dhp}, for the plating of deckhouses, bulwarks and first tier and above superstructures is given by:

$$P_{dhp} = C_1 P_d \text{ kN/m}^2$$

For structures other than windows:

C_1 = 1,25 for deckhouse and superstructure fronts on upper deck within the forward third of L_R
= 1,15 for deckhouse and superstructure fronts on upper deck outside the forward third of L_R and exposed machinery casings on the upper deck
= 1,0 for deckhouse and superstructure fronts above the lowest tier
= 0,8 for superstructure sides. A value of 0,64 may be used where the sides of the superstructure are stepped in from the sides of the craft by 1,0 m or more
= 0,5 elsewhere

L_R = Rule length in metres, *see* 2.2.1

For windows of toughened safety glass:

$$C_1 = W_1 W_2 W_3$$

In no case is the design pressure for windows of toughened safety glass to be taken less than $P_{dhp,min}$ as given by:

$$P_{dhp,min} = W_1 G_f S_f (10 + 0,04L_{WL}) \text{ kN/m}^2$$

where

x_b = distance, in metres, from AP
y = vertical distance, in metres, from the static load waterline at the deepest design draught to the structural element considered
F = $(D - T)$ in metres

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L_{WL} = waterline length, in metres, *see* 2.1.19.
W_1 = 2,0 for the lowest tier of unprotected front
= 1,5 for superstructure fronts above the lowest tier
= 1,0 for superstructure sides. A value of 0,8 may be used where the sides of the superstructure are stepped in from the sides of the craft by 1,0 m or more
= 0,67 elsewhere
W_2 = 0,67 + 0,33 (x_b/L_{WL}) where $x_b > 0{,}5L_{WL}$ from AP
= 0,67 elsewhere
W_3 = $1 - (y - F)/y$
G_f and S_f are defined in Chapter 3 or Chapter 4 as appropriate.
P_d is defined in 4.5.
D and T are as defined in Pt 3, Ch 1,6.2.

7.2 Watertight and deep tank bulkheads

7.2.1 The design pressure, P_{bh}, on watertight and deep tank bulkheads is to be taken as:

P_{bh} = $11{,}2h_b$ kN/m^2 for deep tank bulkheads
= $7{,}2h_b$ kN/m^2 for watertight bulkheads

where
h_b = load head in metres, measured vertically as follows:

(a) Watertight bulkheads
(i) Plating: the distance from a point one-third of the height of the plate above its lower edge to the bulkhead deck at side.
(ii) Stiffeners: the distance from mid-point of stiffener span to the bulkhead deck at side.

(b) Deep tank bulkheads
For determination of head, the overflow is to be taken as not less than 1,8 m above the crown of the tank.
(i) Plating: the greater of:
- the distance from a point one-third of the height of the plate above its lower edge to the top of the tank
- half the distance from a point one third of the height of the plate above its lower edge to the top of the overflow.

(ii) Stiffeners: the greater of:
- the distance from mid-point of span to the top of the tank
- half the distance from mid point of span to the top of the overflow.

7.3 Pillars

7.3.1 The design load, P_{PI}, supported by a pillar is to be taken as:

P_{PI} = $S_{gt}\, b_{gt}\, P_c + P_a$ kN

where
b_{gt} = distance between centres of two adjacent spans of girders or transverses supported by the pillar, in metres
P_a = load, in kN, from pillar or pillars above, assumed zero if there are no pillars over
P_c = basic deck girder design pressure, as appropriate, plus any other loadings directly above the pillar, in kN/m^2
S_{gt} = spacing, or mean spacing, of girders or transverses, in metres

P_{PI} is not to be taken less than 5 kN.

7.4 Deck area designed for cargo, stores and equipment

7.4.1 The cargo deck design pressure, P_{cd}, for plating is to be taken as:

P_{cd} = $W_{CDP}(1 + 0{,}5a_x)$ kN/m^2

where a_x is given in Ch 2,3.1.7 and is not to be taken as less than 1,0.
W_{CDP} is the pressure exerted by the cargo on deck specified by the designer in kN/m^2.

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Local Design Criteria for Craft Operating in Non-Displacement Mode

Section

1 **General**

2 **Nomenclature and design factors**

3 **Hull envelope design criteria**

Section 1 General

1.1 Application

1.1.1 The design criteria given in this Chapter are applicable to craft when operating in the non-displacement mode, *see* Ch 1,1.1.

1.1.2 Planing and semi-planing craft are craft with Taylor's Quotient, Γ, as defined in Ch 2,2.1.17, greater than or equal to 3,0.

1.1.3 Light displacement craft are craft with displacement, Δ, in tonnes, less than or equal to $0{,}04(L_R\,B)^{1,5}$, as defined in Pt 1, Ch 2,2.2.10.

1.1.4 The design criteria detailed in this Chapter are to be used in conjunction with the load criteria given in Chapter 2 together with the strength formulae given in Parts 6, 7 and 8 to determine the scantlings of steel, aluminium alloy and composite craft respectively as defined in Part 1.

1.1.5 Alternative methods of establishing the design criteria will be specially considered, provided that they are based on established Codes or Standards acceptable to LR. In such cases, full details of the methods used are to be provided when plans are submitted for approval.

Section 2 Nomenclature and design factors

2.1 Nomenclature

2.1.1 The nomenclature used in this Chapter is given below:

P_p = pitching pressure, *see* Ch 2,4.4
P_{dl} = impact pressure, *see* Ch 2,5.2
P_{fb} = impact pressure for craft supported by hydrodynamic lift provided by foils or other lifting devices, *see* Ch 2,5.3
P_s = shell envelope pressure, *see* Ch 2,4.2
P_f = forebody impact pressure, *see* Ch 2,5.5
P_{cd} = cargo deck pressure, *see* Ch 2,7.4
P_{dhp} = deckhouse, bulwarks and superstructure pressure, *see* Ch 2,7.1
P_{bh} = watertight and deep tank bulkhead pressure, *see* Ch 2,7.2
P_{pc} = impact pressure acting on the cross-deck structure, *see* Ch 2,6.2
P_{wl} = pressure on weather deck, *see* Ch 2,4.5
P_{BP} = design pressure for bottom plating
P_{BF} = design pressure for bottom stiffening
P_{SP} = design pressure for side shell plating
P_{SF} = design pressure for side shell stiffening
P_{CP} = design pressure for cross-deck plating
P_{CF} = design pressure for cross-deck stiffening
P_h = hydrostatic pressure, *see* Ch 2,4.3
P_{WDP} = design pressure for weather deck plating
P_{WDF} = design pressure for weather deck stiffening
P_{CRP} = design pressure for coachroof plating
P_{CRF} = design pressure for coachroof stiffening
P_{IDP} = design pressure for interior deck plating
P_{IDF} = design pressure for interior deck stiffening
P_{IBP} = design pressure for inner bottom plating
P_{IBF} = design pressure for inner bottom stiffening
P_{DHP} = design pressure for deckhouse, bulwarks and superstructures plating and windows
P_{DHF} = design pressure for deckhouse, bulwarks and superstructure stiffening
P_{BHP} = design pressure for bulkheads
P_{CDP} = design pressure for cargo deck plating

Δ and Γ are defined in Ch 2,2.2.2 and Ch 2,2.1.17
T, L_R and B are as defined in Pt 3, Ch 1,6.2.

2.1.2 The unit for pressure is kN/m^2.

2.1.3 The design pressure, P, used in the scantling formulae given in Parts 3, 6, 7 and 8 is to be taken as equal to the appropriate value as defined in this Chapter.

2.2 Design factors

2.2.1 The design pressures on structural components are to be calculated taking into consideration the following factors:

(a) Hull notation assigned as defined in Pt 1, Ch 2,3.4.
(b) Service area restriction notation assigned as defined in Pt 1, Ch 2,3.5.
(c) Service type notation assigned as defined in Pt 1, Ch 2,3.6.
(d) Craft type notation assigned as defined in Pt 1, Ch 2,3.7.
(e) Type of stiffening members.

2.2.2 In general, the design pressure, in kN/m^2, for a particular structural component is to be determined as follows:

$$\text{Design pressure} = \delta_f H_f G_f S_f C_f \times \text{load criterion}$$

where

C_f = craft type notation factor given in Table 3.2.4
G_f = service area restriction notation factor given in Table 3.2.2
H_f = hull notation factor given in Table 3.2.1
S_f = service type factor notation given in Table 3.2.3
δ_f = stiffening type factor as given in Table 3.2.5.

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Table 3.2.1 Hull notation factor, H_f

Hull notation	Factor
HSC **LDC**	1,0 0,95
NOTE For a craft eligible for both **HSC** and **LDC** notation, the higher value is to be used. H_f is to be taken as 1,0 for a craft not eligible for either the **HSC** or the **LDC** notation.	

Table 3.2.2 Service area notation factor, G_f

Service area restriction notation	Factor
G1 **G2** **G2A** **G3** **G4** **G5** **G6**	0,6 0,75 0,8 0,85 1,0 1,2 1,25

Table 3.2.3 Service type notation factor, S_f

Service type notation	Factor
Cargo (A) **Cargo (B)** **Passenger** **Passenger (A)** **Passenger (B)** **Patrol** **Pilot** **Yacht** **Workboat**	1,0 1,1 1,0 1,0 1,1 1,2 1,25 1,1 1,25

Table 3.2.4 Craft type notation factor, C_f

Craft type notation	Factor
Catamaran **Hydrofoil** **Mono** **Multi** **RIB** **SES** **SWATH**	1,0 1,1 1,0 1,1 1,15 1,0 1,0

Table 3.2.5 Stiffening type factor, δ_f

Type	δ_f
Primary stiffening members and transverse frames	0,5
Secondary and local stiffening members Transverse beams	0,8

■ *Section 3*
Hull envelope design criteria

3.1 Hull structures

3.1.1 The design pressures, in kN/m^2, to be used to determine the scantlings of structural elements are to be taken as specified in Table 3.3.1.

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Table 3.3.1 Design pressures for non-displacement craft

Category/location	Craft type	Symbol	Plating pressure	Min.	Symbol	Stiffener pressure	Min.
Mono-hull craft							
Bottom shell	Basic craft	P_{BP}	Greater of $H_f S_f P_s$ $H_f S_f C_f P_{dl}$ $H_f S_f G_f C_f P_f$		P_{BF}	Greater of $\delta_f H_f S_f P_s$ $\delta_f H_f S_f C_f P_{dl}$ $\delta_f H_f S_f G_f C_f P_f$	
	Craft with foils or other lifting devices	P_{BP}	Greater of $H_f S_f P_s$ $H_f S_f C_f P_{fb}$		P_{BF}	Greater of $\delta_f H_f S_f P_s$ $\delta_f H_f S_f C_f P_{fb}$	
Side shell		P_{SP}	P_{BP}		P_{SF}	$\delta_f P_{BP}$	
Multi-hull craft							
Bottom shell	Basic craft	P_{BP}	Greater of $H_f S_f P_s$ $H_f S_f C_f P_{dl}$ $H_f S_f G_f C_f P_f$		P_{BF}	Greater of $\delta_f H_f S_f P_s$ $\delta_f H_f S_f C_f P_{dl}$ $\delta_f H_f S_f G_f C_f P_f$	
	Craft with foils or other lifting devices	P_{BP}	Greater of $H_f S_f P_s$ $H_f S_f C_f P_{fb}$		P_{BF}	Greater of $\delta_f H_f S_f P_s$ $\delta_f H_f S_f C_f P_{fb}$	
	Fully submerged hulls	P_{BP}	Greater of $H_f S_f P_s$ $H_f S_f G_f P_f$		P_{BF}	Greater of $\delta_f H_f S_f P_s$ $\delta_f H_f S_f G_f P_f$	
Outboard side shell		P_{SP}	P_{BP}		P_{SF}	$\delta_f P_{BP}$	
Inboard side shell		P_{SP}	Greater of P_{BP} 1,6 P_{WDP} at wet deck		P_{SF}	Greater of $\delta_f P_{BP}$ 1,9 P_{WDP} at wet deck	
Wet deck		P_{CP}	Greater of $H_f S_f P_p$ $H_f S_f P_{pc}$		P_{CF}	Greater of $\delta_f H_f S_f P_p$ $\delta_f H_f S_f P_{pc}$	
Components							
Weather deck *see* Note 1		P_{WDP}	Greater of $H_f S_f G_f C_f P_{wl}$ P_{cd}	7	P_{WDF}	Greater of $\delta_f H_f S_f G_f C_f P_{wl}$ P_{cd}	7
Coachroof, *see* Note 1		P_{CRP}	$H_f S_f G_f C_f P_{wl}$	7	P_{CRF}	$\delta_f H_f S_f G_f C_f P_{wl}$	7
Interior deck		P_{IDP}	Greater of $H_f S_f C_f P_{wl}$ P_{cd}	3,5	P_{IDF}	Greater of $\delta_f H_f S_f C_f P_{wl}$ P_{cd}	3,5
Deckhouses, bulwarks and superstructure		P_{DHP}	$H_f S_f G_f C_f P_{dhp}$		P_{DHF}	$\delta_f H_f S_f G_f C_f P_{dhp}$	
Inner bottom		P_{IBP}	$H_f S_f P_m + P_h$	$10T$	P_{IBF}	$\delta_f (H_f S_f P_m + P_h)$	$10T$
Watertight and deep tank bulkheads		P_{BHP}	P_{bh}		P_{BHF}	P_{bh}	

NOTES
1. G_f is not to be taken less than 1,0.
2. The result of each row in each cell is found as the product of all items on that row in that cell.

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Local Design Criteria for Craft Operating in Displacement Mode

Section

1 **General**

2 **Nomenclature and design factors**

3 **Hull envelope design criteria**

Section 1 General

1.1 Application

1.1.1 The design criteria given in this Chapter are applicable to all craft when operating in the displacement mode.

1.1.2 Displacement craft are craft with Taylor's Quotient, Γ, as defined in Ch 2,2.1.17, less than 3,0 and with displacement, Δ, in tonnes, greater than $0{,}04(L_R\,B)^{1,5}$, as defined in Ch 2,2.2.2.

1.1.3 The design criteria detailed in this Chapter are to be used in conjunction with the load criteria given in Chapter 2 together with the strength formulae given in Parts 6, 7 and 8 to determine the scantlings of steel, aluminium alloy and composite craft as defined in Part 1.

1.1.4 Alternative methods of establishing the design criteria will be specially considered, provided that they are based on established Codes or Standards acceptable to LR. In such cases, full details of the methods used are to be provided when plans are submitted for approval.

Section 2 Nomenclature and design factors

2.1 Nomenclature

2.1.1 The nomenclature used in this Chapter is given below:

P_p = pitching pressure, *see* Ch 2,4.4
P_{dh} = impact pressure, *see* Ch 2,5.1
P_{dhp} = deckhouse, bulwarks and superstructure pressure, *see* Ch 2,7.1
P_s = shell envelope pressure, *see* Ch 2,4.1
P_f = forebody impact pressure, *see* Ch 2,5.4
P_{pc} = impact pressure acting on the cross-deck structure, *see* Ch 2,6.2
P_{wh} = pressure on weather deck, *see* Ch 2,4.5
P_{cd} = cargo deck pressure, *see* Ch 2,7.4
P_{bh} = watertight and deep tank bulkhead pressure, *see* Ch 2,7.2
P_{BP} = design pressure for bottom plating
P_{BF} = design pressure for bottom stiffening
P_h = hydrostatic pressure, *see* Ch 2,4.3
P_{SP} = design pressure for side shell plating
P_{SF} = design pressure for side shell stiffening
P_{CP} = design pressure for cross-deck plating
P_{CF} = design pressure for cross-deck stiffening
P_{WDP} = design pressure for weather deck plating
P_{WCDF} = design pressure for weather deck stiffening
P_{CRP} = design pressure for coachroof plating
P_{CRF} = design pressure for coachroof stiffening
P_{IDP} = design pressure for interior deck plating
P_{IDF} = design pressure for interior deck stiffening
P_{IBP} = design pressure for inner bottom plating
P_{IBF} = design pressure for inner bottom stiffening
P_{DHP} = design pressure for deckhouse, bulwarks and superstructures plating and windows
P_{DHF} = design pressure for deckhouse, bulwarks and superstructure stiffening
P_{BHP} = design pressure for bulkheads
P_{CDP} = design pressure for cargo deck plating

Δ and Γ are defined in Ch 2,2.2.2 and Ch 2,2.1.17
T, L_R and B are as defined in Pt 3, Ch 1,6.2.

2.1.2 The unit for pressure is kN/m^2.

2.1.3 The design pressure, P, used in the scantling formulae given in Parts 3, 6, 7 and 8 is to be taken as equal to the appropriate value as defined in this Chapter.

2.2 Design factors

2.2.1 The design pressures on structural components are to be calculated taking into consideration the following factors:

(a) Hull notation assigned as defined in Pt 1, Ch 2,3.4.
(b) Service area restriction notation assigned as defined in Pt 1, Ch 2,3.5.
(c) Service type notation assigned as defined in Pt 1, Ch 2,3.6.
(d) Type of stiffening members.

2.2.2 In general the design pressure, in kN/m^2, for a particular structural component is to be determined as follows:

$$\text{Design pressure} = \delta_f H_f G_f S_f \times \text{load criterion}$$

where

G_f = service area restriction notation factor given in Table 4.2.1
H_f = 1,05
S_f = service type factor notation given in Table 4.2.2
δ_f = stiffening type factor as given in Table 4.2.3.

Table 4.2.1 Service area restriction notation factor, G_f

Service area restriction notation	Factor
G1	0,6
G2	0,75
G2A	0,8
G3	0,85
G4	1,0
G5	1,2
G6	1,25

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Table 4.2.2 Service type notation factor, S_f

Service type notation factor	Factor
Cargo (A)	1,0
Cargo (B)	1,1
Passenger	1,0
Passenger (A)	1,0
Passenger (B)	1,1
Patrol	1,2
Pilot	1,25
Yacht	1,1
Workboat	1,25

Table 4.2.3 Stiffening type factor, δ_f

Type	δ_f
Primary stiffening members and transverse frames	0,5
Secondary and local stiffening members Transverse beams	0,8

■ *Section 3* Hull envelope design criteria

3.1 Hull structures

3.1.1 The design pressures, in kN/m^2, to be used to determine the scantlings of structural elements are to be taken as specified in Table 4.3.1.

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Table 4.3.1 Design pressures for displacement craft

Category/location	Craft type	Symbol	Plating pressure	Min.	Symbol	Stiffener pressure	Min.
Mono-hull craft							
Bottom shell	Basic craft	P_{BP}	Greater of $H_f S_f P_s$ $H_f S_f G_f P_{dh}$ $H_f S_f G_f P_f$		P_{BF}	Greater of $\delta_f H_f S_f P_s$ $\delta_f H_f S_f G_f P_{dh}$ $\delta_f H_f S_f G_f P_f$	
Side shell		P_{SP}	P_{BP}		P_{SF}	$\delta_f P_{BP}$	
Multi-hull craft							
Bottom shell	Partially submerged hulls	P_{BP}	Greater of $H_f S_f P_s$ $H_f S_f G_f P_{dh}$ $H_f S_f G_f P_f$		P_{BF}	Greater of $\delta_f H_f S_f P_s$ $\delta_f H_f S_f G_f P_{dh}$ $\delta_f H_f S_f G_f P_f$	
	Fully submerged hulls	P_{BP}	Greater of $H_f S_f P_s$ $H_f S_f G_f P_f$		P_{BF}	Greater of $\delta_f H_f S_f P_s$ $\delta_f H_f S_f G_f P_f$	
Outboard side shell		P_{SP}	P_{BP}		P_{SF}	$\delta_f P_{BP}$	
Inboard side shell		P_{SP}	Greater of P_{BP} 1,6 P_{WDP} at wet deck		P_{SF}	Greater of $\delta_f P_{BP}$ 1,9 P_{WDP} at wet deck	
Wet deck		P_{CP}	Greater of $H_f S_f P_p$ $H_f S_f P_{pc}$		P_{CF}	Greater of $\delta_f H_f S_f P_p$ $\delta_f H_f S_f P_{pc}$	
Components							
Weather deck *see* Note 1		P_{WDP}	Greater of $H_f S_f G_f P_{wl}$ P_{cd}	7	P_{WDF}	Greater of $\delta_f H_f S_f G_f P_{wh}$ P_{cd}	7
Coachroof, *see* Note 1		P_{CRP}	$H_f S_f G_f P_{wl}$	7	P_{CRF}	$\delta_f H_f S_f G_f P_{wh}$	7
Interior deck		P_{IDP}	Greater of $H_f S_f P_{wh}$ P_{cd}	3,5	P_{IDF}	Greater of $\delta_f H_f S_f P_{wh}$ P_{cd}	3,5
Deckhouses, bulwarks and superstructure		P_{DHP}	$H_f S_f G_f P_{dhp}$		P_{DHF}	$\delta_f H_f S_f G_f P_{dhp}$	
Inner bottom		P_{IBP}	$H_f S_f P_m + P_h$	$10T$	P_{IBF}	$\delta_f (H_f S_f P_m + P_h)$	$10T$
Watertight and deep tank bulkheads		P_{BHP}	P_{bh}		P_{BHF}	P_{bh}	

NOTES
1. G_f is not to be taken less than 1,0.
2. The result of each row in each cell is found as the product of all items on that row in that cell.

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Section

1 **General**

2 **Hull girder load criteria for mono-hull craft**

3 **Hull girder load criteria for multi-hull craft**

4 **Primary load criteria for multi-hull craft**

5 **Design criteria and load combinations**

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■ *Section 1* General

1.1 Introduction

1.1.1 The global load and design criteria detailed in this Chapter are to be used in conjunction with Parts 6, 7 and 8 to determine the global hull strength requirements for steel, aluminium alloys and composite craft respectively as defined in Pt 1, Ch 2,2.1.1.

1.1.2 The global load and design criteria given in this Chapter are also provided to enable the designer/Builder to check global hull strength against ductile failure modes involving gross deformation.

1.1.3 The global load criteria are divided into two categories:

(a) Hull girder loads
The types of hull girder loads which are to be considered for strength purposes are distinguished on the basis of their frequencies and they are defined as follows:
(i) Still water bending moments and associated shear forces arising from mass distribution and buoyancy forces.
(ii) Vertical wave bending moments and associated shear forces arising from low frequency hydrodynamic forces.
(iii) Dynamic bending moments and associated shear forces arising from high frequency bottom slamming.

(b) Primary loads for multi-hull craft
These loads arise from the interaction between the hulls and waves.

1.1.4 Alternative methods of establishing the global load and design criteria will be specially considered, provided that they are based on model tests, full scale measurements or other generally accepted theories. In such cases, full details of the methods used and the results are to be provided when plans are submitted for approval.

1.1.5 Longitudinal strength calculations are to be carried out and submitted for approval for craft as required in Parts 6, 7 and 8, as appropriate, covering the range of load and ballast conditions proposed, in order to determine the required hull girder strength. The calculations of still water shear forces and bending moments are to cover both departure and arrival conditions and any special mid-voyage conditions caused by changes in ballast distribution.

1.1.6 L_R, B, D, T and C_b are as defined in Pt 3, Ch 1,6.

1.1.7 The vertical acceleration at the LCG, a_v, in terms of g, as defined in Ch 2,3.2, as appropriate, is not to be taken less than 1,0 for the purpose of determining the global load and design criteria.

■ *Section 2* Hull girder load criteria for mono-hull craft

2.1 General

2.1.1 The vertical bending moments specified here are applicable to all mono-hull craft as defined in Pt 1, Ch 2,2.2.12.

2.2 Vertical wave bending moments

2.2.1 For all craft except patrol craft in Service Group G6, the minimum value of vertical wave bending moment, M_W at any position along the craft may be taken as follows:

$M_W = F_f D_f M_o$ kNm

where

F_f = –1,1 for sagging (negative) moment
= $1{,}9C_b/(C_b + 0{,}7)$ for hogging (positive) moment

D_f = the longitudinal distribution factor
= 0 at aft end of L_R
= 1,0 between $0{,}4L_R$ and $0{,}65L_R$
= 0 at forward end of L_R

Intermediate values of D_f are to be determined by linear interpolation

$M_o = 0{,}1L_f G_f L_R^2 B (C_b + 0{,}7)$ kNm

L_f = $0{,}0412L_R + 4{,}0$, for $L_R < 90$ m
= $10{,}75 - (3 - 0{,}01L_R)^{1{,}5}$, for $L_R \geq 90$ m

G_f = Service group factor, *see* Pt 1, Ch 2,3.5.5
= 0,5 for G1 craft
= 0,6 for G2 craft
= 0,65 for G2A craft
= 0,7 for G3 craft
= 0,8 for G4 craft
= 1,0 for G5 and G6 craft (yachts only)

L_R = Rule length, in metres, as defined in Pt 3, Ch 1,6

C_b to be taken not less than 0,60.

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2.2.2 For patrol craft in Service Group G6, the minimum value of vertical wave bending moment, M_W, at any position along the ship may be taken as follows:

$M_W = F_f D_f M_o$ kNm

where

F_f is the hogging, F_{fH}, or sagging, F_{fS}, correction factor based on the amount of bow flare, stern flare, length and effective buoyancy of the aft end of the craft above the waterline. F_{fS} is the sagging (negative) moment correction factor and is to be taken as:

$F_{fS} = -1{,}10 R_A^{0,3}$ for values of $R_A \geq 1{,}0$

$F_{fS} = -1{,}10$ for values of $R_A < 1{,}0$

R_A is an area ratio factor, *see* 2.2.3

An area ratio value of 1,0 results in a sagging correction factor of –1,10

F_{fH} is the hogging (positive) moment correction factor and is to be taken as

$F_{fH} \equiv 1{,}9C_b/(C_b + 0{,}7)$

D_f = the longitudinal distribution factor

= 0 at aft end of L_R

= 1,0 between $0{,}4L_R$ and $0{,}65L_R$

= 0 at forward end of L_R

Intermediate values of D_f are to be determined by linear interpolation

$M_o = 0{,}1 L_f L_R^2 B_{WL} (C_b + 0{,}7)$ kNm

$L_f = 0{,}0412L_R + 4{,}0$, for $L_R < 90$ m

$= 10{,}75 - (3 - 0{,}01L_R)^{1,5}$, for $L_R \geq 90$ m

B_{WL} = maximum breadth at the design waterline, in metres

C_b to be taken not less than 0,60.

2.2.3 The area ratio factor, R_A, for the combined stern and bow shape is to be derived as follows:

$$R_A = \frac{30\,(A_{BF} + 0{,}5A_{SF})}{L_R B_{WL}}$$

where

A_{BF} is the bow flare area, in m^2, *see* 2.2.4

A_{SF} is the stern flare area, in m^2, *see* 2.2.5.

2.2.4 The bow flare area, A_{BF}, is illustrated in Fig. 5.2.1 and may be derived as follows:

$A_{BF} = A_{UB} - A_{LB}$ m^2

where

A_{UB} = half the water plane area at a waterline of $T_{C,U}$ of the bow region of the hull forward of $0{,}8L_R$ from the AP.

A_{LB} = half the water plane area at the design waterline of the bow region of the hull forward of $0{,}8L_R$ from the AP.

Note the AP is to be taken at the aft end of the Rule length, L_R

The design waterline is to be taken at T, *see* Pt 3, Ch 1.

Alternatively the following formula may be used:

$A_{BF} = 0{,}05L_R (b_0 + 2b_1 + b_2) + b_0 a/2$ m^2

where

b_0 = projection of $T_{C,U}$ waterline outboard of the design waterline at the FP, in metres, *see* Fig. 5.2.1

b_1 = projection of $T_{C,U}$ waterline outboard of the design waterline at $0{,}9L_R$ from the AP, in metres

b_2 = projection of $T_{C,U}$ waterline outboard of the design waterline at $0{,}8L_R$ from the AP, in metres

a = projection of $T_{C,U}$ waterline forward of the FP, in metres

$T_{C,U}$ is a waterline taken $L_f/2$ m above the design waterline

$T_{C,U} = T + L_f/2$ m

L_f is given in 2.2.2.

For ships with large bow flare angles above the $T_{C,U}$ waterline the bow flare area may need to be specially considered.

2.2.5 The stern flare area, A_{SF}, is illustrated in Fig. 5.2.1 and is to be derived as follows:

$A_{SF} = A_{US} - A_{LS}$ m^2

where

A_{US} = half the water plane area at a waterline of $T_{C,U}$ of the stern region of the hull from aft to $0{,}2L_R$ forward of the AP

A_{LS} = half the water plane area at a waterline of $T_{C,L}$ of the stern region of the hull from aft to $0{,}2L_R$ forward of the AP

$T_{C,L}$ is a waterline taken $L_f/2$ m below the design waterline

$T_{C,L} = T - L_f/2$ m

L_f is given in 2.2.2.

For craft with tumblehome in the stern region, the maximum breadth at any waterline less than $T_{C,U}$ is to be used in the calculation of A_{US}. The effects of appendages including bossings are to be ignored in the calculation of A_{LS}.

2.2.6 The sagging correction factor, F_{fS} , in the vertical wave bending moment formulation in 2.2.2 may be derived by direct calculation methods. Appropriate direct calculation methods may include a combination of long term ship motion analysis, non linear ship motion analysis and static balance on a wave crest or trough.

2.3 Still water bending moments

2.3.1 The still water bending moment, M_S, hogging and sagging is the maximum moment calculated from the loading conditions.

2.3.2 Still water bending moments are to be calculated along the craft length. For these calculations, downward loads are to be taken as positive values and are to be integrated in the forward direction from the aft end of L_R. Hogging bending moments are positive.

2.4 Wave shear force

2.4.1 The wave shear force, Q_W, at any position along the craft is given by:

$$Q_W = \frac{3K_f M_o}{L_R} \text{ kN}$$

where K_f is to be taken as follows:

(a) Positive shear force:

K_f = 0 at aft end of L_R

= $1{,}589C_b/(C_b + 0{,}7)$ between $0{,}2L_R$ and $0{,}3L_R$ from aft end of L_R

= 0,7 between $0{,}4L_R$ and $0{,}6L_R$ from aft end of L_R

= 1,0 between $0{,}7L_R$ and $0{,}85L_R$ from aft end of L_R

= 0 at forward end of L_R

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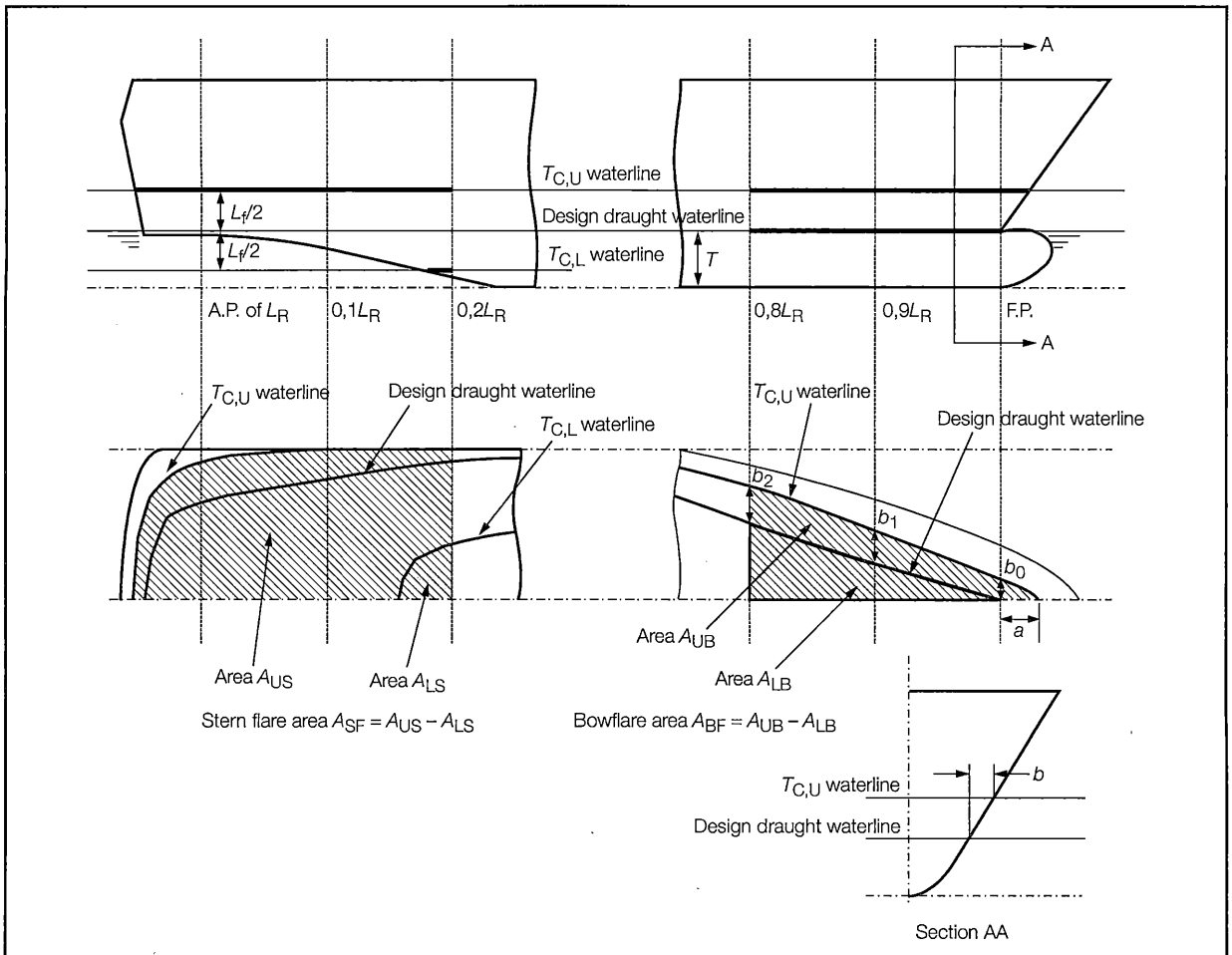

Fig. 5.2.1 Derivation of bow and stern flare areas

(b) Negative shear force:

K_f = 0 at aft end of L_R
= –0,92 between $0,2L_R$ and $0,3L_R$ from aft end of L_R
= –0,7 between $0,4L_R$ and $0,6L_R$ from aft end of L_R
= $-1,727C_b/(C_b + 0,7)$ between $0,7L_R$ and $0,85L_R$ from aft end of L_R
= 0 at forward end of L_R

Intermediate values to be determined by linear interpolation.

M_0, C_b are as defined in 2.2.1 and 2.2.2.

2.5 Still water shear force

2.5.1 The still water shear force, Q_s, at each transverse section along the hull is to be taken as the maximum positive and negative value found from the longitudinal strength calculations.

2.5.2 Still water shear forces are to be calculated at each section along the craft length. For these calculations, downward loads are to be taken as positive values and are to be integrated in a forward direction from the aft end of L_R. The shear force is positive when the algebraic sum of all vertical forces aft of the section is positive.

2.5.3 The actual shear force obtained from the longitudinal strength calculations may be corrected for the effect of local forces at the transverse bulkhead, if applicable.

2.6 Dynamic bending moments and associated shear forces

2.6.1 The dynamic bending moments, including wave and still water effects, specified here are applicable to all non-displacement mono-hull craft as defined in Pt 1, Ch 2,2.2.12.

2.6.2 The dynamic bending moment, due to slamming effects at amidships, is to be calculated using the following expression:

$M_{DW} = F_f D_f |M_D|$ kNm

where

$|M_D|$ is taken to be the absolute value of the function, irrespective of signs

$M_D = 51\Delta L_R (16a_v - 4a_b - 17a_s - 5)\ 10^{-3}$ kNm

Δ = displacement, in tonnes, as defined in Ch 2,2.2.2

F_f = –1,0 for sagging (negative) moment
= 1,0 for hogging (positive) moment

D_f = 0 at aft end of L_R

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= 1,0 between $0,4L_R$ and $0,65L_R$ from aft
= 0 at forward end of L_R

a_v = vertical acceleration at the LCG, in terms of g, as defined in Ch 2,3.2.4, *see also* 1.1.6

a_b = vertical acceleration at forward end of L_R, in terms of g

a_s = vertical acceleration at aft end of L_R, in terms of g

If the values of a_b and a_s are unknown, the distributions given in Ch 2,3.2.7 are applicable.

2.6.3 The bottom longitudinal amidships are additionally subjected to the following effective pressure, P_s:

$$P_s = 0,14P_{dl} + 8T \text{ kN/m}^2$$

where

P_{dl} is as defined in Ch 2,5.2.1. T is as defined in Pt 3, Ch 1,6.

2.6.4 The bottom plating amidships is subjected to the following additional effective pressure, P_t:

$$P_t = 0,175P_{dl} + 10T \text{ kN/m}^2$$

where

P_{dl} is as defined in Ch 2,5.2.1. T is as defined in Pt 3, Ch 1,6.

2.6.5 The dynamic shear force, Q_{DW}, at any position along the craft is given by:

$$Q_{DW} = \frac{4K_f M_D}{L_R} \text{ kN}$$

where M_D is as defined in 2.6.2 and K_f is as defined in 2.4.1.

■ *Section 3*
Hull girder load criteria for multi-hull craft

3.1 General

3.1.1 The vertical bending moments specified here are applicable to all multi-hull craft as defined in Pt 1, Ch 2,2.2.13.

3.1.2 L_R and T are as defined in Pt 3, Ch 1,6.

3.2 Vertical wave bending moments and associated shear forces

3.2.1 The vertical wave bending moments, M_{MW}, including wave and still water effects, at amidship is given by the following:

$$M_{MW} = F_f D_f M_M \text{ kNm}$$

where

$M_M = S_f G_f E_f C_{WP} L_S^{2,5} B_M$ kNm

C_{WP} = the waterplane area coefficient and is to be taken not less than 0,5

G_f = service group factor, *see* Pt 1, Ch 2,3.5.5
= 0,5 for G1 craft
= 0,6 for G2 craft
= 0,65 for G2A craft
= 0,7 for G3 craft
= 0,8 for G4 craft
= 1,0 for G5 and G6 craft

S_f = 1,1 for passenger and cargo craft
= 1,15 for craft other than cargo and passenger craft

E_f = 0,125 for sagging moment
= 0,2 for hogging moment

F_f = –1,0 for sagging (negative) moment
= 1,0 for hogging (positive) moment

D_f = 0 at aft end of L_R
= 1,0 between $0,4L_R$ and $0,65L_R$ from aft end of L_R
= 0 at forward end of L_R

B_M = total breadth of hulls or struts at LCG at the waterline, in metres, excluding tunnels

L_S = Rule length, L_R, in metres, for partially submerged hulls
= strut length, in metres, for fully submerged hulls.

3.2.2 The wave shear force, Q_{MW}, at any position along the craft is given by:

$$Q_{MW} = \frac{3K_f M_M}{L_S} \text{ kN}$$

where M_M is as defined in 3.2.1 and K_f is as defined in 2.4.1.

3.3 Dynamic bending moments

3.3.1 The dynamic bending moments, including wave and still water effects, specified here are applicable to all non-displacement multi-hull craft as defined in Pt 1, Ch 2,2.2.13.

3.3.2 The dynamic bending moment, M_{MDW}, due to slamming effects at amidships is to be calculated using the following expression:

$$M_{MDW} = F_f D_f M_{MD} \text{ kNm}$$

where

$M_{MD} = 52\Delta L_S (20 a_v - 5) \times 10^{-3}$ kNm

F_f = –1,0 for sagging (negative) moment
= 1,0 for hogging (positive) moment

D_f = 0 at aft end of L_R
= 1,0 between $0,4L_R$ and $0,65L_R$ from aft
= 0 at forward end of L_R

a_v = vertical acceleration at the LCG, in terms of g, as defined in Ch 2,3.2.5 as appropriate, *see also* 1.1.6

Δ = displacement, in tonnes, as defined in Ch 2,2.2.2

L_S is as defined in 3.2.1.

3.3.3 The bottom longitudinals amidships are additionally subjected to the following effective pressure, P_s:

$$P_s = 0,14P_{dl} + 8T \text{ kN/m}^2$$

where

P_{dl} is as defined in Ch 2,5.2.1. T is as defined in Pt 3, Ch 1,6.

3.3.4 The bottom plating amidships is subjected to the following additional effective pressure, P_t:

$$P_t = 0,175P_{dl} + 10T \text{ kN/m}^2$$

where

P_{dl} is as defined in Ch 2,5.2.1. T is as defined in Pt 3, Ch 1,6.

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3.3.5 The dynamic shear force, Q_{MDW}, at any position along the craft is given by:

$$Q_{MDW} = \frac{4K_f M_{MD}}{L_S} \text{ kN}$$

where M_{MD} is as defined in 3.3.2. and K_f as defined in 2.4.1.

Section 4
Primary load criteria for multi-hull craft

4.1 General

4.1.1 For multi-hull craft, the strength of the cross deck structure is to be checked for the loadings specified in this Section, *see also* 5.3.

4.1.2 Other values may be used provided they are verified by model experiments, full scale measurements or any other generally accepted theories. Full details are to be submitted for appraisal.

4.1.3 L_R and T are as defined in Pt 3, Ch 1,6.

4.2 Global loads for multi-hull craft with partially submerged hulls

4.2.1 The twin hull transverse bending moment, M_B, about a longitudinal axis is given by:

$M_B = G_f b \Delta a_v$ kNm

where

a_v = the vertical acceleration as defined in Ch 2,3.2, *see also* 1.1.6

b = transverse distance, in metres, between the centre of the two hulls

G_f = service group factor, *see* Pt 1, Ch 2,3.5.5
= 1,25 for G1 and G2
= 1,35 for G2A
= 1,50 for G3
= 2,00 for G4
= 2,50 for G5 and G6

Δ = displacement, in tonnes, as defined in Ch 2,2.2.2.

4.2.2 The twin hull torsional connecting moment, M_T, is given by:

$M_T = G_f \Delta L_R a_v$ kNm

where

G_f = service group factor, *see* Pt 1, Ch 2,3.5.5
= 0,63 for G1 and G2
= 0,70 for G2A
= 0,75 for G3
= 1,00 for G4
= 1,25 for G5 and G6

Δ = displacement, in tonnes, as defined in Ch 2,2.2.2

L_R = Rule length, in metres, as defined in Pt 3, Ch 1,6

a_v = the vertical acceleration as defined in Ch 2,3.2, *see also* 1.1.6.

4.2.3 The vertical shear force, Q_T, at the centreline of the cross-deck structure between the twin hulls is given by:

$Q_T = G_f \Delta a_v$ kN

where

G_f = service group factor, *see* Pt 1, Ch 2,3.5.5
= 1,25 for G1 and G2
= 1,35 for G2A
= 1,50 for G3
= 2,00 for G4
= 2,50 for G5 and G6

Δ = displacement, in tonnes, as defined in Ch 2,2.2.2

a_v = the vertical acceleration as defined in Ch 2,3.2, *see also* 1.1.6.

4.3 Global loads for multi-hull craft with fully submerged hulls

4.3.1 The design side force acting at mid-draught of the hull is given by:

$F_{FS} = G_f T \Delta^{2/3} \Psi_1 \Psi_2$ kN

where

G_f = service group factor, *see* Pt 1, Ch 2,3.5.5
= 8,5 for G1 and G2
= 9,4 for G2A
= 10,2 for G3
= 13,6 for G4
= 17,0 for G5 and G6

Δ = displacement, in tonnes, as defined in Ch 2,2.2.2

$\Psi_1 = 1{,}55 - 0{,}75\tanh(\Delta/11000)$

$\Psi_2 = 0{,}75 + 0{,}35\tanh(1{,}64 L_S \Delta^{-1/3} - 6)$

L_S = strut length, in metres, at waterline.

4.3.2 The lateral pressure acting on the outboard hull may be assumed to be constant and is given by:

$$P_{FS} = \frac{F_{FS}}{A_{FS}} \text{ kN/m}^2$$

where A_{FS} is the projected area, in m^2, of the struts with length L_S at waterline at draught T.

4.3.3 The design transverse bending moment, M_B, due to the side force is given as:

$M_B = F_{FS}(F + 0{,}5T)$ kNm

where F is the distance, in metres, from the waterline to the top of cross structure.

4.3.4 The twin hull torsional connecting moment, M_T, is given by:

$M_T = G_f \Delta L_R a_v$ kNm

where

G_f = service group factor, *see* Pt 1, Ch 2,3.5.5
= 0,63 for G1 and G2
= 0,70 for G2A
= 0,75 for G3
= 1,00 for G4
= 1,25 for G5 and G6

Δ = displacement, in tonnes, as defined in Ch 2,2.2.2

a_v = the vertical acceleration as defined in Ch 2,3.2, *see also* 1.1.6

L_R = Rule length, in metres, as defined in Pt 3, Ch 1,6

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4.3.5 The vertical shear force, Q_T, at the centreline of the cross-deck structure between the twin hulls is given by:

$Q_T = G_f \Delta a_v$ kN

where

G_f = service group factor, *see* Pt 1, Ch 2,3.5.5
= 1,25 for G1 and G2
= 1,35 for G2A
= 1,50 for G3
= 2,00 for G4
= 2,50 for G5 and G6

Δ = displacement, in tonnes, as defined in Ch 2,2.2.2

a_v = the vertical acceleration as defined in Ch 2,3.2, *see also* 1.1.6.

■ *Section 5* Design criteria and load combinations

5.1 Hull girder design criteria for mono-hull craft

5.1.1 The Rule bending moment, M_R, and associated shear forces, Q_R, for non-displacement craft are to be determined as follows:

(a) The Rule bending moment, M_R, is to be taken as the greater of $(M_w + M_S)$, as defined in 2.2 and 2.3 and M_{DW}, as defined in 2.6, taking into account the hogging and sagging conditions.

(b) The Rule shear forces, Q_R, is to be taken as the greater of $(Q_w + Q_S)$, as defined in 2.4 and 2.5 and Q_{DW}, as defined in 2.6, taking into account of the hogging and sagging conditions.

5.1.2 The Rule bending moment, M_R, and associated shear forces, Q_R, for displacement craft are taken to be the greater of the following:

(a) The Rule bending moment, M_R, is to be taken as $(M_w + M_S)$, as defined in 2.2 and 2.3, taking into account the hogging and sagging conditions.

(b) The Rule shear forces, Q_R, are to be taken as $(Q_w + Q_S)$, as defined in 2.4 and 2.5, taking into account the hogging and sagging conditions.

5.1.3 L_R and B are as defined in Pt 3, Ch 1,6. Γ and Δ are defined in Ch 2,2.1.17 and Ch 2,2.2.2 respectively.

5.2 Hull girder design criteria for multi-hull craft

5.2.1 The Rule bending moment, M_R, and associated shear forces, Q_R, for non-displacement craft are to be determined as follows:

(a) The Rule bending moment, M_R, is to be taken as the greater of M_{MW}, as defined in 3.2 and M_{MDW}, as defined in 3.3, taking into account the hogging and sagging conditions.

(b) The Rule shear forces, Q_R, are to be taken as the greater of Q_{MW}, as defined in 3.2 and Q_{MDW}, as defined in 3.3, taking into account the hogging and sagging conditions.

5.2.2 The Rule bending moment, M_R, and associated shear forces, Q_R, for displacement craft are taken to be the greater of the following:

(a) The Rule bending moment, M_R, is to be taken as M_{MW}, as defined in 3.2, taking into account the hogging and sagging conditions.

(b) The Rule shear forces, Q_R, are to be taken as Q_{MW}, as defined in 3.2, taking into account the hogging and sagging conditions.

5.2.3 L_R and B are as defined in Pt 3, Ch 1,6. Γ and Δ are defined in Ch 2,2.1.17 and Ch 2,2.2.2 respectively.

5.3 Primary load combinations applicable to the cross-deck structure of multi-hull craft

5.3.1 If the global load criteria given in this Chapter are utilised to check cross-deck strength against ductile failure modes involving gross deformation, the following load combinations are to be considered depending on heading of the craft:

(a) Head sea
$0{,}1M_B + M_R + 0{,}1M_T$

(b) Beam sea
$M_B + 0{,}1M_R + 0{,}2M_T$

(c) Quartering sea
$0{,}1M_B + 0{,}4M_R + M_T$

M_B, M_T and M_R are to be taken from 4.2.1, 4.2.3 and 5.2 for multi-hull craft with partially submerged hulls.

M_B, M_T and M_R are to be taken from 4.3.1, 4.3.3 and 5.2 for multi-hull craft with fully submerged hulls.

5.3.2 The strength calculations are, in general, to be conducted using the finite element analysis techniques with a three dimensional model.

■ *Section 6* Loading guidance information

6.1 General

6.1.1 Sufficient information is to be supplied to every craft to enable the Master to arrange loading and ballasting in such a way as to avoid the creation of unacceptable stresses in the craft's structure.

6.1.2 This information is to be provided by means of a Loading Manual and in addition, where required, by means of an approved loading instrument.

6.1.3 An Operational manual which contains the craft's assigned operational envelope is to be provided on board, *see* Pt 1, Ch 2,2 and Ch 1,1.

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6.2 Loading Manuals

6.2.1 A Loading Manual is to be supplied to all craft where longitudinal strength calculations have been required, *see* Ch 5,1. The Manual is to be submitted for approval in respect of strength aspects. Where both Loading Manual and loading instrument are supplied the Loading Manual must nevertheless be approved from the strength aspect. In this case the Manual is to be endorsed to the effect that any departures from these conditions in service are to be arranged on the basis of the loading instrument and the allowable local loadings shown in the Manual.

6.2.2 The Loading Manual is to be based on the final data of the craft and is to include well-defined lightweight distribution and buoyancy data.

6.2.3 Details of the loading conditions are to be included in the manual as applicable.

6.2.4 The Loading Manual is also to contain the following:

(a) Values of actual and permissible still water bending moments and shear forces and where applicable limitations due to torsional loads.

(b) The allowable local loadings for the structure.

(c) Details of cargo carriage constraints imposed by the use of an accepted coating in association with a system of corrosion control.

(d) A note saying:
'Scantlings approved for minimum draught forward of ...m with ballast tanks No ... filled. In heavy weather conditions the forward draught is not to be less than this value. If, in the opinion of the Master, sea conditions are likely to cause regular slamming, then other appropriate measures such as change in speed, heading or an increase in draught forward may also need to be taken.'

6.2.5 Where alteration to structure, lightweight, cargo distribution or draught is proposed, revised information is to be submitted for approval.

6.3 Loading instrument

6.3.1 In addition to a Loading Manual, an approved type loading instrument is to be provided for craft when it is deemed necessary by Lloyd's Register (hereinafter referred to as LR).

6.3.2 The loading instrument is to be capable of calculating shear forces and bending moments, and where necessary cargo torque, in any load or ballast condition at specified readout points and is to indicate the permissible values. The instrument is to be certified in accordance with LR's *Approval of Longitudinal Strength and Stability Calculation Programs.*

6.3.3 The instrument readout points are usually selected at the position of the transverse bulkheads or other obvious boundaries. As many readout points as considered necessary by LR are to be included, e.g. between bulkheads.

6.3.4 A notice is to be displayed on the loading instrument stating:
'Scantlings approved for minimum draught forward of ... m with ballast tanks No ... filled. In heavy weather conditions the forward draught is not be to less than this value. If, in the opinion of the Master, sea conditions are likely to cause regular slamming, then other appropriate measures such as change in speed, heading or an increase in draught forward may also need to be taken.'

6.3.5 Where alteration to structure, lightweight or cargo distribution is proposed, the loading instrument is to be modified accordingly and details submitted for approval.

6.3.6 The operation of the loading instrument is to be verified by the Surveyor upon installation and at Annual and Periodical Surveys as required in Pt 1, Ch 3. An Operation Manual for the instrument is to be verified as being available on board.

6.3.7 Where an onboard computer system having a longitudinal strength or a stability computation capability is provided as an Owner's option, it is recommended that the system be certified in accordance with LR's document entitled *Approval of Longitudinal Strength and Stability Calculation Programs.* For systems having a stability computation capability and installed on a new ship, *see also* Pt 1, Ch 2,1.1.10. For systems having a stability computation capability and installed on an existing craft, it is recommended that the system be certified in accordance with LR's document entitled, *Approval of Longitudinal Strength and Stability Calculation Programs.*

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Rules and Regulations for the Classification of Special Service Craft

Volume 4
Part 6
Hull Construction in Ships
July 2012

Lloyd's Register
LIFE MATTERS

002632

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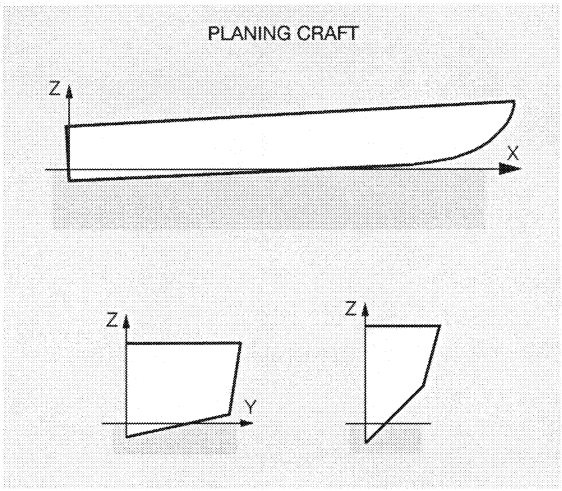
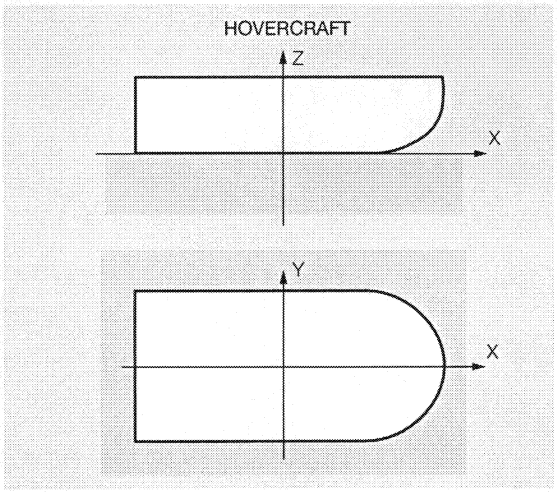
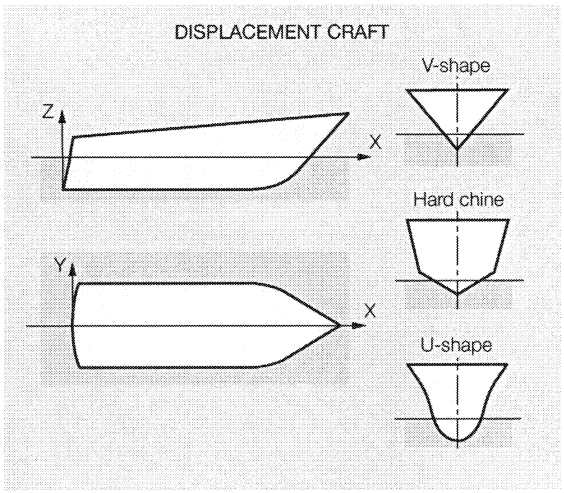
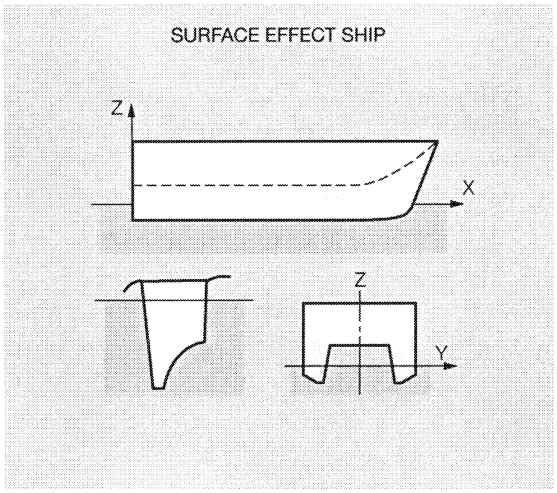
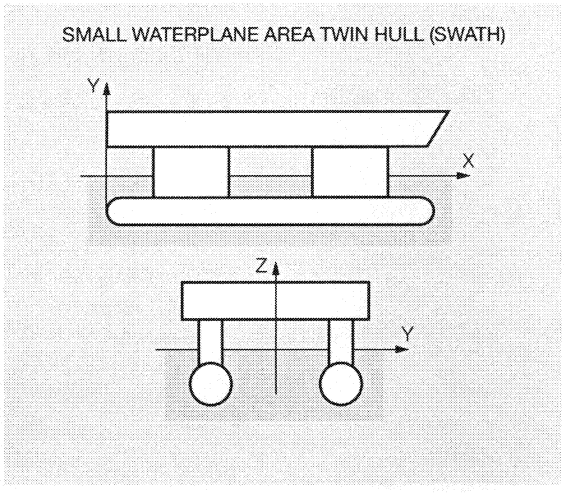
DIFFERENT TYPES OF HULL FORMS COVERED BY THE SPECIAL SERVICE CRAFT RULES

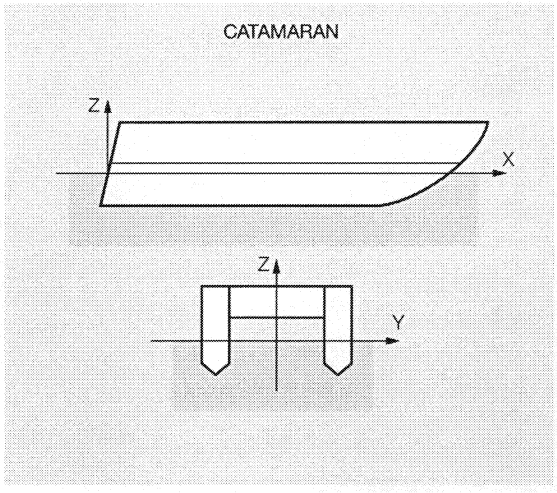












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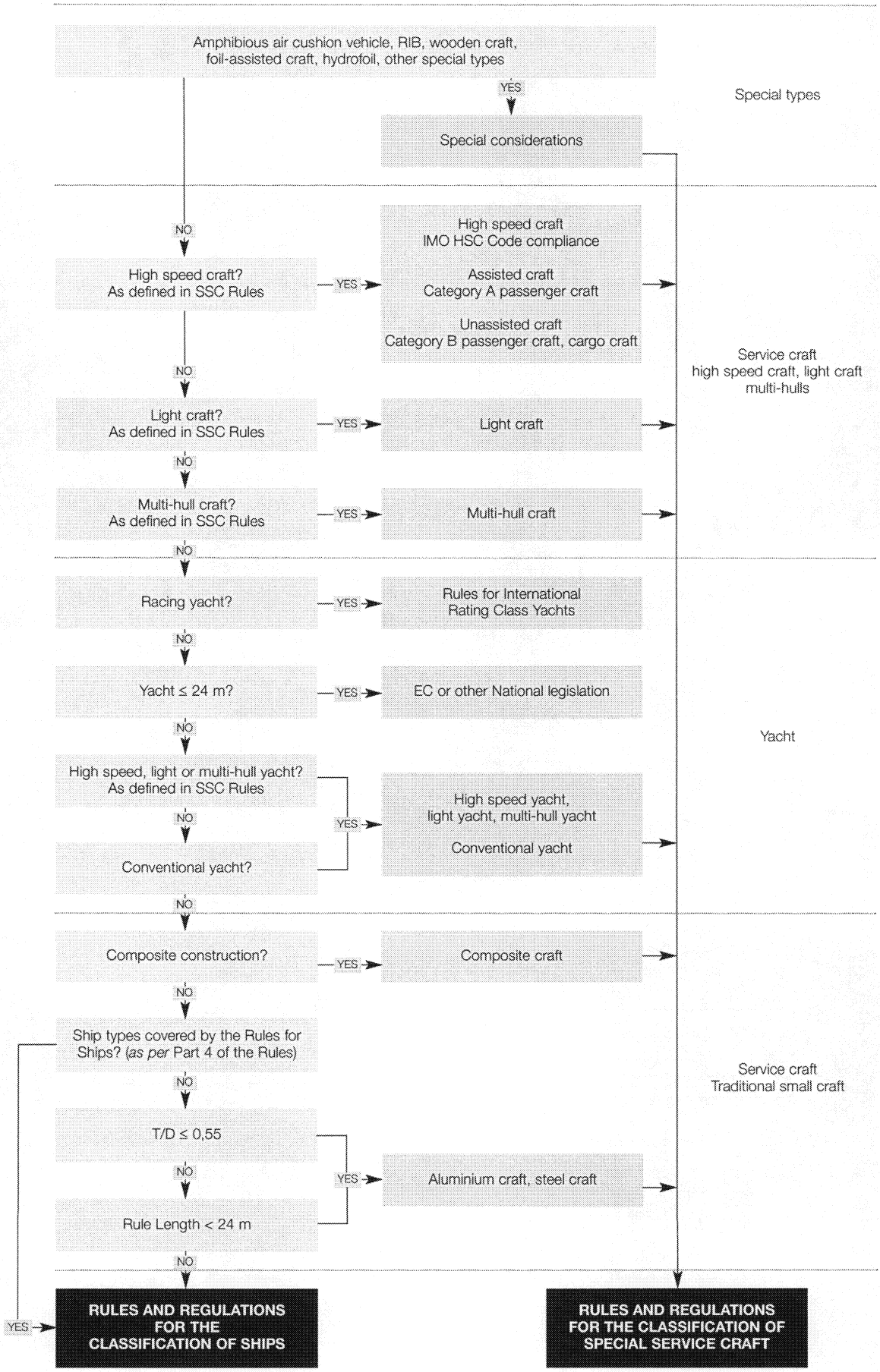

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Section

1 **Application**

2 **General requirements**

■ *Section 1* Application

1.1 General

1.1.1 The Rules apply to mono and multi-hull craft of normal form, proportions and speed. Although the Rules are, in general, for steel craft of all welded construction, other materials for use in hull construction will be specially considered on the basis of the Rules.

1.2 Interpretation

1.2.1 The interpretation of the Rules is the sole responsibility and at the sole discretion of Lloyd's Register (hereinafter referred to as 'LR'). Where there is any doubt regarding the interpretation of the Rules it is the Builders' and/or designers' responsibility to obtain clarification from LR prior to submission of plans and data for appraisal.

1.2.2 Where applicable, the Rules take into account unified requirements and interpretations established by the International Association of Classification Societies (IACS).

1.2.3 Attention is drawn to the fact that Codes of Practice issued by IMO contain requirements which are outside classification as defined in the Rules.

1.3 Equivalents

1.3.1 Alternative scantlings and arrangements may be accepted as equivalent to the Rule requirements. Details of such proposals are to be submitted for consideration in accordance with Pt 3, Ch 1,3.

1.4 Symbols and definitions

1.4.1 The symbols and definitions for use throughout this Part are as defined within the appropriate Chapters and Sections.

■ *Section 2* General requirements

2.1 General

2.1.1 Limitations with regard to the application of these Rules are indicated in the various Chapters for differing craft types.

2.2 Aesthetics

2.2.1 LR is not concerned with the general arrangement, layout and appearance of the craft; the responsibility for such matters remains with the Builders and/or designers to ensure that the agreed specification is complied with. LR is however concerned with the quality of workmanship, in this respect the acceptance criteria as required by Rules are to be complied with.

2.3 Constructional configuration

2.3.1 The Rules provide for the basic structural configurations for both single and multi-deck mono and multi-hull craft with multi-deck or a single deck hulls which include a double bottom, or a single bottom arrangement. The structural configuration may also include a single or multiple arrangement of cargo hatch openings, and side tanks.

2.3.2 The Rules provide for longitudinal and transverse framing systems.

2.3.3 Novel or other types of framing systems will be considered on the basis of the Rules.

2.4 Plans to be submitted

2.4.1 Plans covering the following items are to be submitted:

- Midship sections showing longitudinal and transverse material.
- Profile and decks.
- Shell expansion.
- Oiltight and watertight bulkheads.
- Propeller brackets.
- Double bottom construction.
- Pillars and girders.
- Aft end construction.
- Engine room construction.
- Engine and thrust seatings.
- Fore end construction.
- Hatch cover construction.
- Deckhouses and superstructures.
- Sternframe.
- Rudder, stock and tiller.
- Equipment.
- Loading Manuals, preliminary and final (where applicable).
- Scheme of corrosion control (where applicable).
- Ice strengthening.
- Welding schedule.

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- Hull penetration plans.
- Support structure for masts, derrick posts or cranes.
- Bilge keels showing material grades, welded connections and detail design.

2.4.2 The following supporting documents are to be submitted:

- General arrangement.
- Capacity plan.
- Lines plan or equivalent.
- Dry-docking plan.
- Towing and mooring arrangements.
- Sail/rigging plan, indicating loadings (as applicable to sailing craft).

2.4.3 The following supporting calculations are to be submitted:

- Equipment Number.
- Hull girder still water and dynamic bending moments and shear forces as applicable.
- Midship section modulus.
- Structural items in the aft end, midship and fore end regions of the craft.
- Preliminary freeboard calculation.

2.5 Novel features

2.5.1 Where the proposed construction of any part of the hull or machinery is of novel design, or involves the use of unusual material, or where experience, in the opinion of LR, has not sufficiently justified the principle or mode of application involved, special tests or examinations before and during service may be required. In such cases a suitable notation may be entered in the *Register Book*.

2.6 Enhanced scantlings

2.6.1 Where the Owner decides to increase the scantling of the bottom shell, side shell and deck plating of a newbuilding, then the craft will be eligible to be assigned the description note **ES**, *see* Pt 1, Ch 2,3.12. For example, the descriptive note **ES+1** would indicate that an extra 1 mm of steel has been fitted to bottom shell, side shell and deck plating.

2.7 Direct calculations

2.7.1 Direct calculations may be specifically required by the Rules and may be required for craft having novel design features or in support of alternative arrangements and scantlings. LR may, when requested, undertake calculations on behalf of designers and make recommendations with regard to suitability of any required model tests.

2.7.2 Where direct calculations are proposed then the requirements of Pt 3, Ch 1,2 are, in general, to be complied with.

2.8 Exceptions

2.8.1 Craft of unusual form, proportions or speed, intended for the carriage of special cargoes, or for special or restricted service, not covered specifically by the Rules, will receive individual consideration based on the general requirements of the Rules.

2.9 Advisory services

2.9.1 The Rules do not cover certain technical characteristics, such as stability, except as mentioned in Pt 1, Ch 2,1.1.11, 1.1.13 and 1.1.14, trim, vibration (other than local stiff end flat panels, *see* Ch 1,5), docking arrangements, etc. The Committee cannot assume responsibility for these matters but is willing to advise upon them on request.

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Section

1 **General**

2 **Materials**

3 **Procedures for welded construction**

4 **Joints and connections**

Section 1 General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull and multi-hull craft of steel construction as defined in Pt 1, Ch 1,1.

1.2 General

1.2.1 This Chapter contains the general Rule requirements for the construction of steel craft using electric arc welding processes. Where alternative methods of construction are proposed, details are to be submitted for consideration by Lloyd's Register (hereinafter referred to as 'LR').

1.3 Symbols and definitions

1.3.1 The symbols and definitions used in this Chapter are defined in the appropriate Section.

1.4 Builder's facilities

1.4.1 The buildings used for production and storage are to be of suitable construction and equipped to provide the required environment, and are also to comply with any local or National Authority requirements.

1.4.2 The Surveyor is to be allowed unrestricted access during working hours to such parts of the Builder's establishment as may be necessary to ensure that the requirements of the Rules are being complied with.

1.5 Works inspection

1.5.1 Prior to the commencement of construction, the facilities are to be inspected to the satisfaction of the attending Surveyor. This will include the minimum quality control arrangements outlined in 1.6.

1.5.2 The Surveyor is to be satisfied that the Builder has the organisation and capability to construct craft to the standards required by the Rules.

1.5.3 The Builder is to be advised of the result of the inspection and all deficiencies are to be rectified prior to the commencement of production.

1.5.4 Where structural components are to be assembled and welded by sub-contractors, the Surveyors are to inspect the sub-contractor's works to ensure that compliance with the requirements of this Chapter can be achieved.

1.6 Quality control

1.6.1 For compliance with 1.5.2, LR's methods of survey and inspection for hull construction and machinery installation are to include procedures involving the shipyard management, organisation and quality systems.

1.6.2 The extent and complexity of the quality systems will vary considerably depending on the size and type of craft and production output. LR will consider certification of the Builder in accordance with the requirements of one of the following systems:

(a) Quality Assurance System in accordance with an International or National Standard (i.e. ISO 9000 and BS ENISO 9001) with assessment and certification carried out by a nationally accredited body.

(b) LR's Quality Assurance Scheme for the Construction of Special Service Craft.

(c) LR's locally accepted Quality Control System – The Builder is implementing a documented Quality Control System which controls the following activities:
  (i) Receipt storage and issue of materials, equipment, etc.
  (ii) Fabrication environment.
  (iii) Weld procedures and welder performance.
  (iv) Production fabrication.
  (v) Inspection of production processes.
  (vi) Installation of machinery and essential systems.
  (vii) Fitting-out.
  (viii) Tests and trials.
  (ix) Drawings and document control.
  (x) Records.

1.6.3 LR's involvement is only in that part of the system which controls the standards required to meet the classification requirements.

1.6.4 The 'documented' quality control system will in general require the Builder to have written procedures that describe clearly and unambiguously how each of the activities specified in 1.6.2(c) is carried out, when it is carried out and by whom. These procedures will form part of the system manual which is also to contain a statement of management policy, organisation chart and statements of responsibilities. The manual is to be controlled in respect to the formal issue and revision.

1.6.5 Further details of LR's requirements are available on request from the local LR office.

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1.7 Building environment

1.7.1 The craft is to be suitably protected during the building period from adverse weather and climatic conditions.

1.8 Storage areas

1.8.1 All materials are to be stored safely and in accordance with the manufacturer's requirements. Storage arrangements are to be such as to prevent deterioration through contact with heat, sunlight, damp, cold and poor handling.

1.8.2 All storage spaces provided by the Builder for welding consumables are to be suitable for maintaining them in good condition and are to be in accordance with the manufacturer's recommendations.

1.8.3 All materials are to be fully identifiable in the storage areas, and identification is to be maintained during issue to production.

1.8.4 Material suspected of being non-conforming is to be segregated from acceptable materials.

1.9 Materials handling

1.9.1 The Builder is to maintain purchasing documents containing a clear description of the materials ordered for use in hull construction and the standards to which the material must conform, together with the identification and certification requirements.

1.9.2 The Builder is to be responsible for ensuring that all incoming plates, sections, castings, components, fabrications and consumables and other materials used in the hull construction are inspected or otherwise verified as conforming to purchase order requirements.

1.9.3 The Builder is to have procedures for the inspection, storage and maintenance of Owner supplied materials and equipment.

1.9.4 The Builder is to record, on receipt, the manufacturing date, or use-by date of critical materials. Any materials which have a shelf life are to be used in order of manufacturing date to ensure stock rotation.

1.9.5 The Builder is to establish and maintain a procedure to ensure that materials and consumables used in the hull construction process are identified (by colour-coding and/or marking as appropriate) from arrival in the yard through to fabrication in such a way as to enable the type and grade to be readily recognised.

1.9.6 Where materials are found to be defective they are to be rejected in accordance with the Builder's quality control procedure.

1.10 Faults

1.10.1 All identified faults are to be recorded under the requirements of the quality control systems. Faults are to be classified according to their severity and are to be monitored during Periodical Survey.

1.10.2 Production faults are to be discussed with the attending Surveyor and a rectification scheme agreed. Deviations from the approved plans are to be locally approved by the attending Surveyor and a copy forwarded to the plan approval office for record purpose.

1.11 Inspection

1.11.1 On acceptance of a 'Request for Services' the attending Surveyor is to inform the Builder of the key stages of the production that are to be inspected and the extent of the inspection to be carried out.

1.11.2 It is the Builder's responsibility to carry out required inspections in accordance with the accepted quality control system.

1.11.3 It is the Surveyor's responsibility to monitor the Builder's quality control records and carry out inspections at key stages and during periodic visits.

1.11.4 Adequate facilities are to be provided to enable the Surveyor to carry out a satisfactory inspection and to facilitate subsequent in-service maintenance. These are to include the provision of access holes in restricted spaces and removable deck head and shipside linings, cabin soles, etc.

1.11.5 During inspections all deviations are to be dealt with in accordance with 1.6.4.

1.12 Acceptance criteria

1.12.1 Classification is dependent upon the work being carried out in accordance with the approved plans and the requirements of an accepted quality control system.

1.12.2 The work is to be carried out to the satisfaction of the attending Surveyor. This will include the verification of the quality control documentation and the remedial action associated with all defects and deficiencies recorded.

1.12.3 Proposed deviations from the approved plans are subject to LR approval and in the first instance are to be discussed with the attending Surveyor. Where applicable, an amended plan is to be submitted to the plan appraisal office. Such deviations will be recorded as endorsements to the classification unless specifically agreed otherwise with the plan appraisal office.

1.12.4 Where the above requirements are met the attending Surveyor will arrange for the relevant certification to be issued.

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1.13 Repair

1.13.1 Minor repairs are to be agreed with the attending Surveyor and a rectification scheme agreed with the Builder. The Builder is to incorporate details of the agreed repair procedures in the quality control system in accordance with 1.6.4.

1.13.2 Repairs which affect the structural integrity are to be discussed with the Builder and the Builder's proposed rectification scheme is to be submitted to the plan appraisal office for consideration.

■ *Section 2* Materials

2.1 General

2.1.1 The materials used in the construction of the craft are to be manufactured and tested in accordance with the appropriate requirements of Chapter 3 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

2.1.2 All materials are to be manufactured at works which have been approved by LR for the type and, where appropriate, grade of steel which is being supplied and for the relevant steel production and processing route.

2.2 Grade of steel

2.2.1 The grade of steel, supply condition and its mechanical properties are to be indicated on the construction plans.

2.2.2 When plate material, intended for welded construction, will be subject to significant strains in a direction perpendicular to the rolled surfaces, it is recommended that consideration be given to the use of special plate material with specified through thickness properties, and tested in accordance with Ch 3,8 of the Rules for Materials.

2.3 Steel castings and forgings

2.3.1 Where steel castings or forgings are used for sternframes, rudder frames, rudder stocks, propeller shaft brackets and other major structural items, they are to comply with Chapter 4 or Chapter 5, as appropriate.

2.4 Mechanical properties for design

2.4.1 The scantlings determined within this Part of the Rules assume that mild steel has the following mechanical properties:

	N/mm^2
Yield strength (minimum)	235
Tensile strength	400 – 490
Modulus of elasticity	200 x 10^3

2.4.2 Steel having a specified minimum yield stress of 235 N/mm^2 (24 kgf/mm^2) is regarded as mild steel. Steel having a higher specified minimum yield stress is regarded as higher tensile steel.

2.4.3 The requirements for global strength considerations in craft incorporating higher tensile steel materials are to be based on a material efficiency factor, η_{HTS}, as given in Table 2.2.1.

Table 2.2.1 Values of η_{HTS}

Specified minimum yield stress in N/mm^2	η_{HTS}
235	1,000
265	0,964
315	0,956
340	0,934
355	0,919
390	0,886
NOTE Intermediate values by interpolation.	

2.4.4 The local scantling requirements of higher tensile steel plating, longitudinals, stiffeners and girders may be based on a k_s factor determined as follows:

$$k_s = \frac{235}{\sigma_s}$$

or 0,66 whichever is the greater

where

σ_s = specified minimum yield strength of material, in N/mm^2.

2.4.5 For the application of the requirements of 2.4.3 and 2.4.4 special consideration will be given to steel where $\sigma_s \geq 390$ N/mm^2. Where such steel grades are used in areas which are subject to fatigue loading the structural details are to be verified using fatigue design assessment methods.

2.5 Corrosion protection

2.5.1 All steelwork, except inside integral fuel tanks, is to be suitably protected against corrosion. This may be by coating or, where applicable, by a system of cathodic protection.

2.5.2 Steelwork is to be suitably cleaned and cleared of millscale before the application of any coating. It is recommended that blast cleaning, or other equally effective means, be employed for this purpose.

2.5.3 Where an impressed current cathodic protection system is fitted, plans showing the proposed layout of anodes and hull penetrations are to be submitted.

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2.6 Paints and coatings

2.6.1 The hull is to be protected against corrosion by a suitable protective coating. All coatings are to be in accordance with the requirements of this Section.

2.6.2 Where a primer is used to coat steel after surface preparation and prior to fabrication, the composition of the coating is to be such that it will have no significant deleterious effect on subsequent welding work and that it is compatible with the paints or other coatings subsequently applied in association with an approved system of corrosion control.

2.6.3 Paints or other coatings are to be suitable for the intended purpose in the locations where they are to be used. Coatings are to be of adequate film thickness, applied in accordance with the paint manufacturer's specification.

2.6.4 Integral fuel tanks are to be cleaned and dried, after testing, and then treated with a suitable coating, in accordance with the manufacturer's recommendations.

2.6.5 Paints, varnishes and similar preparations having a nitro-cellulous or other highly flammable base are not to be used in accommodation or machinery spaces.

2.6.6 Protective coatings are generally to be hard coatings. Other coating systems (e.g. soft coatings) may be considered as alternatives provided they are applied and maintained in compliance with the manufacturer's specification.

2.6.7 The paint or coating is to be compatible with any previously applied primer, *see* 2.6.

2.7 Galvanic action

2.7.1 Where bimetallic connections are made, involving dissimilar metals, measures are to be incorporated to preclude galvanic corrosion. In order to prevent galvanic corrosion, special attention is to be given to the penetrations of, and connections to the hull, bulkheads and decks by piping and, equipment where dissimilar materials are involved.

2.8 Bimetallic connections

2.8.1 The design shall ensure that the location of all bimetallic connections allows for regular inspection and maintenance of the joints and penetrations during service.

2.9 External immersed areas

2.9.1 For the deferment of dry docking or where an **IWS** (In-water Survey) notation is to be assigned protection of the underwater portion of the hull is to be provided by means of a suitable high resistant paint applied in accordance with the manufacturer's requirements. Details of the high resistant paint are to be submitted for information.

2.10 External cathodic protection

2.10.1 Where an impressed current cathodic protection system is fitted, plans showing the proposed layout of anodes, reference cells, wiring diagram and the means of bonding-in of the rudder and propeller, are to be submitted.

2.10.2 The arrangement for glands, where cables pass through the shell, are to include a small cofferdam. Cables to anodes are not to be led through tanks containing low flash point oils.

2.11 Protection of ballast spaces

2.11.1 Cathodic protection may be used in association with coatings for the protection of ballast spaces.

2.11.2 The anodes are to be of approved design and sufficiently rigid to avoid resonance in the anode support. Steel cores are to be fitted, and these are to be so designed as to retain the anode even when the latter is wasted.

2.11.3 Anodes are to be attached to the structure in such a way that they remain secure both initially and during service. The following methods of attachment would be acceptable:

(a) Steel core connected to the structure by continuous welding of adequate section.

(b) Steel core bolted to separate supports, provided that a minimum of two bolts with lock nuts are used at each support. The separate supports are to be connected to the structure by continuous welding of adequate section.

(c) Approved means of mechanical clamping.

2.11.4 Anodes are to be attached to stiffeners, or may be aligned in way of stiffeners on plane bulkhead plating, but they are not to be attached to the shell. The two ends are not to be attached to separate members which are capable of relative movement.

2.11.5 Where cores or supports are welded to the main structure, they are to be kept clear of the toes of brackets and similar stress raisers. Where they are welded to asymmetrical stiffeners, they are to be connected to the web with the welding kept at least 25 mm away from the edge of the web. In the case of stiffeners or girders with symmetrical face plates, the connection may be made to the web or to the centreline of the face plate but well clear of the free edges. However, it is recommended that anodes are not fitted to face plates of higher tensile steel longitudinals.

2.12 Deck coverings

2.12.1 Where plated decks are sheathed with wood, the sheathing is to be efficiently attached to the deck, caulked and sealed, to the satisfaction of the Surveyor in accordance with the approved drawings.

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2.12.2 Deck coverings in the following positions are to be of a type which will not readily ignite when used on decks:

(a) Forming the crown of machinery or cargo spaces within accommodation spaces of cargo craft.

(b) Within accommodation spaces, control stations, stairways and corridors of passenger craft.

2.13 Corrosion margin

2.13.1 The scantlings determined from the formulae provided in the Rules assume that the materials used are selected, manufactured and protected in such a way that there is negligible loss in strength by corrosion.

2.13.2 Where steel is not protected against corrosion, by painting or other approved means, the scantlings may require to be further considered.

2.14 Fracture control

2.14.1 Construction procedures, materials and welding are to be in accordance with the requirements of this Chapter such that stress corrosion cracking is avoided.

2.14.2 High local stresses are to be avoided by the use of suitable design detail. *See also* LR's *Guidance Notes for Structural Details*.

2.14.3 The resistance to fracture is controlled, in part, by the notch toughness of the steel used in the structure. Steels with different levels of notch toughness are specified in the Rules for Materials. The grade of steel to be used is, in general, related to the thickness of the material and the stress pattern associated with its location.

2.14.4 Where tee or cruciform connections employ full penetration welds, and the plate material is subject to significant strains in a direction perpendicular to the rolled surfaces, it is recommended that consideration be given to the use of special plate material with specified through thickness properties, as detailed in Ch 3,8 of the Rules for Materials.

2.14.5 For craft operating for long periods in low air temperature the material of exposed structures will, in general, be specially considered.

■ *Section 3* Procedures for welded construction

3.1 General

3.1.1 All welded construction is to be conducted in accordance with the requirements specified in Chapter 13 of the Rules for Materials.

3.2 Information to be submitted

3.2.1 The plans and information submitted for approval are to clearly indicate details of the welded connections of the main structural members, including the type, disposition and size of welds.

3.3 Defined practices and welding sequence

3.3.1 Rudder, sterntubes, propeller brackets and jet units. The final boring out of propeller brackets and sterntubes and the fit-up and alignment of rudder bearings and jet units are to be carried out after the major part of the welding of the aft end of the craft is complete. The contacts between rudder stocks and propeller shafts with bearings are to be checked before the final mounting.

3.4 Structural arrangements and access

3.4.1 Ceilings, cabin sole, side and overhead linings are to be secured in such a manner as to be easily removed for the maintenance and inspection of the structure below.

3.5 Inspection

3.5.1 Inspection of welded construction is to be conducted in accordance with the requirements specified in Chapter 13 of the Rules for Materials.

3.5.2 Checkpoints examined at the pre-fabrication stage are to include ultrasonic testing on examples of the stop/start points of automatic welding and magnetic particle inspections of weld ends.

3.5.3 Typical locations for volumetric examination and number of checkpoints to be taken are shown in Table 2.3.1. A list of the proposed items to be examined is to be submitted for approval.

3.6 Acceptance criteria

3.6.1 All finished welds are to be sound and free from cracks and substantially free from lack of fusion, incomplete penetration, porosity and tungsten inclusions. The surfaces of welds are to be reasonably smooth and substantially free from undercut and overlap. Care is to be taken to ensure that the specified dimensions of welds have been achieved and that both excessive reinforcement and underfill of welds are avoided.

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Table 2.3.1 Non-destructive examinations of welds

Volumetric non-destructive examinations – Recommended extent of testing, *see* 3.5.3		
Item	Location	Checkpoints, *see* Note 1
Intersections of butts and seams of fabrication and section welds	Throughout: • hull envelope • longitudinal and transverse bulkheads • inner bottom and hopper bottom	The summation of checkpoint lengths, *see* Note 2, examined at intersections is to be *L*, where *L* is the overall length of the ship in metres
Butt welds in plating	Throughout	1 m in 25 m, *see* Note 3
Seam welds in plating	Throughout	1 m in 100 m
Butts in longitudinals	Hull envelope within 0,4*L* amidships Hull envelope outside 0,4*L* amidships	1 in 10 welds 1 in 20 welds
Bilge keel butts	Throughout	1 in 10 welds
Structural items when made with full penetration welding as follows: • connection of stool and bulkhead to lower stool shelf plating • vertical corrugations to an inner bottom • hopper knuckles • sheerstrake to deck stringer • hatchways coaming to deck	Throughout	1 m in 20 m

NOTES
1. The length of each checkpoint is to be between 0,3 m and 0,5 m.
2. For checkpoints at intersections the measured dimension of length is to be in the direction of the butt weld.
3. Checkpoints in butt welds and seam welds are in addition to those at intersections.
4. Agreed locations are not to be indicated on the blocks prior to the welding taking place, nor is any special treatment to be given at these locations.
5. Particular attention is to be given to repair rates in longitudinal butts. Additional welds are to be tested in the event that defects, such as lack of fusion or incomplete penetrations, are repeatedly observed.

■ *Section 4*
Joints and connections

4.1 General

4.1.1 Requirements are given in this Chapter for welding connection details, aluminium/steel transition joints, steel/wood connection, riveting of light structure and chemical bonding.

4.1.2 Welded joints are to be detailed such that crevices or inaccessible pockets capable of retaining dirt or moisture are avoided. Where cavities are unavoidable, they are to be sealed by welding or protective compounds or made accessible for inspection and maintenance.

4.2 Weld symbols

4.2.1 Weld symbols, where used, are to conform to a recognised National or International Standard. Details of such Standards are to be indicated on the welding schedule, which is to be submitted for appraisal.

4.3 Welding schedule

4.3.1 A welding schedule containing not less than the following information is to be submitted:
(a) Weld throat thickness or leg lengths.
(b) Grades, tempers, and thicknesses of materials to be welded.
(c) Locations, types of joints and angles of abutting members.
(d) Reference to welding procedures to be used.
(e) Sequence of welding of assemblies and joining up of assemblies.

4.4 Butt welds

4.4.1 All structural butt joints are to be made by means of full penetration welds and, in general, the edges of plates to be joined by welding are to be bevelled on one or both sides of the plates. Full details of the proposed joint preparation are to be submitted for approval, *see also* 4.24.

4.4.2 Where butt welds form a T-junction, the leg of the T is, where practicable, to be completed first including any back run. During the welding operation special attention is to be given to the completion of the weld at the junction, which is to be chipped back to remove crater cracks, etc., before the table is welded.

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4.5 Fillet welds

4.5.1 The throat thickness of fillet welds is to be determined from:

$$\text{Throat thickness} = t_p \times \text{weld factor} \times \left(\frac{d}{s}\right) \text{ mm}$$

where

s = the length of correctly proportioned weld fillet, clear of end craters, in mm, and is to be 10 x plate thickness, t_p, or 75 mm, whichever is the lesser, but in no case to be taken less than 40 mm

d = the distance between successive weld fillet, in mm

t_p = plate thickness, in mm, on which weld fillet size is based, *see* 4.5.6

Weld factors are contained in Table 2.4.1.

NOTE

For double continuous fillet welding $\left(\frac{d}{s}\right)$ is to be taken as 1, *see* 4.8.1.

4.5.2 For ease of welding, it is recommended that the ratio of the web height to the flange breadth is greater than or equal to 1,5, *see* Fig. 2.4.1.

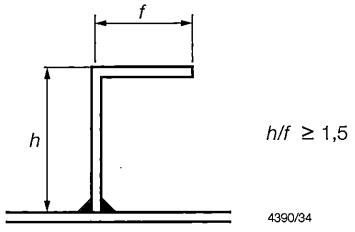

Fig. 2.4.1 Web height/flange breadth ratio

4.5.3 The leg length of the weld is to be not less than $\sqrt{2}$ times the specified throat thickness.

4.5.4 The plate thickness t_p to be used in 4.5.2 is generally to be that of the thinner of the two parts being joined. Where the difference in thickness is considerable, the size of fillet weld will be specially considered.

4.6 Throat thickness limits

4.6.1 The throat thickness limits given in Table 2.4.2 are to be complied with.

4.7 Double continuous fillet welding

4.7.1 Where double continuous fillet welding is proposed the throat thickness is to be in accordance with 4.5.2 taking $\left(\frac{d}{s}\right)$ equal to 1.

4.7.2 Double continuous fillet welding is to be adopted in the following locations and may be used elsewhere if desired:

(a) Boundaries of weathertight decks and erections, including hatch coamings, companionways and other openings.

(b) Boundaries of tank and watertight compartments.

(c) Main engine seatings.

(d) Bottom framing structure in machinery spaces of high speed craft.

(e) The side and bottom shell structure in the impact area of high speed motor craft.

(f) The underside of the cross-deck structure in the impact area of high speed multi-hull craft.

(g) Structure in way of ride control systems, stabilisers, thrusters, bilge keels, foundations and other areas subject to high stresses.

(h) The shell structure in the vicinity of the propeller blades.

(j) Stiffening members to plating in way of end connections scallops and of end brackets to plating in the case of lap connections.

(k) Primary and secondary members to plating in way of end connections, and end brackets to plating in the case of lap connections.

(l) Face flats to webs of built-up/fabricated stiffening members in way of knees/end brackets and for a distance beyond such knees/end brackets of not less than the web depth of stiffener in way.

4.8 Intermittent fillet welding (staggered)

4.8.1 Staggered intermittent welding may be used, outside of the impact area in the bottom shell or crossdeck structure of high speed craft.

4.9 Intermittent fillet welding (chain)

4.9.1 Chain intermittent welding may be used, outside of the impact area in the bottom shell or crossdeck structure of high speed craft.

4.10 Single sided fillet welding

4.10.1 Continuous single sided fillet welding may be used in lieu of intermittent fillet welding (staggered and chain), outside of the impact area in the bottom shell or crossdeck structure of high speed craft.

4.11 Connections of primary structure

4.11.1 Depending on the structural design of the joint and design loads on the primary member, full penetration welding of flanges and web plates may be required to attain full section properties in the end connections of primary members. *See also* Ch 3,1.22. Otherwise weld factors for the connections of primary structure are given in Table 2.4.1.

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Table 2.4.1 Weld factors (*see continuation*)

Item	Weld Factor	Remarks
(1) General application:		except as required below
Watertight plate boundaries	0,34	
Non-tight plate boundaries	0,13	
Longitudinals,frames,beams, and other secondary members to shell, deck or bulkhead plating	0,10 0,13 0,21	 in tanks in way of end connections
Panel stiffeners	0,10	
Overlap welds generally	0,27	
(2) Bottom construction:		
Non-tight centre girder: to keel to inner bottom	0,27 0,21	 no scallops
Non-tight boundaries of floors, girders and brackets	0,21 0,27	in way of 0,2 x span at ends in way of brackets at lower end of main frame
Inner bottom longitudinals, or face flat to floors reverse frames	0,13	
Connection of floors to inner bottom where bulkhead is supported on tank top. The supporting floors are to be continuously welded to the inner bottom	0,44	Weld size based on floor thickness Weld material compatible with floor material
(3) Hull framing:		
Webs of web frames and stringers: to shell to face plate	 0,16 0,13	
(4) Decks and supporting structure:		
Weather deck plating to shell	0,44	
Other decks to shell and bulkheads (except where forming tank boundaries)	0,21	generally continuous
Webs of cantilevers to deck and to shell in way of root bracket	0,44	
Webs of cantilevers to face plate	0,21	
Girder webs to deck clear of end brackets	0,10	
Girder webs to deck in way of end brackets	0,21	
Web of girder to face plate	0,10	
Pillars: fabricated end connections end connections (tubular)	0,10 0,34 full penetration	
Girder web connections and brackets in way of pillar heads and heels	0,21	continuous

4.11.2 The weld connection to shell, deck or bulkhead is to take account of the material lost in the notch where longitudinals or stiffeners pass through the member. Where the width of notch exceeds 15 per cent of the stiffener spacing, the weld factor is to be multiplied by:

$$\frac{0{,}85 \times \text{stiffener spacing}}{\text{length of web plating between notches}}$$

4.11.3 Where direct calculation procedures have been adopted, the weld factors for the 0,2 x overall length at the ends of the members will be considered in relation to the calculated loads.

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Table 2.4.1 Weld factors (*continued*)

Item	Weld Factor	Remarks
(5) Bulkheads and tank construction:		
Plane and corrugated watertight bulkhead boundary at bottom , bilge, inner bottom, deck and connection to shelf plate, where fitted	0,44	weld size to be based on thickness of bulkhead plating weld material to be compatible with bulkhead plating material
Secondary members, where acting as pillars	0,13	
Non-watertight pillar bulkhead boundaries	0,13	
Perforated flats and wash bulkhead boundaries	0,10	
Deep tank horizontal boundaries at vertical corrugations	full penetration	
(6) Structure in machinery space:		
Centre girder to keel and inner bottom	0,27	no scallops to inner bottom
Floors to centre girder in way of engine thrust bearers	0,27	
Floors and girders to shell and inner bottom	0,21	
Main engine foundation girders: to top plate to hull structure	 deep penetration to depend on design	 edge to be prepared with maximum root 0,33t_p deep penetration generally
Floors to main engine foundation girders	0,27	
Brackets, etc., to main engine foundation girders	0,21	
Transverse and longitudinal framing to shell	0,13	
(7) Superstructures and deckhouses:		
Connection of external bulkheads to deck	0,34 0,21	1st and 2nd tier erections elsewhere
Internal bulkheads	0,13	
(8) Steering control systems:		
Rudder: Fabricated mainpiece and mainpiece to side plates and webs	 0,44	
Slot welds inside plates	0,44	
Remaining construction	0,21	
Fixed and steering nozzles: Main structure Elsewhere	 0,44 0,21	
Fabricated housing and structure of thruster units, stabilisers, etc.: Main structure Elsewhere	 0,44 0,21	

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Table 2.4.1 Weld factors (*conclusion*)

Item	Weld Factor	Remarks
(9) Miscellaneous fittings and equipment:		
Rings for manhole type covers, to deck or bulkhead	0,34	
Frames of shell and weathertight bulkhead doors	0,34	
Stiffening of doors	0,21	
Ventilator, air pipes, etc., coamings to deck	0,34 0,21	Load Line Position 1 and 2 elsewhere
Ventilator, etc., fittings	0,21	
Scuppers and discharges, to deck	0,44	
Masts, crane pedestals, etc., to deck	0,44	full penetration welding may be required
Deck machinery seats to deck	0,21	generally
Mooring equipment seats	0,21	generally, but increased or full penetration may be required
Bulwark stays to deck	0,21	
Bulwark attachment to deck	0,34	
Guard rails, stanchions, etc., to deck	0,34	
Bilge keel ground bars to shell	0,34	continuous fillet weld, minimum throat thickness 4 mm
Bilge keels to ground bars	0,21	light continuous or staggered intermittent fillet weld, minimum throat thickness 3 mm
Fabricated anchors	full penetration	

Table 2.4.2 Throat thickness limits

Item	Throat thickness mm	
	Minimum	Maximum
(1) Double continuous welding	$0,21t_p$	$0,44t_p$
(2) Intermittent welding	$0,27t_p$	$0,44t_p$ or 4,5
(3) Overriding minimum:		
(a) Continuous welds	2,5	—
(b) Intermittent welds:		
(i) Plate thickness $t_p \leq 7,5$ mm		
Hand or automatic welding	3,0	—
Automatic deep penetration welding	3,0	—
(ii) Plate thickness $t_p \geq 7,5$ mm		
Hand or automatic welding	3,25	—
Automatic deep penetration welding	3,0	—

NOTES
1. In all cases the limiting value is to be taken as the greatest of the applicable values above.
2. The maximum throat thicknesses shown are intended only as a design limit for the approval of fillet welded joints. Any welding in excess of these limits is to be to the Surveyor's satisfaction.

4.12 Primary and secondary member end connection welds

4.12.1 Welding of end connections of primary members is to be such that the area of welding is not less than the cross-sectional area of the member, and the weld factor is to be not less than 0,34 in tanks or 0,27 elsewhere.

4.12.2 The welding of secondary member end connections is to be not less than as required by Table 2.4.3. Where two requirements are given the greater is to be complied with.

4.12.3 The area of weld, A_w, is to be applied to each arm of the bracket or lapped connection.

4.12.4 Where a longitudinal strength member is cut at a primary support and the continuity of strength is provided by brackets, the area of weld is to be not less than the cross-sectional area of the member.

4.13 Weld connection of strength deck plating to sheerstrake

4.13.1 The weld connection of strength deck plating to sheerstrake is to be by double continuous fillet welding with a weld factor of 0,44. The welding procedure, including joint preparation, is to be specified and the procedure qualified and approved for individual Builders.

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Table 2.4.3 Secondary member end connection welds

Connection	Weld area, A_w, in cm^2	Weld factor
(1) Stiffener welded direct to plating	$0{,}25A_s$ or 6,5 cm^2 whichever is the greater	0,34
(2) Bracketless connection of stiffeners or stiffener lapped to bracket or bracket lapped to stiffener:		
(a) in dry space	$1{,}2\sqrt{Z}$	0,27
(b) in tank	$1{,}4\sqrt{Z}$	0,34
(c) main frame to tank side bracket in $0{,}15L_R$ forward	as (a) or (b)	0,34
(3) Bracket welded to face of stiffener and bracket connection to plating	–	0,34
(4) Stiffener to plating for 0,1 x span at ends, or in way of the end bracket if that be greater	–	0,34

Symbols

A_s = cross section area of the stiffener, in cm^2
A_w = the area of the weld, in cm^2, and is calculated as total length of weld, in cm, x throat thickness, in cm
Z = the section modulus, in cm^3, of the stiffener on which the scantlings of the end bracket are based

NOTE
For maximum and minimum weld fillet sizes, *see* Table 10.2.2.

4.14 Air and drain holes

4.14.1 Air and drain holes are to be kept clear of the toes of brackets, etc. Openings are to be well rounded with smooth edges. *See also* LR's *Guidance Notes for Structural Details*.

4.15 Notches and scallops

4.15.1 Notches and scallops are to be kept clear of the toes of brackets, etc. Openings are to be well rounded with smooth edges.

4.15.2 Scallops are to be of such a size, and in such a position that a satisfactory weld can be made around the ends of openings.

4.16 Watertight collars

4.16.1 Watertight collars are to be fitted, where stiffeners are continuous through watertight or oiltight boundaries. *See also* LR's *Guidance Notes for Structural Details*.

4.17 Lug connections

4.17.1 The area of the weld connecting secondary stiffeners to primary structure in the bottoms of the hulls and cross-deck structure in areas subjected to impact pressures is to be not less than the shear area from the Rules. This area is to be obtained by fitting two lugs or by other equivalent arrangements. Some typical lug connections are shown in Fig. 2.4.2 and Fig. 3.1.7 in Chapter 3.

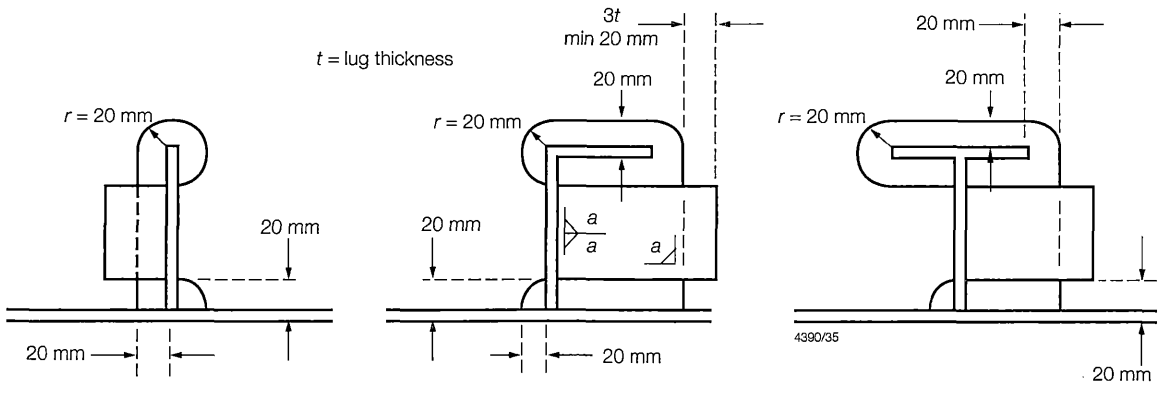

Fig. 2.4.2 Typical lug connections

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4.17.2 Lugs or tripping brackets are to be fitted where shell longitudinals are continuous through web frames in way of highly stressed areas of the side shell (e.g. in way of fenders, etc.).

4.17.3 Lugs or tripping brackets are also to be fitted where continuous secondary stiffeners are greater than half the depth of the primary stiffeners.

4.18 Insert plates

4.18.1 Where thick insert plates are butt welded to thin plates, the edge of the thick plate may require to be tapered. The slope of the taper is generally not to exceed one in three.

4.18.2 The corners of insert plates are to be suitably radiused.

4.19 Doubler plates

4.19.1 Doubler plates are to be avoided in areas where corrosion may be a problem and access for inspection and maintenance is limited.

4.19.2 Where doubler plates are fitted, they are to have well radiused corners and the perimeter is to be continuously welded. Large doubler plates are also to be suitably slot welded, the details of which are to be submitted for consideration.

4.20 Joint preparation

4.20.1 Typical butt joints are shown in LR's *Guidance Notes for Structural Details*.

4.21 Construction tolerances

4.21.1 The minimum requirements for construction tolerances are to be in accordance with Pt 3, Ch 1,8.

4.22 Riveting of light structure

4.22.1. Where it is proposed to adopt riveted construction, full details of the rivets or similar fastenings, including mechanical test results, are to be indicated on the construction plans submitted for approval or a separate riveting schedule is to be submitted.

4.22.2 Samples may be required of typical riveted joints made by the Builder under representative construction conditions and tested to destruction in the presence of the Surveyor in shear, tension, compression or peel at LR's discretion.

4.22.3 Where riveting strength data sheets have been issued by a recognised Authority, the values quoted in these sheets will normally be accepted for design purposes.

4.22.4 Where two dissimilar metals are to be joined by riveting, precautions are to be taken to eliminate electrolytic corrosion to LR's satisfaction, and where practicable, the arrangements are to be such as to enable the joint to be kept under observation at each survey without undue removal of lining and other items.

4.22.5 Where a sealing compound is used to obtain an airtight or watertight joint, details are to be submitted of its proposed use and of any tests made or experience gained in its use for similar applications.

4.22.6 Sealing paints or compounds are not to be used with hot driven rivets.

4.23 Chemical bonding of structure

4.23.1 Where chemical bonding of any load-bearing structure is proposed, details of the materials and the processes to be used are to be submitted for approval. These details are to include test results of samples manufactured under LR survey under workshop conditions to verify the strength, ageing effects and moisture resistance.

4.23.2 The adhesive manufacturer's recommendations in respect of the specified jointing system, comprising preparation of the surfaces to be adhered, the adhesive, bonding and curing processes, are to be strictly followed as variation of any step can severely affect the performance of the joint.

4.23.3 Meticulous preparation is essential where the joint is to be made by chemical bonding. The method of producing bonded joints is to be documented so that the process is repeatable after the procedure has been properly established.

4.23.4 Bonded joints are suitable for carrying shear loads, but are not, in general, to be used in tension or where the load causes peeling or other forces tending to open the joint. Loads are to be carried over as large an area as possible.

4.23.5 Bonded joints are to be suitably supported after assembly for the period necessary to allow the optimum bond strength of the adhesive to be to be developed. Entrained air pockets are to be avoided.

4.23.6 The use of adhesive for main structural joints is not to be contemplated unless considerable testing has established its validity, including environmental testing and fatigue testing where considered necessary by LR.

4.24 Triaxial stress considerations

4.24.1 Particular care is to be taken to avoid triaxial stresses which may result from poor joint design. Some recommendations in this respect are contained in LR's *Guidance Notes for Structural Details*.

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4.25 Aluminium/Steel transition joints

4.25.1 Provision is made in this Section for explosion bonded composite aluminium/steel transition joints used for connecting aluminium structures to steel plating. Such joints are to be used in accordance with the manufacturer's requirements, *see also* Ch 8,4 of the Rules for Materials.

4.25.2 Transition joints are to be manufactured by an approved producer in accordance with an approved specification which is to include the maximum temperature allowable at the interface during welding.

4.25.3 The steel material is to comply with the requirements of Section 2 and the aluminium is to be of an appropriate grade complying with the requirements of *Chapter 8 of the Rules for Materials.*

4.25.4 Alternative materials which comply with International, National or proprietary specifications may be accepted provided that they give equivalence to the requirements of 4.24.3 or are approved for a specific application.

4.25.5 Intermediate layers between the aluminium and steel may be used, in which case the material of any such layer is to be specified by the manufacturer and is to be recorded in the approval certificate. Any such intermediate layer is then to be used in all production transition joints.

4.25.6 Bimetallic joints where exposed to seawater or used internally within wet spaces are to be suitably protected to prevent galvanic corrosion.

4.26 Steel/Wood connection

4.26.1 To minimise corrosion of steel when in contact with wood in a damp or marine environment the timber is to be primed and painted in accordance with good practice. Alternatively the surface of the steel in contact with the timber is to be coated with a substantial thickness of a suitable sealant.

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Scantling Determination for Mono-Hull Craft

Section

1 **General**

2 **Minimum thickness requirements**

3 **Shell envelope plating**

4 **Shell envelope framing**

5 **Single bottom structure and appendages**

6 **Double bottom structure**

7 **Bulkheads and deep tanks**

8 **Deck structures**

9 **Superstructures, deckhouses and bulwarks**

10 **Pillars and pillar bulkheads**

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull craft of steel construction as defined in Pt 1, Ch 2,2.

1.2 General

1.2.1 The formulae contained within this Chapter are to be used in conjunction with the design loadings from Part 5 to determine the Rule scantling requirements.

1.3 Direct calculations

1.3.1 Where the craft is of unusual design, form or proportions, or where the speed of the craft exceeds 60 knots the scantlings are to be determined by direct calculation.

1.3.2 The requirements of this Chapter may be modified where direct calculation procedures are adopted to analyse the stress distribution in the primary structure.

1.4 Equivalents

1.4.1 Lloyd's Register (hereinafter referred to as 'LR') will consider direct calculations for the derivation of scantlings as an alternative and equivalent to those derived by Rule requirements in accordance with Pt 3, Ch 1,3.

1.5 Symbols and definitions

1.5.1 The symbols used in this Chapter are defined below and in the appropriate Section:

L_R = Rule length of craft, in metres, as defined in Pt 3, Ch 1,6

B = moulded breadth of craft, in metres, as defined in Pt 3, Ch 1,6

Z = section modulus of stiffening member, in cm^3

I = moment of inertia, in cm^4

A_w = shear area of stiffener web, in cm^2

l = stiffener overall length, in metres

l_e = effective span length, in metres, as defined in 1.19

p = design pressure, in kN/m^2 as given in Part 5

s = stiffener spacing, in mm

t_p = plating thickness, in mm

β = panel aspect ratio correction factor as defined in 1.15

γ = convex curvature correction factor as defined in 1.14

k_s = high tensile steel factor
= $235/\sigma_s$, *see also* Ch 2,2.4

σ_s = guaranteed minimum yield strength of the material, in N/mm^2

$\tau_s = \frac{\sigma_s}{\sqrt{3}}$

E = modulus of elasticity, in N/mm^2.

1.6 Rounding policy for Rule plating thickness

1.6.1 Where plating thicknesses as determined by the Rules require to be rounded then this should be carried out to the nearest full or half millimetre, with thicknesses 0,75 and 0,25 being rounded up.

1.7 Dimensional tolerance

1.7.1 Dimensional tolerances for materials are to be in accordance with Chapter 8 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials), or an acceptable National or International Standard.

1.7.2 The under thickness tolerance acceptable for classification is to be considered as the lower limit of a range of thickness tolerance which could be found in the normal production of a conventional rolling mill manufacturing material, on average, to the nominal thickness.

1.7.3 The Shipowner and Shipbuilder may agree in individual cases whether they wish to specify a more stringent under thickness tolerance than that given in 1.7.2.

1.7.4 The minus tolerance on sections (except for wide flats) is to be in accordance with a National or International Standard.

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1.7.5 The thickness of plates and strip is to be measured at random locations whose distance from an edge is to be at least 25 mm. Local surface depressions resulting from imperfections and ground areas resulting from the elimination of defects may be disregarded provided that they are in accordance with the requirements of a National or International Standard.

1.7.6 The responsibility for maintaining the required tolerances and making the necessary measurements rests with the manufacturer/Builder. Occasional checking by the Surveyor does not absolve the manufacturer/Builder from the responsibility.

1.8 Material properties

1.8.1 The basic grade of steel used in the determination of the Rule scantling requirements is taken as mild steel with the following mechanical properties:

	N/mm^2
Yield strength (minimum)	235
Tensile strength	400 – 490
Modulus of elasticity	200×10^3.

1.9 Higher tensile steels

1.9.1 Steels having a yield stress not less than 265 N/mm^2 are regarded as higher tensile steels.

1.9.2 Where higher tensile steels are to be used, due allowance is given in the determination of the Rule requirement for plating thickness and stiffener section modulus, inertia and cross-sectional area by use of the following correction factors:

(a) Plating thickness factor = $\sqrt{k_s}$

(b) Section modulus and cross-sectional area factor = k_s

where

k_s is as defined in 1.5.1.

1.9.3 The minimum moment of inertia of higher tensile steel stiffening members is to be not less than that required for mild steel stiffening members.

1.9.4 For determination of hull girder section modulus in craft incorporating higher tensile steel materials, *see* Ch 6,2.2.1, 2.2.2 and Ch 2,2.4.3.

1.10 Effective width of attached plating

1.10.1 The effective geometric properties of rolled or built sections are to be calculated directly from the dimensions of the section and associated effective area of attached plating. Where the web of the section is not normal to the actual plating, and the angle exceeds 20°, the properties of the section are to be determined about an axis parallel to the attached plating.

1.10.2 For stiffening members, the geometric properties of rolled or built sections are to be calculated in association with an effective area of attached load bearing plating of thickness t_p, in mm and a breadth b_e in mm. b_e is as defined in 1.10.3 and 1.10.4.

1.10.3 The effective width of attached plating to secondary members b_e is to be taken as $2t_p\sqrt{E/\sigma_s}$ but not greater than s. σ_s is not to be taken as greater than 235 N/mm^2 for mild steel or 340 N/mm^2 for higher tensile steel. E, s and σ_s are as defined in 1.5.1.

1.10.4 The effective breadth of attached plating to primary support members (girders, transverses, webs etc.) b_e is to be taken as bf, where b and f are as defined in Pt 3, Ch 2, 3.2.1.

1.11 Other materials

1.11.1 Special consideration will be given to the use of materials other than steel. Details of the type of material, the specification to which it was manufactured and its mechanical properties are to be submitted for appraisal.

1.12 Aluminium alloys

1.12.1 The use of aluminium alloys in construction is to be in accordance with Part 7.

1.13 Fibre reinforced plastic (FRP)

1.13.1 The use of FRP in construction is to be in accordance with Part 8.

1.14 Convex curvature correction

1.14.1 The thickness of plating as determined by the Rules may be reduced where significant curvature exists between the supporting members. In such cases a plate curvature correction factor may be applied:

γ = plate curvature factor
= $1 - h/s$, and is not to be taken as less than 0,7,

h = the distance, in mm, measured perpendicularly from the chord length, s, (i.e. spacing) to the highest point of the curved plating arc between the two supports, *see* Fig. 3.1.1.

1.15 Aspect ratio correction

1.15.1 The thickness of plating as determined by the Rules may be reduced when the panel aspect ratio is taken into consideration. In such cases a panel aspect ratio correction factor may be applied:

β = aspect ratio correction factor
= $A_R(1 - 0{,}25A_R)$ for $A_R \leq 2$
= 1 for $A_R > 2$

A_R = panel aspect ratio
= panel length/panel breadth.

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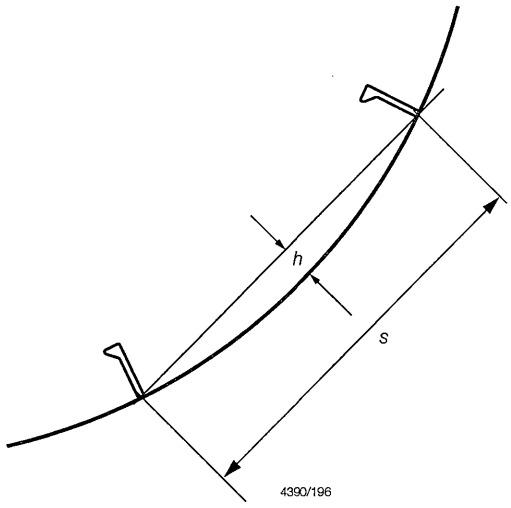

Fig. 3.1.1 Convex curvature

1.16 Plating general

1.16.1 The requirements for the thickness of plating, t_p, is, in general, to be in accordance with the following:

$$t_p = 22{,}4\, s\, \gamma\, \beta \sqrt{\frac{p}{f_\sigma\, \sigma_s}} \times 10^{-3} \text{ mm}$$

where

f_σ = limiting bending stress coefficient for the plating element under consideration given in Table 7.3.1 in Chapter 7.

s, γ, β, p, σ_s are as defined in 1.5.1.

1.17 Stiffening general

1.17.1 The requirements for section modulus, inertia and web area of stiffening members are, in general, to be in accordance with the following:

(a) Section modulus:

$$Z = \Phi_Z \frac{p\, s\, l_e^2}{f_\sigma\, \sigma_s} \text{ cm}^3$$

where

Φ_Z = section modulus coefficient dependent on the loading model assumption taken from Table 3.1.1

f_σ = limiting bending stress coefficient for stiffening member given in Table 7.3.1 in Chapter 7.

p, s, l_e, and σ_s are as defined in 1.5.1.

(b) Inertia:

$$I = \Phi_I\, f_\delta \frac{p\, s\, l_e^3}{E} \times 100 \text{ cm}^4$$

where

Φ_I = inertia coefficient dependent on the loading model assumption taken from Table 3.1.1

f_δ = limiting deflection coefficient for stiffener member given in Table 7.2.1 in Chapter 7.

p, s, l_e, and E are as defined in 1.5.1.

(c) Web area:

$$A_w = \Phi_A \frac{p\, s\, l_e}{100\, f_\tau\, \tau_s} \text{ cm}^2$$

where

Φ_A = web area coefficient dependent on the loading model assumption taken from Table 3.1.1

f_τ = limiting shear stress coefficient for stiffener member given in Table 7.3.1 in Chapter 7

p, s, l_e, and τ_s are as defined in 1.5.1.

1.18 Geometric properties and proportions of stiffener sections

1.18.1 From structural stability and local buckling considerations, the proportions of stiffening members are, in general, to be in accordance with Table 3.1.2.

1.19 Determination of span point

1.19.1 The effective span length, l_e, of a stiffening member is generally less than the overall length, l, by an amount which depends on the design of the end connections. The span points, between which the value of l_e is measured, are to be determined as follows:

(a) For rolled or built-up secondary stiffening members:
The span point is to be taken at the point where the depth of the end bracket, measured from the face of the secondary stiffening member, is equal to the depth of the member, *see* Fig. 3.1.2. Where there is no end bracket, the span point is to be measured between primary member webs.

(b) For primary support members:
The span point is to be taken at a point distant, b_e, from the end of the member

$$b_e = b_b \left(1 - \frac{d_w}{d_b}\right)$$

where

b_e, b_b, d_w and d_b are as shown in Fig. 3.1.2.

1.19.2 Where the stiffening member is inclined to a vertical or horizontal axis and the inclination exceeds 10°, the span is to be measured along the member.

1.19.3 Where the stiffening member is curved then the span is to be taken as the effective chord length between span points.

1.19.4 Where there is a pronounced turn of bilge, chine or the structure is significantly pitched, the span may be measured as in Fig. 3.1.2.

1.19.5 It is assumed that the ends of stiffening members are substantially fixed against rotation and displacement. If the arrangement of supporting structure is such that this condition is not achieved, consideration will be given to the effective span to be used for the stiffener.

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Table 3.1.1 Section modulus, inertia and web area coefficients

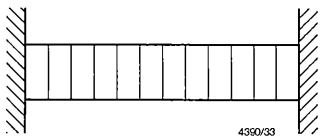
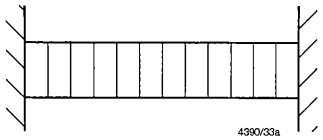
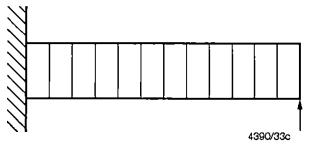
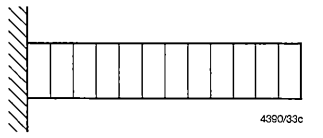
Load model	Position 1	Position 2	Position 3	Position	Web area coefficient Φ_A	Section modulus coefficient Φ_Z	Inertia coefficient Φ_I	Application
(a)	 4390/33			1 2 3	1/2 — 1/2	1/12 1/24 1/12	— 1/384 —	Primary and other members where the end fixity is considered encastre
(b)	 4390/33a			1 2 3	1/2 — 1/2	1/10 1/10 1/10	— 1/288 —	Local, secondary and other members where the end fixity is considered to be partial
(c)	 4390/33c			1 2 3	5/8 — 3/8	1/8 9/128 —	— 1/185 —	Various
(d)	 4390/33c			1 2 3	1 — —	1/2 — —	— — 1/8	Various
(e)	4390/33d			1 2 3	1/2 — 1/2	— 1/8 —	— 5/384 —	Hatch covers, glazing and other members where the ends are simply supported

Table 3.1.2 Stiffener proportions

Type of stiffener	Requirement
(1) Flat bar	Minimum web thickness: $t_w = d_w/18 \quad \geq 2{,}5$ mm
(2) Rolled or built sections	(a) Minimum web thickness: $t_w = d_w/65 \quad \geq 2{,}5$ mm (b) Maximum unsupported face plate (or flange) width: $b_f = 16t_f$
Symbols	
t_w = web thickness of stiffener with unstiffened webs, in mm d_w = web depth of stiffener, in mm b_f = face plate (or flange) unsupported width, in mm t_f = face plate (or flange) thickness, in mm	

1.20 Secondary member end connections

1.20.1 Secondary members, that is longitudinals, beams, frames and bulkhead stiffeners forming part of the hull structure, are to be effectively continuous and are to be suitably bracketed at their end connections. Where it is desired to adopt bracketless connections, the proposed arrangements will be individually considered, *see also* Ch 2,4.10 and Table 2.4.5 in Chapter 2.

1.20.2 Where bracketed end connections are fitted in accordance with these requirements, they may be taken into account in determining the effective span of the member.

1.20.3 The scantlings of secondary member end connections are to be in accordance with 1.21.

1.21 Scantlings of end brackets

1.21.1 Where a longitudinal strength member is cut at a primary support and the continuity of strength is provided by brackets, the scantlings of the brackets are to be such that their section modulus and effective cross-sectional area are not less than those of the member. Care is to be taken to ensure correct alignment of the brackets on each side of the primary member.

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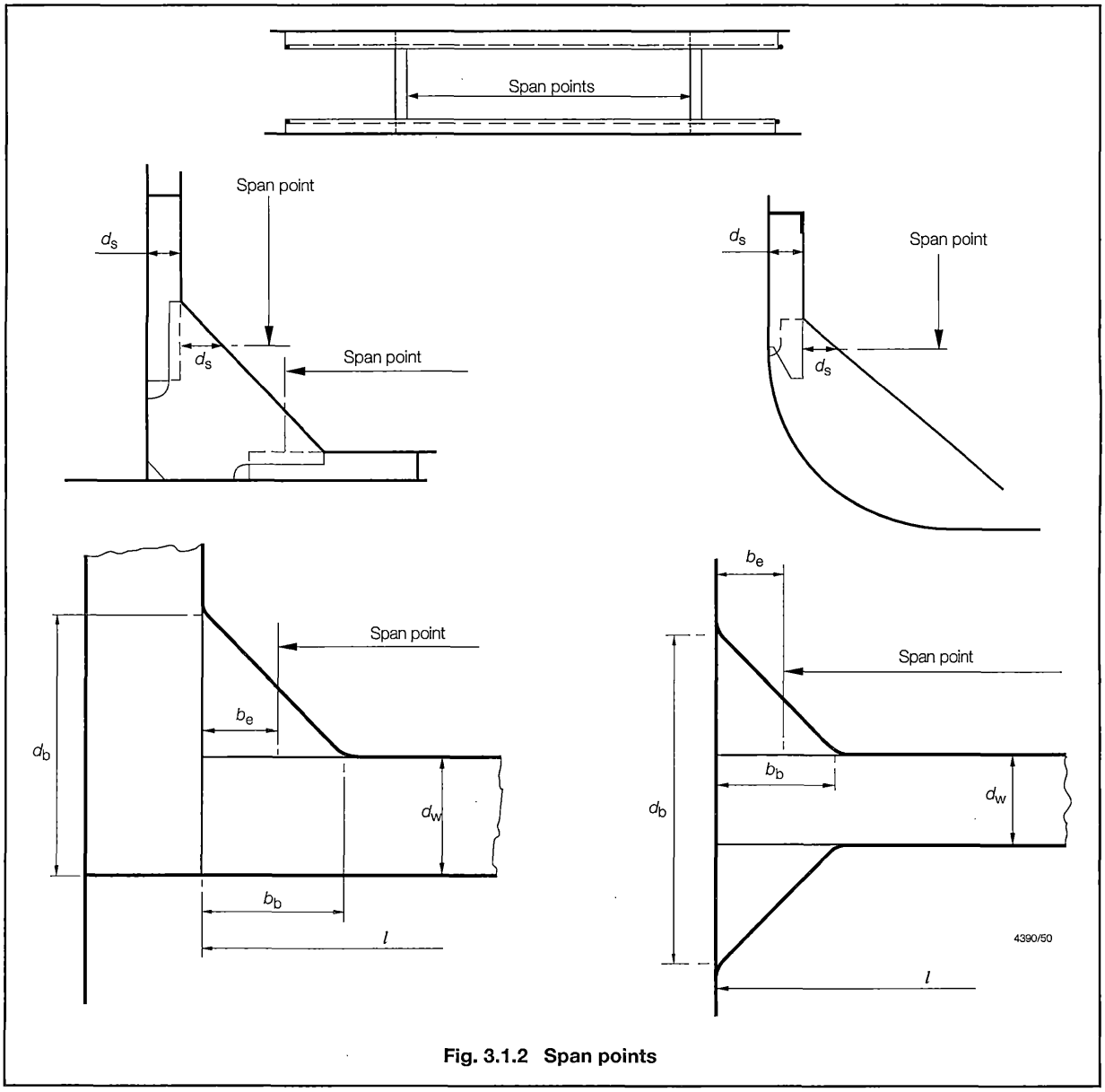

Fig. 3.1.2 Span points

1.21.2 In other cases the scantlings of the bracket are to be based on the modulus as follows:

(a) Bracket connecting stiffener to primary member – modulus of the stiffener.

(b) Bracket at the head of a main transverse frame where frame terminates – modulus of the frame.

(c) Brackets connecting lower deck beams or longitudinals to the main frame in the forward $0{,}5L_R$ – modulus of the frame.

(d) Elsewhere – the lesser modulus of the members being connected by the bracket.

1.21.3 The web thickness and face flat area of end brackets are not in general to be less than those of the connecting stiffeners. Additionally, the stiffener proportion requirements of 1.18 are to be satisfied.

1.21.4 Typical arrangements of stiffener end brackets are shown diagrammatically in Fig. 3.1.3.

1.21.5 The lengths, *a* and *b*, of the arms are to be measured from the plating to the toe of the bracket and are to be such that:

(a) $a + b \geq 2{,}0l_b$

(b) $a \geq 0{,}8l_b$

(c) $b \geq 0{,}8l_b$

where *a* and *b* are the actual lengths of the two arms of the bracket, in mm, measured from the plating to the toe of the bracket.

$$l_b = 90\left(2\sqrt{\frac{Z}{14+\sqrt{Z}}} - 1\right) \text{ mm}$$

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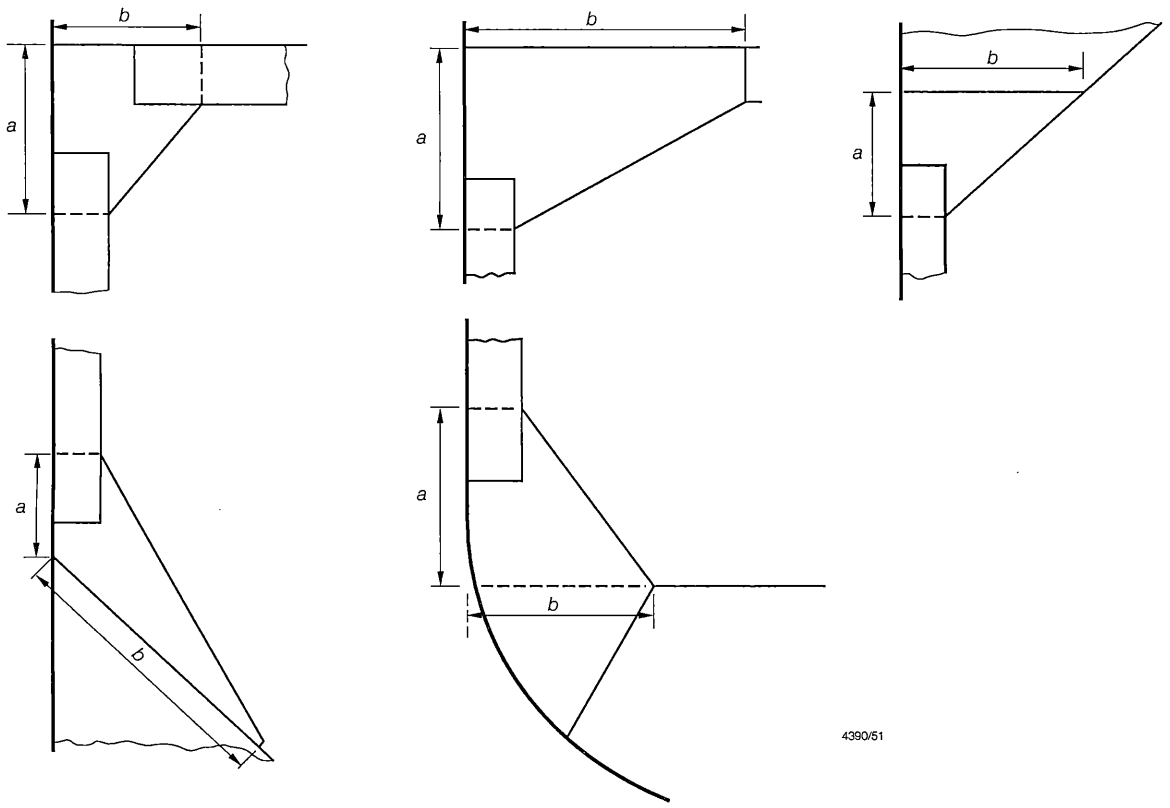

Fig. 3.1.3 Stiffener end brackets

Z = the section modulus of the secondary member, in cm^3
In no case is l_b to be taken as less than twice the web depth of the stiffener on which the bracket scantlings are to be based.

1.21.6 The free edge of the bracket is to be stiffened where any of the following apply:
(a) The section modulus, Z, exceeds 500 cm^3.
(b) The length of free edge exceeds 40 times the bracket thickness.
(c) The bracket is fitted at the lower end of main transverse side framing.

1.21.7 Where a face flat is fitted, its breadth, b_f, is to be not less than:

$$b_f = 40\left(1 + \frac{Z}{1000}\right) \text{ mm}$$

but not less than 50 mm

1.21.8 Where the edge is stiffened by a welded face flat, the cross-sectional area of the face flat is to be not less than:
(a) $0{,}009 k_s b_f T_B$ cm^2 for offset edge stiffening.
(b) $0{,}014 k_s b_f T_B$ cm^2 for symmetrically placed stiffening
where
b_f = breadth of face flat, in mm
T_B = the thickness of the bracket, in mm
k_s is as defined in 1.5.1.

1.21.9 Where the stiffening member is lapped on to the bracket, the length of overlap is to be adequate to provide for the required area of welding. In general, the length of overlap is not to be less than $10\sqrt{Z}$ mm, or the depth of stiffener, whichever is the greater.

1.21.10 Where the free edge of the bracket is hollowed out, it is to be stiffened or increased in size to ensure that the modulus of the bracket through the throat is not less than that of the required straight edged bracket.

1.21.11 The arrangement of the connection between the stiffener and the bracket is to be such that at no point in the connection is the actual modulus reduced to less than that of the stiffener with associated plating.

1.21.12 The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint.

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1.22 Primary member end connections

1.22.1 The requirements for section modulus and inertia (if applicable) of primary members are given in the appropriate Chapter. The scantling requirements for primary member end connections in dry spaces and in tanks of all craft types are generally to comply with the requirements of 1.21, taking Z as the section modulus of the primary member.

1.22.2 Primary members are to be so arranged as to ensure effective continuity of strength, and abrupt changes of depth or section are to be avoided. Where members abut on both sides of a bulkhead, or on other members, arrangements are to be made to ensure that they are in alignment. Primary members in tanks are to form a continuous line of support and wherever possible, a complete ring system.

1.22.3 The members are to have adequate lateral stability and web stiffening and the structure is to be arranged to minimise hard spots and other sources of stress concentration. Openings are to have well rounded corners and smooth edges and are to be located having regard to the stress distribution and buckling strength of the panel.

1.22.4 Primary members are to be provided with adequate end fixity by end brackets or equivalent structure. The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint and effective distribution of the load from the member.

1.22.5 Where the primary member is supported by structure which provides only a low degree of restraint against rotation, the member is generally to be extended beyond the point of support and thereafter tapered and/or scarfed into the adjacent structure over a distance generally not less than two frame spaces.

1.22.6 Where primary members are subject to concentrated loads, particularly if these are out of line with the member web, additional strengthening may be required.

1.22.7 The thickness of the bracket is to be not less than that of the primary member web. The free edge of the bracket is to be stiffened.

1.22.8 Where a deck girder or transverse is connected to a vertical member on the shell or bulkhead, the scantlings of the latter may be required to be increased to provide adequate stiffness to resist rotation of the joint.

1.22.9 Where a member is continued over a point of support, such as a pillar or pillar bulkhead stiffener, the design of the end connection is to be such as to ensure the effective distribution of the load into the support. Proposals to fit brackets of reduced scantlings, or alternative arrangements, will be considered.

1.22.10 Connections between primary members forming a ring system are to minimise stress concentrations at the junctions. Integral brackets are generally to be radiused or well rounded at their toes. The arm length of the bracket, measured from the face of the member, is to be not less than the depth of the smaller member forming the connection.

1.23 Tank boundary penetrations

1.23.1 Where structural members pass through the boundary of a tank, and leakage into the adjacent space could be hazardous or undesirable, full penetration welding is to be adopted for the members for at least 150 mm on each side of the boundary. Alternatively a small scallop of suitable shape may be cut in the member close to the boundary outside the compartment, and carefully welded all round.

1.24 Web stability

1.24.1 Primary members of asymmetrical section are to be supported by tripping brackets at alternate secondary members. If the section is symmetrical, the tripping brackets may be four spaces apart.

1.24.2 Tripping brackets are in general required to be fitted at the toes of end brackets and in way of heavy or concentrated loads such as the heels of pillars. *See also* LR's *Guidance Notes for Structural Details*.

1.25 Openings in the web

1.25.1 Where openings are cut in the web, the depth of opening is not to exceed 50 per cent of the web depth, and the opening is to be so located that the edges are not less than 25 per cent of the web depth from the face plate. The length of opening is not to exceed the web depth or 60 per cent of the secondary member spacing, whichever is the greater, and the ends of the openings are to be equidistant from the corners of cut-outs for secondary members. Where larger openings are proposed, the arrangements and compensation required will be specially considered.

1.25.2 Openings are to have smooth edges and well rounded corners.

1.26 Continuity and alignment

1.26.1 The arrangement of material is to be such as will ensure structural continuity. Abrupt changes of shape or section, sharp corners and points of stress concentration are to be avoided.

1.26.2 Where members abut on both sides of a bulkhead or similar structure, care is to be taken to ensure good alignment.

1.26.3 Pillars and pillar bulkheads are to be fitted in the same vertical line wherever possible, and elsewhere arrangements are to be made to transmit the out of line forces satisfactorily. The load at head and heel of pillars is to be effectively distributed and arrangements are to be made to ensure the adequacy and lateral stability of the supporting members.

1.26.4 Continuity is to be maintained where primary members intersect and where the members are of the same depth, a suitable gusset plate is to be fitted, *see* Fig. 3.1.4.

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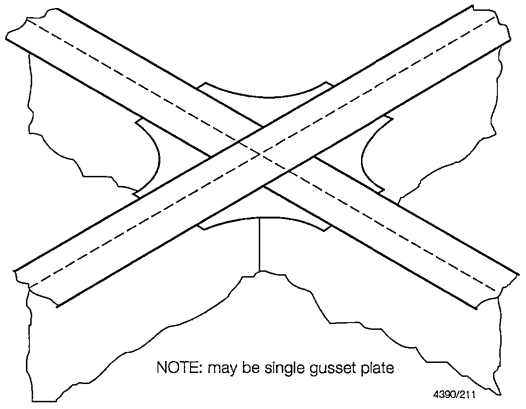

Fig. 3.1.4 Primary member intersection

1.26.5 End connections of structural members are to provide adequate end fixity and effective distribution of the load into the supporting structure.

1.26.6 The toes of brackets, etc., are not to land on unstiffened panels of plating. Special care is to be taken to avoid notch effects at the toes of brackets, by making the toe concave or otherwise tapering it off. *See also* LR's *Guidance Notes for Structural Details*.

1.26.7 Particular care is to be paid to the design of the end bracket toes in order to minimise stress concentrations. Sniped face plates which are welded onto the edge of primary member brackets are to be carried well around the radiuses bracket toe and are to incorporate a taper not exceeding one in three. Where sniped face plates are welded adjacent to the edge of primary member brackets, adequate cross sectional area is to be provided through the bracket toe at the end of the snipe. In general, this area measured perpendicular to the face plate, is to be not less than 60 per cent of the full cross-sectional area of the face plate, *see* Fig. 3.1.5.

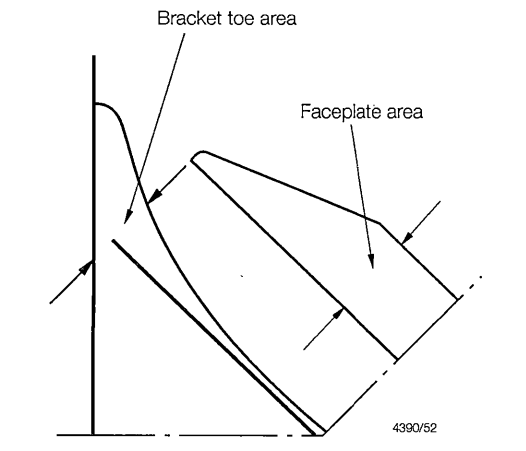

Fig. 3.1.5 Bracket toe construction

1.27 Arrangement with offset stiffener

1.27.1 Where the stiffeners of the double bottom floors and transverse bulkheads are unconnected to the secondary members and offset from them (*see* Fig. 3.1.6) the collar arrangement for the secondary members are to satisfy the requirements of 1.28. In addition, the fillet welds attaching the lugs to the secondary members are to be based on a weld factor of 0,44 for the throat thickness. To facilitate access for welding the offset stiffeners are to be located 50 mm from the slot edge furthest from the web of the secondary member. The ends of the offset stiffeners are to be suitably tapered and softened.

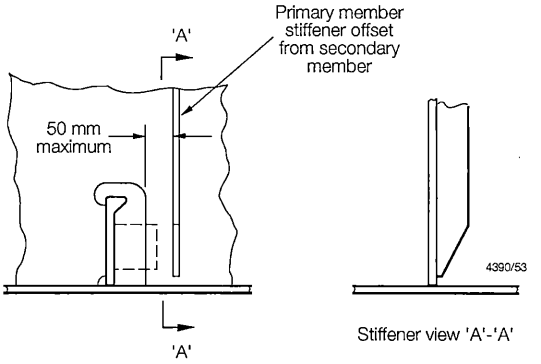

Fig. 3.1.6 Arrangement with offset stiffener

1.27.2 Alternative arrangements will be considered on the basis of their ability to transmit load with equivalent effectiveness. Details of the calculations made and testing procedures are to be submitted.

1.28 Arrangements at intersection of continuous secondary and primary members

1.28.1 Cut-outs for the passage of secondary members through the webs of primary members, and the related collaring arrangements, are to be designed to minimise stress concentrations around the perimeter of the opening and in the attached hull envelope or bulkhead plating. The critical shear buckling stress of the panel in which the cut-out is made is to be investigated. Cut-outs for longitudinals will be required to have double lugs in areas of high stress.

1.28.2 The breadth of cut-outs is to be as small as practicable, with the top edge suitably radiused. Cut-outs are to have smooth edges, and the corner radii are to be as large as practicable, with a minimum of 20 per cent of the breadth of the cut-out or 25 mm, whichever is the greater. It is recommended that the web plate connection to the hull envelope, or bulkhead, end in a smooth tapered 'soft toe'. Recommended shapes of cut-out are shown in Fig. 3.1.7, but consideration will be given to other shapes on the basis of maintaining equivalent strength and minimising stress concentration. *See also* LR's *Guidance Notes for Structural Details*.

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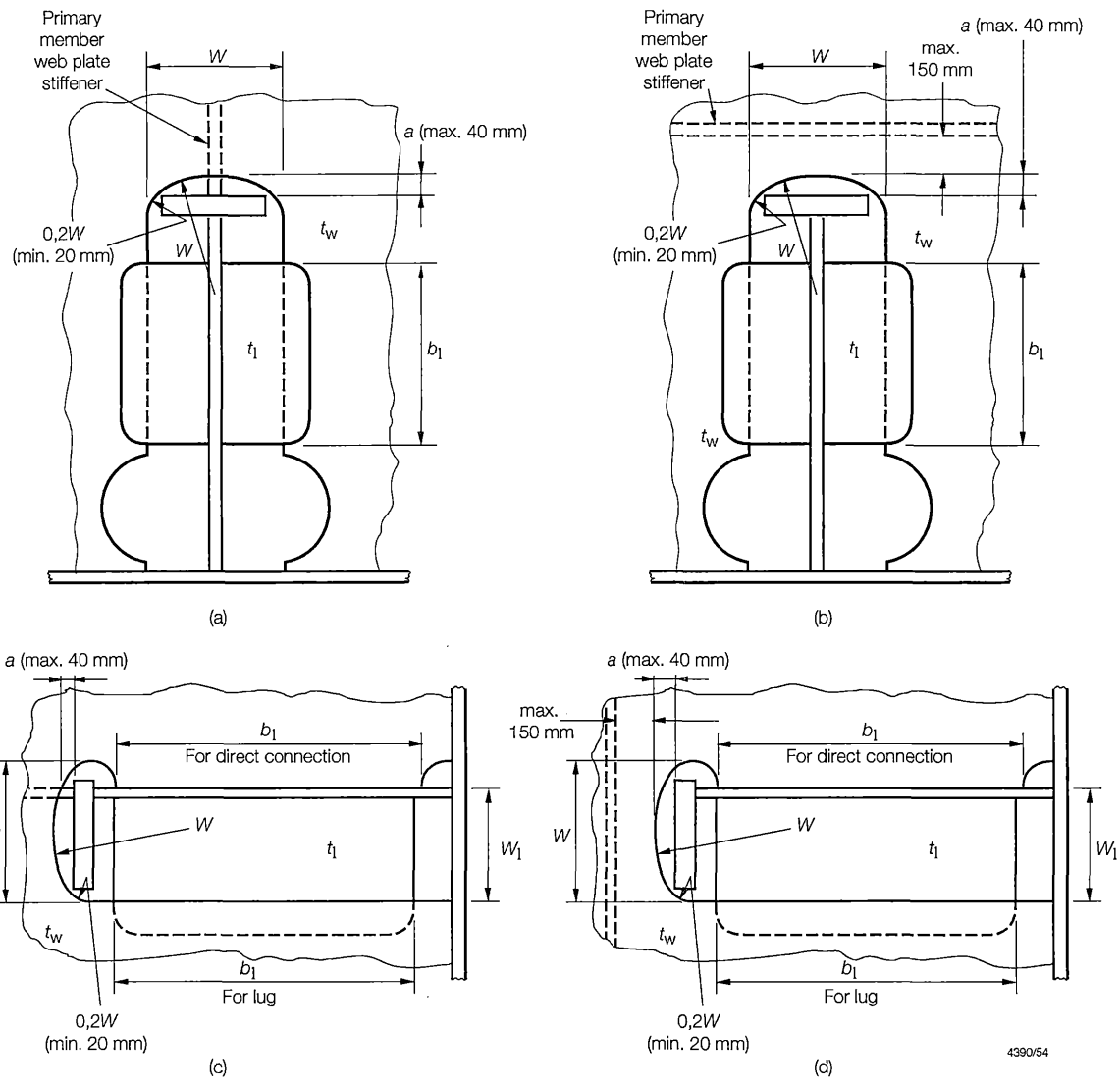

Fig. 3.1.7 Cut-outs and connections

1.28.3 Consideration is to be given to the provision of adequate drainage and unimpeded flow of air and water when designing the cut-outs and connection details.

1.28.4 Asymmetrical secondary members are to be connected on the heel side to the primary member web plate. Additional connection by lugs on the opposite side may be required.

1.28.5 Symmetrical secondary members are to be connected by lugs on one or both sides, as necessary.

1.28.6 Where the primary member stiffener is connected to the secondary member it is to be aligned with the web of the secondary member, except where the face plate of the latter is offset and abutted to the web, in which case the stiffener connection is to be lapped.

1.28.7 Fabricated longitudinals having the face plate welded to the underside of the web, leaving the edge of the web exposed, are not recommended for side shell and longitudinal bulkhead longitudinals. Where it is proposed to fit such sections, a symmetrical arrangement of connection to transverse members is to be incorporated. This can be achieved by fitting backing structure on the opposite side of the transverse web or bulkhead.

1.28.8 Where a bracket is fitted to the primary member web plate in addition to a connected stiffener it is to be arranged on the opposite side to, and in alignment with, the stiffener. The arm length of the bracket is to be not less than the depth of the stiffener, and its cross-sectional area through the throat of the bracket is to be included in the calculation of the area of the primary web stiffener in way of the connection.

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1.28.9 Alternative arrangements will be considered on the basis of their ability to transmit load with equivalent effectiveness. Details of the calculations made and testing procedures are to be submitted.

1.29 Openings

1.29.1 Manholes, lightening holes and other cut-outs are to be avoided in way of concentrated loads and areas of high shear. In particular, manholes and similar openings are not to be cut in vertical or horizontal diaphragm plates in narrow cofferdams or in floors and double bottom girders close to their span ends, or below the heels of pillars, unless the stresses in the plating and the panel buckling characteristics have been calculated and found satisfactory.

1.29.2 Manholes, lightening holes and other openings are to be suitably framed and stiffened where necessary.

1.29.3 Air and drain holes, notches and scallops are to be kept at least 200 mm clear of the toes of end brackets and other areas of high stress. Openings are to be well rounded with smooth edges. Closely spaced scallops are not permitted. Widely spaced air or drain holes may be accepted, provided that they are of elliptical shape, or equivalent, to minimise stress concentration and are, in general, cut clear of the weld connection.

1.30 Fittings and attachments, general

1.30.1 The quality of welding and general workmanship of fittings and attachments as given in 1.31 and 1.32 are to be in accordance with Chapter 13 of the Rules for Materials.

1.31 Bilge keels and ground bars

1.31.1 It is recommended that bilge keels are not fitted in the forward $0{,}3L_R$ region on ships intended to navigate in ice conditions.

1.31.2 Bilge keels are to be attached to a continuous ground bar as shown in Fig. 3.1.8. Butt welds in shell plating, ground bar and bilge keels are to be staggered.

1.31.3 The thickness of the ground bar is to be not less than the thickness of the bottom shell or 6 mm, whichever is the greater, but need not be taken as greater than 12 mm.

1.31.4 The material class, grade and quality of the ground bar are to be similar to those of the adjacent shell plating.

1.31.5 The ground bar is to be connected to the shell with a continuous fillet weld and the bilge keel to the ground bar with a light continuous fillet weld.

1.31.6 Direct connection between ground bar butt welds and shell plating, and between bilge keel butt welds and ground bar is to be avoided.

1.31.7 The end details of bilge keels and intermittent bilge keels, where adopted, are to be as shown in Fig. 3.1.9.

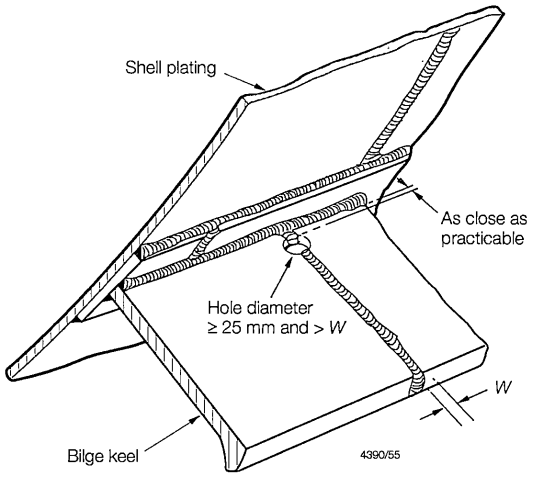

Fig. 3.1.8 Bilge keel construction

1.31.8 The ground bar and bilge keel ends are to be tapered or rounded. Where the ends are tapered, the tapers are to be gradual with ratios of at least 3:1, *see* Figs. 3.1.9(a) and (b). Where the ends are rounded, details are to be as shown in Fig. 3.1.9(c). Cut-outs on the bilge keel web within zone 'A' (*see* Fig. 3.1.9(b)) are not permitted.

1.31.9 The end of the bilge keel web is to be between 50 mm and 100 mm from the end of the ground bar, *see* Fig. 3.1.9(a).

1.31.10 An internal transverse support is to be positioned as close as possible to halfway between the end of the bilge keel web and the end of the ground bar, *see* Fig. 3.1.9(b).

1.31.11 Where an internal longitudinal stiffener is fitted in line with the bilge keel web, the longitudinal stiffener is to extend to at least the nearest transverse member outside zone 'A', *see* Fig. 3.1.9(b). In this case, the requirement of 1.31.10 does not apply.

1.31.12 For craft over 65 m in length, L_R, holes are to be drilled in the bilge keel butt welds. The size and position of these holes are to be as illustrated in Fig. 3.1.8. Where the butt weld has been subject to non-destructive examination the stop hole may be omitted.

1.31.13 Bilge keels of a different design from that shown in Fig. 3.1.8 and Fig. 3.1.9 will be specially considered.

1.31.14 Within zone 'B' (*see* Fig. 3.1.9(a)), welds at the ends of the ground bar and the bilge plating, and at the ends of the bilge keel web and ground bar, are to have weld factors of 0,44 and 0,34 respectively. These welds are to be ground and to blend smoothly with the base materials.

1.31.15 A plan of the bilge keels is to be submitted for approval of material grades, welded connections and detail design.

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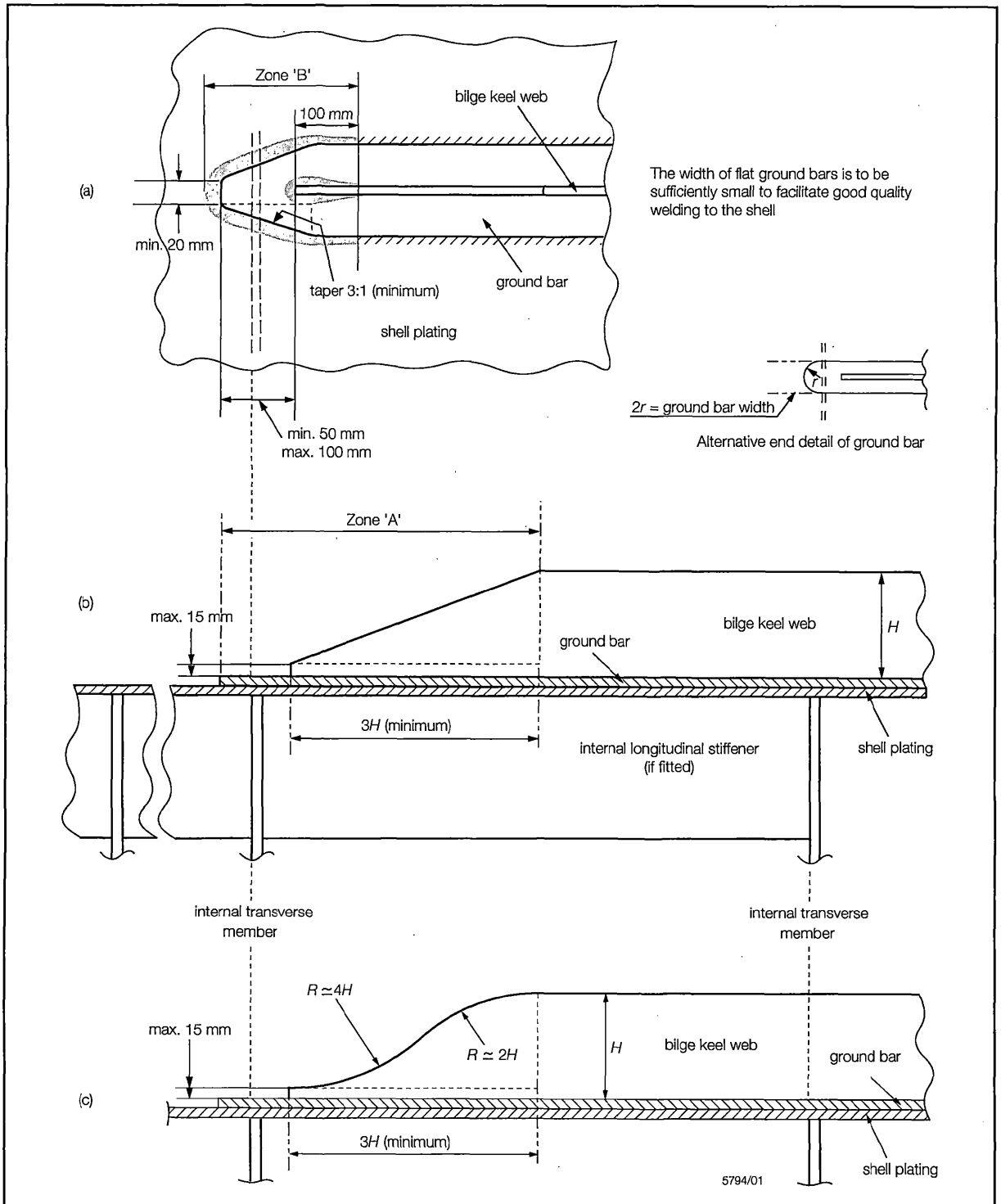

Fig. 3.1.9 Bilge keel end design

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1.32 Other fittings and attachments

1.32.1 Gutterway bars at the upper deck are to be so arranged that the effect of main hull stresses on them is minimised.

1.32.2 Minor attachments, such as pipe clips, staging lugs and supports, are generally to be kept clear of toes of end brackets, corners of openings and similar areas of high stress. Where connected to asymmetrical stiffeners, the attachments may be in line with the web provided the fillet weld leg length is clear of the offset face plate or flange edge. Where this cannot be achieved the attachments are to be connected to the web, and in the case of flanged stiffeners they are to be kept at least 25 mm clear of the flange edge. On symmetrical stiffeners, they may be connected to the web or to the centreline of the face plate in line with the web.

1.32.3 Where necessary in the construction of the craft, lifting lugs may be welded to the hull plating but they are not to be slotted through. Where they are subsequently removed, this is to be carried out by mechanical cutting close to the plate surface, and the remaining material and welding ground off. After removal the area is to be carefully examined to ensure freedom from cracks or other defects in the plate surface.

■ *Section 2*
Minimum thickness requirements

2.1 General

2.1.1 The thickness of plating and stiffeners determined from the Rule scantling requirements is in no case to be less than that given in Table 3.2.1 for the craft type.

2.1.2 In addition, where plating contributes to the global strength of the craft, the thickness is to be not less than that required to satisfy the global strength requirements detailed in Chapter 6.

2.2 Corrosion margin

2.2.1 The minimum thicknesses given in Table 3.2.1 are based on the assumption that there is negligible loss in strength by corrosion. Where this is not the case the minimum thickness will be specially considered.

2.3 Impact consideration

2.3.1 Due consideration is to be given to the scantlings of all structure which may be subject to local impact loadings. Impact testing may be required to be carried out at the discretion of LR to demonstrate the suitability of the proposed scantlings for a particular application.

2.4 Sheathing

2.4.1 Areas of shell and deck which are subject to additional wear by abrasion, e.g. from passenger routes, working areas of fishing vessels, forefoot region, etc., are to be suitably protected by local reinforcement or sheathing. This sheathing may be of timber, rubber, steel, additional layers of reinforcement, etc., as appropriate. Details of such sheathing and the method of attachment are to be submitted for consideration.

2.4.2 The attachment of sheathing by mechanical means such as bolting or other methods is not to impair the watertight integrity of the craft. Through bolting of the hull is to be kept to a minimum and avoided where practicable. The design arrangements in way of any through bolting are to be such that damage to the sheathing will not impair the watertight integrity of the hull.

2.5 Operation in ice

2.5.1 The minimum plating thickness of craft intended for operation in ice conditions is to comply with Ch 5,7.

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Table 3.2.1 Minimum thickness requirements

Item	Minimum thickness (mm)		
	Mono-hull	Hydrofoil	Rigid inflatable boat (RIB)
Shell envelope			
Bottom shell plating	$\omega\sqrt{k_{ms}}\ (0,4\sqrt{L_R}+2,0) \geq 3,5\omega$	$\omega\sqrt{k_{ms}}\ (0,4\sqrt{L_R}+2,0) \geq 3,5\omega$	$\omega\sqrt{k_{ms}}\ (0,4\sqrt{L_R}+2,0) \geq 3,5\omega$
Side shell plating	$\omega\sqrt{k_{ms}}\ (0,38\sqrt{L_R}+1,2) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,38\sqrt{L_R}+1,2) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,38\sqrt{L_R}+1,2) \geq 3,0\omega$
Single bottom structure			
Centre girder web	$\omega\sqrt{k_{ms}}\ (0,8\sqrt{L_R}+1,0) \geq 4,0\omega$	$\omega\sqrt{k_{ms}}\ (0,8\sqrt{L_R}+1,0) \geq 4,0\omega$	$\omega\sqrt{k_{ms}}\ (0,8\sqrt{L_R}+1,0) \geq 4,0\omega$
Floor webs	$\omega\sqrt{k_{ms}}\ (0,6\sqrt{L_R}+0,8) \geq 3,5\omega$	$\omega\sqrt{k_{ms}}\ (0,6\sqrt{L_R}+0,8) \geq 3,5\omega$	$\omega\sqrt{k_{ms}}\ (0,6\sqrt{L_R}+0,8) \geq 3,5\omega$
Side girder webs	$\omega\sqrt{k_{ms}}\ (0,6\sqrt{L_R}+0,8) \geq 3,5\omega$	$\omega\sqrt{k_{ms}}\ (0,6\sqrt{L_R}+0,8) \geq 3,5\omega$	$\omega\sqrt{k_{ms}}\ (0,6\sqrt{L_R}+0,8) \geq 3,5\omega$
Double bottom structure			
Centre girder			
(1) Within $0,4L_R$ amidships	$\omega\sqrt{k_{ms}}\ (0,8\sqrt{L_R}+1,0) \geq 4,0\omega$	$\omega\sqrt{k_{ms}}\ (0,8\sqrt{L_R}+1,0) \geq 4,0\omega$	$\omega\sqrt{k_{ms}}\ (0,8\sqrt{L_R}+1,0) \geq 4,0\omega$
(2) Outside $0,4L_R$ amidships	$\omega\sqrt{k_{ms}}\ (0,7\sqrt{L_R}+1,0) \geq 4,0\omega$	$\omega\sqrt{k_{ms}}\ (0,7\sqrt{L_R}+1,0) \geq 4,0\omega$	$\omega\sqrt{k_{ms}}\ (0,7\sqrt{L_R}+1,0) \geq 4,0\omega$
Floors and side girders	$\omega\sqrt{k_{ms}}\ (0,6\sqrt{L_R}+0,8) \geq 3,5\omega$	$\omega\sqrt{k_{ms}}\ (0,6\sqrt{L_R}+0,8) \geq 3,5\omega$	$\omega\sqrt{k_{ms}}\ (0,6\sqrt{L_R}+0,8) \geq 3,5\omega$
Inner bottom plating	$\omega\sqrt{k_{ms}}\ (0,5\sqrt{L_R}+1,0) \geq 2,5\omega$	$\omega\sqrt{k_{ms}}\ (0,5\sqrt{L_R}+1,0) \geq 2,5\omega$	$\omega\sqrt{k_{ms}}\ (0,5\sqrt{L_R}+1,0) \geq 2,5\omega$
Bulkheads			
Watertight bulkhead plating	$\omega\sqrt{k_{ms}}\ (0,33\sqrt{L_R}+1,0) \geq 2,5\omega$	$\omega\sqrt{k_{ms}}\ (0,33\sqrt{L_R}+1,0) \geq 2,5\omega$	$\omega\sqrt{k_{ms}}\ (0,33\sqrt{L_R}+1,0) \geq 2,5\omega$
Deep tank bulkhead plating	$\omega\sqrt{k_{ms}}\ (0,38\sqrt{L_R}+1,2) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,38\sqrt{L_R}+1,2) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,38\sqrt{L_R}+1,2) \geq 3,0\omega$
Deck plating and stiffeners			
Strength/Main deck plating	$\omega\sqrt{k_{ms}}\ (0,38\sqrt{L_R}+1,2) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,38\sqrt{L_R}+1,2) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,38\sqrt{L_R}+1,2) \geq 3,0\omega$
Lower deck/Inside deckhouse	$\omega\sqrt{k_{ms}}\ (0,18\sqrt{L_R}+1,7) \geq 2,0\omega$	$\omega\sqrt{k_{ms}}\ (0,18\sqrt{L_R}+1,7) \geq 2,0\omega$	$\omega\sqrt{k_{ms}}\ (0,18\sqrt{L_R}+1,7) \geq 2,0\omega$
Superstructures and deckhouses			
Superstructure side plating	$\omega\sqrt{k_{ms}}\ (0,3\sqrt{L_R}+1,0) \geq 2,0\omega$	$\omega\sqrt{k_{ms}}\ (0,3\sqrt{L_R}+1,0) \geq 2,0\omega$	$\omega\sqrt{k_{ms}}\ (0,3\sqrt{L_R}+1,0) \geq 2,0\omega$
Deckhouse front 1st tier	$\omega\sqrt{k_{ms}}\ (0,47\sqrt{L_R}+1,5) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,47\sqrt{L_R}+1,5) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,47\sqrt{L_R}+1,5) \geq 3,0\omega$
Deckhouse front upper tiers	$\omega\sqrt{k_{ms}}\ (0,42\sqrt{L_R}+1,3) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,42\sqrt{L_R}+1,3) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,42\sqrt{L_R}+1,3) \geq 3,0\omega$
Deckhouse aft	$\omega\sqrt{k_{ms}}\ (0,2\sqrt{L_R}+0,6) \geq 2,0\omega$	$\omega\sqrt{k_{ms}}\ (0,2\sqrt{L_R}+0,6) \geq 2,0\omega$	$\omega\sqrt{k_{ms}}\ (0,2\sqrt{L_R}+0,6) \geq 2,0\omega$
Pillars			
Wall thickness of tubular pillars	$\omega\sqrt{k_{ms}}\ 0,05d_p$	$\omega\sqrt{k_{ms}}\ 0,05d_p$	$\omega\sqrt{k_{ms}}\ 0,05d_p$
Wall thickness of rectangular pillars	$\omega\sqrt{k_{ms}}\ 0,05b_p$	$\omega\sqrt{k_{ms}}\ 0,05d_p$	$\omega\sqrt{k_{ms}}\ 0,05d_p$

Symbols

ω = service type correction factor as determined from Table 3.2.2

k_{ms} = $635/(\sigma_s + \sigma_u)$

σ_s = specified minimum yield strength of the material, in N/mm^2

σ_u = specified minimum ultimate tensile strength of the material, in N/mm^2

b_p = minimum breadth of cross section of hollow rectangle pillar, in mm

d_p = outside diameter of tubular pillar, in mm

L_R is as defined in 1.5.1.

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Table 3.2.2 Service type correction factor (ω)

Service type notation	ω
Cargo	1,1
Passenger	1,0
Patrol	1,0
Pilot	1,1
Yacht	1,0
Workboat MFV	1,2

■ *Section 3* Shell envelope plating

3.1 General

3.1.1 The requirements of this Section are applicable to longitudinally and transversely framed shell envelope plating.

3.1.2 The thickness of the shell envelope plating is in no case to be less than the appropriate minimum requirement given in Section 2.

3.2 Plate keel

3.2.1 The breadth, b_k, and thickness, t_k, of the plate keel are not to be taken as less than:

$$b_k = 7{,}0L_R + 340 \text{ mm}$$

$$t_k = \sqrt{k_s}\ 1{,}35L_R^{0,45} \text{ mm}$$

where

L_R and k_s are as defined in 1.5.1.

3.2.2 In no case is the thickness of the plate keel to be less than that of the adjacent bottom shell plating.

3.2.3 The width and thickness of the plate keel are to be maintained throughout the length of the craft from the transom to a point not less than 25 per cent of the freeboard (measured at the forward perpendicular) above the deepest load waterline on the stem. Thereafter the keel thickness may be reduced to that required by 3.3.1 for the stem.

3.2.4 For large or novel craft and for yachts with externally attached ballast keels, the scantlings of the keel will be specially considered.

3.2.5 For bar keels, *see* 5.2.2.

3.3 Plate stem

3.3.1 The thickness of plate stems, t_S, is not to be taken as less than:

$$t_s = \sqrt{k_s}\ (0{,}1L_R + 3) \text{ mm}$$

where

L_R and k_s are as defined in 1.5.1.

3.3.2 In no case is the thickness of the plate stem to be taken as less than the thickness of the adjacent shell plating.

3.3.3 Plate stems are to be supported by horizontal diaphragms, and where the stem radius is large, a centreline stiffener or web may be required. Where this is impracticable due to fabrication access considerations, alternative supporting arrangements will be specially considered

3.3.4 For large or novel craft the scantlings of the stem will be specially considered.

3.3.5 The breadth of plate stems is to be not less than the width of keel as required by 3.2.1.

3.4 Bottom shell plating

3.4.1 The thickness of the bottom shell plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.4.2 For all craft types the minimum thickness requirement for bottom shell plating, *see* Fig. 3.3.1, as detailed in Section 2, is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

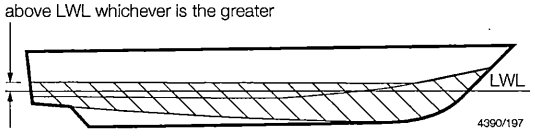

Fig. 3.3.1 Extent of bottom shell

3.5 Side shell plating

3.5.1 The thickness of the side shell plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

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3.6 Sheerstrake

3.6.1 The sheerstrake is generally to be taken as the side shell, locally reinforced in way of deck/hull connection and fender attachment. The amount of local reinforcement will be dependent upon the arrangement of structure and the proposed service.

3.6.2 The fendering arrangements for all craft types are the responsibility of the designers/Builders and are outside the scope of classification.

3.6.3 Where the pressure or impact loadings that a particular type of craft will experience in service are considered by the Builder, or subsequent Owner, to be not covered by or be greater than those indicated in Part 5 of the Rules, details of the loadings together with the calculations of how these will be satisfactorily distributed into the craft's structure, are to be submitted for consideration with the relevant construction plans.

3.6.4 The arrangements indicated in 3.6.5, 3.6.6, 4.18.2 and 4.18.3 for pilot and fishing craft are for the guidance of the Builder and subsequent Owners/operators of the craft. Where the intended service for either of these types of craft, or other types of craft which may be subject to loadings resulting from contact with other craft, jetties or similar loading or boarding facilities, is such that the loadings are greater than those that can be satisfactorily distributed into the craft's structure by the arrangements indicated, the strengthening arrangements are to be increased accordingly.

3.6.5 For pilot craft which may be subject to repeated impact loadings from contact with other craft etc., the sheerstrake plating is to be increased locally by not less than 50 per cent of the side shell thickness. The increased thickness is to extend from the bow aft over a distance of $0{,}33L_R$ or 500 mm aft of the point at which the deckline reaches its greatest breadth, whichever is the greater and forward of the quarter and over the transom for a distance of $0{,}075L_R$ or 1,0 m, whichever is the greater. It is in general to extend from the deck edge to below the first longitudinal stiffener, or a vertical distance equivalent to 1/3 the freeboard height whichever is the greater. The additional thickness is then to be tapered out to the side shell thickness in accordance with the Rules.

3.6.6 Fishing craft are in general to have their shell plating scantlings as required to satisfy the Rule loadings, increased by 20 per cent. Additionally the side shell is not to be taken less than as bottom shell thickness, and where there are gallows, gantries, nets, or lines etc., the plating in way is to be further increased locally and/or suitably protected by sheathing or other means.

3.6.7 Individual consideration will be given to lesser scantlings than those required by 3.6.3. for fishing craft used for pleasure, light duties, etc.; details of the service are to be submitted.

3.6.8 Where a rounded sheerstrake is adopted the radius is, in general, to be not less than 15 times the thickness.

3.6.9 The sheerstrake thickness is to be increased by 20 per cent at the ends of a bridge superstructure extending out to the craft's side. In the case of a bridge superstructure exceeding $0{,}15L_R$, the side plating at the ends of the superstructure is also to be increased by 25 per cent and tapered gradually into the upper deck sheerstrake.

3.6.10 In general, compensation will not be required for openings in the sheerstrake which are clear of the gunwale or deck openings and whose depth does not exceed 20 per cent of the depth of the sheerstrake. Openings are not to be cut in a rounded gunwale.

3.7 Chines

3.7.1 The chine plate thickness is to be equivalent to the bottom shell thickness required to satisfy the Rule pressure loading, increased by 20 per cent, or 6 mm, whichever is the greater.

3.7.2 Where tube is used in chine construction, the minimum wall thickness is to be not less than the thickness of the bottom shell plating increased by 20 per cent.

3.7.3 Full penetration welding of shell plating in way of chines is always to be maintained.

3.7.4 Chine details are to be such that the continuity of structural strength across the panel is maintained. Details of chines are to be submitted for consideration. *See also* LR's *Guidance Notes for Structural Details.*

3.8 Skegs

3.8.1 The thickness of the skeg plating is to be not less than the thickness of the adjacent bottom shell and additionally is to satisfy the requirements for solepieces given in Pt 3, Ch 3,3.

3.9 Transom

3.9.1 The thickness of the stern or transom is to be not less than that required for the side or bottom shell as appropriate. Where water jet or sterndrive units are fitted, the scantlings of the plating in way of the nozzles and connections will be specially considered.

3.10 Fin and tuck

3.10.1 The thickness of the plating is to be increased locally in way of the fin and tuck areas of yachts which have either internal fixed ballast or external attached ballast keels.

3.10.2 The plating thickness is to be not less than 1,25 times the thickness of the adjacent shell plating but need not be greater than the plate keel thickness as required by 3.2.

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3.11 Shell openings

3.11.1 Sea-inlets, or other openings, are to have well rounded corners and, so far as is practicable, are to be kept clear of the bilge radius, chine or radiused sheerstrake. Arrangements are to be made to maintain the strength in way of the openings.

3.11.2 Openings on or near the bilge radius may be accepted provided that they are of elliptical shape, or equivalent, to minimize stress concentrations and are, in general, to be cut clear of weld connections.

3.12 Sea inlet boxes

3.12.1 The thickness of the sea inlet box plating is to be 2 mm thicker than the adjacent shell plating, or 6 mm, whichever is the greater.

3.13 Local reinforcement/Insert plates

3.13.1 The thickness of the shell envelope plating determined in accordance with 3.4 and 3.5 is to be increased locally, by generally not less than 50 per cent in way of sternframe, propeller brackets, rudder horn, stabilisers, hawse pipes, anchor recess, etc. Details of such reinforcement are to be submitted for approval.

3.13.2 Insert plates are to extend outside the line of adjacent supporting structure and then be tapered over a distance of not less than three times the difference in thickness, *see also* Ch 2,4.22.

3.14 Appendages

3.14.1 The scantlings of appendages will be subject to special consideration on the basis of the Rules and the design loadings anticipated, but are, in no case, to be taken as less than that of the surrounding structure.

3.15 Fender attachment

3.15.1 Wood belting and fenders are to be bolted to lugs welded to a ground bar attached to the shell and not through-bolted to the shell plating.

3.16 Novel features

3.16.1 Where the Rules do not specifically define the requirements for novel features then the scantlings and arrangements are to be determined by direct calculation. Such calculations are to be carried out on the basis of the Rules or recognised standards. Details are to be submitted for consideration.

■ *Section 4* Shell envelope framing

4.1 General

4.1.1 The requirements in this Section apply to longitudinally and transversely framed shell envelopes.

4.1.2 For each stiffening member an assumed load model is stated. Where the proposed stiffener arrangement differs from that assumed, consideration will be given to an alternative load model.

4.1.3 The geometric properties of stiffener sections are to be in accordance with 1.18.

4.2 Bottom longitudinal stiffeners

4.2.1 Bottom longitudinal stiffeners are to be supported by bottom transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.2.2 Bottom longitudinals are to be continuous through the supporting structures.

4.2.3 Where it is impracticable to comply with the requirements of 4.2.2, or where it is proposed to terminate the bottom longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.2.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b).

4.3 Bottom longitudinal primary stiffeners

4.3.1 Bottom longitudinal primary stiffeners are to be supported by bottom deep transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 6 m apart.

4.3.2 Bottom longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

4.3.3 Where it is impracticable to comply with the requirements of 4.3.2, or where it is proposed to terminate the stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

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4.3.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

4.4 Bottom transverse stiffeners

4.4.1 Bottom transverse stiffeners are defined as local stiffening members which support the bottom shell, and which may be continuous or intercostal.

4.4.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b).

4.5 Bottom transverse frames

4.5.1 Bottom transverse frames are defined as stiffening members which support the bottom shell. They are to be effectively continuous and bracketed at their end connections to side frames and bottom floors as appropriate.

4.5.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

4.6 Bottom transverse web frames

4.6.1 Bottom transverse web frames are defined as primary stiffening members which support bottom shell longitudinals. They are to be continuous and substantially bracketed at their end connections to side web frames and bottom floors.

4.6.2 Where it is impracticable to comply with the requirements of 4.6.1, or where it is proposed to terminate the bottom transverse web frames in way of longitudinal primary girders, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.6.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

4.7 Side longitudinal stiffeners

4.7.1 The side longitudinal stiffeners are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.7.2 Side longitudinals are to be continuous through the supporting structures.

4.7.3 Where it is impracticable to comply with the requirements of 4.7.2, or where it is proposed to terminate the side longitudinal in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.7.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b).

4.8 Side longitudinal primary stiffeners

4.8.1 Side longitudinal primary stiffeners are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 6 m apart.

4.8.2 Side longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

4.8.3 Where it is impracticable to comply with the requirements of 4.8.2, or where it is proposed to terminate the side longitudinal in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.8.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

4.9 Side transverse stiffeners

4.9.1 Side transverse stiffeners are defined as local stiffening members supporting the side shell and may be continuous or intercostal.

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4.9.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b).

4.10 Side transverse frames

4.10.1 Side transverse frames are defined as stiffening members supporting the side shell and spanning continuously between bottom floors/frames and decks. They are to be effectively constrained against rotation at their end connections.

4.10.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

4.11 Side transverse web frames

4.11.1 Side transverse web frames are defined as primary stiffening members which support side shell longitudinals. They are to be continuous and substantially bracketed at their head and heel connections to deck transverses and bottom web frames respectively.

4.11.2 Where it is impracticable to comply with the requirements of 4.11.1, or where it is proposed to terminate the web frames in way of side longitudinal primary stiffeners, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.11.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

4.12 Grouped frames

4.12.1 For the purposes of satisfying Rule scantling requirements, frames may, subject to agreement by LR, be grouped. The number of frames in any group shall not in general exceed five. The summation of the section moduli and inertia for the group of frames is not to be less than the summation of the Rule requirement for the individual framing members. In addition, in no case is the proposed scantling of an individual framing member within the group to be less than ninety per cent of the Rule value for that member.

4.13 Grillage structures

4.13.1 For complex girder systems, a complete structural analysis using numerical methods may have to be performed to demonstrate that the stress levels are acceptable when subjected to the most severe and realistic combination of loading conditions intended.

4.13.2 General or special purpose computer programs or any other analytical techniques may be used provided that the effects of bending, shear, axial and torsion are properly accounted for and the theory and idealisation used can be justified.

4.13.3 In general, grillages consisting of slender girders may be idealised as frames based on beam theory provided proper account of the variations of geometric properties is taken. For cases where such an assumption is not applicable, finite element analysis or equivalent methods may have to be used.

4.14 Combined framing systems

4.14.1 Where longitudinal and transverse primary stiffeners form grillage structures the scantlings may be derived in accordance with 4.13.

4.15 Floating framing systems

4.15.1 Floating framing systems, where proposed, will be subject to special consideration.

4.16 Frame struts

4.16.1 Where struts are fitted to side shell transverse web frames or longitudinal primary stiffeners to carry axial loads, the strut cross-sectional area is to be derived as for pillars in Section 10. If fitted at the stiffener half span point, the stiffener section modulus may be taken as half the modulus derived above.

4.16.2 Design of end connections is to be such that the area of the welding is to be not less than the minimum cross-sectional area of the strut derived in 4.16.1. To achieve this, full penetration welding may be required. The weld connections between the face flats and webs of the pillar supporting structure are to be welded using double continuous welding of an equivalent area to that derived by 4.16.1.

4.17 Arrangements and details

4.17.1 The arrangement of the connection between the stiffener and the bracket is to be such that at no point in the connection are the section modulus and inertia reduced to less than that of the stiffener with associated plating.

4.17.2 The web stability, openings in the web and continuity and alignment are to be in accordance with 1.24, 1.25 and 1.26 respectively.

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4.17.3 Secondary and primary end connections and arrangements at intersection of continuous secondary and primary members are to be in accordance with 1.20, 1.22 and 1.28, respectively.

4.17.4 Stiffeners in slamming areas are to be lugged or bracketed.

4.18 Structure in way of fenders

4.18.1 **For craft**, including pilot boats and fishing vessels, which may be subject to repeated impact loadings from contact with other craft whilst in service, due consideration is to be given to increasing the scantlings of stiffening members in way of fenders. Details of anticipated loadings and calculations for the required increased scantlings are to be submitted, *see also* 3.6.3 and 3.6.4.

4.18.2 **Pilot craft** are to be fitted with large knees in way of the sheerstrake in areas as indicated in 3.6. The knees are to be aligned between the transverse frames and the deck beams. In the case of longitudinally framed craft, intermediate knees are to be fitted with a spacing in general not greater than 500 mm. Where such intermediate brackets are fitted they are to terminate on a side longitudinal with a section modulus of, in general, twice that of the Rule longitudinal for the web frame spacing, and a deck longitudinal. The side longitudinal is to be positioned below any fendering to carry the heel of the knee. Consideration will be given to the termination of such brackets by use of a 'soft-toe' in way of the deck. The thickness of the webs for these knees is to be twice that required by 1.21.

4.18.3 **Fishing craft** engaged in pair trawling and other modes of fishing, and which may be subject to repeated impact loading from contact with the other craft are to have additional stiffening fitted in way of the impact areas. This may be in the form of large knees, intermediate knees, substantial fendering/rubbing strakes.

4.19 Novel features

4.19.1 The scantlings are to be determined by direct calculation where the shell framing is of unusual design, form or proportions.

■ *Section 5*
Single bottom structure and appendages

5.1 General

5.1.1 The requirements of this Section provide for single bottom construction in association with transverse and longitudinal framing systems.

5.1.2 All girders are to extend as far forward and aft as practicable and care is to be taken to avoid any abrupt discontinuity. Where girders are cut at bulkheads, their longitudinal strength is to be maintained.

5.1.3 Particular care is to be taken to ensure that the continuity of structural strength in way of the intersection of transverse floors and longitudinal girders is maintained. The face flats of such stiffening members are to be effectively connected.

5.1.4 The single bottom structure in way of the keel and girders is to be sufficient to withstand the forces imposed by dry-docking the craft.

5.1.5 The scantlings of the single bottom structure are to comply with the appropriate minimum requirements given in Section 2.

5.2 Keel

5.2.1 The breadth, and thickness of plate keels are to comply with the requirements of 3.2.

5.2.2 The cross-sectional area, A_k, and thickness, t_k, of bar keels are not, in general, be taken as less than:

$$A_k = k_s (L_R + 1) \text{ cm}^2$$

$$t_k = \sqrt{k_s}\ (0{,}5L_R + 6) \text{ mm}$$

where

L_R and k_s are as defined in 1.5.1.

5.3 Centre girder

5.3.1 A centreline girder is, in general, to be fitted throughout the length of the hull in association with transverse frames, transverses supporting longitudinals or where the breadth of floors at the upper edge is greater than 1,5 m.

5.3.2 Centreline girders are to be formed of intercostal or continuous plate webs with a face flat welded to the upper edge. In all cases the face flat is to be continuous. Where girder webs are intercostal, additional bracketing and local reinforcement will be required to maintain the continuity of structural strength.

5.3.3 The web depth of the centre girder is in general to be equal to the depth of the floors at the centreline as specified in 5.5.3.

5.3.4 The web thickness, t_w, is to be taken not less than:

$$t_w = \sqrt{k_s}\ \left(\sqrt{L_R} + 1\right) \text{ mm}$$

where

L_R and k_s are as defined in 1.5.1.

5.3.5 The geometric properties of the centre girder are to be in accordance with 1.18.

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5.3.6 The face flat area of the centre girder, A_f, is to be not less than:

$$A_f = 0{,}3L_R k_s \text{ cm}^2$$

where

L_R and k_s are as defined in 1.5.1.

5.3.7 The face flat area of the centre girder outside $0{,}5L_R$ may be 80 per cent of the value given in 5.3.6.

5.3.8 The face flat thickness is to be not less than the thickness of the web.

5.3.9 The ratio of the width to thickness of the face flat is to be not less than 8 but is not to exceed 16.

5.3.10 Additionally, the requirements of 4.3 for bottom longitudinal primary stiffeners are to be complied with.

5.4 Side girders

5.4.1 Where the floor breadth at the upper edge exceeds 6,0 m side girders are to be fitted at each side of the centre girder such that the spacing between the side and centre girders or between the side girders themselves is not greater than 3 metres. Side girders where fitted are to extend as far forward and aft as practicable and are, in general, to terminate in way of bulkheads, deep floors or other primary transverse structure.

5.4.2 The web thickness of side girders is to be taken as not less than:

$$t_w = \sqrt{(k_s L_R)} \text{ mm}$$

where

L_R and k_s are as defined in 1.5.1.

5.4.3 The face flat area and thickness of side girders are to comply with the requirements for plate floors as defined in 5.5.6 and 5.5.7.

5.4.4 Watertight side girders and side girders forming the boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads and deeptanks as detailed in 7.3 and 7.5 respectively.

5.4.5 In the engineroom, additional side girders are generally to be fitted in way of main machinery seatings. Where fitted, they are to be integrated into the structure of the craft and extended forward and aft as far as practicable.

5.4.6 Additionally, the requirements of 4.3 for bottom longitudinal primary stiffeners are to be complied with.

5.5 Floors general

5.5.1 In transversely framed craft, plate floors are generally to be fitted at each frame.

5.5.2 In longitudinally framed craft, plate floors are to be fitted at every transverse web frame and generally at a spacing not exceeding 2 m. Additional transverse floors or webs are in general to be fitted at half web-frame spacing in way of engine seatings and thrust bearings, pillars, skegs, ballast/bilge keels and the bottom of the craft forward.

5.5.3 The overall depth, d_f, of plate floors at the centreline is not to be taken as less than:

when $B < 10$ m $\quad d_f = 40\,(B + 0{,}85D)$ mm

when $B \geq 10$ m $\quad d_f = 40\,(1{,}5B + 0{,}85D) - 200$ mm

where

D is defined in Pt 3, Ch 1,6.2.6

B is as defined in 1.5.1.

5.5.4 The web thickness, t_w, of plate floors, is to be accordance with 1.18 and is to be taken as not less than:

$$t_w = \sqrt{k_s}\left(\frac{3{,}4d_f}{1000} + 2{,}25\right)\left(\frac{s}{1000} + 0{,}5\right) \text{ mm}$$

where

d_f is to be determined from 5.5.3

k_s and s are as defined in 1.5.1.

5.5.5 If the side frames of the craft are attached to the floors by brackets, the depth of floor may be reduced by 15 per cent and the floor thickness determined using the reduced depth. The brackets are to be flanged and have the same thickness as the floors, and their arm lengths clear of the frame are to be the same as the reduced floor depth given above.

5.5.6 The face flat area of floors, A_f, is not to be taken as less than:

$$A_f = k_s\, 0{,}15L_R \text{ cm}^2$$

where

k_s and L_R are defined in 1.5.1.

5.5.7 The face flat thickness is to be not less than the thickness of the web and the ratio of the web to the thickness of the face flat is to be not less than 8 but is not to exceed 16.

5.5.8 Additionally the requirements of 4.6 for bottom transverse web frames are to be complied with.

5.5.9 Floors are generally to be continuous from side to side.

5.5.10 The tops of floors, in general, may be level from side to side. However, in craft having considerable rise of floor the depth of the floor plate may require to be increased to maintain the required section modulus.

5.5.11 The floors in the aft peak are to extend over and provide effective support to the stern tube(s) where applicable.

5.5.12 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deeptanks as detailed in 7.3 and 7.5.

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5.6 Floors in machinery spaces

5.6.1 The thickness, t_W, of the floors in machinery spaces is to be 1 mm greater than that required by 5.5.4.

5.6.2 The depth and section modulus of floors anywhere between engine or gearbox girders is to be not less than that required to maintain continuity of structural integrity or 50 per cent of the depth given in 5.5.3. The face flat area and web thickness for such reduced floor heights are to be increased appropriately in order to maintain continuity of structural strength, *see also* 4.12.

5.7 Machinery seatings

5.7.1 The general requirements for machinery seatings are given in Pt 3, Ch 2,6.9, *see also* Pt 9, Ch 1,5.

5.7.2 Engine holding-down bolts are to be arranged as near as practicable to floors and longitudinal girders. When this cannot be achieved, bracket floors are to be fitted.

5.7.3 Welding in way of machinery seatings is to be double continuous and/or full penetration where appropriate.

5.8 Drainholes in bottom structure

5.8.1 Sufficient limber holes are to be cut in the internal bottom structure to allow for the drainage of water from all parts of the bilge to the pump suctions.

5.8.2 Particular care is to be given to the positioning of limber holes to ensure adequate drainage and to avoid stress concentrations.

5.8.3 Suitable arrangements are to be made to provide free passage of air from all parts of tanks to the air pipes.

5.9 Rudder horns

5.9.1 The shell plating thickness in way of the rudder horn is to be increased locally, by generally not less than 50 per cent, but need not be taken as greater than the keel thickness required by 3.2.

5.9.2 The scantlings of the rudder horn are to be such that the section modulus against transverse bending, Z_r, at any horisontal section XX (*see* Fig. 3.5.1) is not less than:

$$Z_r = 1{,}5k_s R_A K_V (V + 3)^2 \sqrt{a^2 + 0{,}5b^2} \quad \text{cm}^3$$

where

R_A = total rudder area, in m^2

V = maximum speed in the fully loaded condition, in knots

K_V = 1,0 for displacement craft with $V/\sqrt{L_{WL}} < 3{,}0$

= $(1{,}12 - 0{,}005V)^3$ for planing and semi-planing craft with $V/\sqrt{L_{WL}} \geq 3{,}0$

a, b = dimensions, in metres, as given in Fig. 3.5.1

L_{WL} is as defined in Pt 3, Ch 1,6.2.5.

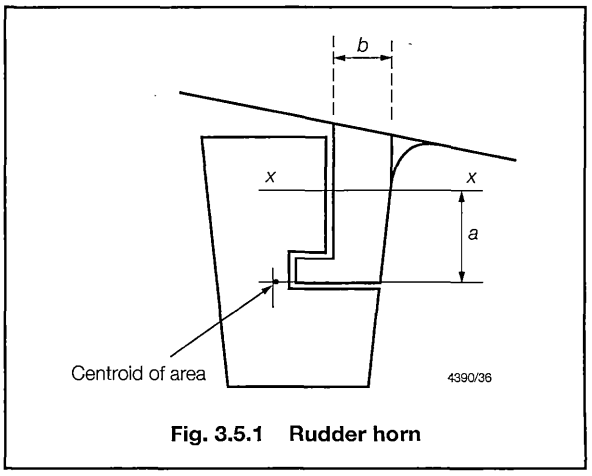

Fig. 3.5.1 Rudder horn

5.9.3 Rudder horns are to be effectively integrated into the adjacent structure and their design is to be such as to facilitate this.

5.10 Sternframes

5.10.1 The scantlings of fabricated and forged/solid sternframes are to comply with the requirements of Pt 3, Ch 3,3 modified for appropriate grade of steel in accordance with Pt 3, Ch 3,1.2.

5.11 Skeg construction

5.11.1 Skegs are to be effectively integrated into the adjacent structure and their design is to be such as to facilitate this.

5.11.2 The scantlings and arrangements for skegs (solepieces) are to be in accordance with Pt 3, Ch 3,3.14.

5.11.3 The scantlings of skegs are to be sufficient to withstand any docking forces that they may be subjected to.

5.12 Forefoot and stem

5.12.1 The thickness of plate stems at the waterline is to comply with the requirements for plate keels as given in 3.2.

5.12.2 The forefoot and stem is to be additionally reinforced with floors.

5.12.3 The cross-sectional area of bar stems, A_{bs}, is not to be taken as less than:

$$A_{bs} = 0{,}8k_s L_R \quad \text{cm}^2$$

where

L_R and k_s are as defined in 1.5.1.

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5.13 Transom knee

5.13.1 Centre and side girders are to be bracketed to the transom framing members by means of substantial knees. The face flat of the girders may be gradually reduced to that of the transom stiffening members in accordance with Fig. 3.5.2.

5.13.2 Hard spots are to be avoided in way of the end connections and care is to be taken to ensure that the stiffening member to which the transom knee is bracketed can satisfactorily carry the transmitted loads.

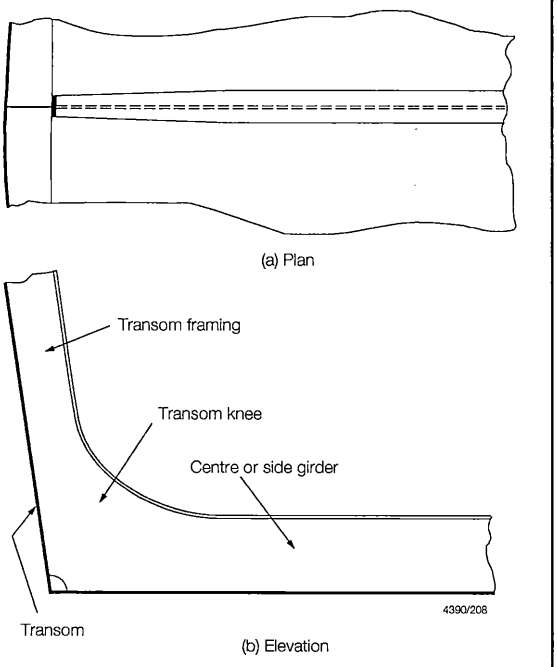

Fig. 3.5.2 Transom knee

Section 6
Double bottom structure

6.1 General

6.1.1 The requirements given in this Section provide for double bottom construction of steel mono-hull craft in association with either transverse or longitudinal framing.

6.1.2 Double bottoms are generally to be fitted in accordance with Pt 3, Ch 2,6.6 and where fitted are to extend from the collision bulkhead to the after peak bulkhead, as far as this is practicable within the design and proper working of the craft. In addition, the inner bottom is to be continued to the craft's side in such a manner as to protect the bottom to the turn of bilge or chine.

6.1.3 The double bottom structure in way of girders and duct keels is to be sufficient to withstand the forces imposed by dry-docking the craft.

6.1.4 The centreline girder and side girders are to extend as far forward and aft as practicable and care is to be taken to avoid any abrupt discontinuity. Where girders are cut at bulkheads, their longitudinal strength is to be maintained.

6.1.5 The scantlings of the double bottom structure are to comply with the appropriate minimum requirements given in Section 2.

6.2 Keel

6.2.1 The scantlings of bar and plate keels are to comply with the requirements of 5.3.

6.2.2 Duct keels, where arranged, are to have a side plate thickness not less than:

$$t_p = \sqrt{k_s}\,(0{,}008d_{DB} + 1) \text{ mm}$$

but need not be taken as greater than 90 per cent of the centre girder thickness given in 6.3.

where

d_{DB} is the Rule centre girder depth given in 6.3.3

k_s as defined in 1.5.1.

6.2.3 Where a duct keel forms the boundary of a tank, the requirements of 7.4 and 7.5 for deep tanks are to be complied with.

6.2.4 The duct keel width is in general to be 15 per cent of the beam or 2 m, whichever is the lesser, but in no case is it to be taken as less than 630 mm. The inner bottom and bottom shell within the duct keel are to be suitably stiffened with primary stiffening in the transverse direction, whilst the continuity of the floors is maintained. Access to the duct keel is to be by means of watertight manholes or trunks.

6.3 Centre girder

6.3.1 A centre girder is to be fitted throughout the length of the craft. The web thickness, t_w, is not to be less than that required by:

$$t_w = \sqrt{k_s}\,(0{,}1L_R + 3) \text{ mm within } 0{,}4L_R \text{ amidships}$$

$$= \sqrt{k_s}\,(0{,}1L_R + 2) \text{ mm at ends.}$$

where

k_s and L_R as defined in 1.5.1.

6.3.2 The geometric properties of the girder section are to be in accordance with 1.18.

6.3.3 The overall depth of the centre girder, d_{DB}, is to be taken as not less than 630 mm and is to be sufficient to give adequate access to all parts of the double bottom.

6.3.4 Additionally, the requirements of 4.3 for bottom longitudinal primary stiffeners are to be complied with.

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6.4 Side girders

6.4.1 Where the floor breadth does not exceed 6,0 m, side girders are not required. Vertical stiffeners are to be fitted to the floors on each side, the number and positions of these stiffeners being dependent on the arrangement of the double bottom structure.

6.4.2 Where the breadth of floor is greater than 6,0 m, additional side girders having the same thickness as the floors are to be fitted. The number of side girders is to be such that the distance between the side girders and centre girder and margin plate, or between the side girders themselves, does not exceed 3,0 m.

6.4.3 Side girders where fitted are to extend as far forward and aft as practicable and are in general to terminate in way of bulkheads, deep floors or other primary transverse structure.

6.4.4 Where additional side girders are fitted in way of main machinery seatings, they are to be integrated into the structure of the craft and extended forward and aft as far as practicable.

6.4.5 Under the main engine, girders extending from the bottom shell to the top plate of the engine seating are to be fitted. The height of the girders is to be not less than the height of the floor. Engine holding-down bolts are to be arranged as near as practicable to the girders and floors. Where this cannot be achieved, bracket floors and/or hanging brackets are to be fitted.

6.4.6 Additionally, the requirements of 4.3 for bottom longitudinal primary stiffeners are to be complied with.

6.5 Plate floors

6.5.1 The web thickness of non-watertight plate floors, t_w, is to be not less than:

$$t_w = \sqrt{k_s}\ (0{,}05L_R + 3{,}5)\ \text{mm}$$

where

k_s and L_R as defined in 1.5.1.

6.5.2 Additionally, the requirements of 4.6 for bottom transverse web frames stiffeners are to be complied with.

6.5.3 Plate floors are, in general, to be continuous between the centre girder and the margin plate.

6.5.4 In longitudinally framed craft, plate floors or equivalent structure are, in general, to be fitted in the following positions:

(a) At every half frame in way of the main engines, thrust bearings, and bottom of the craft forward.
(b) Outboard of the engine seatings, at every frame within the engine room.
(c) Underneath pillars and bulkheads.
(d) Outside of the engine room at a spacing not exceeding 2,0 m.

6.5.5 Vertical flat bar stiffeners are to be fitted to all plate floors at each longitudinal. Each stiffener is to have a depth of not less than $10t_w$ and a thickness of not less than t_w, where

t_w is the thickness of the plate floor as calculated in 6.5.1.

6.5.6 In transversely framed craft, plate floors are to be fitted at every frame in the engine room, under bulkheads, in way of change in depth of double bottom and elsewhere at a spacing not exceeding 2,0 m.

6.6 Bracket floors

6.6.1 Between plate floors, the shell and inner bottom plating is to be supported by bracket floors. The brackets are to have the same thickness as plate floors and are to be stiffened on the unsupported edge.

6.6.2 In longitudinally framed craft, the brackets are to extend from the centre girder and margin plate to the adjacent longitudinal, but in no case is the breadth of the bracket to be taken as not less than 75 per cent of the depth of the centre girder. They are to be fitted at every web frame at the margin plate, and those at the centre girder are to be spaced not more than 1,0 m apart.

6.6.3 In transversely framed craft, the breadth of the brackets, attaching the bottom and inner bottom frames to the centre girder and margin plate, is to be not less than 75 per cent of the depth of the centre girder.

6.7 Watertight floors

6.7.1 The scantlings of watertight floors are to comply with the requirements for plate floors as given in 6.5.

6.7.2 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deep tanks as detailed in 7.3 or 7.5 respectively.

6.8 Tankside brackets

6.8.1 The scantlings of tankside brackets are to comply with the requirements for plate floors given in 6.5.

6.9 Inner bottom plating

6.9.1 The thickness of the inner bottom plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

6.9.2 Inner bottom plating forming the boundaries of tank spaces is, in addition, to comply with the requirements for watertight bulkheads or deeptanks as detailed in 7.2 or 7.4 respectively. Where the plating forms vehicle, passenger or other decks the requirements of Section 8 are to be complied with.

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6.10 Inner bottom longitudinals

6.10.1 Inner bottom longitudinals are to be supported by inner bottom transverse web frames, floors, bulkheads or other primary structure, generally spaced not more than 2 m apart.

6.10.2 The inner bottom longitudinals are to be continuous through the supporting structure and are to be satisfactorily stiffened against buckling.

6.10.3 Where it is impracticable to comply with the requirements of 6.10.2, or where it is desired to terminate the inner bottom longitudinals in way of bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

6.10.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b).

6.11 Inner bottom transverse web framing

6.11.1 Inner bottom transverse web frames are defined as primary stiffening members which support inner bottom longitudinals. They are to be continuous and to be substantially bracketed at their end connections to bottom web frames, bottom floors and tankside brackets.

6.11.2 Where it is impracticable to comply with the requirements of 6.11.1, or where it is desired to terminate the inner bottom transverse web frames in way of centre or side girders, bulkheads or integral tank boundaries, etc., they are to be bracketed in way of their end connections, to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

6.11.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

6.12 Margin plates

6.12.1 A margin plate, if fitted, is to have a thickness as required for inner bottom plating.

6.13 Wells

6.13.1 Small wells constructed in the double bottom structure are not to extend in depth more than necessary. A well extending to the outer bottom may, however, be permitted at the after end of the shaft tunnel of the craft. Other well arrangements (e.g. for lubricating oil under main engines) may be considered provided they give protection equivalent to that afforded by the double bottom.

6.14 Transmission of pillar loads

6.14.1 In double bottoms under widely spaced pillars, the connections of the floors to the girders, and of the floors and girders to the inner bottom, are to be suitably increased. Where pillars are not directly above the intersection of plate floors and girders, partial floors and intercostals are to be fitted as necessary to support the pillars. Manholes are not to be cut in the floors and girders below the heels of pillars. Where longitudinal framing is adopted in the double bottom, equivalent stiffening under the heels of pillars is to be provided, and where the heels of pillars are carried on a tunnel, suitable arrangements are to be made to support the load.

6.15 Manholes

6.15.1 Sufficient manholes are to be cut in the inner bottom, floors and side girders to provide adequate access to, and ventilation of, all parts of the double bottom. The size of the manhole openings is not, in general, to exceed 50 per cent of the double bottom depth unless edge reinforcement is provided. Holes are not to be cut in the centre girder, except in tanks at the forward and after ends of the craft, and elsewhere where tank widths are reduced unless additional stiffening and/or compensation is fitted to maintain the structural integrity.

6.16 Pressure testing

6.16.1 Double bottoms are to be tested upon completion with a head of water representing the maximum internal pressure which could be experienced in service, but not less than a head of water equivalent to the level of the upper deck.

6.17 Drainholes in bottom structure

6.17.1 Sufficient limber holes are to be cut in the internal bottom structure to allow for the drainage of water from all parts of the bilge to the pump suctions.

6.17.2 Particular care is to be given to the positioning of limber holes to ensure adequate drainage and to avoid stress concentrations.

6.17.3 Suitable arrangements are to be made to provide free passage of air from all parts of tanks to the air pipes.

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Section 7
Bulkheads and deep tanks

7.1 General

7.1.1 The requirements of this Section apply to a vertical system of stiffening on bulkheads. They may also be applied to a horizontal system of stiffening provided that equivalent support and alignment are provided.

7.1.2 The number and disposition of transverse watertight bulkheads are to be in accordance with Pt 3, Ch 2,4.

7.1.3 Bulkheads, or part bulkheads, forming the boundary of tanks are to comply with the requirements of 7.5 and 7.6.

7.1.4 For bulkheads in way of partially filled holds or tanks, sloshing forces may be required to be taken into account. Where such forces are likely to be significant, the scantlings will be required to be verified by additional calculations.

7.1.5 A centreline bulkhead is, generally, to be fitted in deep tanks which extend from side to side. The bulkhead may be intact or perforated as desired. If intact, the scantlings are to comply with the requirements of 7.5 and 7.6 for tank boundary bulkheads. If perforated, they are to comply with the requirements of 7.13 for washplates.

7.1.6 The minimum requirements in Section 2 are to be complied with.

7.2 Watertight bulkhead plating

7.2.1 The thickness of the watertight bulkhead plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

7.3 Watertight bulkhead stiffening

7.3.1 The Rule requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 using the appropriate load model.

7.3.2 Bulkheads are to be suitably strengthened, if necessary, at the ends of deck girders and where subjected to concentrated loads.

7.4 Deep tank plating

7.4.1 The thickness of deep tank plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

7.5 Deep tank stiffening

7.5.1 Deep tank bulkhead stiffeners are to be bracketed at both ends. The thickness of the brackets is to be not less than the web thickness of the stiffener.

7.5.2 The Rule requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4, 3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for load model (b).

7.6 Double bottom tanks

7.6.1 The scantlings of double bottom tanks are to comply with the requirements for deep tanks given in 7.4 and 7.5.

7.6.2 Where the crown of a double bottom tank forms a vehicle, passenger or other deck, the requirements of Section 8 are to be complied with.

7.7 Collision bulkheads

7.7.1 The scantlings of collision bulkheads are to comply with the requirements of 7.2 and 7.3 except that the thickness of plating and modulus of stiffeners are not to be less than 12 and 25 per cent greater respectively, than required by 7.2 and 7.3. If the collision bulkhead forms the boundary of a deep tank or cofferdam then the requirements of 7.4 and 7.5 are also to be complied with.

7.8 Gastight bulkheads

7.8.1 Where gastight bulkheads are fitted, in accordance with Pt 3, Ch 2,4 the scantling requirements for watertight bulkheads are to be complied with.

7.8.2 Gastight bulkheads are to be fitted to protect accommodation spaces from gases and vapour fumes from machinery exhaust and fuel systems.

7.9 Non-watertight or partial bulkheads

7.9.1 Where a bulkhead is structural but non-watertight the scantlings are in general to be as for watertight bulkheads or equivalent in strength to web frames in the same position. Partial bulkheads that are non-structural are outside the scope of LR classification.

7.10 Transmission of pillar loads

7.10.1 Bulkheads that are required to act as pillars in way of underdeck girders and other structures subject to heavy loads are to comply with the requirements of Section 10.

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7.11 Corrugated bulkheads

7.11.1 The plating thickness and section modulus for symmetrical corrugated bulkheads are to be in accordance with watertight bulkheads or deep tank bulkheads as appropriate. The spacing, s, is to be taken as s_c, as defined in Fig. 2.3.1 in Pt 3, Ch 2.

7.11.2 In addition, the section geometric properties of 1.18 are to be complied with.

7.11.3 The actual section modulus may be derived in accordance with Pt 3, Ch 2,3.2.

7.12 Stiffeners passing through bulkheads

7.12.1 Primary longitudinal stiffening members are to be continuous through transverse bulkheads.

7.12.2 Pipe or cable runs through watertight bulkheads are to be fitted with suitable watertight glands.

7.13 Wash plates

7.13.1 Tanks are to be sub-divided as necessary by internal baffles or wash plates. Baffles or wash plates which support hull framing are to have scantlings equivalent to web frames in the same position.

7.13.2 Wash plates and wash bulkheads are, in general, to have an area of perforation not less than 10 per cent of the total area of the bulkhead. The perforations are to be so arranged that the efficiency of the bulkhead as a support is not impaired.

7.13.3 The plate thickness is to be not less than the structural element from which the wash bulkhead is formed.

7.13.4 The general stiffener requirements are to be in accordance with 7.5. However, the section modulus may be 50 per cent of that required by 7.5.

7.14 Cofferdams

7.14.1 A cofferdam is to be fitted between freshwater and oil fuel or sanitary tanks. The scantlings of cofferdams are to comply with the requirements of deep tank bulkheads or non-watertight bulkheads as appropriate.

7.15 Coatings

7.15.1 Integral freshwater and oil fuel tanks are to be cleaned and dried after testing and then treated with a suitable coating, in accordance with the manufacturer's recommendations.

7.16 Air pipes

7.16.1 Air pipes of sufficient number and area are to be fitted to each tank in accordance with Pt 15, Ch 2,11.

7.17 Fire protection

7.17.1 Fire protection requirements given in Part 17 are to be complied with.

7.18 Access

7.18.1 Compartments within the craft are to be sufficiently accessible to allow for maintenance and future structural surveys. Linings on craft sides, deckheads and bulkheads, etc., must be capable of being removed. Sufficient space is to be available below lower decks/soles to allow access to the bottom structure. An adequate number of manholes, removable panels, etc., are to provided.

7.18.2 Doors and hatches fitted through watertight bulkheads are to be of equivalent construction to the bulkhead in which they are fitted, be permanently attached and capable of being closed watertight from both sides of the bulkhead. They are to be tested watertight.

7.18.3 Doors and hatches are not to be fitted in collision bulkheads, except in craft of less than 21 metres Rule length, L_R, or in the case where it would be impracticable to arrange access to the forepeak other than through the collision bulkhead. Where fitted, the doors and hatches are to be watertight, as small as practicable and open into the forepeak compartment. Doors in collision bulkheads are to be kept closed at all times while the craft is at sea, *see* Pt 3, Ch 2,4.3.4.

7.18.4 Particular care is to be given to the design and workmanship of the tanks, and adequate access manholes are to be fitted, *see* Pt 3, Ch 1,7.

7.19 Testing

7.19.1 Deep tanks are to be tested on completion, with a head of water to the top of the overflow, or 1,8 m above the crown of the tank, whichever is the greater. The pressure to which the tanks will be subjected to in service is to be indicated on the plans submitted.

■ *Section 8*
Deck structures

8.1 General

8.1.1 The deck plating is to be supported by transverse beams with fore and aft girders or by longitudinals with deep transverse beams. The transverse and deep transverse beams are to align with side main frames and side web frames respectively.

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8.1.2 Beams are to be fitted at every frame and bracketed to the frames. Strong beams and deep transverse beams are to align with and be effectively connected to the side web frames. They are also to be fitted at the ends of large openings in the deck.

8.1.3 The deck plating and supporting structure are to be suitably reinforced in way of cranes, masts, derrick posts and deck machinery.

8.1.4 Primary stiffening members are to be continuous and substantially bracketed at their end connections to maintain continuity of structural strength.

8.1.5 Secondary stiffening members are to be effectively continuous and bracketed at their end connections as appropriate.

8.1.6 Primary and secondary stiffener end connection arrangements are, in general, to be in accordance with 1.22 and 1.20, respectively.

8.1.7 The ends of beams, longitudinals, girders and transverses are to be effectively built into the adjacent structure, or equivalent arrangements provided.

8.1.8 Tripping brackets are to be fitted on deep webs.

8.1.9 Deck structures subject to concentrated loads, are to be suitably reinforced. Where concentrations of loading on one side of a stiffening member may occur, such as pillars out of line, the member is to be adequately stiffened against torsion. Additional reinforcements may be required in way of localised areas of high stress.

8.1.10 The thickness of the deck plating is in no case to be less than the appropriate minimum requirement given in Section 2.

8.1.11 The geometric properties of stiffener sections are to be in accordance with 1.18.

8.2 Strength/Weather deck plating

8.2.1 The thickness of strength/weather deck plating is to be determined from the general plating equation given in 1.16 using the design pressure head from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

8.2.2 The scantlings of watertight cockpits are to be of equivalent strength to those of the strength/weather deck, *see also* Part 4.

8.2.3 It is recommended that the working areas of the weather deck have an anti-slip surface.

8.2.4 Where decks are sheathed with wood or other materials, details of the method of attachment are to be submitted, *see also* 2.4.

8.3 Lower deck/Inside deckhouse plating

8.3.1 The thickness of the lower deck/inside deckhouse plating is to be determined from the general plating equation given in 1.16 using the design pressure head from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

8.4 Accommodation deck plating

8.4.1 Accommodation decks are in general to be treated as lower deck/inside deckhouse decks, with their plating requirements determined in accordance with 8.3.

8.5 Cargo deck plating

8.5.1 The thickness of cargo deck plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

8.5.2 For vehicle decks, plating thickness requirements are to comply with the requirements of Ch 5,3.

8.6 Decks forming crowns of tanks

8.6.1 Decks forming the crown of tanks are to comply with the requirements for the appropriate deck, and are to be additionally examined for compliance with the requirements for deep tank plating given in 7.4.

8.7 Strength/Weather deck stiffening

8.7.1 The Rule requirements for section modulus, inertia and web area for the **strength/weather deck primary stiffening** are to be determined from the general equations given in 1.17, using the design pressure heads from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

8.7.2 The Rule requirements for section modulus, inertia and web area for the **strength/weather deck secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.7.3 Longitudinal framing is, in general, to be adopted at the strength deck outside line of openings, but special consideration will be given to proposals for transverse framing.

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8.8 Lower deck/Inside deckhouse stiffening

8.8.1 The Rule requirements for section modulus, inertia and web area for lower deck/inside deckhouse stiffening are to be determined from the general equations given in 1.17 using the design pressure head from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1. Primary members are assumed to be load model (a) and secondary members load model (b). However, special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.9 Accommodation deck stiffening

8.9.1 Accommodation decks are in general to be treated as lower deck/inside deckhouse decks, with their scantling requirements determined in accordance with 8.8.

8.10 Cargo deck stiffening

8.10.1 The Rule requirements for section modulus, inertia and web area for cargo deck stiffening are to be determined from the general equations given in 1.17 using the design pressure head from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1. Primary members are assumed to be load model (a) and secondary members load model (b). However, special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.10.2 In addition, where the cargo comprises wheeled vehicles, the requirements of Ch 5,3 are to be complied with.

8.11 Deck openings

8.11.1 All openings are to be supported by an adequate framing system, pillars or cantilevers. When cantilevers are used scantlings may be derived from direct calculations.

8.11.2 Where stiffening members terminate in way of an opening they are to be attached to carlings, girders, transverses or coaming plates.

8.11.3 The corners of large hatchways in the strength/weather deck within $0{,}5L_R$ amidships are to be elliptical, parabolic or rounded, with a radius generally not less than 1/24 of the breadth of the opening.

8.11.4 Where elliptical corners are arranged, the major axis is to be fore and aft, the ratio of the major to minor axis is to be not less than two to one nor greater than 2.5 to 1, and the minimum half-length of the major axis is to be defined by l_1 in Fig. 3.8.1. Where parabolic corners are arranged, the dimensions are also to be as shown in Fig. 3.8.1.

8.11.5 Where the corners are parabolic or elliptical, insert plates are not required.

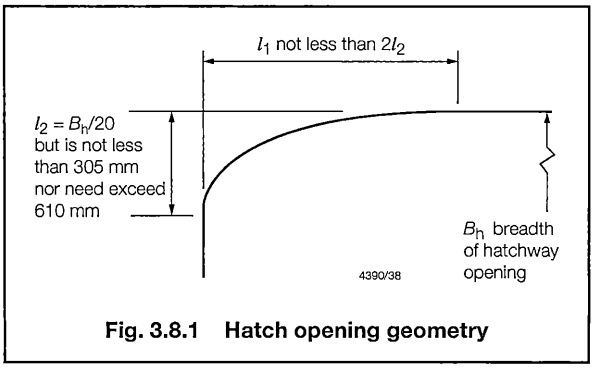

Fig. 3.8.1 Hatch opening geometry

8.11.6 For other shapes of corner, insert plates of the size and extent shown in Fig. 3.8.2 will, in general, be required. The required thickness of the insert plate is to be not less than 25 per cent greater than the adjacent deck thickness, outside line of openings.

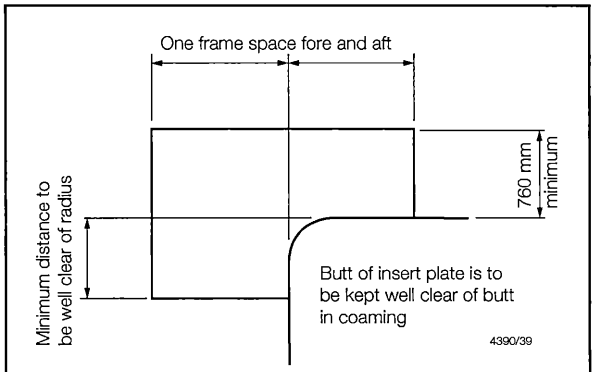

Fig. 3.8.2 Inserts in way of hatch opening

8.11.7 For lower decks the corners of large openings are to be rounded, with a radius generally not less than 1/24 of the breadth of the opening.

8.11.8 Insert plates will be required at lower decks in way of any rapid change in hull form to compensate for loss of deck cross-sectional area. Otherwise, insert plates will not normally be required.

8.11.9 Adequate transverse strength is to be provided in the deck area between large hatch openings, subjected to transverse and buckling loads.

8.11.10 The requirements for closing arrangements and outfit are given in Pt 3, Ch 4.

8.12 Sheathing

8.12.1 The requirements for deck sheathing given in 2.4 are to be complied with.

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8.13 Novel features

8.13.1 Where large or novel hatch openings are proposed, detailed calculations are to be submitted to demonstrate that the scantlings and arrangements in way of the openings are adequate to maintain continuity of structural strength.

■ *Section 9* Superstructures, deckhouses and bulwarks

9.1 General

9.1.1 Where practicable, superstructures and deckhouses are to be designed with well cambered decks and well radiused corners to build rigidity into the structure.

9.1.2 The plating and supporting structure are to be suitably reinforced in way of localised areas of high stress such as corners of openings, cranes, masts, derrick posts, machinery, fittings and other heavy or vibrating loads.

9.1.3 Primary stiffening members are to be continuous and substantially bracketed at their end connections to maintain continuity of structural strength.

9.1.4 Secondary stiffening members are to be effectively continuous and bracketed at their end connections as appropriate.

9.1.5 Structures subject to concentrated loads are to be suitably reinforced. Where concentrations of loading on one side of a stiffener may occur, such as pillars out of line, the stiffener is to be adequately stiffened against torsion.

9.1.6 The plating thickness of superstructures, deckhouses and bulwarks is no case to be less than the appropriate minimum requirement given in Section 2.

9.1.7 Stiffener sections and geometric properties are to be in accordance with 1.18.

9.2 Symbols and definitions

9.2.1 The term 'house' is used in this Section to include both superstructures and deckhouses.

9.2.2 The symbols applicable to this Section are defined in 1.5.1.

9.3 House side plating

9.3.1 The thickness of house side plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

9.4 House front plating

9.4.1 The thickness of the house front plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

9.5 House end plating

9.5.1 The thickness of the house end plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

9.6 House top plating

9.6.1 The thickness of the house top plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

9.7 Coachroof plating

9.7.1 The thickness of the coachroof plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

9.8 Machinery casing plating

9.8.1 The thickness of the plating of machinery casings is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

9.9 Forecastle requirements

9.9.1 The forecastle side plating may be a continuation of the hull side shell plating or fitted as a separate assembly. In both cases the plating thickness is to be the same as the side shell plating at deck edge. Where fitted as a separate assembly, suitable arrangements are to be made to ensure continuity of the effect of the sheerstrake at the break and at the upper edge of the forecastle side. Full penetration welding is to be used.

9.9.2 The side plating is to be stiffened by side frames effectively connected to the deck structure. Deep webs are to be fitted to ensure overall rigidity.

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9.9.3 The deck plating thickness is to be increased by 20 per cent in way of the end of the forecastle if this occurs at a position aft of $0,25L_R$ from the FP. No increase is required if the forecastle end bulkhead lies forward of $0,2L_R$ from the FP. The increase at intermediate positions of end bulkhead is to be obtained by interpolation.

9.10 House side stiffeners

9.10.1 The Rule requirements for section modulus, inertia and web area for the **house side primary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

9.10.2 The Rule requirements for section modulus, inertia and web area for **house side secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.11 House front stiffeners

9.11.1 The Rule requirements for section modulus, inertia and web area for **house front primary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

9.11.2 The Rule requirements for section modulus, inertia and web area for **house front secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.12 House aft end stiffeners

9.12.1 The Rule requirements for section modulus, inertia and web area for **house aft end primary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

9.12.2 The Rule requirements for section modulus, inertia and web area for **house aft end secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.13 House top stiffeners

9.13.1 The house top is to be effectively supported by a system of transverse or longitudinal beams and girders. The span of the beams is in general not to exceed 2,4 m and the beams are to be effectively connected to the house upper coamings and girders.

9.13.2 The Rule requirements for section modulus, inertia and web area for **house top primary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

9.13.3 The Rule requirements for section modulus, inertia and web area for **house top secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.14 Coachroof stiffeners

9.14.1 The Rule requirements for section modulus, inertia and web area for **coachroof primary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

9.14.2 The Rule requirements for section modulus, inertia and web area for **coachroof secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

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9.15 Machinery casing stiffeners

9.15.1 The Rule requirements for section modulus, inertia and web area for **machinery casing primary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

9.15.2 The Rule requirements for section modulus, inertia and web area for **machinery casing secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.15.3 Where casing sides act as girders supporting decks, care is to be taken that access openings do not seriously weaken the structure. Openings are to be effectively framed and reinforced if found necessary. Particular care is to be paid to stiffening where the casing supports the funnel or exhaust uptakes.

9.15.4 Where casing stiffeners carry loads from deck transverses, girders, etc., or where they are in line with pillars below, they are to be suitably reinforced.

9.16 Forecastle stiffeners

9.16.1 The scantlings of forecastle primary and secondary stiffening members are to be equivalent to those for the side shell envelope framing at the deck edge as required by Section 4.

9.17 Superstructures formed by extending side structures

9.17.1 Superstructure first tier sides formed by extending the hull side structure are to be in accordance with the requirements for house fronts given in 9.4 and 9.11 for plating and stiffeners respectively, but need not be taken as greater than the side structure requirements at the deck edge at the same longitudinal position.

9.18 Fire aspects

9.18.1 The requirements for fire detection, protection and extinction are given in Part 17.

9.19 Openings

9.19.1 All openings are to be substantially framed and have well rounded corners. Arrangements are to be made to minimise the effect of discontinuities in erections. Continuous coamings or girders are to be fitted below and above doors and similar openings.

9.19.2 Particular care is to be paid to the effectiveness of end bulkheads, and the upper deck stiffening in way, when large openings for doors and windows are fitted.

9.19.3 Special care is to be taken to minimise the size and number of openings in the side bulkheads in the region of the ends of erections within $0{,}5L_R$ amidships. Account is to be taken of the high vertical shear loading which can occur in these areas.

9.19.4 For closing arrangements and outfit the requirements are given in Pt 3, Ch 4.

9.20 Mullions

9.20.1 Window openings are to be suitably framed and mullions will in general be required.

9.20.2 The scantlings of mullions are to be not less than as required for a stiffener in the same position.

9.20.3 When determining the stiffener requirements, the width of effective plating is in no case to be taken as greater than the distance between adjacent window openings.

9.20.4 Where significant shear forces are to be vertically transmitted by the window frames, adequate shear rigidity is to be verified by direct calculation.

9.21 Global strength

9.21.1 Transverse rigidity is to be maintained throughout the length of the erection by means of web frames, bulkheads or partial bulkheads. Particular care is to be paid when an upper tier is wider than its supporting tier and when significant loads are carried on the house top.

9.21.2 Where practicable, web frames are to be arranged in line with bulkheads below.

9.21.3 Internal bulkheads are to be fitted in line with bulkheads or deep primary stiffeners below.

9.22 House/deck connection

9.22.1 Adequate support under the ends of erections is to be provided in the form of webs, pillars, diaphragms or bulkheads in conjunction with reinforced deck beams.

9.22.2 Special attention is to be given to the connection of the erection to the deck in order to provide an adequate load distribution and avoid stress concentrations.

9.22.3 Connections between the erection and the deck by means of bimetallic joints are to comply with Ch 2,4.24.

9.22.4 Typical design details of house/deck connections are given in LR's *Guidance Notes for Structural Details*.

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9.23 Sheathing

9.23.1 Sheathing arrangements are to comply with the requirements of 2.4.

9.24 Erections contributing to longitudinal strength

9.24.1 For craft above 40 m in length, L_R, or for designs where the superstructure is designed to absorb global loads the effectiveness of superstructures to carry these loads is to be determined. The effectiveness may be assessed in accordance with Ch 6,2.5.

9.24.2 Where 9.17 applies and the first or second tier is regarded as the strength deck according to Ch 6,2.5, the hull upper deck scantlings at the forward and aft ends of the superstructure may need to be increased due to the lesser efficiency of the superstructure tiers at their ends. The scantlings of the side structure in way of these areas may also be required to be increased.

9.24.3 When large openings or a large number of smaller openings are cut in the superstructure sides, reducing the capability to transmit shear force between decks, an assessment or structural efficiency may be required.

9.25 Novel features

9.25.1 Direct calculations may be required to determine the plating and stiffener requirements where the house is of unusual design, form or proportions.

9.26 Bulwarks

9.26.1 General requirements for bulwarks are given in Pt 3, Ch 4,8.

9.26.2 The thickness of the bulwark plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

9.26.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (d).

9.26.4 Bulwarks are not to be cut for gangway or other openings near the breaks of superstructures.

9.26.5 Attention is to be paid to avoid discontinuity of strength of the bulwark, particularly in way of local increases in stress and changes in height.

9.26.6 Welding of bulwark to the top edge of sheer-strake within $0{,}5L_R$ amidship, is generally to be avoided. However, if this arrangement is not practicable welding to the sheerstrake may be accepted if care is taken to minimise any notch effects.

9.26.7 **Fishing craft** are to have bulwarks fitted. The bulwark may be formed from a continuation of the side shell plating or connected as a separate assembly. Where the bulwark is considered to be stressed and contributing to the global strength of the craft, the plate thickness of the bulwark is not to be less than the sheer-strake thickness. In no case is the thickness of the bulwark plating to be taken as less than 80 per cent of the side shell thickness. The bulwark is to be supported by suitable stiffening members which may be formed from a continuation of the side frames, or from flanged plate stays of the same thickness as the bulwark. In general these frames are to be spaced not more than two side frame spacings apart.

9.26.8 In way of gantries, trawl gallows, mooring pipes etc., the plate thickness in way is to be increased by not less than 50 per cent.

9.26.9 **Pilot craft** are to be fitted with sufficient hand rails adjacent to the exposed areas of the working decks and platforms. In addition these areas are to have non-skid surfaces.

9.27 Freeing arrangements

9.27.1 Requirements for freeing arrangements are given in Pt 3, Ch 4,9.

9.28 Free flow area

9.28.1 The requirements for the free flow area are given in Pt 3, Ch 4,9.3.

9.29 Guard rails

9.29.1 The requirements for guard rails are given in Pt 3, Ch 4,8.4.

■ *Section 10* Pillars and pillar bulkheads

10.1 Application

10.1.1 Pillars are to be arranged to transmit loads from decks and superstructures into the bottom structure. Pillars are generally to be constructed from solid, tubular, or I beam section. A pillar may be a fabricated trunk or partial bulkhead.

10.2 Determination of span length

10.2.1 The effective span length of the pillar, l_{ep}, is in general the distance between the head and heel of the pillar. Where substantial brackets are fitted, l_{ep} may be reduced by 2/3 the depth of the bracket at each end.

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10.3 Head and heel connections

10.3.1 Pillars are to be attached at their heads to plates supported by efficient brackets, in order to transmit the load effectively. Doubling or insert plates are to be fitted to decks under large pillars and to the inner bottom under the heels of tubular or hollow square pillars. The pillars are to have a bearing fit and are to be attached to the head and heel plates by continuous welding. At the heads and heels of pillars built of rolled sections, the load is to be well distributed by means of longitudinal and transverse brackets.

10.4 Alignment and arrangement

10.4.1 Pillars are to be located on main structural members. They are in general to be fitted below windlasses, winches, capstans, the corners of deckhouses and elsewhere where considered necessary.

10.4.2 Wherever possible, deck pillars are to be fitted in the same vertical line as pillars above and below, and effective arrangements are to be made to distribute the load at the heads and heels of all pillars.

10.4.3 Where pillars support eccentric loads, or are subjected to lateral pressures, they are to be suitably strengthened for the additional bending moment imposed upon them.

10.4.4 Doublers are generally to be fitted on decks and inner bottoms, other than within tanks where doublers are not allowed. Brackets may be used instead of doublers.

10.5 Minimum thickness

10.5.1 The minimum wall thickness of hollow pillars is to be taken as not less than 1/20 of the external dimension of the pillar.

10.6 Design loads

10.6.1 The design loading, P_p, to be used in the determination of pillar scantlings is as follows:

$$P_p = S_{gt}\, b_{gt}\, P_c + P_a \text{ kN}$$

where

P_p = design load supported by the pillar, to be taken as not less than 5 kN

P_c = basic deck girder design pressure, as appropriate, plus any other loadings directly above the pillar, in kN/m^2

P_a = load, in kN, from pillar or pillars above, assumed zero if there are no pillars over

S_{gt} = spacing, or mean spacing, of girders or transverses, in metres

b_{gt} = distance between centres of two adjacent spans of girders or transverses supported by the pillar, in metres.

10.7 Scantlings determination

10.7.1 The cross-sectional area of the pillar, A_p, is not to be less than:

$$A_p = 10\,\frac{P_p}{\sigma_p} \text{ cm}^2$$

where

P_p = design load, in kN, supported by the pillar as determined from 10.6

σ_p = permissible compressive stress, in N/mm^2

$$= \frac{f_p\,\sigma_s}{1 + 0{,}0051\sigma_s\, k\left(\frac{l_{ep}}{r}\right)^2} \text{N/mm}^2$$

where

f_p = pillar location factor defined in Table 3.10.1

σ_s = specified minimum yield strength of the material, in N/mm^2

k_f = pillar end fixity factor
= 0,25 for full fixed/bracketed
= 0,50 for partially fixed
= 1,0 for free ended

r = least radius of gyration of pillar cross-section, in cm

$$= \sqrt{\frac{I_p}{A_p}} \text{ cm}$$

I_p = least moment of inertia of cross-section of pillar or stiffener/plate combination, in cm^4

l_{ep} = effective span of pillar, in metres, or bulkhead as defined in 10.2.

Table 3.10.1 Pillar location factors

Location	f_p
Supporting weather deck	0,50
Supporting vehicle deck	0,50
Supporting passenger deck	0,50
Supporting lower/inner deck	0,75
Supporting coachroof	0,75
Supporting deckhouse top	1,00

10.8 Maximum slenderness ratio

10.8.1 The slenderness ratio (l_{ep}/r) of pillars is not to be taken greater than 1,1. Where l_{ep} and r are as defined in 10.7.1. Pillars with slenderness ratio in excess of 1,1 may be accepted subject to special consideration on a case by case basis and provided that the remaining requirements of the Rules are complied with.

10.9 Pillars in tanks

10.9.1 In no circumstances are pillars to pass through tanks. Where loads are to be transmitted through tanks, pillars within the tanks are to be carefully aligned with the external pillars.

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10.9.2 Pillars within tanks are, in general, to be of solid cross section. Where it is proposed to use hollow section pillars each case will be subject to special consideration and the scantlings as determined from the Rules may require to be increased dependent upon the material to be used, the fluid contained and the arrangement of the pillars. Hollow pillars are to be adequately drained and vented.

10.9.3 Where pillars within tanks may be subjected to tensile stresses due to hydrostatic pressure, the design is to provide sufficient welding to withstand the tensile load imposed.

10.9.4 Doubling plates at ends of pillars within tanks are not acceptable.

10.10 Pillar bulkheads

10.10.1 The stiffener/plate combination used in the determination of pillar bulkhead scantlings is to be that of a stiffener with an effective width of attached plating as determined from 1.11.

10.10.2 The cross-sectional area of the pillar bulkhead, A_{pb}, is to be determined in accordance with 10.7 using the design loading, P_{pb}, as follows:

$$P_{pb} = S_{bs}\, b_{pb}\, P_c + P_a \text{ kN}$$

where

P_{pb} = design load supported by the stiffener plate combination of the pillar bulkhead

P_c = basic deck girder design pressure, as appropriate, plus any other loadings directly above the pillar, in kN/m^2

S_{bs} = spacing, or mean spacing, of bulkheads or effective transverses/longitudinal stiffeners, in metres

b_{pb} = distance between centres of two adjacent spans of girders or transverses supported by the pillar bulkhead, in metres, and can be taken as the distance between pillar bulkhead stiffeners where the stiffeners at the top of the bulkhead effectively distributes the load evenly into the stiffeners.

10.10.3 The thickness of the bulkhead plating is in no case to be taken as less than 4 mm.

10.11 Direct calculations

10.11.1 As an alternative to 10.6, pillars may be designed on the basis of direct calculation. The method adopted and the stress levels proposed for the material of construction are to be submitted together with the calculations for consideration.

10.12 Fire aspects

10.12.1 Pillars and pillar bulkheads are to be suitably protected against fire, and, where necessary, be self-extinguishing or capable of resisting fire damage. All pillars are to comply with the requirements of Part 17.

10.13 Novel features

10.13.1 Where unusual or novel pillar designs are proposed that are unable to comply with the requirements of this Section, their design together with the direct calculations are to be submitted for special consideration.

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Section

1 **General**

2 **Minimum thickness requirements**

3 **Shell envelope plating**

4 **Shell envelope framing**

5 **Single bottom structure and appendages**

6 **Double bottom structure**

7 **Bulkheads and deep tanks**

8 **Deck structures**

9 **Superstructures, deckhouses, pillars and bulwarks**

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to multi-hull craft of steel construction as defined in Pt 1, Ch 1,1.

1.2 General

1.2.1 Except as otherwise specified within this Chapter, the scantlings and arrangements of multi-hull craft are to be determined in accordance with the procedures described in, or required by Chapter 3 for mono-hull craft, using the pressures from Part 5 appropriate to multi-hulls.

1.3 Direct calculations

1.3.1 Where the craft is of unusual design, form or proportions, or where the speed of the craft exceeds 60 knots the scantlings are to be determined by direct calculation.

1.3.2 The requirements of this Chapter may be modified where direct calculation procedures are adopted to analyse the stress distribution in the primary structure.

1.4 Equivalents

1.4.1 Lloyd's Register (hereinafter referred to as 'LR') will consider direct calculations for the derivation of scantlings as an alternative and equivalent to those derived by Rule requirements in accordance with Pt 3, Ch 1,3.

1.5 Symbols and definitions

1.5.1 The symbols used in this Chapter are defined below and in the appropriate Section:

L_R = Rule length of craft, in metres

s = stiffener spacing, in mm

t_p = plating thickness, in mm

k_s = high tensile steel factor
$= 235/\sigma_s$

σ_s = specified minimum yield strength of the material, in N/mm^2.

1.5.2 **Bottom outboard.** For high speed craft, where the scantlings of the bottom shell are governed by impact pressure considerations, the bottom outboard shell is defined as the area of the hull between the outboard edge of the keel and the outer bilge tangential point. For displacement and semi displacement type craft where the scantlings of the bottom shell are governed by either hydrostatic or pitching pressures the bottom outboard shell is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

1.5.3 **Bottom inboard.** For high speed craft, where the scantlings of the bottom shell are governed by impact pressure considerations, the bottom inboard shell is defined as the area of the hull between the inboard edge of the keel and the inner bilge tangential point. For displacement and semi displacement type craft where the scantlings of the bottom shell are governed by either hydrostatic or pitching pressures the bottom inboard shell is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

1.5.4 **Cross-deck.** The cross-deck is defined as the structure which forms the bridge connection between any two adjacent hulls.

1.5.5 **Haunch.** The haunch is defined as the transition area between the cross-deck and the inboard side shell plating.

1.5.6 **Side inboard.** The side inboard is defined as the area between the bottom inboard shell and the wet-deck (or lower edge of the haunches, where fitted).

1.5.7 **Side outboard.** The side outboard is defined as the area between bottom outboard shell and the deck at side.

1.5.8 **Wet-deck.** The wet-deck is defined as the area between the upper edges of the side inboard plating (or upper edges of the haunches, where fitted).

■ *Section 2* Minimum thickness requirements

2.1 General

2.1.1 Unless otherwise specified in this Section, the requirements of Ch 3,2 are to be complied with.

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2.1.2 The thickness of plating and stiffeners determined from the Rule requirements is in no case to be less than the appropriate minimum requirement given in Table 4.2.1 for craft type.

2.1.3 In addition, where plating contributes to the global strength of the craft, the thickness is to be not less than that required to satisfy global strength requirements.

Table 4.2.1 Minimum thickness requirements

Item	Minimum thickness (mm)		
	Catamaran	Multi-hull	Swath
Shell envelope Bottom shell plating	$\omega\sqrt{k_{ms}}\ (0,4\sqrt{L_R}+2,0) \geq 3,5\omega$	$\omega\sqrt{k_{ms}}\ (0,4\sqrt{L_R}+2,0) \geq 3,5\omega$	$\omega\sqrt{k_{ms}}\ (0,4\sqrt{L_R}+2,0) \geq 3,5\omega$
Side shell plating	$\omega\sqrt{k_{ms}}\ (0,38\sqrt{L_R}+1,2) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,38\sqrt{L_R}+1,2) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,38\sqrt{L_R}+1,2) \geq 3,0\omega$
Wet-deck plating	$\omega\sqrt{k_{ms}}\ (0,38\sqrt{L_R}+1,2) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,38\sqrt{L_R}+1,2) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,38\sqrt{L_R}+1,2) \geq 3,0\omega$
Single bottom structure Centre girder web	$\omega\sqrt{k_{ms}}\ (0,8\sqrt{L_R}+1,0) \geq 4,0\omega$	$\omega\sqrt{k_{ms}}\ (0,8\sqrt{L_R}+1,0) \geq 4,0\omega$	$\omega\sqrt{k_{ms}}\ (0,8\sqrt{L_R}+1,0) \geq 4,0\omega$
Floor webs	$\omega\sqrt{k_{ms}}\ (0,6\sqrt{L_R}+0,8) \geq 3,5\omega$	$\omega\sqrt{k_{ms}}\ (0,6\sqrt{L_R}+0,8) \geq 3,5\omega$	$\omega\sqrt{k_{ms}}\ (0,6\sqrt{L_R}+0,8) \geq 3,5\omega$
Side girder webs	$\omega\sqrt{k_{ms}}\ (0,6\sqrt{L_R}+0,8) \geq 3,5\omega$	$\omega\sqrt{k_{ms}}\ (0,6\sqrt{L_R}+0,8) \geq 3,5\omega$	$\omega\sqrt{k_{ms}}\ (0,6\sqrt{L_R}+0,8) \geq 3,5\omega$
Double bottom structure Centre girder:			
(1) Within $0,4L_R$ amidships	$\omega\sqrt{k_{ms}}\ (0,8\sqrt{L_R}+1,0) \geq 4,0\omega$	$\omega\sqrt{k_{ms}}\ (0,8\sqrt{L_R}+1,0) \geq 4,0\omega$	$\omega\sqrt{k_{ms}}\ (0,8\sqrt{L_R}+1,0) \geq 4,0\omega$
(2) Outside $0,4L_R$ amidships	$\omega\sqrt{k_{ms}}\ (0,7\sqrt{L_R}+1,0) \geq 4,0\omega$	$\omega\sqrt{k_{ms}}\ (0,7\sqrt{L_R}+1,0) \geq 4,0\omega$	$\omega\sqrt{k_{ms}}\ (0,7\sqrt{L_R}+1,0) \geq 4,0\omega$
Floors and side girders	$\omega\sqrt{k_{ms}}\ (0,6\sqrt{L_R}+0,8) \geq 3,5\omega$	$\omega\sqrt{k_{ms}}\ (0,6\sqrt{L_R}+0,8) \geq 3,5\omega$	$\omega\sqrt{k_{ms}}\ (0,6\sqrt{L_R}+0,8) \geq 3,5\omega$
Inner bottom plating	$\omega\sqrt{k_{ms}}\ (0,5\sqrt{L_R}+1,0) \geq 2,5\omega$	$\omega\sqrt{k_{ms}}\ (0,5\sqrt{L_R}+1,0) \geq 2,5\omega$	$\omega\sqrt{k_{ms}}\ (0,5\sqrt{L_R}+1,0) \geq 2,5\omega$
Bulkheads Watertight bulkhead plating	$\omega\sqrt{k_{ms}}\ (0,33\sqrt{L_R}+1,0) \geq 2,5\omega$	$\omega\sqrt{k_{ms}}\ (0,33\sqrt{L_R}+1,0) \geq 2,5\omega$	$\omega\sqrt{k_{ms}}\ (0,33\sqrt{L_R}+1,0) \geq 2,5\omega$
Deep tank bulkhead plating	$\omega\sqrt{k_{ms}}\ (0,38\sqrt{L_R}+1,2) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,38\sqrt{L_R}+1,2) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,38\sqrt{L_R}+1,2) \geq 3,0\omega$
Deck plating and stiffeners Strength/Main deck plating	$\omega\sqrt{k_{ms}}\ (0,38\sqrt{L_R}+1,2) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,38\sqrt{L_R}+1,2) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,38\sqrt{L_R}+1,2) \geq 3,0\omega$
Lower deck/Inside deckhouse	$\omega\sqrt{k_{ms}}\ (0,18\sqrt{L_R}+1,7) \geq 2,0\omega$	$\omega\sqrt{k_{ms}}\ (0,18\sqrt{L_R}+1,7) \geq 2,0\omega$	$\omega\sqrt{k_{ms}}\ (0,18\sqrt{L_R}+1,7) \geq 2,0\omega$
Superstructures and deckhouses Superstructure side plating	$\omega\sqrt{k_{ms}}\ (0,3\sqrt{L_R}+1,0) \geq 2,0\omega$	$\omega\sqrt{k_{ms}}\ (0,3\sqrt{L_R}+1,0) \geq 2,0\omega$	$\omega\sqrt{k_{ms}}\ (0,3\sqrt{L_R}+1,0) \geq 2,0\omega$
Deckhouse front 1st tier	$\omega\sqrt{k_{ms}}\ (0,47\sqrt{L_R}+1,5) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,47\sqrt{L_R}+1,5) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,47\sqrt{L_R}+1,5) \geq 3,0\omega$
Deckhouse front upper tiers	$\omega\sqrt{k_{ms}}\ (0,42\sqrt{L_R}+1,3) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,42\sqrt{L_R}+1,3) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,42\sqrt{L_R}+1,3) \geq 3,0\omega$
Deckhouse aft	$\omega\sqrt{k_{ms}}\ (0,2\sqrt{L_R}+0,6) \geq 2,0\omega$	$\omega\sqrt{k_{ms}}\ (0,2\sqrt{L_R}+0,6) \geq 2,0\omega$	$\omega\sqrt{k_{ms}}\ (0,2\sqrt{L_R}+0,6) \geq 2,0\omega$
Pillars Wall thickness of tubular pillars	$\omega\sqrt{k_{ms}}\ 0,05d_p$	$\omega\sqrt{k_{ms}}\ 0,05d_p$	$\omega\sqrt{k_{ms}}\ 0,05d_p$
Wall thickness of rectangular pillars	$\omega\sqrt{k_{ms}}\ 0,05b_p$	$\omega\sqrt{k_{ms}}\ 0,05b_p$	$\omega\sqrt{k_{ms}}\ 0,05b_p$

Symbols

ω = service type factor as determined from Table 3.2.2 in Chapter 3
k_{ms} = $635/(\sigma_s + \sigma_u)$
σ_s = specified minimum yield strength of the material, in N/mm^2
σ_u = specified minimum ultimate tensile strength of the material, in N/mm^2
b_p = minimum breadth of cross section of hollow rectangular pillar, in mm
d_p = outside diameter of tubular pillar, in mm

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■ *Section 3*
Shell envelope plating

3.1 General

3.1.1 Unless otherwise specified within this Section, the scantlings and arrangements for shell envelope plating are to be determined in accordance with the procedures described in, or as required by, Ch 3,3 for mono-hull craft using the pressures from Part 5 appropriate to multi-hulls.

3.1.2 The thickness of the shell envelope plating is in no case to be less than the appropriate minimum requirement given in Section 2.

3.2 Keel plates

3.2.1 The breadth, b_k, and thickness, t_k, of plate keels are not to be taken as less than:

$$b_k = 5{,}0L_R + 250 \text{ mm}$$

$$t_k = \sqrt{k_s}\ 1{,}35L_R^{0,45} \text{ mm}$$

where

L_R and k_s are as defined in 1.5.1.

3.2.2 In no case is the thickness of the keel to be less than that of the adjacent bottom shell plating.

3.2.3 The width and thickness of plate keels are to be maintained throughout the length of the craft from the transom to a point not less than 25 per cent of the freeboard (measured at the forward perpendicular) above the deepest load waterline on the stem. Thereafter the keel thickness may be reduced to that required by Ch 3,3.3.1 for the stem.

3.2.4 For large or novel craft and for yachts with externally attached ballast keels, the scantlings of the keel will be specially considered.

3.3 Bottom outboard

3.3.1 The thickness of the bottom outboard plating is to be determined from the general plating equation given in Ch 3,1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.3.2 For all craft types, the minimum bottom outboard shell thickness requirement given in Section 2 is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

3.4 Bottom inboard

3.4.1 The thickness of the bottom inboard plating is to be determined from the general plating equation given in Ch 3,1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.4.2 For all craft types, the minimum bottom inboard shell thickness requirement given in Section 2 is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

3.5 Side outboard

3.5.1 The thickness of the side outboard plating is to be determined from the general plating equation given in Ch 3,1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.6 Side inboard

3.6.1 The thickness of the side inboard plating is to be determined from the general plating equation given in Ch 3,1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.7 Wet-deck

3.7.1 The thickness of the wet-deck plating is to be determined from the general plating equation given in Ch 3,1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.7.2 Additionally, the thickness of the wet-deck plating is in no case to be less than the thickness of the side inboard shell plating determined from 3.6.

3.7.3 The wet-deck plating on the underside of the cross-deck structure may require to be additionally protected, particularly where the air gap is small and there is a high risk of localised impact due to collision with floating debris, ice, etc., in the service area. In such cases the sheathing requirements given in Ch 3,2.4 are to be complied with.

3.8 Transom

3.8.1 The scantlings and arrangements of the stern or transom are to be not less than that required for the adjacent bottom inboard or side outboard structure as appropriate. Where water jet or sterndrive units are fitted, the scantlings of the plating in way of the nozzles and connections will be specially considered.

3.9 Haunch reinforcement (SWATH)

3.9.1 For craft above 40 m in Rule length, L_R, the stresses in the haunch area are to be derived using a two dimensional fine mesh finite element analysis. The model is to extend horizontally into the box structure and vertically into the strut structure. All discontinuities and cut-outs are to be modelled in order to determine shear stresses at critical locations and stresses for the determination of fatigue strength.

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3.9.2 Due consideration is to be given to shear lag when determining the effective breadth of the attached plating.

3.10 Lower hull (SWATH)

3.10.1 Where the lower hull structure incorporates ring frames and attached shell plating fitted between bulkheads or diaphragms, the thickness of the lower hull shell plating may be derived from an established method for shell analysis or recognised standard for pressure vessels using the design pressure loading from Pt 5, Ch 3,3.1 or Ch 4,3.1 as appropriate. Other loads considered significant for the scantling determination are to be taken into account. Modes of failure to be considered are buckling, frame collapse, inter-frame shell collapse and overall frame shell collapse between bulkheads. A copy of the direct calculations are to be submitted for consideration.

3.11 Novel features

3.11.1 Where the Rules do not specifically define the requirements for plating elements with novel features then the scantlings and arrangements are to be determined by direct calculations. Such calculations are to be carried out on the basis of the Rules, Recognised Standards and good practice, and are to be submitted for consideration.

■ *Section 4* Shell envelope framing

4.1 General

4.1.1 Unless otherwise specified in this Section, the scantlings and arrangements for shell envelope framing are to be determined in accordance with the procedures described in, or as required by, Ch 3,3 for mono-hull craft using the pressures from Part 3 appropriate to multi-hulls.

4.1.2 The requirements in this Section apply to longitudinally and transversely framed shell envelopes.

4.2 Bottom outboard longitudinal stiffeners

4.2.1 Bottom outboard longitudinal stiffeners are to be supported by transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.2.2 Bottom outboard longitudinals are to be continuous through the supporting structures.

4.2.3 Where it is impracticable to comply with the requirements of 4.2.2, or where it is proposed to terminate the bottom outboard longitudinals in way of the transom, bulkheads or integral tank boundaries, all longitudinals are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets.

4.2.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b).

4.3 Bottom outboard longitudinal primary stiffeners

4.3.1 Bottom outboard longitudinal primary stiffeners are to be supported by deep transverse web frames, floors, bulkheads, or other primary structures, generally spaced not more than 4 m apart.

4.3.2 Bottom outboard longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

4.3.3 Where it is impracticable to comply with the requirements of 4.3.2, or where it is proposed to terminate the stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.3.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.4 Bottom outboard transverse stiffeners

4.4.1 Bottom outboard transverse stiffeners are defined as local stiffening members which support the bottom shell and which may be continuous or intercostal.

4.4.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b).

4.5 Bottom outboard transverse frames

4.5.1 Bottom outboard transverse frames are defined as stiffening members which support the bottom shell. They are to be effectively continuous and bracketed at their end connections to side frames and bottom floors as appropriate.

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4.5.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.6 Bottom outboard transverse web frames

4.6.1 Bottom outboard transverse web frames are defined as primary stiffening members which support bottom shell longitudinals. They are to be continuous and substantially bracketed at their end connections to side web frames and bottom floors.

4.6.2 Where it is impracticable to comply with the requirements of 4.6.1, or where it is proposed to terminate the web frames in way of bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.6.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.7 Bottom inboard longitudinal stiffeners

4.7.1 The scantlings and arrangements for bottom inboard longitudinal stiffeners are to be determined in accordance with the procedures described in 4.2 using the bottom inboard stiffening member design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.8 Bottom inboard longitudinal primary stiffeners

4.8.1 The scantlings and arrangements for bottom inboard longitudinal primary stiffeners are to be determined in accordance with the procedures described in 4.3 using the bottom inboard stiffening member design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.9 Bottom inboard transverse stiffeners

4.9.1 The scantlings and arrangements for bottom inboard transverse stiffeners are to be determined in accordance with the procedures described in 4.4 using the bottom inboard stiffening member design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.10 Bottom inboard transverse frames

4.10.1 The scantlings and arrangements for bottom inboard transverse frames are to be determined in accordance with the procedures described in 4.5 using the bottom inboard stiffening member design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.11 Bottom inboard transverse web frames

4.11.1 The scantlings and arrangements for bottom inboard transverse frames are to be determined in accordance with the procedures described in 4.6 using the bottom inboard stiffening design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.12 Side outboard longitudinal stiffeners

4.12.1 The side outboard longitudinal stiffeners are to be supported by transverse web frames, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.12.2 Side outboard longitudinals are to be continuous through the supporting structures.

4.12.3 Where it is impracticable to comply with the requirements of 4.12.2, or where it is proposed to terminate the side outboard longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets.

4.12.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b).

4.13 Side outboard longitudinal primary stiffeners

4.13.1 Side outboard longitudinal primary stiffeners are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 4 m apart.

4.13.2 Side outboard longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

4.13.3 Where it is impracticable to comply with the requirements of 4.13.2, or where it is proposed to terminate the side outboard longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

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4.13.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.14 Side outboard transverse stiffeners

4.14.1 Side outboard transverse stiffeners are defined as local stiffening members supporting the side shell and may be continuous or intercostal.

4.14.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b).

4.15 Side outboard transverse frames

4.15.1 Side outboard transverse frames are defined as stiffening members supporting the side shell and spanning continuously between bottom floors/frames and decks. They are to be effectively constrained against rotation at their end connections.

4.15.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.16 Side outboard transverse web frames

4.16.1 Side outboard transverse web frames are defined as primary stiffening members which support side shell longitudinals. They are to be continuous and substantially bracketed at their head and heel connections to deck beams and bottom web frames respectively.

4.16.2 Where it is impracticable to comply with the requirements of 4.16.1, or where it is proposed to terminate the side outboard longitudinals in way of bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.16.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.17 Side inboard longitudinal stiffeners

4.17.1 The scantlings and arrangements for side inboard longitudinal stiffeners are to be determined in accordance with the procedures described in 4.12 using the side inboard design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.18 Side inboard longitudinal primary stiffeners

4.18.1 The scantlings and arrangements for side inboard longitudinal primary stiffeners are to be determined in accordance with the procedures described in 4.13 using the side inboard design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.19 Side inboard transverse stiffeners

4.19.1 The scantlings and arrangements for side inboard transverse stiffeners are to be determined in accordance with the procedures described in 4.14 using the side inboard design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.20 Side inboard transverse frames

4.20.1 The scantlings and arrangements for side inboard transverse frames are to be determined in accordance with the procedures described in 4.15 using the side inboard design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.21 Side inboard transverse web frames

4.21.1 The scantlings and arrangements for side inboard transverse web frames are to be determined in accordance with the procedures described in 4.16 using the side inboard design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.22 Wet-deck longitudinal stiffeners

4.22.1 The wet-deck longitudinal stiffeners are to be supported by transverse web frames, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.22.2 Wet-deck longitudinals are to be continuous through the supporting structures.

4.22.3 Where it is impracticable to comply with the requirements of 4.22.2, or where it is proposed to terminate the wet-deck longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

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4.22.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b).

4.22.5 In no case are the scantlings and arrangements for the wet-deck longitudinal stiffeners to be taken as less than those required for the side inboard longitudinal stiffeners detailed in 4.17.

4.23 Wet-deck longitudinal primary stiffeners

4.23.1 Wet-deck longitudinal primary stiffeners are to be supported by transverse web frames, bulkheads, or other primary structure, generally spaced not more than 4 m apart.

4.23.2 Wet-deck longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

4.23.3 Where it is impracticable to comply with the requirements of 4.23.2, or where it is proposed to terminate the wet-deck longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.23.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.23.5 In no case are the scantlings and arrangements for the wet-deck longitudinal primary stiffeners to be taken as less than those required for the side inboard longitudinal primary stiffeners detailed in 4.18.

4.23.6 Additionally the requirements of Chapter 6 relating to global strength are to be complied with.

4.24 Wet-deck transverse stiffeners

4.24.1 Wet-deck transverse stiffeners are defined as local stiffening members supporting the wet-deck and may be continuous or intercostal.

4.24.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b).

4.24.3 In no case are the scantlings and arrangements for the wet-deck transverse stiffeners to be taken as less than those required for the side inboard transverse stiffeners detailed in 4.19.

4.25 Wet-deck transverse frames

4.25.1 Wet-deck transverse frames are defined as stiffening members which support the wet-deck. They are to be effectively continuous and bracketed at their end connections to side frames.

4.25.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.25.3 In no case are the scantlings and arrangements for the wet-deck transverse frames to be taken as less than those required for the side inboard transverse frames detailed in 4.20.

4.26 Wet-deck transverse web frames

4.26.1 Wet-deck transverse web frames are defined as primary stiffening members which support wet-deck longitudinals. They are to be continuous and substantially bracketed at their end connections to side transverse web frames.

4.26.2 Where it is impracticable to comply with the requirements of 4.26.1, or where it is proposed to terminate the wet-deck longitudinals in way of the bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.26.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.26.4 In no case are the scantlings and arrangements for the wet-deck transverse web frames to be taken as less than those required for the side inboard transverse web frames detailed in 4.21.

4.26.5 Primary transverse web frames that link the strength deck to the wet-deck structure and which carry the transverse global loading are additionally to comply with Ch 6,3.4.

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4.26.6 Particular attention is to be taken to ensure that the continuity of transverse structural strength is maintained. All primary transverse members are to be continuous through the inboard side structure and integrated into transverse bulkheads or other primary structure within each hull (*see* Fig. 4.4.1). In the case of trimaran type craft the primary transverse members are to be continuous through the centre hull. Additionally the side inboard shell plating in way of the intersection is to be increased locally by not less than 50 per cent.

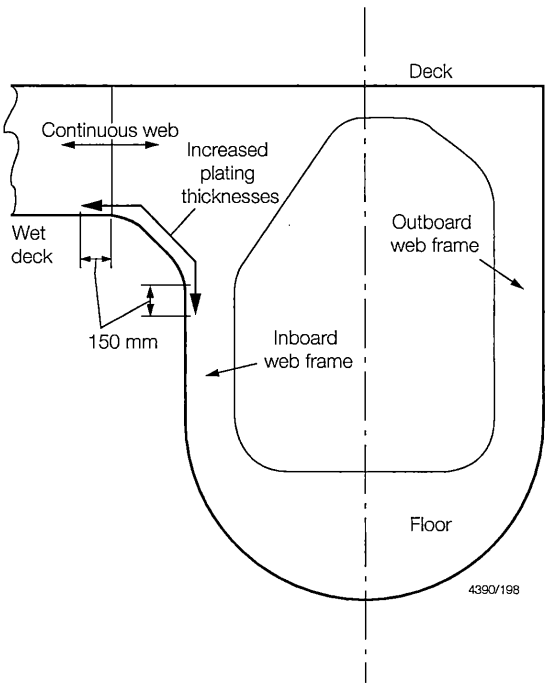

Fig. 4.4.1
End connection details, wet-deck structure

4.27 Lower hull (SWATH)

4.27.1 Where the lower hull structure incorporates ring frames and attached shell plating fitted between bulkheads or diaphragms, the scantlings of the lower hull shell stiffening may be derived from an established method for stiffening analysis or Recognised Standard for pressure vessels using the design loading from Pt 5, Ch 4,4.1. Modes of failure to be considered are buckling, frame collapse, inter frame shell collapse and overall frame shell collapse between bulkheads. A copy of the direct calculations is to be submitted for consideration.

4.28 Scantlings of end brackets

4.28.1 The scantlings of end brackets in way of transverse web frames/crossdeck primary structure which carry transverse global loading, are to be as large as practicable and be additionally reinforced as necessary. The webs of deep brackets are to be stiffened as necessary to resist buckling, *see also* Ch 6,3.5.

■ *Section 5*
Single bottom structure and appendages

5.1 General

5.1.1 Unless otherwise specified in this Section, the scantlings and arrangements for single bottom structure and appendages are to be determined in accordance with the procedures described in, or as required by, Ch 3,5 for mono-hull craft using the pressures from Part 5 appropriate to multi-hulls.

5.1.2 The thickness of single bottom structural members is in no case to be less than the appropriate minimum requirement given in Section 2.

5.2 Keel

5.2.1 The scantlings and arrangements of plate keels are to be in accordance with 3.2.

5.2.2 Where fitted, the cross-sectional area, A_{bk}, and thickness, t_{bk}, of bar keels are not, in general, be taken as less than:

$$A_{bk} = 0{,}75 L_R k_s \text{ cm}^2$$

$$t_{bk} = \sqrt{k_s}\,(0{,}5 L_R + 2) \text{ mm}$$

where

L_R and k_s are as defined in 1.5.1.

5.3 Centre girder

5.3.1 Centreline girders are to be fitted throughout the length of each hull and are generally to be fitted in association with transverse frames, transverses supporting longitudinals or where the breadth of floors at the upper edge is greater than 1,5 m.

5.3.2 Centreline girders may be formed with intercostal or continuous plate webs. In all cases the face flat is to be continuous. Where girder webs are intercostal, additional bracketing and local reinforcement are to be provided to maintain the continuity of structural strength.

5.3.3 The web depth of the centre girder is, in general, to be equal to the depth of the floors at the centreline as specified in 5.5.3.

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5.3.4 The web thickness, t_w, of the centre girder is to be taken not less than:

$$t_w = \sqrt{k_s}\,(0{,}8\sqrt{L_R} + 1) \text{ mm}$$

where

L_R and k_s are as defined in 1.5.1.

5.3.5 The face flat area, A_f, of the centre girder is to be not less than:

$$A_f = k_s\, 0{,}22 L_R \text{ cm}^2$$

where

L_R and k_s are as defined in 1.5.1.

5.3.6 The geometric section properties of the centre girder are to be in accordance with Ch 3,1.18.

5.3.7 The face flat area of the centre girder outside $0{,}5L_R$ may be 80 per cent of the value given in 5.3.5.

5.3.8 The face flat thickness is to be not less than the thickness of the web, t_w, as determined from 5.3.4.

5.3.9 The ratio of the width to thickness of the face flat is to be not less than eight but is not to exceed 16.

5.3.10 Additionally, the requirements of 4.8 for bottom inboard longitudinal primary stiffeners are to be complied with.

5.4 Side girders

5.4.1 Where the floor breadth at the upper edge exceeds 4,0 m, side girders are to be fitted at each side of the centre girder such that the spacing between the side and centre girders or between the side girders themselves is not greater than 2 metres. Side girders where fitted are to extend as far forward and aft as practicable and are, in general, to be scarfed into the bottom structure forward and aft of the support at which they terminate, i.e. in way of bulkheads, deep floors or other primary transverse structure.

5.4.2 The web thickness, t_w, of side girder webs is to be taken as not less than:

$$t_w = \sqrt{(0{,}43 k_s L_R)} \text{ mm}$$

where

L_R and k_s are as defined in 1.5.1.

5.4.3 The face flat area and thickness of side girders are to comply with the requirements for plate floors as defined in 5.5.6 and 5.5.7.

5.4.4 Additionally, the requirements of 4.8 for bottom inboard longitudinal primary stiffeners are to be complied with.

5.4.5 Watertight side girders and side girders forming the boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads and deep tanks as detailed in Ch 3,7.2 and Ch 3,7.4 respectively.

5.4.6 In the engineroom, additional side girders are generally to be fitted in way of main machinery seatings. Where fitted they are to be integrated into the structure of the craft and extended forward and aft as far as practicable.

5.5 Floors

5.5.1 In transversely framed craft, floors are generally to be fitted at every frame and underneath each bulkhead.

5.5.2 In longitudinally framed craft, floors are in general to be fitted at every transverse web frame and bulkhead and generally at a spacing not exceeding 2 m. Additional transverse floors or webs are to be fitted at half web-frame spacing in way of engine seatings and thrust bearings, pillars, skegs, ballast/bilge keels and the bottom of the craft in the forefoot region.

5.5.3 The overall depth, d_f, of floors at the centreline, is not to be taken as less than:

$$d_f = 6{,}2L_R + 50 \text{ mm}$$

where

L_R is as defined in 1.5.1.

5.5.4 The web thickness of plate floors, t_w, is to be in accordance with Ch 3,1.18 and not less than:

$$t_w = \sqrt{k_s}\left(\frac{3{,}4d_f}{1000} + 2{,}25\right)\left(\frac{s}{1000} + 0{,}5\right) \text{ mm}$$

where

d_f is to be determined from 5.5.3

k_s and s are as defined in 1.5.1.

5.5.5 If the side frames of the craft are attached to the floors by brackets, the depth of floor may be reduced by 15 per cent and the floor thickness determined using the reduced depth. The brackets are to be flanged and have the same thickness as the floors, and their arm lengths clear of the frame are to be the same as the reduced floor depth given above.

5.5.6 The face flat area, A_f, of floors is not to be taken as less than:

$$A_f = 0{,}11 k_s L_R \text{ cm}^2$$

where

L_R and k_s are as defined in 1.5.1.

5.5.7 The face flat thickness, t_f, is to be not less than the thickness of the web and the ratio of the web to the thickness of the face flat is to be not less than eight but is not to exceed 16.

5.5.8 Additionally, the requirements of 4.11 for bottom inboard transverse web frames are to be complied with.

5.5.9 Floors are in general to be continuous from side to side.

5.5.10 The tops of floors, in general, may be level from side to side. However, in craft having considerable rise of floor the depth of the floor plate may require to be increased to maintain the required section modulus.

5.5.11 The floors in the aft peak are to extend over and provide efficient support to the stern tube(s) where applicable.

5.5.12 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deep tanks as detailed in Ch 3,7.3 and Ch 3,7.5.

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5.6 Floors in machinery space

5.6.1 The web thickness, t_w, of floors in machinery spaces is to be 1 mm greater than that required by 5.5.4.

5.6.2 The depth and mechanical strength properties of floors between engine or gearbox girders is to be not less than that required to maintain continuity of structural integrity or 50 per cent of the depth given in 5.5.3. The face flat area and web thickness of such reduced height floors are to be increased appropriately in order to maintain the continuity of structural strength, *see also* Ch 3,4.12.

5.7 Forefoot and stem

5.7.1 The thickness of plate stems at the waterline is to comply with the requirements for plate keels as given in 3.2.

5.7.2 The forefoot and stem is to be additionally reinforced with floors.

5.7.3 The cross-sectional area of bar stems, A_{bs}, is not to be taken as less than:

$$A_{bs} = 0{,}6k_s L_R \text{ cm}^2$$

where

k_s and L_R are as defined in 1.5.1.

■ *Section 6*
Double bottom structure

6.1 General

6.1.1 Unless otherwise specified in this Section, the scantlings and arrangements for the double bottom structure are to be determined in accordance with the procedures described in, or as required by, Ch 3,6 for mono-hull craft using the pressures from Part 5 appropriate to multi-hulls.

6.1.2 The thickness of double bottom structural members is in no case to be less than the appropriate minimum requirement given in Section 2.

6.2 Keel

6.2.1 The scantlings of plate and bar keels are to comply with the requirements of 5.2.

6.3 Centreline girder

6.3.1 A centre girder is to be fitted throughout the length of the craft. The web thickness, t_w, is not to be less than that required by:

$$t_w = \sqrt{k_s}\,(0{,}06L_R + 3) \text{ mm within } 0{,}4L_R \text{ amidships}$$

$$= \sqrt{k_s}\,(0{,}06L_R + 2) \text{ mm at ends}$$

where

k_s and L_R are as defined in 1.5.1.

6.3.2 The geometric properties of the girder section are to be in accordance with Ch 3,1.18.

6.3.3 The overall web depth, d_w, of the centre girder is to be taken as not less than 630 mm and is to be sufficient to give adequate access to all parts of the double bottom.

6.3.4 Additionally, the requirements of 4.8 for bottom inboard longitudinal primary stiffeners are to be complied with.

6.4 Side girders

6.4.1 Where the floor breadth does not exceed 4,0 m, side girders are not required. Vertical stiffeners are to be fitted to the floors on each side, the number and positions of these stiffeners being dependent on the arrangement of the double bottom structure.

6.4.2 Where the breadth of floor is greater than 4,0 m, additional side girders having the same thickness as the floors are to be fitted. The number of side girders is to be such that the distance between the side girders and centre girder and margin plate, or between the side girders themselves, does not exceed 2,0 m.

6.4.3 Side girders, where fitted, are to extend as far forward and aft as practicable and are in general to to be scarfed into the bottom structure forward and aft of the supporting bulkheads, deep floors or other primary transverse structure.

6.4.4 Where additional side girders are fitted in way of main machinery seatings, they are to be integrated into the structure of the craft and extended forward and aft as far as practicable.

6.4.5 Under the main engine, girders extending from the bottom shell to the top plate of the engine seating are to be fitted. The height of the girders is to be not less than the height of the floor. Engine holding-down bolts are to be arranged as near as practicable to the girders and floors. Where this cannot be achieved, bracket floors and/or hanging brackets are to be fitted.

6.4.6 The geometric properties of the girder section are to be in accordance with Ch 3,1.18.

6.4.7 Additionally, the requirements of 4.8 for bottom inboard longitudinal primary stiffeners are to be complied with.

6.5 Plate floors

6.5.1 The web thickness, t_w, of non-watertight plate floors is to be not less than:

$$t_w = \sqrt{k_s}\,(0{,}03L_R + 3{,}5) \text{ mm}$$

where

k_s and L_R are as defined in 1.5.1.

6.5.2 The geometric properties of the floor section are to be in accordance with Ch 3,1.18.

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6.5.3 Additionally, the requirements of 4.6 for bottom inboard transverse web frames are to be complied with.

6.5.4 Plate floors are, in general, to be continuous between the centre girder and the margin plate.

6.5.5 In longitudinally framed craft, plate floors are to be fitted in the following positions:

(a) At every half frame in way of the main engines, thrust bearings, and bottom of the craft forward.
(b) Outboard of the engine seatings, at every frame within the engineroom.
(c) Underneath pillars and bulkheads.
(d) Outside of the engine room at a spacing not exceeding 2,0 m.

6.5.6 Vertical flat bar stiffeners are to be fitted to all plate floors at each longitudinal. Each stiffener is to have a depth of not less than $10t_w$ and a thickness of not less than t_w, where t_w is thickness of the plate floor as calculated in 6.5.1.

6.5.7 In transversely framed craft, plate floors are to be fitted at every frame in the engineroom, under bulkheads, in way of change in depth of double bottom and elsewhere at a spacing not exceeding 2,0 m.

6.6 Additional requirements for watertight floors

6.6.1 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deep tanks as detailed in Ch 3,7.2 or Ch 3,7.4 respectively.

■ *Section 7*
Bulkheads and deep tanks

7.1 General

7.1.1 Unless otherwise specified in this Section, the scantlings and arrangements for bulkheads and deep tanks are to be determined in accordance with the procedures described in, or as required by Ch 3,3 for mono-hull craft using the pressures from Part 5 appropriate to multi-hulls.

7.2 Longitudinal bulkheads within the cross-deck structure

7.2.1 Longitudinal bulkheads are to be fitted within the cross-deck structure to prevent cross flooding and the spread of flame and smoke. The minimum number of such bulkheads is to be:

- one for catamarans of Rule length, L_R, less than or equal to 24 m;
- two for catamarans of Rule length, L_R, greater than 24 m; and
- four for trimarans.

Quadrimarans and other craft of novel configuration will be specially considered.

7.2.2 The scantlings and arrangements for cross-deck longitudinal bulkheads are to be determined in accordance with the procedures described in Ch 3,7.2 and Ch 3,7.3 for bulkheads in mono-hull craft.

7.2.3 In addition the requirements of 7.4 with regard to global strength are to be complied with.

7.3 Transverse bulkheads within the cross-deck structure

7.3.1 The scantlings of cross-deck transverse bulkheads are to be determined in accordance with the procedures described in Ch 3,7.2 and Ch 3,7.3 for bulkheads in mono-hull craft.

7.3.2 In addition the requirements of 7.4 in respect of global strength are to be complied with.

7.4 Additional strength required for global loading

7.4.1 Where transverse bulkheads or deep tank bulkheads within the cross-deck structure are to assist in resisting torsional or bending loads between the hulls, then the watertight/deep tank bulkheads may be required to be additionally stiffened and the plating or skin thicknesses may require to be increased. For hull girder strength requirements, *see* Ch 6,3.

7.4.2 Longitudinal bulkheads within the cross-deck structure that are to assist in maintaining the longitudinal strength of the craft are to satisfy both bulkhead/deep tank and longitudinal strength requirements. This may require additional stiffening and increase in plate thickness requirements. For hull girder strength requirements, *see* Ch 6,3.

7.4.3 Where longitudinal or transverse cross-deck bulkheads/deep tanks are to carry global loads, detailed calculations are to be submitted.

7.4.4 For longitudinal or transverse cross-deck members carrying global loads, consideration is to be given to stiffener arrangement, alignment, and continuity in order to maximise the rigidity and stiffness of the structure, in resisting the torsional/bending loads. Discontinuity of structural bulkheads is to be avoided.

7.5 Access

7.5.1 Access through the cross-deck structure may be permitted, provided that the global strength requirements are satisfied. Cut outs through the bulkhead are not to exceed 50 per cent of its depth, *see also* Ch 3,7.18.

7.5.2 Where the cross-deck structure acts as a watertight bulkhead pipe or cable runs through the watertight bulkheads are to be fitted with suitable watertight glands.

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7.6 Local reinforcement

7.6.1 Bulkheads forming the cross-deck structure are to be suitably strengthened, if necessary, in way of deck girders and where subjected to concentrated loads.

7.7 Integral/deep tanks within cross-deck structure

7.7.1 Where the cross-deck structure forms the boundaries of deep tanks, the scantlings of these boundaries are to satisfy both deep tank and global strength requirements. For general and structural requirements for deep tanks, *see* Ch 3,7. For global considerations of strength, *see* Ch 6,3.

■ *Section 8*
Deck structures

8.1 General

8.1.1 Unless otherwise specified in this Section, the scantlings and arrangements for deck structures are to be determined in accordance with the procedures described in, or as required by, Ch 3,8 for mono-hull craft using the pressures from Part 5 appropriate to multi-hulls.

8.2 Arrangements

8.2.1 Design loads to be applied for cross-deck scantling calculations are transverse vertical bending moment and shear force, twin hull torsional connecting moment, external pressure load and appropriate internal loads as defined in Part 3.

8.2.2 For craft up to 50 m in Rule length, L_R, where the cross-deck is formed by transverse primary stiffeners or bulkheads, and subjected to global transverse loads in accordance with 8.2.1 the scantling requirements to satisfy the global loading condition are given in Ch 6,3.5.

8.2.3 Superstructures fitted on the cross-deck structures, on craft up to 50 m in Rule length, L_R, will, in general, be considered as non load carrying and are not to be included in the strength of the cross-deck. For designs where the superstructure is designed to absorb global loads, the requirements are given in Ch 6,3.2.

8.2.4 For craft more than 50 m in Rule length, L_R, global analysis is required to determine the response of the deck and superstructure as a system. Deck scantlings may then be derived for compliance with the requirements of Ch 6,3.

8.3 Cross-deck plating

8.3.1 The thickness of the cross-deck plating is to be determined from the general plating equation given in Ch 3,1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

8.3.2 The thickness of the cross-deck plating is in no case to be less than the appropriate minimum requirement given in Section 2.

8.3.3 The scantlings of watertight cockpits are to be of equivalent strength to those of the strength/weather deck, *see also* Part 4.

8.3.4 It is recommended that the working areas of the weather deck have an anti-slip surface.

8.3.5 Where decks are sheathed with wood or other materials, details of the method of attachment are to be submitted, *see also* Ch 3,2.4.

8.4 Cross-deck stiffening

8.4.1 The Rule requirements for section modulus, inertia and web area for the cross-deck primary stiffeners are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

8.4.2 The Rule requirements for section modulus, inertia and web area of the strength/weather deck secondary stiffening are to be determined the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.4.3 The geometric properties of stiffener sections are to be in accordance with Ch 3,1.18.

8.4.4 For cases where there may be excessive rotations or deflections at supports or where the lateral pressure distribution is non-uniform, the above scantlings may require increasing appropriately.

8.4.5 Where stiffeners are subject to concentrated loads such as pillars, the concentrated loads are to be superimposed on the lateral pressure and strength calculations carried out to demonstrate compliance with the deflection and stress criteria given in Ch 7,2 and Ch 7,3.

8.4.6 Where stiffening members support plating of the extruded plank type, or the floating frame system is used, the plating is not to be included in the scantling derivation of the supporting structure.

8.4.7 Openings in the cross-deck for hatches, etc., are to comply with the requirements of Ch 3,8.11.

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8.5 Novel features

8.5.1 Where the cross-deck structure is of unusual design, form or proportions, the scantlings are to be determined by direct calculation and a copy submitted for consideration.

■ *Section 9*
Superstructures, deckhouses, pillars and bulwarks

9.1 General

9.1.1 The scantlings and arrangements for superstructures, deckhouses and bulwarks are to be determined in accordance with the procedures described in, or as required by, Ch 3,9 for mono-hull craft.

9.1.2 The scantlings and arrangements for pillars and pillar bulkheads are to be determined in accordance with the procedures described in, or as required by, Ch 3,10 for mono-hull craft.

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Section

1 **General**

2 **Special features**

3 **Vehicle decks**

4 **Bow doors**

5 **Movable decks**

6 **Helicopter landing areas**

7 **Strengthening requirements for navigation in ice conditions**

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull and multi-hull craft of steel construction as defined in Pt 1, Ch 1,1.

1.2 Symbols and definitions

1.2.1 The symbols and definitions used in this Chapter are defined below and in the appropriate Section:

s = stiffener spacing, in mm

k_s = higher tensile steel factor
= $235/\sigma_s$

σ_s = specified minimum yield strength of the material, in N/mm^2.

■ *Section 2* Special features

2.1 Water jet propulsion systems – Construction

2.1.1 The requirements for the construction and installation of water jet units apply irrespective of rated power.

2.1.2 Water jet ducts may be fabricated as an integral part of the hull structure, or as a bolted-in unit. In either case, detailed plans indicating dimensions, scantlings and materials of construction of the following are to be submitted in triplicate:

(a) Arrangement of the system including intended method of attachment to the hull and building-in, geometry of tunnel, shell opening, method of stiffening, reinforcement, etc.
(b) Shaft sealing arrangements.
(c) Details of any shafting support or guide vanes used in the water jet system.
(d) Details and arrangements of inspection ports, their closing appliances and sealing arrangement, etc.
(e) Details and arrangements of protection gratings and their attachments.

2.1.3 When submitting the plans requested in 2.1.2, details of the designers' loadings and their positions of application in the hull are to be submitted. These are to include maximum applied thrust, moments and tunnel pressures for which approval is sought.

2.1.4 All materials used in construction are to be manufactured and tested in accordance with the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

2.1.5 Steels are to be of suitable grades in accordance with the requirements of Ch 2,2.

2.1.6 Irrespective of the material used, the strength and supporting structure of all tunnels are to be examined by direct calculation procedures which are to be submitted. In no case are the scantlings to be taken as less than the Rule requirements for the surrounding structure. The strength of the hull structure in way of tunnels is to be maintained. The structure is to be adequately reinforced and compensated as necessary. All openings are to be suitably reinforced and have radiused corners.

2.1.7 Consideration is to be given to providing the inlet to the tunnel with a suitable guard to prevent the ingress of large objects into the rotodynamic machinery. The dimensions of the guard are to strike a balance between undue efficiency loss due to flow restriction and viscous losses, the size of object allowed to pass and susceptibility to clog with weed and other flow restricting matter.

2.1.8 The inlet profile of the tunnel is to be so designed as to provide a smooth uptake of water over the range of craft operating trims and avoid significant separation of the flow into the rotating machinery.

2.1.9 Single or multiple water jet unit installations having a total rated power in excess of 500 kW are to be contained within their own watertight compartment. Other arrangements for maintaining watertight integrity may be specially considered depending on the size and installation layout.

2.1.10 For details of machinery requirements, *see* Pt 12, Ch 2.

2.2 Water jet propulsion systems – Installation

2.2.1 Standard units built for 'off the shelf' supply and which include the duct are to be installed strictly in accordance with the manufacturer's instructions, *see also* 2.1.4.

2.2.2 Integral water jet ducts are to be constructed in accordance with the manufacturer's requirements and the relevant plans submitted as required by 2.1.

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2.2.3 Where load is transmitted into the transom and/or bottom shell, the thickness of the plating adjacent to the jet unit is to be increased. The increase in thickness is to be not less than 50 per cent of the calculated transom and bottom plating thicknesses respectively or 8 mm, whichever is the greater. Such reinforcement is to extend beyond the surrounding stiffening structure.

2.2.4 For 'bolted in' units, hull receiving rings are to be of a material compatible with the hull. Scantlings of the receiving rings are to be as required by the jet unit manufacturer and suitably edge prepared prior to welding in place. The receiving ring is to be installed using an approved welding procedure. Where a manufacturer's specification is not provided, full details are to be submitted.

2.2.5 Bolt sizes and spacings are to be specified by the manufacturer, and are to be of suitable marine grade, insulated as appropriate and locked by suitable means.

2.2.6 Where studs are proposed for the receiving ring(s), the remaining thickness below the depth of blind tap is to be not less than the bottom shell plating thickness plus 2 mm. Bottoms of all blind taps are to be free of sharp corners.

2.2.7 The use of approved alignment resins may be considered where accurate seating and faying surfaces are required. Details are to be submitted for consideration and approval.

2.2.8 Where a water jet unit forms an integral part of the hull structure, such units are to be installed using an approved weld procedure and in accordance with the manufacturer's instructions. Materials to be welded are to be of compatible specifications.

2.2.9 Water jet units transmitting thrust into the transom structure are to be supported by a system of radial, athwartship and vertical stiffening. Drawings are to be accompanied by a set of detailed structural calculations. Where complex installations are proposed, a finite element model may be submitted in lieu of direct calculations.

2.2.10 Water jet units transmitting thrust to a bottom shell connection or intermediate tunnel connection are to be supported by additional stiffening, the details of which are to be submitted.

2.3 Foil support arrangements

2.3.1 The materials and construction of the lifting surface will be considered on a case by case basis.

2.3.2 The design and performance of the lifting surface is outside the scope of classification. However, when submitting structural plans for the hull connection installation, the designer/Builder is to define:

(a) Operating mode, i.e. fully submerged or surface piercing.
(b) Maximum operational speed for which approval is sought.
(c) Maximum, direct, bending, shear and torque loads generated by the foil at the point of attachment(s).
(d) The type of profile or section used, e.g. N.A.C.A.
(e) Supply of lift/drag profile.
(f) If the foil is fixed, movable or retractable.
(g) If the foil is fitted with control surfaces.
(h) If the vertical leg(s) act as a rudder(s).
(j) If shaft liners are carried to the foils at which support arrangements are provided.
(k) If water intakes/scoops are fitted.
(l) If propulsion units are fitted.

2.3.3 The scantlings and arrangements of foils and their supporting structure will require to be specially considered in the following cases where:

(a) Propulsion units are incorporated within the foil.
(b) Foils carry shaft support arrangements.
(c) The foils are of novel design.

2.3.4 Where fully submerged foils are 'built-in' to the hull, the attachment area is to be contained within a watertight compartment the structural arrangements of 2.4 are to be complied with as appropriate.

2.3.5 Where foils are to be bolted to the structural foundation, calculations are to be submitted to demonstrate that the effect of loading arising from high speed impact, grounding, fouling, etc., is limited to failure of the bolted connection. In all cases the structural and watertight integrity of the craft is to be maintained.

2.3.6 Attachment points of foils are in all cases to be contained within a watertight compartment.

2.3.7 Foils attached by riveted means are in addition to comply with Ch 2,4.21.

2.3.8 Bow fairing doors fitted on forward retracting bow foils are to be weathertight and comply with Pt 3, Ch 4.

2.3.9 Aft bulkheads of bow foil compartments are to comply with the requirements for collision bulkheads as detailed in Ch 3,7.7.

2.3.10 Hydraulically operated retracting systems are to be equipped with low pressure and are to include a manual system of operation in the event of system failure.

2.3.11 A mechanical locking system is to be provided on retracting systems when the system is in both the operational and 'stowed' conditions.

2.4 Surface drive mountings

2.4.1 Transoms through which surface drive systems pass and which are required to carry thrust, significant weight, torque, moment, etc., are to be adequately reinforced.

2.4.2 The thickness of transom plating in way is to be not less than 1,5 times the thickness of the adjacent plating or as advised by the drive manufacturer, whichever is the greater.

2.4.3 Steering rams are to be mounted on suitably reinforced areas of plating supported by additional internal stiffening, details of which are to be submitted for consideration.

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2.5 Sea inlet scoops

2.5.1 Sea inlet scoops may be integral with or an appendage to the hull.

2.5.2 Scoops are to be suitably positioned to minimise ventilation.

2.5.3 Suitable protective arrangements are to be provided to minimise the ingress of debris. The net area through the proposed arrangement is to be not less than twice that of the valves connected to the scoop. Provision is to be made for clearing the scoops by the use of suitable means and proposals are to be submitted.

2.5.4 Scoops are to be contained within a watertight compartment.

2.5.5 The plating thickness in way of integral scoops is to be not less than 1,5 times the thickness of the adjacent shell plating, with additional reinforcement at the leading edge.

2.5.6 For craft navigating in ice, the arrangements will be specially considered on an individual basis.

2.6 Crane support arrangements

2.6.1 Crane pedestals are to be efficiently supported and in general, are to be carried through the deck and satisfactorily scarfed into the surrounding structure. Alternatively, crane pedestals may comprise a foundation, in which case the foundation and its supporting structure are to be of substantial construction. Proposals for other support arrangements will be specially considered.

2.6.2 The pedestal or proposed arrangement is to be designed with respect to the worst possible combinations of loads resulting from the crane self weight, live load, wind and crane accelerations together with those resulting from the craft's heel and trim.

2.6.3 Stowage arrangements are to be taken into account when calculating the loads applied to the pedestal.

2.6.4 When submitting plans for the proposed foundation, the designer is to include design calculations covering the parameters indicated in 2.6.2.

2.6.5 Insert plates are to be incorporated in the deck plating in way of crane foundations. The thickness of the insert plates is to be as required by the designer's calculations but is in no case to be taken as less than 1,5 times the thickness of the adjacent attached plating.

2.6.6 All inserts are to have well radiused corners and be suitably edge prepared prior to welding. All welding in way is to be double continuous and full penetration where necessary. Tapers are to be not less than three to one.

2.7 Skirt attachment

2.7.1 The design and scantlings of the skirt are outside the scope of classification, however the designer/builder is to submit their proposals in respect of the attachment detail. The following supporting information is to be submitted:

(a) cushion pressure,

(b) calculations demonstrating that the effect of damage to the flexible membrane and/or the retaining section arising from high speed impact, grounding, fouling, etc., will not compromise the structural and watertight integrity of the craft.

2.7.2 The skirt is to be securely attached around its periphery and is to be suitably reinforced by the use of backing plates.

2.7.3 Where the skirt is retained by bolting, the retaining bars are to be as long as practicable with a fastener spacing of not more than 50 mm.

2.7.4 Where the design of the skirt is such that the flexible edge is retained by the use of a pre-formed channel, only the bolted hull connection of the preform to the hull structure is considered.

2.8 Trim tab arrangements

2.8.1 The shape, design and scantlings of the trim tabs are outside the scope of classification, however Lloyd's Register (hereinafter referred to as 'LR') is concerned with their attachment to the hull structure.

2.8.1 The designer/Builder is to submit the following:

(a) Detailed calculations indicating the maximum lift force generated by the tab for which acceptance is sought together with the corresponding speed and displacement.

(b) Details and calculations of the hull attachment.

(c) Details and calculations of the local internal reinforcement in way of the attachment.

2.8.3 Bearing materials used are to be of an approved type.

2.8.4 Fully submerged retractable trim tabs will be specially considered on a case by case basis.

2.9 Spray rails

2.9.1 Spray rails may be integrated into the hull structure or added in the form of an appendage on completion of the hull shell.

2.9.2 Where spray rails are integrated, they are to have a plating thickness not less than the adjacent bottom shell and additionally have a section modulus and inertia equivalent to that required for a longitudinal stiffener in the same position.

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2.9.3 Where spray rails are added as an appendage, they are to be attached by double continuous welding and are additionally to comply with the strength requirements of 2.9.2.

2.9.4 Spray rails are to be supported by the internal stiffening arrangements and by additional local reinforcement as necessary.

2.9.5 In no case are the toes of spray rails to terminate on unsupported plating.

2.10 Other lifting surfaces

2.10.1 Other lifting surfaces not specifically covered by the Rules will be individually considered on the basis of submitted direct calculations.

2.10.2 Structure or hull shapes above the running waterline designed to generate aerodynamic lift may be individually considered on a case by case basis.

2.10.3 Aerodynamic, hydrodynamic and aero-hydrodynamic stability are outside the scope of classification and are subject to the approval of the National Administration concerned.

2.11 Propeller ducting

2.11.1 Where propellers are fitted within ducts/tunnels the plating thickness in way of the blades is to be increased by 50 per cent.

2.11.2 The tunnel wall in way of the propeller blades is to be additionally stiffened.

2.12 Ride control ducting and installation for Surface Effect Ships (SES)

2.12.1 Ducts penetrating the side inboard shell plating are to comply with the scantling requirements for side inboard structures, over their entire length in the appropriate material.

2.12.2 Ducts penetrating the wet-deck are to comply with the scantling requirements for wet-deck structures over their entire length in the appropriate material.

2.12.3 Open ends of ducts are to be fitted with a suitable protective grille.

2.12.4 The vent assembly, its design, construction and operation is outside the scope of classification and is the responsibility of the ride control system designer.

2.12.5 Details of the installation and securing arrangements of the vent valve assembly into the duct are to be submitted for approval.

■ *Section 3* Vehicle decks

3.1 General

3.1.1 These requirements are applicable to longitudinally or transversely framed craft intended for the carriage of wheeled vehicles, or where wheeled vehicles are to be used for cargo handling.

3.1.2 The deck and supporting structure are to be designed on the basis of the maximum loading to which they may be subjected in service. Where applicable, the hatch covers are to be similarly designed. In no case, however, are the scantlings to be less than would be required for a weather or cargo deck, or hatch cover, as applicable.

3.1.3 Details of the deck loading resulting from the proposed stowage or operation of vehicles are to be supplied by the Builder. These details are to include axle and wheel spacing, the wheel load, type of tyre and tyre print dimensions for the vehicles. The vehicle types and wheel loads for which the vehicle decks, including hatch covers where applicable, have been approved are to be included in the craft's documentation and contained in a notice displayed on each deck. For design purpose, the wheel loading is to be taken as not less than 3,0 kN.

3.1.4 The scantling requirements are based on structural strength and limitations on stress and deflection, with no allowance made for wear and tear. Local reinforcement is to be fitted as necessary, particularly in way of vehicle lanes and passenger routes.

3.1.5 The webs of vehicle deck stiffening members are in no cases to be scalloped.

3.2 Definitions

3.2.1 **Load Area.** The load area is defined as the footprint area of an individual wheel or the area enclosing a group of wheels when the distance between footprints is less than the smaller dimension of the individual prints.

3.3 Deck plating

3.3.1 The thickness, t_p, of vehicle deck plating is to be taken as not less than:

$$t_p = \frac{\alpha\, s}{1000\ k_s} \text{ mm}$$

where

P_1 = corrected patch load, in tonnes, obtained from Table 5.3.1

α = thickness coefficient obtained from Fig. 5.3.1

s = secondary stiffener spacing, in mm

β_p = tyre print coefficient used in Fig. 5.3.1

$$= \log_{10}\left(\frac{P_1\, k_s^2}{s^2} \times 10^7\right)$$

s and k_s are as defined in 1.2.

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Table 5.3.1 Deck plate thickness calculation

Symbols	Expression
a, s, u, and v as defined in Fig. 5.3.1 n = tyre correction factor as detailed in Table 5.3.2 P_1 = corrected patch load, in tonnes λ = dynamic magnification factor P_w = load, in tonnes, on the tyre print. For closely spaced wheels the shaded area shown in Fig. 5.3.1 may be taken as the combined print ϕ_1 = patch aspect ratio correction factor ϕ_1 = panel aspect ratio correction factor ϕ_1 = wide patch load factor	$P_1 = \phi_1\ \phi_2\ \phi_3\ \lambda\ P_w$ $\phi_1 = \dfrac{2v_1 + 1{,}1s}{u_1 + 1{,}1s}$ $v_1 = v$, but $\le s$; $u_1 = u$, but $\le a$ $\phi_2 = 1{,}0$ for $u \le (a - s)$ $= \dfrac{1}{1{,}3 - \dfrac{0{,}3}{s}(a - u)}$ for $a \ge u > (a - s)$ $= 0{,}77\ \dfrac{a}{u}$ for $u > a$ $\phi_3 = 1{,}0$ for $v < s$ $= 0{,}6\ (s/v) + 0{,}4$ for $1{,}5 > (v/s) > 1{,}0$ $= 1{,}2\ (s/v)$ for $(v/s) \ge 1{,}5$ λ = 1,25 for craft operating in G1 = (1 + 0,35n) for craft operating in G2 = (1 + 0,42n) for craft operating in G3 = (1 + 0,49n) for craft operating in G4 = (1 + 0,56n) for craft operating in G5 = (1 + 0,70n) for craft operating in G6 G1, G2, G3, G4, G5 and G6 as defined in Pt 1, Ch 2,3.5.5.

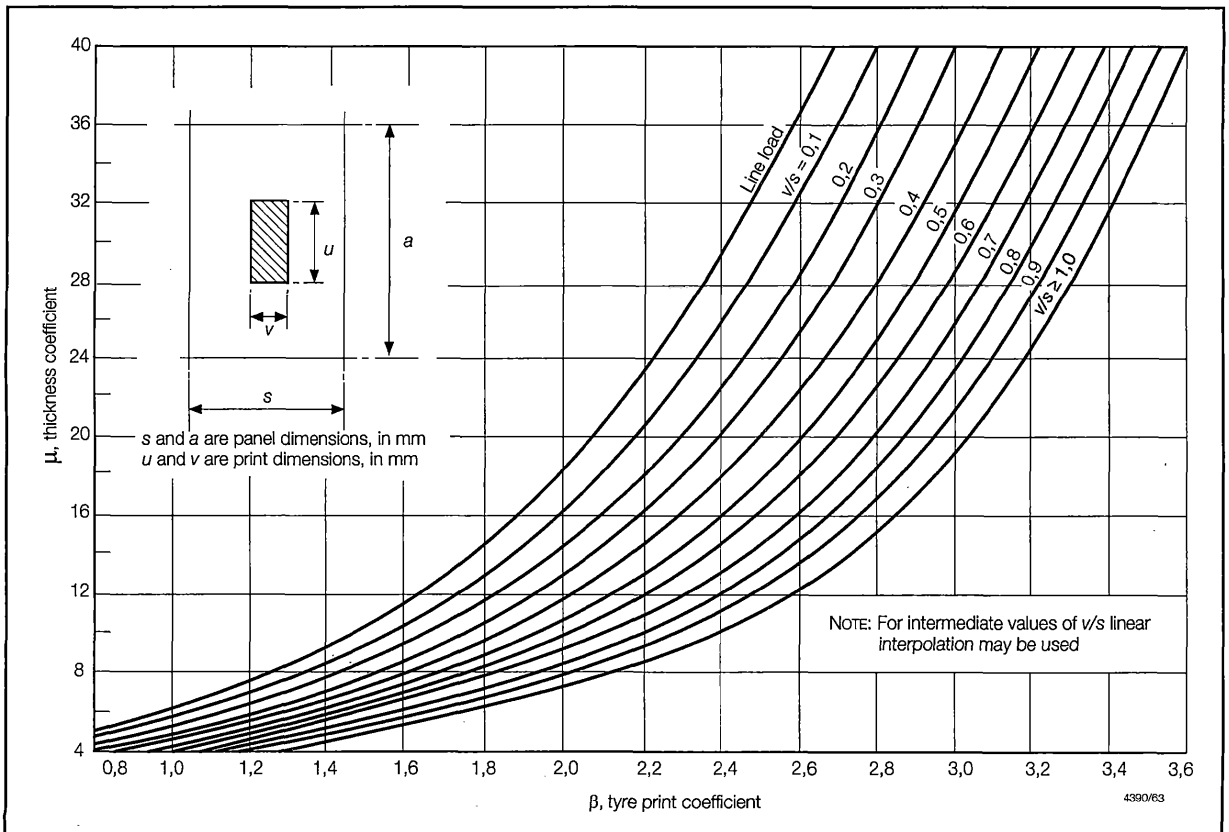

Fig. 5.3.1 Tyre print chart

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3.4 Secondary stiffening

3.4.1 The scantlings of vehicle deck stiffeners are to be as required to satisfy the most severe arrangement of print wheel loads in conjunction with the cargo/weather deck design head.

3.4.2 The minimum requirements for section modulus, inertia and web area of vehicle deck secondary stiffeners subject to wheel loading are to be calculated in accordance with Table 5.3.3, *see also* Fig. 5.3.1 and Table 5.3.2.

Table 5.3.2 Tyre correction factor, *n*

Number of wheels in idealised patch	Pneumatic tyres correction factor, *n*	Solid rubber tyres correction factor, *n*
1	0,6	0,8
2 or more	0,75	0,9

3.4.3 When two or more load areas are located simultaneously on the same stiffener span, the scantling requirements are to be specially considered on the basis of direct calculation.

3.4.4 Where continuous secondary stiffeners pass through the webs of primary members, they are to be fully collared or lugged in way. The shear stresses at the connections are to be in compliance with Table 7.3.1 in Chapter 7.

3.5 Primary stiffening

3.5.1 The scantlings of vehicle deck primary girders and transverse web frames are to be determined on the basis of direct calculation in association with the limiting permissible stress and deflection criteria contained in Chapter 7.

3.6 Securing arrangements

3.6.1 Details of the connections to the hull of vehicle securing arrangements are to be submitted for approval.

3.6.2 Deck fittings in way of vehicle lanes are to be recessed.

3.6.3 The vehicle deck structure is to be of adequate strength for the upward forces imposed at fixed securing points. Local reinforcement is to be fitted as necessary.

Table 5.3.3 Secondary stiffener requirements

Scantling requirement	Load case	
	$d \le l$	$d > l$
Section modulus (Z) (cm^3)	$Z = \left(\frac{P\, k_w\, (3l^2 - d^2)}{24\, l\, f_\sigma\, \sigma_s} \right) \times 10^3 + Z_{dk}$	$Z = \left(\frac{k_w\, P\, l^2}{10 d\, f_\sigma\, \sigma_s} \right) \times 10^3 + Z_{dk}$
Inertia (I) (cm^4)	$I = \left(\frac{f_\delta\, P\, k_w\, (2l^3 - 2d^2\, l + d^3)}{384 E\, l} \right) \times 10^5 + I_{dk}$	$I = \left(\frac{f_\delta\, k_w\, P\, l^3}{384 E\, d} \right) \times 10^5 + I_{dk}$
Web area (A_w) (cm^2)	$A_w = \frac{10 P\, k_w\, (m^3 - 2m^2 + 2)}{2 f_\tau\, \tau_s} + A_{dk}$ where $m = d/l$	$A_w = \frac{k_w\, P\, l}{2 d\, f_\tau\, \tau_s} + A_{dk}$

Symbols

P = maximum effective load per wheel or group of wheels, in kN
l = overall secondary stiffener length, in metres
s = stiffener spacing, in metres
d = dimension of load area parallel to stiffener axis, in metres
E = Young's Modulus of elasticity of material, in N/mm^2
w = dimension of load area perpendicular to stiffener axis, in metres
k_w = lateral loading factor
= 1 for $w \le s$
= s/w for $w > s$
f_σ = limiting bending stress coefficient taken from Table 7.3.1 in Chapter 7
f_τ = limiting shear stress coefficient taken from Table 7.3.1 in Chapter 7
f_δ = limiting deflection coefficient taken from Table 7.2.1 in Chapter 7
σ_s = specified minimum yield strength of the material, in N/mm^2
τ_s = shear stress of material, in N/mm^2
= $\frac{\sigma_s}{\sqrt{3}}$

Z_{dk}, I_{dk}, A_{dk} = stiffener requirements for weather/cargo decks to be determined in accordance with Ch 3,8.7 and Ch 3,8.10 using the appropriate design head for weather/cargo. In no case is the head to be taken as less than 2 kN/m^2.

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3.7 Access

3.7.1 Bow doors are to comply with the requirements of Section 4.

3.7.2 Where access to the vehicle deck is provided by side and stern doors, the doors are to have scantlings equivalent to the structure in which they are fitted, *see also* Pt 3, Ch 4,4.

3.7.3 Doors providing pedestrian access between vehicle decks and accommodation spaces are to be gastight, have scantlings equivalent to the surrounding structure and where applicable are to comply with the requirements of Part 17.

3.8 Hatch covers

3.8.1 The scantlings and arrangements of hatches and hatch covers located within vehicle decks are to be not less than that required by the Rules for the supporting structure in which such hatches are fitted. In general the end fixity of primary stiffening members is to be taken as simply supported. Local and secondary stiffening members may be either partially or fully fixed at their end connections dependent upon the proposed arrangement.

3.8.2 In no case, however, are the scantlings of plating and stiffeners to be less than would be required for a weather or cargo deck, or hatch cover, as applicable.

3.8.3 Where unusual arrangements of hatch cover stiffening are proposed, the scantlings of plating and stiffeners may be determined by direct calculations using a two dimensional grillage model. Copies of calculations are to be submitted.

3.9 Heavy and special loads

3.9.1 Where heavy or special loads are proposed to be carried, the scantlings and arrangements of the deck structure will be individually considered on the basis of submitted calculations.

3.9.2 Due account is to be taken of the acceleration levels due to craft motion as applicable to particular items of heavy mass such as vehicles, containers, pallets, etc.

3.10 Direct calculations

3.10.1 LR will consider direct calculations for the derivation of scantlings as an alternative to and equivalent to those derived by Rule requirements. The assumptions made and the calculation procedures used are to be submitted for appraisal in accordance with Pt 3, Ch 1,2.

■ *Section 4* Bow doors

4.1 Application

4.1.1 The requirements of this Section are applicable to the arrangement, strength and securing of bow doors, both the visor and the side opening type doors, and inner doors leading to a complete or long forward enclosed superstructure.

4.1.2 Other types of bow door will be specially considered.

4.2 General

4.2.1 The attention of Owners and Builders is drawn to the additional statutory regulations for bow doors that may be imposed by the National Authority.

4.2.2 Bow doors are to be situated above the freeboard deck. A watertight recess in the freeboard deck located forward of the collision bulkhead and above the deepest waterline fitted for arrangement of ramps or other related mechanical devices may be regarded as a part of the freeboard deck.

4.2.3 An inner door is to be fitted. The inner door is to be part of the collision bulkhead. The inner door need not be fitted directly above the bulkhead below, provided it is located within the limits specified for the position of the collision bulkhead, *see* Pt 3, Ch 2,4. A vehicle ramp may be arranged for this purpose, provided its position complies with Pt 3, Ch 2,4 and the ramp is weathertight over its complete length. In this case the upper part of the ramp higher than 2,3 m above the freeboard deck may extend forward of the limit specified in Pt 3, Ch 2,4. If this is not possible a separate inner weathertight door is to be installed, as far as practicable within the limits specified for the position of the collision bulkhead.

4.2.4 Bow doors are to be fitted as to ensure tightness consistent with operational conditions and to give effective protection to inner doors. Inner doors forming part of the collision bulkhead are to be weathertight over the full height of the cargo space and arranged with fixed sealing supports on the aft side of the doors.

4.2.5 Bow doors and inner doors are to be arranged so as to preclude the possibility of the bow door causing structural damage to the inner door or to the collision bulkhead in the case of damage to or detachment of the bow door. If this is not possible, a separate inner weathertight door is to be installed, as indicated in 4.2.3.

4.2.6 The requirements for inner doors are based on the assumption that vehicles are effectively lashed and secured against movement in the stowed position.

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4.3 Symbols and definitions

4.3.1 The symbols used in this Section are defined as follows:

A_s = area stiffener web, in cm^2

A_x = area, in m^2, of the transverse vertical projection of the door between the levels of the bottom of the door and the upper deck or between the bottom of the door and the top of the door, whichever is the lesser, as shown in Fig. 5.4.2

A_y = area, in m^2, of the longitudinal vertical projection of the door between the levels of the bottom of the door and the upper deck or between the bottom of the door and the top of the door, whichever is the lesser

A_z = area of the horizontal projection of the door between the levels of the bottom of the door and the upper deck or between the bottom of the door and the top of the door, in m^2, whichever is the lesser, as shown in Fig. 5.4.2

a_{bv} = vertical distance, in metres, from visor pivot to the centroid of the transverse vertical projected area of the visor door, as shown in Fig. 5.4.2

b_{bv} = horizontal distance, in metres, from visor pivot to the centroid of the horizontal projected area of the visor door, as shown in Fig. 5.4.2

c_{bv} = horizontal distance, in metres, from visor pivot to the centre of gravity of visor mass, as shown in Fig. 5.4.2

d_{bv} = Vertical distance, in metres, from bow door pivot to the centre of gravity of the bow door, as shown in Fig. 5.4.2

h = height of the door between the levels of the bottom of the door and the upper deck or between the bottom of the door and the top of the door, in metres, whichever is the lesser, as shown in Fig. 5.4.1

K_s = higher tensile steel factor
= $235/\sigma_s$

l_d = length of the door at a height $h/2$ above the bottom of the door, in metres, as shown in Fig. 5.4.2

Q_{bd} = shear force, in kN, in the stiffener calculated by using uniformly distributed external pressure P_e as given in 4.5.1

W_{bv} = mass of the visor door, in tonnes

W = breadth of the door at a height $h/2$ above the bottom of the door, in metres, as shown in Fig. 5.4.2

σ = bending stress, in N/mm^2

σ_{eq} = equivalent stress, in N/mm^2
= $\sqrt{\sigma^2 + 3\tau^2}$

σ_s = specified minimum yield strength of the material, in N/mm^2

τ = shear stress, in N/mm^2.

4.3.2 **Locking device.** A device that locks a securing device in the closed position.

4.3.3 **Securing device.** A device used to keep the door closed by preventing it from rotating about its hinges.

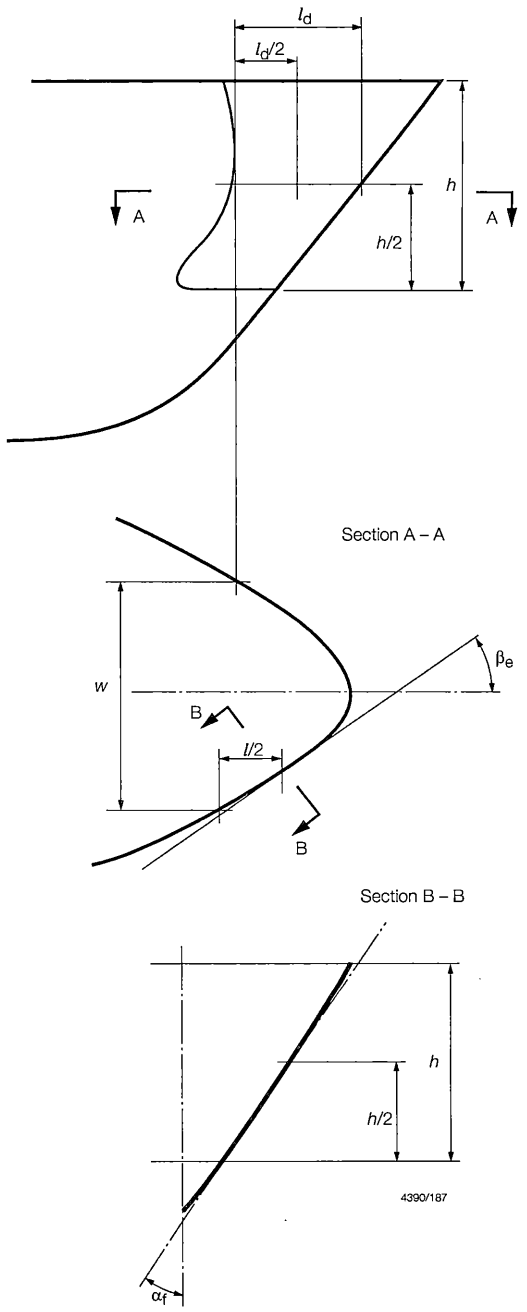

Fig. 5.4.1 Measurement of α_f and β_e

4.3.4 **Side-opening doors.** Side-opening doors are opened either by rotating outwards about a vertical axis through two or more hinges located near the outboard edges or by horizontal translation by means of linking arms arranged with pivoted attachments to the door and the craft. It is anticipated that side-opening doors are arranged in pairs.

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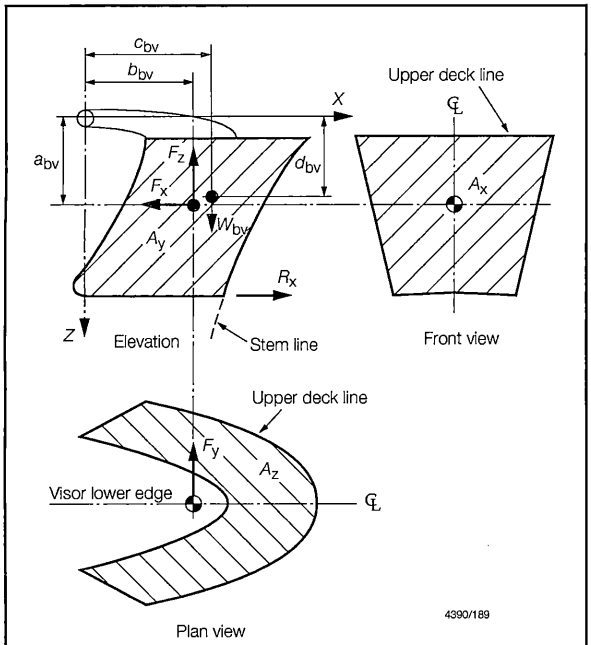

Fig. 5.4.2 Bow visor (upward hinging)

4.3.5 **Supporting device.** A device used to transmit external or internal loads from the door to a securing device and from the securing device to the craft's structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, that transmits loads from the door to the craft's structure.

4.3.6 **Visor doors.** Visor doors are opened by rotating upwards and outwards about a horizontal axis through two or more hinges located near the top of the door and connected to the primary structure of the door by longitudinally arranged lifting arms.

4.4 Strength criteria

4.4.1 Scantlings of the primary members, securing and supporting devices of bow doors and inner doors are to be able to withstand the design loads defined in 4.5. The shear, bending and equivalent stresses are not to exceed $80/k_s$ N/mm^2, $120/k_s$ N/mm^2 and $150/k_s$ N/mm^2 respectively.

4.4.2 The buckling strength of primary members is to be verified as being adequate, *see* Ch 7,4.

4.4.3 For steel to steel bearings in securing and supporting devices, the nominal bearing pressure calculated by dividing the design force by the projected bearing area is not to exceed 80 per cent of the yield stress of the bearing material. For other bearing materials, the permissible bearing pressure is to be determined according to the manufacturer's specification.

4.4.4 The arrangement of securing and supporting devices is to be such that threaded bolts do not carry support forces. The maximum tension in way of threads of steel bolts not carrying support forces is not to exceed $125/k_s$ N/mm^2.

4.5 Design loads

4.5.1 The design external pressure, P_e, for the determination of scantlings for primary members, securing and supporting devices of bow doors is to be taken not less than the following:

$$P_e = 2{,}75\lambda_G C_H (0{,}22 + 0{,}15\tan\alpha_f)$$

$$(0{,}4V_{max}\sin\beta_e + 0{,}6L_R^{0,5})^2 \quad \text{kN/m}^2$$

where

V_{max} = maximum speed, in knots, as defined in Pt 1, Ch 2, 2.2.10

L_R = Rule length of craft, in metres, as defined in Pt 3, Ch 1,6

λ_G = Service group factor for mono-hull craft, *see* Pt 1, Ch 2
= 0,5 for Group 1 and Group 2
= 0,6 for Group 3
= 0,8 for Group 4
= 1,0 for Group 5 and Group 6
For multi-hull craft, λ_G will be specially considered and may be reduced where the freeboard is significant

C_H = $0{,}0125L_R$ for $L_R < 80$ m
= 1,0 for $L_R \geq 80$ m

α_f = flare angle, in degrees, at the point to be considered, defined as the angle between a vertical line and the tangent to the side shell plating, measured in a vertical plane normal to the horizontal tangent to the shell plating, *see* Fig. 5.4.1

β_e = entry angle, in degrees, at the point to be considered, defined as the angle between a longitudinal line parallel to the centreline and the tangent to the shell plating in a horizontal plane, *see* Fig. 5.4.1.

4.5.2 The design external forces, F_x, F_y and F_z, in kN, for the determination of scantlings of securing and supporting devices of bow doors are taken to be not less than $P_e A_x$, $P_e A_y$ and $P_e A_z$ respectively:

where

P_e is the external pressure, defined in 4.5.1, with the flare angle α_f, and the entry angle β_e, measured at the point on the bow door

$l_d/2$ aft of the stem line on the plane, and

$h/2$ above the bottom of the door, as shown in Fig. 5.4.1

A_x, A_y, A_z and h as defined in 4.3.1.

4.5.3 For bow doors, including bulwark, of unusual form or proportions, the areas used for the determination of the design values of external forces will be specially considered.

4.5.4 For visor doors the closing moment, M_y, under external loads, is to be taken as:

$$M_y = F_x a_{bv} + 10W_{bv} c_{bv} - F_z b_{bv} \quad \text{kNm}$$

where

W_{bv}, a_{bv}, b_{bv} and c_{bv} are as defined in 4.3.1,
F_x and F_z are as defined in 4.5.2.

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4.5.5 The lifting arms of a visor and its supports are to be dimensioned for the static and dynamic forces applied during the lifting and lowering operations, and a minimum wind pressure of 1,5 kN/m^2 is to be taken.

4.5.6 The design external pressure, in kN/m^2, for the determination of scantlings for primary members, securing and supporting devices and surrounding structure of inner doors is to be taken as the greater of $0{,}45L_R$ and $10h_2$, where h_2 is the distance, in m, from the load point to the top of the cargo space and L_R as defined in Pt 3, Ch 1,6.2.1.

4.5.7 The design internal pressure for the determination of scantlings for securing devices of inner doors is not to be taken less than 25 kN/m^2.

4.6 Scantlings of bow doors

4.6.1 The strength of bow doors is to be commensurate with that of the surrounding structure.

4.6.2 Bow doors are to be adequately stiffened and means are to be provided to prevent lateral or vertical movement of the doors when closed. For visor doors adequate strength for the opening and closing operations is to be provided in the connections of the lifting arms to the door structure and to the craft structure.

4.6.3 The thickness of the bow plating is not to be less than that required for the side shell plating, using bow door stiffener spacing, but in no case less than the minimum required thickness of fore end shell plating.

4.6.4 The section modulus of horizontal or vertical stiffeners is not to be less than that required for end framing. Consideration is to be given, where necessary, to differences in fixity between the craft's frames and bow doors stiffeners.

4.6.5 The stiffener webs are to have a net sectional area A_s, not less than:

$$A_s = \frac{23{,}5Q_{bd}}{\sigma_s} \text{ cm}^2$$

where

A_s, Q_{bd} and σ_s are as defined in 4.3.1.

4.6.6 The bow door secondary stiffeners are to be supported by primary members constituting the main stiffening of the door.

4.6.7 The primary members of the bow door and the hull structure in way are to have sufficient stiffness to ensure integrity of the boundary support of the door.

4.6.8 Scantlings of the primary members are generally to be supported by direct calculations in association with the external pressure given in 4.5.1 and permissible stresses given in 4.4.2.

4.7 Scantlings of inner doors

4.7.1 Scantlings of the primary members are generally to be supported by direct calculations in association with the external pressure and permissible stresses given in 4.4.1. In general, formulae for simple beam theory may be applied.

4.7.2 Where inner doors also serve as a vehicle ramps, the scantlings are not to be less than those required for vehicle decks.

4.7.3 The distribution of forces acting on the securing and supporting devices is, in general, to be supported by direct calculations taking into account the flexibility of the structure and actual position and stiffness of the supports.

4.8 Securing and supporting of bow doors

4.8.1 Bow doors are to be fitted with adequate means of securing and supporting so as to be commensurate with the strength and stiffness of the surrounding structure. The hull supporting structure in way of the bow doors is to be suitable for the same design loads and design stresses as the securing and supporting devices. Where packing is required, the packing material is to be of a comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be considered. Maximum design clearance between securing and supporting devices is, in general, not to exceed 3 mm. A means is to be provided for mechanically fixing the door in the open position.

4.8.2 Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be included and considered to calculate the reaction forces acting on the devices. Small and/or flexible devices such as cleats intended to provide load compression of the packing material are, in general, not to be included in the calculations called for in 4.8.8. The number of securing and supporting devices are, in general, to be the minimum practical whilst taking into account the requirements for redundant provision given in 4.8.9 and 4.8.10 and the available space for adequate support in the hull structure.

4.8.3 For opening outwards visor doors, the pivot arrangement is generally to be such that the visor is self-closing under external loads, that is $M_y > 0$. Moreover, the closing moment, M_y, as given in 4.5.4 is to be not less than:

$$M_y = 10W_{bv}\, c_{bv} + 0{,}1(a_{bv}^2 + b_{bv}^2)^{0,5}\ (F_x^2 + F_z^2)^{0,5}$$

where

W_{bv}, a_{bv}, b_{bv} and c_{bv} are as defined in 4.3.1, F_x and F_z are as defined in 4.5.2.

4.8.4 Securing and supporting devices are to be adequately designed so that they can withstand the reaction forces within the permissible stresses given in 4.4.1.

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4.8.5 For **visor doors** the reaction forces applied on the effective securing and supporting devices assuming the door as a rigid body are determined for the following combination of external loads acting simultaneously together with the self weight of the door.

Case 1 F_x and F_z

Case 2 $0,7F_y$ acting on each side separately together with $0,7F_x$ and $0,7F_z$.

where

F_x, F_y and F_z are to be determined as indicated in 4.5.2 and applied at the centroid of projected areas.

4.8.6 For **side-opening doors** the reaction forces applied on the effective securing and supporting devices assuming the door as a rigid body are determined for the following combination of external loads acting simultaneously together with the self weight of the door:

Case 1 F_x, F_y and F_z acting on both doors.

Case 2 $0,7F_x$ and $0,7F_z$ acting on both doors and $0,7F_y$ acting on each door separately.

where

F_x, F_y and F_z are to be determined as indicated in 4.5.2 and applied at the centroid of projected areas.

4.8.7 The support forces as determined according to 4.8.5 and 4.8.6 are generally to give rise to a zero moment about the transverse axis through the centroid of the area A_x. For visor doors, longitudinal reaction forces of pin and/or wedge supports at the door base contributing to this moment are not to be of the forward direction.

4.8.8 The distribution of the reaction forces acting on the securing and supporting devices may require to be supported by direct calculations taking into account the flexibility of the hull structure and the actual position and stiffness of the supports.

4.8.9 The arrangement of securing and supporting devices in way of these securing devices is to be designed with redundancy so that in the event of failure of any single securing or supporting device the remaining devices are capable to withstand the reaction forces without exceeding by more than 20 per cent the permissible stresses as given in 4.4.1.

4.8.10 For visor doors, two securing devices are to be provided at the lower part of the door, each capable of providing the full reaction force required to prevent opening of the door within the permissible stresses given in 4.4.1. The opening moment, M_o, to be balanced by this reaction force, is not to be taken less than:

$$M_o = 10W_{bv}\, d_{bv} + 5A_x\, a_{bv} \text{ kNm}$$

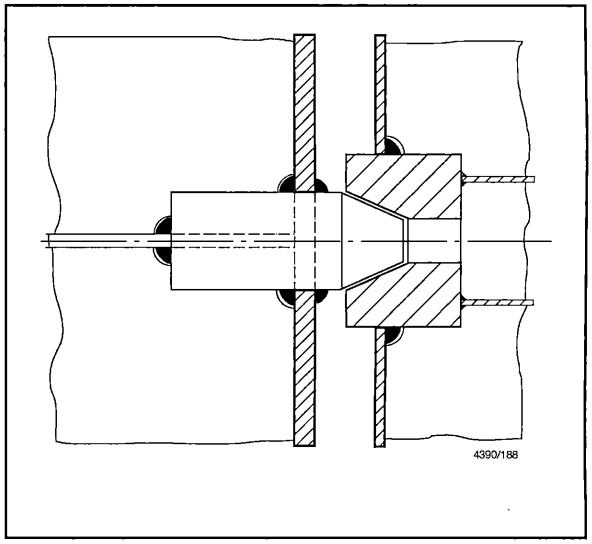
where

W_{bv}, A_x, d_{bv} and a_{bv} as defined in 4.3.1.

4.8.11 For visor doors, the securing and supporting devices excluding the hinges should be capable of resisting the vertical design force ($F_z - 10W_{bv}$), in kN, within the permissible stresses given in 4.4.1.

4.8.12 All load transmitting elements in the design load path, from door through securing and supporting devices into the craft structure, including welded connections, are to be the same strength.

4.8.13 For side-opening doors, thrust bearing has to be provided in way of girder ends at the closing of the two leaves to prevent one leaf to shift towards the other one under effect of unsymmetrical pressure, *see* Fig. 5.4.3. Each part of the thrust bearing has to be kept secured on the other part by means of securing devices. Any other arrangements serving the same purpose are to be submitted for appraisal.



4.9 Securing and locking arrangement

4.9.1 Securing devices are to be simple to operate and easily accessible. Securing devices are to be equipped with mechanical locking arrangements (self locking or separate arrangement), or be of the gravity type. The opening and closing systems as well as securing and locking devices are to be interlocked in such a way that they can only operate in the proper sequence.

4.9.2 Bow doors and inner doors giving access to vehicle decks are to be provided with an arrangement for remote control, from a position above the freeboard deck, of:

(a) the closing and opening of the doors; and

(b) associated securing and locking devices for every door.

Indication of the open/closed position of every door and every securing and locking device is to be provided at the remote control stations. The operating panels for operation of doors are to be inaccessible to unauthorised persons. A notice plate, giving instructions to the effect that all securing devices are to be closed and locked before leaving harbour, is to be placed at each operating panel and is to be supplemented by warning indicator lights.

4.9.3 Where hydraulic securing devices are applied, the system is to be mechanically lockable in closed position so that in the event of loss of the hydraulic fluid, the securing devices remain locked. The hydraulic system for securing and locking devices is to be isolated from other hydraulic circuits when in closed position.

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4.9.4 Separate indicator lights and audible alarms are to be provided on the navigation bridge and on the operating panel to show that the bow door and inner door are closed and that their securing and locking devices are properly positioned. The indication panel is to be provided with a lamp test function. The indicator lights are to be provided with a permanent power supply, and arrangements are to be such that it is not possible to turn off these lights in service.

4.9.5 The indicator system is to be designed on the fail-safe principle and is to show by visual alarms if the door is not fully closed and not fully locked and by audible alarms if securing devices become open or locking devices become unsecured. The power supply for the indicator system is to be independent of the power supply for operating and closing the doors. The sensors of the indicator system are to be protected from water, ice formation and mechanical damage.

4.9.6 The indication panel on the navigation bridge is to be equipped with a mode selection function 'harbour/sea voyage', so arranged that audible alarm is given if the craft leaves harbour with the bow door or inner door not closed and with any of the securing devices not in the correct position.

4.9.7 A water leakage detection system with audible alarm and television surveillance is to be arranged to provide an indication to the navigation bridge and to the engine control room of leakage through the inner door.

4.9.8 Between the bow door and the inner door a television surveillance system is to be fitted with a monitor on the navigation bridge and in the engine control room. The system is to be able to monitor the position of doors and a sufficient number of their securing devices. Special consideration is to be given for lighting and contrasting colour of objects under surveillance.

4.9.9 A drainage system is to be arranged in the area between bow door and ramp, as well as in the area between the ramp and inner door where fitted. The system is to be equipped with an audible alarm function to the navigation bridge for water level in these areas exceeding 0,5 m above the car deck level.

4.10 Operating and Maintenance Manual

4.10.1 An Operating and Maintenance Manual for the bow door and inner door is to be provided on board and contain necessary information on:

(a) main particulars and design drawings;
(b) service conditions, e.g. service area restrictions and acceptable clearances for supports;
(c) maintenance and function testing;
(d) register of inspections and repairs.

This manual is to be submitted for approval.

4.10.2 Documented operating procedures for closing and securing the bow door and inner door are to be kept on board and posted at an appropriate place.

■ *Section 5* Movable decks

5.1 Classification

5.1.1 Movable decks other than those described in 5.1.2 are not a classification item, although consideration must be given to associated supporting structure. Where movable decks are fitted, it is recommended that they be based on the requirements of this Section.

5.1.2 At the Owner's or Builder's request, however, movable decks will be included as a classification item, and the class notation **Movable decks** will be entered in the *Register Book*. In such cases, all movable decks on board the ship are to comply with the requirements of this Section.

5.2 Arrangements and designs

5.2.1 Movable decks are generally to be constructed as pontoons comprising a web structure with top decking. Other forms of construction will be individually considered.

5.2.2 Positive means of control are to be provided to secure decks in the lowered position.

5.2.3 The decks are to be efficiently supported, and hinges, pillars, chains or other means (or a combination of these) are to be designed on the basis of the imposed loads. Where supporting chains and fittings are required, they are to have a factor of safety of at least two on the proof load.

5.2.4 Plans showing the proposed scantlings and arrangements of the system are to be submitted.

5.2.5 Where it is proposed to stow the pontoons on deck, when not in use, details of the proposals for racks, fittings, etc., are to be submitted for consideration.

5.3 Loading

5.3.1 Details of the deck loading resulting from the proposed stowage arrangements of vehicles are to be supplied by the Shipbuilder. These details are to include the axle and wheel spacing, the wheel load, type of tyre and tyre print dimensions for the vehicles. For design purposes the wheel loading is to be taken as not less than 3,0 kN, *see* Section 3.

5.3.2 Where it is proposed also to use the decks for general cargo, the design loadings are to be submitted for consideration.

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5.4 Scantling requirements

5.4.1 The scantlings and arrangements of removable decks are to be not less than those required by the Rules for the supporting structure in which the movable decks are fitted. In general the end fixity of primary stiffening members is to be taken as simply supported. Local and secondary stiffening members may be either partially or fully fixed at their end connections dependent upon the proposed arrangement.

5.5 Deflection

5.5.1 Where wheeled vehicles are to be used, the supporting arrangements are to be such that the movement at the edge of one pontoon relative to the next does not exceed 50 mm during loading or unloading operations.

■ *Section 6* Helicopter landing areas

6.1 General

6.1.1 The landing area may be located on an appropriate area of the weather deck or on a platform specifically designed for this purpose and permanently connected to the craft structure.

6.1.2 The structure is to be designed to accommodate the largest helicopter type which it is intended to use. In general, the diameter of the landing area is to be not less than 1,25 times the rotor diameter.

6.1.3 Attention is drawn to the requirements of National and other Authorities concerning the construction of helicopter landing platforms and the operation of helicopters as they affect the craft.

6.1.4 Plans are to be submitted showing the proposed scantlings and arrangements of the structure. The type, size and weight of helicopters to be used are also to be indicated. Details of the helicopter types to be used are to be included in the craft's documentation, and be contained in a notice displayed on the helicopter landing deck.

6.1.5 Where the landing area forms part of a weather or erection deck, the scantlings are to be not less than those required for decks in the same position.

6.1.6 The requirements for fire protection, detection and extinction for yachts are to comply with Part 17. The requirements for other types of craft are outside the scope of classification and are therefore to comply with the requirements of the National Authority. Special consideration is to be given to the insulation standard if the space below the helicopter deck is a high fire-risk space.

6.2 Arrangements

6.2.1 The landing area is to be sufficiently large to allow for the landing and manoeuvring of the helicopter, and is to be approached by a clear landing and take-off sector complying in extent with the applicable regulations.

6.2.2 The landing area is to be free of any projections above the level of the deck. Projections in the zone surrounding the landing area are to be kept below the heights permitted by the regulations.

6.2.3 Suitable arrangements are to be made to minimise the risk of personnel or machinery sliding off the landing area. A non-slip surface and anchoring devices, and in the case of independent platforms, safety nets, are to be provided.

6.2.4 Arrangements are to be made for drainage of the platform, including drainage of spilt fuel.

6.2.5 Details of arrangements for securing the helicopter to the deck are to be submitted for approval.

6.3 Landing area plating

6.3.1 The deck plate thickness, t_p, within the landing area is to be not less than:

$$t_p = \frac{\alpha\, s}{1000\ k_s}$$

α = thickness coefficient obtained from Fig. 5.3.1

β_p = tyre print coefficient used in Fig. 5.3.1

$$= \log_{10}\left(\frac{P_1\, k_s^2}{s^2} \times 10^7\right)$$

where

s and k_s are defined in 1.2.

The plating is to be designed for the emergency landing case taking

$P_1 = 2{,}5\ \phi_1\ \phi_2\ \phi_3\ f\ \gamma\ P_w$ tonnes

where

ϕ_1, ϕ_2, ϕ_3 are to be determined from Table 5.3.1

f = 1,15 for landing decks over manned spaces, e.g. deckhouses, bridges, control rooms, etc.
= 1,0 elsewhere

P_h = the maximum all up weight of the helicopter, in tonnes

P_w = landing load on the tyre print, in tonnes;
For helicopters with a single main rotor, P_w is to be taken as P_h divided equally between the two main undercarriage wheels.
For helicopters with tandem main rotors, P_w is to be taken as P_h distributed between all main undercarriage wheels in proportion to the static loads they carry.
For helicopters fitted with landing gear consisting of skids, P_w is to be taken as P_h distributed in accordance with the actual load distribution given by the airframe manufacturer. If this is unknown, P_w is to be taken as $1/6P_h$ for each of the two forward contact points and $1/3P_h$ for each of the two aft contact points. The load may be assumed to act as a 300 mm x 10 mm line load at each end of each skid when applying Fig. 5.3.1.

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γ = a location factor given in Table 5.6.1

For wheeled undercarriages, the tyre print dimensions specified by the manufacturer are to be used for the calculation. Where these are unknown it may be assumed that the print area is 300 mm x 300 mm and this assumption is to be indicated on the submitted plan.

For skids and tyres with an asymmetric print, the print is to be considered oriented both parallel and perpendicular to the longest edge of the plate panel and the greatest corresponding value of α taken from Fig. 5.3.1.

Table 5.6.1 Location factor, γ

Location	γ
On decks forming part of the hull girder:	
(a) within $0,4L_R$ amidships	0,71 Values for intermediate locations are to be determined by interpolation
(b) at the F.P. or A.P.	0,6
Elsewhere	0,6

6.4 Deck stiffening and supporting structure

6.4.1 The helicopter deck stiffening and the supporting structure are to be designed for the load cases given in Table 5.6.2, with the helicopter being positioned so as to produce the most severe loading condition for each structural member under consideration.

6.4.2 The minimum requirements for section modulus, inertia and web area of secondary stiffeners are to be in accordance with Table 5.3.3.

6.4.3 For primary stiffening, and where a grillage arrangement is adopted, it is recommended that direct calculation procedures be used to determine the scantling requirements, in association with the limiting permissible stress criteria given in Chapter 7. A copy of the calculations is to be submitted for consideration.

■ *Section 7*
Strengthening requirements for navigation in ice conditions

7.1 General

7.1.1 Where an ice class notation is to be included in the class of a craft, the scantlings will require special consideration, *see* Pt 3, Ch 2,9.

7.2 Shell plating

7.2.1 Changes in plating thicknesses in the longitudinal direction are to take place gradually.

7.2.2 In general, all welded seams and butts in way of the main ice belt are to be dressed smooth.

Table 5.6.2 Design load cases for deck stiffening and supporting structure

Loadcase	Loads (tonnes)			
	Landing area		Supporting structure, *see* Note 1	
	UDL, in kN/m^2	Helicopter patch load *see* Note 2	Self weight	Horizontal load *see* Note 2
(1) Overall distributed loading	2	–	–	–
(2) Helicopter emergency landing	0,5	$2,5P_w f$	W_h	$0,5P_h$
(3) Normal Usage	0,5	$1,5P_w$	W_h	$0,5P_h + 0,5W_h$

Symbols

P_h, P_w and f are as defined in 6.3.1.
UDL = Uniformly distributed vertical load over entire landing area
W_h = structural self-weight of helicopter platform, in tonnes

NOTES
1. For the design of the supporting structure for helicopter platforms applicable self weight and horizontal loads are to be added to the landing area loads.
2. The helicopter is to be so positioned as to produce the most severe loading condition for each structural member under consideration.

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Section

1 **General**

2 **Hull girder strength for mono-hull craft**

3 **Additional hull girder strength requirements for multi-hull craft**

Section 1 General

1.1 Application

1.1.1 The requirements for longitudinal and transverse global strength for mono-hull and multi-hull craft of steel construction, are contained within this Chapter. Due consideration is taken of the dynamic effects, where appropriate, in both the crest and trough wave landing conditions.

1.2 Symbols and definitions

1.2.1 The symbols and definitions applicable to this Chapter are defined below or in the appropriate sub-Section.

L_R = Rule length of the craft, in metres

B = moulded breadth of craft, *see* Pt 3, Ch 1,6.2.1, in metres (to be taken as the breadth of a single hull for multi-hull craft)

l = overall span length of stiffening member, in metres

l_e = effective span length of stiffening member, in metres

p = design pressure as appropriately given in Part 3, in kN/m^2

s = spacing of stiffener, in mm

t_p = thickness of plating, in mm

σ_s = specified minimum yield strength of the material, in N/mm^2

β = panel aspect ratio correction, *see* Ch 3,1.15

$$\tau_s = \frac{\sigma_s}{\sqrt{3}}$$

1.2.2 The strength deck is to be taken as follows:

(a) Where there is a complete upper deck the strength deck is the upper deck.

(b) Where the upper deck is stepped, as in the case of raised quarterdeck craft, the strength deck is stepped as shown in Fig. 6.1.1.

1.3 General

1.3.1 The additional pressures arising from the influence of the global loading are considered in the determination of the longitudinal strength requirements for local and secondary stiffening and bottom shell plating.

1.3.2 In general, the effective sectional area of continuous longitudinal strength members, after deduction of openings, is to be used for the calculation of midship section modulus.

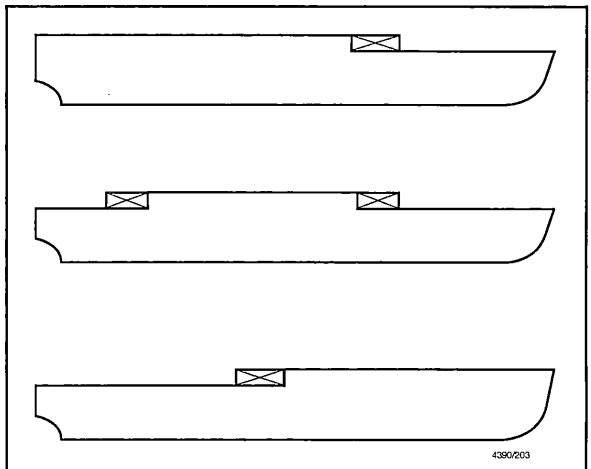

Fig. 6.1.1 Strength deck

1.3.3 Structural members which contribute to the overall hull girder strength are to be carefully aligned so as to avoid discontinuities resulting in abrupt variations of stresses and are to be kept clear of any form of openings which may affect their structural performances.

1.3.4 In general, superstructures or deckhouses will not be accepted as contributing to the global longitudinal or transverse strength of the craft. However, where it is proposed to include substantial, continuous stiffening members, special consideration will be given to their inclusion on submission of the designer's/Builder's calculations.

1.3.5 Where continuous deck longitudinals or deck girders are arranged above the strength deck, special consideration may be given to the inclusion of their sectional area in the calculation of the hull section modulus (Z). The lever is to be taken to a position corresponding to the depth of the longitudinal member above the moulded deckline at side amidships. Each such case will be individually considered.

1.3.6 Adequate transition brackets are to be fitted at the ends of effective continuous longitudinal strength members in the deck and bottom structures.

1.3.7 Scantlings of all continuous longitudinal members of the hull girder based on the minimum section stiffness requirements determined from 2.2 are to be maintained within $0{,}4L_R$ amidships. However, in special cases, based on consideration of type of ship, hull form and loading conditions, the scantlings may be gradually reduced towards the ends of the $0{,}4L_R$ part, bearing in mind the desire not to inhibit the craft's loading and operational flexibility.

1.4 Openings

1.4.1 Deck openings having a length in the fore and aft directions exceeding $0{,}1B$ m or a breadth exceeding $0{,}05B$ m are in all cases to be deducted from the sectional areas used in the section modulus calculation.

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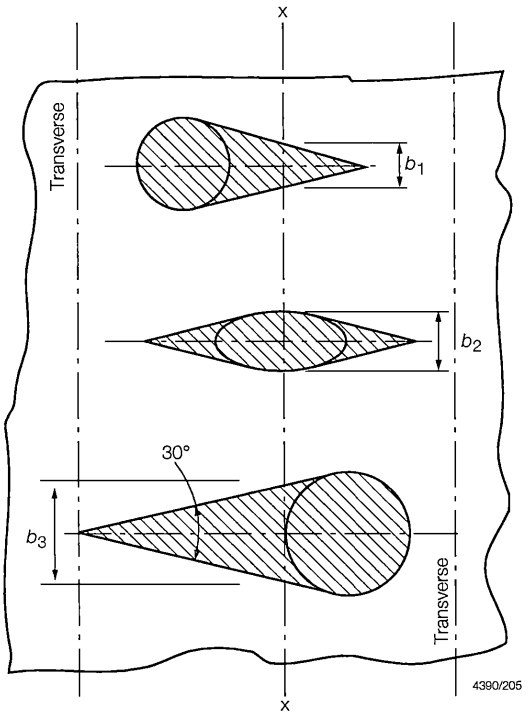
1.4.2 Deck openings smaller than stated in 1.4.1, including manholes, need not be deducted provided they are isolated and the sum of their breadths or shadow area breadths (*see* 1.4.3) in one transverse section does not exceed 0,06 ($B_o - \Sigma b_o$).
where
B_o = breadth of craft, in metres, at section considered
Σb_o = sum of breadths, in metres, of deductible openings
Where a large number of deck openings are proposed in any transverse space, special consideration will be required.

1.4.3 Where calculating deduction-free openings, the openings are assumed to have longitudinal extensions as shown by the shaded areas in Fig. 6.1.2. The shadow area is obtained by drawing two tangent lines to an opening angle of 30°. The section to be considered is to be perpendicular to the centreline of the ship and is to result in the maximum deduction in each transverse space.



Total equivalent breadth of small openings at xx = $b_1 + b_2 + b_3$

Fig. 6.1.2 Isolated openings

1.4.4 Isolated openings in longitudinals or longitudinal girders need not be deducted if their depth does not exceed 25 per cent of the web depth or 75 mm, whichever is the lesser.

1.4.5 Openings are considered isolated if they are spaced not less than 1 m apart.

1.4.6 A reduction for drainage holes and scallops in beams and girders, etc., is not necessary so long as the original section stiffness at deck or keel is reduced by no more than 3,0 per cent.

1.5 Direct calculation procedure

1.5.1 In direct calculation procedures capable of deriving the wave induced loads on the craft, and hence the required modulus, account is to be taken of the craft's actual form and weight distribution.

1.5.2 Lloyd's Register's (hereinafter referred to as 'LR') direct calculation method involves derivation of response to regular waves by strip theory, short-term response to irregular waves using the sea spectrum concept, and long-term response predictions using statistical distributions of sea states. Other direct calculation methods submitted for approval are normally to contain these three elements and produce similar and consistent results when compared with LR's methods.

1.6 Approved calculation systems

1.6.1 Where the assumptions, method and procedures of a longitudinal strength calculation system have received general approval from LR, calculations using the system for a particular craft may be submitted.

1.7 Information required

1.7.1 In order that an assessment of the longitudinal strength requirements can be made, the following information is to be submitted, in LR's standard format where appropriate:
(a) General arrangement and capacity plan or list, showing details of the volume and position of centre of gravity of all tanks and compartments.
(b) Bonjean data, in the form of tables or curves, for at least 21 equally spaced stations along the hull. A lines plan and/or tables of offsets may also be required.
(c) Details of the calculated lightweight and its distribution.
(d) Details of the weights and centres of gravity of all deadweight items for each of the main loading conditions. It is recommended that this information be submitted in the form of a preliminary Loading Manual, to include the calculated still water and dynamic bending moments and shear forces.

1.8 Loading guidance information

1.8.1 Sufficient information is to be supplied to the Master of every craft to enable him to arrange loading in such a way as to avoid the creation of unacceptable stresses in the craft's structure.

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Section 2
Hull girder strength for mono-hull craft

2.1 General

2.1.1 Longitudinal strength calculations are to be submitted for all craft with a Rule length, L_R, exceeding 50 m covering the range of load and ballast conditions proposed, in order to determine the required hull girder strength. Still water, static wave and dynamic bending moments and shear forces are to be calculated for both departure and arrival conditions.

2.1.2 For craft of ordinary hull form with a Rule length, L_R, less than 50 m, the minimum hull girder strength requirements are generally satisfied by scantlings obtained from local strength requirements. However longitudinal strength calculations may be required at LR's discretion, dependent upon the form, constructional arrangement and proposed loading.

2.1.3 Where the Rule length, L_R, of the craft exceeds 75 m, or for new designs of large, structurally complicated craft, the design loads and scantling determination formulae in this Chapter are to be supplemented by direct calculation and structural analysis by 3-D finite element methods. These supplementary calculations are to include the results of model tests and full scale measurement where available or required by LR. Full details of such methods and all assumptions and calculations, which are to be based on generally accepted theories, are to be submitted for appraisal.

2.2 Bending strength

2.2.1 The effective geometric properties of the midship section are to be calculated directly from the dimensions of the section using only the effective material elements which contribute to the global longitudinal strength irrespective of the grades of steel incorporated in the construction. For the purposes of this analysis an element may be of deck plating, longitudinal girder, inner bottom, etc., or other continuous member.

2.2.2 The contribution that higher tensile steel makes to the global strength is based upon the strain in that material in relation to the allowable strain in mild steel. Therefore, the maximum permissible hull vertical bending stress, σ_p, for the design analysis is not to be taken greater than that determined from the following:

$$\sigma_{p\,(HTS)} = \sigma_{p\,(MS)} \frac{\overline{y}_{(HTS)}}{\overline{y}_{(MS)}}$$

where

σ_p is as defined in 2.2.3

$\overline{y}_{(HTS)}$ = the maximum distance, in metres, above or below the neutral axis of the hull cross-section to any effective higher tensile steel element contributing to global longitudinal strength

$\overline{y}_{(MS)}$ = the maximum distance, in metres, above or below the neutral axis of the hull cross-section to any effective mild steel element contributing to global longitudinal strength.

2.2.3 The longitudinal strength of craft with $\frac{V}{\sqrt{L_{WL}}} \geq 3{,}0$ is to satisfy both the following criteria:

$$\sigma_k + \sigma_l + \sigma_t < 1{,}2\sigma_P \text{ and}$$
$$\sigma_d < \sigma_P$$

where

σ_P = maximum permissible hull vertical bending stress, in N/mm^2 and is not to be taken greater than that determined from 2.2.2

= $f_{\sigma gH}$, σ_s or the value determined from 2.2.2, whichever is the lesser

$f_{\sigma gH}$ = limiting hull bending stress coefficient taken from Table 7.3.2 in Chapter 7

L_{WL} is as defined in Pt 3, Ch 1,6.2.5

σ_k, σ_l, σ_t and σ_d are given in Table 6.2.1

σ_s is as defined in 1.2.1.

Table 6.2.1 Longitudinal component stresses

Component stress type	Nominal stress (N/mm^2)
Hull girder bending stress at strength deck amidships	$\sigma_d = \frac{M_R}{1000Z_d}$
Hull girder bending stress at keel amidships	$\sigma_k = \frac{M_R}{1000Z_k}$
Actual stress in bottom longitudinals amidships due to design pressure load	$\sigma_l = \frac{p_s s l_e^2}{12Z_l}$
Actual stress in bottom plating amidships due to design pressure load	$\sigma_t = 0{,}34P_t\left(\frac{\beta s}{t_p}\right)^2 \times 10^{-3}$
Symbols and definitions	
M_R = design longitudinal midship bending moment, in kNm, given in Pt 5, Ch 5,5 p_s = additional effective pressure loading, in kN/m^2, on bottom longitudinals from global dynamic load model, given in Pt 5, Ch 5,2.6.3 P_t = additional effective pressure loading, in kN/m^2, on bottom plating from global dynamic load model, given in Pt 5, Ch 5,2.6.4 Z_d = actual section modulus at deck, in m^3 Z_k = actual section modulus at keel, in m^3 Z_l = maximum section modulus of bottom longitudinal stiffener, associated with plating, amidships, in cm^3 s, l_e, β and t_p are as defined in 1.2.	

2.2.4 The longitudinal strength of craft with $\frac{V}{\sqrt{L_{WL}}} < 3{,}0$ is to satisfy both the following criteria:

$$\sigma_k < \sigma_P$$
$$\sigma_d < \sigma_P$$

where

σ_P is as defined in 2.2.3

σ_k and σ_d are given in Table 6.2.1

L_{WL} is as defined in Pt 3, Ch 1,6.2.5.

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2.3 Minimum hull section modulus

2.3.1 For patrol craft in Service Group G6, the hull midship modulus about the transverse neutral axis, at the deck or the keel, is to be not less than:

$$Z_{min} = \eta_{HTS} L_f L_R^2 B_{WL} (C_b + 0,7) \times 10^{-6} \quad m^3$$

where

η_{HTS} is as defined in Ch 2,2.4.3

L_R and C_b are as given in Pt 5, Ch 2,2.2.2

C_b to be taken not less than 0,6

L_f is as given in Pt 5, Ch 5,2.2.2

B_{WL} = maximum breadth at the design waterline, in metres.

2.4 Shear strength

2.4.1 The shear strength of the craft at any position along its length is to satisfy the following criterion:

$$\frac{Q_R}{A_\tau} 10^{-3} \leq \tau_p$$

where

Q_R = design hull shear force at any section along the Rule length, L_R, in kN determined from Pt 5, Ch 5,5

A_τ = shear area of transverse section, in m^2, is to be taken as the effective net sectional area of the shell plating and longitudinal bulkheads after deductions for openings. For longitudinal strength members which are inclined to the vertical, the area of the member to be included in the calculation is to be based on the area projected onto the vertical plane, *see* Fig. 6.2.1

τ_p = maximum permissible mean shear stress, in N/mm^2
= $f_{\tau gH} \tau_s$

$f_{\tau gH}$ = limiting hull shear stress coefficient taken from Table 7.3.2 in Chapter 7

τ_s is as defined in 1.2.1.

2.5 Torsional strength

2.5.1 Torsional stresses are typically small for mono hulls of ordinary form of Rule length, L_R, less than 75 m and can generally be ignored.

2.5.2 The calculation of torsional stresses and/or deflections may be required when considering craft with large deck openings, unusual form or proportions. Calculations may in general be required to be carried out using a direct calculation procedure. Such calculations are to be submitted in accordance with 1.5.

2.6 Superstructures global strength

2.6.1 The effectiveness of the superstructure in absorbing hull girder bending loads is to be established where the first tier of the superstructure extends within 0,4*L* amidships and where:

$$l_1 > b_1 + 3h_1$$

where

l_1 = length of first tier, in metres

b_1 = breadth of first tier, in metres

h_1 = 'tween deck height of first tier, in metres.

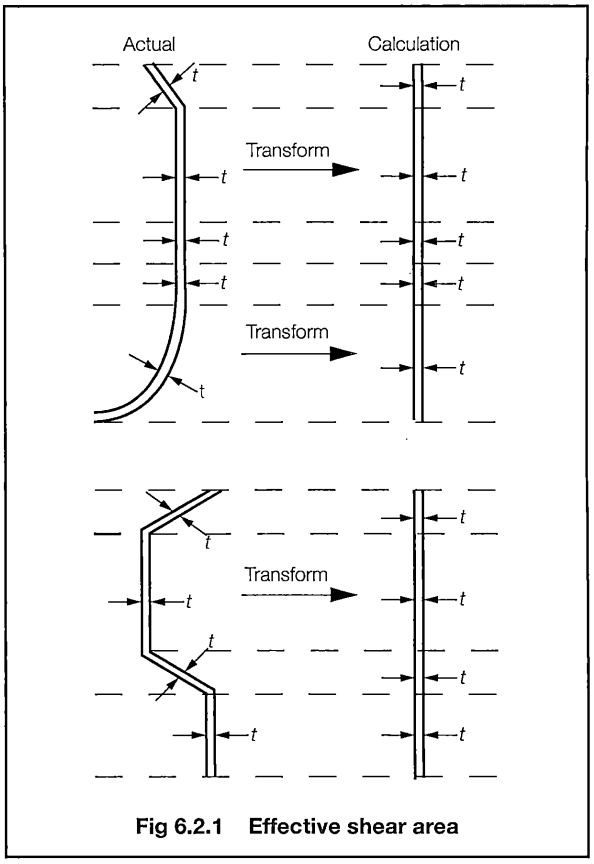

Fig 6.2.1 Effective shear area

2.6.2 For superstructures with one or two tiers extending outboard to the craft's side shell, the effectiveness in absorbing hull girder bending loads in the uppermost effective tier may be assessed by the following factor:

$$\eta_s = 7 [(\varepsilon - 5) \gamma^4 + 94 (5 - \varepsilon) \gamma^3 + 2800 (\varepsilon - 5,8) \gamma^2 + 27660 (9 - \varepsilon) \gamma] f(\lambda, N) \times 10^{-7}$$

where

$f(\lambda, N = 1) = 1$

$f(\lambda, N = 2) = 0,90\lambda^3 - 2,17\lambda^2 + 1,73\lambda + 0,50$

and

N = 1 if $l_2 < 0,7l_1$
= 2 if $l_2 \geq 0,7l_1$

$\lambda = \frac{l_w}{L_R}$ or 1, whichever is less

$\varepsilon = \frac{b_1}{h_1}$ or 5, whichever is less

$\gamma = \frac{l_w}{h_1}$ or 25, whichever is less

l_w = l_1 for $N = 1$

= $\frac{(2l_1 + l_2)}{3}$ for $N = 2$

L_R = as defined in 1.2.1, in metres

l_1, b_1, h_1 = as defined in 2.5.1, in metres

l_2 = length of second tier, in metres.

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2.6.3 The hull girder compressive bending stress σ_L, in the uppermost effective tier at side may be derived according to the following formula:

$$\sigma_L = \eta_s \frac{M_R}{1000 Z_{100}} \text{ N/mm}^2$$

where

M_R = hull girder bending moment at midships due to sagging as determined in Pt 5, Ch 5,5, in kNm

Z_{100} = section modulus at uppermost effective tier of hull and effective tiers, assuming tiers to be 100 per cent effective, in m^3

η_s = as defined in 2.6.2.

2.6.4 The compressive stress, σ_L, in the uppermost effective tier at side is to be checked against buckling in accordance with Ch 7,4.

2.6.5 The uppermost effective tier may need to fulfil the requirements for strength deck when the following applies:

$$\eta_s > \left(1 + \frac{Z_0 h}{I_{100}}\right)^{-1}$$

where

η_s = as defined in 2.6.2

Z_0 = section modulus of hull only at hull upper deck, in m^3

I_{100} = moment of inertia of hull and effective tiers, assuming tiers to be 100 per cent effective, in m^4

h = height from hull upper deck to uppermost effective tier, in metres.

Section 3
Additional hull girder strength requirements for multi-hull craft

3.1 General

3.1.1 Except as otherwise specified within this Section, the global strength requirements for multi-hull craft are to comply with Section 2.

3.1.2 Longitudinal strength calculations are to be submitted for all craft with a length, L_R, exceeding 40 m covering the range of load and ballast conditions proposed, in order to determine the required hull girder strength. Still water, static wave and dynamic bending moments and shear forces are to be calculated for both departure and arrival conditions.

3.1.3 For craft of ordinary hull form length with a Rule length, L_R, less than 40 m, the minimum hull girder strength requirements are generally satisfied by scantlings obtained from local strength requirements. However longitudinal strength calculations may be required at LR's discretion, dependent upon the proposed loading.

3.1.4 Where the length, L_R, of the craft exceeds 60 m, or for new designs of large, structurally complicated craft, the design loads and scantling determination formulae in this Chapter are to be supplemented by direct calculation and structural analysis by 3-D finite element methods. These supplementary calculations are to include the results of model tests and full scale measurement where available or required by LR. Full details of such methods and all assumptions and calculations, which are to be based on generally accepted theories, are to be submitted for appraisal.

3.1.5 The strength deck plating in way of the cross-deck structure, the wet-deck plating, longitudinal bulkheads and girders, and other continuous members may be included in the determination of the midship section stiffness.

3.1.6 Special consideration will be given to the global strength requirements for craft with more than two hulls linked by cross-deck structure.

3.2 Hull longitudinal bending strength

3.2.1 The requirements of 2.2 are in general to be complied with, using the appropriate design bending moment and effective pressure loadings applicable to multi-hull craft, as determined from Pt 5, Ch 5,5.

3.3 Hull shear strength

3.3.1 The requirements of 2.3 are to be complied with so far as they are applicable.

3.4 Torsional strength

3.4.1 Where a craft is of unusual form or novel construction, or at the discretion of LR, the torsional stress is to be determined by direct calculation methods using the twin hull torsional connecting moment as defined in Pt 5, Ch 5,5. Such calculations are to be submitted in accordance with 1.5.

3.5 Strength of cross-deck structures

3.5.1 Design loads to be applied for scantling calculations are transverse vertical bending moment and shear force, twin hull torsional connecting moment, external pressure load and appropriate internal loads as defined in Part 5.

3.5.2 The primary stiffening members of the cross-deck structure are to provide sufficient strength to satisfy the stress criteria given in Table 6.3.1.

3.5.3 The component nominal stresses may be determined in accordance with Table 6.3.2 in the case where the cross-deck is formed by transverse primary stiffeners or bulkheads and the following assumptions are taken:

(a) The cross-deck is symmetrical forward and aft of a transverse axis at its half length.

(b) Primary stiffeners having the same scantlings and spacing.

3.5.4 Other cross-deck designs subjected to global transverse loads will require a two-dimensional grillage analysis to be performed to demonstrate compliance with 3.5.2.

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Table 6.3.1 Primary member stress criteria

Stress type	Component stresses	Allowable stress level (N/mm^2)
Total direct stress, σ_P	$\sigma_P = \sigma_{MB} + \sigma_{MT} + \sigma_d$	$f_{\sigma gV}\,\sigma_s$
Total shear stress, τ_P	$\tau_P = \tau_T + \tau_{MBT} + \tau_{MT}$	$f_{\tau gV}\,\tau_s$
Equivalent stress, σ_{eq}	$\sigma_{eq} = \sqrt{\sigma^2 + 3\tau^2}$	$1{,}2 f_{\sigma eg}\,\sigma_s$
Symbols and definitions		
σ_{MB}, σ_{MT}, τ_T, τ_{MBT} σ_d, and τ_{MT} are component stresses, in N/mm^2, to be taken from Table 6.3.2 $f_{\sigma gV}$, $f_{\tau gV}$ and $f_{\sigma eg}$ are limiting stress coefficients for cross-deck structures to be taken from Table 7.3.2 in Chapter 7 σ_s and τ_s are defined in 1.2		

Table 6.3.2 Cross-deck component stresses for designs complying with 3.5.3

Component stress type	Nominal stress (N/mm^2)
Hull girder bending stress at strength deck amidships, *see* Table 6.2.1	$\sigma_d = f_{MR}\,\dfrac{M_R}{1000 Z_d}$
Stress induced by the transverse bending moment M_B, as defined in Pt 5, Ch 5,5	$\sigma_{MB} = f_{MB}\,\dfrac{M_B}{nZ}\,10^3$
Stress induced by the torsional moment M_T, as defined in Pt 5, Ch 5,5	$\sigma_{MT} = f_{MT}\,\dfrac{3x_H M_T}{n(n+1)s_p Z}\,10^3$
Shear stress induced by the vertical shear force Q_T, as defined in Pt 5, Ch 5,5	$\tau_T = f_{MB}\,\dfrac{5Q_T}{nA_w}$
Bending shear stress induced by the torsional moment M_T, as defined in Pt 5, Ch 5,5	$\tau_{MBT} = f_{MT}\,\dfrac{60M_T}{n(n+1)s_p A_w}$
Shear stress induced by the torsional moment M_T, as defined in Pt 5, Ch 5,5	$\tau_{MT} = f_{MT}\,\dfrac{46\kappa x_H^2 M_T}{n(n^2+1)s_p^2 I_y}\,10^3$
Symbols and definitions	

Q_T = vertical shear force, in kN, as determined from Pt 5, Ch 5,5
M_B = transverse bending moment in kNm, as determined from Pt 5, Ch 5,5
M_T = torsional moment in kNm, as determined from Pt 5, Ch 5,5
n = total number of transverse primary stiffeners or bulkheads
A_W = stiffener web area, cm^2
Z = primary stiffeners section modulus, in cm^3
s_p = stiffener spacing, in metres
I_y = moment of inertia of stiffener, cm^4
x_H = transverse distance between the centre of the two hulls, in metres
κ = t_f, for symmetrical I-section, in mm
= $b_b\,h/(b_b + h)$, for constant thickness box sections, in mm
σ_{MB} = stress induced by the transverse bending moment M_B, as defined in Pt 5, Ch 5,5, in N/mm^2
σ_{MT} = stress induced by the torsional moment M_T, as defined in Pt 5, Ch 5,5, in N/mm^2
τ_T = shear stress induced by the vertical shear force Q_T, as defined in Pt 5, Ch 5,5, in N/mm^2
τ_{MBT} = bending shear stress induced by the torsional moment M_T, as defined in Pt 5, Ch 5,5, in N/mm^2
τ_{MT} = shear stress induced by the torsional moment M_T, as defined in Pt 5, Ch 5,5, in N/mm^2
t_f = face plate thickness, in mm
b_b = breadth of box section, in mm
h_b = height of box section, in mm

f_{MR}, f_{MB} and f_{MT} are load combination factors reflecting the portions of each component global design load, M_R, Q_T, M_B and M_T, corresponding to the most severe load combinations, The most severe load combinations are the combinations of loads resulting in the maximum bending, shear and effective stress, respectively. The assessment of these load combinations need to take due consideration for the component load magnitude variation with wave heading and also the phasing in time between them. Generally, f_{MR}, f_{MB}, and f_{MT} are to be taken as indicated in Table 6.3.3.

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Table 6.3.3 Load combination factors

Heading	Factors		
	f_{MB}	f_{MR}	f_{MT}
Head sea	0,1	1,0	0,1
Beam sea	1,0	0,1	0,2
Quartering sea	0,1	0,4	1,0

3.5.5 Section properties are to be calculated using an effective breadth of plating to be determined in accordance with Ch 3,1.11.

3.5.6 Where primary stiffening members support areas of plating of the extruded plank type, or the floating frame system is used, the effect of the plating attached to the secondary stiffening members is to be ignored when determining the global section modulus requirements.

3.6 Grillage structures

3.6.1 For complex girder systems, a complete structural analysis using numerical methods may be required to be performed to demonstrate that the stress levels are acceptable when subjected to the most severe and realistic combination of loading conditions intended.

3.6.2 In general, the transverse and vertical girders, bottom and side structures, bridge structure, deck structures and any other parts of the craft which LR considers critical to the craft's structural integrity are to be included in the numerical modelling of the craft.

3.7 Analysis techniques

3.7.1 General or special purpose computer programs or any other analytical techniques may be used provided that the effects of bending, shear, axial and torsion are properly accounted for and the theory and idealisation used can be justified.

3.7.2 In general, grillages consisting of slender girders may be idealised as frames based on beam theory provided proper account of the variations of geometric properties is taken. For cases where such an assumption is not applicable, finite element analysis or equivalent methods may have to be used.

3.7.3 Analysis of the cross-deck structures with regard to impact loads due to slamming may have to be carried out using advanced structural analysis techniques.

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Section

1 **General**

2 **Deflection control**

3 **Stress control**

4 **Buckling control**

5 **Vibration control**

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull and multi-hull craft of steel construction as defined in Ch 1,1.1.

1.2 General

1.2.1 The failure modes criteria contained within this Chapter are to be used in the formulae from the preceding Chapters to determine the scantling requirements. In addition, they are to be used when direct calculation methods are proposed as an alternative.

1.3 Symbols and definitions

1.3.1 The symbols and definitions applicable to this Chapter are defined below or in the appropriate Section.

1.4 Direct calculations

1.4.1 Where direct calculations are proposed, the requirements of Pt 3, Ch 1,2 are to be complied with.

1.4.2 In addition, with the agreement of Lloyd's Register (hereinafter referred to as 'LR'), tests may be conducted to demonstrate the actual response of the structure and the results verified against the failure mode criteria in this Chapter.

■ *Section 2* Deflection control

2.1 General

2.1.1 The limiting deflection requirements for plate panels and stiffening members are given in terms of limiting deflection coefficient, *see* Table 7.2.1. The coefficient equates to a span/deflection ratio, f_δ, in consistent units.

Table 7.2.1 Limiting deflection ratio

Item	Deflection ratio, f_δ
Bottom structure:	
• secondary stiffening	800
• primary girders and web frames	1000
Side structure:	
• secondary stiffening	800
• primary girders and web frames	1000
Main/strength deck structures:	
• secondary stiffening	1000
• primary girders and web frames	1250
• hatch covers	1250
Superstructures/deckhouses stiffeners:	
(a) Generally: • secondary	600
• primary	750
(b) Coachroof: • secondary	800
• primary	1000
(c) House top: • secondary	600
• primary	600
Lower/inner decks and house top subject to personnel loading:	
• secondary members	800
• primary members	1000
Deep tank stiffeners:	
• secondary members	1000
• primary members	1250
Watertight bulkhead stiffeners:	
• secondary members	600
• primary members	750
Multi-hull cross-deck stiffeners:	
• secondary members	800
• primary members	1000
Vehicle deck stiffeners:	
• secondary members	1000
• primary members	1250
Helicopter/flight decks stiffeners:	
• secondary members	1000
• primary members	1250
NOTE Where significant curvature exists over the span of the stiffener or breadth of the panel, the allowable deflections will be specially considered.	

■ *Section 3* Stress control

3.1 General

3.1.1 The nominal limiting stress requirements for plating and primary and secondary stiffening members subject to local loading conditions are given in terms of limiting stress coefficients, see Table 7.3.1. The coefficients are expressed as a proportion of the yield stress of the material.

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3.1.2 The limiting stress coefficients for structural elements subject to global loading conditions are given in Table 7.3.2.

3.1.3 In the determination of the magnitude of the equivalent stress, σ_{eq}, it is assumed that the stresses are combined using the following formula:

$$\sigma_{eq} = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x \sigma_y + 3\tau^2}$$

where

σ_x = direct stress in the x direction
σ_y = direct stress in the y direction
τ = shear stress in the xy plane

Table 7.3.1 Limiting stress coefficients for local loading *(see continuation)*

Item	Limiting stress coefficient		
	Bending f_σ	Shear f_τ	Equivalent f_e
Shell envelope:			
(a) Bottom shell plating: • slamming zone	0,85	–	–
• elsewhere	0,75	–	–
(b) Side shell plating: • slamming zone	0,85	–	–
• elsewhere	0,75	–	–
(c) Keel	0,75	–	–
Bottom structure:			
(a) Secondary stiffening: • slamming zone	0,75	0,75	–
• elsewhere	0,65	0,65	–
(b) Primary girders and web frames	0,65	0,65	0,75
(c) Engine girders	0,55	0,55	0,75
Side structure:			
(a) Secondary stiffening: • slamming zone	0,75	0,75	–
• elsewhere	0,65	0,65	–
(b) Primary girders and web frames	0,65	0,65	0,75
Bow doors:			
(a) Plating	0,65	–	–
(b) Secondary stiffening	0,51	0,433	–
(c) Primary stiffening	0,51	0,34	0,64
Main/strength deck plating and stiffeners:			
(a) Plating	0,75	–	–
(b) Secondary stiffening	0,65	0,65	–
(c) Primary girders and web frame	0,65	0,65	0,75
(d) Hatch covers	0,55	0,55	0,64
Superstructures/deckhouses:			
(a) Deckhouse front, 1st tier: • plating	0,65	–	–
• stiffening	0,60	0,60	–
(b) Deckhouse front upper tiers: • plating	0,75	–	–
• stiffening	0,65	0,65	–
(c) Deckhouse aft and sides: • plating	0,75	–	–
• stiffening	0,75	0,75	–
(d) Coachroof: • plating	0,65	–	–
• stiffening	0,65	0,65	–
(e) House top: • plating	0,75	–	–
• stiffening	0,75	0,75	–
(f) Lower/inner decks and house top subject to personnel loading:			
• plating	0,75	–	–
• stiffening	0,60	0,60	–

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Table 7.3.1 Limiting stress coefficients for local loading (*conclusion*)

Item		Limiting stress coefficient		
		Bending f_σ	Shear f_τ	Equivalent f_e
Bulkheads:				
(a) Watertight bulkhead:	• plating	1,0	—	—
	• secondary stiffening	0,95	0,95	—
	• primary stiffening	0,90	0,90	1,0
(b) Watertight bulkhead doors		0,825	0,825	—
(c) Structure supporting watertight doors		0,80	0,80	
(d) Minor bulkheads:	• plating	0,65	—	—
	• secondary stiffening	0,65	0,65	—
	• primary stiffening	0,65	0,65	0,75
(e) Deep tank bulkheads:	• plating	0,65	—	—
	• secondary stiffening	0,65	0,65	—
	• primary stiffening	0,75	0,75	—
Multi-hull cross-deck structure:				
(a) Plating:	• slamming zone	0,85	—	—
	• elsewhere	0,75	—	—
(b) Secondary stiffening:	• slamming zone	0,75	0,75	—
	• elsewhere	0,65	0,65	—
(c) Primary stiffening		0,65	0,65	0,75
Vehicle deck:				
(a) Plating		0,6	—	—
(b) Secondary stiffening		0,425	0,425	—
(c) Primary stiffening		0,525	0,525	0,75
Helicopter/flight decks:				
(a) Normal usage:	• plating	0,65	—	—
	• secondary stiffening	0,75	0,75	—
	• primary stiffening	0,625	0,625	0,6
(b) Emergency landing:	• plating	0,75	—	—
	• secondary stiffening	1,0	1,00	—
	• primary stiffening	0,825	0,825	0,9
(c) Crane pedestal/foundation structural elements		0,7	0,70	0,75

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Table 7.3.2 Limiting stress coefficients for global loading

Operational mode of craft	Limiting stress coefficient					
	Hull girder			Cross-deck		
	Bending $f_{\sigma gH}$	Shear $f_{\tau gH}$	Equivalent $f_{\sigma eg}$	Bending $f_{\sigma gV}$	Shear $f_{\tau gV}$	Equivalent $f_{\sigma eg}$
$\Gamma \geq 3,0$ or $\Delta \leq 0,04(L_R B)^{1,5}$	$0,80\ \eta_{HTS}$	$0,80\ \eta_{HTS}$	$0,825\ \eta_{HTS}$	$0,80\ \eta_{HTS}$	$0,80\ \eta_{HTS}$	$0,825\ \eta_{HTS}$
$\Gamma < 3,0$ and $\Delta > 0,04(L_R B)^{1,5}$	$0,72\ \eta_{HTS}$	$0,72\ \eta_{HTS}$	$0,75\ \eta_{HTS}$	$0,72\ \eta_{HTS}$	$0,72\ \eta_{HTS}$	$0,75\ \eta_{HTS}$

NOTES
$f_{\sigma gH}$ = limiting hull bending stress coefficient
$f_{\tau gH}$ = limiting hull shear stress coefficient
$f_{\sigma gV}$ = limiting cross-deck bending stress coefficient
$f_{\tau gV}$ = limiting cross-deck shear stress coefficient
$f_{\sigma eg}$ = limiting equivalent stress coefficient
Δ is the displacement as defined in Pt 5, Ch 2,2
Γ is the Taylor Quotient as defined in Pt 5, Ch 2,2.1.16
L_R and B are as defined in Pt 3, Ch 1,6.2
η_{HTS} is as defined in Ch 2,2.4.3

Section 4
Buckling control

4.1 General

4.1.1 This Section contains the requirements for buckling control of plate panels subject to in-plane compressive and/or shear stresses and buckling control of primary and secondary stiffening members subject to axial compressive and shear stresses.

4.1.2 The requirements for buckling control of plate panels are contained in 4.3 to 4.6. The requirements for secondary stiffening members are contained in 4.7 to 4.8. The requirements for primary members are contained in 4.9 and 4.10.

4.1.3 In general all areas of the structure are to meet the buckling strength requirements for the design stresses. The design stresses are to be taken as follows:

(a) Global hull girder bending and shear stresses given in Chapter 6, but not including stresses σ_l and σ_t as defined in Table 6.2.1 in Chapter 6.

(b) Stresses from local compressive loads.

4.1.4 The buckling requirements are to be met using the net scantlings, hence any additional thickness for corrosion margin or Owners extra is not included in scantlings used to assess the buckling performance.

4.2 Symbols

4.2.1 The symbols used in this Section are defined below and in the appropriate sub-Section:

t_p = thickness of plating, in mm

A_R = panel aspect ratio

$$= \frac{a}{b}$$

a = panel length, i.e. parallel to direction of compressive stress being considered, in mm

b = panel breadth, i.e. perpendicular to direction of compressive stress being considered, in mm

S_p = span of primary members, in metres

σ_o = specified minimum yield strength of the material, in N/mm^2

σ_e = elastic compressive buckling stress, in N/mm^2

σ_c = critical compressive buckling stress, including the effects of plasticity where appropriate, in N/mm^2

τ_o = specified minimum yield shear stress of the material, in N/mm^2

$$= \frac{\sigma_o}{\sqrt{3}} \text{ N/mm}^2$$

E = modulus of elasticity of material in N/mm^2

τ_e = elastic shear buckling stress, in N/mm^2

τ_c = critical shear buckling stress, in N/mm^2

b_{eb} = lesser of $1,9t_p\sqrt{\frac{E}{\sigma_o}}$ or $0,8b$ mm

A_{te} = cross-sectional area of secondary stiffener, in cm^2, including an effective breadth of attached plating, b_{eb}

s = length of shorter edge of plate panel, in mm (typically the spacing of secondary stiffeners)

l = length of longer edge of plate panel, in metres.

S = spacing of primary member, in metres (measured in direction of compression).

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4.3 Plate panel buckling requirements

4.3.1 This Section gives methods for evaluating the buckling strength of plate panels subjected to the following load fields:

(a) uni-axial compressive loads;
(b) shear loads;
(c) bi-axial compressive loads;
(d) uni-axial compressive loads and shear loads;
(e) bi-axial compressive loads and shear loads.

4.3.2 The plate panel buckling requirements will be satisfied if the buckling interaction equations given in Table 7.4.2 for the above load fields are complied with.

4.3.3 The critical compressive buckling stresses and critical shear buckling stresses required for Table 7.4.2 are to be derived in accordance with 4.4.

4.3.4 The buckling factors of safety λ_σ and λ_τ required by Table 7.4.2 are given in Table 7.4.4 for the structural member concerned.

4.3.5 For all structural members which contribute to the hull girder strength, the plate panel buckling requirements for uni-axial compressive loads, Table 7.4.2(a), and shear loads, Table 7.4.2(b) are to be complied with.

4.3.6 In addition to 4.3.5, structural members which are subjected to local compressive loads and/or shear loads are to be verified using the plate panel buckling requirements in Table 7.4.2(c) to (e).

4.3.7 However, where some members of the structure have been designed such that elastic buckling of the plate panel between the stiffeners is allowable, then the requirements of 4.5 must be applied to the buckling analysis of the stiffeners supporting the plating. In addition, panels which do not satisfy the panel buckling requirements must be indicated on the appropriate drawing and the effect of these panels not being effective in transmitting compressive loads taken into account for the hull girder strength calculation.

4.3.8 In general the plate panel buckling requirements for more complex load fields, *see* 4.3.1(c), (d) and (e), are to be complied with. Where this is not possible, due to elastic buckling of the panel, then the critical buckling stress, σ_c, may be based on the ultimate collapse strength of the plating, σ_u from 4.5.4, instead of the elastic buckling stress, σ_e, derived in 4.3.5. In addition, the requirements of 4.5 are to be met for the supporting secondary stiffeners and primary members.

4.4 Derivation of the buckling stress for plate panels

4.4.1 The critical compressive buckling stress, σ_c, for a plate panel subjected to uni-axial in-plane compressive loads is to be derived in accordance with Table 7.4.1(a).

4.4.2 The critical shear buckling stress, τ_c, for a plate panel subjected to pure in-plane shear load is to be derived in accordance with Table 7.4.1(b).

4.4.3 For welded plate panels with plating thicknesses below 8 mm the critical compressive buckling stress is to be reduced to account for the presence of residual welding stresses. The critical buckling stress is to be taken as the minimum of:

$\sigma_{cr} = \sigma_e - \sigma_r$

or σ_c as derived using 4.4.1

where

σ_r = reduction in compressive buckling stress due to residual welding stresses

$$= \frac{2\beta_{RS}\,\sigma_o}{b/t_p}$$

β_{RS} = residual stress coefficient dependent on type of weld (average value of β_{RS} to be taken as 3)

b, t_p and σ_o are defined in 4.2.1.

4.4.4 In general the effect of lateral loading on plate panels (for example hydrostatic pressure on bottom shell plating) may be neglected and the critical buckling stresses calculated considering the in-plane stresses only.

4.4.5 Unless indicated otherwise, the effect of initial deflection on the buckling strength of plate panels may be ignored.

4.5 Additional requirements for plate panels which buckle elastically

4.5.1 Elastic buckling of plate panels between stiffeners occurs when both the following conditions are satisfied:

(a) The design compressive stress, σ_d, is greater than the elastic buckling stress of the plating, σ_e,

$\sigma_d > \sigma_e$

(b) The elastic buckling stress is less than half the yield stress

$$\sigma_e \leq \frac{\sigma_o}{2}$$

4.5.2 Elastic buckling of local plating between stiffeners, including girders or floors, etc., may be allowed if all of the following conditions are satisfied:

(a) The critical buckling stress of the stiffeners in all buckling modes is greater than the axial stress in the stiffeners after redistribution of the load from the elastically buckled plating into the stiffeners, hence

$$\frac{\sigma_{de}}{\sigma_{c\,(i)}} \leq \frac{1}{\lambda_\sigma}$$

(b) Maximum predicted loadings are used in the calculations.

(c) Functional requirements will allow a degree of plating deformation.

where

σ_{de} is the stiffener axial stress given in 4.5.5

$\sigma_{c\,(i)}$ is given by Table 7.4.3

where

i = a, t, w or f depending on the mode of buckling.

λ_σ is the buckling factor of safety

= 1,25.

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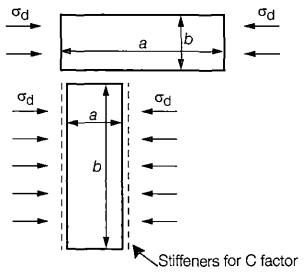
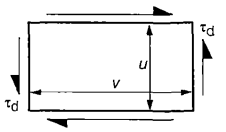
Table 7.4.1 Buckling stress of plate panels

Mode	Elastic buckling stress, N/mm^2, *see* Note 1	
(a) Uni-axial compression: (i) Long narrow panels, loaded on the narrow edge	$A_R \geq 1$ $\sigma_e = 3{,}62\varphi E \left(\frac{t_p}{b}\right)^2$	
(ii) Short broad panels, loaded on the broad edge	$A_R < 1$ $\sigma_e = 0{,}9C\varphi \left(\frac{b}{a} + \frac{a}{b}\right)^2 E \left(\frac{t_p}{b}\right)^2$	
(b) Pure shear:	$\tau_e = 3{,}62\left(1{,}335 + \left(\frac{u}{v}\right)^2\right) E \left(\frac{t_p}{u}\right)^2$ *See* Note 2	

NOTES

1. The critical buckling stresses, in N/mm^2, are to be derived from the elastic buckling stresses as follows:

$\sigma_c = \sigma_e$ when $\sigma_e < \frac{\sigma_o}{2}$

$= \sigma_o\left(1 - \frac{\sigma_o}{4\sigma_e}\right)$ when $\sigma_e \geq \frac{\sigma_o}{2}$

σ_c is defined in 4.2.1
σ_o is defined in 4.2.1

$\tau_c = \tau_e$ when $\tau_e < \frac{\tau_o}{2}$

$= \tau_o\left(1 - \frac{\tau_o}{4\tau_e}\right)$ when $\tau_e \geq \frac{\tau_o}{2}$

τ_c is defined in 4.2.1
τ_o is defined in 4.2.1

2. u is to be the minimum dimension

Symbols and definitions

A_R = panel aspect ratio, *see* 4.2.1
σ_e = elastic compressive buckling stress, in N/mm^2
τ_e = elastic shear buckling stress, in N/mm^2
a and b are the panel dimensions in mm, *see* figures above
t_p = thickness of plating, in mm
φ = stress distribution factor for linearly varying compressive stress across plate width
= $0{,}47\mu^2 - 1{,}4\mu + 1{,}93$ for $\mu \geq 0$
= 1 for constant stress

$\mu = \frac{\sigma_{d1}}{\sigma_{d2}}$ where σ_{d1} and σ_{d2} are the smaller and larger average compressive stresses respectively

E = Young's Modulus of elasticity of material, in N/mm^2
C = stiffener influence factor for panels with stiffeners perpendicular to compressive stress
= 1,3 when plating stiffened by floors or deep girders
= 1,21 when stiffeners are built up profiles or rolled angles
= 1,10 when stiffeners are bulb flats
= 1,05 when stiffeners are flat bars
σ_d and τ_d are the design compressive and design shear stresses in the direction illustrated in the figures. With linearly varying stress across the plate panel, σ_d is to be taken as σ_{d2}

4.5.3 The effective breadth of attached plating for stiffeners, girder or beams that is to be used for the determination of the critical buckling stress of the stiffeners attached to plating which buckles elastically is to be taken as follows:

$$b_{eu} = \frac{b\sigma_u}{\sigma_o} \text{ mm}$$

where

σ_u = ultimate buckling strength of plating as given in 4.5.4
b_{eu} = effective panel breadth perpendicular to direction of compressive stress being considered

b is given in 4.2.1.

4.5.4 The ultimate buckling strength of plating, σ_u, which buckles elastically, may be determined as follows:

(a) shortest edge loaded, i.e. $A_R \geq 1$:

$$\sigma_u = \sigma_o\left(\frac{1{,}9}{\Omega} - \frac{0{,}8}{\Omega^2}\right) \text{ N/mm}^2$$

(b) longest edge loaded, i.e. $A_R < 1$:

$$\sigma_u = \frac{1{,}77\sigma_o A_R^{0{,}78}}{\Omega} \text{ N/mm}^2$$

where

$$\Omega = \frac{s}{t_p}\sqrt{\frac{\sigma_o}{E}}$$

A_R and s are defined in 4.2.1.
t_p, E and σ_o are defined in 4.2.1.

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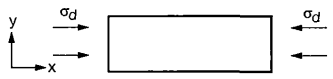
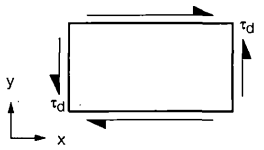
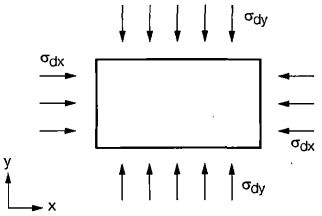
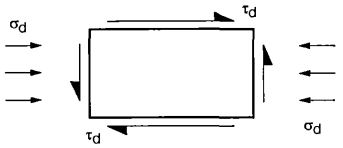
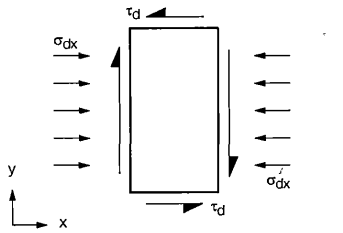
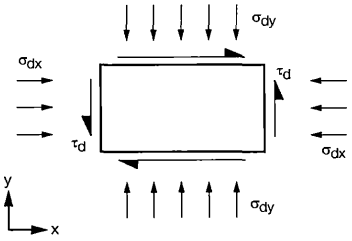
Table 7.4.2 Plate panel buckling requirements

	Stress field	Buckling interaction formula	
(a)	uni-axial compressive loads	$\frac{\sigma_d}{\sigma_c} \le \frac{1}{\lambda_\sigma}$	
(b)	shear loads	$\frac{\tau_d}{\tau_c} \le \frac{1}{\lambda_\tau}$	
(c)	bi-axial compressive loads	for $A_R = 1,0$ $\frac{\sigma_{dx}}{\sigma_{cx}} + \frac{\sigma_{dy}}{\sigma_{cy}} \le 1,0$ for other aspect ratios, i.e. $A_R \ne 1,0$ $\frac{\sigma_{dx}}{\sigma_{cx}} + \frac{\sigma_{dy}}{\sigma_{cy}} \le G$ where G is taken from Fig. 7.4.3	
(d)	uni-axial compressive loads plus shear load	for $A_R > 1$ $\left(\frac{\sigma_d}{\sigma_c}\right) + \left(\frac{\tau_d}{\tau_c}\right)^2 \le 1$ for $A_R \le 1$ $\left(\frac{1 + 0,6A_R}{1,6}\right)\left(\frac{\sigma_d}{\sigma_c}\right) + \left(\frac{\tau_d}{\tau_c}\right)^2 \le 1$	 
(e)	bi-axial compressive loads plus shear loads	$\frac{0,625\left(1 + \frac{0,6}{A_R}\right)\left(\frac{\sigma_{dy}}{\sigma_{cy}}\right)}{1 - 0.625\left(\frac{\sigma_{dx}}{\sigma_{cx}}\right)} + \frac{\left(\frac{\tau_d}{\tau_c}\right)^2}{1 - \left(\frac{\sigma_{dx}}{\sigma_{cx}}\right)} \le 1$	

Symbols

σ_d = design compressive stress, *see* 4.1.3
σ_c = critical compressive buckling stress, in N/mm^2, for uniaxial compressive load acting independently, *see* 4.3.5
σ_{dx} = design compressive stress in x direction
σ_{dy} = design compressive stress in the y direction
σ_{cx} = critical compressive buckling stress in x direction, *see* 4.3.5
σ_{cy} = critical compressive buckling stress in y direction, *see* 4.3.5
λ_σ = buckling factor of safety for compressive stresses, *see* 4.3.4
λ_τ = buckling factor of safety for shear stresses, *see* 4.3.4
τ_d = design shear stress, in N/mm^2
τ_c = critical shear buckling stress, in N/mm^2, acting independently, *see* 4.3.5

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Table 7.4.3 Buckling stress of secondary stiffeners (*see continuation*)

Mode	Elastic buckling stress, N/mm^2	Critical buckling stress, N/mm^2 *see* Note 1
(a) Overall buckling (perpendicular to plane of plating without rotation of cross-section)	$\sigma_{e(a)} = C_f\, 0{,}001\, E\, \frac{I_a}{A_{te}\, l_e^2}$	$\sigma_{c(a)}$
(b) Torsional buckling	$\sigma_{e(t)} = \frac{0{,}001 E\, I_w}{I_p\, l_e^2}\left(m^2 + \frac{K}{m^2}\right) + 0{,}385E\, \frac{I_t}{I_p}$	$\sigma_{c(t)}$
(c) Web buckling (excluding flat bar stiffeners)	$\sigma_{e(w)} = 3{,}8\, E \left(\frac{t_w}{d_w}\right)^2$	$\sigma_{c(w)}$
(d) Flange buckling	$\sigma_{e(f)} = 0{,}39\, E \left(\frac{t_f}{b_f}\right)^2$	$\sigma_{c(f)}$

Symbols

d_w = web depth, in mm, (excluding flange thickness for rolled sections), *see* Fig. 7.4.4

t_w = web thickness, in mm

b_f = flange width, in mm (including web thickness)

t_f = flange thickness, in mm. For bulb plates, the mean thickness of the bulb may be used, *see* Fig. 7.4.4

l_e = effective span length of stiffener, in metres

C_f = end constraint factor

= 1 where both ends are pinned

= 2 where one end is pinned and the other end is fixed

= 4 where both ends are fixed

E = Young's Modulus of elasticity of the material, in N/mm^2

I_a = moment of inertia, in cm^4, of longitudinal, including attached plating of effective width b_{eb}, *see* Note 2

t_p and σ_o are given in 4.2.1

A_{te} and b_{eb} are given in 4.2.1

I_t = St.Venant's moment of inertia, in cm^4, of longitudinal (without attached plating)

$= \frac{d_w\, t_w^3}{3}\, 10^{-4}$ for flat bars

$= \frac{1}{3}\left[d_w\, t_w^3 + b_f\, t_f^3 \left(1 - \frac{0{,}63\, t_f}{b_f}\right)\right] 10^{-4}$ for built up profiles, rolled angles and bulb plates

I_p = polar moment of inertia, in cm^4, of profile about connection of stiffener to plating

$= \frac{d_w^3\, t_w}{3}\, 10^{-4}$ for flat bars

$= \left(\frac{d_w^3\, t_w}{3} + d_w^2\, b_f\, t_f\right) 10^{-4}$ for built up profiles, rolled angles and bulb plates

I_w = sectorial moment of inertia, in cm^6, of profile and connection of stiffener to plating

$= \frac{d_w^3\, t_w^3}{36}\, 10^{-6}$ for flat bars

$= \frac{t_f\, b_f^3\, d_w^2}{12}\, 10^{-6}$ for 'Tee' profiles

$= \frac{b_f^3\, d_w^2}{12\,(b_f + d_w)^2}\left(t_f\,(b_f^2 + 2b_f\, d_w + 4d_w^2) + 3t_w\, b_f\, d_w\right) 10^{-6}$ for '*L*' profiles, rolled angles and bulb plates

C = spring stiffness exerted by supporting plate panel

$= \frac{k_p\, E\, t_p^3}{3b\left(1 + \frac{1{,}33 k_p\, d_w\, t_p^3}{b\, t_w^3}\right)}$

k_p = $1 - \eta_p$, and is not to be taken as less than zero. For built up profiles, rolled angles and bulb plates, k_p need not be taken less than 0,1

$\eta_p = \frac{\sigma_d}{\sigma_{ep}}$

σ_{ep} = elastic critical buckling stress, in N/mm^2, of the supporting plate derived from Table 7.4.1

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Table 7.4.3 Buckling stress of secondary stiffeners (*conclusion*)

m is determined as follows; e.g. $m = 2$ for $K = 25$

K	0 to 4	4 to 36	36 to 144	144 to 400	400 to 900	900 to 1764	$(m-1)^2 m^2$ to $m^2 (m+1)^2$
m	1	2	3	4	5	6	m

$$K = \frac{1{,}03CS^4}{E I_w} 10^4$$

σ_d is the design stress, in N/mm^2
all other symbols are as defined in 4.2.1.

NOTES

1. The critical buckling stresses are to be derived from the elastic buckling stresses as follows:

$$\sigma_c = \sigma_e \text{ when } \sigma_e < \frac{\sigma_o}{2}$$

$$= \sigma_o\left(1 - \frac{\sigma_o}{4\sigma_e}\right) \text{when } \sigma_e \geq \frac{\sigma_o}{2}$$

2. For stiffeners attached to plating which buckles elastically, *see* 4.5, the effective width of plating is to be taken as b_{eu}.

4.5.5 The axial stress in stiffeners attached to plating which is likely to buckle elastically is to be derived as follows:

$$\sigma_{de} = \sigma_d \frac{A_t}{A_{tb}}$$

where

σ_d is the axial stress in the stiffener when the plating can be considered fully effective

$$A_t = A_s + \frac{bt}{100} \text{ cm}^2$$

$$A_{tb} = A_s + \frac{b_{eu}\, t}{100} \text{ cm}^2$$

where

b and b_{eu} are given in 4.5.3
t is the plating thickness, in mm
A_s is the stiffener area in cm^2.

4.6 Shear buckling of stiffened panels

4.6.1 The shear buckling capability of longitudinally stiffened panels between primary members is to satisfy the following condition:

$$\frac{\tau_d}{\tau_c} \leq \frac{1}{\lambda_\tau}$$

where

τ_c is derived from 4.6.3
τ_d is the design shear stress
λ_τ is given in Table 7.4.4.

Table 7.4.4 Buckling factor of safety

Structural item	Buckling factor of safety [2] Compressive stresses, λ_σ	Buckling factor of safety [3] Shear stresses, λ_τ
Bottom shell plating	1,0	—
Inner bottom plating	1,0	—
Deck plating	1,0	—
Side shell plating	1,0	1,1
Longitudinal bulkhead plating	1,0	1,1
Double bottom girders	1,0	1,1
Longitudinal girders	1,0	1,1
Superstructures/deckhouses (partially longitudinally effective)	1,0	—
Longitudinal secondary stiffeners	1,1[1]	—
Girder and floor web plating subject to local loads	1,1	1,2

NOTES

1. The buckling factor of safety for stiffeners attached to plating which is allowed to buckle in the elastic mode due to the applied loads is to be taken as 1,25, *see also* 4.5.
2. Buckling factor of safety to be applied to the compressive stress due to global longitudinal stresses.
3. Buckling factor of safety to be applied to the shear stress.

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4.6.2 The elastic shear buckling stress of longitudinally stiffened panels between primary members may be taken as:

$$\tau_e = K_s E \left(\frac{t}{s}\right)^2 \quad \text{for } A_R \geq 1$$

where

$$K_s = 4{,}5\left(\left(\frac{s}{1000l}\right)^2 + \frac{1}{N^2} + \left(\frac{N^2-1}{N^2}\right)\left(\frac{\omega}{1+\omega}\right)^r\right)$$

N = number of subpanels

$$= \frac{1000S_p}{s}$$

$$\omega = \frac{10I_{se}}{l t^3}$$

I_{se} = moment of inertia of a section, in cm^4, consisting of the longitudinal stiffener and a plate flange of effective width $s/2$

$$r = 1 - 0{,}75\left(\frac{s}{1000l}\right)$$

s, l, E and S_p are as defined in 4.2.1, *see also* Fig. 7.4.1.

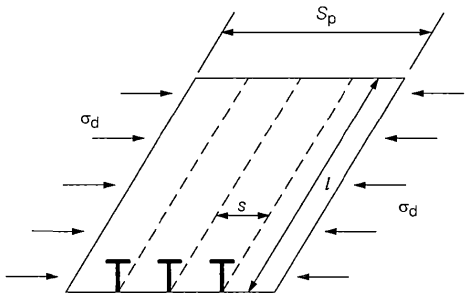

Fig. 7.4.1 Shear buckling of stiffened panels

4.6.3 The critical shear buckling stress, τ_c, may be determined from τ_e, *see* Note 2 in Table 7.4.1.

4.7 Secondary stiffening in direction of compression

4.7.1 The buckling performance of stiffeners will be considered satisfactory if the following conditions are satisfied:

$$\frac{\sigma_d}{\sigma_{c(a)}} \leq \frac{1}{\lambda_\sigma} \qquad \frac{\sigma_d}{\sigma_{c(t)}} \leq \frac{1}{\lambda_\sigma}$$

$$\frac{\sigma_d}{\sigma_{c(w)}} \leq \frac{1}{\lambda_\sigma} \qquad \frac{\sigma_d}{\sigma_{c(f)}} \leq \frac{1}{\lambda_\sigma}$$

where

$\sigma_{c(a)}$, $\sigma_{c(t)}$, $\sigma_{c(w)}$ and $\sigma_{c(f)}$ are the critical buckling stress of the stiffener for each mode of failure, *see* 4.7.2

σ_d is the design compressive stress, *see also* 4.5 and 4.1.3

λ_σ is the buckling factor of safety given in Table 7.4.4. The value of λ_σ to be chosen depends on the buckling assessment of the attached plating, *see* Note 1, Table 7.4.4.

4.7.2 The critical buckling stresses for the overall, torsional, web and flange buckling modes of longitudinals and secondary stiffening members under axial compressive loads are to be determined in accordance with Table 7.4.3.

4.7.3 To prevent torsional buckling of secondary stiffeners from occurring before buckling of the plating, the critical torsional buckling stress, $\sigma_{c(t)}$, is to be greater than the critical buckling stress of the attached plating as detailed in 4.4.1.

4.7.4 The critical buckling stresses of the stiffener web, $\sigma_{c(w)}$, and flange, $\sigma_{c(f)}$, are to be greater than the critical torsional buckling stress, hence:

$\sigma_{c(w)} > \sigma_{c(t)}$

$\sigma_{c(f)} > \sigma_{c(t)}$

4.7.5 To ensure that overall buckling of the stiffened panel cannot occur before local buckling of the secondary stiffener, the critical overall buckling stress $\sigma_{c(a)}$, is to be greater than the critical torsional buckling stress, hence:

$\sigma_{c(a)} > \sigma_{c(t)}$

4.8 Secondary stiffening perpendicular to direction of compression

4.8.1 Where a stiffened panel of plating is subjected to a compressive load perpendicular to the direction of the stiffeners, *see* Fig. 7.4.2, e.g. a transversely stiffened panel subject to longitudinal compressive load, the requirements of this Section are to be applied.

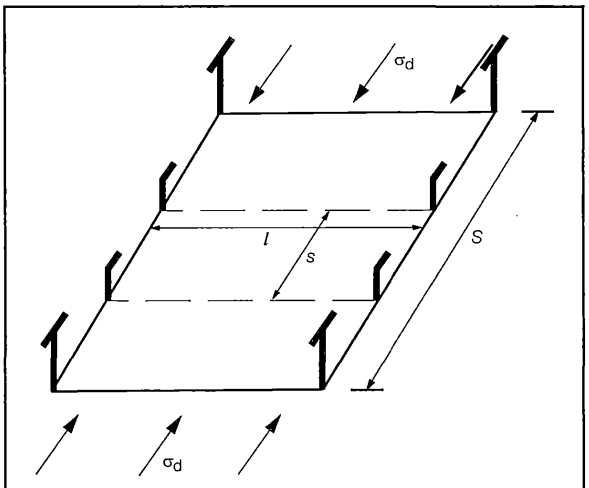

Fig. 7.4.2
Secondary stiffening perpendicular to direction of compression

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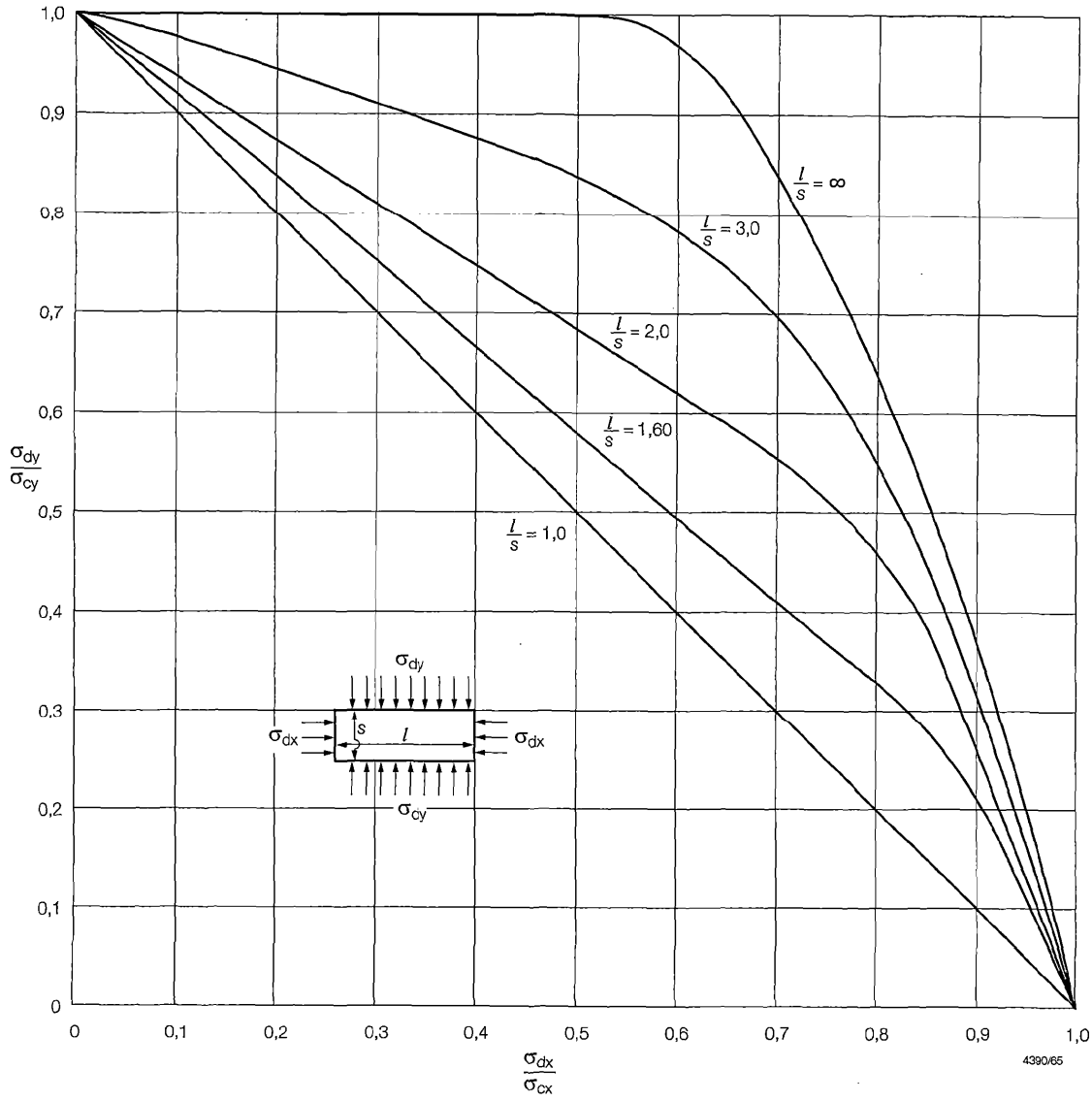

Fig. 7.4.3
Interaction limiting stress curves of G for plate panels subject to bi-axial compression, see Table 7.4.2(c)

4.8.2 The minimum area moment of inertia of each stiffener including attached plating of width, s, to ensure that overall panel buckling does not precede plate buckling is to be taken as:

$$I_s = \frac{D\,s\,(4N_L^2 - 1)((N_L^2 - 1)^2 - 2\,(N_L^2 + 1)\,\kappa + \kappa^2)}{2\,(5N_L^2 + 1 - \kappa)\,\Pi^4\,E} \text{ mm}^4$$

where

$$D = \frac{E\,t_p^3}{12\,(1 - \upsilon^2)}$$

$\kappa = A_R^2\,\Pi^2$

A_R = plate panel aspect ratio

$$= \frac{s}{1000l}$$

$$\Pi = \frac{S}{l}$$

N_L = number of plate panels

$N_L - 1$ = number of stiffeners

υ = 0,3

s, l and S are defined in 4.2.1 and shown in Fig. 7.4.2.

t_p and E are defined in 4.2.1.

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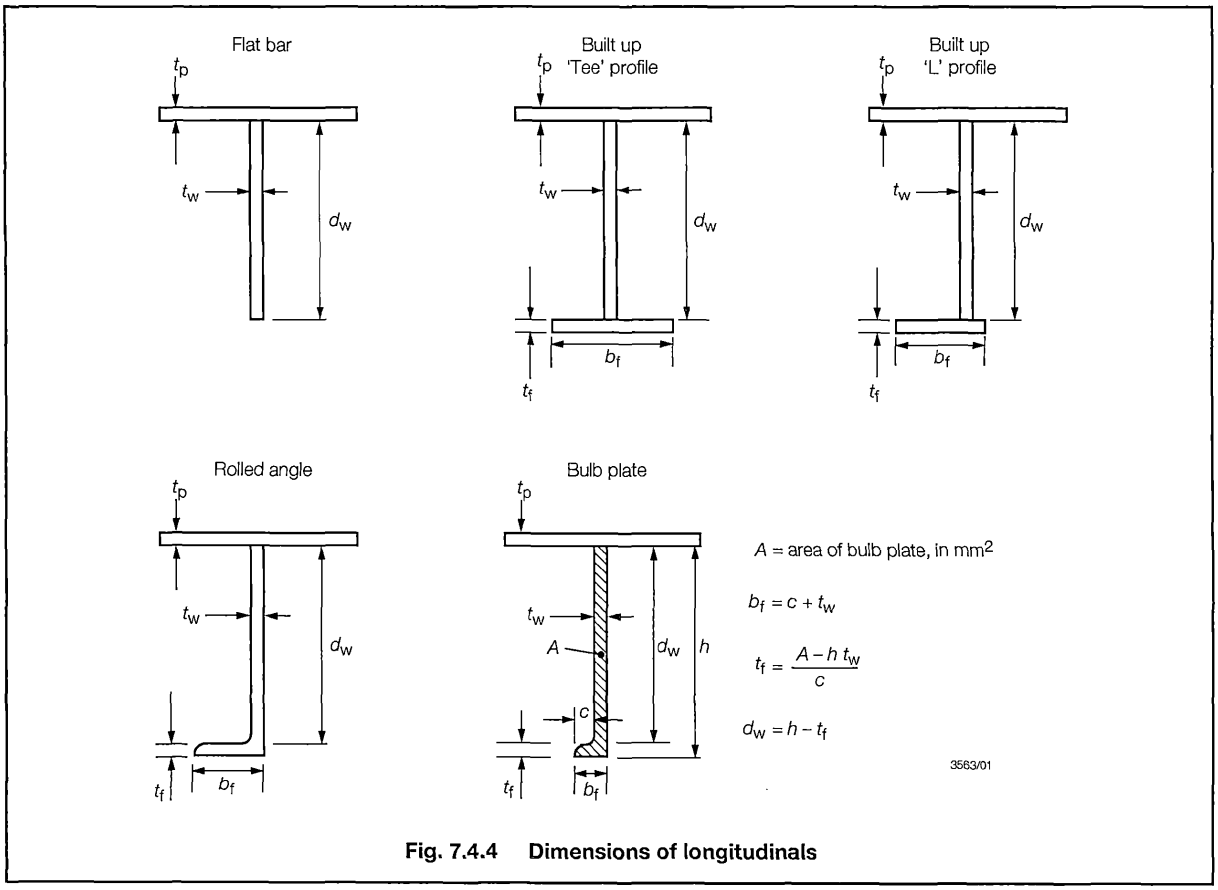

Fig. 7.4.4 Dimensions of longitudinals

4.9 Buckling of primary members

4.9.1 Where primary girders are subject to axial compressive loading, the buckling requirements for lateral, torsional, web and flange buckling modes detailed in 4.7 are to be satisfied.

4.9.2 To prevent global buckling from occurring before local panel buckling, transverse primary girders supporting axially loaded longitudinal stiffeners are to have a sectional moment of inertia, including attached plating, of not less than the following:

$$I_g = \frac{0{,}35 S_p^4 I_s}{l^3 s} \times 10^3 \quad cm^4$$

S_p and s are as defined in 4.2.1, *see also* Fig. 7.4.1

I_g = sectional moment of inertia including attached plating

I_s = moment of inertia of secondary stiffeners, in cm^4, required to satisfy the overall elastic column buckling mode requirement specified in Table 7.4.3

$$= \frac{\sigma_{ep} A_{te} l_e^2}{0{,}001E}$$

where

$$\sigma_{ep} = 1{,}2\sigma_d \text{ N/mm}^2 \text{ for } \sigma_{e(a)} < \frac{\sigma_o}{2}$$

$$= \frac{\sigma_o^2}{4(\sigma_o - 1{,}2\sigma_d)} \text{ for } \sigma_{e(a)} \geq \frac{\sigma_o}{2}$$

σ_d is design stress, in N/mm^2

σ_o and A_{te} are as defined in 4.2.1

$\sigma_{e(a)}$ is the elastic column buckling stress, *see* 4.7.2

E is defined in 4.2.1.

l_e is defined in Table 7.4.3.

4.10 Shear buckling of girder webs

4.10.1 Local panels in girder webs subject to in-plane shear loads are to satisfy the shear buckling requirements in Table 7.4.2, item (b).

4.10.2 The critical shear buckling stress, τ_c, is to be determined using the following formula for τ_e and Note 1 in Table 7.4.1.

$$\tau_e = 3{,}62\left(1{,}335 + \left(\frac{d_w}{1000\, l_p}\right)^2\right) E \left(\frac{t_w}{d_w}\right)^2 \text{ N/mm}^2$$

where

d_w = web height, in mm

t_w = web thickness, in mm

l_p = unsupported length of web, in metres

E is defined in 4.2.1.

4.11 Pillars and pillar bulkheads

4.11.1 Pillars and pillar bulkheads are to comply with the requirements of Ch 3,10.

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Section 5
Vibration control

5.1 General

5.1.1 Natural frequencies are to be investigated for local unstiffened and stiffened panels expected to be exposed to excessive structural vibrations being induced from machinery, propulsion unit or other potential excitation sources.

5.1.2 Where the structural configurations are such that basic structural elements may be modelled individually the natural frequencies may be derived in accordance with 5.3, 5.4 and 5.5, as appropriate. Under other circumstances finite element analysis is to be employed to evaluate the vibration characteristics of the structure considered.

5.2 Frequency band

5.2.1 The natural frequency of panels is generally not to lie within a band of ±20 per cent of a significant excitation frequency.

5.3 Natural frequency of plate

5.3.1 The natural frequency of a clamped plate in air is given by the following:

$$f_{air} = 5{,}544 \frac{t_p}{ab} \sqrt{\left(\frac{a}{b}\right)^2 + \left(\frac{b}{a}\right)^2 + 0{,}6045} \text{ Hz}$$

where

a = panel length, in metres
b = panel breadth, in metres
t_p = panel thickness, in mm

5.4 Natural frequency of plate stiffener

5.4.1 The natural frequency of a plate stiffener in air is given by the following:

$$f_{air,i} = \frac{K_i}{2\pi L_b^2} \sqrt{\frac{EI}{m\left(1 + \frac{\pi^2 EI}{L_b^2 GA}\right)}} \text{ Hz}$$

where

EI = flexural rigidity of plate stiffener combination, in Nm^2
GA = shear rigidity of plate stiffener combination, in N
L_b = beam length, in metres
m = mass per unit length of the stiffener and associated plating, in kg/m
K_i = constant where i refers to the mode of vibration as given in Table 7.5.1.

Table 7.5.1 Vibration mode constant K_i

Mode	1	2	3	4	5
K_i	22,40	61,70	121,0	200,0	299,0

5.5 Effect of submergence

5.5.1 To obtain the frequency, f_{water}, of a plate with one side exposed to air and the other side exposed to a liquid, the frequency calculated in air, f_{air}, may be modified by the following formula:

$$f_{water} = \psi f_{air}$$

where

$$\psi = \sqrt{\frac{\kappa_p}{\kappa_p + \frac{\rho_l}{\rho_p}}}$$

ρ_l = density of the liquid, in kg/m^3
ρ_p = density of the plate, in kg/m^3

$$\kappa_p = \frac{\pi t_p}{1000 a b} \sqrt{a^2 + b^2}$$

where

a, b and t_p are as defined in 5.3.1.

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Rules and Regulations for the Classification of Special Service Craft

Volume 5
Part 7
Hull Construction in Aluminium
July 2012

Lloyd's Register
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DIFFERENT TYPES OF HULL FORMS COVERED BY THE SPECIAL SERVICE CRAFT RULES

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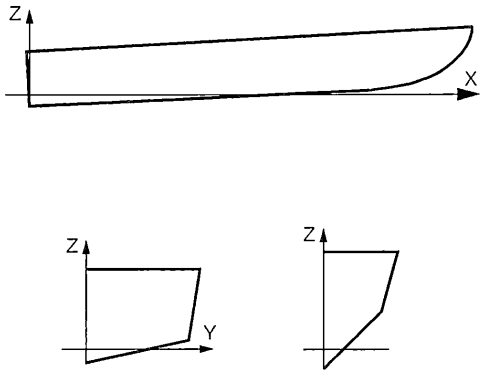
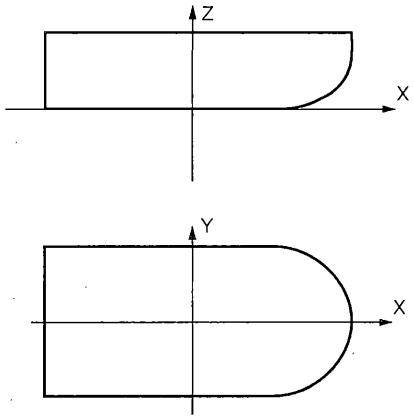


HOVERCRAFT



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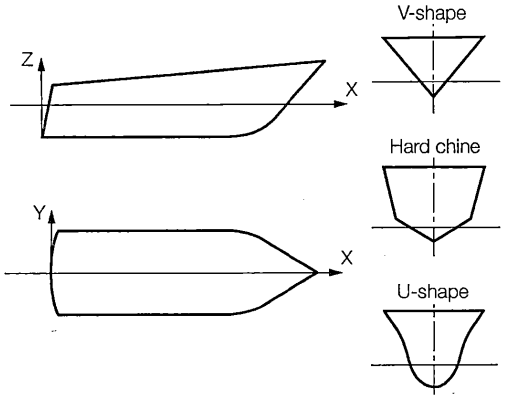
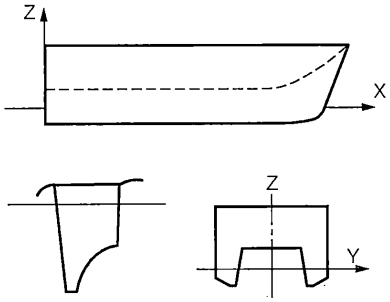
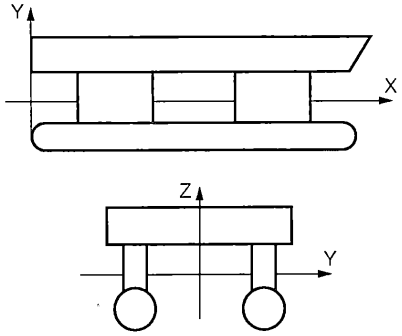


SURFACE EFFECT SHIP



SMALL WATERPLANE AREA TWIN HULL (SWATH)



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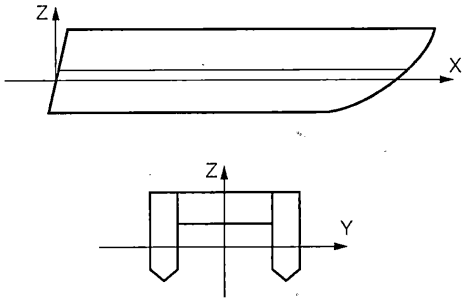

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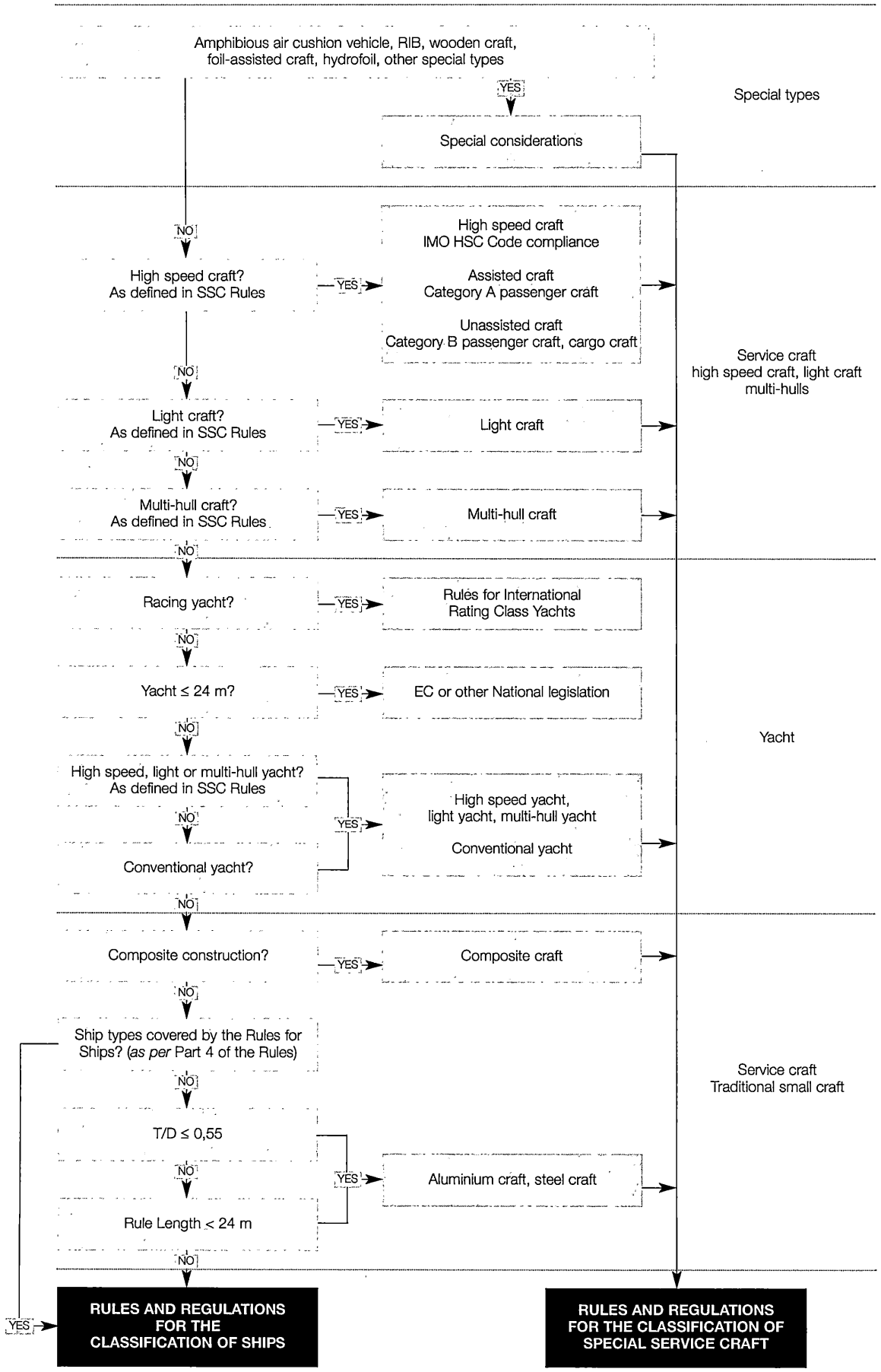
DIFFERENT TYPES OF CRAFT COVERED BY THE SPECIAL SERVICE CRAFT RULES



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Section

1 **Application**

2 **General requirements**

Section 1 Application

1.1 General

1.1.1 The Rules apply to mono and multi-hull craft of normal form, proportions and speed. Although the Rules are, in general, for aluminium craft of all welded construction, other materials for use in hull construction will be specially considered on the basis of the Rules.

1.2 Interpretation

1.2.1 The interpretation of the Rules is the sole responsibility and at the sole discretion of Lloyd's Register (hereinafter referred to as 'LR'). Where there is any doubt, regarding the interpretation of the Rules it is the Builder's and/or designer's responsibility to obtain clarification from LR prior to submission of plans and data for appraisal.

1.2.2 Where applicable, the Rules take into account unified requirements and interpretations established by the International Association of Classification Societies (IACS).

1.2.3 Attention is drawn to the fact that Codes of Practice issued by IMO contain requirements which are outside classification as defined in the Rules.

1.3 Equivalents

1.3.1 Alternative scantlings and arrangements may be accepted as equivalent to the Rule requirements. Details of such proposals are to be submitted for consideration in accordance with Pt 3, Ch 1,3.

1.4 Symbols and definitions

1.4.1 The symbols and definitions for use throughout this Part are as defined within the appropriate Chapters and Sections.

Section 2 General requirements

2.1 General

2.1.1 Limitations with regard to the application of these Rules are indicated in the various Chapters for differing craft types.

2.2 Aesthetics

2.2.1 LR is not concerned with the general arrangement, layout and appearance of the craft; the responsibility for such matters remains with the Builders and/or designers to ensure that the agreed specification is complied with. LR is however concerned with the quality of workmanship, in this respect the acceptance criteria as required by the Rules are to be complied with.

2.3 Constructional configuration

2.3.1 The Rules provide for the basic structural configurations for both single and multi-deck mono and multi-hull craft with multi-deck or single deck hulls which include a double bottom, or a single bottom arrangement. The structural configuration may also include a single or multiple arrangement of cargo hatch openings and side tanks.

2.3.2 The Rules provide for longitudinal and transverse framing systems.

2.3.3 Novel or other types of framing systems will be considered on the basis of the Rules.

2.4 Plans to be submitted

2.4.1 Plans covering the following items are to be submitted:

- Midship sections showing longitudinal and transverse material.
- Profile and decks.
- Shell expansion.
- Oiltight and watertight bulkheads.
- Propeller brackets.
- Double bottom construction.
- Pillars and girders.
- Aft end construction.
- Engine room construction.
- Engine and thrust seatings.
- Fore end construction.
- Hatch cover construction.
- Deckhouses and superstructures.
- Sternframe.
- Rudder, stock and tiller.
- Equipment.
- Loading Manuals, preliminary and final (where applicable).
- Scheme of corrosion control (where applicable).
- Ice strengthening.
- Welding schedule.
- Hull penetration plans.
- Support structure for masts, derrick posts or cranes.
- Bilge keels showing material grades, welded connections and detail design.

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2.4.2 The following supporting documents are to be submitted:

- General arrangement.
- Capacity plan.
- Lines plan or equivalent.
- Dry-docking plan.
- Towing and mooring arrangements.
- Sail/rigging plan, indicating loadings (as applicable to sailing craft).

2.4.3 The following supporting calculations are to be submitted:

- Equipment Number.
- Hull girder still water and dynamic bending moments and shear forces as applicable.
- Midship section modulus.
- Structural items in the aft end, midship and fore end regions of the craft.
- Preliminary freeboard calculation.

2.5 Novel features

2.5.1 Where the proposed construction of any part of the hull or machinery is of novel design, or involves the use of unusual material, or where experience, in the opinion of LR, has not sufficiently justified the principle or mode of application involved, special tests or examinations before and during service may be required. In such cases a suitable notation may be entered in the *Register Book*.

2.6 Enhanced scantlings

2.6.1 Where the Owner decides to increase the scantling of the bottom shell, side shell and deck plating of a newbuilding, then the craft will be eligible to be assigned the description note **ES**, *see* Pt 1, Ch 2,3.12. For example, the descriptive note **ES+1** would indicate that an extra 1 mm of aluminium has been fitted to bottom shell, side shell and deck plating.

2.7 Direct calculations

2.7.1 Direct calculations may be specifically required by the Rules and may be required for craft having novel design features or in support of alternative arrangements and scantlings. LR may, when requested, undertake calculations on behalf of designers and make recommendations with regard to suitability of any required model tests.

2.7.2 Where direct calculations are proposed then the requirements of Pt 3, Ch 1,2 of the Rules are, in general, to be complied with.

2.8 Exceptions

2.8.1 Craft of unusual form, proportions or speed, intended for the carriage of special cargoes, or for special or restricted service, not covered specifically by the Rules, will receive individual consideration based on the general requirements of the Rules.

2.9 Advisory services

2.9.1 The Rules do not cover certain technical characteristics, such as stability except as mentioned in Pt 1, Ch 2,1.1.11, 1.1.13 and 1.1.14, trim, vibration (other than local stiffened flat panels, *see* Ch 7,5), docking arrangements, etc. The Committee cannot assume responsibility for these matters but is willing to advise upon them on request.

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Section

1 **General**

2 **Materials**

3 **Procedures for welded construction**

4 **Joints and connections**

Section 1 General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull and multi-hull craft of aluminium construction as defined in Pt 1, Ch 1,1.

1.2 General

1.2.1 This Chapter contains the general Rule requirements for the construction of aluminium craft using the metal inert gas (MIG) and tungsten inert gas (TIG) welding processes. Where alternative methods of construction are proposed, details are to be submitted for consideration by Lloyd's Register (hereinafter referred to as 'LR').

1.3 Symbols and definitions

1.3.1 The symbols and definitions used in this Chapter are defined in the appropriate Section.

1.4 Builder's facilities

1.4.1 The buildings used for production and storage are to be of suitable construction and equipped to provide the required environment, and also to comply with any local or National Authority requirements.

1.4.2 The Surveyor is to be allowed unrestricted access during working hours to such parts of the Builder's establishment as may be necessary to ensure that the requirements of the Rules are being complied with.

1.5 Works inspection

1.5.1 Prior to the commencement of construction, the facilities are to be inspected to the satisfaction of the attending Surveyor. This will include the minimum quality control arrangements outlined in 1.6.

1.5.2 The Surveyor is to be satisfied that the Builder has the organisation and capability to construct craft to the standards required by the Rules.

1.5.3 The Builder is to be advised of the result of the inspection and all deficiencies are to be rectified prior to the commencement of production.

1.5.4 Where structural components are to be assembled and welded by sub-contractors, the Surveyors are to inspect the sub-contractor's works to ensure that compliance with the requirements of this Chapter can be achieved.

1.6 Quality control

1.6.1 For compliance with 1.5.2, LR's methods of survey and inspection for hull construction and machinery installation are to include procedures involving the shipyard management, organisation and quality systems.

1.6.2 The extent and complexity of the quality systems, will vary considerably depending on the size and type of craft and production output. LR will consider certification of the Builder in accordance with the requirements of one of the following systems:

(a) Quality Assurance System in accordance with an International or National Standard (i.e. ISO 9000 and BS ENISO 9001) with assessment and certification carried out by a nationally accredited body.

(b) LR's *Quality Assurance Scheme for the Construction of Special Service Craft*.

(c) LR's locally accepted Quality Control System – The Builder is required to implement a documented Quality Control System which controls the following activities:
  (i) Receipt storage and issue of materials, equipment, etc.
  (ii) Fabrication environment.
  (iii) Weld procedures and welder performance.
  (iv) Production fabrication.
  (v) Inspection of production processes.
  (vi) Installation of machinery and essential systems.
  (vii) Fitting-out.
  (viii) Tests and trials.
  (ix) Drawings and document control.
  (x) Records.

1.6.3 LR's involvement is only in that part of the system which controls the standards required to meet the classification requirements.

1.6.4 The 'documented' quality control system will in general require the Builder to have written procedures that describe clearly and unambiguously how each of the activities specified in 1.6.2(c) is carried out, when it is carried out and by whom. These procedures will form part of the system manual which is also to contain a statement of management policy, organisation chart and statements of responsibilities. The manual is to be controlled in respect to the formal issue and revision.

1.6.5 Further details of LR's requirements are available on request from the local LR office.

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1.7 Building environment

1.7.1 The craft is to be suitably protected during the building period from adverse weather and climatic conditions.

1.8 Storage areas

1.8.1 All materials are to be stored safely and in accordance with the manufacturer's requirements. Storage arrangements are to be such as to prevent deterioration through contact with heat, sunlight, damp, cold and poor handling.

1.8.2 Aluminium is to be stored in dry places, clear of the ground. Contact with other metals and with materials such as cement and damp timber is to be avoided. Aluminium sheet and plate are to be stacked, in general, on end in racks to avoid distortion.

1.8.3 All storage spaces provided by the Builder for welding consumables are to be suitable for maintaining them in good condition and are to be in accordance with the manufacturer's recommendations.

1.8.4 All materials are to be fully identifiable in the storage areas, and identification is to be maintained during issue to production.

1.8.5 Material suspected of being non-conforming is to be segregated from acceptable materials.

1.9 Materials handling

1.9.1 The Builder is to maintain purchasing documents containing a clear description of the materials ordered for use in hull construction and the standards to which the material must conform, together with the identification and certification requirements.

1.9.2 The Builder is to be responsible for ensuring that all incoming plates, sections, castings, components, fabrications and consumables and other materials used in the hull construction are inspected or otherwise verified as conforming to purchase order requirements.

1.9.3 The Builder is to have procedures for the inspection, storage and maintenance of Owner supplied materials and equipment.

1.9.4 The Builder is to record on receipt the manufacturing date, or use-by date of critical materials. Any materials which have a shelf life are to be used in order of manufacturing date to ensure stock rotation.

1.9.5 The Builder is to establish and maintain a procedure to ensure that materials and consumables used in the hull construction process are identified (by colour-coding and/or marking as appropriate) from arrival in the yard through to fabrication in such a way as to enable the type and grade to be readily recognised.

1.9.6 Where materials are found to be defective they are to be rejected in accordance with the Builder's quality control procedure.

1.10 Faults

1.10.1 All identified faults are to be recorded under the requirements of the quality control systems. Faults are to be classified according to their severity and are to be monitored during periodical survey.

1.10.2 Production faults are to be discussed with the attending Surveyor and a rectification scheme agreed. Deviations from the approved plans are to be locally approved by the attending Surveyor and a copy forwarded to the plan approval office for record purpose.

1.11 Inspection

1.11.1 On acceptance of a 'Request for Services' the attending Surveyor is to inform the Builder of the key stages of the production that are to be inspected and the extent of the inspection to be carried out.

1.11.2 It is the Builder's responsibility to carry out required inspections in accordance with the accepted quality control system.

1.11.3 It is the Surveyor's responsibility to monitor the Builder's quality control records and carry out inspections at key stages and during periodic visits.

1.11.4 Adequate facilities are to be provided to enable the Surveyor to carry out a satisfactory inspection and to facilitate subsequent in-service maintenance. These are to include the provision of access holes in restricted spaces and removable deckhead and shipside linings, cabin soles, etc.

1.11.5 During inspections all deviations are to be dealt with in accordance with 1.6.4.

1.12 Acceptance criteria

1.12.1 Classification is dependent upon the work being carried out in accordance with the approved plans and the requirements of an accepted quality control system.

1.12.2 The work is to be carried out to the satisfaction of the attending Surveyor. This will include the verification of the quality control documentation and the remedial action associated with all defects and deficiencies recorded.

1.12.3 Proposed deviations from the approved plans are subject to LR approval and in the first instance are to be discussed with the attending Surveyor. Where applicable, an amended plan is to be submitted to the plan appraisal office. Such deviations will be recorded as endorsements to the certification unless specifically agreed otherwise with the plan appraisal office.

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1.12.4 Where the above requirements are met the attending Surveyor will arrange for the relevant certification to be issued.

1.13 Repair

1.13.1 Minor repairs are to be agreed with the attending Surveyor and a rectification scheme agreed with the Builder. The Builder is to incorporate details of the agreed repair procedures in the quality control system in accordance with 1.6.4.

1.13.2 Repairs which affect the structural integrity are to be discussed with the Builder and the Builder's proposed rectification scheme is to be submitted to the plan appraisal office for consideration.

■ *Section 2* Materials

2.1 General

2.1.1 The materials used in the construction of the craft are to be manufactured and tested in accordance with the appropriate requirements of Chapter 8 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

2.1.2 As an alternative to 2.1.1, materials may be accepted for specific applications, provided they are manufactured and tested in accordance with the requirements of national or proprietary specifications which give reasonable equivalence to the requirements of the Rules for Materials. Additional tests may be required to prove that the materials are suitable for the intended purpose in respect of mechanical properties, weldability and corrosion resistance.

2.1.3 All materials are to be manufactured at works which have been approved by LR for the type and, where appropriate, grade of aluminium which is being supplied and for the relevant aluminium production and processing route.

2.2 Aluminium alloy plates, bars and sections

2.2.1 Materials are, in general, to be limited to the supply conditions detailed in Ch 8,1.6 of the Rules for Materials. Other supply conditions may be accepted but, as materials in a condition other than annealed are subject to a loss of mechanical strength in the vicinity of welded joints, the strength used in design calculations are to be as given in 2.4.

2.2.2 For applications where the material will be subject to high local stresses, it is recommended that the scantlings, when using higher strength materials, be determined on the basis of the mechanical properties of the material in the as-welded annealed condition.

2.3 Aluminium alloy castings

2.3.1 All structural castings are to be manufactured and tested in accordance with the appropriate requirements of Ch 8,3 of the Rules for Materials.

2.4 Mechanical properties for design

2.4.1 The minimum tensile strength properties of aluminium alloys approved for structural use are given in Ch 13,8.3.2 of the Rules for Materials. Other alloys and conditions of temper may be accepted in accordance with 2.1.3.

2.4.2 In general, for welded structure, the maximum value for the strength of the material, σ_a, to be used in the scantling derivation is that of the aluminium alloy in the welded condition, where σ_a is defined as the 0,2 per cent butt welded proof stress or 70 per cent of the ultimate strength of the material in the welded condition in N/mm^2, whichever is the lesser.

2.4.3 The tensile modulus of elasticity to be used in scantling calculations is 69×10^3 N/mm^2 for all aluminium alloy materials.

2.4.4 The type of material, specification to which it is manufactured (including grade and temper) and minimum guaranteed mechanical properties are to be indicated on the construction drawings.

2.5 Cathodic protection

2.5.1 The potential of the aluminium-magnesium (5000 Series) and the aluminium-magnesium-silicon (6000 Series) alloys is generally in the range –0,7 to –0,9 Volts with reference to a silver/silver chloride sea-water reference electrode. A negative potential swing of at least 0,1 Volts from the corrosion potential is necessary to provide cathodic protection in sea-water (i.e. –0,8 to –1,0 Volts). The limit of negative potential is, however, not to exceed –1,1 Volts with reference to a silver/silver chloride sea-water reference electrode. Zinc or aluminium-zinc-indium or aluminium-zinc-tin anodes may be used for cathodic protection but aluminium anodes containing mercury are not acceptable.

2.5.2 Where an impressed current cathodic protection system is fitted, plans showing the proposed layout of anodes and hull penetrations are to be submitted.

2.6 Paints and coatings

2.6.1 The hull, deck, deckhouse and superstructure and other structure which is exposed to the marine environment is to be protected against corrosion by a suitable protective coating. All coatings are to be in accordance with the requirements of this Section. Internal structure need not in general be coated provided that they are built of aluminium alloy grades shown in Chapter 8 of the Rules for Materials.

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2.6.2 Aluminium alloy is to be suitably cleaned, cleared of oxide and degreased before the application of any protective coating.

2.6.3 Paints or other coatings are to be suitable for the intended purpose in the locations where they are to be used. Coatings are to be of adequate film thickness, applied in accordance with the paint manufacturer's specification. The paint or coating is to be compatible with any previously applied primer.

2.6.4 Paints containing lead, mercury or copper are not to be used in conjunction with aluminium alloys.

2.6.5 Paints, varnishes and similar preparations having a nitro-cellulose or other highly flammable base are not to be used in accommodation or machinery spaces.

2.7 Galvanic action

2.7.1 Where bimetallic connections are made, involving dissimilar metals, measures are to be incorporated to preclude galvanic corrosion. In order to prevent galvanic corrosion, special attention is to be given to the penetrations of and connections to the hull, bulkheads and decks by piping and equipment where dissimilar materials are involved.

2.8 Bimetallic connections

2.8.1 The design is to ensure that the location of all bimetallic connections allows for regular inspection and maintenance of the joints and penetrations during service.

2.9 Deck coverings

2.9.1 Where plated decks are sheathed with wood, the sheathing is to be efficiently attached to the deck, caulked and sealed, to the satisfaction of the Surveyor in accordance with the approved drawings.

2.9.2 Deck coverings in the following positions are to be of a type which will not readily ignite where used on decks:

(a) Forming the crown of machinery or cargo spaces within accommodation spaces of cargo craft.

(b) Within accommodation spaces, control stations, stairways and corridors of passenger craft.

2.10 Corrosion margin

2.10.1 The scantlings determined from the formulae provided in the Rules assume that the materials used are selected, manufactured and protected in such a way that there is negligible loss in strength by corrosion.

2.10.2 Where aluminium alloy is not protected against corrosion, by painting or other approved means, the scantlings may require to be further considered.

2.11 Fracture control

2.11.1 Aluminium alloys in commercial use are in general not subject to unstable crack growth in an elastic stress field because fracture toughness is high. However, for alloys with higher strength and/or temper, special tests may be required to provide information on fracture toughness.

2.11.2 Construction procedures, materials and welding are to be in accordance with the requirements of this Chapter such that stress corrosion cracking is avoided.

2.11.3 High local stresses are to be avoided by the use of suitable design detail, *see also* LR's *Guidance Notes for Structural Details*.

■ *Section 3* Procedures for welded construction

3.1 General

3.1.1 Except as otherwise indicated below, all welded construction is to be conducted in accordance with the requirements specified in Chapter 13 of the Rules for Materials.

3.1.2 The requirements of this Section are applicable to aluminium alloys welded using the metal inert gas (MIG) or tungsten inert gas (TIG) processes. Where it is proposed to use alternative welding processes, details are to be submitted for approval, prior to the start of fabrication.

3.2 Information to be submitted

3.2.1 The plans and information submitted for approval are to clearly indicate details of the welded connections of the main structural members, including the type, disposition and size of welds.

3.3 Welding consumables

3.3.1 All welding consumables are to be approved by LR and are to be suitable for the type of joint and grade of material, *see* Ch 11,9 of the Rules for Materials.

3.3.2 The 5083 and 5086 alloys are normally welded using the 5356, 5556 or 5183 consumables and the 6061 and 6082 alloys are normally welded using the 4043 consumables.

3.3.3 Only approved filler wires are to be used. Testing requirements for welding consumables are contained in the Rules for Materials.

3.3.4 Cast aluminium alloys are not in general to be welded directly to wrought high magnesium alloys unless the welding is carried out in accordance with an agreed procedure.

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3.3.5 Special care is to be taken in the distribution, storage and handling of all welding consumables. Aluminium filler metals are to be kept in a heated dry storage area with a relatively uniform temperature. Condensation on the metal surface during storage and use is to be avoided. Other welding consumables such as bare wire and welding studs are to be stored under dry conditions to prevent corrosion. Effective facilities for protecting consumables are to be provided close to working areas.

3.4 Defined practices and welding sequence

3.4.1 Details of the welding procedures and the sequence of welding assemblies and joining up of assemblies are to be submitted.

3.4.2 The proposed sequence of welding is to be agreed with the Surveyor prior to construction.

3.4.3 The type and disposition of connections and sequences of welding are to be so planned that any restraint during welding operations is reduced to a minimum.

3.4.4 Special attention is to be given to the examination of plating in way of all lifting eye plate positions to ensure freedom from cracks. This examination is not restricted to the positions where eye plates have been removed but includes the positions where lifting eye plates are permanent fixtures.

3.4.5 Careful consideration is to be given to assembly sequence and overall shrinkage of plate panels, assemblies, etc., resulting from welding processes employed. Welding is to proceed systematically with each welded joint being completed in correct sequence without undue interruption. Where practicable, welding is to commence at the centre of a joint and proceed outwards or at the centre of an assembly and progress outwards towards the perimeter so that each part has freedom to move in one or more directions. Generally, the welding of stiffener members including transverses, frames, girders, etc., to welded plate panels by automatic processes is to be carried out in such a way as to minimise angular distortion of the stiffener.

3.4.6 Butt welds are to be finished full at the ends and cut back before welding the seams. Seams are generally not to be welded within 300 mm of an unwelded butt weld or welded across an unwelded butt joint.

3.4.7 The final boring out of propeller brackets and sterntubes and the fit-up and alignment of rudder bearings and jet units are to be carried out after the major part of the welding of the aft end of the craft is complete. The contacts between rudder stocks and propeller shafts with bearings are to be checked before the final mounting.

3.4.8 Precautions are to be taken to screen and pre-warm the general and local weld areas as necessary. Surfaces are to be dry.

3.5 Structural arrangements and access

3.5.1 Ceilings, cabin sole, side and overhead linings are to be secured in such a manner as to be easily removed for the maintenance and inspection of the structure below.

3.5.2 Structural arrangements are to be such as will allow adequate ventilation and access for preheating, where required, and for the satisfactory completion of all welding operations. Welded joints are to be so arranged as to facilitate the use of downhand welding wherever possible.

3.6 Heat treatment

3.6.1 Pre-heating is to be applied in accordance with the requirements specified in Chapter 13 of the Rules for Materials.

3.6.2 For aluminium-magnesium alloys, the preheating temperature is to be limited to 60°C to avoid the risk of stress corrosion cracking.

3.6.3 With the 6000 series heat-treatable alloys, it is sometimes beneficial to apply a post-weld heat treatment in the form of artificial ageing. The procedure to be used depends on the alloy and, in order to quantify the benefits, tests are required using representative specimens which accurately simulate the true situation in terms of metal thickness, geometry, filler metal and welding parameters, as well as the post-weld treatment employed.

3.7 Testing

3.7.1 Inspection of welded construction is to be conducted in accordance with the requirements specified in Chapter 13 of the Rules for Materials.

3.7.2 Checkpoints for volumetric examination are to be selected so that a representative sample of welding is examined.

3.7.3 Typical locations for volumetric examination and number of checkpoints to be taken are shown in Table 2.3.1. A list of the proposed items to be examined is to be submitted for approval.

3.8 Acceptance criteria

3.8.1 All finished welds are to be sound and free from cracks and substantially free from lack of fusion, incomplete penetration, porosity and tungsten inclusions. The surfaces of welds are to be reasonably smooth and substantially free from undercut and overlap. Care is to be taken to ensure that the specified dimensions of welds have been achieved and that both excessive reinforcement and underfill of welds are avoided.

3.8.2 The quality and workmanship of welding of all fittings and attachments to main structure, both permanent and temporary, are to be equivalent to those of the main hull structure.

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Table 2.3.1 Non-destructive examinations of welds

Volumetric non-destructive examinations – Recommended extent of testing, *see* 3.7.3		
Item	Location	Checkpoints, *see* Note 1
Intersections of butts and seams of fabrication and section welds	*Throughout:* hull envelope longitudinal and transverse bulkheads inner bottom and hopper bottom	*The summation of checkpoint lengths (see* Note 2) examined at intersections is to be *L*, where *L* is the overall length of the ship in metres
Butt welds in plating	Throughout	1 m in 25 m, *see* Note 3
Seam welds in plating	Throughout	1 m in 100 m
Butts in longitudinals	Hull envelope within 0,4*L* amidships Hull envelope outside 0,4*L* amidships	1 in 10 welds 1 in 20 welds
Bilge keel butts	Throughout	1 in 10 welds
Structural items when made with full penetration welding as follows: connection of stool and bulkhead to lower stool shelf plating vertical corrugations to an inner bottom hopper knuckles sheerstrake to deck stringer hatchways coaming to deck	Throughout	1 m in 20 m

NOTES
1. The length of each checkpoint is to be between 0,3 m and 0,5 m.
2. For checkpoints at intersections the measured dimension of length is to be in the direction of the butt weld.
3. Checkpoints in butt welds and seam welds are in addition to those at intersections.
4. Agreed locations are not to be indicated on the blocks prior to the welding taking place, nor is any special treatment to be given at these locations.
5. Particular attention is to be given to repair rates in longitudinal butts. Additional welds are to be tested in the event that defects, such as lack of fusion or incomplete penetrations, are repeatedly observed.

3.8.3 Visual examination of all welds is to be supplemented by non-destructive testing as considered necessary by the Surveyor.

3.8.4 Fairing, by linear or spot heating, to correct distortions due to welding is, in general, not to be carried out unless procedures have been approved to ensure that the properties of the material are not adversely affected. Visual examination of all heat affected areas and welds in the vicinity is to be carried out to ensure freedom from defects.

■ *Section 4* Joints and connections

4.1 General

4.1.1 Requirements are given in this Chapter for welding connection details, aluminium/steel transition joints, aluminium/wood connection, riveting of light structure and chemical bonding.

4.1.2 Welded joints are to be detailed such that crevices or inaccessible pockets capable of retaining dirt or moisture are avoided. Where cavities are unavoidable, they are to be sealed by welding or protective compounds or made accessible for inspection and maintenance.

4.2 Weld symbols

4.2.1 Weld symbols, where used, are to conform to a recognised National or International Standard. Details of such Standards are to be indicated on the welding schedule, which is to be submitted for appraisal.

4.3 Welding schedule

4.3.1 A welding schedule containing not less than the following information is to be submitted:
(a) Weld throat thickness or leg lengths.
(b) Grades, tempers, and thicknesses of materials to be welded.
(c) Locations, types of joints and angles of abutting members.
(d) Reference to welding procedures to be used.
(e) Sequence of welding of assemblies and joining up of assemblies.

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4.4 Butt welds

4.4.1 All structural butt joints are to be made by means of full penetration welds and, in general, the edges of plates to be joined by welding are to be bevelled on one or both sides of the plates. Full details of the proposed joint preparation are to be submitted for approval, *see also* 4.20.

4.4.2 Where butt welds form a T-junction, the leg of the T is, where practicable, to be completed first including any back run. During the welding operation special attention is to be given to the completion of the weld at the junction, which is to be chipped back to remove crater cracks, etc., before the table is welded.

4.4.3 For guidance purposes, a number of typical joint preparations for TIG and MIG welding are shown in Tables 2.4.1 and 2.4.2 respectively.

4.5 Fillet welds

4.5.1 The throat thickness of fillet welds is to be determined from:

$$\text{Throat thickness} = t_p \times \text{Weld factor} \times \left(\frac{d}{s}\right) \text{ mm}$$

where

s = the length of correctly proportioned weld fillet, clear of end craters, in mm, and is to be 10 x plate thickness, t_p, or 75 mm, whichever is the lesser, but in no case to be taken less than 40 mm

d = the distance between successive weld fillets, in mm

t_p = plate thickness, in mm, on which weld fillet size is based, *see* 4.5.4.

Weld factors are contained in Table 2.4.3.

NOTE:

for double continuous fillet welding $\left(\frac{d}{s}\right)$ is to be taken as 1 (*see* 4.8.1).

4.5.2 For ease of welding, it is recommended that the ratio of the web height to the flange breadth be greater than or equal to 1,5, *see* Fig. 2.4.1.

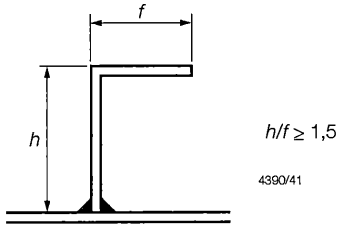

Fig. 2.4.1 Web height/flange breadth ratio

4.5.3 The leg length of the weld is to be not less than $\sqrt{2}$ times the specified throat thickness.

4.5.4 The plate thickness t_p to be used in 4.5.1 is generally to be that of the thinner of the two parts being joined. Where the difference in thickness is considerable, the size of fillet will be specially considered.

4.6 Throat thickness limits

4.6.1 The throat thickness limits given in Table 2.4.4 are to be complied with.

4.7 Single sided welding

4.7.1 Temporary backing bars for single sided welding may be austenitic stainless steel, glass tape, ceramic, or anodised aluminium of the same material as the base metal. Backing bars are not to be made of copper to avoid weld contamination and corrosion problems.

4.7.2 Temporary backing bars are to be suitably grooved in way of the weld to ensure full penetration.

4.8 Double continuous welding

4.8.1 Where double continuous fillet welding is proposed the throat thickness is to be in accordance with 4.5.1 taking $\left(\frac{d}{s}\right)$ equal to 1.

4.8.2 Double continuous welding is to be adopted in the following locations and may be used elsewhere if desired:

(a) Boundaries of weathertight decks and erections, including hatch coamings, companionways and other openings.

(b) Boundaries of tank and watertight compartments.

(c) Main engine seatings.

(d) Bottom framing structure of high speed craft in way of machinery and jet room spaces as appropriate.

(e) The side and bottom shell structure in the impact area of high speed motor craft.

(f) The underside of the cross-deck structure in the impact area of high speed multi-hull craft.

(g) Structure in way of ride control systems, stabilisers, thrusters, bilge keels, foundations and other areas subject to high stresses.

(h) The shell structure in the vicinity of the propeller blades.

(j) Stiffening members to plating in way of end connections scallops and of end brackets to plating in the case of lap connections.

(k) Primary and secondary members to plating in way of end connections, and end brackets to plating in the case of lap connections.

(l) Face flats to webs of built-up/fabricated stiffening members in way of knees/end brackets and for a distance beyond such knees/end brackets of not less than the web depth of stiffener in way.

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Table 2.4.1 Typical joint preparations for TIG welding of aluminium alloys

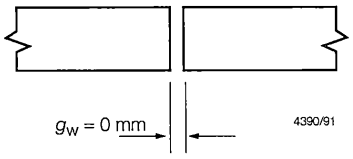
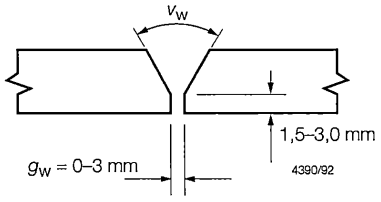
Thickness (mm)	Joint design	Welding position/comments
2,5 – 3,0		Flat Horizontal Vertical Overhead
3,0 – 10,0		Flat and Vertical V = 60° Horizontal and Overhead V = 90° – 110°
Symbols and definitions		
g_w = weld gap, in mm V_w = weld preparation angle, in degrees		

Table 2.4.2 Typical joint preparations for semi-automatic MIG welding

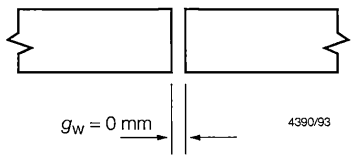
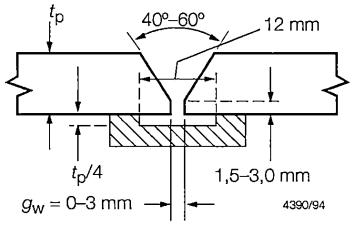
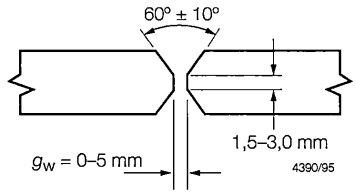
Thickness (mm)	Joint design	Welding position/comments
5,0 – 6,5		Flat
7,0 – 15,0		Flat Horizontal Vertical Overhead One sided welding with temporary backing
12,0 – 25,0		All positions
Symbols and definitions		
t_p = plate thickness, in mm g_w = weld gap, in mm		

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Table 2.4.3 Weld factors (*see continuation*)

Item	Weld Factor	Remarks
(1) General application:		except as required below
(a) Watertight plate boundaries	0,34	
(b) Non-tight plate boundaries	0,13	
(c) Longitudinals, frames, beams, and other secondary members to shell, deck, or bulkhead plating	0,10 0,13 0,21	 in tanks in way of end connections
(d) Panel stiffeners	0,10	
(e) Overlap welds generally	0,27	
(f) Longitudinals of the flat-bar type to plating		*see* 4.8.2
(2) Bottom construction:		
(a) Non-tight centre girder: • to keel • to inner bottom	 0,27 0,21	 no scallops
(b) Non-tight boundaries of: • floors, girders and • brackets	 0,21 0,27	 in way of 0,2 x span at ends in way of brackets at lower end of main frame
(c) Inner bottom longitudinals, or face flat to floors reverse frames	0,13	
(d) Connection of floors to inner bottom where bulkhead supported on tank top. The supporting floors are to be continuously welded to the inner bottom	0,44	Weld size based on floor thickness Weld material compatible with floor material
(3) Hull framing:		
(a) Webs of web frames and stringers: • to shell • to face plate	 0,16 0,13	
(4) Decks and supporting structure:		
(a) Weather deck plating to shell Other decks to shell and bulkheads (except where forming tank boundaries)	0,44 0,21	 generally continuous
(b) Webs of cantilevers to deck and to shell in way of root bracket	0,44	
(c) Webs of cantilevers to face plate	0,21	
(d) Girder webs to deck clear of end brackets	0,10	
(e) Girder webs to deck in way of end brackets	0,21	
(f) Web of girder to face plate	0,10	
(g) Pillars: • fabricated • end connections • end connections (tubular)	 0,10 0,34 full penetration	
(h) Girder web connections and brackets in way of pillar heads and heels	0,21	continuous

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Table 2.4.3 Weld factors (*see continuation*)

Item	Weld Factor	Remarks
(5) Bulkheads and tank construction:		
(a) Plane and corrugated watertight bulkhead boundary at bottom, bilge, inner bottom, deck and connection to shelf plate, where fitted	0,44	Weld size to be based on thickness of bulkhead plating Weld material to be compatible with bulkhead plating material
(b) Secondary members where acting as pillars	0,13	
(c) Non-watertight pillar bulkhead boundaries	0,13	
(d) Perforated flats and wash bulkhead boundaries	0,10	
(e) Deep tank horizontal boundaries at vertical corrugations	full penetration	
(6) Structure in machinery space:		
(a) Centre girder to keel and inner bottom	0,27	no scallops to inner bottom
(b) Floors to centre girder in way of engine thrust bearers	0,27	
(c) Floors and girders to shell and inner bottom	0,21	
(d) Main engine foundation girders: • to top plate • to hull structure	{ deep penetration to depend on design	{ edge to be prepared with maximum root $0,33t_p$ deep penetration, generally
(e) Floors to main engine foundation girders	0,27	
(f) Brackets, etc., to main engine foundation girders	0,21	
(g) Transverse and longitudinal framing to shell	0,13	
(7) Superstructures and deckhouses:		
(a) Connection of external bulkheads to deck	0,34 0,21	1st and 2nd tier erections elsewhere
(b) Internal bulkheads	0,13	
(8) Steering control systems:		
(a) Rudder: • Fabricated mainpiece and • mainpiece to side plates and webs	0,44	
(b) Slot welds inside plates	0,44	
(c) Remaining construction	0,21	
(d) Fixed and steering nozzles: • Main structure • Elsewhere	0,44 0,21	
(e) Fabricated housing and structure of thruster units, stabilisers, etc.: • Main structure • Elsewhere	0,44 0,21	

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Table 2.4.3 Weld factors (*conclusion*)

Item	Weld Factor	Remarks
(9) Miscellaneous fittings and equipment:		
(a) Rings for manhole type covers, to deck or bulkhead	0,34	
(b) Frames of shell and weathertight bulkhead doors	0,34	
(c) Stiffening of doors	0,21	
(d) Ventilator, air pipes, etc., coamings to deck	0,34 0,21	Load Line Positions 1 and 2 elsewhere
(e) Ventilator, etc., fittings	0,21	
(f) Scuppers and discharges, to deck	0,44	
(g) Masts, crane pedestals, etc., to deck	0,44	full penetration welding may be required
(h) Deck machinery seats to deck	0,21	generally
(j) Mooring equipment seats	0,21	generally, but increased or full penetration may be required
(k) Bulwark stays to deck	0,21	
(l) Bulwark attachment to deck	0,34	
(m) Guard rails, stanchions, etc., to deck	0,34	
(n) Bilge keel ground bars to shell	0,34	continuous fillet weld, minimum throat thickness 4 mm
(o) Bilge keels to ground bars	0,21	light continuous or staggered intermittent fillet weld, minimum throat thickness 3 mm
(p) Fabricated anchors		full penetration

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Table 2.4.4 Throat thickness limits

Item	Throat thickness mm	
	Minimum	Maximum
(1) Double continuous welding	$0,21t_p$	$0,44t_p$
(2) Intermittent welding	$0,27t_p$	$0,44t_p$ or 4,5
(3) Overriding minimum:		
(a) Continuous welds	2,5	
(b) Intermittent welds:		
(i) Plate thickness $t_p \leq 7,5$ mm Hand or automatic welding	3,0	
Automatic deep penetration welding	3,0	
(ii) Plate thickness $t_p \geq 7,5$ mm Hand or automatic welding	3,25	
Automatic deep penetration welding	3,0	

NOTES
1. In all cases the limiting maximum value is to be taken as the greatest of the applicable values above.
2. The maximum throat thicknesses shown are intended only as a design limit for the approval of fillet welded joints. Any welding in excess of these limits is to be to the Surveyor's satisfaction.

4.9 Intermittent welding (staggered)

4.9.1 Staggered intermittent welding may be used, outside of the impact area in the bottom shell or crossdeck structure of high speed craft.

4.10 Intermittent welding (chain)

4.10.1 Chain intermittent welding may be used, outside of the impact area in the bottom shell or crossdeck structure of high speed craft.

4.11 Connections of primary structure

4.11.1 Depending on the structural design of the joint and design loads on the primary member, full penetration welding of flanges and web plates may be required to attain full section properties in the end connections of primary members. *See also* Pt 6, Ch 3,1.22. Otherwise weld factors for the connections of primary structure are given in Table 2.4.3.

4.11.2 The weld connection to shell, deck or bulkhead is to take account of the material lost in the notch where longitudinals or stiffeners pass through the member. Where the width of notch exceeds 15 per cent of the stiffener spacing, the weld factor is to be multiplied by:

$$\frac{0,85 \times \text{stiffener spacing}}{\text{length of web plating between notches}}$$

4.11.3 Where direct calculation procedures have been adopted, the weld factors for the 0,2 x overall length at the ends of the members will be considered in relation to the calculated loads.

4.12 Primary and secondary member end connection welds

4.12.1 Welding of end connections of primary members is to be such that the area of welding is not less than the cross-sectional area of the member, and the weld factor is to be not less than 0,34 in tanks or 0,27 elsewhere.

4.12.2 The welding of secondary member end connections is to be not less than as required by Table 2.4.5. Where two requirements are given the greater is to be complied with.

4.12.3 The area of weld, A_w, is to be applied to each arm of the bracket or lapped connection.

4.12.4 Where a longitudinal strength member is cut at a primary support and the continuity of strength is provided by brackets, the area of weld is to be not less than the cross-sectional area of the member.

4.13 Weld connection of strength deck plating to sheerstrake

4.13.1 The weld connection of strength deck plating to sheerstrake is to be by double continuous fillet welding with a weld factor of 0,44. The welding procedure, including joint preparation, is to be specified and the procedure qualified and approved for individual Builders.

4.14 Air and drain holes

4.14.1 Air and drain holes are to be kept clear of the toes of brackets, etc. Openings are to be well rounded with smooth edges, *see also* LR's *Guidance Notes for Structural Details*.

4.15 Notches and scallops

4.15.1 Notches and scallops are to be kept clear of the toes of brackets, etc. Openings are to be well rounded with smooth edges. Details of scallops are shown in Fig. 13.2.1 in Chapter 13 of the Rules for Materials.

4.15.2 Scallops are to be of such a size, and in such a position that a satisfactory weld can be made around the ends of openings.

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Table 2.4.5 Secondary member end connection welds

Connection	Weld area, A_w, in cm^2	Weld factor
(1) Stiffener welded direct to plating	$0{,}25A_s$ or 6,5 cm^2 whichever is the greater	0,34
(2) Bracketless connection of stiffeners or stiffener lapped to bracket or bracket lapped to stiffener:		
(a) in dry space	$1{,}2\sqrt{Z}$	0,27
(b) in tank	$1{,}4\sqrt{Z}$	0,34
(c) main frame to tank side bracket in $0{,}15L_R$ forward	as (a) or (b)	0,34
(3) Bracket welded to face of stiffener and bracket connection to plating	—	0,34
(4) Stiffener to plating for 0,1 x span at ends, or in way of the end bracket if that be greater	—	0,34

Symbols

A_s = cross section area of the stiffener, in cm^2

A_w = the area of the weld, in cm^2, and is calculated as total length of weld, in cm, x throat thickness, in cm

Z = the section modulus, in cm^3, of the stiffener on which the scantlings of the end bracket are based.

NOTE
For maximum and minimum weld fillet sizes, *see* Table 2.4.4.

4.16 Watertight collars

4.16.1 Watertight collars are to be fitted, where stiffeners are continuous through watertight or oiltight boundaries, *see also* LR's *Guidance Notes for Structural Details*.

4.17 Lug connections

4.17.1 The area of the weld connecting secondary stiffeners to primary structure in the bottoms of the hulls and cross-deck structure in areas subjected to impact pressures is to be not less than the shear area from the Rules. This area is to be obtained by fitting two lugs or by other equivalent arrangements. Some typical lug connections are shown in Fig. 2.4.2 and Fig. 3.1.7 in Chapter 3.

4.17.2 Lugs or tripping brackets are to be fitted where shell longitudinals are continuous through web frames in way of highly stressed areas of the side shell (e.g. in way of fenders, etc.).

4.17.3 Lugs or tripping brackets are also to be fitted where continuous secondary stiffeners are greater than half the depth of the primary stiffeners.

4.18 Insert plates

4.18.1 Where thick insert plates are butt welded to thin plates, the edge of the thick plate may require to be tapered. The slope of the taper is generally not to exceed one in three.

4.18.2 The corners of insert plates are to be suitably radiused.

4.19 Doubler plates

4.19.1 Doubler plates are to be avoided in areas where corrosion may be a problem and access for inspection and maintenance is limited.

4.19.2 Where doubler plates are fitted, they are to have well radiused corners and the perimeter is to be continuously welded. Large doubler plates are also to be suitably slot welded, the details of which are to be submitted for consideration.

4.20 Joint preparation

4.20.1 Typical butt joints are shown in Tables 2.4.1 and 2.4.2, *see also* LR's *Guidance Notes for Structural Details*.

4.21 Construction tolerances

4.21.1 The minimum requirements for construction tolerances are to be in accordance with Pt 3, Ch 1,8.

4.22 Riveting of light structure

4.22.1 Where it is proposed to adopt riveted construction, full details of the rivets or similar fastenings, including mechanical test results, are to be indicated on the construction plans submitted for approval or a separate riveting schedule is to be submitted.

4.22.2 Samples may be required of typical riveted joints made by the Builder under representative construction conditions and tested to destruction in the presence of the Surveyor in shear, tension, compression or peel at LR's discretion.

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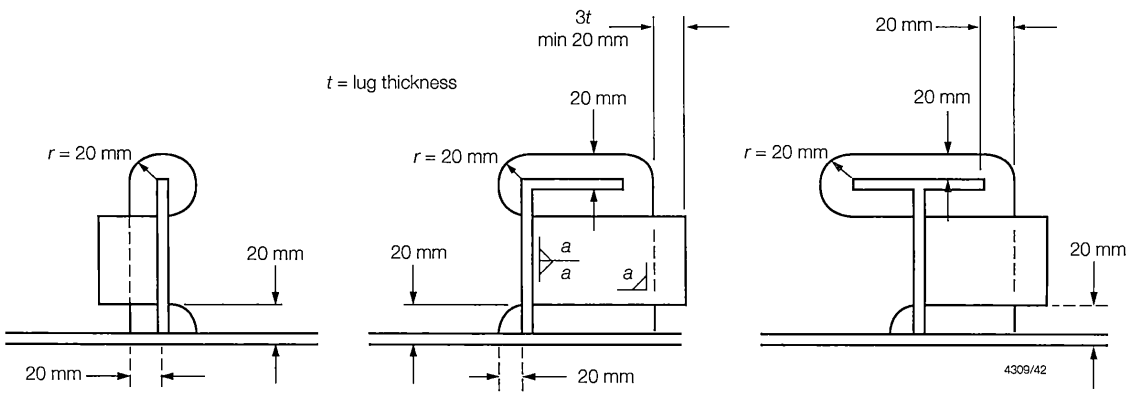

Fig. 2.4.2 Typical lug connections

4.22.3 Where riveting strength data sheets have been issued by a recognised Authority, the values quoted in these sheets will normally be accepted for design purposes.

4.22.4 Where two dissimilar metals are to be joined by riveting, precautions are to be taken to eliminate electrolytic corrosion to LR's satisfaction, and where practicable, the arrangements should be such as to enable the joint to be kept under observation at each survey without undue removal of lining and other items.

4.22.5 Where a sealing compound is used to obtain an airtight or watertight joint, details are to be submitted of its proposed use and of any tests made or experience gained in its use for similar applications.

4.22.6 Aluminium alloy rivets in accordance with Ch 8,2 of the Rules for Materials are to be used where practicable. However, in the case of composite structures, including steel and GRP, consideration will be given to the use of steel rivets. In such cases, the mating surfaces are to be coated with a sealing paint.

4.22.7 Sealing paints or compounds are not to be used with hot driven rivets.

4.23 Chemical bonding of structure

4.23.1 Where chemical bonding of aluminium alloy of any load-bearing structure is proposed, details of the materials and the processes to be used are to be submitted for approval. These details are to include test results of samples manufactured under LR survey under workshop conditions to verify the strength, ageing effects and moisture resistance.

4.23.2 The adhesive manufacturer's recommendations in respect of the specified jointing system, comprising preparation of the surfaces to be adhered, the adhesive, bonding and curing processes, are to be strictly followed as variation of any step can severely affect the performance of the joint.

4.23.3 Meticulous preparation is essential where the joint is to be made by chemical bonding. The method of producing bonded joints is to be documented so that the process is repeatable after the procedure has been properly established.

4.23.4 Bonded joints are suitable for carrying shear loads, but are not in general to be used in tension or where the load causes peeling or other forces tending to open the joint. Loads are to be carried over as large an area as possible.

4.23.5 Bonded joints are to be suitably supported after assembly for the period necessary to allow the optimum bond strength of the adhesive to be to be developed. Entrained air pockets are to be avoided.

4.23.6 The use of adhesives for main structural joints is not to be contemplated unless considerable testing has established its validity, including environmental testing and fatigue testing where considered necessary by LR.

4.24 Triaxial stress considerations

4.24.1 Particular care is to be taken to avoid triaxial stresses which may result from poor joint design. Detailed joint design is of particular importance in aluminium structures more so than many other materials. Some recommendations in this respect are contained in LR's *Guidance Notes for Structural Details*.

4.25 Butt straps

4.25.1 In general, the scantling derivation of welded structures are to be determined using the mechanical properties of the aluminium alloy in the welded condition in accordance with 2.4. However, where stiffeners are butt welded, special consideration will be given to the use of suitable butt straps on the flanges which sufficiently reinforce the area of the weld to allow the scantlings to be determined using the unwelded mechanical properties. The butt weld is to be completed and generally made flush with the flange of the stiffening member before the butt strap is fitted and the

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butt strap weld is to be continuous. Where this jointing method is proposed, the scantlings, arrangements and locations of all joints and butt straps are to be submitted. Additionally, LR may require mechanical tests to be carried out to demonstrate the effectiveness of such arrangements.

4.26 Extruded 'planking'

4.26.1 Joints between adjacent extruded aluminium alloy planking, and the attachment of the planking to the supporting structure is in general to be by means of continuous welding.

4.26.2 The planking is generally not to be included in the determination of the section properties for both section modulus and inertia. However, special consideration will be given to the inclusion of such materials on the basis of the efficiency of the connection to the supporting structure.

4.27 Aluminium/steel transition joints

4.27.1 Provision is made in this Section for explosion bonded composite aluminium/steel transition joints used for connecting aluminium structures to steel plating. Such joints are to be used in accordance with the manufacturer's requirements, *see also* Ch 8,4 of the Rules for Materials.

4.27.2 Transition joints are to be manufactured by an approved producer in accordance with an approved specification which is to include the maximum temperature allowable at the interface during welding.

4.27.3 The aluminium material is to comply with the requirements of Section 2 and the steel is to be of an appropriate grade complying with the requirements of Ch 3,2 of the Rules for Materials.

4.27.4 Alternative materials which comply with International, National or proprietary specifications may be accepted provided that they give equivalence to the requirements of 4.31.3 or are approved for a specific application.

4.27.5 Intermediate layers between the aluminium and steel may be used, in which case the material of any such layer is to be specified by the manufacturer and is to be recorded in the approval certificate. Any such intermediate layer is then to be used in all production transition joints.

4.27.6 Bimetallic joints where exposed to seawater or used internally within wet spaces are to be suitably protected to prevent galvanic corrosion.

4.28 Aluminium/wood connection

4.28.1 To minimise corrosion of aluminium when in contact with wood in a damp or marine environment the timber is to be primed and painted in accordance with good practice. Alternatively the surface of the aluminium in contact with the timber is to be coated with a substantial thickness of a suitable sealant.

4.28.2 Timbers such as western red cedar, oak and chestnut are not, unless well seasoned, to be directly in contact with aluminium.

4.28.3 Timber preservatives of the following types should be avoided: copper napthanate, copper-chrome-arsenate, borax-boric acid.

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Scantling Determination for Mono-Hull Craft

Section

1 **General**

2 **Minimum thickness requirements**

3 **Shell envelope plating**

4 **Shell envelope framing**

5 **Single bottom structure and appendages**

6 **Double bottom structure**

7 **Bulkheads**

8 **Deck structures**

9 **Superstructures, deckhouses and bulwarks**

10 **Pillars and pillar bulkheads**

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull craft of aluminium construction as defined in Pt 1, Ch 2,2.

1.2 General

1.2.1 The formulae contained within this Chapter are to be used in conjunction with the design loadings from Part 5 to determine the Rule scantling requirements.

1.3 Direct calculations

1.3.1 Where the craft is of unusual design, form or proportions, or where the speed of the craft exceeds 60 knots the scantlings are to be determined by direct calculation.

1.3.2 The requirements of this Chapter may be modified where direct calculation procedures are adopted to analyse the stress distribution in the primary structure.

1.4 Equivalents

1.4.1 Lloyd's Register (hereinafter referred to as 'LR') will consider direct calculations for the derivation of scantlings as an alternative and equivalent to those derived by Rule requirements in accordance with Pt 3, Ch 1,3.

1.5 Symbols and definitions

1.5.1 The symbols used in this Chapter are defined below and in the appropriate Section:

k_a = alloy factor
$= 125/\sigma_a$
l = stiffener overall length, in metres
l_e = effective span length, in metres, as defined in 1.19
p = design pressure, in kN/m^2, as given in Part 5
s = stiffener spacing, in mm
t_p = plating thickness, in mm
A_w = shear area of stiffener web, in cm^2
B = moulded breadth of craft, in metres, as defined in Pt 3, Ch 1,6
E = modulus of elasticity, in N/mm^2
I = moment of inertia, in cm^4
L_R = Rule length of craft, in metres, as defined in Pt 3, Ch 1,6
Z = section modulus of the stiffening member, in cm^3
β = panel aspect ratio correction factor as defined in 1.15
γ = convex curvature correction factor as defined in 1.14
σ_a = guaranteed minimum 0,2 per cent proof stress of the alloy in the welded condition, in N/mm^2, *see also* Ch 2,2.4.2

$$\tau_a = \frac{\sigma_a}{\sqrt{3}}$$

1.6 Rounding policy for Rule plating thickness

1.6.1 Where plating thicknesses as determined by the Rules require to be rounded then this is to be carried out to the nearest full or half millimetre, with thicknesses 0,75 and 0,25 being rounded up.

1.7 Dimensional tolerance

1.7.1 Dimensional tolerances for materials are to be in accordance with Chapter 8 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials), or an acceptable National or International Standard.

1.7.2 The under thickness tolerance acceptable for classification is to be considered as the lower limit of a range of thickness tolerance which could be found in the normal production of a conventional rolling mill manufacturing material, on average, to the nominal thickness.

1.7.3 The Owners and Builders may agree in individual cases whether they wish to specify a more stringent under thickness tolerance than that given in 1.7.2.

1.7.4 The minus tolerance on sections (except for wide flats) is to be in accordance with a National or International Standard.

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1.7.5 The thickness of plates and strip is to be measured at random locations whose distance from an edge is to be at least 25 mm. Local surface depressions resulting from imperfections and ground areas resulting from the elimination of defects may be disregarded provided that they are in accordance with the requirements of a National or International Standard.

1.7.6 The responsibility for maintaining the required tolerances and making the necessary measurements rests with the manufacturer/Builder. Occasional checking by the Surveyor does not absolve the manufacturer/Builder from the responsibility.

1.8 Material properties

1.8.1 The basic grade of aluminium alloy is taken as marine grade 5083-0 with the following mechanical properties:

	N/mm^2
0,2 per cent proof stress (minimum)	125
Tensile strength	260
Modulus of elasticity	69×10^3

1.8.2 Where other alloy grades with differing mechanical properties are to be used, due allowance is given in the determination of the Rule requirement for plating thickness, section modulus, inertia and cross-sectional area by use of the following correction factors:

(a) Plating thickness factor = $\sqrt{k_a}$

(b) Section modulus and cross section area factor = k_a where k_a is as defined in 1.5.1.

1.9 High strength sheet and plate

1.9.1 Particular attention is to be given to the welding procedures for the welding of high strength sheet and plate. The 0,2 per cent yield strength values in the welded condition will, in general, be significantly less than in the unwelded condition. These reduced values are to be used in the determination of the Rule scantlings.

1.10 High strength extrusions

1.10.1 The requirements of 1.9 are to be complied with. However, special consideration will be given to the use of un-welded strength properties for use in the determination of the Rule scantlings provided that suitable compensation is provided in way of welding on the face of the stiffener. This compensation can be provided by butt-straps or other acceptable arrangements, *see also* Ch 2,4.28.

1.10.2 The application of high strength extrusions is in general limited to superstructures, deckhouses, decks and bulkheads. Special consideration will be given to their use in other areas.

1.10.3 Butt welds and seams are to be carefully positioned clear of areas of high stress and where practicable are to be orientated parallel to the direction of the main stresses.

1.11 Effective width of attached plating

1.11.1 The effective geometric properties of rolled or built sections are to be calculated directly from the dimensions of the section and associated effective area of attached plating. Where the web of the section is not normal to the actual plating, and the angle exceeds 20°, the properties of the section are to be determined about an axis parallel to the attached plating.

1.11.2 For stiffening members, the geometric properties of rolled or built sections are to be calculated in association with an effective area of attached load bearing plating of thickness t_p, in mm and a breadth b_e, in mm, b_e is as defined in 1.11.3 and 1.11.4.

1.11.3 The effective width of attached plating to secondary members b_e is to be taken as $2t_p\sqrt{E/\sigma_a}$ but not greater than s. σ_a is not to be taken as greater than 169 N/mm^2 for aluminium alloy. E, s and σ_a are as defined in 1.5.1.

1.11.4 The effective breadth of attached plating to primary support members (girders, transverses, webs, etc.) b_e is to be taken as bf, where b and f are as defined in Pt 3, Ch 2,3.2.1.

1.11.5 Where primary stiffening members support areas of plating of the extruded plank type, or the floating frame system is used, the effect of the plating attached to the secondary stiffening members is to be ignored when calculating the actual section modulus and inertia of the primary stiffening members, i.e. the full section modulus and inertia are to be provided by the primary stiffening member only, *see also* Ch 2,4.27.

1.12 Other materials

1.12.1 Special consideration will be given to the use of materials other than aluminium alloy. Details of the type of material, the specification to which it was manufactured and its mechanical properties are to be submitted for appraisal.

1.13 Fibre reinforced plastic (FRP)

1.13.1 The use of FRP in construction is to be in accordance with Part 8.

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1.14 Convex curvature correction

1.14.1 The thickness of plating as determined by the Rules may be reduced where significant curvature exists between the supporting members. In such cases a plate curvature correction factor may be applied:

γ = plate curvature factor
= $1 - h/s$, and is not to be taken as less than 0,7

h = the distance, in mm, measured perpendicularly from the chord length s (i.e. spacing) to the highest point of the curved plating arc between the two supports

See Fig. 3.1.1.

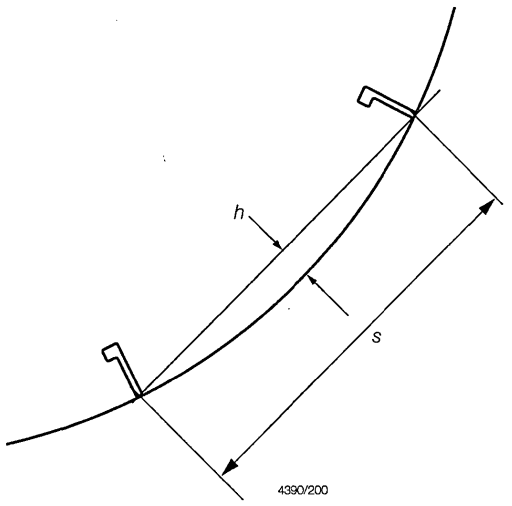

Fig. 3.1.1 Convex curvature

1.15 Aspect ratio correction

1.15.1 The thickness of plating as determined by the Rules may be reduced when the panel aspect ratio is taken into consideration. In such cases a panel aspect ratio correction factor may be applied:

β = aspect ratio correction factor
= $A_R (1 - 0{,}25A_R)$ for $A_R \leq 2$
= 1 for $A_R > 2$

where

A_R = panel aspect ratio
= panel length/panel breadth.

1.16 Plating general

1.16.1 The requirements for the thickness of plating, t_p, is, in general, to be in accordance with the following:

$$t_p = 22{,}4s\,\gamma\,\beta\sqrt{\frac{p}{f_\sigma\,\sigma_a}} \times 10^{-3} \text{ mm}$$

where

f_σ = limiting bending stress coefficient for the plating element under consideration is given in Table 7.3.1 in Chapter 7.

s, γ, β, p, σ_a are as defined in 1.5.1.

1.17 Stiffening general

1.17.1 The requirements for section modulus, inertia and web area of stiffening members are in general to be in accordance with the following:

(a) Section modulus:

$$Z = \Phi_Z \frac{p\,s\,l_e^2}{f_\sigma\,\sigma_a} \text{ cm}^3$$

where

Φ_z = section modulus coefficient dependent on the loading model assumption taken from Table 3.1.1

f_σ = limiting bending stress coefficient for stiffening member given in Table 7.3.1 in Chapter 7.

p, s, l_e and σ_a are as defined in 1.5.

(b) Inertia:

$$I = \Phi_I f_\delta \frac{p\,s\,l_e^3}{E} \times 100 \text{ cm}^4$$

where

Φ_I = inertia coefficient dependent on the loading model assumption taken from Table 3.1.1

f_δ = limiting deflection coefficient for stiffener member given in Table 7.2.1 in Chapter 7.

p, s, l_e and E are as defined in 1.5.1.

(c) Web area:

$$A_w = \Phi_A \frac{p\,s\,l_e}{100 f_\tau\,\tau_a} \text{ cm}^2$$

where

Φ_A = web area coefficient dependent on the loading model assumption taken from Table 3.1.1

f_τ = limiting shear stress coefficient for stiffener member given in Table 7.3.1 in Chapter 7

p, s, l_e and τ_a are as defined in 1.5.1.

1.18 Geometric properties and proportions of stiffener sections

1.18.1 From structural stability and local buckling considerations, the proportions of stiffening members are, in general, to be in accordance with Table 3.1.2.

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Table 3.1.1 Section modulus, inertia and web area coefficients

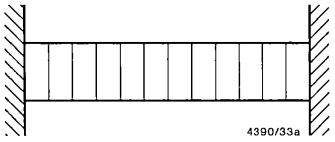
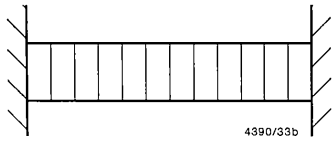
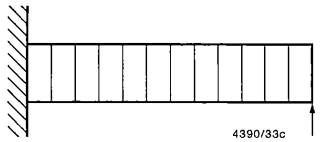
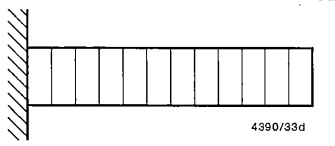
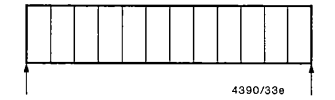
Load model	Position 1	Position 2	Position 3	Position	Web area coefficient Φ_A	Section modulus coefficient Φ_Z	Inertia coefficient Φ_I	Application
(a)	 4390/33a			1 2 3	1/2 — 1/2	1/12 1/24 1/12	— 1/384 —	Primary and other members where the end fixity is considered encastre
(b)	 4390/33b			1 2 3	1/2 — 1/2	1/10 1/10 1/10	— 1/288 —	Local, secondary and other members where the end fixity is considered to be partial
(c)	 4390/33c			1 2 3	5/8 — 3/8	1/8 9/128 —	— 1/185 —	Various
(d)	 4390/33d			1 2 3	1 — —	1/2 — —	— — 1/8	Various
(e)	 4390/33e			1 2 3	1/2 — 1/2	— 1/8 —	— 5/384 —	Hatch covers, glazing and other members where the ends are simply supported

Table 3.1.2 Stiffener proportions

Type of stiffener	Requirement
(1) Flat bar	Minimum web thickness: $t_w = d_w/15$ ≥ 3 mm
(2) Rolled or built sections	(a) Minimum web thickness: $t_w = d_w/50$ ≥ 3 mm (b) Maximum unsupported face plate (or flange) width: $b_f = 16\ t_f$
Symbols	
t_w = web thickness of stiffener with unstiffened webs, in mm d_w = web depth of stiffener, in mm b_f = face plate (or flange) unsupported width, in mm t_f = face plate (or flange) thickness, in mm	

1.19 Determination of span point

1.19.1 The effective length of span, l_e, of a stiffening member is generally less than the overall length, l, by an amount which depends on the design of the end connections. The span points, between which the value of l_e is measured, are to be determined as follows:

(a) For rolled or built-up secondary stiffening members:
The span point is to be taken at the point where the depth of the end bracket, measured from the face of the secondary stiffening member, is equal to the depth of the member, *see* Fig. 3.1.2. Where there is no end bracket, the span point is to be measured between primary member webs.

(b) For primary support members:
The span point is to be taken at a point distant, b_e from the end of the member, where

$$b_e = b_b\left(1 - \frac{d_w}{d_b}\right)$$

where b_e, b_b, d_w and d_B are as shown in Fig. 3.1.2.

1.19.2 Where the stiffener member is inclined to a vertical or horizontal axis and the inclination exceeds 10°, the span is to be measured along the member.

1.19.3 Where the stiffening member is curved then the span is to be taken as the effective chord length between span points.

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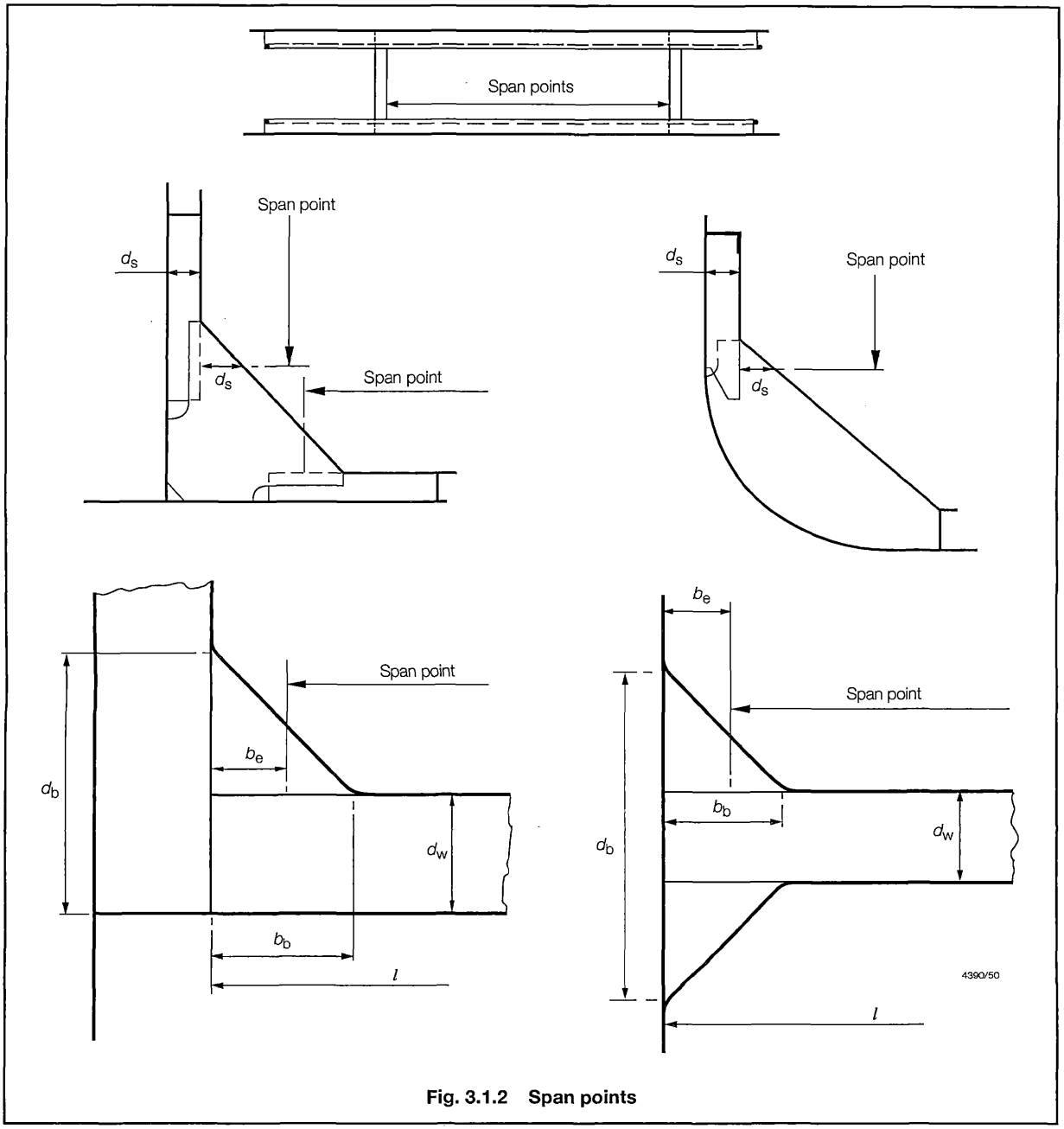

Fig. 3.1.2 Span points

1.19.4 Where there is a pronounced turn of bilge, chine or the structure is significantly pitched, the span may be measured as in Fig. 3.1.2.

1.19.5 It is assumed that the ends of stiffening members are substantially fixed against rotation and displacement. If the arrangement of supporting structure is such that this condition is not achieved, consideration will be given to the effective span to be used for the stiffener.

1.20 Secondary member end connections

1.20.1 Secondary members, that is longitudinals, beams, frames and bulkhead stiffeners forming part of the hull structure, are to be effectively continuous and are to be suitably bracketed at their end connections. Where it is desired to adopt bracketless connections, the proposed arrangements will be individually considered, *see also* Ch 2,4.15 and Table 2.4.5 in Chapter 2.

1.20.2 Where bracketed end connections are fitted in accordance with these requirements, they may be taken into account in determining the effective span of the member.

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1.20.3 The scantlings of secondary member end connections are to be in accordance with 1.21.

1.21 Scantlings of end brackets

1.21.1 Where a longitudinal strength member is cut at a primary support and the continuity of strength is provided by brackets, the scantlings of the end brackets are to be such that their section modulus and effective cross-sectional area are not less than those of the member. Care is to be taken to ensure correct alignment of the brackets on each side of the primary member.

1.21.2 In other cases the scantlings of the bracket are to be based on the modulus as follows:

(a) Bracket connecting stiffener to primary member – modulus of the stiffener.

(b) Bracket at the head of a main transverse frame where frame terminates – modulus of the frame.

(c) Brackets connecting lower deck beams or longitudinals to the main frame in the forward $0{,}5L_R$ – modulus of the frame.

(d) Elsewhere – the lesser modulus of the members being connected by the bracket.

1.21.3 The web thickness and face flat area of end brackets are not in general to be less than those of the connecting stiffeners. Additionally, the stiffener proportion requirements of 1.18 are to be satisfied.

1.21.4 Typical arrangements of stiffener end brackets are shown diagrammatically in Fig. 3.1.3.

1.21.5 The lengths, a and b of the arms are to be measured from the plating to the toe of the bracket and are to be such that:

(a) $a + b \geq 2{,}0l_b$

(b) $a \geq 0{,}8l_b$

(c) $b \geq 0{,}8l_b$

where a and b are the actual lengths of the two arms of the bracket, in mm, measured from the plating to the toe of the bracket.

$$l_b = 90\left(2\sqrt{\frac{Z}{14+\sqrt{Z}}} - 1\right) \text{ mm}$$

Z = the section modulus of the secondary member, in cm^3

In no case is l_b to be taken as less than twice the web depth of the stiffener on which the bracket scantlings are to be based.

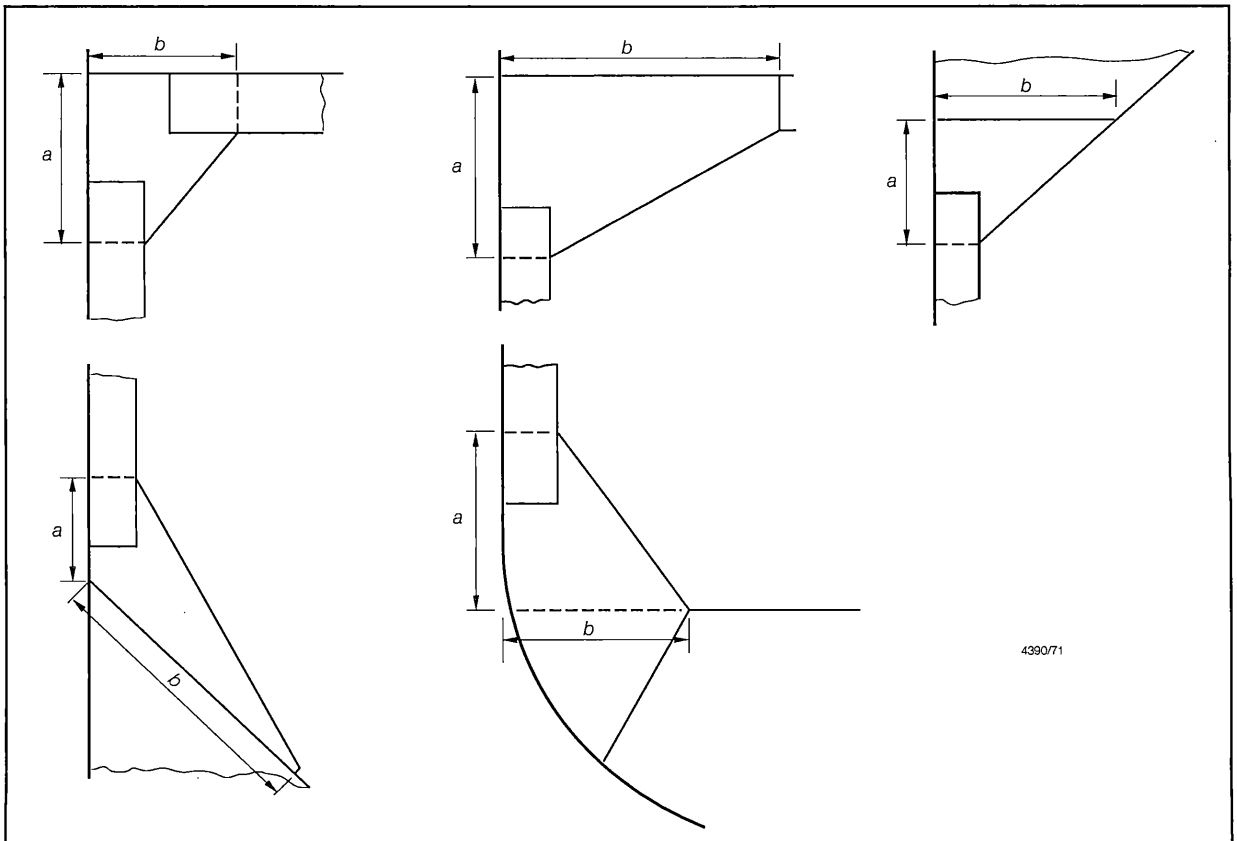

Fig. 3.1.3 Stiffener end brackets

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1.21.6 The free edge of the bracket is to be stiffened where any of the following apply:

(a) The section modulus, Z, exceeds 500 cm^3.

(b) The length of free edge exceeds 40 times the bracket thickness.

(c) The bracket is fitted at the lower end of main transverse side framing.

1.21.7 Where a face flat is fitted, its breadth, b_f, is to be not less than:

$$b_f = 30\left(1 + \frac{Z}{1000}\right) \text{ mm}$$

but not less than 40 mm.

1.21.8 Where the edge is stiffened by a welded face flat, the cross-sectional area of the face flat is to be not less than:

(a) $0{,}017 k_a b_f T_B$ cm^2 for offset edge stiffening.

(b) $0{,}014 k_a b_f T_B$ cm^2 for symmetrically placed stiffening.

b_f = breadth of face flat, in mm

T_B = the thickness of the bracket, in mm

k_a is as defined in 1.5.1.

1.21.9 Where the stiffening member is lapped onto the bracket, the length of overlap is to be adequate to provide for the required area of welding. In general, the length of overlap is not to be less than 10 $\sqrt{Z}$, or the depth of stiffener, whichever is the greater.

1.21.10 Where the free edge of the bracket is hollowed out, it is to be stiffened or increased in size to ensure that the modulus of the bracket through the throat is not less than that of the required straight edged bracket.

1.21.11 The arrangement of the connection between the stiffener and the bracket is to be such that at no point in the connection is the actual modulus reduced to less than that of the stiffener with associated plating.

1.21.12 The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint.

1.22 Primary member end connections

1.22.1 The requirements for section modulus and inertia (if applicable) of primary members are given in the appropriate Chapter. The scantling requirements for primary member end connections in dry spaces and in tanks of all craft types are generally to comply with the requirements of 1.21, taking Z as the section modulus of the primary member.

1.22.2 Primary members are to be so arranged as to ensure effective continuity of strength, and abrupt changes of depth or section are to be avoided. Where members abut on both sides of a bulkhead, or on other members, arrangements are to be made to ensure that they are in alignment. Primary members in tanks are to form a continuous line of support and wherever possible, a complete ring system.

1.22.3 The members are to have adequate lateral stability and web stiffening and the structure is to be arranged to minimise hard spots and other sources of stress concentration. Openings are to have well rounded corners and smooth edges and are to be located having regard to the stress distribution and buckling strength of the panel.

1.22.4 Primary members are to be provided with adequate end fixity by end brackets or equivalent structure. The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint and effective distribution of the load from the member.

1.22.5 Where the primary member is supported by structure which provides only a low degree of restraint against rotation, the member is generally to be extended beyond the point of support and thereafter tapered and/or scarfed into the adjacent structure over a distance generally not less than two frame spaces.

1.22.6 Where primary members are subject to concentrated loads, particularly if these are out of line with the member web, additional strengthening may be required.

1.22.7 The thickness of the bracket is to be not less than that of the primary member web. The free edge of the bracket is to be stiffened.

1.22.8 Where a deck girder or transverse is connected to a vertical member on the shell or bulkhead, the scantlings of the latter may be required to be increased to provide adequate stiffness to resist rotation of the joint.

1.22.9 Where a member is continued over a point of support, such as a pillar or pillar bulkhead stiffener, the design of the end connection is to be such as to ensure the effective distribution of the load into the support. Proposals to fit brackets of reduced scantlings, or alternative arrangements, will be considered.

1.22.10 Connections between primary members forming a ring system are to minimise stress concentrations at the junctions. Integral brackets are generally to be radiused or well rounded at their toes. The arm length of the bracket, measured from the face of the member, is to be not less than the depth of the smaller member forming the connection.

1.23 Tank boundary penetrations

1.23.1 Where structural members pass through the boundary of a tank, and leakage into the adjacent space could be hazardous or undesirable, full penetration welding is to be adopted for the members for at least 150 mm on each side of the boundary. Alternatively a small scallop of suitable shape may be cut in the member close to the boundary outside the compartment, and carefully welded all round.

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1.24 Web stability

1.24.1 Primary members of asymmetrical section are to be supported by tripping brackets at alternate secondary members. If the section is symmetrical, the tripping brackets may be four spaces apart.

1.24.2 Tripping brackets are in general required to be fitted at the toes of end brackets and in way of heavy or concentrated loads such as the heels of pillars. *See also* LR's *Guidance Notes for Structural Details*.

1.25 Openings in the web

1.25.1 Where openings are cut in the web, the depth of opening is not to exceed 50 per cent of the web depth, and the opening is to be so located that the edges are not less than 25 per cent of the web depth from the face plate. The length of opening is not to exceed the web depth or 60 per cent of the secondary member spacing, whichever is the greater, and the ends of the openings are to be equidistant from the corners of cut-outs for secondary members. Where larger openings are proposed, the arrangements and compensation required will be specially considered.

1.25.2 Openings are to have smooth edges and well rounded corners.

1.26 Continuity and alignment

1.26.1 The arrangement of material is to be such as will ensure structural continuity. Abrupt changes of shape or section, sharp corners and points of stress concentration are to be avoided.

1.26.2 Where members abut on both sides of a bulkhead or similar structure, care is to be taken to ensure good alignment.

1.26.3 Pillars and pillar bulkheads are to be fitted in the same vertical line wherever possible, and elsewhere arrangements are to be made to transmit the out of line forces satisfactorily. The load at head and heel of pillars is to be effectively distributed and arrangements are to be made to ensure the adequacy and lateral stability of the supporting members.

1.26.4 Continuity is to be maintained where primary members intersect and where the members are of the same depth, a suitable gusset plate is to be fitted, *see* Fig. 3.1.4.

1.26.5 End connections of structural members are to provide adequate end fixity and effective distribution of the load into the supporting structure.

1.26.6 The toes of brackets, etc., are not to land on unstiffened panels of plating. Special care is to be taken to avoid notch effects at the toes of brackets, by making the toe concave or otherwise tapering it off, *see also* LR's *Guidance Notes for Structural Details*.

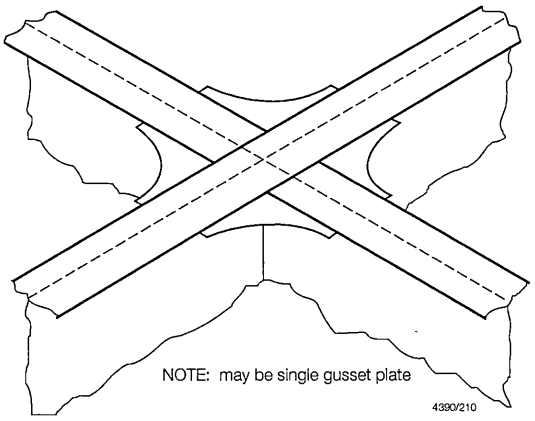

Fig. 3.1.4 Primary member intersection

1.26.7 Particular attention is to be paid to the design of the end bracket toes in order to minimise stress concentrations. Sniped face plates which are welded onto the edge of primary member brackets are to be carried well around the radiused part of the bracket toe and are to incorporate a taper not exceeding one in three. Where sniped face plates are welded adjacent to the edge of primary member brackets, adequate cross sectional area is to be provided through the bracket toe at the end of the snipe. In general, this area measured perpendicular to the face plate, is to be not less than 60 per cent of the full cross-sectional area of the face plate, *see* Fig. 3.1.5.

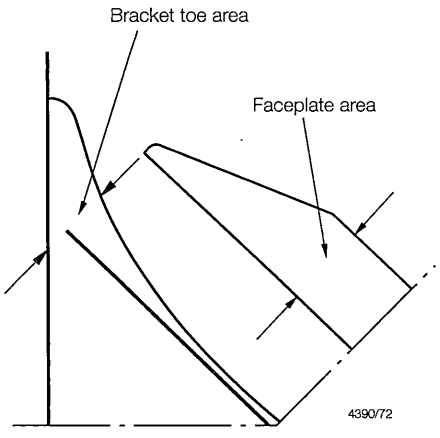

Fig. 3.1.5 Bracket toe construction

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1.27 Arrangement with offset stiffener

1.27.1 Where the stiffeners of the double bottom floors and transverse bulkheads are unconnected to the secondary members and offset from them, *see* Fig. 3.1.6, the collar arrangement for the secondary members are to satisfy the requirements of 1.28. In addition, the fillet welds attaching the lugs to the secondary members are to be based on a weld factor of 0,44 for the throat thickness. To facilitate access for welding the offset stiffeners are to be located 50 mm from the slot edge furthest from the web of the secondary member. The ends of the offset stiffeners are to be suitably tapered and softened.

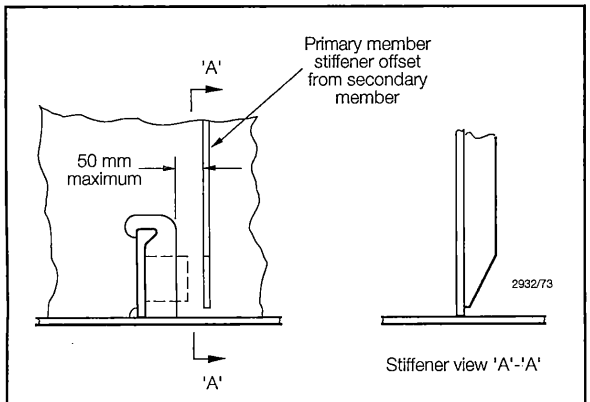

Fig. 3.1.6 Arrangement with offset stiffener

1.27.2 Alternative arrangements will be considered on the basis of their ability to transmit load with equivalent effectiveness. Details of the calculations made and testing procedures are to be submitted.

1.28 Arrangements at intersection of continuous secondary and primary members

1.28.1 Cut-outs for the passage of secondary members through the webs of primary members, and the related collaring arrangements, are to be designed to minimise stress concentrations around the perimeter of the opening and in the attached hull envelope or bulkhead plating. The critical shear buckling stress of the panel in which the cut-out is made is to be investigated. Cut-outs for longitudinals will be required to have double lugs in areas of high stress.

1.28.2 The breadth of cut-outs is to be as small as practicable, with the top edge suitably radiused. Cut-outs are to have smooth edges, and the corner radii are to be as large as practicable, with a minimum of 20 per cent of the breadth of the cut-out or 25 mm, whichever is the greater. It is recommended that the web plate connection to the hull envelope, or bulkhead, end in a smooth tapered 'soft toe'. Recommended shapes of cut-out are shown in Fig. 3.1.7, but consideration will be given to other shapes on the basis of maintaining equivalent strength and minimising stress concentration, *see also* LR's *Guidance Notes for Structural Details*.

1.28.3 Consideration is to be given to the provision of adequate drainage and unimpeded flow of air and water when designing the cut-outs and connection details.

1.28.4 Asymmetrical secondary members are to be connected on the heel side to the primary member web plate. Additional connection by lugs on the opposite side may be required.

1.28.5 Symmetrical secondary members are to be connected by lugs on one or both sides, as necessary.

1.28.6 Where the primary member stiffener is connected to the secondary member it is to be aligned with the web of the secondary member, except where the face plate of the latter is offset and abutted to the web, in which case the stiffener connection is to be lapped.

1.28.7 Fabricated longitudinals having the face plate welded to the underside of the web, leaving the edge of the web exposed, are not recommended for side shell and longitudinal bulkhead longitudinals. Where it is proposed to fit such sections, a symmetrical arrangement of connection to transverse members is to be incorporated. This can be achieved by fitting backing structure on the opposite side of the transverse web or bulkhead.

1.28.8 Where a bracket is fitted to the primary member web plate in addition to a connected stiffener it is to be arranged on the opposite side to, and in alignment with the stiffener. The arm length of the bracket is to be not less than the depth of the stiffener, and its cross-sectional area through the throat of the bracket is to be included in the calculation of the area of the primary web stiffener in way of the connection.

1.28.9 Alternative arrangements will be considered on the basis of their ability to transmit load with equivalent effectiveness. Details of the calculations made and testing procedures are to be submitted.

1.29 Openings

1.29.1 Manholes, lightening holes and other cut-outs are to be avoided in way of concentrated loads and areas of high shear. In particular, manholes and similar openings are not to be cut in vertical or horizontal diaphragm plates in narrow cofferdams or in floors and double bottom girders close to their span ends, or below the heels of pillars, unless the stresses in the plating and the panel buckling characteristics have been calculated and found satisfactory.

1.29.2 Manholes, lightening holes and other openings are to be suitably framed and stiffened where necessary.

1.29.3 Air and drain holes, notches and scallops are to be kept at least 200 mm clear of the toes of end brackets and other areas of high stress. Openings are to be well rounded with smooth edges. Closely spaced scallops are not permitted. Widely spaced air or drain holes may be accepted, provided that they are of elliptical shape, or equivalent, to minimise stress concentration and are, in general, cut clear of the weld connection.

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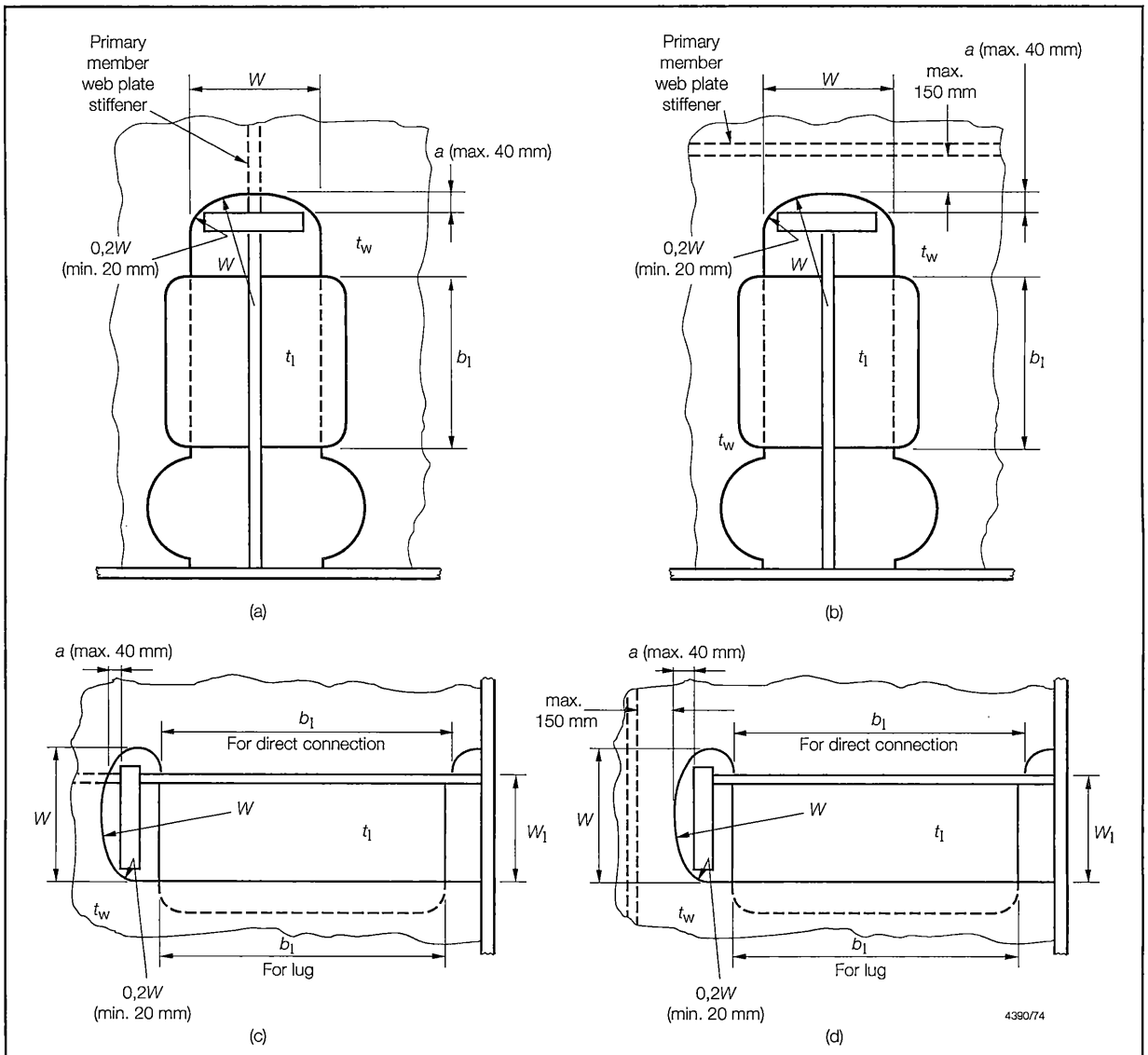

Fig. 3.1.7 Cut-outs and connections

1.30 Fittings and attachments, general

1.30.1 The quality of welding and general workmanship of fittings and attachments as given in 1.31 and 1.32 are to be in accordance with Ch 2,3.8.

1.31 Bilge keels and ground bars

1.31.1 It is recommended that bilge keels are not to be fitted in the forward $0{,}3L_R$ region on ships intended to navigate in ice conditions.

1.31.2 Bilge keels are to be attached to a continuous ground bar as shown in Fig. 3.1.8. Butt welds in shell plating, ground bar and bilge keels are to be staggered.

1.31.3 The thickness of the ground bar is to be not less than the thickness of the bottom shell or 8 mm, whichever is the greater, but need not be taken as greater than 15 mm.

1.31.4 The material class, grade and quality of the ground bar are to be similar to those of the adjacent shell plating.

1.31.5 The ground bar is to be connected to the shell with a continuous fillet weld and the bilge keel to the ground bar with a light continuous fillet weld.

1.31.6 Direct connection between ground bar butt welds and shell plating, and between bilge keel butt welds and ground bar is to be avoided.

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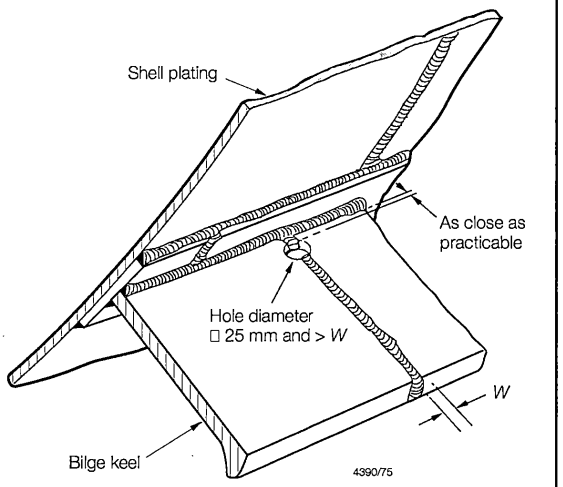

Fig. 3.1.8 Bilge keel construction

1.31.7 The end details of bilge keels and intermittent bilge keels, where adopted, are to be as shown in Fig. 3.1.9.

1.31.8 The ground bar and bilge keel ends are to be tapered or rounded. Where the ends are tapered, the tapers are to be gradual with ratios of at least 3:1, *see* Figs. 3.1.9(a) and (b). Where the ends are rounded, details are to be as shown in Fig. 3.1.9(c). Cut-outs on the bilge keel web within zone 'A' (*see* Fig. 3.1.9(b)) are not permitted.

1.31.9 The end of the bilge keel web is to be between 50 mm and 100 mm from the end of the ground bar, *see* Fig. 3.1.9(a).

1.31.10 An internal transverse support is to be positioned as close as possible to halfway between the end of the bilge keel web and the end of the ground bar, *see* Fig. 3.1.9(b).

1.31.11 Where an internal longitudinal stiffener is fitted in line with the bilge keel web, the longitudinal stiffener is to extend to at least the nearest transverse member outside zone 'A', *see* Fig. 3.1.9(b). In this case, the requirement of 1.31.10 does not apply.

1.31.12 For craft over 65 m in length, L_R, holes are to be drilled in the bilge keel butt welds. The size and position of these holes are to be as illustrated in Fig. 3.1.8. Where the butt weld has been subject to non-destructive examination the stop hole may be omitted.

1.31.13 Bilge keels of a different design from that shown in Fig. 3.1.8 and Fig. 3.1.9 will be specially considered.

1.31.14 Within zone 'B' (*see* Fig. 3.1.9(a)), welds at the ends of the ground bar and the bilge plating, and at the ends of the bilge keel web and ground bar, are to have weld factors of 0,44 and 0,34 respectively. These welds are to be ground and to blend smoothly with the base materials.

1.31.15 A plan of the bilge keels is to be submitted for approval of material grades, welded connections and detail design.

1.32 Other fittings and attachments

1.32.1 Gutterway bars at the upper deck are to be so arranged that the effect of main hull stresses on them is minimised.

1.32.2 Minor attachments, such as pipe clips, staging lugs and supports, are generally to be kept clear of toes of end brackets, corners of openings and similar areas of high stress. Where connected to asymmetrical stiffeners, the attachments may be in line with the web providing the fillet weld leg length is clear of the offset face plate or flange edge. Where this cannot be achieved the attachments are to be connected to the web, and in the case of flanged stiffeners they are to be kept at least 25 mm clear of the flange edge. On symmetrical stiffeners, they may be connected to the web or to the centre-line of the face plate in line with the web.

1.32.3 Where necessary in the construction of the craft, lifting lugs may be welded to the hull plating but they are not to be slotted through. Where they are subsequently removed, this is to be carried out by mechanical cutting close to the plate surface, and the remaining material and welding ground off. After removal the area is to be carefully examined to ensure freedom from cracks or other defects in the plate surface.

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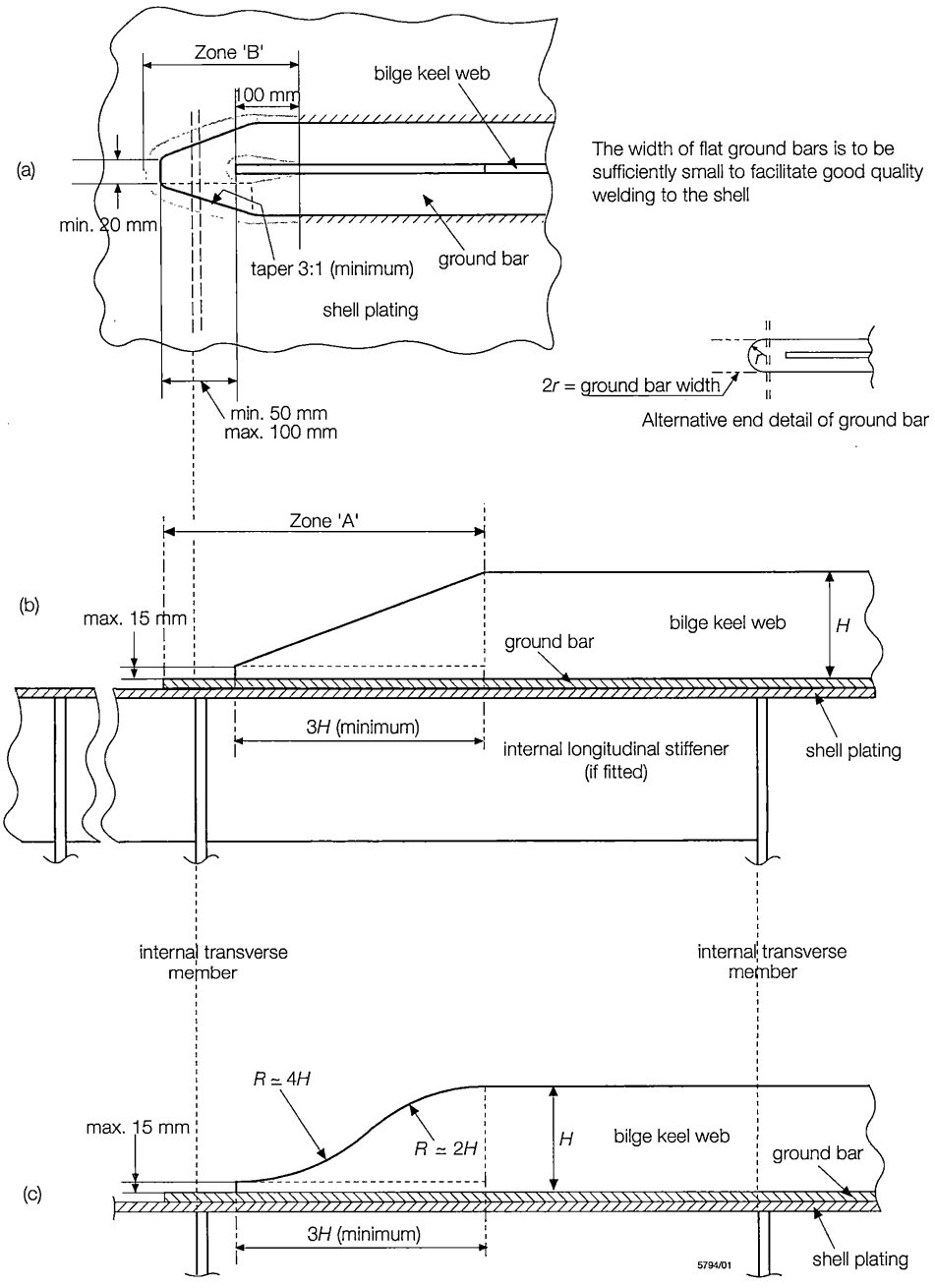

Fig. 3.1.9 Bilge keel end design

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■ *Section 2* Minimum thickness requirements

2.1 General

2.1.1 The thickness of plating and stiffeners determined from the Rule scantling requirements is in no case to be less than that given in Table 3.2.1 for the craft type.

2.1.2 In addition, where plating contributes to the global strength of the craft, the thickness is to be not less than that required to satisfy the global strength requirements detailed in Chapter 6.

2.2 Corrosion margin

2.2.1 The minimum thicknesses given in Table 3.2.1 are based on the assumption that there is negligible loss in strength by corrosion. Where this is not the case the minimum thickness will be specially considered.

Table 3.2.1 Minimum thickness requirements

Item	Minimum thickness (mm)		
	Mono-hull	Hydrofoil	Rigid inflatable boat (RIB)
Shell envelope			
Bottom shell plating	$\omega\ \sqrt{k_m}\,(0{,}7\sqrt{L_R} + 1{,}0) \geq 4{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}7\sqrt{L_R} + 1{,}0) \geq 4{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}7\sqrt{L_R} + 1{,}0) \geq 4{,}0\ \omega$
Side shell plating	$\omega\ \sqrt{k_m}\,(0{,}5\sqrt{L_R} + 1{,}4) \geq 3{,}5\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}5\sqrt{L_R} + 1{,}4) \geq 3{,}5\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}5\sqrt{L_R} + 1{,}4) \geq 3{,}5\ \omega$
Single bottom structure			
Centre girder web	$\omega\ \sqrt{k_m}\,(1{,}1\sqrt{L_R} + 1{,}4) \geq 5{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(1{,}1\sqrt{L_R} + 1{,}4) \geq 5{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(1{,}1\sqrt{L_R} + 1{,}4) \geq 5{,}0\ \omega$
Floor webs	$\omega\ \sqrt{k_m}\,(0{,}8\sqrt{L_R} + 1{,}1) \geq 4{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}8\sqrt{L_R} + 1{,}1) \geq 4{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}8\sqrt{L_R} + 1{,}1) \geq 4{,}0\ \omega$
Side girder webs	$\omega\ \sqrt{k_m}\,(0{,}8\sqrt{L_R} + 1{,}1) \geq 4{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}8\sqrt{L_R} + 1{,}1) \geq 4{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}8\sqrt{L_R} + 1{,}1) \geq 4{,}0\ \omega$
Double bottom structure			
Centre girder			
(1) Within $0{,}4L_R$ amidships	$\omega\ \sqrt{k_m}\,(1{,}1\sqrt{L_R} + 1{,}4) \geq 5{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(1{,}1\sqrt{L_R} + 1{,}4) \geq 5{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(1{,}1\sqrt{L_R} + 1{,}4) \geq 5{,}0\ \omega$
(2) Outside $0{,}4L_R$ amidships	$\omega\ \sqrt{k_m}\,(0{,}95\sqrt{L_R} + 1{,}4) \geq 5{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}95\sqrt{L_R} + 1{,}4) \geq 5{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}95\sqrt{L_R} + 1{,}4) \geq 5{,}0\ \omega$
Floors and side girders	$\omega\ \sqrt{k_m}\,(0{,}8\sqrt{L_R} + 1{,}1) \geq 4{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}8\sqrt{L_R} + 1{,}1) \geq 4{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}8\sqrt{L_R} + 1{,}1) \geq 4{,}0\ \omega$
Inner bottom plating	$\omega\ \sqrt{k_m}\,(0{,}7\sqrt{L_R} + 1{,}3) \geq 3{,}5\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}7\sqrt{L_R} + 1{,}3) \geq 3{,}5\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}7\sqrt{L_R} + 1{,}3) \geq 3{,}5\ \omega$
Bulkheads			
Watertight bulkhead plating	$\omega\ \sqrt{k_m}\,(0{,}43\sqrt{L_R} + 1{,}2) \geq 3{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}43\sqrt{L_R} + 1{,}2) \geq 3{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}43\sqrt{L_R} + 1{,}2) \geq 3{,}0\ \omega$
Deep tank bulkhead plating	$\omega\ \sqrt{k_m}\,(0{,}5\sqrt{L_R} + 1{,}4) \geq 3{,}5\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}5\sqrt{L_R} + 1{,}4) \geq 3{,}5\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}5\sqrt{L_R} + 1{,}4) \geq 3{,}5\ \omega$
Deck plating and stiffeners			
Strength/Main deck plating	$\omega\ \sqrt{k_m}\,(0{,}5\sqrt{L_R} + 1{,}4) \geq 3{,}5\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}5\sqrt{L_R} + 1{,}4) \geq 3{,}5\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}5\sqrt{L_R} + 1{,}4) \geq 3{,}5\ \omega$
Lower deck/Inside deckhouse	$\omega\ \sqrt{k_m}\,(0{,}3\sqrt{L_R} + 1{,}3) \geq 3{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}3\sqrt{L_R} + 1{,}3) \geq 3{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}3\sqrt{L_R} + 1{,}3) \geq 3{,}0\ \omega$
Superstructures and deckhouses			
Superstructure side plating	$\omega\ \sqrt{k_m}\,(0{,}4\sqrt{L_R} + 1{,}1) \geq 3{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}4\sqrt{L_R} + 1{,}1) \geq 3{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}4\sqrt{L_R} + 1{,}1) \geq 3{,}0\ \omega$
Deckhouse front 1st tier	$\omega\ \sqrt{k_m}\,(0{,}62\sqrt{L_R} + 1{,}8) \geq 3{,}5\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}62\sqrt{L_R} + 1{,}8) \geq 3{,}5\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}62\sqrt{L_R} + 1{,}8) \geq 3{,}5\ \omega$
Deckhouse front upper tiers	$\omega\ \sqrt{k_m}\,(0{,}55\sqrt{L_R} + 1{,}5) \geq 3{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}55\sqrt{L_R} + 1{,}5) \geq 3{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}55\sqrt{L_R} + 1{,}5) \geq 3{,}0\ \omega$
Deckhouse aft	$\omega\ \sqrt{k_m}\,(0{,}25\sqrt{L_R} + 0{,}7) \geq 2{,}5\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}25\sqrt{L_R} + 0{,}7) \geq 2{,}5\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}25\sqrt{L_R} + 0{,}7) \geq 2{,}5\ \omega$
Pillars			
Wall thickness of tubular pillars	$\omega\ \sqrt{k_m}\ 0{,}07d_p$	$\omega\ \sqrt{k_m}\ 0{,}07d_p$	$\omega\ \sqrt{k_m}\ 0{,}07d_p$
Wall thickness of rectangular pillars	$\omega\ \sqrt{k_m}\ 0{,}07b_p$	$\omega\ \sqrt{k_m}\ 0{,}07b_p$	$\omega\ \sqrt{k_m}\ 0{,}07b_p$

Symbols

ω = service type correction factor as determined from Table 3.2.2
k_m = $385/(\sigma_A + \sigma_u)$
σ_A = specified minimum yield stress or 0,2% proof stress of the alloy in unwelded condition, in N/mm^2
σ_u = specified minimum ultimate tensile strength of the alloy in unwelded condition, in N/mm^2
b_p = minimum breadth of cross section of hollow rectangle pillar, in mm
d_p = outside diameter of tubular pillar, in mm
L_R is as defined in 1.5.1.

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Table 3.2.2 Service type correction factors (ω)

Service type notation	ω
Cargo	1,1
Passenger	1,0
Patrol	1,0
Pilot	1,1
Yacht	1,0
Workboat MFV	1,2

2.3 Impact considerations

2.3.1 Due consideration is to be given to the scantlings of all structure which may be subject to local impact loadings. Impact testing may be required to be carried out at the discretion of LR to demonstrate the suitability of the proposed scantlings for a particular application.

2.4 Sheathing

2.4.1 Areas of shell and deck which are subject to additional wear by abrasion e.g. passenger routes, working areas of fishing craft, forefoot region etc, are to suitably protected by local reinforcement or sheathing. This sheathing may be of timber, rubber, steel, additional layers of reinforcement, etc., as appropriate. Details of such sheathing and the method of attachment are to be submitted for consideration.

2.4.2 The attachment of sheathing by mechanical means such as bolting or other methods is not to impair the watertight integrity of the craft. Through bolting of the hull is to be kept to a minimum and avoided where practicable. The design arrangements in way of any through bolting are to be such that damage to the sheathing will not impair the watertight integrity of the hull.

2.5 Operation in ice

2.5.1 The minimum plating thickness of craft intended for operation in ice conditions is to comply with Ch 5,7.

■ *Section 3* Shell envelope plating

3.1 General

3.1.1 The requirements of this Section are applicable to longitudinally and transversely framed shell envelopes.

3.1.2 The thickness of the shell envelope plating is in no case to be less than the appropriate minimum requirement given in Section 2.

3.2 Plate keel

3.2.1 The breadth, b_k, and thickness, t_k, of the plate keel are not to be taken as less than:

$$b_k = 7{,}0L_R + 340 \text{ mm}$$

$$t_k = 1{,}85\sqrt{k_a}\, L_R^{0,45} \text{ mm}$$

where L_R and k_a are as defined in 1.5.1.

3.2.2 In no case is the thickness of the plate keel to be less than that of the adjacent bottom shell plating.

3.2.3 The width and thickness of the plate keel are to be maintained throughout the length of the craft from the transom to a point not less than 25 per cent of the freeboard (measured at the forward perpendicular) above the deepest load waterline on the stem. Thereafter the keel thickness may be reduced to that required by 3.3.1 for the stem.

3.2.4 For large or novel craft and for yachts with externally attached ballast keels, the scantlings of the keel will be specially considered.

3.2.5 For bar keels, *see* 5.2.2.

3.3 Plate stem

3.3.1 The thickness of plate stems, t_s, is not to be taken as less than:

$$t_s = \sqrt{k_a}\,(0{,}14L_R + 4) \text{ mm}$$

L_R and k_a are as defined in 1.5.1.

3.3.2 In no case is the thickness of the plate stem to be taken as less than the thickness of the adjacent shell plating.

3.3.3 Plate stems are to be supported by horizontal diaphragms, and where the stem radius is large, a centreline stiffener or web may be required. Where this is impracticable due to fabrication access considerations, alternative supporting arrangements will be specially considered

3.3.4 For large or novel craft the scantlings of the stem will be specially considered.

3.3.5 The breadth of plate stems is to be not less than the width of keel as required by 3.2.1.

3.4 Bottom shell plating

3.4.1 The thickness of the bottom shell plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.4.2 For all craft types the minimum thickness requirement for bottom shell plating as, detailed in Section 2, is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater. *See* Fig. 3.3.1.

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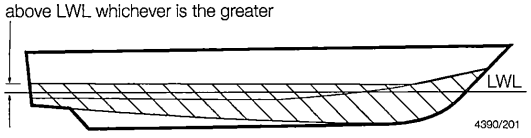

Fig. 3.3.1 Extent of bottom shell

3.5 Side shell plating

3.5.1 The thickness of the side shell plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.6 Sheerstrake

3.6.1 The sheerstrake is generally to be taken as the side shell, locally reinforced in way of deck/hull connection and fender attachment. The amount of local reinforcement will be dependent upon the arrangement of structure and the proposed service.

3.6.2 The fendering arrangements for all craft types are the responsibility of the designers/Builders and are outside the scope of classification.

3.6.3 Where the pressure or impact loadings that a particular type of craft will experience in service are considered by the Builder, or subsequent Owner, to be not covered by or be greater than those indicated in Part 5 of the Rules, details of the loadings together with the calculations of how these will be satisfactorily distributed into the craft's structure, are to be submitted for consideration with the relevant construction plans.

3.6.4 The arrangements indicated in 3.6.5, 3.6.6, 4.18.2 and 4.18.3 for pilot and fishing craft are for the guidance of the Builder and subsequent Owners/operators of the craft. Where the intended service for either of these types of craft, or other types of craft which may be subject to loadings resulting from contact with other craft, jetties or similar loading or boarding facilities, is such that the loadings are greater than those that can be satisfactorily distributed into the craft's structure by the arrangements indicated, then the strengthening arrangements are to be increased accordingly.

3.6.5 For pilot craft which may be subject to repeated impact loadings from contact with other craft etc., the sheerstrake plating is to be increased locally by not less than 50 per cent of the side shell thickness. The increased thickness is to extend from the bow aft over a distance of $0{,}33L_R$ or 500 mm aft of the point which the deckline reaches its greatest breadth whichever is the greater and forward of the quarter and over the transom for a distance of $0{,}075L_R$ or 1,0 m, whichever is the greater. It is in general to extend from the deck edge to below the first longitudinal stiffener, or a vertical distance equivalent to 1/3 the freeboard height whichever is the greater. The additional thickness is then to be tapered out to the side shell thickness in accordance with the Rules.

3.6.6 Fishing craft are in general to have their shell plating scantling as required to satisfy the Rule loadings, increased by 20 per cent. Additionally the side shell is not to be taken less than as bottom shell thickness, and where there are gallows, gantries, nets, or lines etc. the plating in way is to be further increased locally and/or suitably protected by sheathing or other means.

3.6.7 Individual consideration will be given to lesser scantlings than those required by 3.6.3. for fishing craft used for pleasure, light duties, etc. Details of the service are to be submitted.

3.6.8 Where a rounded sheerstrake is adopted the radius, in general, is to be not less than 15 times the thickness.

3.6.9 The sheerstrake thickness is to be increased by 20 per cent at the ends of a bridge superstructure extending out to the craft's side. In the case of a bridge superstructure exceeding $0{,}15L_R$, the side plating at the ends of the superstructure is also to be increased by 25 per cent and tapered gradually into the upper deck sheerstrake.

3.6.10 In general, compensation will not be required for openings in the sheerstrake which are clear of the gunwale or deck openings and whose depth does not exceed 20 per cent of the depth of the sheerstrake. Openings are not to be cut in a rounded gunwale.

3.7 Chines

3.7.1 The chine plate thickness is to be equivalent to the bottom shell thickness required to satisfy the Rule pressure loading, increased by 20 per cent, or 6 mm, whichever is the greater.

3.7.2 Where tube is used in chine construction, the minimum wall thickness is to be not less than the thickness of the bottom shell plating increased by 20 per cent.

3.7.3 Full penetration welding of shell plating in way of chines is always to be maintained.

3.7.4 Chine details are to be such that the continuity of structural strength across the panel is maintained. Details of chines are to be submitted for consideration. *See also* LR's *Guidance Notes for Structural Details*.

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3.8 Skegs

3.8.1 The thickness of the skeg plating is to be not less than the thickness of the adjacent bottom shell and additionally is to satisfy the requirements for sole pieces given in Ch 3,3 of the Rules for Materials.

3.9 Transom

3.9.1 The thickness of the stern or transom is to be not less than that required for the side or bottom shell as appropriate. Where water jet or sterndrive units are fitted, the scantlings of the plating in way of the nozzles and connections will be specially considered.

3.10 Fin and tuck

3.10.1 The thickness of the plating is to be increased locally in way of the fin and tuck areas of yachts which have either internal fixed ballast or external attached ballast keels.

3.10.2 The plating thickness is to be not less than 1,25 times the thickness of the adjacent shell plating but need not be greater than the plate keel thickness as required by 3.2.

3.11 Shell openings

3.11.1 Sea-inlets, or other openings, are to have well rounded corners and, so far as is practicable, are to be kept clear of the bilge radius, chine or radiused sheerstrake. Arrangements are to be made to maintain the strength in way of the openings.

3.11.2 Openings on or near the bilge radius may be accepted provided that they are of elliptical shape, or equivalent, to minimise stress concentrations and are, in general, to be cut clear of weld connections.

3.12 Sea inlet boxes

3.12.1 The thickness of the sea inlet box plating is to be 1 mm thicker than the adjacent shell plating, or 8 mm, whichever is the greater.

3.13 Local reinforcement/insert plates

3.13.1 The thickness of the shell envelope plating determined in accordance with 3.4 and 3.5 is to be increased locally, by generally not less than 50 per cent in way of sternframe, propeller brackets, rudder horn, stabilisers, hawse pipes and anchor recess. Details of such reinforcement are to be submitted for approval.

3.13.2 Insert plates are to extend outside the line of adjacent supporting structure and then be tapered over a distance of not less than three times the difference in thickness, *see also* Ch 2,4.21.

3.14 Appendages

3.14.1 The scantlings of appendages will be subject to special consideration on the basis of the Rules and the design loadings anticipated, but in no case are to be taken as less than that of the surrounding structure.

3.15 Fender attachment

3.15.1 Wood belting and fenders are to be bolted to lugs welded to a ground bar attached to the shell and not through-bolted to the shell plating.

3.16 Novel features

3.16.1 Where the Rules do not specifically define the requirements for novel features then the scantlings and arrangements are to be determined by direct calculation. Such calculations are to be carried out on the basis of the Rules or recognised standards. Details are to be submitted for consideration.

■ *Section 4*
Shell envelope framing

4.1 General

4.1.1 The requirements in this Section apply to longitudinally and transversely framed shell envelopes.

4.1.2 For each stiffening member an assumed load model is stated. Where the proposed stiffener arrangement differs from that assumed, consideration will be given to an alternative load model.

4.1.3 The geometric properties of stiffener sections are to be in accordance with 1.18.

4.2 Bottom longitudinal stiffeners

4.2.1 Bottom longitudinal stiffeners are to be supported by bottom transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.2.2 Bottom longitudinals are to be continuous through the supporting structures.

4.2.3 Where it is impracticable to comply with the requirements of 4.2.2, or where it is proposed to terminate the bottom longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets.

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4.2.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b).

4.3 Bottom longitudinal primary stiffeners

4.3.1 Bottom longitudinal primary stiffeners are to be supported by bottom deep transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 6 m apart.

4.3.2 Bottom longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

4.3.3 Where it is impracticable to comply with the requirements of 4.3.2, or where it is proposed to terminate the stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.3.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

4.4 Bottom transverse stiffeners

4.4.1 Bottom transverse stiffeners are defined as local stiffening members which support the bottom shell, and which may be continuous or intercostal.

4.4.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b).

4.5 Bottom transverse frames

4.5.1 Bottom transverse frames are defined as stiffening members which support the bottom shell. They are to be effectively continuous and bracketed at their end connections to side frames and bottom floors as appropriate.

4.5.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

4.6 Bottom transverse web frames

4.6.1 Bottom transverse web frames are defined as primary stiffening members which support bottom shell longitudinals. They are to be continuous and substantially bracketed at their end connections to side web frames and bottom floors.

4.6.2 Where it is impracticable to comply with the requirements of 4.6.1, or where it is proposed to terminate the bottom transverse web frames in way of longitudinal primary girders bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.6.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

4.7 Side longitudinal stiffeners

4.7.1 The side longitudinal stiffeners are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.7.2 Side longitudinals are to be continuous through the supporting structures.

4.7.3 Where it is impracticable to comply with the requirements of 4.7.2, or where it is proposed to terminate the side longitudinal in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.7.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b).

4.8 Side longitudinal primary stiffeners

4.8.1 Side longitudinal primary stiffeners are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 6 m apart.

4.8.2 Side longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

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4.8.3 Where it is impracticable to comply with the requirements of 4.8.2, or where it is proposed to terminate the side longitudinally in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.8.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

4.9 Side transverse stiffeners

4.9.1 Side transverse stiffeners are defined as local stiffening members supporting the side shell and may be continuous or intercostal.

4.9.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b).

4.10 Side transverse frames

4.10.1 Side transverse frames are defined as stiffening members supporting the side shell and spanning continuously between bottom floors/frames and decks. They are to be effectively constrained against rotation at their end connections.

4.10.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

4.11 Side transverse web frames

4.11.1 Side transverse web frames are defined as primary stiffening members which support side shell longitudinally. They are to be continuous and substantially bracketed at their head and heel connections to deck transverses and bottom web frames respectively.

4.11.2 Where it is impracticable to comply with the requirements of 4.11.1, or where it is proposed to terminate the web frames in way of side longitudinal primary stiffeners bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.11.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

4.12 Grouped frames

4.12.1 For the purposes of satisfying Rule scantling requirements, frames may, subject to agreement by LR, be grouped. The number of frames in any group shall not in general exceed five. The summation of the section moduli and inertia for the group of frames is not to be less than the summation of the Rule requirement for the individual framing members. In addition, in no case is the proposed scantling of an individual framing member within the group to be less than ninety per cent of the Rule value for that member.

4.13 Grillage structures

4.13.1 For complex girder systems, a complete structural analysis using numerical methods may have to be performed to demonstrate that the stress levels are acceptable when subjected to the most severe and realistic combination of loading conditions intended.

4.13.2 General or special purpose computer programs or any other analytical techniques may be used provided that the effects of bending, shear, axial and torsion are properly accounted for and the theory and idealisation used can be justified.

4.13.3 In general, grillages consisting of slender girders may be idealised as frames based on beam theory provided proper account of the variations of geometric properties is taken. For cases where such an assumption is not applicable, finite element analysis or equivalent methods may have to be used.

4.14 Combined framing systems

4.14.1 Where longitudinal and transverse primary stiffeners form grillage structures the scantlings may be derived in accordance with 4.13.

4.15 Floating framing systems

4.15.1 Floating framing systems, where proposed, will be subject to special consideration.

4.16 Frame struts

4.16.1 Where struts are fitted to side shell transverse web frames or longitudinal primary stiffeners to carry axial loads, the strut cross-sectional area is to be derived as for pillars in Section 10. If fitted at the stiffener half span point the stiffener section modulus may be taken as half the modulus derived above.

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4.16.2 Design of end connections is to be such that the area of the welding is to be not less than the minimum cross-sectional area of the strut derived in 4.16.1. To achieve this full penetration welding may be required. The weld connections between the face flats and webs of the pillar supporting structure are to be welded using double continuous welding of an equivalent area to that derived by 4.16.1.

4.17 Arrangements and details

4.17.1 The arrangement of the connection between the stiffener and the bracket is to be such that at no point in the connection are the section modulus and inertia reduced to less than that of the stiffener with associated plating.

4.17.2 The web stability, openings in the web and continuity and alignment are to be in accordance with 1.24, 1.25 and 1.26 respectively.

4.17.3 Secondary and primary end connections and arrangements at intersection of continuous secondary and primary members are to be in accordance with 1.20, 1.22 and 1.28 respectively.

4.17.4 Stiffeners in slamming areas are to be lugged or bracketed.

4.18 Structure in way of fenders

4.18.1 For craft, including pilot craft and fishing craft, which may be subject to repeated impact loadings from contact with other craft whilst in service, due consideration is to be given to increasing the scantlings of stiffening members in way of fenders. Details of anticipated loadings and calculations for the required increased scantlings are to be submitted, *see also* 3.6.3 and 3.6.4.

4.18.2 **Pilot craft** are to be fitted with large knees in way of the sheerstrake in areas as indicated in 3.6. The knees are to be aligned between the transverse frames and the deck beams. In the case of longitudinally framed craft, intermediate knees are to be fitted with a spacing in general not greater than 500 mm. Where such intermediate brackets are fitted they are to terminate on a side longitudinal with a section modulus of, in general, twice that of the Rule longitudinal for the web frame spacing, and a deck longitudinal. The side longitudinal is to be positioned below any fendering to carry the heel of the knee. Consideration will given to the termination of such brackets by use of a 'soft-toe' in way of the deck. The thickness of the webs for these knees is to be twice that required by 1.21.

4.18.3 **Fishing craft** engaged in pair trawling and other modes of fishing, and which may be subject to repeated impact loading from contact with the other craft are to have additional stiffening fitted in way of the impact areas. This may be in the form of large knees, intermediate knees, substantial fendering/ rubbing strakes.

4.19 Novel features

4.19.1 The scantlings are to be determined by direct calculation where the shell framing is of unusual design, form or proportions.

■ *Section 5*
Single bottom structure and appendages

5.1 General

5.1.1 The requirements of this Section provide for single bottom construction in association with transverse and longitudinal framing systems.

5.1.2 All girders are to extend as far forward and aft as practicable and care is to be taken to avoid any abrupt discontinuity. Where girders are cut at bulkheads, their longitudinal strength is to be maintained.

5.1.3 Particular attention is to be taken to ensure that the continuity of structural strength in way of the intersection of transverse floors and longitudinal girders is maintained. The face flats of such stiffening members are to be effectively connected.

5.1.4 The single bottom structure in way of the keel and girders is to be sufficient to withstand the forces imposed by dry-docking the craft.

5.1.5 The scantlings of the single bottom structure are to comply with the appropriate minimum requirements given in Section 2.

5.2 Keel

5.2.1 The breadth, and thickness of plate keels are to comply with the requirements of 3.2.

5.2.2 The cross-sectional area, A_k, and thickness, t_k, of bar keels are not, in general, be taken as less than:

$$A_k = k_a(1{,}85L_R + 2) \text{ cm}^2$$

$$t_k = \sqrt{k_a}\,(0{,}7L_R + 8{,}25) \text{ mm}$$

where

L_R and k_a are as defined in 1.5.1.

5.3 Centre girder

5.3.1 A centreline girder is, in general, to be fitted throughout the length of the hull in association with transverse frames, transverses supporting longitudinals or where the breadth of floors at the upper edge is greater than 1,5 m.

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5.3.2 Centreline girders are to be formed of intercostal or continuous plate webs with a face flat welded to the upper edge. In all cases the face flat is to be continuous. Where girder webs are intercostal, additional bracketing and local reinforcement will be required to maintain the continuity of structural strength.

5.3.3 The web depth of the centre girder is, in general, to be equal to the depth of the floors at the centreline as specified in 5.5.3.

5.3.4 The web thickness, t_w, is to be taken not less than:

$$t_w = 1{,}4\sqrt{k_a}\ (\sqrt{L_R} + 1)\ \text{mm}$$

where

L_R and k_a are as defined in 1.5.1.

5.3.5 The geometric properties of the centre girder are to be in accordance with 1.18.

5.3.6 The face flat area of the centre girder, A_f, is to be not less than:

$$A_f = 0{,}56 L_R k_a\ \text{cm}^2.$$

5.3.7 The face flat area of the centre girder outside $0{,}5L_R$ amidships may be 80 per cent of the value given in 5.3.6.

5.3.8 The face flat thickness is to be not less than the thickness of the web.

5.3.9 The ratio of the width to thickness of the face flat is to be not less than eight but should not exceed 16.

5.3.10 Additionally, the requirements of 4.3 for bottom longitudinal primary stiffeners are to be complied with.

5.4 Side girders

5.4.1 Where the floor breadth at the upper edge exceeds 6,0 m side girders are to be fitted at each side of the centre girder such that the spacing between the side and centre girders or between the side girders themselves is not greater than 3 m. Side girders where fitted are to extend as far forward and aft as practicable and are, in general, to terminate in way of bulkheads, deep floors or other primary transverse structure.

5.4.2 The web thickness of side girders is to be taken as not less than:

$$t_w = 1{,}4\sqrt{k_a L_R}\ \text{mm}$$

where

L_R and k_a are as defined in 1.5.1.

5.4.3 The face flat area and thickness of side girders are to comply with the requirements for plate floors as defined in 5.5.6 and 5.5.7.

5.4.4 Watertight side girders, and side girders forming the boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads and deeptanks as detailed in 7.3 and 7.5 respectively.

5.4.5 In the engineroom, additional side girders are generally to be fitted in way of main machinery seatings. Where fitted, they are to be integrated into the structure of the craft and extended forward and aft as far as practicable.

5.4.6 Additionally, the requirements of 4.3 for bottom longitudinal primary stiffeners are to be complied with.

5.5 Floors general

5.5.1 In transversely framed craft, plate floors are generally to be fitted at each frame.

5.5.2 In longitudinally framed craft, plate floors are to be fitted at every transverse web and generally at a spacing not exceeding 2 m. Additional transverse floors or webs are in general to be fitted at half web-frame spacing in way of engine seatings and thrust bearings, pillars, skegs, ballast/bilge keels and the bottom of the craft forward.

5.5.3 The overall depth, d_f, of plate floors at the centreline is not to be taken as less than:

when $B < 10$ m $\quad d_f = 40(B + 0{,}85D)$ mm

when $B \geq 10$ m $\quad d_f = 40(1{,}5B + 0{,}85D) - 200$ mm

where

D is defined in Pt 3, Ch 1,6.2.8.

5.5.4 The web thickness, t_w, of plate floors, is to be accordance with 1.18 and is to be taken as not less than:

$$t_w = \sqrt{k_a}\left(\frac{4{,}7 d_f}{1000} + 3{,}1\right)\left(\frac{s}{1000} + 0{,}5\right)\ \text{mm}$$

where

d_f is to be determined from 5.5.3

k_a and s are as defined in 1.5.1.

5.5.5 If the side frames of the craft are attached to the floors by brackets, the depth of floor may be reduced by 15 per cent and the floor thickness determined using the reduced depth. The brackets are to be flanged and have the same thickness as the floors, and their arm lengths clear of the frame are to be the same as the reduced floor depth given above.

5.5.6 The face flat area of floors, A_f, is not to be taken as less than:

$$A_f = 0{,}28 k_a L_R\ \text{cm}^2$$

where

k_a and L_R are defined in 1.5.1.

5.5.7 The face flat thickness is to be not less than the thickness of the web and the ratio of the web to the thickness of the face flat is to be not less than eight but is not to exceed 16.

5.5.8 Additionally the requirements of 4.6 for bottom transverse web frames are to be complied with.

5.5.9 Floors are generally to be continuous from side to side.

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5.5.10 The tops of floors, in general, may be level from side to side. However, in craft having considerable rise of floor the depth of the floor plate may require to be increased to maintain the required section modulus.

5.5.11 The floors in the aft peak are to extend over and provide effective support to the stern tube(s) where applicable.

5.5.12 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deeptanks as detailed in 7.3 and 7.5.

5.6 Floors in machinery spaces

5.6.1 The thickness, t_w, of the floors in machinery spaces is to be 1 mm greater than that required by 5.5.4.

5.6.2 The depth and section modulus of floors anywhere between engine or gearbox girders is to be not less than that required to maintain continuity of structural integrity or 50 per cent of the depth given in 5.5.3. The face flat area and web thickness for such reduced floor heights are to be increased appropriately in order to maintain continuity of structural strength, *see also* 4.12.

5.7 Machinery seatings

5.7.1 The general requirements for machinery seatings are given in Pt 3, Ch 2,6.9, *see also* Pt 9, Ch 1,5.

5.7.2 Engine holding-down bolts are to be arranged as near as practicable to floors and longitudinal girders. When this cannot be achieved, bracket floors are to be fitted.

5.7.3 Welding in way of machinery seatings is to be double continuous and/or full penetration where appropriate.

5.8 Drainholes in bottom structure

5.8.1 Sufficient limber holes are to be cut in the internal bottom structure to allow for the drainage of water from all parts of the bilge to the pump suctions.

5.8.2 Particular attention is to be given to the positioning of limber holes to ensure adequate drainage and to avoid stress concentrations.

5.8.3 Suitable arrangements are to be made to provide free passage of air from all parts of tanks to the air pipes.

5.9 Rudder horns

5.9.1 The shell plating thickness in way of the rudder horn is to be increased locally, by generally not less than 50 per cent but need not to be taken as greater than the keel thickness required by 3.2.

5.9.2 The scantlings of the rudder horn are to be such that the section modulus against transverse bending at any horizontal section XX (*see* Fig. 3.5.1) is not less than:

$$Z = 2{,}8 k_a R_A K_V (V + 3)^2 \sqrt{a^2 + 0{,}5b^2} \quad \text{cm}^3$$

where

R_A = total rudder area, in m^2

V = Maximum speed in the fully loaded condition, in knots

K_V = 1,0 for displacement craft with $\frac{V}{\sqrt{L_{WL}}} < 3{,}0$

= $(1{,}12 - 0{,}005V)^3$ for planing and semi-planing craft with $\frac{V}{\sqrt{L_{WL}}} \geq 3{,}0$

a, b = dimensions, in metres, as given in Fig. 3.5.1

L_{WL} = waterline length as defined in Pt 3, Ch 1,6.2.5.

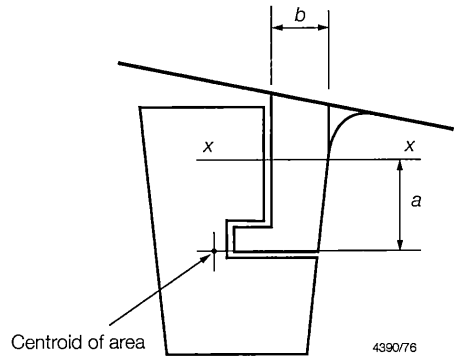

Fig. 3.5.1 Rudder horn

5.9.3 Rudder horns are to be effectively integrated into the adjacent structure and their design is to be such as to facilitate this.

5.10 Sternframes

5.10.1 The scantlings of fabricated and forged/solid sternframes are to comply with the requirements of Pt 3, Ch 3,3 modified for appropriate grade of aluminium in accordance with Pt 3, Ch 3,1.2.

5.11 Skeg construction

5.11.1 Skegs are to be effectively integrated into the adjacent structure and their design is to be such as to facilitate this.

5.11.2 The scantlings and arrangements for skegs (solepieces) are to be in accordance with Pt 3, Ch 3,3.14.

5.11.3 The scantlings of skegs are to be sufficient to withstand any docking forces that they may be subjected to.

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5.12 Forefoot and stem

5.12.1 The thickness of plate stems at the waterline is to comply with the requirements for plate keels as given in 3.2.

5.12.2 The forefoot and stem is to be additionally reinforced with floors.

5.12.3 The cross-sectional area of bar stems, A_{bs}, is not to be taken as less than:

$$A_{bs} = 1{,}5k_a L_R \text{ cm}^2$$

where

L_R and k_a are as defined in 1.5.1.

5.13 Transom knee

5.13.1 Centre and side girders are to be bracketed to the transom framing members by means of substantial knees. The face flat of the girders may be gradually reduced to that of the transom stiffening members in accordance with Fig. 3.5.2.

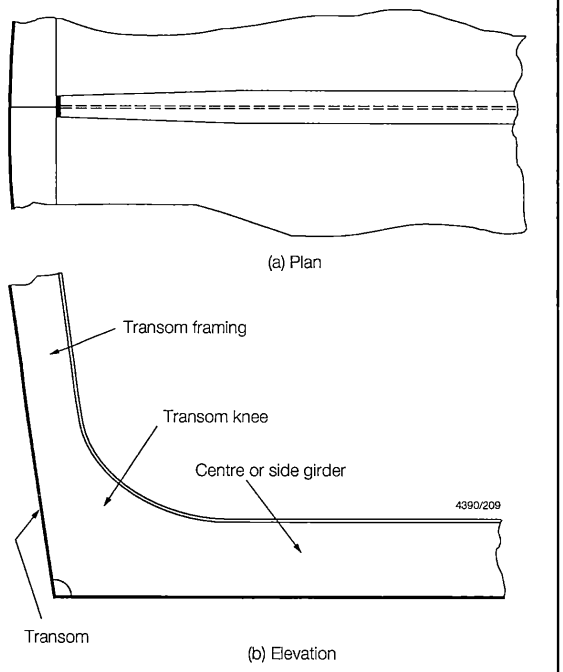

Fig. 3.5.2 Transom knee

5.13.2 Hard spots are to be avoided in way of the end connections and care is to be taken to ensure that the stiffening member to which the transom knee is bracketed can satisfactorily carry the transmitted loads.

Section 6
Double bottom structure

6.1 General

6.1.1 The requirements given in this Section provide for double bottom construction of aluminium mono-hull craft in association with either transverse or longitudinal framing.

6.1.2 Double bottoms are generally to be fitted in accordance with Pt 3, Ch 2,6.6 and where fitted are to extend from the collision bulkhead to the after peak bulkhead, as far as this is practicable within the design and proper working of the craft. In addition, the inner bottom is to be continued to the craft's side in such a manner as to protect the bottom to the turn of bilge or chine.

6.1.3 The double bottom structure in way of girders and duct keels is to be sufficient to withstand the forces imposed by dry-docking the craft.

6.1.4 The centreline girder and side girders are to extend as far forward and aft as practicable and care is to be taken to avoid any abrupt discontinuity. Where girders are cut at bulkheads, their longitudinal strength is to be maintained.

6.1.5 The scantlings of the double bottom structure are to comply with the appropriate minimum requirements given in Section 2.

6.2 Keel

6.2.1 The scantlings of bar and plate keels are to comply with the requirements of 5.3.

6.2.2 Duct keels, where arranged, are to have a side plate thickness not less than:

$$t = \sqrt{k_a}\ (0{,}01d_{DB} + 2) \text{ mm}$$

but need not be taken as greater than 90 per cent of the centre girder thickness given in 6.3.

d_{DB} is the Rule centre girder depth given in 6.3.3

k_a is as defined in 1.5.1.

6.2.3 Where a duct keel forms the boundary of a tank, the requirements of 7.4 and 7.5 for deep tanks are to be complied with.

6.2.4 The duct keel width is in general to be 15 per cent of the beam or 2 m, whichever is the lesser, but in no case is it to be taken as less than 630 mm. The inner bottom and bottom shell within the duct keel are to be suitably stiffened with primary stiffening in the transverse direction, whilst the continuity of the floors is maintained. Access to the duct keel is to be by means of watertight manholes or trunks.

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6.3 Centre girder

6.3.1 A centre girder is to be fitted throughout the length of the craft. The web thickness, t_w, is not to be less than that required by:

$t_w = \sqrt{k_a}\ (0{,}14L_R + 4)$ mm within $0{,}4L_R$ amidships

$= \sqrt{k_a}\ (0{,}14\ L_R + 2{,}75)$ mm at ends.

where

k_a and L_R are as defined in 1.5.1.

6.3.2 The geometric properties of the girder section are to be in accordance with 1.18.

6.3.3 The overall depth of the centre girder, d_{DB}, is to be taken as not less than 630 mm and is to be sufficient to give adequate access to all parts of the double bottom.

6.3.4 Additionally, the requirements of 4.3 for bottom longitudinal primary stiffeners are to be complied with.

6.4 Side girders

6.4.1 Where the floor breadth does not exceed 6,0 m, side girders are not required. Vertical stiffeners are to be fitted to the floors on each side, the number and positions of these stiffeners being dependent on the arrangement of the double bottom structure.

6.4.2 Where the breadth of floor is greater than 6,0 m, additional side girders having the same thickness as the floors are to be fitted. The number of side girders is to be such that the distance between the side girders and centre girder and margin plate, or between the side girders themselves, does not exceed 3,0 m.

6.4.3 Side girders where fitted are to extend as far forward and aft as practicable and are in general to terminate in way of bulkheads, deep floors or other primary transverse structure.

6.4.4 Where additional side girders are fitted in way of main machinery seatings, they are to be integrated into the structure of the craft and extended forward and aft as far as practicable.

6.4.5 Under the main engine, girders extending from the bottom shell to the top plate of the engine seating are to be fitted. The height of the girders is to be not less than the height of the floor. Engine holding-down bolts are to be arranged as near as practicable to the girders and floors. Where this cannot be achieved, bracket floors and/or hanging brackets are to be fitted.

6.4.6 Additionally, the requirements of 4.3 for bottom longitudinal primary stiffeners are to be complied with.

6.5 Plate floors

6.5.1 The web thickness of non-watertight plate floors, t_w, is to be not less than:

$t_w = \sqrt{k_a}\ (0{,}07L_R + 4{,}75)$ mm

where

k_a and L are as defined in 1.5.1.

6.5.2 Additionally, the requirements of 4.6 for bottom transverse web frames stiffeners are to be complied with.

6.5.3 Plate floors are, in general, to be continuous between the centre girder and the margin plate.

6.5.4 In longitudinally framed craft, plate floors or equivalent structure are in general to be fitted in the following positions:

(a) At every half frame in way of the main engines, thrust bearings and bottom of the craft forward.
(b) Outboard of the engine seatings, at every frame within the engine room.
(c) Underneath pillars and bulkheads.
(d) Outside of the engine room at a spacing not exceeding 2,0 m.

6.5.5 Vertical flat bar stiffeners are to be fitted to all plate floors at each longitudinal. Each stiffener is to have a depth of not less than $10t_w$ and a thickness of not less than t_w, where t_w is thickness of the plate floor as calculated in 6.5.1.

6.5.6 In transversely framed craft, plate floors are to be fitted at every frame in the engine room, under bulkheads, in way of change in depth of double bottom and elsewhere at a spacing not exceeding 2,0 m.

6.6 Bracket floors

6.6.1 Between plate floors, the shell and inner bottom plating is to be supported by bracket floors. The brackets are to have the same thickness as plate floors and are to be stiffened on the unsupported edge.

6.6.2 In longitudinally framed craft, the brackets are to extend from the centre girder and margin plate to the adjacent longitudinal, but in no case is the breadth of the bracket to be taken as not less than 75 per cent of the depth of the centre girder. They are to be fitted at every web frame at the margin plate, and those at the centre girder are to be spaced not more than 1,0 m apart.

6.6.3 In transversely framed craft, the breadth of the brackets, attaching the bottom and inner bottom frames to the centre girder and margin plate, is to be not less than 75 per cent of the depth of the centre girder.

6.7 Watertight floors

6.7.1 The scantlings of watertight floors are to comply with the requirements for plate floors as given in 6.5.

6.7.2 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deep tanks as detailed in 7.3 or 7.5 respectively.

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6.8 Tankside brackets

6.8.1 The scantlings of tankside brackets are to comply with the requirements for plate floors given in 6.5.

6.9 Inner bottom plating

6.9.1 The thickness of the inner bottom plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

6.9.2 Inner bottom plating forming the boundaries of tank spaces is, in addition, to comply with the requirements for watertight bulkheads or deeptanks as detailed in 7.2 or 7.4 respectively. Where the plating forms vehicle, passenger or other decks the requirements of Section 8 are to be complied with.

6.9.3 Inner bottom longitudinals are to be supported by inner bottom transverse web frames, floors, bulkheads or other primary structure, generally spaced not more than 2 m apart.

6.9.4 The inner bottom longitudinals are to be continuous through the supporting structure and are to be satisfactorily stiffened against buckling.

6.9.5 Where it is impracticable to comply with the requirements of 6.9.4, or where it is desired to terminate the inner bottom longitudinals in way of bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

6.9.6 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b).

6.10 Inner bottom transverse web framing

6.10.1 Inner bottom transverse web frames are defined as primary stiffening members which support inner bottom longitudinals. They are to be continuous and to be substantially bracketed at their end connections to bottom web frames, bottom floors and tankside brackets.

6.10.2 Where it is impracticable to comply with the requirements of 6.10.1, or where it is desired to terminate the inner bottom transverse web frames in way of centre or side girders, bulkheads or integral tank boundaries, etc., they are to be bracketed in way of their end connections, to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

6.10.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

6.11 Margin plates

6.11.1 A margin plate, if fitted, is to have a thickness as required for inner bottom plating.

6.12 Wells

6.12.1 Small wells constructed in the double bottom structure are not to extend in depth more than necessary. A well extending to the outer bottom may, however, be permitted at the after end of the shaft tunnel of the craft. Other well arrangements (e.g. for lubricating oil under main engines) may be considered provided they give protection equivalent to that afforded by the double bottom.

6.13 Transmission of pillar loads

6.13.1 In double bottoms under widely spaced pillars, the connections of the floors to the girders, and of the floors and girders to the inner bottom, are to be suitably increased. Where pillars are not directly above the intersection of plate floors and girders, partial floors and intercostals are to be fitted as necessary to support the pillars. Manholes are not to be cut in the floors and girders below the heels of pillars. Where longitudinal framing is adopted in the double bottom, equivalent stiffening under the heels of pillars is to be provided, and where the heels of pillars are carried on a tunnel, suitable arrangements are to be made to support the load.

6.14 Manholes

6.14.1 Sufficient manholes are to be cut in the inner bottom, floors and side girders to provide adequate access to, and ventilation of, all parts of the double bottom. The size of the manhole openings is not, in general, to exceed 50 per cent of the double bottom depth unless edge reinforcement is provided. Holes are not to be cut in the centre girder, except in tanks at the forward and after ends of the craft, and elsewhere where tank widths are reduced unless additional stiffening and/or compensation is fitted to maintain the structural integrity.

6.15 Pressure testing

6.15.1 Double bottoms are to be tested upon completion with a head of water representing the maximum internal pressure which could be experienced in service, but not less than a head of water equivalent to the level of the upper deck.

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6.16 Drainholes in bottom structure

6.16.1 Sufficient limber holes are to be cut in the internal bottom structure to allow for the drainage of water from all parts of the bilge to the pump suctions.

6.16.2 Particular care is to be given to the positioning of limber holes to ensure adequate drainage and to avoid stress concentrations.

6.16.3 Suitable arrangements are to be made to provide free passage of air from all parts of tanks to the air pipes.

■ *Section 7* Bulkheads

7.1 General

7.1.1 The requirements of this Section apply to a vertical system of stiffening on bulkheads. They may also be applied to a horizontal system of stiffening provided that equivalent support and alignment are provided.

7.1.2 The number and disposition of transverse watertight bulkheads are to be in accordance with Pt 3, Ch 2,4.

7.1.3 Bulkheads, or part bulkheads, forming the boundary of tanks are to comply with the requirements of 7.5 and 7.6.

7.1.4 For bulkheads in way of partially filled holds or tanks, sloshing forces may be required to be taken into account. Where such forces are likely to be significant, the scantlings will be required to be verified by additional calculations.

7.1.5 A centreline bulkhead is, generally, to be fitted in deep tanks which extend from side to side. The bulkhead may be intact or perforated as desired. If intact, the scantlings are to comply with the requirements of 7.5 and 7.6 for tank boundary bulkheads. If perforated, they are to comply with the requirements of 7.13 for washplates.

7.1.6 The minimum requirements in Section 2 are to be complied with.

7.2 Watertight bulkhead plating

7.2.1 The thickness of the watertight bulkhead plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5 Ch 4,3.1 for non-displacement or displacement craft as appropriate.

7.3 Watertight bulkhead stiffening

7.3.1 The Rule requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 using the appropriate load model.

7.3.2 Bulkheads are to be suitably strengthened, if necessary, at the ends of deck girders and where subjected to concentrated loads.

7.4 Deep tank plating

7.4.1 The thickness of deep tank plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

7.5 Deep tank stiffening

7.5.1 Deep tank bulkhead stiffeners are to be bracketed at both ends. The thickness of the brackets is to be not less than the web thickness of the stiffener.

7.5.2 The Rule requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for load model (b).

7.6 Double bottom tanks

7.6.1 The scantlings of double bottom tanks are to comply with the requirements for deep tanks given in 7.4 and 7.5.

7.6.2 Where the crown of a double bottom tank forms a vehicle, passenger or other deck, the requirements of Section 8 are to be complied with.

7.7 Collision bulkheads

7.7.1 The scantlings of collision bulkheads are to comply with the requirements of 7.2 and 7.3 except that the thickness of plating and modulus of stiffeners are not to be less than 12 and 25 per cent greater respectively, than required by 7.2 and 7.3. If the collision bulkhead forms the boundary of a deep tank or cofferdam then the requirements of 7.4 and 7.5 are also to be complied with.

7.8 Gastight bulkheads

7.8.1 Where gastight bulkheads are fitted, in accordance with Pt 3, Ch 2,4 the scantling requirements for watertight bulkheads are to be complied with.

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7.8.2 Gastight bulkheads are to be fitted to protect accommodation spaces from gases and vapour fumes from machinery exhaust and fuel systems.

7.9 Non-watertight or partial bulkheads

7.9.1 Where a bulkhead is structural but non-watertight the scantlings are in general to be as for watertight bulkheads or equivalent in strength to web frames in the same position. Partial bulkheads that are non-structural are outside the scope of classification.

7.10 Transmission of pillar loads

7.10.1 Bulkheads that are required to act as pillars in way of underdeck girders and other structures subject to heavy loads are to comply with the requirements of Section 10.

7.11 Corrugated bulkheads

7.11.1 The plating thickness and section modulus for symmetrical corrugated bulkheads are to be in accordance with watertight bulkheads or deep tank bulkheads as appropriate. The spacing, s, is to be taken as s_c, as defined in Fig. 2.3.1 in Pt 3, Ch 2.

7.11.2 In addition, the section geometric properties of 1.18 are to be complied with.

7.11.3 The actual section modulus may be derived in accordance with Pt 3, Ch 2,3.2.

7.12 Stiffeners passing through bulkheads

7.12.1 Primary longitudinal stiffening members are to be continuous through transverse bulkheads.

7.12.2 Pipe or cable runs through watertight bulkheads are to be fitted with suitable watertight glands.

7.13 Wash plates

7.13.1 Tanks are to be subdivided as necessary by internal baffles or wash plates. Baffles or wash plates which support hull framing are to have scantlings equivalent to web frames in the same position.

7.13.2 Wash plates and wash bulkheads are, in general, to have an area of perforation not less than 10 per cent of the total area of the bulkhead. The perforations are to be so arranged that the efficiency of the bulkhead as a support is not impaired.

7.13.3 The plate thickness is to be not less than the structural element from which the wash bulkhead is formed.

7.13.4 The general stiffener requirements are to be in accordance with 7.5. However, the section modulus may be 50 per cent of that required by 7.5.

7.14 Cofferdams

7.14.1 A cofferdam is to be fitted between freshwater and oil fuel or sanitary tanks. The scantlings of cofferdams are to comply with the requirements of deep tank bulkheads or non-watertight bulkheads as appropriate.

7.15 Coatings

7.15.1 Integral freshwater and oil fuel tanks need not in general be coated provided they are constructed from suitable marine grade aluminium alloys in accordance with Chapter 8 of the Rules for Materials. Where tanks are to be coated, then all surfaces are to be cleaned and dried after testing and then treated with a suitable coating in accordance with the coating manufacturer's recommendations. *See* Ch 2,2.6.

7.16 Air pipes

7.16.1 Air pipes of sufficient number and area are to be fitted to each tank in accordance with Pt 15, Ch 2,11.

7.17 Fire protection

7.17.1 Fire protection requirements given in Part 17 are to be complied with.

7.18 Access

7.18.1 Compartments within the craft are to be accessible in order to facilitate proper maintenance and future structural surveys. Linings on craft sides, deckheads and bulkheads, etc., must be capable of being removed. Similarly sufficient space must be available below lower decks/soles to provide proper access to the bottom structure. An adequate number of manholes, removable panels etc. are to be provided.

7.18.2 Doors and hatches fitted through watertight bulkheads are to be of equivalent construction to the bulkhead in which they are fitted, to be permanently attached and capable of being closed watertight from both sides of the bulkhead. They are to be tested watertight.

7.18.3 Doors and hatches are not to be fitted in collision bulkheads, except in craft of less than 21 m Rule length or where it would be impracticable to arrange access to the forepeak other than through the collision bulkhead. Where fitted, the doors and hatches are to be watertight, as small as practicable and open into the forepaw compartment. Doors in collision bulkheads are to be kept closed at all times while the craft is at sea, *see* Pt 3, Ch 2,4.3.4.

7.18.4 Particular attention is to be given to the design and workmanship of the tanks, and adequate access manholes are to be fitted, *see* Pt 3, Ch 1,7.

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7.19 Testing

7.19.1 Deep tanks are to be tested on completion, with a head of water to the top of the overflow, or 1,8 m above the crown of the tank, whichever is the greater, The pressure to which the tanks will be subjected in service is to be indicated on the plans submitted.

■ *Section 8*
Deck structures

8.1 General

8.1.1 The deck plating is to be supported by transverse beams with fore and aft girders or by longitudinals with deep transverse beams. The transverse and deep transverse beams are to align with side main frames and side web frames respectively.

8.1.2 Beams are to be fitted at every frame and bracketed to the frames. Strong beams and deep transverse beams are to align with and be effectively connected to the side web frames. They are also to be fitted at the ends of large openings in the deck.

8.1.3 The deck plating and supporting structure are to be suitably reinforced in way of cranes, masts, derrick posts and deck machinery.

8.1.4 Primary stiffening members are to be continuous and substantially bracketed at their end connections to maintain continuity of structural strength.

8.1.5 Secondary stiffening members are to be effectively continuous and bracketed at their end connections as appropriate.

8.1.6 Primary and secondary stiffener end connection arrangements are, in general, to be in accordance with 1.22 and 1.20, respectively.

8.1.7 The ends of beams, longitudinals, girders and transverses are to be effectively built into the adjacent structure, or equivalent arrangements provided.

8.1.8 Tripping brackets are to be fitted on deep webs.

8.1.9 Deck structures subject to concentrated loads, are to be suitably reinforced. Where concentrations of loading on one side of a stiffening member may occur, such as pillars out of line, the member is to be adequately stiffened against torsion. Additional reinforcements may be required in way of localised areas of high stress.

8.1.10 The thickness of the deck plating is in no case to be less than the appropriate minimum requirement given in Section 2.

8.1.11 The geometric properties of stiffener sections are to be in accordance with 1.18.

8.2 Strength/weather deck plating

8.2.1 The thickness of strength/weather deck plating is to be determined from the general plating equation given in 1.16 using the design pressure head from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

8.2.2 The scantlings of watertight cockpits are to be of equivalent strength to those of the strength/weather deck. *See also* Part 4.

8.2.3 It is recommended that the working areas of the weather deck have an anti-slip surface.

8.2.4 Where decks are sheathed with wood or other materials, details of the method of attachment are to be submitted. *See also* 2.4.

8.3 Lower deck/inside deckhouse plating

8.3.1 The thickness of the lower deck/inside deckhouse plating is to be determined from the general plating equation given in 1.16 using the design pressure head from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

8.4 Accommodation deck plating

8.4.1 Accommodation decks are in general to be treated as lower deck/inside deckhouse decks, with their plating requirements determined in accordance with 8.3.

8.5 Cargo deck plating

8.5.1 The thickness of cargo deck plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

8.5.2 For vehicle decks, the plating thickness is to comply with the requirements of Ch 5,3.

8.6 Decks forming crowns of tanks

8.6.1 Decks forming the crown of tanks are to comply with the requirements for the appropriate deck, and are to be additionally examined for compliance with the requirements for deep tank plating given in 7.4.

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8.7 Strength/weather deck stiffening

8.7.1 The Rule requirements for section modulus, inertia and web area for the **strength/weather deck primary stiffening** are to be determined from the general equations given in 1.17, using the design pressure heads from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

8.7.2 The Rule requirements for section modulus, inertia and web area for the **strength/weather deck secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.7.3 Longitudinal framing is, in general, to be adopted at the strength deck outside line of openings, but special consideration will be given to proposals for transverse framing.

8.8 Lower deck/inside deckhouse stiffening

8.8.1 The Rule requirements for section modulus, inertia and web area for lower deck/inside deckhouse stiffening are to be determined from the general equations given in 1.17 using the design pressure head from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1. Primary members are assumed to be load model (a) and secondary members load model (b). However, special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.9 Accommodation deck stiffening

8.9.1 Accommodation decks are in general to be treated as lower deck/inside deckhouse decks, with their scantling requirements determined in accordance with 8.8.

8.10 Cargo deck stiffening

8.10.1 The Rule requirements for section modulus, inertia and web area for cargo deck stiffening are to be determined from the general equations given in 1.17 using the design pressure head from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1. Primary members are assumed to be load model (a) and secondary members load model (b). However, special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.10.2 In addition, where the cargo comprises wheeled vehicles, the requirements of Ch 5,3 are to be complied with.

8.11 Deck openings

8.11.1 All openings are to be supported by an adequate framing system, pillars or cantilevers. When cantilevers are used scantlings may be derived from direct calculations.

8.11.2 Where stiffening members terminate in way of an opening they are to be attached to carlings, girders, transverses or coaming plates.

8.11.3 The corners of large hatchways in the strength/weather deck within $0{,}5L_R$ amidships are to be elliptical, parabolic or rounded, with a radius generally not less than 1/24 of the breadth of the opening.

8.11.4 Where elliptical corners are arranged, the major axis is to be fore and aft, the ratio of the major to minor axis is to be not less than two to one nor greater than 2,5 to one, and the minimum half-length of the major axis is to be defined by l_1 in Fig. 3.8.1. Where parabolic corners are arranged, the dimensions are also to be as shown in Fig. 3.8.1.

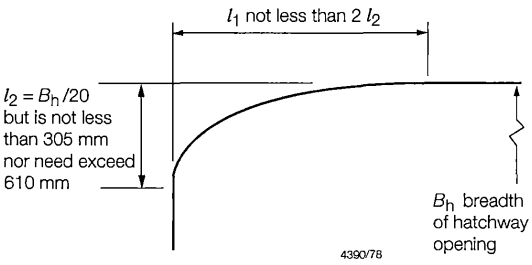

Fig. 3.8.1 Hatch opening geometry

8.11.5 Where the corners are parabolic or elliptical, insert plates are not required.

8.11.6 For other shapes of corner, insert plates of the size and extent shown in Fig. 3.8.2 will, in general, be required. The required thickness of the insert plate is to be not less than 25 per cent greater than the adjacent deck thickness, outside line of openings.

8.11.7 For lower decks the corners of large openings are to be rounded, with a radius generally not less than 1/24 of the breadth of the opening.

8.11.8 Insert plates will be required at lower decks in way of any rapid change in hull form to compensate for loss of deck cross-sectional area. Otherwise, insert plates will not normally be required.

8.11.9 Adequate transverse strength is to be provided in the deck area between large hatch openings, subjected to transverse and buckling loads.

8.11.10 The requirements for closing arrangements and outfit are given in Pt 3, Ch 4.

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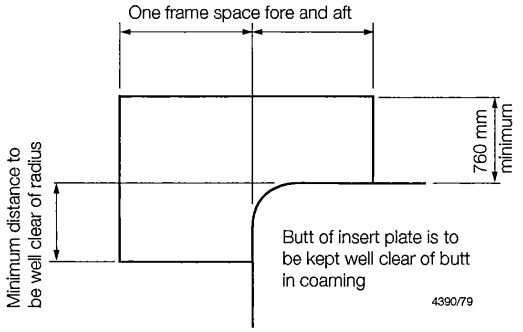

Fig. 3.8.2 Inserts in way of hatch opening

8.12 Sheathing

8.12.1 The requirements for deck sheathing given in 2.4 are to be complied with.

8.13 Novel features

8.13.1 Where large or novel hatch openings are proposed, detailed calculations are to be submitted to demonstrate that the scantlings and arrangements in way of the openings are adequate to maintain continuity of structural strength.

■ *Section 9* Superstructures, deckhouses and bulwarks

9.1 General

9.1.1 Where practicable, superstructures and deckhouses are to be designed with well cambered decks and well radiused corners to build rigidity into the structure.

9.1.2 The plating and supporting structure are to be suitably reinforced in way of localised areas of high stress such as corners of openings, cranes, masts, derrick posts, machinery, fittings and other heavy or vibrating loads.

9.1.3 Primary stiffening members are to be continuous and substantially bracketed at their end connections to maintain continuity of structural strength.

9.1.4 Secondary stiffening members are to be effectively continuous and bracketed at their end connections as appropriate.

9.1.5 Structures subject to concentrated loads are to be suitably reinforced. Where concentrations of loading on one side of a stiffener may occur, such as pillars out of line, the stiffener is to be adequately stiffened against torsion.

9.1.6 The plating thickness of superstructures, deckhouses and bulwarks is in no case to be less than the appropriate minimum requirement given in Section 2.

9.1.7 Stiffener sections and geometric properties are to be in accordance with 1.18.

9.2 Symbols and definitions

9.2.1 The term 'house' is used in this Section to include both superstructures and deckhouses.

9.2.2 The symbols applicable to this Section are defined in 1.5.1.

9.3 House side plating

9.3.1 The thickness of house side plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

9.4 House front plating

9.4.1 The thickness of the house front plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4, 3.1 for non-displacement or displacement craft as appropriate.

9.5 House end plating

9.5.1 The thickness of the house end plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

9.6 House top plating

9.6.1 The thickness of the house top plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

9.7 Coachroof plating

9.7.1 The thickness of the coachroof plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

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9.8 Machinery casing plating

9.8.1 The thickness of the plating of machinery casings is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

9.9 Forecastle requirements

9.9.1 The forecastle side plating may be a continuation of the hull side shell plating or fitted as a separate assembly. In both cases the plating thickness is to be the same as the side shell plating at deck edge. Where fitted as a separate assembly, suitable arrangements are to be made to ensure continuity of the effect of the sheerstrake at the break and at the upper edge of the forecastle side. Full penetration welding is to be used.

9.9.2 The side plating is to be stiffened by side frames effectively connected to the deck structure. Deep webs are to be fitted to ensure overall rigidity.

9.9.3 The deck plating thickness is to be increased by 20 per cent in way of the end of the forecastle if this occurs at a position aft of $0{,}25L_R$ from the F.P. No increase is required if the forecastle end bulkhead lies forward of $0{,}2L_R$ from the F.P. The increase at intermediate positions of end bulkhead is to be obtained by interpolation.

9.10 House side stiffeners

9.10.1 The Rule requirements for section modulus, inertia and web area for the **house side primary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

9.10.2 The Rule requirements for section modulus, inertia and web area for **house side secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.11 House front stiffeners

9.11.1 The Rule requirements for section modulus, inertia and web area for **house front primary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

9.11.2 The Rule requirements for section modulus, inertia and web area for **house front secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.12 House aft end stiffeners

9.12.1 The Rule requirements for section modulus, inertia and web area for **house aft end primary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

9.12.2 The Rule requirements for section modulus, inertia and web area for **house aft end secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.13 House top stiffeners

9.13.1 The house top is to be effectively supported by a system of transverse or longitudinal beams and girders. The span of the beams is in general not to exceed 2,4 m and the beams are to be effectively connected to the house upper coamings and girders.

9.13.2 The Rule requirements for section modulus, inertia and web area for **house top primary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

9.13.3 The Rule requirements for section modulus, inertia and web area for house top **secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

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9.14 Coachroof stiffeners

9.14.1 The Rule requirements for section modulus, inertia and web area for coachroof **primary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

9.14.2 The Rule requirements for section modulus, inertia and web area for coachroof **secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.15 Machinery casing stiffeners

9.15.1 The Rule requirements for section modulus, inertia and web area for machinery casing **primary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

9.15.2 The Rule requirements for section modulus, inertia and web area for machinery casing **secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.15.3 Where casing stiffeners carry loads from deck transverses, girders, etc., or where they are in line with pillars below, they are to be suitably reinforced.

9.15.4 Where casing sides act as girders supporting decks over, care is to be taken that access openings do not seriously weaken the structure. Openings are to be effectively framed and reinforced if found necessary. Particular attention is to be paid to stiffening where the casing supports the funnel or exhaust uptakes.

9.16 Forecastle stiffeners

9.16.1 The scantlings of forecastle primary and secondary stiffening members are to be equivalent to those for the side shell envelope framing at the deck edge as required by Section 4.

9.17 Superstructures formed by extending side structures

9.17.1 Superstructure first tier sides formed by extending the hull side structure are to be in accordance with the requirements for house fronts given in 9.4 and 9.11 for plating and stiffeners respectively, but need not be taken as greater than the side structure requirements at the deck edge at the same longitudinal position.

9.18 Fire aspects

9.18.1 The requirements for fire detection, protection and extinction are given in Part 17.

9.19 Openings

9.19.1 All openings are to be substantially framed and have well rounded corners. Arrangements are to be made to minimise the effect of discontinuities in erections. Continuous coamings or girders are to be fitted below and above doors and similar openings.

9.19.2 Particular attention is to be paid to the effectiveness of end bulkheads, and the upper deck stiffening in way, when large openings for doors and windows are fitted.

9.19.3 Special care is to be taken to minimise the size and number of openings in the side bulkheads in the region of the ends of erections within $0{,}5L_R$ amidships. Account is to be taken of the high vertical shear loading which can occur in these areas.

9.19.4 For closing arrangements and outfit the requirements are given in Pt 3, Ch 4.

9.20 Mullions

9.20.1 Window openings are to be suitably framed and mullions will in general be required.

9.20.2 The scantlings of mullions are to be not less than as required for a stiffener in the same position.

9.20.3 When determining the stiffener requirements, the width of effective plating is in no case to be taken as greater than the distance between adjacent window openings.

9.20.4 Where significant shear forces are to be vertically transmitted by the window frames, adequate shear rigidity is to be verified by direct calculation.

9.21 Global strength

9.21.1 Transverse rigidity is to be maintained throughout the length of the erection by means of web frames, bulkheads or partial bulkheads. Particular attention is to be paid when an upper tier is wider than its supporting tier and when significant loads are carried on the house top.

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9.21.2 Where practicable, web frames are to be arranged in line with bulkheads below.

9.21.3 Internal bulkheads are to be fitted in line with bulkheads or deep primary stiffeners below.

9.22 House/deck connection

9.22.1 Adequate support under the ends of erections is to be provided in the form of webs, pillars, diaphragms or bulkheads in conjunction with reinforced deck beams.

9.22.2 Special attention is to be given to the connection of the erection to the deck in order to provide an adequate load distribution and avoid stress concentrations.

9.22.3 Connections between the erection and the deck by means of bimetallic joints are to comply with Ch 2,4.28.

9.22.4 Typical design details of house/deck connections are given in LR's *Guidance Notes for Structural Details*.

9.23 Sheathing

9.23.1 Sheathing arrangements are to comply with the requirements of 2.4.

9.24 Erections contributing to longitudinal strength

9.24.1 For craft above 40 m in length, L_R, or for designs where the superstructure is designed to absorb global loads the effectiveness of superstructures to carry these loads is to be determined. The effectiveness may be assessed in accordance with Ch 6,2.5.

9.24.2 Where 9.17 applies and the first or second tier is regarded as the strength deck according to Ch 6,2.5, the hull upper deck scantlings at the forward and aft ends of the superstructure may need to be increased due to the lesser efficiency of the superstructure tiers at their ends. The scantlings of the side structure in way of these areas may also need to be increased.

9.24.3 When large openings or a large number of smaller openings are cut in the superstructure sides, reducing the capability to transmit shear force between decks, an assessment or structural efficiency may be required.

9.25 Novel features

9.25.1 Direct calculations may be required to determine the plating and stiffener requirements where the house is of unusual design, form or proportions.

9.26 Bulwarks

9.26.1 General requirements for bulwarks are given in Pt 3, Ch 4,8.

9.26.2 The thickness of the bulwark plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

9.26.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (d).

9.26.4 Bulwarks are not to be cut for gangway or other openings near the breaks of superstructures.

9.26.5 Attention is to be paid to avoid discontinuity of strength of the bulwark, particularly in way of local increases in stress and changes in height.

9.26.6 Welding of bulwark to the top edge of sheer strake within $0{,}5L_R$ amidship, is generally to be avoided. However, if this arrangement is not practicable welding to the sheerstrake may be accepted if care is taken to minimise any notch effects.

9.26.7 **Fishing craft** are to have bulwarks fitted. The bulwark may be formed from a continuation of the side shell plating or connected as a separate assembly. Where the bulwark is considered to be stressed and contributing to the global strength of the craft, the plate thickness of the bulwark is not to be less than the sheerstrake plating thickness. In no case is the thickness of the bulwark plating to be taken as less than 80 per cent of the side shell thickness. The bulwark is to be supported by suitable stiffening members which may be formed from a continuation of the side frames, or from flanged plate stays of the same thickness as the bulwark. In general these frames are to be spaced not more than two side frame spacings apart.

9.26.8 In way of gantries, trawl gallows, mooring pipes, etc., the plate thickness in way is to be increased by not less than 50 per cent.

9.26.9 **Pilot craft** are to be fitted with sufficient hand rails adjacent to the exposed areas of the working decks and platforms. In addition these areas are to have non-skid surfaces.

9.27 Freeing arrangements

9.27.1 Requirements for freeing arrangements are given in Pt 3, Ch 4,9.

9.28 Free flow area

9.28.1 The requirements for the free flow area are given in Pt 3, Ch 4,9.3.

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9.29 Guard rails

9.29.1 The requirements for guard rails are given in Pt 3, Ch 4,8.4.

Section 10
Pillars and pillar bulkheads

10.1 Application

10.1.1 Pillars are to be arranged to transmit loads from decks and superstructures into the bottom structure. Pillars are generally to be constructed from solid, tubular, or *I* beam section. A pillar may be a fabricated trunk or partial bulkhead.

10.2 Determination of span length

10.2.1 The effective span length of the pillar, l_{ep}, is in general the distance between the head and heel of the pillar. Where substantial brackets are fitted, l_{ep} may be reduced by 2/3 the depth of the bracket at each end.

10.3 Head and heel connections

10.3.1 Pillars are to be attached at their heads to plates supported by efficient brackets, in order to transmit the load effectively. Doubling or insert plates are to be fitted to decks under large pillars and to the inner bottom under the heels of tubular or hollow square pillars. The pillars are to have a bearing fit and are to be attached to the head and heel plates by continuous welding. At the heads and heels of pillars built of rolled sections, the load is to be well distributed by means of longitudinal and transverse brackets.

10.4 Alignment and arrangement

10.4.1 Pillars are to be located on main structural members. They are in general to be fitted below windlasses, winches, capstans, the corners of deckhouses and elsewhere where considered necessary.

10.4.2 Wherever possible, deck pillars are to be fitted in the same vertical line as pillars above and below, and effective arrangements are to be made to distribute the load at the heads and heels of all pillars.

10.4.3 Where pillars support eccentric loads, or are subjected to lateral pressures, they are to be suitably strengthened for the additional bending moment imposed upon them.

10.4.4 Doublers are generally to be fitted on decks and inner bottoms, other than within tanks where doublers are not allowed. Brackets may be used instead of doublers.

10.5 Minimum thickness

10.5.1 The minimum wall thickness of hollow pillars is to be taken as not less than 1/20 of the external dimension of the pillar.

10.6 Design loads

10.6.1 The design loading, P_p, is not to be less than:

$$P_p = S_{gt}\, b_{gt}\, P_c + P_a \quad \text{kN}$$

where

P_p = design load supported by the pillar, to be taken as not less than 5 kN

P_c = basic deck girder design pressure, as appropriate, plus any other loadings directly above the pillar, in kN/m^2

P_a = load, in kN, from pillar or pillars above, assumed zero if there are no pillars over

S_{gt} = spacing, or mean spacing, of girders or transverses, in metres

b_{gt} = distance between centres of two adjacent spans of girders or transverses supported by the pillar, in metres.

10.7 Scantlings determination

10.7.1 The cross-sectional area of the pillar, A_p, is not to be less than:

$$A_p = 10\,\frac{P_p}{\sigma_p} \quad \text{cm}^2$$

where

P_p = design load, in kN, supported by the pillar as determined from 10.6

σ_p = permissible compressive stress, in N/mm^2

$$= \frac{f_p\,\sigma_A}{1 + 0{,}015\sigma_A\, k_f \left(\frac{l_{ep}}{r}\right)^2} \quad \text{N/mm}^2$$

where

f_p = pillar location factor defined in Table 3.10.1

σ_A = 0,2 per cent proof stress of the alloy in the unwelded condition, in N/mm^2

k_f = pillar end fixity factor

= 0,25 for full fixed/bracketed

= 0,50 for partially fixed

= 1,0 for free ended

r = least radius of gyration of pillar cross-section, in cm, and may be taken as:

$$r = \sqrt{\frac{I_p}{A_p}} \quad \text{cm}$$

I_p = least moment of inertia of cross-section of pillar or stiffener/plate combination, in cm^4

l_{ep} = effective span of pillar or bulkhead, in metres, as defined in 10.2.

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Table 3.10.1 Pillar location factors

Location	f_p
Supporting weather deck	0,50
Supporting vehicle deck	0,50
Supporting passenger deck	0,50
Supporting lower/inner deck	0,75
Supporting coachroof	0,75
Supporting deckhouse top	1,00

10.8 Maximum slenderness ratio

10.8.1 The slenderness ratio (l_{ep}/r) of pillars is not to be taken greater than 1,1, where l_{ep} and r are as defined in 10.7.1. Pillars with slenderness ratio in excess of 1,1 may be accepted subject to special consideration on a case by case basis and provided that the remaining requirements of the Rules are complied with.

10.9 Pillars in tanks

10.9.1 In no circumstances are pillars to pass through tanks. Where loads are to be transmitted through tanks, pillars within the tanks are to be carefully aligned with the external pillars.

10.9.2 Pillars within tanks are, in general, to be of solid cross section. Where it is proposed to use hollow section pillars each case will be subject to special consideration and the scantlings as determined from the Rules may require to be increased dependent upon the material to be used, the fluid contained and the arrangement of the pillars. Hollow pillars are to be adequately drained and vented.

10.9.3 Where pillars within tanks may be subjected to tensile stresses due to hydrostatic pressure, the design is to provide sufficient welding to withstand the tensile load imposed.

10.9.4 Doubling plates at ends of pillars within tanks are not acceptable.

10.10 Pillar bulkheads

10.10.1 The stiffener/plate combination used in the determination of pillar bulkhead scantlings is to be that of a stiffener with an effective width of attached plating as determined from 1.11.

10.10.2 The cross-sectional area of the pillar bulkhead, A_{pb}, is to be determined in accordance with 10.7 using the design loading, P_{pb}, as follows:

$$P_{pb} = S_{bs}\, b_{pb}\, P_c + P_a \text{ kN}$$

where

P_{pb} = design load supported by the stiffener plate combination of the pillar bulkhead

P_c = basic deck girder design pressure, as appropriate, plus any other loadings directly above the pillar, in kN/m^2

S_{bs} = spacing, or mean spacing, of bulkheads or effective transverses/longitudinal stiffeners, in metres

b_{pb} = distance between centres of two adjacent spans of girders or transverses supported by the pillar bulkhead, in metres, and can be taken as the distance between pillar bulkhead stiffeners where the stiffeners at the top of the bulkhead effectively distributes the load evenly into the stiffeners.

10.10.3 The thickness of the bulkhead plating is in no case to be taken less than 4 mm.

10.11 Direct calculations

10.11.1 As an alternative to 10.6, pillars may be designed on the basis of direct calculation. The method adopted and the stress levels proposed for the material of construction are to be submitted together with the calculations for consideration.

10.12 Fire aspects

10.12.1 Pillars and pillar bulkheads are to be suitably protected against fire, and, where necessary, be self-extinguishing or capable of resisting fire damage. All pillars are to comply with the requirements of Part 17.

10.13 Novel features

10.13.1 Where unusual or novel pillar designs are proposed that are unable to comply with the requirements of this Section, their design together with the direct calculations are to be submitted for special consideration.

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Section

1 **General**

2 **Minimum thickness requirements**

3 **Shell envelope plating**

4 **Shell envelope framing**

5 **Single bottom structure and appendages**

6 **Double bottom structure**

7 **Bulkheads and deep tanks**

8 **Deck structures**

9 **Superstructures, deckhouses, pillars and bulwarks**

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to multi-hull craft of aluminium construction as defined in Pt 1, Ch 1,1.

1.2 General

1.2.1 Except as otherwise specified within this Chapter, the scantlings and arrangements of multi-hull craft are to be determined in accordance with the procedures described in, or required by Chapter 3 for mono-hull craft, using the pressures from Part 5 appropriate to multi-hulls.

1.3 Direct calculations

1.3.1 Where the craft is of unusual design, form or proportions, or where the speed of the craft exceeds 60 knots the scantlings are to be determined by direct calculation.

1.3.2 The requirements of this Chapter may be modified where direct calculation procedures are adopted to analyse the stress distribution in the primary structure.

1.4 Equivalents

1.4.1 Lloyd's Register (hereinafter referred to as 'LR') will consider direct calculations for the derivation of scantlings as an alternative and equivalent to those derived by Rule requirements in accordance with Pt 3, Ch 1,3.

1.5 Symbols and definitions

1.5.1 The symbols used in this Chapter are defined below and in the appropriate Section:

k_a = alloy factor
= $125/\sigma_a$
s = stiffener spacing, in mm
t_p = plating thickness, in mm
L_R = Rule length of craft, in metres
σ_a = 0,2 per cent proof stress of the alloy in the welded condition, in N/mm^2.

1.5.2 **Bottom outboard.** For high speed craft, where the scantlings of the bottom shell are governed by impact pressure considerations, the bottom outboard shell is defined as the area of the hull between the outboard edge of the keel and the outer bilge tangential point. For displacement and semi displacement type craft where the scantlings of the bottom shell are governed by either hydrostatic or pitching pressures the bottom outboard shell is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

1.5.3 **Bottom inboard.** For high speed craft, where the scantlings of the bottom shell are governed by impact pressure considerations, the bottom inboard shell is defined as the area of the hull between the inboard edge of the keel and the inner bilge tangential point. For displacement and semi displacement type craft where the scantlings of the bottom shell are governed by either hydrostatic or pitching pressures the bottom inboard shell is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

1.5.4 **Cross-deck.** The cross-deck is defined as the structure which forms the bridge connection between any two adjacent hulls.

1.5.5 **Haunch.** The haunch is defined as the transition area between the cross-deck and the inboard side shell plating.

1.5.6 **Side inboard.** The side inboard is defined as the area between the bottom inboard shell and the wet-deck (or lower edge of the haunches, where fitted).

1.5.7 **Side outboard.** The side outboard is defined as the area between bottom outboard shell and the deck at side.

1.5.8 **Wet-deck.** The wet-deck is defined as the area between the upper edges of the side inboard plating (or upper edges of the haunches, where fitted).

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Section 2
Minimum thickness requirements

2.1 General

2.1.1 Unless otherwise specified in this Section, the requirements of Ch 3,2 are to be complied with.

2.1.2 The thickness of plating and stiffeners determined from the Rule requirements is in no case to be less than the appropriate minimum requirement given in Table 4.2.1 for craft type.

2.1.3 In addition, where plating contributes to the global strength of the craft, the thickness is to be not less than that required to satisfy global strength requirements.

Table 4.2.1 Minimum thickness requirements

Item	Minimum thickness (mm)		
	Catamaran	Multi-hull	Swath
Shell envelope			
Bottom shell plating	$\omega\sqrt{k_m}\,(0{,}7\sqrt{L_R}+1{,}0)\geq 4{,}0\,\omega$	$\omega\sqrt{k_m}\,(0{,}7\sqrt{L_R}+1{,}0)\geq 4{,}0\,\omega$	$\omega\sqrt{k_m}\,(0{,}7\sqrt{L_R}+1{,}0)\geq 4{,}0\,\omega$
Side shell plating	$\omega\sqrt{k_m}\,(0{,}5\sqrt{L_R}+1{,}4)\geq 3{,}5\,\omega$	$\omega\sqrt{k_m}\,(0{,}5\sqrt{L_R}+1{,}4)\geq 3{,}5\,\omega$	$\omega\sqrt{k_m}\,(0{,}5\sqrt{L_R}+1{,}4)\geq 3{,}5\,\omega$
Wet-deck plating	$\omega\sqrt{k_m}\,(0{,}5\sqrt{L_R}+1{,}4)\geq 3{,}5\,\omega$	$\omega\sqrt{k_m}\,(0{,}5\sqrt{L_R}+1{,}4)\geq 3{,}5\,\omega$	$\omega\sqrt{k_m}\,(0{,}5\sqrt{L_R}+1{,}4)\geq 3{,}5\,\omega$
Single bottom structure			
Centre girder web	$\omega\sqrt{k_m}\,(1{,}1\sqrt{L_R}+1{,}4)\geq 5{,}0\,\omega$	$\omega\sqrt{k_m}\,(1{,}1\sqrt{L_R}+1{,}4)\geq 5{,}0\,\omega$	$\omega\sqrt{k_m}\,(1{,}1\sqrt{L_R}+1{,}4)\geq 5{,}0\,\omega$
Floor webs	$\omega\sqrt{k_m}\,(0{,}8\sqrt{L_R}+1{,}1)\geq 4{,}0\,\omega$	$\omega\sqrt{k_m}\,(0{,}8\sqrt{L_R}+1{,}1)\geq 4{,}0\,\omega$	$\omega\sqrt{k_m}\,(0{,}8\sqrt{L_R}+1{,}1)\geq 4{,}0\,\omega$
Side girder webs	$\omega\sqrt{k_m}\,(0{,}8\sqrt{L_R}+1{,}1)\geq 4{,}0\,\omega$	$\omega\sqrt{k_m}\,(0{,}8\sqrt{L_R}+1{,}1)\geq 4{,}0\,\omega$	$\omega\sqrt{k_m}\,(0{,}8\sqrt{L_R}+1{,}1)\geq 4{,}0\,\omega$
Double bottom structure			
Centre girder			
(1) Within 0,4*L* amidships	$\omega\sqrt{k_m}\,(1{,}1\sqrt{L_R}+1{,}4)\geq 5{,}0\,\omega$	$\omega\sqrt{k_m}\,(1{,}1\sqrt{L_R}+1{,}4)\geq 5{,}0\,\omega$	$\omega\sqrt{k_m}\,(1{,}1\sqrt{L_R}+1{,}4)\geq 5{,}0\,\omega$
(2) Outside 0,4*L* amidships	$\omega\sqrt{k_m}\,(0{,}95\sqrt{L_R}+1{,}4)\geq 5{,}0\,\omega$	$\omega\sqrt{k_m}\,(0{,}95\sqrt{L_R}+1{,}4)\geq 5{,}0\,\omega$	$\omega\sqrt{k_m}\,(0{,}95\sqrt{L_R}+1{,}4)\geq 5{,}0\,\omega$
Floors and side girders	$\omega\sqrt{k_m}\,(0{,}8\sqrt{L_R}+1{,}1)\geq 4{,}0\,\omega$	$\omega\sqrt{k_m}\,(0{,}8\sqrt{L_R}+1{,}1)\geq 4{,}0\,\omega$	$\omega\sqrt{k_m}\,(0{,}8\sqrt{L_R}+1{,}1)\geq 4{,}0\,\omega$
Inner bottom plating	$\omega\sqrt{k_m}\,(0{,}7\sqrt{L_R}+1{,}3)\geq 3{,}5\,\omega$	$\omega\sqrt{k_m}\,(0{,}7\sqrt{L_R}+1{,}3)\geq 3{,}5\,\omega$	$\omega\sqrt{k_m}\,(0{,}7\sqrt{L_R}+1{,}3)\geq 3{,}5\,\omega$
Bulkheads			
Watertight bulkhead plating	$\omega\sqrt{k_m}\,(0{,}43\sqrt{L_R}+1{,}2)\geq 3{,}0\,\omega$	$\omega\sqrt{k_m}\,(0{,}43\sqrt{L_R}+1{,}2)\geq 3{,}0\,\omega$	$\omega\sqrt{k_m}\,(0{,}43\sqrt{L_R}+1{,}2)\geq 3{,}0\,\omega$
Deep tank bulkhead plating	$\omega\sqrt{k_m}\,(0{,}5\sqrt{L_R}+1{,}4)\geq 3{,}5\,\omega$	$\omega\sqrt{k_m}\,(0{,}5\sqrt{L_R}+1{,}4)\geq 3{,}5\,\omega$	$\omega\sqrt{k_m}\,(0{,}5\sqrt{L_R}+1{,}4)\geq 3{,}5\,\omega$
Deck plating and stiffeners			
Strength/Main deck plating	$\omega\sqrt{k_m}\,(0{,}5\sqrt{L_R}+1{,}4)\geq 3{,}5\,\omega$	$\omega\sqrt{k_m}\,(0{,}5\sqrt{L_R}+1{,}4)\geq 3{,}5\,\omega$	$\omega\sqrt{k_m}\,(0{,}5\sqrt{L_R}+1{,}4)\geq 3{,}5\,\omega$
Lower deck/Inside deckhouse	$\omega\sqrt{k_m}\,(0{,}3\sqrt{L_R}+1{,}3)\geq 3{,}0\,\omega$	$\omega\sqrt{k_m}\,(0{,}3\sqrt{L_R}+1{,}3)\geq 3{,}0\,\omega$	$\omega\sqrt{k_m}\,(0{,}3\sqrt{L_R}+1{,}3)\geq 3{,}0\,\omega$
Superstructures and deckhouses			
Superstructure side plating	$\omega\sqrt{k_m}\,(0{,}4\sqrt{L_R}+1{,}1)\geq 3{,}0\,\omega$	$\omega\sqrt{k_m}\,(0{,}4\sqrt{L_R}+1{,}1)\geq 3{,}0\,\omega$	$\omega\sqrt{k_m}\,(0{,}4\sqrt{L_R}+1{,}1)\geq 3{,}0\,\omega$
Deckhouse front 1st tier	$\omega\sqrt{k_m}\,(0{,}62\sqrt{L_R}+1{,}8)\geq 3{,}5\,\omega$	$\omega\sqrt{k_m}\,(0{,}62\sqrt{L_R}+1{,}8)\geq 3{,}5\,\omega$	$\omega\sqrt{k_m}\,(0{,}62\sqrt{L_R}+1{,}8)\geq 3{,}5\,\omega$
Deckhouse front upper tiers	$\omega\sqrt{k_m}\,(0{,}55\sqrt{L_R}+1{,}5)\geq 3{,}0\,\omega$	$\omega\sqrt{k_m}\,(0{,}55\sqrt{L_R}+1{,}5)\geq 3{,}0\,\omega$	$\omega\sqrt{k_m}\,(0{,}55\sqrt{L_R}+1{,}5)\geq 3{,}0\,\omega$
Deckhouse aft	$\omega\sqrt{k_m}\,(0{,}25\sqrt{L_R}+0{,}7)\geq 2{,}5\,\omega$	$\omega\sqrt{k_m}\,(0{,}25\sqrt{L_R}+0{,}7)\geq 2{,}5\,\omega$	$\omega\sqrt{k_m}\,(0{,}25\sqrt{L_R}+0{,}7)\geq 2{,}5\,\omega$
Pillars			
Wall thickness of tubular pillars	$\omega\sqrt{k_m}\,0{,}07d_p$	$\omega\sqrt{k_m}\,0{,}07d_p$	$\omega\sqrt{k_m}\,0{,}07d_p$
Wall thickness of rectangular pillars	$\omega\sqrt{k_m}\,0{,}07b_p$	$\omega\sqrt{k_m}\,0{,}07b_p$	$\omega\sqrt{k_m}\,0{,}07b_p$

Symbols

ω = service type factor as determined from Table 4.2.2
k_m = $385/(\sigma_A+\sigma_u)$
σ_A = specified minimum yield stress or 0,2% proof stress of the alloy in unwelded condition, in N/mm^2
σ_u = specified minimum ultimate tensile strength of the alloy in unwelded condition, in N/mm^2
b_p = minimum breadth of cross section of hollow rectangle pillar, in mm
d_p = outside diameter of tubular pillar, in mm
L_R = as defined in 1.5.1

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Table 4.2.2 Service type correction factors (ω)

Service type notation	ω
Cargo	1,1
Passenger	1,0
Patrol	1,0
Pilot	1,1
Yacht	1,0
Workboat MFV	1,2

■ *Section 3* Shell envelope plating

3.1 General

3.1.1 Unless otherwise specified within this Section, the scantlings and arrangements for shell envelope plating are to be determined in accordance with the procedures described in, or as required by, Ch 3,3 for mono-hull craft using the pressures from Part 5 appropriate to multi-hulls.

3.1.2 The thickness of the shell envelope plating is in no case to be less than the appropriate minimum requirement given in Section 2.

3.2 Keel plates

3.2.1 The breadth, b_k, and thickness, t_k, of plate keels are not to be taken as less than:

$$b_k = 5{,}0L_R + 250 \text{ mm}$$

$$t_k = \sqrt{k_a}\ 1{,}85L_R^{0,45} \text{ mm}$$

where

L_R and k_a are as defined in 1.5.1.

3.2.2 In no case is the thickness of the keel to be less than that of the adjacent bottom shell plating.

3.2.3 The width and thickness of plate keels are to be maintained throughout the length of the craft from the transom to a point not less than 25 per cent of the freeboard (measured at the forward perpendicular) above the deepest load waterline on the stem. Thereafter the keel thickness may be reduced to that required by Ch 3,3.3.1 for the stem.

3.2.4 For large or novel craft and for yachts with externally attached ballast keels, the scantlings of the keel will be specially considered.

3.3 Bottom outboard

3.3.1 The thickness of the bottom outboard plating is to be determined from the general plating equation given in Ch 3,1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.3.2 For all craft types, the minimum bottom outboard shell thickness requirement given in Section 2 is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

3.4 Bottom inboard

3.4.1 The thickness of the bottom inboard plating is to be determined from the general plating equation given in Ch 3,1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.4.2 For all craft types, the minimum bottom inboard shell thickness requirement given in Section 2 is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

3.5 Side outboard

3.5.1 The thickness of the side outboard plating is to be determined from the general plating equation given in Ch 3,1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.6 Side inboard

3.6.1 The thickness of the side inboard plating is to be determined from the general plating equation given in Ch 3,1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.7 Wet-deck

3.7.1 The thickness of the wet-deck plating is to be determined from the general plating equation given in Ch 3,1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.7.2 Additionally, the thickness of the wet-deck plating is in no case to be less than the thickness of the side inboard shell plating determined from 3.6.

3.7.3 The wet-deck plating on the underside of the cross-deck structure may require to be additionally protected, particularly where the air gap is small and there is a high risk of localised impact due to collision with floating debris, ice, etc., in the service area. In such cases the sheathing requirements given in Ch 3,2.4 are to be complied with.

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3.8 Transom

3.8.1 The scantlings and arrangements of the stern or transom are to be not less than that required for the adjacent bottom inboard or side outboard structure as appropriate. Where water jet or sterndrive units are fitted, the scantlings of the plating in way of the nozzles and connections will be specially considered.

3.9 Haunch reinforcement (SWATH)

3.9.1 For craft above 40 m in Rule length, L_R, the stresses in the haunch area are to be derived using a two dimensional fine mesh finite element analysis. The model is to extend horizontally into the box structure and vertically into the strut structure. All discontinuities and cut-outs are to be modelled in order to determine shear stresses at critical locations and stresses for the determination of fatigue strength.

3.9.2 Due consideration is to be given to shear lag when determining the effective breadth of the attached plating.

3.10 Lower hull (SWATH)

3.10.1 Where the lower hull structure incorporates ring frames and attached shell plating fitted between bulkheads or diaphragms, the thickness of the lower hull shell plating may be derived from an established method for shell analysis or recognised standard for pressure vessels using the design pressure loading from Pt 5, Ch 4,3.1. Other loads considered significant for the scantling determination are to be taken into account. Modes of failure to be considered are buckling, frame collapse, inter-frame shell collapse and overall frame shell collapse between bulkheads. A copy of the direct calculations is to be submitted for consideration.

3.11 Novel features

3.11.1 Where the Rules do not specifically define the requirements for plating elements with novel features then the scantlings and arrangements are to be determined by direct calculations. Such calculations are to be carried out on the basis of the Rules, Recognised Standards and good practice, and are to be submitted for consideration.

■ *Section 4* Shell envelope framing

4.1 General

4.1.1 Unless otherwise specified in this Section, the scantlings and arrangements for shell envelope framing are to be determined in accordance with the procedures described in, or as required by, Ch 3,3 for mono-hull craft using the pressures from Part 5 appropriate to multi-hulls.

4.1.2 The requirements in this Section apply to longitudinally and transversely framed shell envelopes.

4.2 Bottom outboard longitudinal stiffeners

4.2.1 Bottom outboard longitudinal stiffeners are to be supported by transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.2.2 Bottom outboard longitudinals are to be continuous through the supporting structures.

4.2.3 Where it is impracticable to comply with the requirements of 4.2.2, or where it is proposed to terminate the bottom outboard longitudinals in way of the transom, bulkheads or integral tank boundaries, all longitudinals are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets.

4.2.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b).

4.3 Bottom outboard longitudinal primary stiffeners

4.3.1 Bottom outboard longitudinal primary stiffeners are to be supported by deep transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 4 m apart.

4.3.2 Bottom outboard longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

4.3.3 Where it is impracticable to comply with the requirements of 4.3.2, or where it is proposed to terminate the stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.3.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

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4.4 Bottom outboard transverse stiffeners

4.4.1 Bottom outboard transverse stiffeners are defined as local stiffening members which support the bottom shell and which may be continuous or intercostal.

4.4.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b).

4.5 Bottom outboard transverse frames

4.5.1 Bottom outboard transverse frames are defined as stiffening members which support the bottom shell. They are to be effectively continuous and bracketed at their end connections to side frames and bottom floors as appropriate.

4.5.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.6 Bottom outboard transverse web frames

4.6.1 Bottom outboard transverse web frames are defined as primary stiffening members which support bottom shell longitudinals. They are to be continuous and substantially bracketed at their end connections to side web frames and bottom floors.

4.6.2 Where it is impracticable to comply with the requirements of 4.6.1, or where it is proposed to terminate the web frames in way of bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.6.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.7 Bottom inboard longitudinal stiffeners

4.7.1 The scantlings and arrangements for bottom inboard longitudinal stiffeners are to be determined in accordance with the procedures described in 4.2 using the bottom inboard stiffening member design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.8 Bottom inboard longitudinal primary stiffeners

4.8.1 The scantlings and arrangements for bottom inboard longitudinal primary stiffeners are to be determined in accordance with the procedures described in 4.3 using the bottom inboard stiffening member design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.9 Bottom inboard transverse stiffeners

4.9.1 The scantlings and arrangements for bottom inboard transverse stiffeners are to be determined in accordance with the procedures described in 4.4 using the bottom inboard stiffening member design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.10 Bottom inboard transverse frames

4.10.1 The scantlings and arrangements for bottom inboard transverse frames are to be determined in accordance with the procedures described in 4.5 using the bottom inboard stiffening member design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.11 Bottom inboard transverse web frames

4.11.1 The scantlings and arrangements for bottom inboard transverse frames are to be determined in accordance with the procedures described in 4.6 using the bottom inboard stiffening design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.12 Side outboard longitudinal stiffeners

4.12.1 The side outboard longitudinal stiffeners are to be supported by transverse web frames, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.12.2 Side outboard longitudinals are to be continuous through the supporting structures.

4.12.3 Where it is impracticable to comply with the requirements of 4.12.2, or where it is proposed to terminate the side outboard longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.12.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b).

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4.13 Side outboard longitudinal primary stiffeners

4.13.1 Side outboard longitudinal primary stiffeners are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 4 m apart.

4.13.2 Side outboard longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

4.13.3 Where it is impracticable to comply with the requirements of 4.13.2, or where it is proposed to terminate the side outboard longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.13.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.14 Side outboard transverse stiffeners

4.14.1 Side outboard transverse stiffeners are defined as local stiffening members supporting the side shell and may be continuous or intercostal.

4.14.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b).

4.15 Side outboard transverse frames

4.15.1 Side outboard transverse frames are defined as stiffening members supporting the side shell and spanning continuously between bottom floors/frames and decks. They are to be effectively constrained against rotation at their end connections.

4.15.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.16 Side outboard transverse web frames

4.16.1 Side outboard transverse web frames are defined as primary stiffening members which support side shell longitudinals. They are to be continuous and substantially bracketed at their head and heel connections to deck beams and bottom web frames respectively.

4.16.2 Where it is impracticable to comply with the requirements of 4.16.1, or where it is proposed to terminate the side outboard longitudinals in way of bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.16.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.17 Side inboard longitudinal stiffeners

4.17.1 The scantlings and arrangements for side inboard longitudinal stiffeners are to be determined in accordance with the procedures described in 4.12 using the side inboard design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.18 Side inboard longitudinal primary stiffeners

4.18.1 The scantlings and arrangements for side inboard longitudinal primary stiffeners are to be determined in accordance with the procedures described in 4.13 using the side inboard design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.19 Side inboard transverse stiffeners

4.19.1 The scantlings and arrangements for side inboard transverse stiffeners are to be determined in accordance with the procedures described in 4.14 using the side inboard design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.20 Side inboard transverse frames

4.20.1 The scantlings and arrangements for side inboard transverse frames are to be determined in accordance with the procedures described in 4.15 using the side inboard design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

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4.21 Side inboard transverse web frames

4.21.1 The scantlings and arrangements for side inboard transverse web frames are to be determined in accordance with the procedures described in 4.16 using the side inboard design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.22 Wet-deck longitudinal stiffeners

4.22.1 The wet-deck longitudinal stiffeners are to be supported by transverse web frames, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.22.2 Wet-deck longitudinals are to be continuous through the supporting structures.

4.22.3 Where it is impracticable to comply with the requirements of 4.22.2, or where it is proposed to terminate the wet-deck longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.22.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b).

4.22.5 In no case are the scantlings and arrangements for the wet-deck longitudinal stiffeners to be taken as less than those required for the side inboard longitudinal stiffeners detailed in 4.17.

4.23 Wet-deck longitudinal primary stiffeners

4.23.1 Wet-deck longitudinal primary stiffeners are to be supported by transverse web frames, bulkheads, or other primary structure, generally spaced not more than 4 m apart.

4.23.2 Wet-deck longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

4.23.3 Where it is impracticable to comply with the requirements of 4.23.2, or where it is proposed to terminate the wet-deck longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.23.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.23.5 In no case are the scantlings and arrangements for the wet-deck longitudinal primary stiffeners to be taken as less than those required for the side inboard longitudinal primary stiffeners detailed in 4.18.

4.23.6 Additionally the requirements of Chapter 6 relating to global strength are to be complied with.

4.24 Wet-deck transverse stiffeners

4.24.1 Wet-deck transverse stiffeners are defined as local stiffening members supporting the wet-deck and may be continuous or intercostal.

4.24.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b).

4.24.3 In no case are the scantlings and arrangements for the wet-deck transverse stiffeners to be taken as less than those required for the side inboard transverse stiffeners detailed in 4.19.

4.25 Wet-deck transverse frames

4.25.1 Wet-deck transverse frames are defined as stiffening members which support the wet-deck. They are to be effectively continuous and bracketed at their end connections to side frames.

4.25.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.25.3 In no case are the scantlings and arrangements for the wet-deck transverse frames to be taken as less than those required for the side inboard transverse frames detailed in 4.20.

4.26 Wet-deck transverse web frames

4.26.1 Wet-deck transverse web frames are defined as primary stiffening members which support wet-deck longitudinals. They are to be continuous and substantially bracketed at their end connections to side transverse web frames.

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4.26.2 Where it is impracticable to comply with the requirements of 4.26.1, or where it is proposed to terminate the wet-deck longitudinals in way of the bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.26.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.26.4 In no case are the scantlings and arrangements for the wet-deck transverse web frames to be taken as less than those required for the side inboard transverse web frames detailed in 4.21.

4.26.5 Primary transverse web frames that link the strength deck to the wet-deck structure and which carry the transverse global loading are additionally to comply with Ch 6,3.4.

4.26.6 Particular care is to be taken to ensure that the continuity of transverse structural strength is maintained. All primary transverse members are to be continuous through the inboard side structure and integrated into transverse bulkheads or other primary structure within each hull (*see* Fig. 4.4.1). In the case of trimaran type craft the primary transverse members are to be continuous through the centre hull. Additionally the side inboard shell plating in way of the intersection is to be increased locally by not less than 50 per cent.

4.27 Lower hull (SWATH)

4.27.1 Where the lower hull structure incorporates ring frames and attached shell plating fitted between bulkheads or diaphragms, the scantlings of the lower hull shell stiffening may be derived from an established method for stiffening analysis or recognised standard for pressure vessels using the design loading from Pt 5, Ch 4,3.1 Modes of failure to be considered are buckling, frame collapse, inter frame shell collapse and overall frame shell collapse between bulkheads. A copy of the direct calculations is to be submitted for consideration.

4.28 Scantlings of end brackets

4.28.1 The scantlings of end brackets in way of transverse web frames/crossdeck primary structure which carry transverse global loading, are to be as large as practicable and be additionally reinforced as necessary. The webs of deep brackets are to be stiffened as necessary to resist buckling, *see also* Ch 6,3.5.

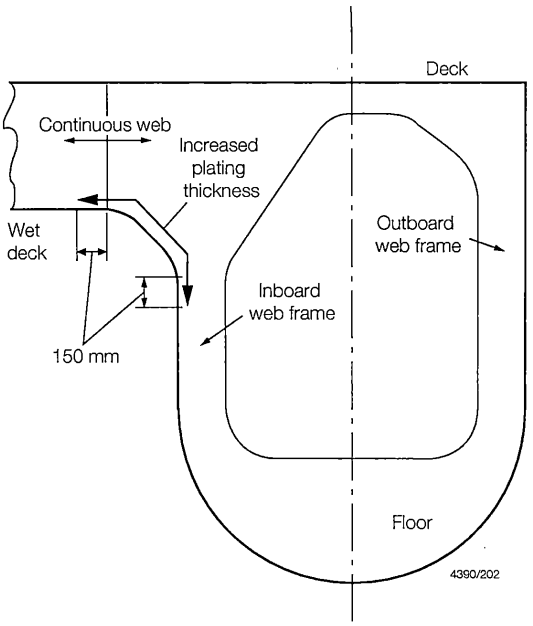

Fig. 4.4.1
End connection details, wet-deck structure

Section 5
Single bottom structure and appendages

5.1 General

5.1.1 Unless otherwise specified in this Section, the scantlings and arrangements for single bottom structure and appendages are to be determined in accordance with the procedures described in, or as required by, Ch 3,5 for monohull craft using the pressures from Part 5 appropriate to multi-hulls.

5.1.2 The thickness of single bottom structural members is in no case to be less than the appropriate minimum requirement given in Section 2.

5.2 Keel

5.2.1 The scantlings and arrangements of plate keels are to be in accordance with 3.2.

5.2.2 Where fitted, the cross-sectional area, A_{bk}, and thickness, t_{bk}, of bar keels should not, in general, be taken as less than:

$$A_{bk} = k_a (1{,}85 L_R + 2) \text{ cm}^2$$

$$t_{bk} = \sqrt{k_a}\ (0{,}7 L_R + 8{,}25) \text{ mm}$$

where

L_R and k_a are as defined in 1.5.1.

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5.3 Centre girder

5.3.1 Centreline girders are to be fitted throughout the length of each hull and are generally to be fitted in association with transverse frames, transverses supporting longitudinals or where the breadth of floors at the upper edge is greater than 1,5 m.

5.3.2 Centreline girders may be formed with intercostal or continuous plate webs. In all cases the face flat is to be continuous. Where girder webs are intercostal, additional bracketing and local reinforcement are to be provided to maintain the continuity of structural strength.

5.3.3 The web depth of the centre girder is, in general, to be equal to the depth of the floors at the centreline as specified in 5.5.3.

5.3.4 The web thickness, t_w, of the centre girder is to be taken as not less than:

$$t_w = \sqrt{k_a}\,(\sqrt{1{,}9L_R} + 1{,}3) \text{ mm}$$

where

k_a and L_R are as defined in 1.5.1.

5.3.5 The face flat area, A_f, of the centre girder is to be not less than:

$$A_f = 0{,}42k_a L_R \text{ cm}^2$$

where

k_a and L_R are as defined in 1.5.1.

5.3.6 The geometric section properties of the centre girder are to be in accordance with Ch 3,1.18.

5.3.7 The face flat area of the centre girder outside $0{,}5L_R$ may be 80 per cent of the value given in 5.3.5.

5.3.8 The face flat thickness, t_w, is to be not less than the thickness of the web.

5.3.9 The ratio of the width to thickness of the face flat is to be not less than eight but is not to exceed 16.

5.3.10 Additionally, the requirements of 4.8 for bottom inboard longitudinal primary stiffeners are to be complied with.

5.4 Side girders

5.4.1 Where the floor breadth at the upper edge exceeds 4,0 m side girders are to be fitted at each side of the centre girder such that the spacing between the side and centre girders or between the side girders themselves is not greater than 2 m. Side girders where fitted are to extend as far forward and aft as practicable and are, in general, to be scarfed into the bottom structure forward and aft of the support at which they terminate, i.e. terminate in way of bulkheads, deep floors or other primary transverse structure.

5.4.2 The web thickness, t_w, of side girders is to be taken as not less than:

$$t_w = \sqrt{0{,}83k_a L_R} \text{ mm}$$

where

k_a and L_R are as defined in 1.5.1.

5.4.3 The face flat area and thickness of side girders are to comply with the requirements for plate floors as defined in 5.5.6 and 5.5.7.

5.4.4 Additionally, the requirements of 4.8 for bottom inboard longitudinal primary stiffeners are to be complied with.

5.4.5 Watertight side girders, and side girders forming the boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads and deeptanks as detailed in Ch 3,7.2 and Ch 3,7.4 respectively.

5.4.6 In the engine room, additional side girders are generally to be fitted in way of main machinery seatings. Where fitted they are to be integrated into the structure of the craft and extended forward and aft as far as practicable.

5.5 Floors general

5.5.1 In transversely framed craft, floors are generally to be fitted at every frame and underneath each bulkhead.

5.5.2 In longitudinally framed craft, floors are, in general, to be fitted at every transverse web frame and bulkhead and generally at a spacing not exceeding 2 m. Additional transverse floors or webs are to be fitted at half web-frame spacing in way of engine seatings and thrust bearings, pillars, skegs, ballast/bilge keels and the bottom of the craft in the forefoot region.

5.5.3 The overall web depth, d_w, of floors at the centre-line, is not to be taken as less than:

$$d_w = 6{,}2L_R + 50 \text{ mm}$$

where

L_R is as defined in 1.5.1.

5.5.4 The web thickness of plate floors, t_w, is to be in accordance with Ch 3,1.18 and not less than:

$$t_w = \sqrt{k_a}\left(\frac{4{,}7d_f}{1000} + 3{,}1\right)\left(\frac{s}{1000} + 0{,}5\right) \text{ mm}$$

where

d_f is determined from 5.5.3 and

k_a and s are as defined in 1.5.1.

5.5.5 If the side frames of the craft are attached to the floors by brackets, the depth of floor may be reduced by 15 per cent and the floor thickness determined using the reduced depth. The brackets are to be flanged and have the same thickness as the floors, and their arm lengths clear of the frame are to be the same as the reduced floor depth given above.

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5.5.6 The face flat area, A_f, of floors is not to be taken as less than:

$$A_f = k_a 0{,}21 L_R \text{ cm}^2$$

where

k_a and L_R are defined in 1.5.1.

5.5.7 The face flat thickness, t_f, is to be not less than the thickness of the web and the ratio of the web to the thickness of the face flat is to be not less than eight but is not to exceed 16.

5.5.8 Additionally, the requirements of 4.11 for bottom inboard transverse web frames are to be complied with.

5.5.9 Floors are in general to be continuous from side to side.

5.5.10 The tops of floors, in general, may be level from side to side. However, in craft having considerable rise of floor the depth of the floor plate may require to be increased to maintain the required section modulus.

5.5.11 The floors in the aft peak are to extend over and provide efficient support to the stern tube(s) where applicable.

5.5.12 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deeptanks as detailed in Ch 3,7.2 and Ch 3,7.4.

5.6 Floors in machinery space

5.6.1 The web thickness, t_w, of floors in machinery spaces is to be 1 mm greater than that required by 5.5.4.

5.6.2 The depth and mechanical strength properties of floors between engine or gearbox girders is to be not less than that required to maintain continuity of structural integrity or 50 per cent of the depth given in 5.5.3. The face flat area and web thickness of such reduced height floors are to be increased appropriately in order to maintain the continuity of structural strength, *see also* Ch 3,4.12.

5.7 Forefoot and stem

5.7.1 The thickness of plate stems at the waterline is to comply with the requirements for plate keels as given in 3.2.

5.7.2 The forefoot and stem are to be additionally reinforced with floors.

5.7.3 The cross-sectional area of bar stems, A_{bs}, is not to be taken as less than :

$$A_{bs} = 1{,}1 k_a L_R \text{ cm}^2$$

where

k_a and L_R are as defined in 1.5.1.

■ *Section 6* Double bottom structure

6.1 General

6.1.1 Unless otherwise specified in this Section, the scantlings and arrangements for the double bottom structure are to be determined in accordance with the procedures described in, or as required by, Ch 3,6 for mono-hull craft using the pressures from Part 5 appropriate to multi-hulls.

6.1.2 The thickness of double bottom structural members is in no case to be less than the appropriate minimum requirement given in Section 2.

6.2 Keel

6.2.1 The scantlings of plate and bar keels are to comply with the requirements of 5.2.

6.3 Centreline girder

6.3.1 A centreline girder is to be fitted throughout the length of the craft. The web thickness, t_w, is to be not less than that required by:

$$t_w = \sqrt{k_a}\,(0{,}082 L_R + 4{,}1) \text{ mm within } 0{,}4L \text{ amidships}$$

$$= \sqrt{k_a}\,(0{,}082 L_R + 2{,}7) \text{ mm at ends}$$

where

k_a and L_R are as defined in 1.5.

6.3.2 The geometric properties of the girder section are to be in accordance with Ch 3,1.18.

6.3.3 The overall web depth, d_w, of the centre girder is to be taken as not less than 630 mm and is to be sufficient to give adequate access to all parts of the double bottom.

6.3.4 Additionally, the requirements of 4.8 for bottom inboard longitudinal primary stiffeners are to be complied with.

6.4 Side girders

6.4.1 Where the floor breadth does not exceed 4,0 m, side girders are not required. Vertical stiffeners are to be fitted to the floors on each side, the number and positions of these stiffeners being dependent on the arrangement of the double bottom structure.

6.4.2 Where the breadth of floor is greater than 4,0 m, additional side girders having the same thickness as the floors are to be fitted. The number of side girders is to be such that the distance between the side girders and centre girder and margin plate, or between the side girders themselves, does not exceed 2,0 m.

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6.4.3 Side girders, where fitted, are to extend as far forward and aft as practicable and are in general to be scarfed into the bottom structure forward and aft of the supporting bulkheads, deep floors or other primary transverse structure.

6.4.4 Where additional side girders are fitted in way of main machinery seatings, they are to be integrated into the structure of the craft and extended forward and aft as far as practicable.

6.4.5 Under the main engine, girders extending from the bottom shell to the top plate of the engine seating are to be fitted. The height of the girders is to be not less than the height of the floor. Engine holding-down bolts are to be arranged as near as practicable to the girders and floors. Where this cannot be achieved, bracket floors and/or hanging brackets are to be fitted.

6.4.6 The geometric properties of the girder section are to be in accordance with Ch 3,1.18.

6.4.7 Additionally, the requirements of 4.8 for bottom inboard longitudinal primary stiffeners are to be complied with.

6.5 Plate floors

6.5.1 The web thickness, t_w, of non-watertight plate floor is to be not less than:

$$t = \sqrt{k_a}\ (0{,}41L_R + 4{,}8)\ \text{mm}$$

where

k_a and L_R are as defined in 1.5.

6.5.2 The geometric properties of the floor section are to be in accordance with Ch 3,1.18.

6.5.3 Additionally, the requirements of 4.11 for bottom inboard transverse web frames are to be complied with.

6.5.4 Plate floors are, in general, to be continuous between the centre girder and the margin plate.

6.5.5 In longitudinally framed craft, plate floors are to be fitted in the following positions:

(a) At every half frame in way of the main engines, thrust bearings, and bottom of the craft forward.
(b) Outboard of the engine seatings, at every frame within the engine room.
(c) Underneath pillars and bulkheads.
(d) Outside of the engine room at a spacing not exceeding 2,0 m.

6.5.6 Vertical flat bar stiffeners are to be fitted to all plate floors at each longitudinal. Each stiffener is to have a depth of not less than $10t_w$ and a thickness of not less than t_w, where t_w is thickness of the plate floor as calculated in 6.5.1.

6.5.7 In transversely framed craft, plate floors are to be fitted at every frame in the engineroom, under bulkheads, in way of change in depth of double bottom and elsewhere at a spacing not exceeding 2,0 m.

6.6 Additional requirements for watertight floors

6.6.1 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deeptanks as detailed in Ch 3,7.2 or Ch 3,7.4 respectively.

■ *Section 7*
Bulkheads and deep tanks

7.1 General

7.1.1 Unless otherwise specified in this Section, the scantlings and arrangements for bulkheads and deep tanks are to be determined in accordance with the procedures described in, or as required by Ch 3,3 for mono-hull craft using the pressures from Part 5 appropriate to multi-hulls.

7.2 Longitudinal bulkheads within the cross-deck structure

7.2.1 Longitudinal bulkheads are to be fitted within the cross-deck structure to prevent cross flooding and the spread of flame and smoke. The minimum number of such bulkheads is to be:

- one for catamarans of Rule length, L_R, less than or equal to 24 m;
- two for catamarans of Rule length, L_R, greater than 24 m; and
- four for trimarans.

Quadrimarans and other craft of novel configuration will be specially considered.

7.2.2 The scantlings and arrangements for cross deck longitudinal bulkheads are to be determined in accordance with the procedures described in Ch 3,7.2 and Ch 3,7.3 for bulkheads in mono-hull craft.

7.2.3 In addition the requirements of 7.4 with regard to global strength are to be complied with.

7.3 Transverse bulkheads within the cross-deck structure

7.3.1 The scantlings of cross deck transverse bulkheads are to be determined in accordance with the procedures described in Ch 3,7.2 and Ch 3,7.3 for bulkheads in mono-hull craft.

7.3.2 In addition the requirements of 7.4 in respect of global strength are to be complied with.

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7.4 Additional strength required for global loadings

7.4.1 Where transverse bulkheads or deep tank bulkheads within the cross deck structure are to assist in resisting torsional or bending loads between the hulls, then the watertight/deep tank bulkheads may be required to be additionally stiffened and the plating or skin thicknesses may require to be increased. For hull girder strength requirements, *see* Ch 6,3.

7.4.2 Longitudinal bulkheads within the cross deck structure that are to assist in maintaining the longitudinal strength of the vessel are to satisfy both bulkhead/deep tank and longitudinal strength requirements. This may require additional stiffening and increase in plate thickness requirements. For hull girder strength requirements, *see* Ch 6,3.

7.4.3 Where longitudinal or transverse cross deck bulkheads/deep tanks are to carry global loads, detailed calculations are to be submitted.

7.4.4 For longitudinal or transverse cross deck members carrying global loads, consideration is to be given to stiffener arrangement, alignment, and continuity in order to maximise the rigidity and stiffness of the structure, in resisting the torsional/bending loads. Discontinuity of structural bulkheads is to be avoided.

7.5 Access

7.5.1 Access through the cross deck structure may be permitted, provided that the global strength requirements are satisfied. Cut outs through the bulkhead are not to exceed 50 per cent of its depth, *see also* Ch 3,7.18.

7.5.2 Where the cross deck structure acts as a watertight bulkhead pipe or cable runs through, the watertight bulkheads are to be fitted with suitable watertight glands.

7.6 Local reinforcement

7.6.1 Bulkheads forming the cross deck structure are to be suitably strengthened, if necessary, in way of deck girders and where subjected to concentrated loads.

7.7 Integral/deep tanks within the cross-deck structure

7.7.1 Where the cross deck structure forms the boundaries of deep tanks, the scantlings of these boundaries are to satisfy both deep tank and global strength requirements. For general and structural requirements for deep tanks, *see* Ch 3,7. For global considerations of strength, *see* Ch 6,3.

■ *Section 8* Deck structures

8.1 General

8.1.1 Unless otherwise specified in this Section, the scantlings and arrangements for deck structures are to be determined in accordance with the procedures described in, or as required by, Ch 3,8 for mono-hull craft using the pressures from Part 5 appropriate to multi-hulls.

8.2 Arrangements

8.2.1 Design loads to be applied for cross-deck scantling calculations are transverse vertical bending moment and shear force, twin hull torsional connecting moment, external pressure load and appropriate internal loads as defined in Part 5.

8.2.2 For craft up to 50 m in Rule length, L_R, where the cross-deck is formed by transverse primary stiffeners or bulkheads, and subjected to global transverse loads in accordance with 8.2.1 the scantling requirements to satisfy the global loading condition are given in Ch 6,3.5.

8.2.3 Superstructures fitted on the cross-deck structures, on craft up to 50 m in Rule length, L_R, will, in general, be considered as non-load carrying and are not to be included in the strength of the cross-deck. For designs where the superstructure is designed to absorb global loads, the requirements are given in Ch 6,3.2.

8.2.4 For craft more than 50 m in Rule length, L_R, global analysis is required to determine the response of the deck and superstructure as a system. Deck scantlings may then be derived for compliance with the requirements of Ch 6,3.

8.3 Cross-deck plating

8.3.1 The thickness of the cross-deck plating is to be determined from the general plating equation given in Ch 3,1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

8.3.2 The thickness of the cross-deck plating is in no case to be less than the appropriate minimum requirement given in Section 2.

8.3.3 The scantlings of watertight cockpits are to be of equivalent strength to those of the strength/weather deck, *see also* Part 4.

8.3.4 It is recommended that the working areas of the weather deck have an anti-slip surface.

8.3.5 Where decks are sheathed with wood or other materials, details of the method of attachment are to be submitted, *see also* Ch 3,2.4.

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8.4 Cross-deck stiffening

8.4.1 The Rule requirements for section modulus, inertia and web area for the cross-deck primary stiffeners are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

8.4.2 The Rule requirements for section modulus, inertia and web area of the strength/weather deck secondary stiffening are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.4.3 The geometric properties of stiffener sections are to be in accordance with Ch 3,1.18.

8.4.4 For cases where there may be excessive rotations or deflections at supports or where the lateral pressure distribution is non-uniform, the above scantlings may require increasing appropriately.

8.4.5 Where stiffeners are subject to concentrated loads such as pillars, the concentrated loads are to be superimposed on the lateral pressure and strength calculations carried out to demonstrate compliance with the deflection and stress criteria given in Ch 7,2 and Ch 7,3.

8.4.6 Where stiffening members support plating of the extruded plank type, or the floating frame system is used, the plating is not to be included in the scantling derivation of the supporting structure.

8.4.7 Openings in the cross-deck for hatches, etc., are to comply with the requirements of Ch 3,8.11.

8.5 Novel features

8.5.1 Where the cross-deck structure is of unusual design, form or proportions, the scantlings are to be determined by direct calculation and a copy is to be submitted for consideration.

■ *Section 9*
Superstructures, deckhouses, pillars and bulwarks

9.1 General

9.1.1 The scantlings and arrangements for superstructures, deckhouses and bulwarks are to be determined in accordance with the procedures described in, or as required by, Ch 3,9 for mono-hull craft.

9.1.2 The scantlings and arrangements for pillars and pillar bulkheads are to be determined in accordance with the procedures described in, or as required by, Ch 3,10 for mono-hull craft.

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Section

1 **General**

2 **Special features**

3 **Vehicle decks**

4 **Bow doors**

5 **Movable decks**

6 **Helicopter landing areas**

7 **Strengthening requirements for navigation in ice conditions**

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull and multi-hull craft of aluminium construction as defined in Pt 1, Ch 1,1.

1.2 Symbols and definitions

1.2.1 The symbols and definitions used in this Chapter are defined below and in the appropriate Section:

k_a = alloy factor
= $125/\sigma_a$
s = stiffener spacing, in mm
σ_a = 0,2 per cent proof stress of the alloy in the welded condition, in N/mm^2.

■ *Section 2* Special features

2.1 Water jet propulsion systems – Construction

2.1.1 The requirements for the construction and installation of water jet units apply irrespective of rated power.

2.1.2 Water jet ducts may be fabricated as an integral part of the hull structure, or as a bolted-in unit. In either case, detailed plans indicating dimensions, scantlings and materials of construction of the following are to be submitted in triplicate:

(a) Arrangement of the system including intended method of attachment to the hull and building-in, geometry of tunnel, shell opening, method of stiffening, reinforcement, etc.
(b) Shaft sealing arrangements.
(c) Details of any shafting support or guide vanes used in the water jet system.
(d) Details and arrangements of inspection ports, their closing appliances and sealing arrangement, etc.
(e) Details and arrangements of protection gratings and their attachments.

2.1.3 When submitting the plans requested in 2.1.2, details of the designers' loadings and their positions of application in the hull are to be submitted. These are to include maximum applied thrust, moments and tunnel pressures for which approval is sought.

2.1.4 All materials used in construction are to be manufactured and tested in accordance with the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

2.1.5 Aluminium alloys are to be of suitable marine grades in accordance with the requirements of Ch 2,2.

2.1.6 Irrespective of the material used, the strength and supporting structure of all tunnels are to be examined by direct calculation procedures which are to be submitted. In no case are the scantlings to be taken as less than the Rule requirements for the surrounding structure. The strength of the hull structure in way of tunnels is to be maintained. The structure is to be adequately reinforced and compensated as necessary. All openings are to be suitably reinforced and have radiused corners.

2.1.7 Consideration is to be given to providing the inlet to the tunnel with a suitable guard to prevent the ingress of large objects into the rotodynamic machinery. The dimensions of the guard are to strike a balance between undue efficiency loss due to flow restriction and viscous losses, the size of object allowed to pass and susceptibility to clog with weed and other flow restricting matter.

2.1.8 The inlet profile of the tunnel is to be so designed as to provide a smooth uptake of water over the range of craft operating trims and avoid significant separation of the flow into the rotating machinery.

2.1.9 Single or multiple water jet unit installations having a total rated power in excess of 500 kW are to be contained within their own watertight compartment. Other arrangements for maintaining watertight integrity may be specially considered depending on the size and installation layout.

2.1.10 For details of machinery requirements, *see* Pt 12, Ch 2.

2.2 Water jet propulsion systems – Installation

2.2.1 Standard units built for 'off the shelf' supply and which include the duct are to be installed strictly in accordance with the manufacturer's instructions, *see also* 2.1.4.

2.2.2 Integral water jet ducts are to be constructed in accordance with the manufacturer's requirements and the relevant plans submitted as required by 2.1.

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2.2.3 Where load is transmitted into the transom and/or bottom shell, the thickness of the plating adjacent to the jet unit is to be increased. The increase in thickness is to be not less than 50 per cent of the calculated transom and bottom plating thicknesses respectively or 8 mm, whichever is the greater. Such reinforcement is to extend beyond the surrounding stiffening structure.

2.2.4 For 'bolted in' units, hull receiving rings are to be of a material compatible with the hull. Scantlings of the receiving rings are to be as required by the jet unit manufacturer and suitably edge prepared prior to welding in place. The receiving ring is to be installed using an approved welding procedure. Where a manufacturer's specification is not provided, full details are to be submitted.

2.2.5 Bolt sizes and spacings are to be specified by the manufacturer, and are to be of suitable marine grade, insulated as appropriate and locked by suitable means.

2.2.6 Where studs are proposed for the receiving ring(s), the remaining thickness below the depth of blind tap is to be not less than the bottom shell plating thickness plus 2 mm. Bottoms of all blind taps are to be free of sharp corners.

2.2.7 The use of approved alignment resins may be considered where accurate seating and faying surfaces are required. Details are to be submitted for consideration and approval.

2.2.8 Where a water jet unit forms an integral part of the hull structure, such units are to be installed using an approved weld procedure and in accordance with the manufacturer's instructions. Materials to be welded are to be of compatible specifications.

2.2.9 Water jet units transmitting thrust into the transom structure are to be supported by a system of radial, athwartship and vertical stiffening. Drawings are to be accompanied by a set of detailed structural calculations. Where complex installations are proposed, a finite element model may be submitted in lieu of direct calculations.

2.2.10 Water jet units transmitting thrust to a bottom shell connection or intermediate tunnel connection are to be supported by additional stiffening, the details of which are to be submitted.

2.3 Foil support arrangements

2.3.1 The materials and construction of the lifting surface will be considered on a case by case basis.

2.3.2 The design and performance of the lifting surface is outside the scope of classification. However, when submitting structural plans for the hull connection installation, the designer/Builder is to define:

(a) Operating mode, i.e. fully submerged or surface piercing.
(b) Maximum operational speed for which approval is sought.
(c) Maximum, direct, bending, shear and torque loads generated by the foil at the point of attachment(s).
(d) The type of profile or section used, e.g. N.A.C.A.
(e) Supply of lift/drag profile.
(f) If the foil is fixed, movable or retractable.
(g) If the foil is fitted with control surfaces.
(h) If the vertical leg(s) act as a rudder(s).
(j) If shaft liners are carried to the foils at which support arrangements are provided.
(k) If water intakes/scoops are fitted.
(l) If propulsion units are fitted.

2.3.3 The scantlings and arrangements of foils and their supporting structure will require to be specially considered in the following cases where:

(a) Propulsion units are incorporated within the foil.
(b) Foils carry shaft support arrangements.
(c) The foils are of novel design.

2.3.4 Where fully submerged foils are 'built-in' to the hull, the attachment area is to be contained within a watertight compartment and the structural arrangements of 2.4 are to be complied with as appropriate.

2.3.5 Where foils are to be bolted to the structural foundation calculations are to be submitted to demonstrate that the effect of loading arising from high speed impact, grounding, fouling, etc., is limited to failure of the bolted connection. In all cases the structural and watertight integrity of the craft is to be maintained.

2.3.6 Attachment points of foils are to be contained within a watertight compartment.

2.3.7 Foils attached by riveted means are in addition to comply with Ch 2,4.25.

2.3.8 Bow fairing doors fitted on forward retracting bow foils are to be weathertight and comply with Pt 3, Ch 4.

2.3.9 Aft bulkheads of bow foil compartments are to comply with the requirements for collision bulkheads as detailed in Ch 3,7.7.

2.3.10 Hydraulically operated retracting systems are to be equipped with low pressure and are to include a manual system of operation in the event of system failure.

2.3.11 A mechanical locking system is to be provided on retracting systems when the system is in both the operational and 'stowed' conditions.

2.4 Surface drive mountings

2.4.1 Transoms through which surface drive systems pass and which are required to carry thrust, significant weight, torque, moment, etc., are to be adequately reinforced.

2.4.2 The thickness of transom plating in way is to be not less than 1,5 times the thickness of the adjacent plating or as advised by the drive manufacturer, whichever is the greater.

2.4.3 Steering rams are to be mounted on suitably reinforced areas of plating supported by additional internal stiffening, details of which are to be submitted for consideration.

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2.5 Sea inlet scoops

2.5.1 Sea inlet scoops may be integral with or an appendage to the hull.

2.5.2 Scoops are to be suitably positioned to minimise ventilation.

2.5.3 Suitable protective arrangements are to be provided to minimise the ingress of debris. The net area through the proposed arrangement is to be not less than twice that of the valves connected to the scoop. Provision is to be made for clearing the scoops by the use of suitable means and proposals are to be submitted.

2.5.4 Scoops are to be contained within a watertight compartment.

2.5.5 The plating thickness in way of integral scoops is to be not less than 1,5 times the thickness of the adjacent shell plating, with additional reinforcement at the leading edge.

2.5.6 For craft navigating in ice, the arrangements will be specially considered on an individual basis.

2.6 Crane support arrangements

2.6.1 Crane pedestals are to be efficiently supported and in general, are to be carried through the deck and satisfactorily scarfed into the surrounding structure. Alternatively, crane pedestals may comprise a foundation, in which case the foundation and its supporting structure are to be of substantial construction. Proposals for other support arrangements will be specially considered.

2.6.2 The pedestal or proposed arrangement is to be designed with respect to the worst possible combinations of loads resulting from the crane self weight, live load, wind and crane accelerations together with those resulting from the craft's heel and trim.

2.6.3 Stowage arrangements are to be taken into account when calculating the loads applied to the pedestal.

2.6.4 When submitting plans for the proposed foundation, the designer is to include design calculations covering the parameters indicated in 2.6.2.

2.6.5 Insert plates are to be incorporated in the deck plating in way of crane foundations. The thickness of the insert plates is to be as required by the designer's calculations but is in no case is to be taken as less than 1,5 times the thickness of the adjacent attached plating.

2.6.6 All inserts are to have well radiused corners and be suitably edge prepared prior to welding. All welding in way is to be double continuous and full penetration where necessary. Tapers are to be not less than three to one.

2.7 Skirt attachment

2.7.1 The design and scantlings of the skirt are outside the scope of classification, however the designers/builders are to submit their proposals in respect of the attachment detail. The following supporting information is to be submitted:

(a) cushion pressure;

(b) calculations demonstrating that the effect of damage to the flexible membrane and/or the retaining section arising from high speed impact, grounding, fouling, etc., will not compromise the structural and watertight integrity of the craft.

2.7.2 The skirt is to be securely attached around its periphery and is to be suitably reinforced by the use of backing plates.

2.7.3 Where the skirt is retained by bolting the retaining bars are to be as long as practicable with a fastener spacing of not more than 50 mm.

2.7.4 Where the design of the skirt is such that the flexible edge is retained by the use of a pre-formed channel, only the bolted hull connection of the preform to the hull structure is considered.

2.8 Trim tab arrangements

2.8.1 The shape, design and scantlings of the trim tabs are outside the scope of classification, however Lloyd's Register (hereinafter referred to as 'LR') is concerned with their attachment to the hull structure.

2.8.2 The designer/Builder is to submit the following:

(a) Detailed calculations indicating the maximum lift force generated by the tab for which acceptance is sought together with the corresponding speed and displacement.

(b) Details and calculations of the hull attachment.

(c) Details and calculations of the local internal reinforcement in way of the attachment.

2.8.3 Bearing materials used are to be of an approved type.

2.8.4 Fully submerged retractable trim tabs will be specially considered on a case by case basis.

2.9 Spray rails

2.9.1 Spray rails may be integrated into the hull structure or added in the form of an appendage on completion of the hull shell.

2.9.2 Where spray rails are integrated, they are to have a plating thickness not less than the adjacent bottom shell and additionally have a section modulus and inertia equivalent to that required for a longitudinal stiffener in the same position.

2.9.3 Where spray rails are added as an appendage, they are to be attached by double continuous welding and are additionally to comply with the strength requirements of 2.9.2.

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2.9.4 Spray rails are to be supported by the internal stiffening arrangements and by additional local reinforcement as necessary.

2.9.5 In no case are the toes of spray rails to terminate on unsupported plating.

2.10 Other lifting surfaces

2.10.1 Other lifting surfaces not specifically covered by the Rules will be individually considered on the basis of submitted direct calculations.

2.10.2 Structure or hull shapes above the running waterline designed to generate aerodynamic lift may be individually considered on a case by case basis.

2.10.3 Aerodynamic, hydrodynamic and aero-hydrodynamic stability are outside the scope of classification and are subject to the approval of the National Administration concerned.

2.11 Propeller ducting

2.11.1 Where propellers are fitted within ducts/tunnels the plating thickness in way of the blades is to be increased by 50 per cent.

2.11.2 The tunnel wall in way of the propeller blades is to be additionally stiffened.

2.12 Ride control ducting and installation for Surface Effect Ships (SES)

2.12.1 Ducts penetrating the side inboard shell plating are to comply with the scantling requirements for side inboard structures, over their entire length in the appropriate material.

2.12.2 Ducts penetrating the wet-deck are to comply with the scantling requirements for wet-deck structures over their entire length in the appropriate material.

2.12.3 Open ends of ducts are to be fitted with a suitable protective grille.

2.12.4 The vent assembly, its design, construction and operation are outside the scope of classification and is the responsibility of the ride control system designer.

2.12.5 Details of the installation and securing arrangements of the vent valve assembly into the duct are to be submitted for approval.

■ *Section 3* Vehicle decks

3.1 General

3.1.1 These requirements are applicable to longitudinally or transversely framed craft intended for the carriage of wheeled vehicles, or where wheeled vehicles are to be used for cargo handling.

3.1.2 The deck and supporting structure are to be designed on the basis of the maximum loading to which they may be subjected in service. Where applicable, the hatch covers are to be similarly designed. In no case, however, are the scantlings to be less than would be required for a weather or cargo deck, or hatch cover, as applicable.

3.1.3 Details of the deck loading resulting from the proposed stowage or operation of vehicles are to be supplied by the Builder. These details are to include axle and wheel spacing, the wheel load, type of tyre and tyre print dimensions for the vehicles. The vehicle types and wheel loads for which the vehicle decks, including hatch covers where applicable, have been approved are to be included in the craft's documentation and contained in a notice displayed on each deck. For design purposes, the wheel loading is to be taken as not less than 3,0 kN.

3.1.4 The scantling requirements are based on structural strength and limitations on stress and deflection, with no allowance made for wear and tear. Local reinforcement is to be fitted as necessary, particularly in way of vehicle lanes and passenger routes.

3.1.5 The webs of vehicle deck stiffening members are in no cases to be scalloped.

3.2 Definitions

3.2.1 **Load area.** The load area is defined as the footprint area of an individual wheel or the area enclosing a group of wheels when the distance between footprints is less than the smaller dimension of the individual prints.

3.3 Deck plating

3.3.1 The thickness, t_p, of vehicle deck plating is to be taken as not less than:

$$t_p = \frac{\alpha s}{1370\sqrt{k_a}} \text{ mm}$$

where

P_1 = corrected patch load, in tonnes, obtained from Table 5.3.1

α = thickness coefficient obtained from Fig. 5.3.1

s = secondary stiffener spacing, in mm

β_p = tyre print coefficient used in Fig. 5.3.1

$$= \log_{10}\left(\frac{3{,}5P_1 k_a^2}{s^2} \times 10^7\right)$$

s and k_a are as defined in 1.2.

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Table 5.3.1 Deck plate thickness calculation

Symbols	Expression
a, *s*, *u*, and *v* as defined in Fig. 5.3.1 n = tyre correction factor as detailed in Table 5.3.2 P_1 = corrected patch load, in tonnes λ = dynamic magnification factor P_w = load, in tonnes, on the tyre print. For closely spaced wheels the shaded area shown in Fig. 5.3.1 may be taken as the combined print λ = dynamic magnification factor ϕ_1 = patch aspect ratio correction factor ϕ_2 = panel aspect ratio correction factor ϕ_3 = wide patch load factor	$P_1 = \phi_1\,\phi_2\,\phi_3\,\lambda\,P_w$ $\phi_1 = \dfrac{2v_1 + 1{,}1s}{u_1 + 1{,}1s}$ $v_1 = v$, but $\le s$; $u_1 = u$, but $\le a$ $\phi_2 = 1{,}0$ for $u \le (a - s)$ $= \dfrac{1}{1{,}3 - \dfrac{0{,}3}{s}(a-u)}$ for $a \ge u > (a - s)$ $= 0{,}77\,\dfrac{a}{u}$ for $u > a$ $\phi_3 = 1{,}0$ for $v < s$ $= 0{,}6\,(s/v) + 0{,}4$ for $1{,}5 > (v/s) > 1{,}0$ $= 1{,}2\,(s/v)$ for $(v/s) \ge 1{,}5$ $\lambda = 1{,}25$ for craft operating in G1 $= (1 + 0{,}35n)$ for craft operating in G2 $= (1 + 0{,}42n)$ for craft operating in G3 $= (1 + 0{,}49n)$ for craft operating in G4 $= (1 + 0{,}56n)$ for craft operating in G5 $= (1 + 0{,}70n)$ for craft operating in G6 G1, G2, G3, G4, G5 and G6 as defined in Pt 1, Ch 2,3.5.5

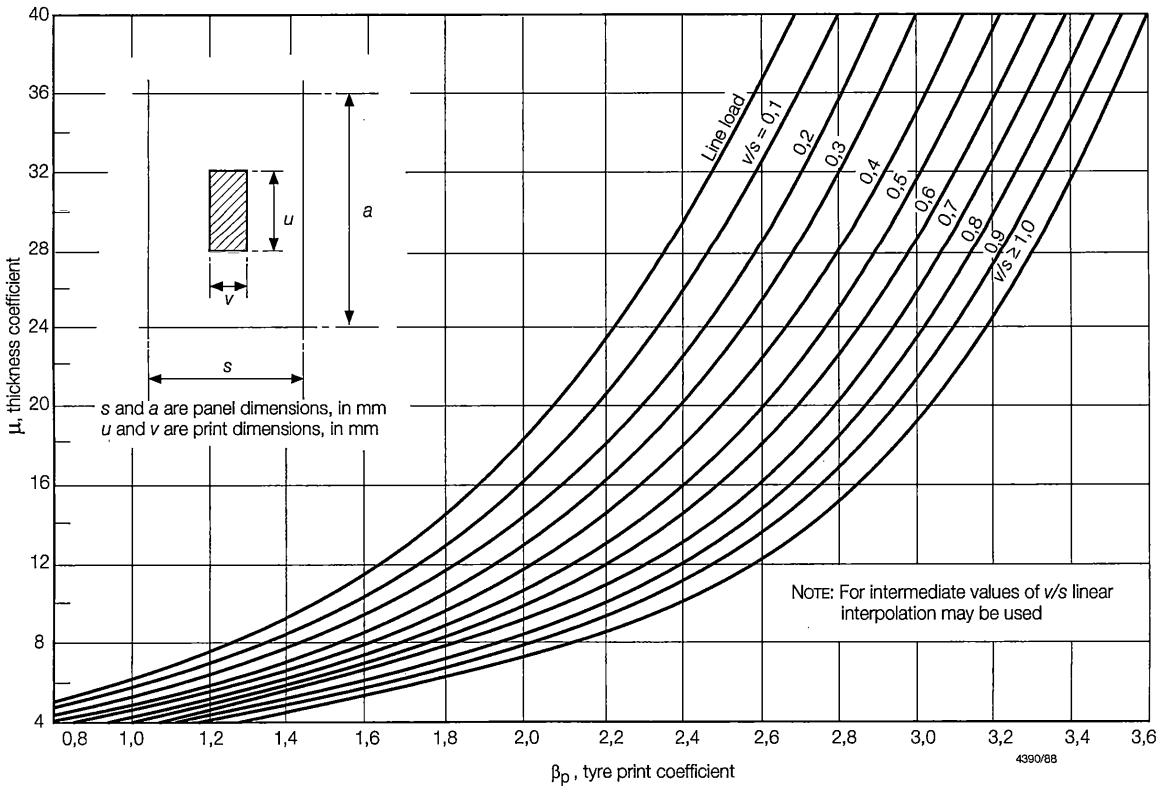

Fig. 5.3.1 Tyre print chart

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3.4 Secondary stiffening

3.4.1 The scantlings of vehicle deck stiffeners are to be as required to satisfy the most severe arrangement of print wheel loads in conjunction with the cargo/weather deck design head.

3.4.2 The minimum requirements for section modulus, inertia and web area of vehicle deck secondary stiffeners subject to wheel loading are to be calculated in accordance with Table 5.3.3, *see also* Fig. 5.3.1 and Table 5.3.2.

Table 5.3.2 Tyre correction factor, *n*

Number of wheels in idealised patch	Pneumatic tyres correction factor, *n*	Solid rubber tyres correction factor, *n*
1	0,6	0,8
2 or more	0,75	0,9

3.4.3 When two or more load areas are located simultaneously on the same stiffener span, the scantling requirements are to be specially considered on the basis of direct calculation.

3.4.4 Where continuous secondary stiffeners pass through the webs of primary members, they are to be fully collared or lugged in way. The shear stresses at the connections are to be in compliance with Table 7.3.1 in Chapter 7.

3.5 Primary stiffening

3.5.1 The scantlings of vehicle deck primary girders and transverse web frames are to be determined on the basis of direct calculation in association with the limiting permissible stress and deflection criteria contained in Chapter 7.

3.6 Securing arrangements

3.6.1 Details of the connections to the hull of vehicle securing arrangements are to be submitted for approval.

3.6.2 Deck fittings in way of vehicle lanes are to be recessed.

3.6.3 The vehicle deck structure is to be of adequate strength for the upward forces imposed at fixed securing points. Local reinforcement is to be fitted as necessary.

Table 5.3.3 Secondary stiffener requirements

Scantling requirement	Load case	
	$d \le l$	$d > l$
Section modulus (Z) (cm^3)	$Z = \left(\frac{P\ k_w\ (3l^2 - d^2)}{24\ l\ f_\sigma\ \sigma_a} \right) \times 10^3 + Z_{dk}$	$Z = \left(\frac{k_w\ P\ l^2}{10\ d\ f_\sigma\ \sigma_a} \right) \times 10^3 + Z_{dk}$
Inertia (I) (cm^4)	$I = \left(\frac{f_\delta\ P\ k_w\ (2l^3 - 2d^2\ l + d^3)}{384\ E\ l} \right) \times 10^5 + I_{dk}$	$I = \left(\frac{f_\delta\ k_w\ P\ l^3}{384\ E\ d} \right) \times 10^5 + I_{dk}$
Web area (A_w) (cm^2)	$A_W = \frac{10P\ k_w\ (m^3 - 2m^2 + 2)}{2\ f_\tau\ \tau_a} + A_{dk}$ where $m = d/l$	$A_W = \frac{k_w\ P\ l}{2\ d\ f_\tau\ \tau_a} + A_{dk}$

Symbols

P = maximum effective load per wheel or group of wheels, in kN
l = overall secondary stiffener length, in metres
s = stiffener spacing, in metres
d = dimension of load area parallel to stiffener axis, in metres
E = Young's modulus of elasticity of material, in N/mm^2
w = dimension of load area perpendicular to stiffener axis, in metres
k_w = lateral loading factor
= 1 for $w \le s$
= s/w for $w > s$
f_σ = limiting bending stress coefficient taken from Table 7.3.1 in Chapter 7
f_τ = limiting shear stress coefficient taken from Table 7.3.1 in Chapter 7
f_δ = limiting deflection coefficient taken from Table 7.2.1 in Chapter 7
σ_a = 0,2% proof stress of material, in N/mm^2
τ_a = shear stress of the alloy, in N/mm^2
= $\frac{\sigma_a}{\sqrt{3}}$
Z_{dk}, I_{dk}, A_{dk} = stiffener requirements for weather/cargo decks to be determined in accordance with Ch 3,8.7 and Ch 3,8.10 using the appropriate design head for weather/cargo. In no case is the head to be taken as less than 2 kN/m^2

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3.7 Access

3.7.1 Bow doors are to comply with the requirements of Section 4.

3.7.2 Where access to the vehicle deck is provided by side and stern doors the doors are to have scantlings equivalent to the structure in which they are fitted, *see also* Pt 3, Ch 4,4.

3.7.3 Doors providing pedestrian access between vehicle decks and accommodation spaces are to be gastight, have scantlings equivalent to the surrounding structure and where applicable are to comply with the requirements of Part 17.

3.8 Hatch covers

3.8.1 The scantlings and arrangements of hatches and hatch covers located within vehicle decks are to be not less than that required by the Rules for the supporting structure in which such hatches are fitted. In general the end fixity of primary stiffening members is to be taken as simply supported. Local and secondary stiffening members may be either partially or fully fixed at their end connections dependent upon the proposed arrangement.

3.8.2 In no case, however, are the scantlings of plating and stiffeners to be less than would be required for a weather or cargo deck, or hatch cover, as applicable.

3.8.3 Where unusual arrangements of hatch cover stiffening are proposed, the scantlings of plating and stiffeners may be determined by direct calculations using a two-dimensional grillage model. A copy of the calculations is to be submitted.

3.9 Heavy and special loads

3.9.1 Where heavy or special loads are proposed to be carried, the scantlings and arrangements of the deck structure will be individually considered on the basis of submitted calculations.

3.9.2 Due account is to be taken of the acceleration levels due to craft motion as applicable to particular items of heavy mass such as vehicles, containers, pallets, etc.

3.10 Direct calculations

3.10.1 LR will consider direct calculations for the derivation of scantlings as an alternative to and equivalent to those derived by Rule requirements. The assumptions made and the calculation procedures used are to be submitted for appraisal in accordance with Pt 3, Ch 1,2.

■ *Section 4* Bow doors

4.1 Application

4.1.1 The requirements of this Section are applicable to the arrangement, strength and securing of bow doors, both the visor and the side opening type doors, and inner doors leading to a complete or long forward enclosed superstructure.

4.1.2 Other types of bow door will be specially considered.

4.2 General

4.2.1 The attention of Owners and Builders is drawn to the additional statutory regulations for bow doors that may be imposed by the National Authority.

4.2.2 Bow doors are to be situated above the freeboard deck. A watertight recess in the freeboard deck located forward of the collision bulkhead and above the deepest waterline fitted for arrangement of ramps or other related mechanical devices may be regarded as a part of the freeboard deck.

4.2.3 An inner door is to be fitted. The inner door is to be part of the collision bulkhead. The inner door need not be fitted directly above the bulkhead below, provided it is located within the limits specified for the position of the collision bulkhead, *see* Pt 3, Ch 2,4. A vehicle ramp may be arranged for this purpose, provided its position complies with Pt 3, Ch 2,4 and the ramp is weathertight over its complete length. In this case the upper part of the ramp higher than 2,3 m above the freeboard deck may extend forward of the limit specified in Pt 3, Ch 2,4. If this is not possible a separate inner weathertight door is to be installed, as far as practicable within the limits specified for the position of the collision bulkhead.

4.2.4 Bow doors are to be fitted as to ensure tightness consistent with operational conditions and to give effective protection to inner doors. Inner doors forming part of the collision bulkhead are to be weathertight over the full height of the cargo space and arranged with fixed sealing supports on the aft side of the doors.

4.2.5 Bow doors and inner doors are to be arranged so as to preclude the possibility of the bow door causing structural damage to the inner door or to the collision bulkhead in the case of damage to or detachment of the bow door. If this is not possible, a separate inner weathertight door is to be installed, as indicated in 4.2.3.

4.2.6 The requirements for inner doors are based on the assumption that vehicles are effectively lashed and secured against movement in the stowed position.

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4.3 Symbols and definitions

4.3.1 The symbols used in this Section are defined as follows:

a_{bv} = vertical distance, in m, from visor pivot to the centroid of the transverse vertical projected area of the visor door, as shown in Fig. 5.4.2

b_{bv} = horizontal distance, in m, from visor pivot to the centroid of the horizontal projected are of the visor door, as shown in Fig. 5.4.2

c_{bv} = horizontal distance, in m, from visor pivot to the centre of gravity of visor mass, as shown in Fig. 5.4.2

h = height of the door between the levels of the bottom of the door and the upper deck or between the bottom of the door and the top of the door, in metres, whichever is the lesser, as shown in Fig. 5.4.1

k_a = alloy factor
= $125/\sigma_a$

l_d = length of the door at a height $h/2$ above the bottom of the door, in metres, as shown in Fig. 5.4.2

A_s = area stiffener web in cm^2

A_x = area, in m^2, of the transverse vertical projection of the door between the levels of the bottom of the door and the upper deck or between the bottom of the door and the top of the door, whichever is the lesser, as shown in Fig. 5.4.2

A_y = area, in m^2, of the longitudinal vertical projection of the door between the levels of the bottom of the door and the upper deck or between the bottom of the door and the top of the door, whichever is the lesser

A_z = area of the horizontal projection of the door between the levels of the bottom of the door and the upper deck or between the bottom of the door and the top of the door, in m^2, whichever is the lesser, as shown in Fig. 5.4.2

Q_{bd} = shear force, in kN, in the stiffener calculated by using uniformly distributed external pressure P_e as given in 4.5.1

W = breadth of the door at a height $h/2$ above the bottom of the door, in metres, as shown in Fig. 5.4.1

W_{bv} = mass of the visor door, in tonnes

σ = bending stress, in N/mm^2

σ_a = material yield stress, in N/mm^2

σ_{eq} = equivalent stress, in N/mm^2
= $\sqrt{\sigma^2 + 3\tau^2}$

τ = shear stress, in N/mm^2.

4.3.2 **Locking device.** A device that locks a securing device in the closed position.

4.3.3 **Securing device.** A device used to keep the door closed by preventing it from rotating about its hinges.

4.3.4 **Side-opening doors.** Side-opening doors are opened either by rotating outwards about a vertical axis through two or more hinges located near the outboard edges or by horizontal translation by means of linking arms arranged with pivoted attachments to the door and the craft. It is anticipated that side-opening doors are arranged in pairs.

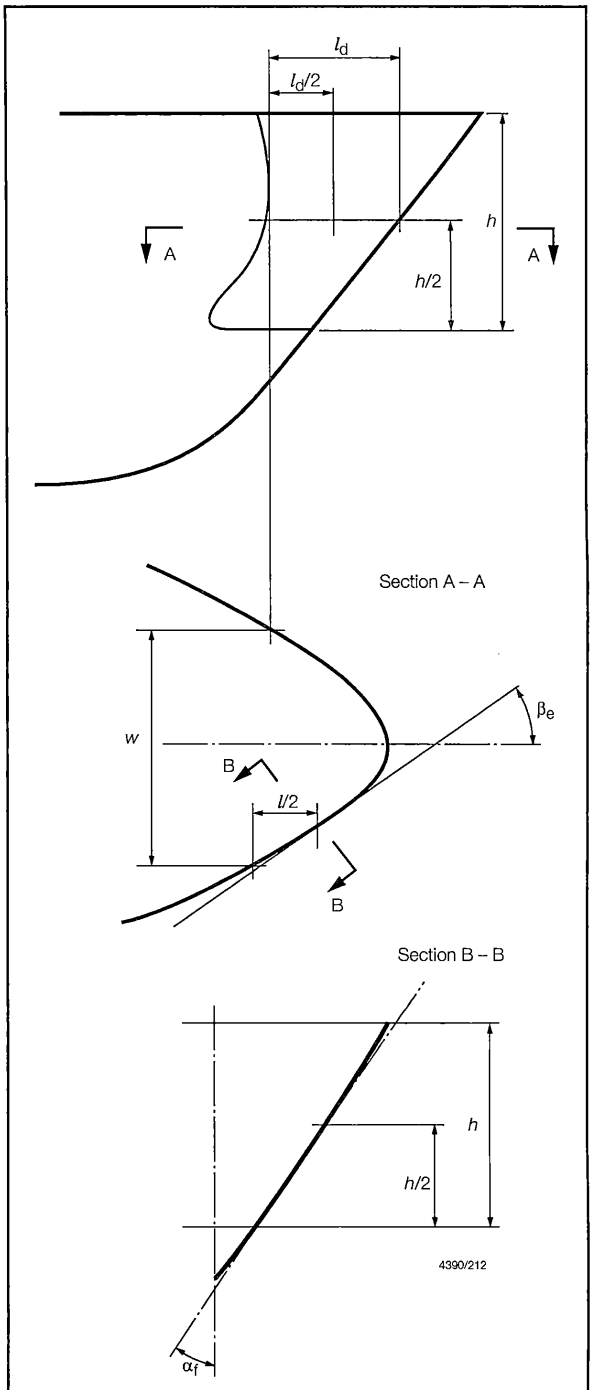

Fig. 5.4.1 Measurement of α_f and β_e

4.3.5 **Supporting device.** A device used to transmit external or internal loads from the door to a securing device and from the securing device to the craft's structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, that transmits loads from the door to the craft's structure.

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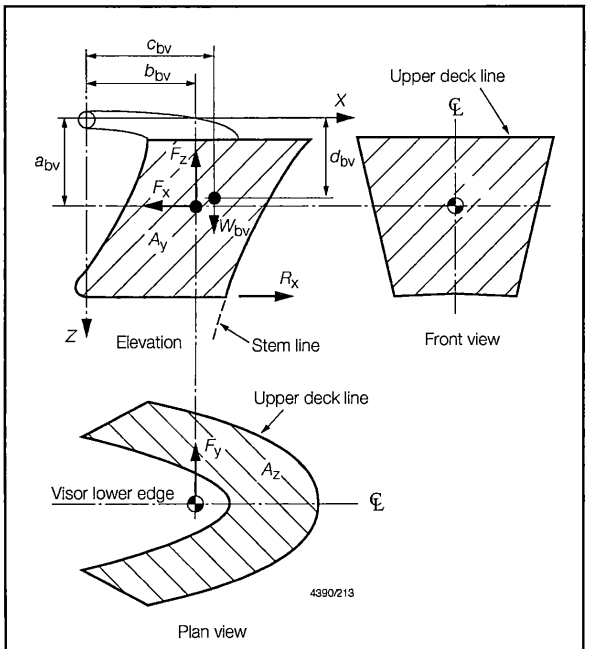

Fig. 5.4.2 Bow visor (upward hinging)

4.3.6 **Visor doors.** Visor doors are opened by rotating upwards and outwards about a horizontal axis through two or more hinges located near the top of the door and connected to the primary structure of the door by longitudinally arranged lifting arms.

4.4 Strength criteria

4.4.1 Scantlings of the primary members, securing and supporting devices of bow doors and inner doors are to be able to withstand the design loads defined in 4.5. The shear, bending and equivalent stresses are not to exceed $43/k_a$ N/mm^2, $64/k_a$ N/mm^2 and $80/k_a$ N/mm^2 respectively.

4.4.2 The buckling strength of primary members is to be verified as being adequate, *see* Ch 7,4.

4.4.3 For metal to metal bearings in securing and supporting devices, the nominal bearing pressure calculated by dividing the design force by the projected bearing area is not to exceed 80 per cent of the yield stress of the bearing material. For other bearing materials, the permissible bearing pressure is to be determined according to the manufacturer's specification.

4.4.4 The arrangement of securing and supporting devices is to be such that threaded bolts do not carry support forces. The maximum tension in way of threads of steel bolts not carrying support forces is not to exceed $125/k_s$ N/mm^2.

4.5 Design loads

4.5.1 The design external pressure, P_e, for the determination of scantlings for primary members, securing and supporting devices of bow doors is taken to be not less than the following:

$$P_e = 2{,}75\lambda_G C_H (0{,}22 + 0{,}15\tan\alpha_f)(0{,}4V_{max}\sin\beta_e + 0{,}6L_R^{0,5})^2 \text{ kN/m}^2$$

where

C_H = $0{,}0125L_R$ for $L_R < 80$ m
= 1,0 for $L_R \geq 80$ m

L_R = Rule length of craft, in m as defined in Pt 3, Ch 1,6

V_{max} = maximum speed in knots as defined in Pt 1, Ch 2, 2.2.10.

λ_G = Service group factor for mono-hull craft, *see* Pt 1, Ch 2
= 0,5 for Group 1 and 2
= 0,6 for Group 3
= 0,8 for Group 4
= 1,0 for Group 5 and 6
For multi-hull craft, λ_G will be specially considered and may be reduced where the freeboard is significant

α_f = flare angle at the point to be considered, defined as the angle between a vertical line and the tangent to the side shell plating, measured in a vertical plane normal to the horizontal tangent to the shell plating, *see* Fig. 5.4.1

β_e = entry angle at the point to be considered, defined as the angle between a longitudinal line parallel to the centreline and the tangent to the shell plating in a horizontal plane, *see* Fig. 5.4.1.

4.5.2 The design external forces, F_x, F_y and F_z, in kN, for the determination of scantlings of securing and supporting devices of bow doors are taken to be not less than $P_e A_x$, $P_e A_y$ and $P_e A_z$ respectively.

where

P_e is the external pressure, defined in 4.5.1, with the flare angle, α_f, and the entry angle, β_e, measured at the point on the bow door, $l_d/2$ aft of the stem line on the plane $h/2$ above the bottom of the door, as shown in Fig. 5.4.1.

A_x, A_y, A_z and h as defined in 4.3.1.

4.5.3 For bow doors, including bulwark, of unusual form or proportions, the areas used for the determination of the design values of external forces will be specially considered.

4.5.4 For visor doors the closing moment, M_y, under external loads, is to be taken as:

$$M_y = F_x a_{bv} + 10W_{bv} c_{bv} - F_z b_{bv} \text{ kNm}$$

where

W_{bv}, a_{bv}, b_{bv} and c_{bv} are as defined in 4.3.1

F_x and F_z are as defined in 4.5.2.

4.5.5 The lifting arms of a visor and its supports are to be dimensioned for the static and dynamic forces applied during the lifting and lowering operations, and a minimum wind pressure of 1,5 kN/m^2 is to be taken.

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4.5.6 The design external pressure, in kN/m^2, for the determination of scantlings for primary members, securing and supporting devices and surrounding structure of inner doors is to be taken as the greater of $0{,}45L_R$ and $10h_2$, where h_2 is the distance, in m, from the load point to the top of the cargo space and L_R is as defined in Pt 3, Ch 1,6.2.1.

4.5.7 The design internal pressure for the determination of scantlings for securing devices of inner doors is not to be taken less than 25 kN/m^2.

4.6 Scantlings of bow doors

4.6.1 The strength of bow doors is to be commensurate with that of the surrounding structure.

4.6.2 Bow doors are to be adequately stiffened and means are to be provided to prevent lateral or vertical movement of the doors when closed. For visor doors adequate strength for the opening and closing operations is to be provided in the connections of the lifting arms to the door structure and to the craft structure.

4.6.3 The thickness of the bow plating is not to be less than that required for the side shell plating, using bow door stiffener spacing, but in no case less than the minimum required thickness of fore end shell plating.

4.6.4 The section modulus of horizontal or vertical stiffeners is not to be less than that required for end framing. Consideration is to be given, where necessary, to differences in fixity between craft's frames and bow doors stiffeners.

4.6.5 The stiffener webs are to have a net sectional area A_s, not less than:

$$A_s = \frac{12{,}5Q_{bd}}{\sigma_a} \text{ cm}^2$$

where

A_s, Q_{bd} and σ_a are as defined in 4.3.1.

4.6.6 The bow door secondary stiffeners are to be supported by primary members constituting the main stiffening of the door.

4.6.7 The primary members of the bow door and the hull structure in way are to have sufficient stiffness to ensure integrity of the boundary support of the door.

4.6.8 Scantlings of the primary members are generally to be supported by direct calculations in association with the external pressure given in 4.5.1 and permissible stresses given in 4.4.2.

4.7 Scantlings of inner doors

4.7.1 Scantlings of the primary members are generally to be supported by direct calculations in association with the external pressure given in and permissible stresses given in 4.4.1. In general, formulae for simple beam theory may be applied.

4.7.2 Where inner doors also serve as a vehicle ramps, the scantlings are not to be less than those required for vehicle decks.

4.7.3 The distribution of the forces acting on the securing and supporting devices is, in general, to be supported by direct calculations taking into account the flexibility of the structure and actual position and stiffness of the supports.

4.8 Securing and supporting of bow doors

4.8.1 Bow doors are to be fitted with adequate means of securing and supporting so as to be commensurate with the strength and stiffness of the surrounding structure. The hull supporting structure in way of the bow doors is to be suitable for the same design loads and design stresses as the securing and supporting devices. Where packing is required, the packing material is to be of a comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be considered. Maximum design clearance between securing and supporting devices is, in general, not to exceed 3 mm. A means is to be provided for mechanically fixing the door in the open position.

4.8.2 Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be included and considered to calculate the reaction forces acting on the devices. Small and/or flexible devices such as cleats intended to provide load compression of the packing material are, in general, not to be included in the calculations called for in 4.8.8. The number of securing and supporting devices are, in general, to be the minimum practical whilst taking into account the requirements for redundant provision given in 4.8.9 and 4.8.10 and the available space for adequate support in the hull structure.

4.8.3 For opening outwards visor doors, the pivot arrangement is generally to be such that the visor is self closing under external loads, that is $M_y > 0$. Moreover, the closing moment, M_y, as given in 4.5.4 is to be not less than:

$$M_{ya} = 10W_{bv}\, c_{bv} + 0{,}1(a_{bv}^2 + b_{bv}^2)^{0{,}5}\, (F_x^2 + F_z^2)^{0{,}5}$$

where

W_{bv}, a_{bv}, b_{bv} and c_{bv} are as defined in 4.3.1

F_x and F_z are as defined in 4.5.2.

4.8.4 Securing and supporting devices are to be adequately designed so that they can withstand the reaction forces within the permissible stresses given in 4.4.1.

4.8.5 For **visor doors** the reaction forces applied on the effective securing and supporting devices assuming the door as a rigid body are determined for the following combination of external loads acting simultaneously together with the self weight of the door.

Case 1 F_x and F_z.

Case 2 $0{,}7F_y$ acting on each side separately together with $0{,}7F_x$ and $0{,}7F_z$

where

F_x, F_y and F_z are to be determined as indicated in 4.5.2 and applied at the centroid of projected areas.

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4.8.6 For **side-opening doors** the reaction forces applied on the effective securing and supporting devices assuming the door as a rigid body are determined for the following combination of external loads acting simultaneously together with the self weight of the door:

Case 1 F_x , F_y and F_z acting on both doors.

Case 2 $0,7F_x$ and $0,7F_z$ acting on both doors and $0,7F_y$ acting on each door separately.

where

F_x, F_y and F_z are to be determined as indicated in 4.5.2 and applied at the centroid of projected areas.

4.8.7 The support forces as determined according to 4.8.5 and 4.8.6 are to generally give rise to a zero moment about the transverse axis through the centroid of the area A_x. For visor doors, longitudinal reaction forces of pin and/or wedge supports at the door base contributing to this moment are not to be of the forward direction.

4.8.8 The distribution of the reaction forces acting on the securing and supporting devices may require to be supported by direct calculations taking into account the flexibility of the hull structure and the actual position and stiffness of the supports.

4.8.9 The arrangement of securing and supporting devices in way of these securing devices is to be designed with redundancy so that in the event of failure of any single securing or supporting device the remaining devices are capable of withstanding the reaction forces without exceeding by more than 20 per cent the permissible stresses as given in 4.4.1.

4.8.10 For **visor doors**, two securing devices are to be provided at the lower part of the door, each capable of providing the full reaction force required to prevent opening of the door within the permissible stresses given in 4.4.1. The opening moment, M_o, to be balanced by this reaction force, is not to be taken less than:

$$M_o = 10W_{bv}\, d_{bv} + 5A_x\, a_{bv} \text{ kNm}$$

where

W_{bv}, A_x, d_{bv} and a_{bv} are as defined in 4.3.1.

4.8.11 For **visor doors**, the securing and supporting devices excluding the hinges should be capable of resisting the vertical design force ($F_z - 10W_{bv}$), in kN, within the permissible stresses given in 4.4.1.

4.8.12 All load transmitting elements in the design load path, from door through securing and supporting devices into the craft structure, including welded connections, are to be the same strength.

4.8.13 For **side-opening doors**, thrust bearing has to be provided in way of girder ends at the closing of the two leaves to prevent one leaf to shift towards the other one under effect of unsymmetrical pressure, *see* Fig. 5.4.3. Each part of the thrust bearing has to be kept secured on the other part by means of securing devices. Any other arrangements serving the same purpose are to be submitted for appraisal.

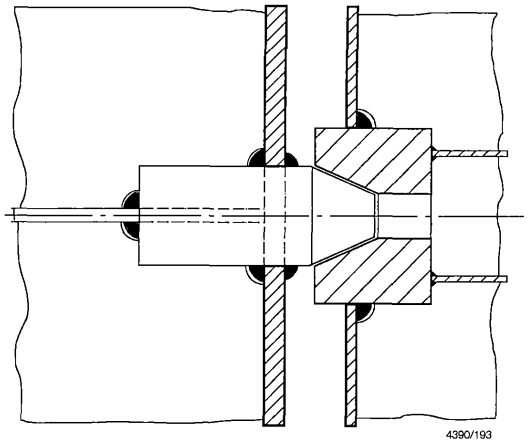

Fig. 5.4.3 Typical thrust bearing

4.9 Securing and locking arrangement

4.9.1 Securing devices are to be simple to operate and easily accessible. Securing devices are to be equipped with mechanical locking arrangement (self locking or separate arrangement), or be of the gravity type. The opening and closing systems as well as securing and locking devices are to be interlocked in such a way that they can only operate in the proper sequence.

4.9.2 Bow doors and inner doors giving access to vehicle decks are to be provided with an arrangement for remote control, from a position above the freeboard deck, of:

(a) the closing and opening of the doors; and

(b) associated securing and locking devices for every door.

Indication of the open/closed position of every door and every securing and locking device is to be provided at the remote control stations. The operating panels for operation of doors are to be inaccessible to unauthorised persons. A notice plate, giving instructions to the effect that all securing devices are to be closed and locked before leaving harbour, is to be placed at each operating panel and is to be supplemented by warning indicator lights.

4.9.3 Where hydraulic securing devices are applied, the system is to be mechanically lockable in the closed position so that in the event of loss of the hydraulic fluid, the securing devices remain locked. The hydraulic system for securing and locking devices is to be isolated from other hydraulic circuits when in the closed position.

4.9.4 Separate indicator lights and audible alarms are to be provided on the navigation bridge and on the operating panel to show that the bow door and inner door are closed and that their securing and locking devices are properly positioned. The indication panel is to be provided with a lamp test function. The indicator lights are to be provided with a permanent power supply, further, arrangements are to be such that it is not possible to turn off these lights in service.

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4.9.5 The indicator system is to be designed on the fail-safe principle and is to show by visual alarms if the door is not fully closed and not fully locked and by audible alarms if securing devices become open or locking devices become unsecured. The power supply for the indicator system is to be independent of the power supply for operating and closing the doors. The sensors of the indicator system are to be protected from water, ice formation and mechanical damages.

4.9.6 The indication panel on the navigation bridge is to be equipped with a mode selection function 'harbour/sea voyage', so arranged that audible alarm is given if the craft leaves harbour with the bow door or inner door not closed and with any of the securing devices not in the correct position.

4.9.7 A water leakage detection system with audible alarm and television surveillance are to be arranged to provide an indication to the navigation bridge and to the engine control room of leakage through the inner door.

4.9.8 Between the bow door and the inner door a television surveillance system is to be fitted with a monitor on the navigation bridge and in the engine control room. The system is to be able to monitor the position of doors and a sufficient number of their securing devices. Special consideration is to be given for lighting and contrasting colour of objects under surveillance.

4.9.9 A drainage system is to be arranged in the area between bow door and ramp, as well as in the area between the ramp and inner door where fitted. The system is to be equipped with an audible alarm function to the navigation bridge for water level in these areas exceeding 0,5 m above the car deck level.

4.10 Operating and Maintenance Manual

4.10.1 An Operating and Maintenance Manual for the bow door and inner door is to be provided on board and contain necessary information on:

(a) main particulars and design drawings,
(b) service conditions, e.g. service area restrictions, acceptable clearances for supports,
(c) maintenance and function testing,
(d) register of inspections and repairs.

This manual is to be submitted for approval.

4.10.2 Documented operating procedures for closing and securing the bow door and inner door are to be kept on board and posted at an appropriate place.

■ *Section 5* Movable decks

5.1 Classification

5.1.1 Movable decks other than those described in 5.1.2 are not a classification item, although consideration must be given to associated supporting structure. Where movable decks are fitted, it is recommended that they be based on the requirements of this Section.

5.1.2 At the Owner's or Builder's request, however, movable decks will be included as a classification item, and the class notation **Movable decks** will be entered in the *Register Book*. In such cases, all movable decks on board the ship are to comply with the requirements of this Section.

5.2 Arrangements and designs

5.2.1 Movable decks are generally to be constructed as pontoons comprising a web structure with top decking. Other forms of construction will be individually considered.

5.2.2 Positive means of control are to be provided to secure decks in the lowered position.

5.2.3 The decks are to be efficiently supported, and hinges, pillars, chains or other means (or a combination of these) are to be designed on the basis of the imposed loads. Where supporting chains and fittings are required, they are to have a factor of safety of at least two on the proof load.

5.2.4 Plans showing the proposed scantlings and arrangements of the system are to be submitted.

5.2.5 Where it is proposed to stow the pontoons on deck, when not in use, details of the proposals for racks, fittings, etc., are to be submitted for consideration.

5.3 Loading

5.3.1 Details of the deck loading resulting from the proposed stowage arrangements of vehicles are to be supplied by the Shipbuilder. These details are to include the axle and wheel spacing, the wheel load, type of tyre and tyre print dimensions for the vehicles. For design purposes the wheel loading is to be taken as not less than 3,0 kN, *see* Section 3.

5.3.2 Where it is proposed also to use the decks for general cargo, the design loadings are to be submitted for consideration.

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5.4 Scantling requirements

5.4.1 The scantlings and arrangements of removable decks are to be not less than those required by the Rules for the supporting structure in which the movable decks are fitted. In general the end fixity of primary stiffening members is to be taken as simply supported. Local and secondary stiffening members may be either partially or fully fixed at their end connections dependent upon the proposed arrangement.

5.5 Deflection

5.5.1 Where wheeled vehicles are to be used, the supporting arrangements are to be such that the movement at the edge of one pontoon relative to the next does not exceed 50 mm during loading or unloading operations.

■ *Section 6* Helicopter landing areas

6.1 General

6.1.1 The landing area may be located on an appropriate area of the weather deck or on a platform specifically designed for this purpose and permanently connected to the craft structure.

6.1.2 The structure is to be designed to accommodate the largest helicopter type which it is intended to use. In general, the diameter of the landing area is to be not less than 1,25 times the rotor diameter.

6.1.3 Attention is drawn to the requirements of National and other Authorities concerning the construction of helicopter landing platforms and the operation of helicopters as they affect the craft.

6.1.4 Plans are to be submitted showing the proposed scantlings and arrangements of the structure. The type, size and weight of helicopters to be used are also to be indicated. Details of the helicopter types to be used are to be included in the craft's documentation, and be contained in a notice displayed on the helicopter landing deck.

6.1.5 Where the landing area forms part of a weather or erection deck, the scantlings are to be not less than those required for decks in the same position.

6.1.6 The requirements for fire protection, detection and extinction for yachts are to comply with Part 17. The requirements for other types of craft are outside the scope of classification and are therefore to comply with the requirements for the National Authority. Special consideration is to be given to the insulation standard if the space below the helicopter deck is a high fire-risk space.

6.2 Arrangements

6.2.1 The landing area is to be sufficiently large to allow for the landing and manoeuvring of the helicopter, and is to be approached by a clear landing and take-off sector complying in extent with the applicable regulations.

6.2.2 The landing area is to be free of any projections above the level of the deck. Projections in the zone surrounding the landing area are to be kept below the heights permitted by the Regulations.

6.2.3 Suitable arrangements are to be made to minimise the risk of personnel or machinery sliding off the landing area. A non-slip surface and anchoring devices, and in the case of independent platforms, safety nets, are to be provided.

6.2.4 Arrangements are to be made for drainage of the platform, including drainage of spilt fuel.

6.2.5 Details of arrangements for securing the helicopter to the deck are to be submitted for approval.

6.3 Landing area plating

6.3.1 The deck plate thickness, t_p, within the landing area is to be not less than:

$$t_p = \frac{\alpha s}{1370\sqrt{k_a}}$$

α = thickness coefficient obtained from Fig. 5.3.1

β_p = tyre print coefficient used in Fig. 5.3.1

$$= \log_{10}\left(\frac{3{,}5\, P_1\, k_a^2}{s^2} \times 10^7\right)$$

where

s and k_a are as defined in 1.2.

The plating is to be designed for the emergency landing case taking:

$$P_1 = 2{,}5\phi_1\, \phi_2\, \phi_3\, f\, \gamma\, P_w \text{ tonnes}$$

where

ϕ_1, ϕ_2, ϕ_3 are to be determined from Table 5.3.1

f = 1,15 for landing decks over manned spaces, e.g., deckhouses, bridges, control rooms, etc.
= 1,0 elsewhere

P_h = the maximum all up weight of the helicopter, in tonnes

P_w = landing load on the tyre print, in tonnes:
For helicopters with a single main rotor, P_w is to be taken as P_h divided equally between the two main undercarriage wheels.
For helicopters with tandem main rotors, P_w is to be taken as P_h distributed between all main undercarriage wheels in proportion to the static loads they carry.

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For helicopters fitted with landing gear consisting of skids, P_w is to be taken as P_h distributed in accordance with the actual load distribution given by the airframe manufacturer. If this is unknown, P_w is to be taken as $1/6P_h$ for each of the two forward contact points and $1/3P_h$ for each of the two aft contact points. The load may be assumed to act as a 300 mm x 10 mm line load at each end of each skid when applying Fig. 5.3.1.

γ = a location factor given in Table 5.6.1

For wheeled undercarriages, the tyre print dimensions specified by the manufacturer are to be used for the calculation. Where these are unknown it may be assumed that the print area is 300 x 300 mm and this assumption is to be indicated on the submitted plan.

For skids and tyres with an asymmetric print, the print is to be considered oriented both parallel and perpendicular to the longest edge of the plate panel and the greatest corresponding value of α taken from Fig. 5.3.1.

6.4 Deck stiffening and supporting structure

6.4.1 The helicopter deck stiffening and supporting structure are to be designed for the load cases given in Table 5.6.2, with the helicopter being positioned so as to produce the most severe loading condition for each structural member under consideration.

6.4.2 The minimum requirements for section modulus, inertia and web area of secondary stiffeners are to be in accordance with Table 5.3.3.

6.4.3 For primary stiffening, and where a grillage arrangement is adopted, it is recommended that direct calculation procedures be used to determine the scantling requirements, in association with the limiting permissible stress criteria given in Chapter 7. A copy of the calculations is to be submitted for consideration.

Table 5.6.1 Location factor, γ

Location	γ
On decks forming part of the hull girder: (a) within $0,4L_R$ amidships (b) at the F.P. or A.P.	0,71 Values for intermediate locations are to be 0,6 determined by interpolation
Elsewhere	0,6

Table 5.6.2 Design load cases for deck stiffening and supporting structure

Loadcase	Loads (tonnes)			
	Landing area		Supporting structure, *see* Note 1	
	UDL, in kN/m^2	Helicopter patch load, *see* Note 2	Self weight	Horizontal load, *see* Note 2
(1) Overall distributed loading	2	—	—	—
(2) Helicopter emergency landing	0,5	$2,5P_w f$	W_h	$0,5P_h$
(3) Normal Usage	0,5	$1,5P_w$	W_h	$0,5P_h + 0,5W_h$
Symbols				
P_h, P_w and f are as defined in 6.3.1 *UDL* = Uniformly distributed vertical load over entire landing area W_h = structural self-weight of helicopter platform, in tonnes				
NOTES 1. For the design of the supporting structure for helicopter platforms applicable self weight and horizontal loads are to be added to the landing area loads. 2. The helicopter is to be so positioned as to produce the most severe loading condition for each structural member under consideration.				

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■ *Section 7*
Strengthening requirements for navigation in ice conditions

7.1 General

7.1.1 Where an ice class notation is to be included in the class of a craft, the scantlings will require special consideration, *see* Pt 3, Ch 2,9.

7.2 Shell plating

7.2.1 In way of the main ice belt zone, the thickness of the shell plating is to be determined by direct calculation. A copy of these direct calculations is to be submitted for consideration.

7.2.2 Changes in plating thicknesses in the longitudinal direction are to take place gradually.

7.2.3 In general, all welded seams and butts in way of the main ice belt are to be dressed smooth.

7.3 Shell framing requirements

7.3.1 The section modulus of an ice framing stiffening member is to be determined by direct calculation. A copy of these direct calculations is to be submitted for consideration.

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Section

1 **General**

2 **Hull girder strength for mono-hull craft**

3 **Additional hull girder strength requirements for multi-hull craft**

■ *Section 1* General

1.1 Application

1.1.1 The requirements for longitudinal and transverse global strength for mono-hull and multi-hull craft of aluminium construction, are contained within this Chapter. Due consideration is taken of the dynamic effects, where appropriate, in both the crest and trough wave loading conditions.

1.2 Symbols and definitions

1.2.1 The symbols and definitions applicable to this Chapter are defined below or in the appropriate sub-Section:

l = length of stiffening member, in metres
l_e = effective span length of stiffening member, in metres
p = design pressure as appropriately given in Part 3, in kN/m^2
s = spacing of stiffener, in mm
t_p = thickness of plating, in mm
B = moulded breadth of craft, in metres (to be taken as the breadth of a single hull for multi-hull craft)
L_R = Rule length of the craft, in metres
β = panel aspect ratio correction, *see* Ch 3,1.15
σ_a = 0,2 per cent proof stress of the alloy in the welded condition, in N/mm^2

$$\tau_a = \frac{\sigma_a}{\sqrt{3}}$$

1.2.2 The strength deck is to be taken as follows:

(a) Where there is a complete upper deck the strength deck is the upper deck.

(b) Where the upper deck is stepped, as in the case of raised quarterdeck craft, the strength deck is stepped as shown in Fig. 6.1.1.

1.3 General

1.3.1 The additional pressures arising from the influence of the global loading are considered in the determination of the longitudinal strength requirements for local and secondary stiffening and bottom shell plating.

1.3.2 In general, the effective sectional area of continuous longitudinal strength members, after deduction of openings, is to be used for the calculation of midship section modulus.

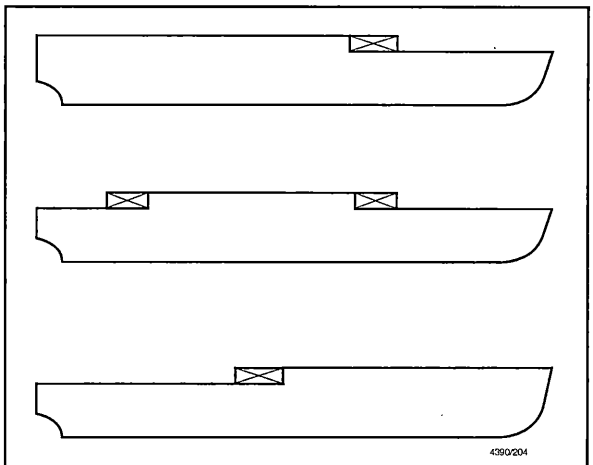

Fig. 6.1.1 Strength deck

1.3.3 Structural members which contribute to the overall hull girder strength are to be carefully aligned so as to avoid discontinuities resulting in abrupt variations of stresses and are to be kept clear of any form of openings which may affect their structural performances.

1.3.4 In general, superstructures or deckhouses will not be accepted as contributing to the global longitudinal or transverse strength of the craft. However, where it is proposed to include substantial, continuous stiffening members, special consideration will be given to their inclusion on submission of the designer's/Builder's calculations.

1.3.5 Where continuous deck longitudinals or deck girders are arranged above the strength deck, special consideration may be given to the inclusion of their sectional area in the calculation of the hull section modulus (Z). The lever is to be taken to a position corresponding to the depth of the longitudinal member above the moulded deckline at side amidships. Each such case will be individually considered.

1.3.6 Adequate transition brackets are to be fitted at the ends of effective continuous longitudinal strength members in the deck and bottom structures.

1.3.7 Scantlings of all continuous longitudinal members of the hull girder based on the minimum section stiffness requirements determined from 2.2 are to be maintained within $0{,}4L_R$ amidships. However, in special cases, based on consideration of type of craft, hull form and loading conditions, the scantlings may be gradually reduced towards the ends of the $0{,}4L_R$ part, bearing in mind the desire not to inhibit the craft's loading and operational flexibility.

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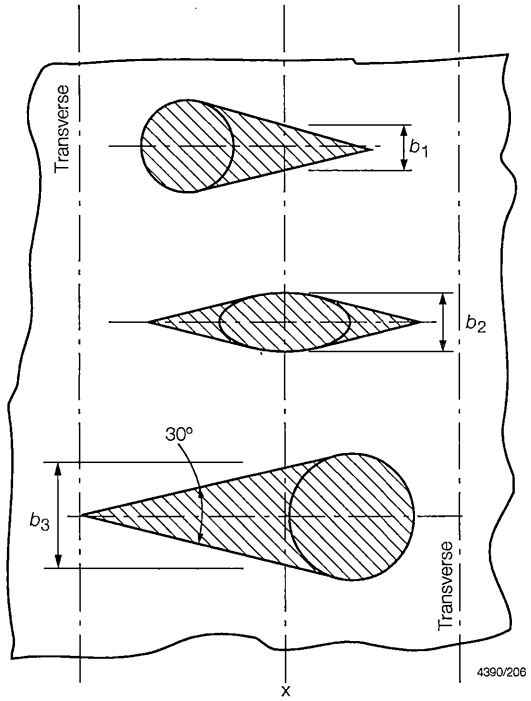
1.4 Openings

1.4.1 Deck openings having a length in the fore and aft directions exceeding 0,1*B* m or a breadth exceeding 0,05*B* m are in all cases to be deducted from the sectional areas used in the section modulus calculation.

1.4.2 Deck openings smaller than stated in 1.4.1, including manholes, need not be deducted provided they are isolated and the sum of their breadths or shadow area breadths (*see* 1.4.3) in one transverse section does not exceed 0,06 ($B_o - \Sigma b_o$):
where
B_o = breadth of craft, in metres, at section considered
Σb_o = sum of breadths, in metres, of deductible openings
Where a large number of deck openings are proposed in any transverse space, special consideration will be required.

1.4.3 Where calculating deduction-free openings, the openings are assumed to have longitudinal extensions as shown by the shaded areas in Fig. 6.1.2. The shadow area is obtained by drawing two tangent lines to an opening angle of 30°. The section to be considered is to be perpendicular to the centreline of the ship and is to result in the maximum deduction in each transverse space.



Total equivalent breadth of small openings at xx = $b_1 + b_2 + b_3$

Fig. 6.1.2 Isolated openings

1.4.4 Isolated openings in longitudinals or longitudinal girders need not be deducted if their depth does not exceed 25 per cent of the web depth or 75 mm, whichever is the lesser.

1.4.5 Openings are considered isolated if they are spaced not less than 1 m apart.

1.4.6 A reduction for drainage holes and scallops in beams and girders, etc., is not necessary so long as the original section stiffness at deck or keel is reduced by no more than three per cent.

1.5 Direct calculation procedure

1.5.1 In direct calculation procedures capable of deriving the wave induced loads on the craft, and hence the required modulus, account is to be taken of the craft's actual form and weight distribution.

1.5.2 Lloyd's Register's (hereinafter referred to as 'LR') direct calculation method involves derivation of response to regular waves by strip theory, short-term response to irregular waves using the sea spectrum concept, and long-term response predictions using statistical distributions of sea states. Other direct calculation methods submitted for approval are normally to contain these three elements and produce similar and consistent results when compared with LR's methods.

1.6 Approved calculation systems

1.6.1 Where the assumptions, method and procedures of a longitudinal strength calculation system have received general approval from LR, calculations using the system for a particular craft may be submitted.

1.7 Information required

1.7.1 In order that an assessment of the longitudinal strength requirements can be made, the following information is to be submitted, in LR's standard format where appropriate:
(a) General arrangement and capacity plan or list, showing details of the volume and position of centre of gravity of all tanks and compartments.
(b) Bonjean data, in the form of tables or curves, for at least 21 equally spaced stations along the hull. A lines plan and/or tables of offsets may also be required.
(c) Details of the calculated lightweight and its distribution.
(d) Details of the weights and centres of gravity of all deadweight items for each of the main loading conditions. It is recommended that this information be submitted in the form of a preliminary Loading Manual, to include the calculated still water and dynamic bending moments and shear forces.

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1.8 Loading guidance information

1.8.1 Sufficient information is to be supplied to the Master of every craft to enable him to arrange loading in such a way as to avoid the creation of unacceptable stresses in the craft's structure.

■ *Section 2* Hull girder strength for mono-hull craft

2.1 General

2.1.1 Longitudinal strength calculations are to be submitted for all craft with a Rule length, L_R, exceeding 45 m covering the range of load and ballast conditions proposed, in order to determine the required hull girder strength. Still water, static wave and dynamic bending moments and shear forces are to be calculated for both departure and arrival conditions.

2.1.2 For craft of ordinary hull form with a Rule length, L_R, less than 45 m, the minimum hull girder strength requirements are generally satisfied by scantlings obtained from local strength requirements. However longitudinal strength calculations may be required at LR's discretion, dependent upon the form, constructional arrangement and proposed loading.

2.1.3 Where the Rule length, L_R, of the craft exceeds 75 m, or for new designs of large, structurally complicated craft, the design loads and scantling determination formulae in this Chapter are to be supplemented by direct calculation and structural analysis by 3-D finite element methods. These supplementary calculations are to include the results of model tests and full scale measurement where available or required by LR. Full details of such methods and all assumptions and calculations, which are to be based on generally accepted theories, are to be submitted for appraisal.

2.2 Bending strength

2.2.1 The effective geometric properties of the midship section are to be calculated directly from the dimensions of the section using only the effective material elements which contribute to the global longitudinal strength. For the purposes of this analysis an element may be of deck plating, longitudinal girder, inner bottom, etc., or other continuous member.

2.2.2 The longitudinal strength of craft with $\frac{V}{\sqrt{L_{WL}}} \geq 3{,}0$ is to satisfy both the following criteria:

$\sigma_k + \sigma_l + \sigma_t < 1{,}2\sigma_P$

$\sigma_d < \sigma_P$

where

σ_P = maximum permissible hull vertical bending stress, in N/mm^2
= $f_{\sigma gH}\,\sigma_a$

$f_{\sigma gH}$ = limiting hull bending stress coefficient taken from Table 7.3.2 in Chapter 7

L_{WL} is as defined in Pt 3, Ch 1,6.2.5

σ_k, σ_l, σ_t and σ_d are given in Table 6.2.1

σ_a is as defined in 1.2.1.

Table 6.2.1 Longitudinal component stresses

Component stress type	Nominal stress (N/mm^2)
Hull girder bending stress at strength deck amidships	$\sigma_d = \frac{M_R}{1000Z_d}$
Hull girder bending stress at keel amidships	$\sigma_k = \frac{M_R}{1000Z_k}$
Actual stress in bottom longitudinals amidships due to design pressure load	$\sigma_l = \frac{p_s\, s\, l_e^2}{12Z_l}$
Actual stress in bottom plating amidships due to design pressure load	$\sigma_t = 0{,}34p_t\left(\frac{\beta s}{t_p}\right)^2 \times 10^{-3}$
Symbols and definitions	
M_R = design longitudinal midship bending moment, in kNm given in Pt 5, Ch 5,5 p_s = additional effective pressure loading, in kN/m^2, on bottom longitudinals from global dynamic load model, given in Pt 5, Ch 5,2.6.3 p_t = additional effective pressure loading, in kN/m^2, on bottom plating from global dynamic load model, given in Pt 5, Ch 5,2.6.4 Z_d = actual section modulus at deck, in m^3 Z_k = actual section modulus at keel, in m^3 Z_l = maximum section modulus of bottom longitudinal stiffener, associated with plating, amidships, in cm^3 s, l_e, β and t_p are as defined in 1.2.	

2.2.3 The longitudinal strength of craft with $\frac{V}{\sqrt{L_{WL}}} < 3{,}0$ is to satisfy both the following criteria:

$\sigma_k < \sigma_P$

$\sigma_d < \sigma_P$

where

σ_P is as defined in 2.2.2

σ_k and σ_d, are given in Table 6.2.1

L_{WL} is as defined in Pt 3, Ch 1,6.2.5.

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2.3 Shear strength

2.3.1 The shear strength of the craft at any position along its length is to satisfy the following criterion:

$$\frac{Q_R}{A_\tau} 10^{-3} \leq \tau_p$$

where

Q_R = design hull shear force at any section along the hull length, L_R, in kN determined from Pt 5, Ch 5,5

A_τ = shear area of transverse section, in m^2, is to be taken as the effective net sectional area of the shell plating and longitudinal bulkheads after deductions for openings. For longitudinal strength members which are inclined to the vertical, the area of the member to be included in the calculation is to be based on the area projected onto the vertical plane, *see* Fig. 6.2.1

τ_p = maximum permissible mean shear stress, in N/mm^2 = $f_{\sigma g}\,\tau_a$

$f_{\sigma g}$ = limiting hull shear stress coefficient taken from Table 7.3.2 in Chapter 7

τ_a is as defined in 1.2.1.

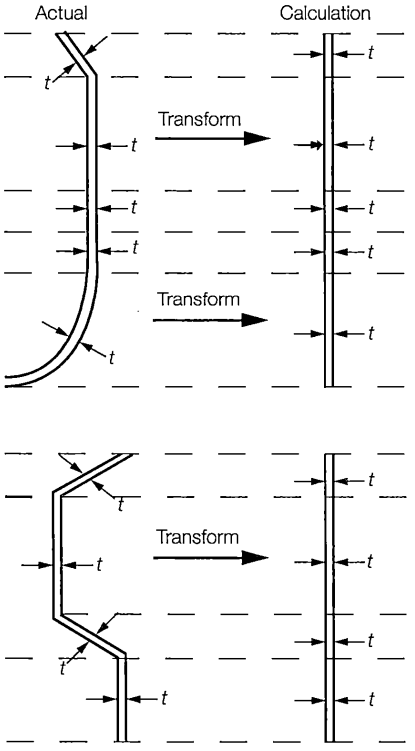

Fig. 6.2.1 Effective shear area

2.4 Torsional strength

2.4.1 Torsional stresses are typically small for mono-hulls of ordinary form of Rule length, L_R, less than 75 m and can generally be ignored.

2.4.2 The calculation of torsional stresses and/or deflections may be required when considering craft with large deck openings, unusual form or proportions. Calculations may in general be required to be carried out using a direct calculation procedure. Such calculations are to be submitted in accordance with 1.5.

2.5 Superstructures global strength

2.5.1 The effectiveness of the superstructure in absorbing hull girder bending loads is to be established where the first tier of the superstructure extends within 0,4*L* amidship and where:

$$l_d > b_d + 3h_d$$

where

l_d = length of first tier, in metres

b_d = breadth of first tier, in metres

h_d = 'tween deck height of first tier, in metres.

2.5.2 For superstructures with one or two tiers extending outboard to the craft's side shell, the effectiveness in absorbing hull girder bending loads in the uppermost effective tier may be assessed by the following factor:

$$\eta_s = 7\left[(\varepsilon - 5)\,\gamma^4 + 94\,(5 - \varepsilon)\,\gamma^3 + 2800\,(\varepsilon - 5{,}8)\,\gamma^2 + 27660\,(9 - \varepsilon)\,\gamma\right] f(\lambda, N) \times 10^{-7}$$

where

$f(\lambda, N = 1) = 1$

$f(\lambda, N = 2) = 0{,}90\lambda^3 - 2{,}17\lambda^2 + 1{,}73\lambda + 0{,}50$

and

N = 1 if $l_2 < 0{,}7l_1$

= 2 if $l_2 \geq 0{,}7l_1$

$\lambda = \frac{l_w}{L_R}$ or 1, whichever is less

$\varepsilon = \frac{b_1}{h_1}$ or 5, whichever is less

$\gamma = \frac{l_w}{h_1}$ or 25, whichever is less

$l_w = l_1$ for $N = 1$

$= \frac{(2l_1 + l_2)}{3}$ for $N = 2$

L_R = is as defined in 1.2.1, in metres

l_1, b_1, h_1 = is as defined in 2.5.1, in metres

l_2 = length of second tier, in metres.

2.5.3 The hull girder compressive bending stress σ_L, in the uppermost effective tier at side may be derived according to the following formula:

$$\sigma_L = \eta_s \frac{M_R}{1000 Z_{100}} \text{ N/mm}^2$$

where

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M_R = hull girder bending moment at midships due to sagging as determined in Pt 5, Ch 5,5, in kNm
Z_{100} = section modulus at uppermost effective tier of hull and effective tiers, assuming tiers to be 100 per cent effective, in m^3
η_s = as defined in 2.5.2.

2.5.4 The compressive stress, σ_L, in the uppermost effective tier at side is to be checked against buckling in accordance with Ch 7,4.

2.5.5 The uppermost effective tier may need to fulfil the requirements for strength deck when the following applies:

$$\eta_s = \left(1 + \frac{Z_0 h}{I_{100}}\right)^{-1}$$

where
η_s = as defined in 2.5.2
Z_0 = section modulus of hull only at hull upper deck, in m^3
I_{100} = moment of inertia of hull and effective tiers, assuming tiers to be 100 per cent effective, in m^4
h = height from hull upper deck to uppermost effective tier, in metres.

Section 3
Additional hull girder strength requirements for multi-hull craft

3.1 General

3.1.1 Except as otherwise specified within this Section, the global strength requirements for multi-hull craft are to comply with Section 2.

3.1.2 Longitudinal strength calculations are to be submitted for all craft with a Rule length, L_R, exceeding 40 m covering the range of load and ballast conditions proposed, in order to determine the required hull girder strength. Still water, static wave and dynamic bending moments and shear forces are to be calculated for both departure and arrival conditions.

3.1.3 For craft of ordinary hull form length with a Rule length, L_R, less than 40 m, the minimum hull girder strength requirements are generally satisfied by scantlings obtained from local strength requirements. However longitudinal strength calculations may be required at LR's discretion, dependent upon the proposed loading.

3.1.4 Where the Rule length, L_R, of the craft exceeds 60 m, or for new designs of large, structurally complicated craft, the design loads and scantling determination formulae in this Chapter are to be supplemented by direct calculation and structural analysis by 3-D finite element methods. These supplementary calculations are to include the results of model tests and full scale measurement where available or required by LR. Full details of such methods and all assumptions and calculations, which are to be based on generally accepted theories, are to be submitted for appraisal.

3.1.5 The strength deck plating in way of the cross-deck structure, the wet-deck plating, longitudinal bulkheads and girders, and other continuous members may be included in the determination of the midship section stiffness.

3.1.6 Special consideration will be given to the global strength requirements for craft with more than two hulls linked by cross-deck structure.

3.2 Hull longitudinal bending strength

3.2.1 The requirements of 2.2 are in general to be complied with, using the appropriate design bending moment and effective pressure loadings applicable to multi-hull craft, as determined from Pt 5, Ch 5,5.

3.3 Hull shear strength

3.3.1 The requirements of 2.3 are to be complied with so far as they are applicable.

3.4 Torsional strength

3.4.1 Where a craft is of unusual form or novel construction, or at the discretion of LR, the torsional stress is to be determined by direct calculation methods using the twin hull torsional connecting moment as defined in Pt 5, Ch 5,5. Such calculations are to be submitted in accordance with 1.5.

3.5 Strength of cross-deck structures

3.5.1 Design loads to be applied for scantling calculations are transverse vertical bending moment and shear force, twin hull torsional connecting moment, external pressure load and appropriate internal loads as defined in Part 5.

3.5.2 The primary stiffening members of the cross-deck structure are to provide sufficient strength to satisfy the stress criteria given in Table 6.3.1.

3.5.3 The component nominal stresses may be determined in accordance with Table 6.3.2 in the case where the cross-deck is formed by transverse primary stiffeners or bulkheads and the following assumptions are taken:
(a) The cross-deck is symmetrical forward and aft of a transverse axis at its half length.
(b) Primary stiffeners having the same scantlings and spacing.

3.5.4 Other cross-deck designs subjected to global transverse loads will require a two-dimensional grillage analysis to be performed to demonstrate compliance with 3.5.2.

3.5.5 Section properties are to be calculated using an effective breadth of plating to be determined in accordance with Ch 3,1.11.

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Table 6.3.1 Primary member stress criteria

Stress type	Component stresses	Allowable stress level (N/mm^2)
Total direct stress, σ_P	$\sigma_P = \sigma_{MB} + \sigma_{MT} + \sigma_d$	$f_{\sigma gV}\,\sigma_a$
Total shear stress, τ_P	$\tau_P = \tau_T + \tau_{MBT} + \tau_{MT}$	$f_{\tau gV}\,\tau_a$
Equivalent stress, σ_{eq}	$\sigma_{eq} = \sqrt{\sigma^2 + 3\tau^2}$	$1{,}2\,f_{\sigma eg}\,\sigma_a$
Symbols and definitions		
σ_{MB}, σ_{MT}, τ_T, τ_{MBT} and τ_{MT} are component stresses, in N/mm^2, to be taken from Table 6.3.2. $f_{\sigma gV}$, $f_{\tau gV}$ and $f_{\sigma eg}$ are limiting stress coefficients for cross-deck structures to be taken from Table 7.3.2 in Chapter 7. σ_a and τ_a are defined in 1.2.		

Table 6.3.2 Cross-deck component stresses for designs complying with 3.5.3

Component stress type	Nominal stress (N/mm^2)
Hull girder bending stress at strength deck amidships, *see* Table 6.2.1	$\sigma_d = f_{MR}\,\dfrac{M_R}{1000 Z_d}$
Stress induced by the transverse bending moment M_B, as defined in Pt 5, Ch 5,5	$\sigma_{MB} = f_{MB}\,\dfrac{M_B}{nZ}\,10^3$
Stress induced by the torsional moment M_T, as defined in Pt 5, Ch 5,5	$\sigma_{MT} = f_{MT}\,\dfrac{3x_H M_T}{n(n+1)s_p Z}\,10^3$
Shear stress induced by the vertical shear force Q_T, as defined in Pt 5, Ch 5,5	$\tau_T = f_{MB}\,\dfrac{5Q_T}{n A_w}$
Bending shear stress induced by the torsional moment M_T, as defined in Pt 5, Ch 5,5	$\tau_{MBT} = f_{MT}\,\dfrac{60M_T}{n(n+1)s_p A_w}$
Shear stress induced by the torsional moment M_T, as defined in Pt 5, Ch 5,5	$\tau_{MT} = f_{MT}\,\dfrac{46\kappa x_H^2 M_T}{n(n^2+1)s_p^2 I_y}\,10^3$
Symbols and definitions	

Q_T = vertical shear force, in kN, as determined from, Pt 5, Ch 5,5
M_B = transverse bending moment in kNm, as determined from Pt 5, Ch 5,5
M_T = torsional moment in kNm, as determined from Pt 5, Ch 5,5
n = total number of transverse primary stiffeners or bulkheads
A_w = stiffener web area, cm^2
Z = primary stiffeners section modulus, in cm^3
s_p = stiffener spacing, in metres
I_y = moment of inertia of stiffener, cm^4
x_H = transverse distance between the centre of the two hulls, in metres
κ = t_f, for symmetrical I-section, in mm
= $b_b\,h/(b_b + h)$, for constant thickness box sections, in mm
σ_{MB} = stress induced by the transverse bending moment M_B, as defined in Pt 5, Ch 5,5, in N/mm^2
σ_{MT} = stress induced by the torsional moment M_T, as defined in Pt 5, Ch 5,5, in N/mm^2
τ_T = shear stress induced by the vertical shear force Q_T, as defined in Pt 5, Ch 5,5, in N/mm^2
τ_{MBT} = bending shear stress induced by the torsional moment M_T, as defined in Pt 5, Ch 5,5, in N/mm^2
τ_{MT} = shear stress induced by the torsional moment M_T, as defined in Pt 5, Ch 5,5, in N/mm^2
t_f = face plate thickness, in mm
b_b = breadth of box section, in mm
h_b = height of box section, in mm

f_{MR}, f_{MB} and f_{MT} are load combination factors reflecting the portions of each component global design load, M_R, Q_T, M_B and M_T, corresponding to the most severe load combinations, The most severe load combinations are the combinations of loads resulting in the maximum bending, shear and effective stress, respectively. The assessment of these load combinations need to take due consideration for the component load magnitude variation with wave heading and also the phasing in time between them. Generally, f_{MR}, f_{MB}, and f_{MT} are to be taken as indicated in Table 6.3.3.

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Table 6.3.3 Load combination factors

Heading	Factors		
	f_{MB}	f_{MR}	f_{MT}
Head sea	0,1	1,0	0,1
Beam sea	1,0	0,1	0,2
Quartering sea	0,1	0,4	1,0

3.5.6 Where primary stiffening members support areas of plating of the extruded plank type, or the floating frame system is used, the effect of the plating attached to the secondary stiffening members is to be ignored when determining the global section modulus requirements.

3.6 Grillage structures

3.6.1 For complex girder systems, a complete structural analysis using numerical methods may be required to be performed to demonstrate that the stress levels are acceptable when subjected to the most severe and realistic combination of loading conditions intended.

3.6.2 In general, the transverse and vertical girders, bottom and side structures, bridge structure, deck structures and any other parts of the craft which LR considers critical to the craft's structural integrity are to be included in the numerical modelling of the craft.

3.7 Analysis techniques

3.7.1 General or special purpose computer programs or any other analytical techniques may be used provided that the effects of bending, shear, axial and torsion are properly accounted for and the theory and idealisation used can be justified.

3.7.2 In general, grillages consisting of slender girders may be idealised as frames based on beam theory provided proper account of the variations of geometric properties is taken. For cases where such an assumption is not applicable, finite element analysis or equivalent methods may have to be used.

3.7.3 Analysis of the cross deck structures with regard to impact loads due to slamming may have to be carried out using advanced structural analysis techniques.

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Section

1 **General**

2 **Deflection control**

3 **Stress control**

4 **Buckling control**

5 **Vibration control**

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull and multi-hull craft of aluminium construction as defined in Pt 1, Ch 1,1.

1.2 General

1.2.1 The failure modes criteria contained within this Chapter are to be used in the formulae from the preceding Chapters to determine the scantling requirements. In addition, they are to be used when direct calculation methods are proposed as an alternative.

1.3 Symbols and definitions

1.3.1 The symbols and definitions applicable to this Chapter are defined in the appropriate Sections.

1.4 Direct calculations

1.4.1 Where direct calculations are proposed, the requirements of Pt 3, Ch 1,2 are to be complied with.

1.4.2 In addition, with the agreement of Lloyd's Register (hereinafter referred to as 'LR'), tests may be conducted to demonstrate the actual response of the structure and the results verified against the failure mode criteria in this Chapter.

■ *Section 2* Deflection control

2.1 General

2.1.1 The limiting deflection requirements for plate panels and stiffening members are given in terms of limiting deflection coefficient, f_δ, *see* Table 7.2.1. The coefficient equates to a span/deflection ratio in consistent units.

Table 7.2.1 Limiting deflection ratio

Item	Deflection ratio, f_δ
Bottom structure:	
• secondary stiffening	475
• primary girders and web frames	625
Side structure:	
• secondary stiffening	475
• primary girders and web frames	625
Main/strength deck structures:	
• secondary stiffening	625
• primary girders and web frames	775
• hatch covers	775
Superstructures/deckhouses stiffeners:	
(a) Generally: • secondary	400
• primary	475
(b) Coachroof: • secondary	475
• primary	625
(c) House top: • secondary	400
• primary	400
Lower/inner decks and house top, subject to personnel loading:	
• secondary members	475
• primary members	625
Deep tank stiffeners:	
• secondary members	625
• primary members	775
Watertight bulkhead stiffeners:	
• secondary members	400
• primary members	475
Multi-hull cross-deck stiffeners:	
• secondary members	475
• primary members	625
Vehicle deck stiffeners:	
• secondary members	625
• primary members	775
Helicopter/flight deck stiffeners:	
• secondary members	625
• primary members	775
NOTE Where significant curvature exists over the span of the stiffener or breadth of the panel, the allowable deflections will be specially considered.	

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■ *Section 3* Stress control

3.1 General

3.1.1 The nominal limiting stress requirements for plating and primary and secondary stiffening members subject to local loading conditions are given in terms of limiting stress coefficients, *see* Table 7.3.1. The coefficients are expressed as a proportion of the 0,2 per cent proof stress of the material.

3.1.2 The limiting stress coefficients for structural elements subject to global loading conditions are given in Table 7.3.2.

3.1.3 In the determination of the magnitude of the equivalent stress, σ_{eq}, it is assumed that the stresses are combined using the following formula:

$$\sigma_{eq} = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x \sigma_y + 3\tau^2}$$

where

σ_x = direct stress in the x direction
σ_y = direct stress in the y direction
τ = shear stress in the xy plane.

Table 7.3.1 Limiting stress coefficients for local loading (*see continuation*)

Item		Limiting stress coefficient		
		Bending f_σ	Shear f_τ	Equivalent f_e
Shell envelope:				
(a) Bottom shell plating:	• slamming zone	0,85	—	—
	• elsewhere	0,75	—	—
(b) Side shell plating:	• slamming zone	0,85	—	—
	• elsewhere	0,75	—	—
(c) Keel		0,75	—	—
Bottom structure:				
(a) Secondary stiffening:	• slamming zone	0,75	0,75	—
	• elsewhere	0,65	0,65	—
(b) Primary girders and web frames		0,65	0,65	0,75
(c) Engine girders		0,55	0,55	0,75
Side structure:				
(a) Secondary stiffening:	• slamming zone	0,75	0,75	—
	• elsewhere	0,65	0,65	—
(b) Primary girders and web frames		0,65	0,65	0,75
Bow doors:				
(a) Plating		0,65	—	—
(b) Secondary stiffening		0,51	0,433	—
(c) Primary stiffening		0,51	0,34	0,64
Main/strength deck plating and stiffeners:				
(a) Plating		0,75	—	—
(b) Secondary stiffening		0,65	0,65	—
(c) Primary girders and web frame		0,65	0,65	0,75
(d) Hatch covers		0,55	0,55	0,64

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Table 7.3.1 Limiting stress coefficients for local loading (*conclusion*)

Item		Limiting stress coefficient		
		Bending f_σ	Shear f_τ	Equivalent f_e
Superstructures/deckhouses:				
(a) Deckhouse front, 1st tier:	• plating	0,65	–	–
	• stiffening	0,60	0,60	–
(b) Deckhouse front, upper tiers:	• plating	0,75	–	–
	• stiffening	0,65	0,65	–
(c) Deckhouse aft and sides:	• plating	0,75	–	–
	• stiffening	0,75	0,75	–
(d) Coachroof:	• plating	0,65	–	–
	• stiffening	0,65	0,65	–
(e) House top:	• plating	0,75	–	–
	• stiffening	0,75	0,75	–
(f) Lower/inner decks and house top, subject to personnel loading:				
	• plating	0,75	–	–
	• stiffening	0,60	0,60	–
Bulkheads:				
(a) Watertight bulkhead:	• plating	1,0	–	–
	• secondary stiffening	0,95	0,95	–
	• primary stiffening	0,90	0,90	1,0
(b) Watertight bulkhead doors		0,825	0,825	0,825
(c) Structure supporting watertight doors		0,80	0,80	–
(d) Minor bulkheads:	• plating	0,65	–	–
	• secondary stiffening	0,65	0,65	–
	• primary stiffening	0,65	0,65	0,75
(e) Deep tank bulkheads:	• plating	0,65	–	–
	• secondary stiffening	0,65	0,65	–
	• primary stiffening	0,75	0,75	–
Multi-hull cross-deck structure:				
(a) Plating:	• slamming zone	0,85	–	–
	• elsewhere	0,75	–	–
(b) Secondary stiffening:	• slamming zone	0,75	0,75	–
	• elsewhere	0,65	0,65	–
(c) Primary stiffening		0,65	0,65	0,75
Vehicle deck:				
(a) Plating		0,60	–	–
(b) Secondary stiffening		0,425	0,425	–
(c) Primary stiffening		0,525	0,525	0,75
Helicopter/flight decks:				
(a) Normal usage:	• plating	0,65	–	–
	• secondary stiffening	0,75	0,75	–
	• primary stiffening	0,625	0,625	0,60
(b) Emergency landing:	• plating	0,75	–	–
	• secondary stiffening	1,0	1,0	–
	• primary stiffening	0,825	0,825	0,9
(c) Crane pedestal/foundation structural elements		0,7	0,7	0,75

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Table 7.3.2 Limiting stress coefficients for global loading

Operational mode of craft	Limiting stress coefficient					
	Hull girder			Cross-deck		
	Bending $f_{\sigma gH}$	Shear $f_{\tau gH}$	Equivalent $f_{\sigma eg}$	Bending $f_{\sigma gV}$	Shear $f_{\tau gV}$	Equivalent $f_{\sigma eg}$
$\Gamma \geq 3,0$ $\Delta \leq 0,04\ (L_R B)^{1,5}$	0,80	0,80	0,825	0,80	0,80	0,825
$\Gamma < 3,0$ and $\Delta > 0,4\ (L_R B)^{1,5}$	0,72	0,72	0,75	0,72	0,72	0,75

Symbols

$f_{\sigma gH}$ = limiting hull bending stress coefficient
$f_{\tau gH}$ = limiting hull shear stress coefficient
$f_{\sigma gV}$ = limiting cross-deck bending stress coefficient
$f_{\tau gV}$ = limiting cross-deck shear stress coefficient
$f_{\sigma eg}$ = limiting equivalent stress coefficient
Γ is the Taylor Quotient as defined in Pt 5, Ch 2,2.1.16
Δ is the displacement as defined in Pt 5, Ch 2,2
L_R and B are as defined in Pt 3, Ch 1,6.2

■ *Section 4* Buckling control

4.1 General

4.1.1 This Section contains the requirements for buckling control of plate panels subject to in-plane compressive and/or shear stresses and buckling control of primary and secondary stiffening members subject to axial compressive and shear stresses.

4.1.2 The requirements for buckling control of plate panels are contained in 4.3 to 4.6. The requirements for secondary stiffening members are contained in 4.7 to 4.8. The requirements for primary members are contained in 4.9 and 4.10.

4.1.3 In general all areas of the structure are to meet the buckling strength requirements for the design stresses. The design stresses are to be taken as follows:

(a) Global hull girder bending and shear stresses given in Chapter 6, but not including stresses σ_l and σ_t as defined in Table 6.2.1 in Chapter 6.

(b) Stresses from local compressive loads.

4.1.4 The buckling requirements are to be met using the net scantlings, hence any additional thickness for corrosion margin or Owner's extra is not included in scantlings used to assess the buckling performance.

4.2 Symbols

4.2.1 The symbols used in this Section are defined below and in the appropriate sub-Section:

a = panel length, i.e. parallel to direction of com-pressive stress being considered, in mm

b = panel breadth, i.e. perpendicular to direction of compressive stress being considered, in mm

b_{eb} = lesser of $1,9t_p\sqrt{\frac{E}{\sigma_a}}$ or $0,8b$ mm

l = length of longer edge of plate panel, in metres

s = length of shorter edge of plate panel, in mm (typically the spacing of secondary stiffeners)

t_p = thickness of plating, in mm

A_R = panel aspect ratio

$= \frac{a}{b}$

A_{te} = cross-sectional area of secondary stiffener, in cm^2, including an effective breadth of attached plating, b_{eb}

E = modulus of elasticity of material in N/mm^2

S = spacing of primary member, in metres (measured in direction of compression)

S_p = span of primary members, in metres

σ_a = 0,2 per cent proof stress of the material, in N/mm^2

σ_e = elastic compressive buckling stress, in N/mm^2

σ_c = critical compressive buckling stress, including the effects of plasticity where appropriate, in N/mm^2

τ_a = specified minimum yield shear stress of the material, in N/mm^2

$= \frac{\sigma_a}{\sqrt{3}}$ N/mm^2

τ_e = elastic shear buckling stress, in N/mm^2

τ_c = critical shear buckling stress, in N/mm^2.

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4.3 Plate panel buckling requirements

4.3.1 This Section gives methods for evaluating the buckling strength of plate panels subjected to the following load fields:

(a) uni-axial compressive loads;
(b) shear loads;
(c) bi-axial compressive loads;
(d) uni-axial compressive loads and shear loads;
(e) bi-axial compressive loads and shear loads.

4.3.2 The plate panel buckling requirements will be satisfied if the buckling interaction equations given in Table 7.4.2 for the above load fields are complied with.

4.3.3 The critical compressive buckling stresses and critical shear buckling stresses required for Table 7.4.2 are to be derived in accordance with 4.4.

4.3.4 The buckling factors of safety λ_σ and λ_τ required by Table 7.4.2 are given in Table 7.4.4 for the structural member concerned.

4.3.5 For all structural members which contribute to the hull girder strength, the plate panel buckling requirements for uni-axial compressive loads, Table 7.4.2(a), and shear loads, Table 7.4.2(b) are to be complied with.

4.3.6 In addition to 4.3.5, structural members which are subjected to local compressive loads and/or shear loads are to be verified using the plate panel buckling requirements in Table 7.4.2(c) to (e).

4.3.7 However, where some members of the structure have been designed such that elastic buckling of the plate panel between the stiffeners is allowable, then the requirements of 4.5 must be applied to the buckling analysis of the stiffeners supporting the plating. In addition, panels which do not satisfy the panel buckling requirements must be indicated on the appropriate drawing and the effect of these panels not being effective in transmitting compressive loads taken into account for the hull girder strength calculation.

4.3.8 In general the plate panel buckling requirements for more complex load fields, *see* 4.3.1(c), (d), (e), are to be complied with. Where this is not possible, due to elastic buckling of the panel, then the critical buckling stress, σ_c, may be based on the ultimate collapse strength of the plating, σ_u from 4.5.4, instead of the elastic buckling stress, σ_e, derived in 4.3.5. In addition, the requirements of 4.5 are to be met for the supporting secondary stiffeners and primary members.

4.4 Derivation of the buckling stress for plate panels

4.4.1 The critical compressive buckling stress, σ_c, for a plate panel subjected to uni-axial in-plane compressive loads is to be derived in accordance with Table 7.4.1(a).

4.4.2 The critical shear buckling stress, τ_c, for a plate panel subjected to pure in-plane shear load is to be derived in accordance with Table 7.4.1(b).

4.4.3 For welded plate panels the critical compressive buckling stress is to be reduced to account for the presence of residual welding stresses. The critical buckling stress is to be taken as the minimum of:

$\sigma_{cr} = \sigma_e - \sigma_r$

σ_c derived using 4.4.1

where

σ_r = reduction in compressive buckling stress due to residual welding stresses

$$= \frac{2\beta_{RS}\,\sigma_a}{b/t_p}$$

β_{RS} = residual stress coefficient dependent on type of weld (average value of β_{RS} to be taken as 3)

b, t_p and σ_a are defined in 4.2.1.

4.4.4 In general the effect of lateral loading on plate panels (for example hydrostatic pressure on bottom shell plating) may be neglected and the critical buckling stresses calculated considering the in-plane stresses only.

4.4.5 Unless indicated otherwise, the effect of initial deflection on the buckling strength of plate panels may be ignored.

4.5 Additional requirements for plate panels which buckle elastically

4.5.1 Elastic buckling of plate panels between stiffeners occurs when both the following conditions are satisfied:

(a) The design compressive stress, σ_d, is greater than the elastic buckling stress of the plating, σ_e,
$\sigma_d > \sigma_e$

(b) The elastic buckling stress is less than half the yield stress

$$\sigma_e \leq \frac{\sigma_a}{2}$$

4.5.2 Elastic buckling of local plating between stiffeners, including girders or floors, etc., may be allowed if all of the following conditions are satisfied:

(a) The critical buckling stress of the stiffeners in all buckling modes is greater than the axial stress in the stiffeners after redistribution of the load from the elastically buckled plating into the stiffeners, hence

$$\frac{\sigma_{de}}{\sigma_{c\,(i)}} \leq \frac{1}{\lambda_\sigma}$$

(b) Maximum predicted loadings are used in the calculations.

(c) Functional requirements will allow a degree of plating deformation.

where

σ_{de} is the stiffener axial stress given in 4.5.5

$\sigma_{c\,(i)}$ is given by Table 7.4.3

where

i = a, t, w or f depending on the mode of buckling

λ_σ is the buckling factor of safety
= 1,25.

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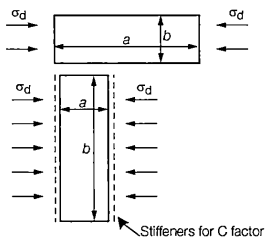
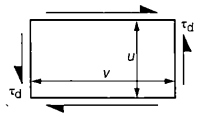
Table 7.4.1 Buckling stress of plate panels

Mode	Elastic buckling stress, N/mm^2, *see* Note	
(a) Uni-axial compression: (i) Long narrow panels, loaded on the narrow edge	$A_R \geq 1$ $\sigma_e = 3{,}62\varphi E \left(\frac{t_p}{b}\right)^2$	
(ii) Short broad panels, loaded on the broad edge	$A_R < 1$ $\sigma_e = 0{,}9C\varphi \left(\frac{b}{a} + \frac{a}{b}\right)^2 E \left(\frac{t_p}{b}\right)^2$	
(b) Pure shear:	$\tau_e = 3{,}62 \left(1{,}335 + \left(\frac{u}{v}\right)^2\right) E \left(\frac{t_p}{u}\right)^2$ NOTE u is to be the minimum dimension	

NOTE
The critical buckling stresses, in N/mm^2, are to be derived from the elastic buckling stresses as follows:

$\sigma_c = \sigma_e$ when $\sigma_e < \frac{\sigma_a}{2}$

$= \sigma_a \left(1 - \frac{\sigma_a}{4\sigma_e}\right)$ when $\sigma_e \geq \frac{\sigma_a}{2}$

σ_c is defined in 4.2.1
σ_a is defined in 4.2.1

$\tau_c = \tau_e$ when $\tau_e < \frac{\tau_a}{2}$

$= \tau_a \left(1 - \frac{\tau_a}{4\tau_e}\right)$ when $\tau_e \geq \frac{\tau_a}{2}$

τ_c is defined in 4.2.1
τ_a is defined in 4.2.1

Symbols

A_R = panel aspect ratio, *see* 4.2.1
σ_e = elastic compressive buckling stress, in N/mm^2
τ_e = elastic shear buckling stress, in N/mm^2
a and b are the panel dimensions in mm, *see* figures above
t_p = thickness of plating, in mm
φ = stress distribution factor for linearly varying compressive stress across plate width
= $0{,}47\mu^2 - 1{,}4\mu + 1{,}93$ for $\mu \geq 0$
= 1 for constant stress

$\mu = \frac{\sigma_{d1}}{\sigma_{d2}}$ where σ_{d1} and σ_{d2} are the smaller and larger average compressive stresses respectively

E = Young's Modulus of elasticity of material, in N/mm^2
C = stiffener influence factor for panels with stiffeners perpendicular to compressive stress
= 1,3 when plating stiffened by floors or deep girders
= 1,21 when stiffeners are built up profiles or rolled angles
= 1,10 when stiffeners are bulb flats
= 1,05 when stiffeners are flat bars
σ_d and τ_d are the design compressive and design shear stresses in the direction illustrated in the figures. With linearly varying stress across the plate panel, σ_d is to be taken as σ_{d2}

4.5.3 The effective breadth of attached plating for stiffeners, girder or beams that is to be used for the determination of the critical buckling stress of the stiffeners attached to plating which buckles elastically is to be taken as follows:

$$b_{eu} = \frac{b\sigma_u}{\sigma_a} \text{ mm}$$

where
σ_u = ultimate buckling strength of plating as given in 4.5.4
b_{eu} = effective panel breadth perpendicular to direction of compressive stress being considered
b is given in 4.2.1.

4.5.4 The ultimate buckling strength of plating, σ_u, which buckles elastically, may be determined as follows:

(a) shortest edge loaded, i.e. $A_R \geq 1$:

$$\sigma_u = \sigma_a \left(\frac{1{,}9}{\Omega} - \frac{0{,}8}{\Omega^2}\right) \text{ N/mm}^2$$

(b) longest edge loaded, i.e. $A_R < 1$:

$$\sigma_u = \frac{1{,}77\sigma_a A_R^{0{,}78}}{\Omega} \text{ N/mm}^2$$

where

$$\Omega = \frac{s}{t_p}\sqrt{\frac{\sigma_a}{E}}$$

A_R and s are defined in 4.2.1.
t_p, E and σ_a are defined in 4.2.1.

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4.5.5 The axial stress in stiffeners attached to plating which is likely to buckle elastically is to be derived as follows:

$$\sigma_{de} = \sigma_d \frac{A_t}{A_{tb}}$$

where

σ_d is the axial stress in the stiffener when the plating can be considered fully effective

$$A_t = A_s + \frac{bt}{100} \text{ cm}^2$$

$$A_{tb} = A_s + \frac{b_{eu}\, t}{100} \text{ cm}^2$$

where

b and b_{eu} are given in 4.5.3

t is the plating thickness, in mm

A_s is the stiffener area in cm^2.

4.6 Shear buckling of stiffened panels

4.6.1 The shear buckling capability of longitudinally stiffened panels between primary members is to satisfy the following condition:

$$\frac{\tau_d}{\tau_c} \leq \frac{1}{\lambda_\tau}$$

where

τ_c is derived from 4.6.3

τ_d is the design shear stress

λ_τ is given in Table 7.4.4.

4.6.2 The elastic shear buckling stress of longitudinally stiffened panels between primary members may be taken as:

$$\tau_e = K_s E \left(\frac{t}{s}\right)^2 \quad \text{for } A_R \geq 1$$

where

$$K_s = 4{,}5\left(\left(\frac{s}{1000l}\right)^2 + \frac{1}{N^2} + \left(\frac{N^2-1}{N^2}\right)\left(\frac{\omega}{1+\omega}\right)\right)^r$$

N = number of subpanels

$$= \frac{1000 S_p}{s}$$

$$\omega = \frac{10 I_{se}}{}$$

I_{se} = moment of inertia of a section, in cm^4, consisting of the longitudinal stiffener and a plate flange of effective width $s/2$

$$r = 1 - 0{,}75\left(\frac{s}{1000l}\right)$$

s, l, E and S_p are as defined in 4.2.1, *see also* Fig. 7.4.1.

4.6.3 The critical shear buckling stress, τ_c, may be determined from τ_e, *see* Note in Table 7.4.1.

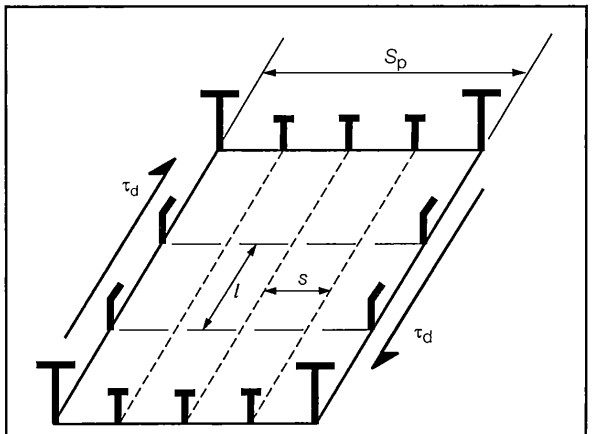

Fig. 7.4.1 Shear buckling of stiffened panels

4.7 Secondary stiffening in direction of compression

4.7.1 The buckling performance of stiffeners will be considered satisfactory if the following conditions are satisfied:

$$\frac{\sigma_d}{\sigma_{c(a)}} \leq \frac{1}{\lambda_\sigma} \qquad \frac{\sigma_d}{\sigma_{c(t)}} \leq \frac{1}{\lambda_\sigma}$$

$$\frac{\sigma_d}{\sigma_{c(w)}} \leq \frac{1}{\lambda_\sigma} \qquad \frac{\sigma_d}{\sigma_{c(f)}} \leq \frac{1}{\lambda_\sigma}$$

where

$\sigma_{c(a)}$, $\sigma_{c(t)}$, $\sigma_{c(w)}$ and $\sigma_{c(f)}$ are the critical buckling stresses of the stiffener for each mode of failure, *see* 4.7.2

σ_d is the design compressive stress, *see also* 4.5 and 4.1.3

λ_σ is the buckling factor of safety given in Table 7.4.4. The value of λ_σ to be chosen depends on the buckling assessment of the attached plating, *see* Note 1 in Table 7.4.4.

4.7.2 The critical buckling stresses for the overall, torsional, web and flange buckling modes of longitudinals and secondary stiffening members under axial compressive loads are to be determined in accordance with Table 7.4.3.

4.7.3 To prevent torsional buckling of secondary stiffeners from occurring before buckling of the plating, the critical torsional buckling stress, $\sigma_{c(t)}$, is to be greater than the critical buckling stress of the attached plating as detailed in 4.4.1.

4.7.4 The critical buckling stresses of the stiffener web, $\sigma_{c(w)}$, and flange, $\sigma_{c(f)}$, are to be greater than the critical torsional buckling stress, hence:

$$\sigma_{c(w)} > \sigma_{c(t)}$$

$$\sigma_{c(f)} > \sigma_{c(t)}$$

4.7.5 To ensure that overall buckling of the stiffened panel cannot occur before local buckling of the secondary stiffener, the critical overall buckling stress $\sigma_{c(a)}$, is to be greater than the critical torsional buckling stress, hence

$$\sigma_{c(a)} > \sigma_{c(t)}$$

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4.8 Secondary stiffening perpendicular to direction of compression

4.8.1 Where a stiffened panel of plating is subjected to a compressive load perpendicular to the direction of the stiffeners, *see* Fig. 7.4.2, e.g. a transversely stiffened panel subject to longitudinal compressive load, the requirements of this Section are to be applied.

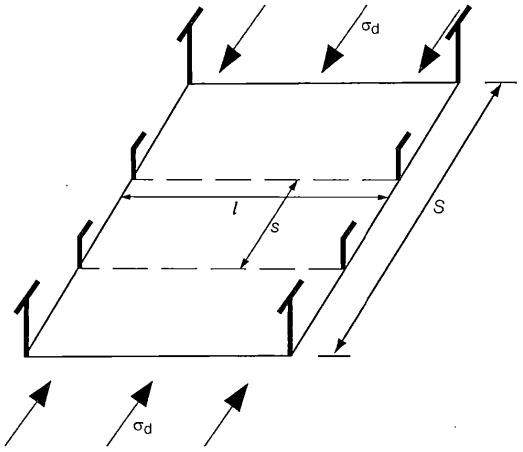

Fig. 7.4.2
Secondary stiffening perpendicular to direction of compression

4.8.2 The minimum area moment of inertia of each stiffener including attached plating of width, s, to ensure that overall panel buckling does not precede plate buckling is to be taken as:

$$I_s = \frac{D\,s\,(4N_L^2 - 1)((N_L^2 - 1)^2 - 2\,(N_L^2 + 1)\,\kappa + \kappa^2)}{2\,(5N_L^2 + 1 - \kappa)\,\Pi^4\,E} \text{ mm}^4$$

where

$$D = \frac{E\,t_p^3}{12\,(1 - \upsilon^2)}$$

$\kappa = A_R^2\,\Pi^2$

A_R = plate panel aspect ratio

$$= \frac{s}{1000l}$$

$$\Pi = \frac{S}{l}$$

N_L = number of plate panels

$N_L - 1$ = number of stiffeners

υ = 0,3

s, l and S are defined in 4.2.1 and shown in Fig.7.4.2

t_p, E are defined in 4.2.1.

4.9 Buckling of primary members

4.9.1 Where primary girders are subject to axial compressive loading, the buckling requirements for lateral, torsional, web and flange buckling modes detailed in 4.7 are to be satisfied.

4.9.2 To prevent global buckling from occurring before local panel buckling, transverse primary girders supporting axially loaded longitudinal stiffeners are to have a sectional moment of inertia, including attached plating, of not less than the following:

$$I_g = \frac{0{,}35S_p^4\,I_s}{l^3\,s} \times 10^3 \text{ cm}^4$$

S_p and s are as defined in 4.2.1, *see also* Fig.7.4.1

I_g = sectional moment of inertia including attached plating

I_s = moment of inertia of secondary stiffeners, in cm^4, required to satisfy the overall elastic column buckling mode requirement specified in Table 7.4.3

$$= \frac{\sigma_{ep}\,A_{te}\,l_e^2}{0{,}001E}$$

where

$$\sigma_{ep} = 1{,}2\sigma_d \text{ N/mm}^2 \text{ for } \sigma_{e(a)} < \frac{\sigma_a}{2}$$

$$= \frac{\sigma_a^2}{4\,(\sigma_a - 1{,}2\sigma_d)} \text{ for } \sigma_{e(a)} \geq \frac{\sigma_a}{2}$$

σ_d is design stress, in N/mm^2

σ_a and A_{te} are as defined in 4.2.1.

$\sigma_{e(a)}$ is the elastic column buckling stress, *see* 4.7.2

E is defined in 4.2.1

l_e is defined in Table 7.4.3.

4.10 Shear buckling of girder webs

4.10.1 Local panels in girder webs subject to in-plane shear loads are to satisfy the shear buckling requirements in Table 7.4.2, item (b).

4.10.2 The critical shear buckling stress, τ_c, is to be determined using the following formula for τ_e and the Note in Table 7.4.1.

$$\tau_e = 3{,}62\left(1{,}335 + \left(\frac{d_w}{1000l_p}\right)^2\right) E\left(\frac{t_p}{d_w}\right)^2 \text{ N/mm}^2$$

where

d_w = web height, in mm

l_p = unsupported length of web, in metres

t_p and E are defined in 4.2.1.

4.11 Pillars and pillar bulkheads

4.11.1 Pillars and pillar bulkheads are to comply with the requirements of Ch 3,10.

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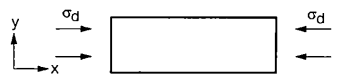
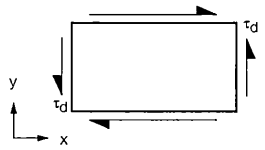
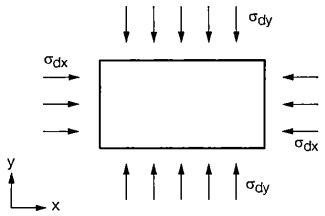
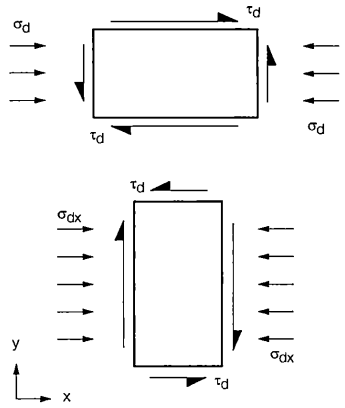
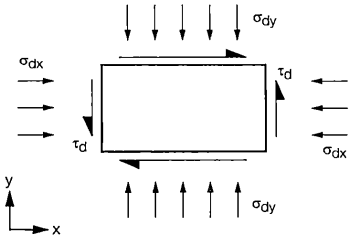
Table 7.4.2 Plate panel buckling requirements

	Stress field	Buckling Interaction formula	
(a)	uni-axial compressive loads	$\frac{\sigma_d}{\sigma_c} \le \frac{1}{\lambda_\sigma}$	
(b)	shear loads	$\frac{\tau_d}{\tau_c} \le \frac{1}{\lambda_\tau}$	
(c)	bi-axial compressive loads	for $A_R = 1,0$ $\frac{\sigma_{dx}}{\sigma_{cx}} + \frac{\sigma_{dy}}{\sigma_{cy}} \le 1,0$ for other aspect ratios, i.e. $A_R \ne 1,0$ $\frac{\sigma_{dx}}{\sigma_{cx}} + \frac{\sigma_{dy}}{\sigma_{cy}} \le G$ when G is taken from Fig. 7.4.3	
(d)	uni-axial compressive loads plus shear load	for $A_R > 1$ $\left(\frac{\sigma_d}{\sigma_c}\right) + \left(\frac{\tau_d}{\tau_c}\right)^2 \le 1$ for $A_R \le 1$ $\left(\frac{1 + 0,6A_R}{1,6}\right)\left(\frac{\sigma_d}{\sigma_c}\right) + \left(\frac{\tau_d}{\tau_c}\right)^2 \le 1$	
(e)	bi-axial compressive loads plus shear loads	$\frac{0,625\left(1 + \frac{0,6}{A_R}\right)\left(\frac{\sigma_{dy}}{\sigma_{cy}}\right)}{1 - 0,625\left(\frac{\sigma_{dx}}{\sigma_{cx}}\right)} + \frac{\left(\frac{\tau_d}{\tau_c}\right)^2}{1 - \left(\frac{\sigma_{dx}}{\sigma_{cx}}\right)} \le 1$	

Symbols

σ_d = design compressive stress, *see* 4.1.3
σ_c = critical compressive buckling stress, in N/mm^2, for uniaxial compressive load acting independently, *see* 4.3.5
σ_{dx} = design compressive stress in x direction
σ_{dy} = design compressive stress in the y direction
σ_{cx} = critical compressive buckling stress in x direction, *see* 4.3.5
σ_{cy} = critical compressive buckling stress in y direction, *see* 4.3.5
λ_σ = buckling factor of safety for compressive stresses, *see* 4.3.4
λ_τ = buckling factor of safety for shear stresses, *see* 4.3.4
τ_d = design shear stress, in N/mm^2
τ_c = critical shear buckling stress, in N/mm^2, acting independently, *see* 4.3.5
A_R = *see* 4.2.1

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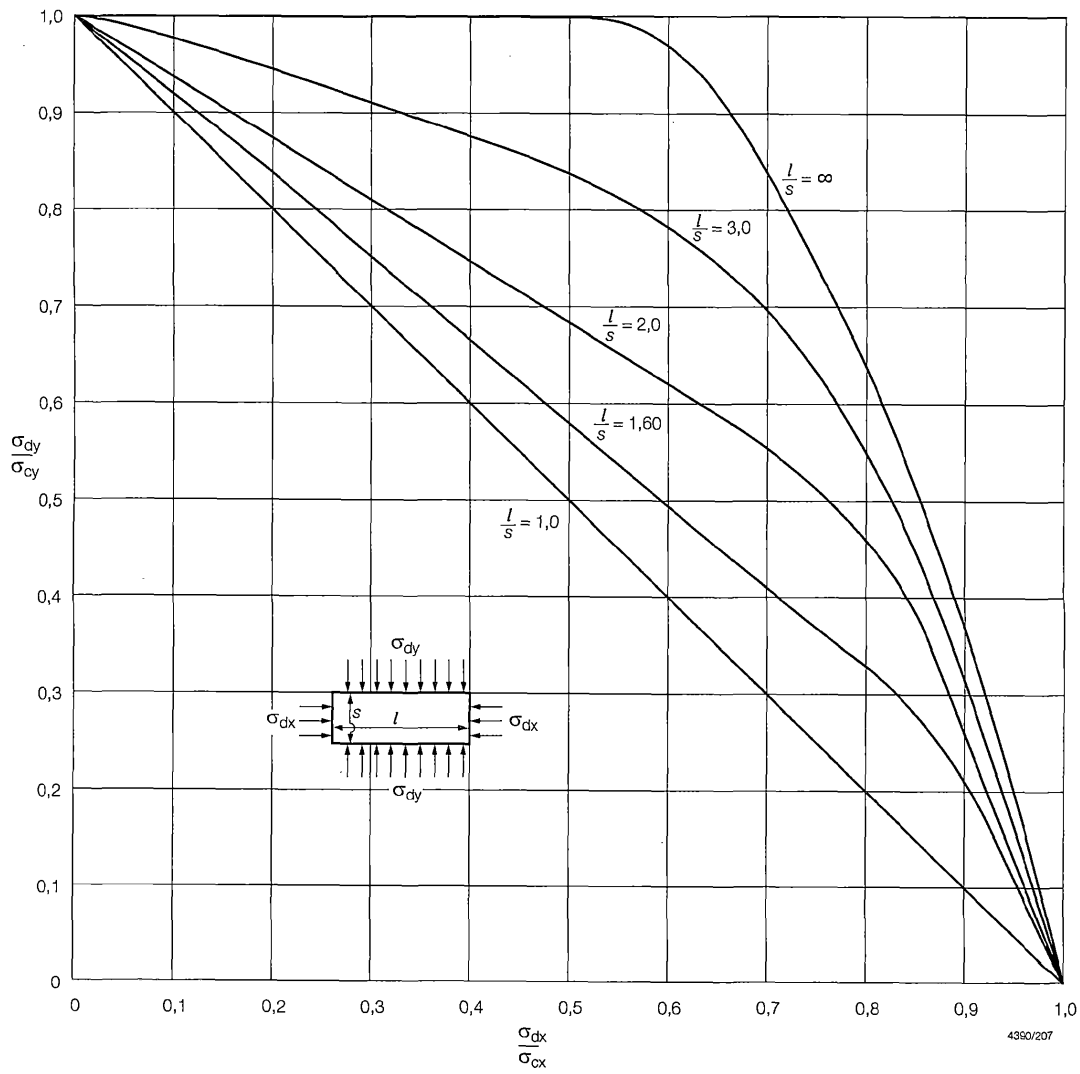

Fig. 7.4.3
Interaction limiting stress curves of G for plate panels subject to bi-axial compression, *see* Table 7.4.2(c)

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Table 7.4.3 Buckling stress of secondary stiffeners (*see continuation*)

Mode	Elastic buckling stress, N/mm^2	Critical buckling stress, N/mm^2 *see* Note
(a) Overall buckling (perpendicular to plane of plating without rotation of cross-section)	$\sigma_{e(a)} = C_f\, 0{,}001\, E \quad I_a$	$\sigma_{c(a)}$
(b) Torsional buckling	$\sigma_{e(t)} = \frac{0{,}001 E I_w}{I_p l_e^2}\left(m^2 + \frac{K}{m^2}\right) + 0{,}385 E \frac{I_t}{I_p}$	$\sigma_{c(t)}$
(c) Web buckling (excluding flat bar stiffeners)	$\sigma_{e(w)} = 3{,}8\, E \left(\frac{t_w}{d_w}\right)^2$	$\sigma_{c(w)}$
(d) Flange buckling	$\sigma_{e(f)} = 0{,}39\, E \left(\frac{t_f}{b_f}\right)^2$	$\sigma_{c(f)}$

The critical buckling stresses are to be derived from the elastic buckling stresses as follows:

$\sigma_c = \sigma_e$ when $\sigma_e < \frac{\sigma_a}{2}$

$= \sigma_a \left(1 - \frac{\sigma_a}{4\sigma_e}\right)$ when $\sigma_e \geq \frac{\sigma_a}{2}$

Symbols

d_w = web depth, in mm, (excluding flange thickness for rolled sections), *see* Fig. 7.4.4
t_w = web thickness, in mm
b_f = flange width, in mm (including web thickness)
t_f = flange thickness, in mm. For bulb plates, the mean thickness of the bulb may be used, *see* Fig. 7.4.4
l_e = effective span length of stiffener, in metres
C_f = end constraint factor
= 1 where both ends are pinned
= 2 where one end pinned and the other end fixed
= 4 where both ends are fixed
E = Youngs Modulus of elasticity of the material, in N/mm^2
I_a = moment of inertia, in cm^4, of longitudinal, including attached plating of effective width b_{eb}, *see* Note
t_p and σ_a are given in 4.2.1
A_{te} and b_{eb} are given in 4.2.1

NOTE
For stiffeners attached to plating which buckles elastically, *see* 4.5, the effective width of plating is to be taken as b_{eu}.

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Table 7.4.3 Buckling stress of secondary stiffeners (*conclusion*)

I_t = St.Venant's moment of inertia, in cm^4, of longitudinal (without attached plating)

$= \frac{d_w t_w^3}{3} 10^{-4}$ for flat bars

$= \frac{1}{3}\left[d_w t_w^3 + b_f t_f^3 \left(1 - \frac{0{,}63 t_f}{b_f}\right)\right] 10^{-4}$ for built up profiles, rolled angles and bulb plates

I_p = polar moment of inertia, in cm^4, of profile about connection of stiffener to plating

$= \frac{d_w^3 t_w}{3} 10^{-4}$ for flat bars

$= \left(\frac{d_w^3 t_w}{3} + d_w^2 b_f t_f\right) 10^{-4}$ for built up profiles, rolled angles and bulb plates

I_w = sectorial moment of inertia, in cm^6, of profile and connection of stiffener to plating

$= \frac{d_w^3 t_w^3}{36} 10^{-6}$ for flat bars

$= \frac{t_f b_f^3 d_w^2}{12} 10^{-6}$ for 'Tee' profiles

$= \frac{b_f^3 d_w^2}{12 (b_f + d_w)^2} (t_f (b_f^2 + 2 b_f d_w + 4 d_w^2) + 3 t_w b_f d_w) 10^{-6}$ for '*L*' profiles, rolled angles and bulb plates

C = spring stiffness exerted by supporting plate panel

$= \frac{k_p E t_p^3}{3b\left(1 + \frac{1{,}33 k_p d_w t_p^3}{b t_w^3}\right)}$

k_p = $1 - \eta_p$, and is not to be taken as less than zero. For built-up profiles, rolled angles and bulb plates, k_p need not be taken less than 0,1

$\eta_p = \frac{\sigma_d}{\sigma_{ep}}$

σ_{ep} = elastic critical buckling stress, in N/mm^2, of the supporting plate derived from Table 7.4.1

m is determined as follows; e.g. $m = 2$ for $K = 25$

K	0 to 4	4 to 36	36 to 144	144 to 400	400 to 900	900 to 1764	$(m-1)^2 m^2$ to $m^2 (m+1)^2$
m	1	2	3	4	5	6	*m*

$K = \frac{1{,}03 C S^4}{E I_w} 10^4$

σ_d is the design stress, in N/mm^2
all other symbols are as defined in 4.2.1

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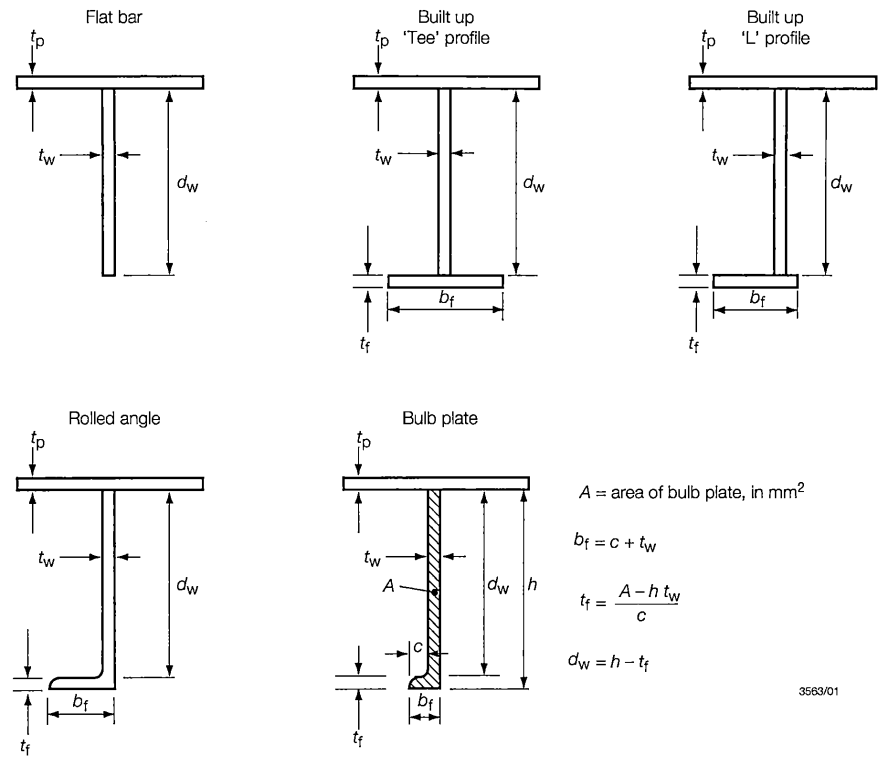

Fig. 7.4.4 Dimensions of longitudinals

Table 7.4.4 Buckling factor of safety

Structural item	Buckling factor of safety [2] Compressive stresses, λ_σ	Buckling factor of safety [3] Shear stresses, λ_τ
Bottom shell plating	1,0	—
Inner bottom plating	1,0	—
Deck plating	1,0	—
Side shell plating	1,0	1,1
Longitudinal bulkhead plating	1,0	1,1
Double bottom girders	1,0	1,1
Longitudinal girders	1,0	1,1
Superstructures/deckhouses (partially longitudinally effective)	1,0	—
Longitudinal secondary stiffeners	1,1[1]	—
Girder and floor web plating subject to local loads	1,1	1,2

NOTES
1. The buckling factor of safety for stiffeners attached to plating which is allowed to buckle in the elastic mode due to the applied loads is to be taken as 1,25, *see also* 4.5.
2. Buckling factor of safety to be applied to the compressive stress due to global longitudinal stresses.
3. Buckling factor of safety to be applied to the shear stress.

■ *Section 5* Vibration control

5.1 General

5.1.1 Natural frequencies are to be investigated for local unstiffened and stiffened panels expected to be exposed to excessive structural vibrations being induced from machinery, propulsion unit or other potential excitation sources.

5.1.2 Where the structural configurations are such that basic structural elements may be modelled individually the natural frequencies may be derived in accordance with 5.3, 5.4 and 5.5, as appropriate. Under other circumstances finite element analysis is to be employed to evaluate the vibration characteristics of the structure considered.

5.2 Frequency band

5.2.1 The natural frequency of panels is generally not to lie within a band of ±20 per cent of a significant excitation frequency.

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5.3 Natural frequency of plate

5.3.1 The natural frequency of a clamped plate in air is given by the following:

$$f_{air} = 5{,}544 \frac{t_p}{ab} \sqrt{\left(\frac{a}{b}\right)^2 + \left(\frac{b}{a}\right)^2 + 0{,}6045} \quad \text{Hz}$$

where

a = panel length, in metres
b = panel breadth, in metres
t_p = panel thickness, in mm.

5.4 Natural frequency of plate stiffener

5.4.1 The natural frequency of a plate stiffener in air is given by the following:

$$f_{air,i} = \frac{K_i}{2\pi L_b^2} \sqrt{\frac{EI}{m\left(1 + \frac{\pi^2 EI}{L_b^2 GA}\right)}} \quad \text{Hz}$$

where

EI = flexural rigidity of plate stiffener combination, in Nm^2
GA = shear rigidity of plate stiffener combination, in N
L_b = beam length, in metres
m = mass per unit length of the stiffener and associated plating, in kg/m
K_i = constant where i refers to the mode of vibration as given in Table 7.5.1.

Table 7.5.1 Vibration mode constant K_i

Mode	1	2	3	4	5
K_i	22,40	61,70	121,0	200,0	299,0

5.5 Effect of submergence

5.5.1 To obtain the frequency, f_{water}, of a plate with one side exposed to air and the other side exposed to a liquid, the frequency calculated in air, f_{air}, may be modified by the following formula:

$$f_{water} = \psi f_{air}$$

where

$$\psi = \sqrt{\frac{\kappa_p}{\kappa_p + \frac{\rho_l}{\rho_p}}}$$

ρ_l = density of the liquid, in kg/m^3
ρ_p = density of the plate, in kg/m^3

$$\kappa_p = \frac{\pi t_p}{1000 a b} \sqrt{a^2 + b^2}$$

where

a, b and t_p are as defined in 5.3.1.

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Rules and Regulations for the Classification of Special Service Craft

Volume 6
Part 8
Hull Construction in Composite
July 2012

Lloyd's Register
LIFE MATTERS

002858

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DIFFERENT TYPES OF HULL FORMS COVERED BY THE SPECIAL SERVICE CRAFT RULES

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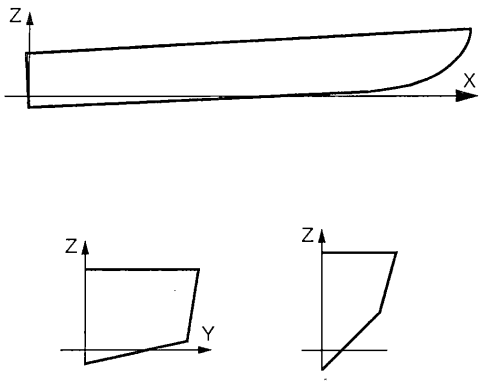
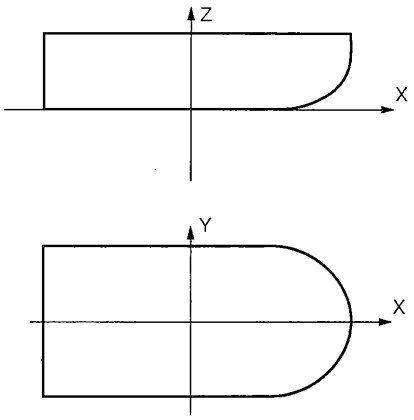


HOVERCRAFT



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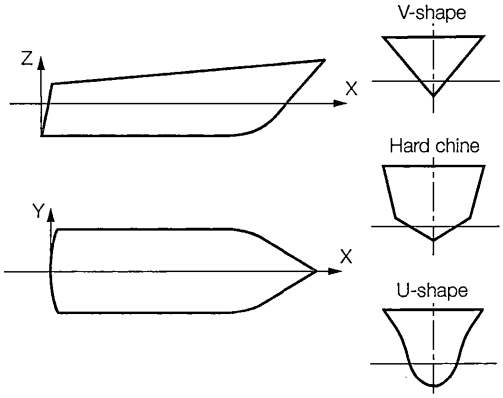

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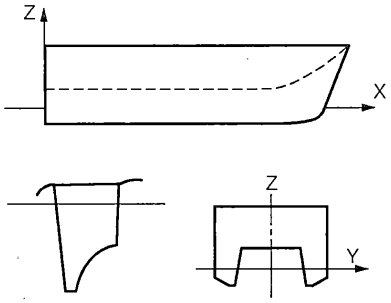
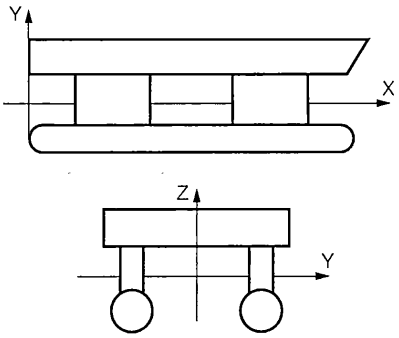
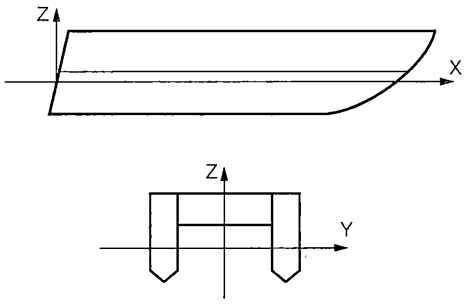


SMALL WATERPLANE AREA TWIN HULL (SWATH)



CATAMARAN



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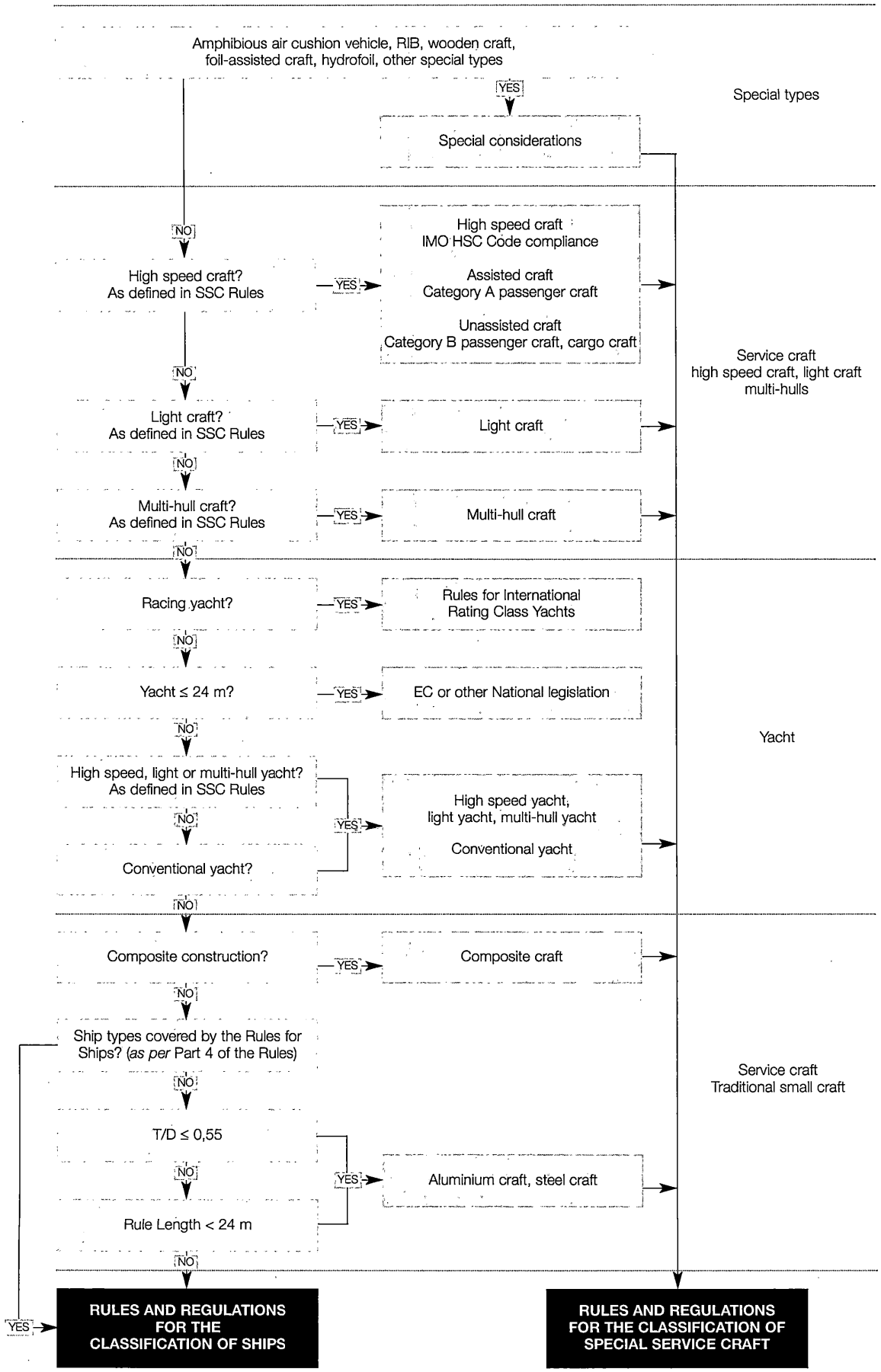

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Section

1 **Application**

2 **General requirements**

■ *Section 1* Application

1.1 General

1.1.1 The Rules are applicable to mono and multi-hull craft of normal form, proportions and speed. Although the Rules are, in general, for fibre reinforced composite craft of laminated construction, other materials for use in hull construction will be specially considered on the basis of the Rules.

1.1.2 The Rules provide for craft of both single and sandwich skin construction.

1.2 Interpretation

1.2.1 The interpretation of the Rules is the sole responsibility and at the sole discretion of Lloyd's Register (hereinafter referred to as 'LR'). Where there is any doubt regarding the interpretation of the Rules it is the Builder's and/or designer's responsibility to obtain clarification from LR prior to submission of plans and data for appraisal.

1.2.2 Where applicable, the Rules take into account unified requirements and interpretations established by the International Association of Classification Societies (IACS).

1.2.3 Attention is drawn to the fact that Codes of Practice issued by IMO or other applicable National Authorities may contain requirements which are outside classification as defined in the Rules.

1.3 Equivalents

1.3.1 Alternative scantlings and arrangements may be accepted as equivalent to the Rule requirements. Details of such proposals are to be submitted for consideration in accordance with Pt 3, Ch 1,3.

1.4 Symbols and definitions

1.4.1 The symbols and definitions for use throughout this Part are as defined within the appropriate Chapters and Sections.

■ *Section 2* General requirements

2.1 General

2.1.1 Specific limitations regarding the application of the Rules are indicated in the various Chapters for differing types of craft.

2.2 Aesthetics

2.2.1 LR is not concerned with the general arrangement, layout and appearance of the craft; the responsibility for such matters remains with the Builders and/or designers to ensure that the agreed specification is complied with. LR is however concerned with the quality of workmanship, and in this respect the acceptance criteria as required by the Rules are to be complied with.

2.3 Constructional configuration

2.3.1 The Rules provide for the basic structural configurations for both single and multi-deck mono and multi-hull craft with single or double bottom arrangements. The structural configuration may also include a single or multiple arrangement of cargo hatch openings and side tanks.

2.3.2 The Rules provide for longitudinal and transverse framing systems.

2.3.3 Novel or other types of framing systems will be considered on the basis of the Rules.

2.4 Plans to be submitted

2.4.1 Plans covering the following items are to be submitted:

- Midship sections showing longitudinal and transverse material.
- Profile and decks.
- Deck hatches.
- Bridging structure.
- Shell expansion.
- Laminate schedule.
- Oiltight and watertight bulkheads.
- Propeller brackets.
- Integral tanks.
- Double bottom construction.
- Pillars and girders.
- Aft end construction.
- Engine room construction.
- Engine and thrust seatings.
- Fore end construction.
- Doors, hatches, windows and portlights.
- Deckhouses and superstructures.
- Sternframe.
- Rudder, stock and tiller.
- Anchoring and mooring equipment.
- Loading manuals, preliminary and final (where applicable).
- Ice strengthening.
- Welding (where applicable).
- Hull penetration plans.

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- Support structure for masts, derrick posts or cranes.
- Bilge keels showing connections and detail design.
- Chain-plates.

2.4.2 The following supporting documents are to be submitted:

- General arrangement.
- Capacity plan.
- Lines plan or equivalent.
- Dry-docking plan.
- Towing and mooring arrangements.
- Sail/rigging plan, indicating loadings (as applicable to sailing craft).

2.4.3 The following supporting calculations are to be submitted, *see also* 2.7:

- Equipment Number.
- Hull girder still water and dynamic wave bending moment and shear force as applicable.
- Midship section stiffness.
- Structural items in the aft end, midship and fore end regions of the craft.
- Preliminary freeboard calculation.

2.5 Materials data sheet

2.5.1 Details of all the approved and accepted plastics materials, as required by the Rules, are to be submitted on LR's Reinforced Plastic Structures Materials Data Sheet (Form 2075) with the initial submission of plans. Reference is to be made to Ch 2,2. The types and quantities of curing systems identified on the Materials Data Sheet are to be those recommended by the resin manufacturer for the approved resin systems.

2.5.2 When specifying materials, the exact manufacturer's type designation, identification and reference numbers are to be quoted.

2.5.3 All sandwich core materials are to be of a type acceptable to LR and are to be clearly identified together with any core bonding adhesive to be used.

2.5.4 Fibre contents by weight for each type of reinforcement are to be reported.

2.5.5 All relevant post curing data is to be documented on the Materials Data Sheet.

2.6 Novel features

2.6.1 Where the proposed construction of any part of the hull or machinery is of novel design, or involves the use of unusual material, or where experience, in the opinion of LR, has not sufficiently justified the principle or mode of application involved, special tests or examinations before and during service may be required. In such cases a suitable notation may be entered in the appropriate *Register Book*.

2.7 Direct calculations

2.7.1 Direct calculations may be specifically required by the Rules and may be required for craft having novel design features or in support of alternative arrangements and scantlings. LR may, when requested, undertake calculations on behalf of the designers and make recommendations in regard to suitability of any required model tests.

2.7.2 Where direct calculations are proposed then the requirements of Pt 3, Ch 1,2 are, in general, to be complied with.

2.8 Exceptions

2.8.1 Craft of unusual form, proportions or speed, intended for the carriage of special cargoes, not covered specifically by the Rules, will receive individual consideration based on the general requirements of the Rules.

2.9 Advisory services

2.9.1 The Rules do not cover certain technical characteristics, such as stability, except as mentioned in Pt 1, Ch 2,1.1.11, 1.1.13 and 1.1.14, trim, vibration, docking arrangements, etc. The Committee cannot assume responsibility for these matters but is willing to advise upon them on request.

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Section

1 **General requirements**

2 **Materials**

3 **General construction process**

4 **Additional procedures for sandwich construction**

5 **Details and fastenings**

Section 1 General requirements

1.1 General

1.1.1 The Rules are applicable to craft generally constructed of fibre reinforced plastic in accordance with 2.1.1.

1.1.2 All construction is to be carried out using materials and techniques approved or accepted by Lloyd's Register (hereinafter referred to as 'LR'). Where non-approved or non-accepted materials or production techniques are proposed, it is the responsibility of the Builder and manufacturer to obtain the necessary approval or acceptance and demonstrate their equivalence on the basis of the Rules.

1.1.3 It is the Builder's responsibility to ensure that all materials are used in accordance with the manufacturer's instructions.

1.2 Definitions

1.2.1 Definitions for use throughout this Chapter are as indicated in the appropriate Sections.

1.3 Symbols

1.3.1 Symbols for use throughout this Chapter are as indicated in the appropriate Sections.

1.4 Builder's facilities

1.4.1 Sections 1.4 and 1.5 are applicable to the facilities and works for the craft under survey.

1.4.2 The buildings used for production and storage are to be of suitable construction and equipped to provide the required environment, and are to comply with any local or National Authority requirements.

1.4.3 Workshops and equipment are to be in accordance with good manufacturing practice and are to be to the satisfaction of the Surveyor.

1.4.4 The Surveyor is to be allowed unrestricted access during working hours to such parts of the Builder's establishment as may be necessary to ensure that the requirements of the Rules are being complied with.

1.5 Works inspection

1.5.1 Prior to the commencement of production the facilities are to be inspected to the satisfaction of the attending Surveyor. This is to include evidence that the mandatory minimum quality control requirements as outlined in 1.6 and Ch 14,5 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials), are fulfilled.

1.5.2 The Surveyor is to be satisfied that the Builder has the organisation and capability to mould craft to the standards required by the Rules.

1.5.3 The Builder is to rectify any deficiencies to the Surveyor's satisfaction prior to the commencement of production.

1.5.4 The validity of the acceptance of the Builder's works for moulding craft under LR survey is subject to an annual QC audit and monitoring by the attending Surveyor. Where there is a break in the continuity of moulding under LR survey, the facilities will in general, be subject to an additional inspection prior to any recommencement of any moulding carried out under LR survey.

1.5.5 For acceptance the survey is to include procedures covering the Builder's management, organisation and quality systems.

1.6 Quality control

1.6.1 The Builder's mandatory quality systems for composite construction, will be subject to inspection and audit, and are to be in accordance with the requirements of one of the following:

(a) Quality Assurance System in accordance with an International or National Standard (i.e., ISO 9000 and BS ENISO 9001) with assessment and certification carried out by a nationally accredited body and must reflect the minimum quality control requirements under (c) being complied with.

(b) LR's *Quality Assurance Scheme for the Construction of Special Service Craft*.

(c) LR's locally accepted Quality Control System – The Builder is implementing a documented Quality Control System which controls the activities as indicated below, *see also* Ch 14,5 of the Rules for Materials:
  (i) Receipt storage and issue of materials, equipment, etc.
  (ii) Moulding shop.
  (iii) Care and preparation of mould tools, etc.
  (iv) Lay-up process control.
  (v) Inspection of FRP mouldings on release.
  (vi) Installation of machinery and essential systems.
  (vii) Fitting-out.
  (viii) Tests and trials.
  (ix) Plans and document control.
  (x) Records.

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1.6.2 LR's involvement is only in that part of the system which controls the standards required to meet the classification requirements.

1.6.3 The mandatory 'documented' quality control system, in general, requires the Builder to have written down procedures that describe clearly and unambiguously how each of the above activities is carried out, when it is carried out and by whom. These procedures will form part of the system manual which is also to contain a statement of management policy, organisation chart and statements of responsibilities. The manual is to be controlled covering formal issue and revision.

1.7 Moulding shop

1.7.1 Where the conventional hand lay-up or spray lay-up processes are used, an even shop temperature of not less than 16°C, and, in general, of not more than 25°C, is to be maintained throughout the moulding area during the lay-up and curing periods. Where the temperature exceeds 25°C, special consideration is to be given to the resin system.

1.7.2 Where moulding processes other than those in 1.7.1 are to be used, the moulding shop temperature will be subject to individual consideration in conjunction with the written recommendations of the manufacturers of the materials.

1.7.3 The relative humidity in the moulding shop is to be kept below 70 per cent, taking into account the dew point, thus avoiding moisture condensation on moulds and materials.

1.7.4 Sufficient temperature and humidity monitoring equipment is to be provided and detailed records are to be kept in accordance with the quality control system.

1.7.5 It is the responsibility of the Builder to ensure that the ventilation and working conditions, together with discharges into the atmosphere, are such that levels of substances are within the limits specified in any pertinent National or International legislation.

1.7.6 The working areas are to be adequately illuminated. Precautions are to be taken to avoid any effects on the resin cure due to direct sunlight or artificial lighting.

1.8 Storage areas

1.8.1 The resins are to be stored under dry, well-ventilated conditions, in accordance with the manufacturer's recommendations.

1.8.2 Where resin tanks or drums are stored outdoors it is the Builder's responsibility to ensure that the resin manufacturer's storage conditions are complied with.

1.8.3 Where the temperature for materials storage drops below that of the moulding shop i.e. minimum 16°C, the materials are to be pre-conditioned to the moulding shop temperature prior to use.

1.8.4 Curing agents are to be stored separately under clean, dry and well-ventilated conditions in accordance with the manufacturer's recommendations and any local or National legislation.

1.8.5 Fillers and additives are to be stored in closed containers that are impervious to dust and moisture.

1.8.6 Reinforcements are to be stored under dust-free and dry conditions.

1.9 Mould construction

1.9.1 Moulds are to be constructed of a suitable material and are to be adequately stiffened to maintain their overall shape and fairness of form.

1.9.2 The materials used in the construction of moulds are not to affect the resin cure.

1.9.3 The finish on a mould is to be such that the mouldings produced are suitable for the purpose intended. The resultant aesthetic appearance of the moulding is strictly a matter between the moulder and the Owner.

1.9.4 Where multiple section moulds are used, the sections are to be carefully aligned to the attending Surveyor's satisfaction prior to moulding. Mismatch between mould sections is to be eliminated.

1.9.5 Where metallic moulds are used, welding is to be minimised to avoid distortion of panels.

1.9.6 The release agent is to be of a type recommended by the resin manufacturer and is not to affect the cure of the resin.

1.9.7 Prior to use all moulds are to be conditioned to the workshop temperature.

1.10 Materials handling

1.10.1 The arrangements for the receipt, verification against certificates of conformity and subsequent handling of materials are to be covered by the Builder's quality control procedures such that the materials do not suffer contamination or degradation and bear adequate identification at all times; *see* Ch 14,3 of the Rules for Materials. Storage is to be arranged such that materials are used by batch wherever possible, in order of receipt. Materials are not to be used after the manufacturer's date of expiry, except with the prior agreement of LR and new certificates of conformity being obtained from the material manufacturer. Details of the new certificates of conformity are to be entered into the quality control system.

1.10.2 Where materials are found to be non-conforming they are to be rejected in accordance with the Builder's quality control procedure.

1.10.3 All non-conforming materials are to be segregated in their storage areas and marked accordingly.

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1.10.4 Resin/catalyst pumps and spray equipment are to be operated in accordance with the manufacturers instructions. Maintenance and calibration of the mix ratio is to be carried out according to written procedures.

1.11 Faults

1.11.1 All faults are to be classified according to their severity and recorded, together with the remedial action taken, under the requirements of the quality control systems, the documentation being subject to review at the Periodical Survey.

1.11.2 Production faults are to be brought to the attention of the attending Surveyor and a rectification scheme agreed. Deviations from the approved plans are to be to the satisfaction of the attending Surveyor.

1.12 Inspection

1.12.1 It is the Builder's responsibility to carry out the required inspections in accordance with the accepted quality control system.

1.12.2 The Surveyor will monitor the Builder's quality control records and carry out inspections of work in progress during his periodical visits.

1.12.3 During inspections all deviations are to be dealt with under the Builder's agreed quality procedures, *see* 1.6.3.

1.13 Acceptance criteria

1.13.1 Classification is dependent upon the work being carried out in accordance with the approved plans and the requirements of an accepted quality system.

1.13.2 The workmanship is to be to the satisfaction of the attending Surveyor. This will include the verification of the quality control documentation and the remedial action associated with all defects and deficiencies recorded.

1.13.3 Proposed deviations from the approved plans are subject to LR approval. An amended plan is to be submitted to the plan appraisal office, prior to any such changes being introduced.

1.14 Repair

1.14.1 Minor repairs are to be agreed with the attending Surveyor prior to being carried out. The Builder is to incorporate details of the agreed repair procedures in the quality control system in accordance with 1.6.3.

1.14.2 Written details of proposed structural repairs are to be submitted to the Plan Approval Office for approval prior to introduction.

1.15 Scaffolding

1.15.1 Scaffolding/platform arrangements are to be provided to permit adequate access for production and inspection purposes. Such arrangements are to conform to National Authority requirements and are not, in general, to be connected to the moulding or impinge on the mould surface.

1.16 Access

1.16.1 The attending Surveyor is to be permitted reasonable access to all areas of the Builder's premises during normal working hours. Scaffolding/platform arrangements are to be made available in accordance with 1.15.

1.17 Lifting arrangements

1.17.1 Lifting arrangements are to be designed such that mouldings are subjected to minimal distortion and unnecessary stressing. Mouldings are to be adequately supported to avoid distortion during final cure.

■ *Section 2* Materials

2.1 General

2.1.1 The Rules are applicable to craft generally constructed of fibre reinforced plastic (typically with unsaturated polyester resin), using hand lay-up, mechanical deposition, contact moulding techniques or vacuum assisted techniques. Construction may be either single-skin or sandwich construction, or a combination of both.

2.1.2 Other materials (i.e., non-FRP materials) are to be of good quality, suitable for the purpose intended and, where applicable, are to comply with LR's requirements appropriate to the material. Details of these materials are to be stated on the relevant construction plans. Where these materials are attached to, or encapsulated within, the plastics construction, the material is not to affect adversely the cure of the plastics materials.

2.1.3 Where moulding techniques and methods of construction differing from those given in Section 3 are proposed, details are to be submitted for consideration by LR.

2.2 Resin system

2.2.1 The resins used are to be of a type that has been approved by LR for marine construction purposes. Samples of the resin batches being used in the construction may be taken for limited quality control examination at the discretion of the Surveyor, *see* Ch 14,5 of the Rules for Materials.

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2.2.2 The cure procedure for the resin system is to be that recommended by the resin manufacturer for the particular application, so that the resin will cure in the required time, in accordance with the approved cure schedule.

2.2.3 Wax additives are only to be added by the resin manufacturer in accordance with the agreed procedure and tested accordingly. The base resin is to be of an approved type.

2.2.4 Where a resin contains an ingredient that can settle within the resin system, it is the Builder's responsibility to ensure that the resin manufacturer's recommendations regarding mixing and conditioning are complied with prior to use.

2.3 Compliant resins

2.3.1 Compliant resins for structural applications are to be of types accepted by LR, *see* Ch 14,2.15 of the Rules for Materials, and are to be used strictly in accordance with the manufacturer's recommendations.

2.3.2 Details of the compliant resin to be used in the construction are to be included on the Material Data Sheet at the initial stages of plan approval. The plans submitted for approval are to identify which compliant resins are used in different applications. Surface preparations and over-bonding are also to be identified on the submitted plans.

2.3.3 Proposals for the use of structural filleting applications using compliant resin are to be submitted in detail. Such proposals will be subject to individual consideration.

2.3.4 The acceptance of the use of structural fillets of compliant resins in place of boundary bonding angle laminates required by Ch 3,1.18, will be subject to the designer/Builder providing the necessary information and test results to demonstrate equivalence with the Rule requirement for boundary bonding angle laminates.

2.3.5 Air inclusions that may affect the structural efficiency of the joint are to be avoided.

2.4 Resin storage

2.4.1 Bulk storage of resin is to be arranged in accordance with the resin manufacturer's recommendations in suitably adapted and insulated tanks. Tanks and pipes are to be periodically flushed in accordance with the resin manufacturer's recommendations. A ready use store is to be provided where appropriate.

2.5 Gel coats, tie coats and water barriers

2.5.1 Gel coats based on orthophthalic polyester resin systems are not acceptable. All gel coats are to be used strictly in accordance with the manufacturer's recommendations. The curing system is to be in accordance with 2.2.2.

2.5.2 Where pigments are to be added reference is to be made to 2.6. Where pigments are added by the Builder, the gel coat is to be allowed to stand for sufficient time to permit entrapped air to be released. The method of mixing is to be carried out strictly in accordance with the resin and pigment manufacturer's instructions.

2.5.3 Where the temperature of the gel coat resin is below that of the workshop, the gel coat resin is to be conditioned to attain the workshop temperature prior to use.

2.5.4 Where the inspection of the mould is an agreed hold point, required by the quality plan, the mould is to be inspected by the attending Surveyor prior to gel coating. The Surveyor may also require to witness the initial application of the gel coat, *see also* 3.3.

2.5.5 Where a gel coat is not used, details of the proposed water barrier are to be submitted for consideration.

2.5.6 Where a painted finish is to be adopted in place of a gel coat a suitable tie coat may be required in accordance with the paint manufacturer's recommendations.

2.5.7 Where the hull is of sandwich construction built on a male plug mould, the water barrier on the outer surface of the hull will be specially considered.

2.6 Curing systems

2.6.1 Curing systems are to be in accordance with 2.2.2 and are to be fully compatible with the resins and reinforcements to be used.

2.6.2 For polyester and vinylester resins the level of catalyst and accelerator are to be as recommended by the manufacturer to ensure full polymerisation of the resin. In general, the rate of gelation is to be controlled by the amount of accelerator added to the resin. The amount of catalyst is not to be less than one per cent, by weight, of the base resin.

2.7 Gelation time

2.7.1 The gelation time is to be suitable for the proposed application such that full wet-out of the reinforcement can be obtained without unnecessary drainage on vertical surfaces or excessive loss of the monomer.

2.7.2 The gelation time quoted on the Material Data Sheet is to be the typical gelation time for a laminate as laid in the mould, i.e., the working life of the resin.

2.7.3 The gelation time may need to be varied to suit changing ambient workshop temperatures. For polyester and vinylester resins this is, in general, to be adjusted by variation of the accelerator and not by variation of the catalyst.

2.7.4 All resins are to be mixed in accordance with the resin manufacturer's recommendations.

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2.8 Colour pigments

2.8.1 The types of pigment used are to be such that the final cure of the resin is not affected.

2.8.2 The pigment may be added to the resin by either the resin manufacturer or the moulder, and when added by the moulder it is to be as a paste dispersal in the same or compatible resin. Pre-pigmented gel coats are recommended. Where pigments are added by the Builder thorough mixing is essential to avoid striations. *See also* 2.2.4 and 2.3.2.

2.8.3 The amount and type of pigment added is not to exceed that recommended by the resin manufacturer for a satisfactory depth of colour. Proposals to use amounts of pigment solids in excess of five per cent, by weight of the base resin, will be subject to individual approval and testing.

2.8.4 It is recommended that pigments are not to be added to the gel coat or laminating resins used in the underwater portion of the hull laminate or in laminates forming the boundaries of oil fuel and water tanks.

2.8.5 The addition of pigments is not to unduly affect the gelation time of the resin system or the physical properties of the gel coat layer of the laminate produced. The resin and/or pigment manufacturer's written confirmation in this respect is to be obtained and recorded in the Builder's quality control documentation.

2.8.6 The aesthetic appearance of mouldings is strictly a matter between the moulder and the Owner.

2.9 Fillers

2.9.1 All fillers added by a Builder are to be of the dispersed type. The amount of filler that may be added to an approved resin is to be that recommended by the resin manufacturer and is not to alter significantly the viscosity of the resin nor is it to affect the overall strength properties of the laminate. Recommendations by the resin manufacturer to adopt amounts of fillers in excess of 13 per cent by weight of the base resin will be subject to individual approval and testing.

2.9.2 Pigments, thixotropes and fire retardant additives are to be considered as fillers in the calculation of total filler content.

2.9.3 Fillers are to be carefully and thoroughly mixed into the base resin that is then to be allowed to stand to ensure that entrapped air is released. The resin manufacturer's recommendations regarding the method of mixing are to be followed.

2.9.4 Fillers are not to be used in the structural laminates forming the boundaries of oil fuel and water tanks.

2.9.5 Details of all fillers and fire retardant additives are to be included on the Material Data Sheet at the initial stages of plan appraisal.

2.9.6 The amount of fire retardant additives may be in excess of that indicated in 2.9.1 provided that due account is taken of the reduced mechanical properties when determining scantlings in accordance with the Rules.

2.10 Fire retardant additives

2.10.1 The attention of Owners and Builders is drawn to the additional statutory regulations regarding fire safety that may be imposed by the National Authority of the country in which the craft is to be registered or the Governments of the states to be visited.

2.10.2 For requirements regarding fire safety, *see* Part 17.

2.10.3 Where laminates are required to have fire retardant or restricting properties, details of the proposals are to be submitted for approval. Where additives to the resin system are used, the type and quantity are to be as recommended by the resin manufacturer. Test results of independently tested fire retardant and fire restricting materials are to be submitted for design purposes.

2.10.4 All fire retardant resin systems are to be used strictly in accordance with the resin manufacturer's recommendations.

2.10.5 The use of fire retardant and fire restricting materials in craft required to comply with statutory requirements will be subject to the individual approval of the National Authority of the country in which the craft is to be registered, or LR where authorised to undertake this work on behalf of the National Authority.

2.11 Fibre reinforcements

2.11.1 All fibre reinforcements are to be of a type approved by LR.

2.11.2 All reinforcements are to be stored strictly in accordance with the manufacturer's recommendations. Rolls of reinforcement are to remain in their original packaging to minimise contamination. The quality control documentation is to provide traceability of all reinforcements using the manufacturer's batch numbers.

2.11.3 The materials are to be free from imperfections, discolouration, foreign matter and other defects.

2.11.4 Pre-impregnated reinforcements are to be suitably stored in an approved area. Detailed storage records are to be maintained as part of the quality control documentation.

2.12 Surfacing materials

2.12.1 Lightweight surfacing materials for reinforcing resin rich surfaces are to be compatible with the resin being used. Details of the materials and the fibre contents, by weight, are to be included on the Materials Data Sheet (Form 2075).

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2.12.2 Where peel ply materials are to be used, the finish is to be such that, after removal, it does not interfere with any subsequent bonding processes.

2.13 Core materials

2.13.1 Core materials for sandwich construction are to be approved by LR, *see* Ch 14,2 of the Rules for Materials.

2.13.2 All core materials are to be used in accordance with the manufacturer's application procedure, a copy of which is to be submitted for information, with the relevant construction plans of the craft. A second copy is to be incorporated into the quality control documentation.

2.13.3 Rigid expanded foam plastics are to:

(a) be of closed-cell types and impervious to water, fuel and oils;
(b) have good ageing stability;
(c) be compatible with the resin system;
(d) have good strength retention at 60°C;
(e) have characteristics and mechanical properties of not less than those indicated in Table 2.2.1; and
(f) if manufactured into formable sheets of small blocks, the open weave backing material and adhesive are to be compatible and soluble, respectively, with the laminating resin.

2.13.4 Balsa wood is to:

(a) be end grained;
(b) have been chemically treated against fungal and insect attack and kiln dried shortly after felling;
(c) have been sterilised;
(d) have been homogenised;
(e) have an average moisture content of 12 per cent;
(f) have characteristics and mechanical properties of not less than those indicated in Table 2.2.2; and
(g) if manufactured into formable sheets of small blocks, the open weave backing material and adhesive are to be compatible and soluble, respectively, with the laminating resin.

2.13.5 Where necessary, foam core materials are to be conditioned in accordance with the manufacturer's recommendations. Conditioning at an elevated temperature, in excess of that which may be experienced in service, may be necessary to ensure the release of any entrapped residual gaseous blowing agents from the cells of the foam core.

2.13.6 Synthetic 'felt' type core materials are to be approved in accordance with Ch 14,2.10 of the Rules for Materials.

2.13.7 Other types of core materials will be individually considered, on the basis of these Rules in relation to their characteristics and intended application.

2.13.8 Balsa wood is to remain in protective packaging until required in production. Part packages are to be sealed to prevent the ingress of moisture.

Table 2.2.1 Minimum characteristics and mechanical properties of rigid expanded foams at 20°C

Material	Apparent density (kg/m^3)	Strength (N/mm^2)			Moduli of elasticity (N/mm^2)	
		Tensile	Compressive	Shear	Compressive	Shear
Polyurethane	96	0,85	0,60	0,50	17,20	8,50
Polyvinylchloride	60					

Table 2.2.2 Minimum characteristics and mechanical properties of end-grain balsa

Apparent density (kg/m^3)	Strength (N/mm^2)					Compressive modulus of elasticity (N/mm^2)		Shear modulus of elasticity (N/mm^2)
	Compressive		Tensile		Shear			
	Direction of stress		Direction of stress			Direction of stress		
	Parallel to grain	Perpendicular to grain	Parallel to grain	Perpendicular to grain		Parallel to grain	Perpendicular to grain	
96	5,00	0,35	9,00	0,44	1,10	2300	35,20	105
144	10,60	0,57	14,60	0,70	1,64	3900	67,80	129
176	12,80	0,68	20,50	0,80	2,00	5300	89,60	145

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2.14 Core bonding materials

2.14.1 Core bonding materials for structural applications are to be of types accepted by LR, and are to be used strictly in accordance with the manufacturer's instructions.

2.14.2 Details of the proposed core bonding paste to be used with the core material are to be indicated on the Materials Data Sheet and the appropriate construction plans.

2.14.3 The Builder is to demonstrate that a uniform thickness of bonding paste is obtained by use of notched trowels or comb gauges. For the use of bonding pastes, *see* 4.2.7.

2.15 Adhesives

2.15.1 Adhesives for structural applications are to be of types accepted by LR, *see* Ch 14,2.15 the Rules for Materials, and are to be used strictly in accordance with the manufacturer's recommendations.

2.15.2 The details of all structural adhesives are to be specified on the Materials Data Sheet and on the relevant construction plans submitted.

2.15.3 Details concerning the handling, mixing and application of adhesives are to form part of the Builder's production plan.

2.15.4 Particular attention is to be given to the surface preparation and cleanliness of the surfaces to be bonded.

2.15.5 Where excessive unevenness of the faying surfaces exists a suitable gap filling adhesive is to be used or local undulations removed by the application of additional reinforcements.

2.15.6 The Builder's quality plan is to identify the level of training required for personnel involved in the application of structural adhesives.

2.16 Materials for integrated structural members

2.16.1 Metallic materials (such as suitable marine grades of stainless steel or aluminium alloys) used in the construction are to comply with the requirements of 2.1.2. Where structural members or components manufactured from these, or other materials, are to be encapsulated within or structurally bonded to laminates, the material is not to adversely affect the cure of the resin system. The surface area of the component that will be in contact with the resin is to be thoroughly cleaned, degreased and, where practicable, either shot blasted or abraded to provide a key.

2.16.2 Where metallic sections are to be bolted into a structure, the bolting requirements are to be determined by direct calculations that are to be submitted for consideration. Appropriate precautions against corrosion are to be taken.

2.16.3 Where plywood and timber members are to be used in structural applications and are to be laminated onto, or encapsulated within the laminate, the surface of the wood is to be suitably prepared and primed prior to laminating.

2.17 Plywood

2.17.1 Plywood, for structural applications, is to be of a high quality marine grade material approved by LR, *see* Ch 14,2.14 of the Rules for Materials. In general, the plywood is to be manufactured to a high standard of finish in accordance with ISO or other Recognised Standards and is to meet, or be equivalent to, the following general requirements:

(a) Have good quality face and core veneers of a durable hardwood species.
(b) The number of veneers is to be in accordance with Table 2.2.3.
(c) The veneers are to be bonded with a WBP (water and boil proof) type adhesive.
(d) Have a moisture content not exceeding 15 per cent.

Table 2.2.3 Number of veneers

Board thickness, mm	Minimum number of plies
up to 9	3
10 to 19	5
20 and above	7

2.17.2 Butts and seams are to be scarfed or butt strapped where necessary. The length of the scarf is to be not less than eight times the plywood thickness. The scarf is to be glued and, if made *in situ*, fitted with a backing strap of width not less than 10 times the panel thickness. The strap is to be glued and fastened with two rows of fastenings of the size given in Table 2.2.4 and spaced at approximately eight times the panel thickness.

2.17.3 Butt straps are to be of the width given in Table 2.2.4 and the same thickness as the panel. The strap is to be glued and double/treble fastened to the panel. Sizes of fastenings are given in Table 2.2.4.

2.17.4 For further information regarding plywood, *see* Ch 3,1.20.

2.18 Timber

2.18.1 The acceptance of timber in the construction will be subject to individual consideration depending upon the intended use and timber involved.

2.18.2 The timber is to be of good quality and properly seasoned. Timber is to be free from heart, sapwood, decay, insect attack, splits, shakes and other imperfections that would adversely affect the efficiency of the material. It is also to be generally free from knots, although an occasional sound intergrown knot would be acceptable.

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Table 2.2.4 Butt strap fastenings

Plywood thickness, mm	Breadth of butt strap, mm		Fastenings		
			Wood screws		Copper boat nails, gauge
			Gauge	Dia.,mm	
6	Double fastened	150	8	4,2	10
8		175	10	4,9	10
10		200	10	4,9	8
13		250	12	5,6	8
16		280	12	5,6	6
19	Treble fastened	330	14	6,3	6
22		355	14	6,3	3
25		380	16	7,0	3

NOTES
1. The gauge of wood screws given in the Table is British Standard Gauge, and that of copper boat nails is Imperial Standard Wire Gauge.
2. The diameter of the wood screw is the nominal diameter of the unthreaded shank.

2.18.3 The moisture content of timber for bonded or over-laminated applications using polyester or epoxy resins is, in general, to be nominally 15 per cent. Contents slightly greater than this value are recommended when resorcinol glues are used, and contents slightly lower than this value are required when phenolic or urea-formaldehyde resins are used.

2.18.4 For further information regarding timber, *see* Ch 3,1.19.

2.19 Release agents

2.19.1 Release agents are to have no inhibiting effect on the gel coat resin and are to be those recommended by the resin manufacturer.

■ *Section 3* General construction process

3.1 General

3.1.1 Provision is made in this Section for the construction of craft built of fibre reinforced plastic using thermosetting materials. Craft built of fibre reinforced thermoplastic materials will be subject to individual consideration.

3.1.2 This Section contains the general Rule requirements to be complied with in the construction of fibre reinforced craft being built under survey. Where detailed requirements are not defined good boat building practices are to be applied.

3.1.3 Craft built of unusual materials or built using unusual techniques will be subject to individual consideration.

3.2 Resin preparation

3.2.1 Curing agents, fillers and pigments are to be added strictly in accordance with the resin manufacturer's recommendations.

3.2.2 Before decanting, all resins are to be thoroughly mixed, deaerated and conditioned to at shop temperature in accordance with the resin manufacturer's instructions.

3.2.3 All measuring equipment is to be certified and suitable for the quantity of material being measured. Valid certificates of calibration are to form part of the quality control documentation.

3.2.4 Where pumping/metering equipment is used it is to be maintained in accordance with the manufacturer's instructions, and a valid certificate of calibration accuracy is to be retained in the quality control documentation.

3.2.5 Quality control records are to be maintained to provide traceability and identification of the resin and all additives used in the resin system. Batch numbers are to be identified.

3.2.6 Any additive used as a production aid must be that recommended by the resin manufacturer and is not to alter the mechanical properties or the characteristics of the cured laminate.

3.3 Laminating

3.3.1 Production is to follow all necessary approved construction plans in accordance with the LR accepted quality plan.

3.3.2 Laminating is to be carried out by skilled operators, who are to be trained and qualified to the level required by the Builder's quality plan and are to be acceptable to LR.

3.3.3 Moulds are to be thoroughly cleaned, dried and allowed to attain the shop temperature before being treated with a suitable release system, *see also* 1.9.7.

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3.3.4 The gel coat resin is to be applied by brush, roller or spraying equipment to give a uniform, nominal film thickness not exceeding 1,5 mm.

3.3.5 The period of exposure of the gel coat between gelation and the application of the first layer of reinforcement is, in general, to be as short as practicable. In no case is this to be longer than that recommended by the resin manufacturer for that particular resin system. Written confirmation of this is to be obtained and recorded in the Builder's quality control documentation.

3.3.6 Where a polyester or vinylester gel coat is used it is to be reinforced by a lightweight, powder bound reinforcement, generally not exceeding 300 g/m^2 in weight, applied at a high resin content to give a glass content, by weight, of not greater than 0,286. This reinforcement is to be consolidated by gentle rolling. Care is to be taken not to damage the gel coat. A surface tissue may be incorporated within the gel coat, the details of which are to be clearly stated in the laminate schedule.

3.3.7 All mouldings are to be manufactured from layers of reinforcement, laid in the approved sequence and orientation, each layer being thoroughly impregnated and consolidated to give the required fibre content, by weight, in accordance with the approved plans.

3.3.8 In composite laminates, containing multiple layers of woven reinforcement, woven reinforcement may be laid on woven reinforcement provided that the inter-laminar shear strength is not less than 13,8 N/mm^2; otherwise, a layer of random fibre reinforcement is to be laid alternately with the woven reinforcements.

3.3.9 Excessive exothermic heat generation caused by thick laminate construction is to be avoided. Where thick laminates are to be laid the Builder is to demonstrate to the Surveyor's satisfaction, that the number of plies can be laid wet on wet and that the resultant temperature during the cure cycle does not have any deleterious effect on the mechanical properties of the cured laminate.

3.3.10 Laminating is to be carried out in a sequence such that the time lapse between the application of the successive layers is within the limits recommended by the resin manufacturer and documented in the quality control procedures for the particular resin system. Similarly, the time lapse between the forming and bonding of structural members is to be kept within these limits and, where this is not practicable, the surface of the laminate is to be prepared, in accordance with the resin manufacturer's instructions, to improve the bond.

3.3.11 When laminating is interrupted, and where other than an epoxy resin system is being used, the first of any subsequent layers of reinforcement to be laid in that area is to be of chopped glass fibre or other type of material to enhance the interlaminar strength properties of the laminate.

3.4 Fibre content

3.4.1 To ensure that the resultant thicknesses of the structure is not less than that required to comply with those indicated on the approved plans, the nominal fibre content, by weight, of the individual plies and overall laminate is to be controlled on the basis of the weight of the constituent materials.

3.4.2 Continuous monitoring of resin/reinforcement usage is required for ongoing fibre content verification and is to be recorded under the quality control system, *see* Ch 14,5 of the Rules for Materials.

3.4.3 A method of validating the completed laminate thickness is to be agreed between the Builder and Surveyor. Where electronic thickness measurement methods are employed, the equipment is to be calibrated against a laminate of identical construction. Alternatively a series of areas are to be identified within the craft where samples can be taken to validate the thickness of the laminate (e.g., in way of overboard discharges/seawater intakes/deck openings, etc.).

3.5 Laminate schedule

3.5.1 The laminate schedule is to clearly define the logical sequence of production and is to identify the specific materials to be used.

3.5.2 The schedule is to define the extent of each reinforcement and state relevant details regarding overlapping, staggering thicknesses and tailoring of reinforcements.

3.5.3 Progressive thickness measurements in accordance with 3.4.3 are to be recorded as part of the quality control documentation and, where required, additional reinforcements are to be laid to attain the required thickness.

3.5.4 Areas of local deficiency requiring additional reinforcement and areas that have been found to be increased thickness are to be recorded in the quality control documentation.

3.6 Spray laminating

3.6.1 The equipment for spray deposition of resin and glass fibres is to be inspected during the Workshop Inspection and a sample panel produced. Documentary evidence of maintenance, calibration, catalyst content, fibre length and overall fibre content by weight are to be entered into the quality control documentation. The spray pattern is to give an even distribution, as recommended by the manufacturer of the equipment and is to be to the satisfaction of the attending Surveyor.

3.6.2 Special consideration is to be given to the production environment, ventilation equipment and quality control arrangements to ensure that the finished product meets the requirements of the approved plans.

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3.6.3 Unless the mechanical properties are confirmed by testing, the chopped fibre length for a structural laminate is to be not less than 35 mm. In no case is the fibre length to be less than 25 mm.

3.6.4 Spray equipment is only to be operated by trained and competent personnel. Training certification is to form part of the quality control documentation. The use of spray lay-up is to be limited to the parts of the structure to which sufficient access can be obtained to ensure satisfactory laminating.

3.6.5 The weights of resin and reinforcement used is to be monitored continuously to check the glass/resin ratio. Samples are also be taken on a regular basis to validate the calibration of the equipment.

3.6.6 Where spray lay-up is used to back up the gel coat the weight of sprayed fibre is not to exceed 300 g/m^2, applied at a high resin content to give a glass content by weight, of not greater than 0,286. This should be consolidated by gentle rolling. This first layer of reinforcement is to be allowed to cure to a trimming state before proceeding with the remainder of the laminate.

3.6.7 Consolidation is to be carried out as soon as is practicable after spray deposition. In general, this is to be carried out when a weight of reinforcement equivalent to a thickness of 2–3 mm has been deposited. The thickness of the resulting laminate is to be periodically checked and recorded.

3.6.8 Particular attention is to be given to localised thinning of the laminate in way of chines, coamings, knuckles and openings. Further deposition may be required in such areas to compensate for any reduction in thickness. Alternatively, layers of other equivalent reinforcements may be laid to achieve the required local thickness.

3.7 Release and curing

3.7.1 After completion of the lay-up, the moulding is to be left in the mould for a period to allow the resin to cure before being removed. This period can vary with ambient temperature, the type of resin and the complexity of the moulding, but is to be not less than 12 hours or that recommended by the resin manufacturer.

3.7.2 Care is to be exercised during removal from the mould to ensure that the hull, deck and other large assemblies are adequately braced and supported to avoid damage to and maintain the form of the moulding.

3.7.3 Where female moulds are adopted, all primary stiffening and transverse bulkheads are to be installed prior to removal from the mould unless agreed otherwise on the approved construction schedule and plans.

3.7.4 Mouldings are not to be stored outside of the workshop environment until they have attained the stage of cure recommended by the resin manufacturer for that particular resin. Provision is to be made for mouldings to be protected against adverse weather conditions.

3.7.5 Mouldings are, in general, to be stabilised in the moulding environment for at least 24 hours, or that recommended by the resin manufacturer before the application of any special cure treatment, details of which are to be submitted for approval.

3.8 Barcol hardness

3.8.1 The degree of cure of mouldings is to be measured using a Barcol impressor model GYZJ 934-1 in accordance with BS 2782: Part 10: Method 1001: 1977 (1989) or other equivalent National or International Standard. Alternative equivalent standards of hardness measurement will be considered.

3.8.2 The hardness meter is to be regularly checked for calibration during use. A calibration certificate is to form part of the quality control documentation.

3.8.3 Removal from the mould is not to be attempted until a minimum Barcol reading recommended by the resin manufacturer or a value of 20 has been attained. Subsequently, the moulding is not to be moved outside of the controlled environment until a minimum Barcol reading recommended by the resin manufacturer of 35 (or equivalent) has been recorded.

3.9 Laminate detail

3.9.1 Changes in laminate thickness are to be made using a gradual taper. The length of such taper is, in general, not to be less than 20 times the difference in thickness. Where the construction changes from sandwich laminate to a solid laminate, the thickness of the core material is, in general, to be reduced by a gradual taper of not less than 2:1.

3.9.2 Framing and stiffening sections are to be built up layer by layer in accordance with an approved procedure, particular attention being given to ensure a satisfactory bond and structural continuity at the ends and intersections.

3.9.3 Discontinuities and hard points in the structure are to be avoided, and where the strength of a stiffening member is impaired by any attachment of fittings, openings, drainage arrangements, etc., compensation is to be provided.

3.9.4 Where items are prefabricated outside the mould, they are to be connected by boundary angles formed by layers of reinforcement, structural fillets or other approved method. Where structural fillets are proposed, the scantlings and arrangements will be specially considered.

3.9.5 Polyester, vinylester or epoxide resin may be used in bonded joints, provided that the joint is so designed that the resin bond is in shear. The contact area is to be as large as practicable and the surfaces are to be suitably prepared in accordance with the resin manufacturer's instructions.

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3.9.6 The submitted plans are to clearly define the laminate sequence at corner joints. In general, corner laminates are to be boxed and all cuts are to be alternately staggered to avoid a fault line. At corner joints vertical and horizontal laminates are to be laid alternately and butts are to be staggered accordingly.

3.9.7 The submitted plans are to clearly define the details of scarfed joints. In general, scarfs are not to not be steeper than a 12:1 taper. Scarf joints may be either ground or stepped and may be single or double taper. Where single taper scarf joints are proposed, a sealing laminate is to be provided, details of which are to be submitted. Where stepped joints are proposed care is to be taken to ensure that over-cutting does not occur. All joints are to be arranged so that they can be reinforced internally to maintain structural continuity of the laminate.

3.9.8 Lap joints may be bolted or adhesively bonded, or both. They may be single or double lapped dependent upon the specific application.

3.9.9 Where tray mouldings form part of the integral structure of the craft, full details are to be indicated on the submitted plans. Information regarding tolerances is to be presented together with details of all adhesives and proposed bonding-in techniques. Particular attention is to be given to the design so as to maintain the structural continuity of the webs of any stiffening members.

3.9.10 The hulls of all craft with a service speed of 25 knots or greater are to be moulded as required by Ch 3,3.15.

3.9.11 Chine details are to be clearly indicated on the submitted plans. Spray rails may form part of the structural laminate or may be installed as a laminated or bolted appendage. Where the chine is a laminated appendage, provision is to be made for a sacrificial ply at which failure may occur without undue damage to the remaining structure of the hull. Sandwich structures are to be returned to single skin laminates at chine rails unless agreed otherwise on the approved construction plans. Chine rails are to be infilled and over laminated on the inner surface of the hull. Additional reinforcement is to be laminated into the chine area in accordance with Ch 3,3.8.

3.9.12 Reinforcements are to be arranged to maintain continuity of strength throughout the laminate. Joints in each layer of reinforcement are, in general, to be overlapped. The length of the overlap is dependent upon the type of reinforcement but is not to be less than 50 mm. The position of the joints in the laminate is to be staggered, in general by 150 mm, to maintain as near uniform laminate thickness as practicable. Tests may be required to demonstrate continuity of strength when bi-directional, multi-axial or cross plied reinforcements are used.

3.9.13 As an alternative to overlapping as required by 3.9.12, individual consideration will be given, on the basis of test results, to partial butting of reinforcements manufactured with a salvedge. For such reinforcements the salvedge tails are to be laid on top of each other to provide continuity. Butts in the same vertical plane are to be separated by not less than five passing plies.

3.9.14 Laminate overlapping and staggering arrangements may require to be tested at the discretion of the Surveyor.

3.9.15 Laminates may be fastened mechanically provided that the fastenings are of a corrosion resistant metal and are spaced and positioned so as not to impair the efficiency of the joint. The fastenings are to be of an acceptable type and, where washer plates are used, they are to be of a compatible material. The edges of the laminates and the fastening holes are to be sealed.

3.9.16 Where plywood and timber members are to be matted onto, or encapsulated within, the laminate, the surface of the wood is to be suitably prepared prior to bonding.

3.9.17 For details of through hull fittings, *see* 5.6.

Section 4
Additional procedures for sandwich construction

4.1 General

4.1.1 The methods used in sandwich construction are, in general, to be either wet or dry core bonding techniques or by laminating directly onto the core (e.g., plug moulding).

4.2 Laminating

4.2.1 The forefoot and stem of all craft of composite construction are to be moulded as required by Ch 3,5.11.1.

4.2.2 Where the core material is to be laid onto a pre-moulded skin, it is to be laid as soon as practicable after the laminate cure has passed the exothermic stage.

4.2.3 Where the core is applied to a laminated surface, particular care is to be taken to ensure that a uniform bond is obtained. Where a core is to be applied to an uneven surface, the Surveyor may request additional building up of the surface or contouring of the core to suit.

4.2.4 Where other than epoxy resins are being used, the reinforcement against either side of the core is to be of the chopped strand mat type. Additional flow coating is not to be applied to the foam core prior to laminating.

4.2.5 The submitted plans are to clearly show the staggering of successive plies in both the transverse and longitudinal directions. In general laminates are to be staggered by 50 mm per layer of reinforcement. Where very thin sandwich skins are adopted the rate of laminate stagger will be individually considered.

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4.2.6 Prior to bonding, the core is to be cleaned and primed (sealed) in accordance with the manufacturer's recommendations. The primer is to be allowed to cure and is not to inhibit the subsequent cure of the materials contained within the manufacturer's recommended bonding process. The primer is to seal the panels, including all the surfaces between the blocks of contoured material, without completely filling the surface cells.

4.2.7 Where panels of rigid core material are to be used then dry vacuum bagging techniques are, in general, to be adopted. The core is to be prepared by providing 'breather' holes to ensure efficient removal of air under the core. Bonding paste is to be visible at such breather holes after vacuum bagging. The number and pitch of such 'breather' holes is to be in accordance with the core manufacturer's application procedure and any specific requirements of the core bonding paste manufacturer, *see also* 4.4.3.

4.2.8 Thermoforming of core materials is to be carried out in accordance with the manufacturer's recommendations. Maximum temperature limits are to be strictly observed.

4.2.9 Where panels of contourable core material are to be used it is necessary to ensure that the core is cut/scored through the entire thickness such that the panels will conform to the desired shape of the moulding. The Builder is to demonstrate that the quantity of bonding material indicated in the core manufacturer's application procedure (*see* 2.11.2) is sufficient to penetrate the full depth of the core between the blocks. It is recommended that grid scored panels using a carrier scrim cloth are adopted.

4.2.10 Where the edges of a panel are to be bevelled to single skin the rate of tapering is to be not greater than 30°. In areas where an insert (e.g. higher density foam or plywood) is to be used the rate of taper is not to be greater than 45°.

4.2.11 In all application procedures cured, excess bonding material is to be removed and the panel cleaned and primed prior to the lamination of the final sandwich skin.

4.3 Inserts

4.3.1 Backing or insert pads where fitted in way of the attachment of fittings are to be arranged so that the load can be satisfactorily transmitted into the surrounding structure. The contact area of these pads is to be suitably prepared and free from contamination.

4.3.2 Inserts in sandwich laminates are to be of a material capable of resisting crushing. Inserts are to be well bonded to the core material and to the laminate skins in strict accordance with the approved plans.

4.3.3 Where plywood inserts are to be used all edges are to be bevelled at an angle of 45°. A small gap is to be provided around each insert to ensure the passage of bonding paste during the vacuum bagging process.

4.4 Vacuum bagging

4.4.1 Where wet vacuum bagging is proposed (with or without a core), full details are to be submitted for consideration.

4.4.2 The Builder is to demonstrate by visual inspection that efficient core bonding can be obtained using the proposed dry vacuum bagging process.

4.4.3 The number, size and distribution of breather holes in panels of rigid core material is to be that recommended in the core manufacturer's application procedure, *see* 4.2.6. Typically, 3 mm diameter breather holes are to be provided at 50 mm centres.

4.4.4 The level of vacuum applied for initial consolidation and during the cure period is not to be higher than that recommended, by the relevant manufacturer of the materials being used, to avoid the possibility of evaporative boiling and excessive loss of monomer.

■ *Section 5* Details and fastenings

5.1 General

5.1.1 This Section contains the general Rule requirements to be complied with for fibre reinforced plastic craft being built under survey. Where detailed requirements are not defined good boat building practices are to be applied. Where different details are to be applied, the Builder is required to provide evidence of satisfactory service experience or acceptable test data.

5.2 Alignment

5.2.1 Details of alignment and building tolerances are to be laid down in the Builder's production plan.

5.2.2 Where details of alignment and building tolerances are not included on the construction plans, or submitted separately for consideration with the plan submission, they may, subject to individual consideration, be agreed locally with the attending Surveyor.

5.2.3 Particular attention is to be given to the accurate alignment of the following:

(a) girder abutting single skin bulkhead;
(b) girder webs with tank sides;
(c) frames with beams;
(d) deck/bottom girders with bulkhead stiffeners;
(e) tank baffles with floors;
(f) longitudinals where broken at tank ends; and
(g) transom stiffeners with bottom/deck girders.

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5.2.4 For larger craft the hull breakage sight-line is to be progressively monitored during the construction of the craft and is to form part of the quality control documentation. The production plan is to identify maximum breakage limits dependent upon the size of the craft.

5.2.5 The production plan is to identify allowable tolerances for the alignment of the primary structural components.

5.2.6 To ensure efficient load transmission intercostal, single skin bulkheads are to be aligned to within half the thickness of the thinner bulkhead. In the case of sandwich construction the tolerance requirements will be individually considered dependent upon the sandwich panel dimensions and the construction of the continuous member. In general, the webs of the intercostal sandwich panel member are to be aligned to within 5 mm. Where poor alignment is identified, additional boundary bonding reinforcements are to be applied as agreed with the attending Surveyor. Such deviations and details of the remedial action taken are to be recorded in the Builder's quality control documentation.

5.2.7 To ensure efficient transmission of shear loads, the alignment tolerance of intercostal 'top hat' stiffener webs is, in general, to be within half of the web thickness. Where poor alignment is identified, additional reinforcements are, in general, to be incorporated into the stiffener webs as agreed with the attending Surveyor. Such deviations and details of the remedial action taken are to be recorded in the Builder's quality control documentation.

5.3 Continuity

5.3.1 Continuity of all primary structural members is to be maintained, as required by the Rules, and abrupt changes of section are to be avoided. Both primary and secondary stiffening members are to be continuous unless otherwise agreed with LR.

5.3.2 Special consideration will be given to the intersection of longitudinal and transverse members. In general the ratio between the depths of the intersecting members is to be 2:1. The shallower member is to be continuous under the supporting members.

5.3.3 Alternative proposals to the requirements given in 5.3.2 will be subject to special consideration in conjunction with the submission of details for maintaining the continuity of reinforcements at intersections in both directions. Where stiffeners are of similar dimensions the primary member is to be continuous. In general the section modulus of the continuous material is to be maintained.

5.4 Openings

5.4.1 All openings are to have well rounded corners and are to be supported on all sides. Cut edges of openings are to be sealed to prevent the ingress of moisture.

5.4.2 All hatch openings are to be supported by a system of transverse and longitudinal stiffeners, the details of which are to be submitted for approval.

5.4.3 The requirements for closing arrangements and outfit are given in Pt 3, Ch 4.

5.4.4 All deck openings are to have corner radii as specified in Ch 3,8.12.

5.4.5 For details of sealing the edges of openings and sandwich panels, *see* 5.10.

5.5 Through bolting and bolted connections

5.5.1 The details of all through bolted structural connections are to be indicated on the relevant construction plans submitted for approval. The design of the joint is to be suitable for its intended purpose with a sufficient number of bolts to satisfactorily close the joint.

5.5.2 Tank tops may be bolted down provided the bolt spacing does not exceed $8d_b$, where d_b is the bolt diameter. A joint, seal or stop water is to be fitted, as necessary, to meet the required integrity.

5.5.3 In general, large headed bolts or large diameter thick washers are to be used to prevent localised crushing damage during tightening.

5.5.4 Where mechanical fastenings are used, the torque is to be indicated on the plans submitted for approval.

5.5.5 Bolting arrangements are, in general, to be in accordance with Ch 2,5.5, 5.6, 5.7 and 5.8. In FRP sandwich construction, inserts of a material capable of resisting crushing are to be fitted in accordance with 4.3.

5.5.6 The diameter of a fastening is not to be less than the thickness of the thinner component being fastened, with a minimum diameter of 6 mm, excepting window frames where the minimum diameter may be 5 mm.

5.5.7 Bolted connections are, in general, to be bonded along all mating surfaces using an accepted structural adhesive, applied in accordance with the manufacturer's requirements. Where connections rely solely on the shear resistance of the connecting bolts the spacing is not to exceed $3d_b$, where d_b is the diameter of the bolt. In areas where subsequent access will either be limited or not possible, self locking nuts are to be provided.

5.5.8 In general, all structural, bolted connections are to use reeled lines of bolts in accordance with the requirements given in Table 2.5.1.

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Table 2.5.1 Bolt pitch requirements in bonded and bolted connections

Location	Pitch
Watertight connections – below static load waterline	$10d_b$
Connections in hull above static load waterline to deck	$15d_b$
Hull to deck connections – bonded with structural adhesive – bolted with mastic sealant (*see* Note 2)	$20d_b$ $20d_b$
Connections in deckhouses	$20d_b$
Deckhouse to deck connections – bonded with structural adhesive – bolted with mastic sealant (*see* Note 2)	$20d_b$ $20d_b$
Minimum distance between reeled lines of bolts	$3d_b$
Minimum distance from centreline of line of bolts to free edge	$2d_b$

NOTES
1. d_b is the diameter of the bolt.
2. Internal boundary sealing angle to be provided.

5.5.9 All structural, single line, bolted connections without adhesive bondings are to be in accordance with the requirements given in Table 4.1.1 in Pt 3, Ch 4.

5.5.10 Care is to be taken to avoid distortion of the frame when window frames are bolted into the structure of the craft. Where necessary, uneven surfaces are to be locally built up to the satisfaction of the attending Surveyor.

5.5.11 Where a restricted service notation of G1 or G2 is applicable the requirements given in this Section will be specially considered dependent upon the sea states for which the craft is designed.

5.5.12 Bolt holes are to be drilled, without undue pressure at break through, having a diametric tolerance of two per cent of the bolt diameter. Where bolted connections are to be made watertight the hole is to be sealed with resin and allowed to cure before the bolt is inserted.

5.5.13 In areas of high stress or where unusual bolting configurations are proposed, testing on the basis of equivalence with the above Rules may be required.

5.6 Through hull fittings

5.6.1 Where fittings penetrate the hull envelope, care is to be taken to seal the hull laminate with resin or other suitable compound, *see* 5.10.

5.6.2 The areas in way of penetrations for fittings in sandwich construction are, in general, to comply with the requirements of 4.3. Where the requirements cannot be complied with, the core is to be replaced locally with a solid core or very high density foam core with compressive properties commensurate with the loads imposed by the securing arrangements, *see* 5.8.2. The exposed edges of such openings are to be sealed watertight, *see* Ch 3,3.10.

5.6.3 All bolted fittings are to be bedded down using a suitable mastic, details of which are to be indicated on the submitted plans.

5.7 Backing bars and tapping plates

5.7.1 The requirements for backing plates and bars will be individually considered, on the basis of the loading imposed, details of which are to be indicated on the submitted plans.

5.7.2 Metallic plates and bars are to comply with the requirements of 2.1.2 (such as suitable marine grades of stainless steel or aluminium alloys).

5.7.3 Tapping plates may be encapsulated within the laminate, laminated to or bolted to the structure, *see also* 2.15.1. Where tapping plate edges or corners are likely to give rise to hard spots or stress concentrations the edges are to be suitably rounded.

5.7.4 Where tapping plates are placed on foam cores the plate is to be mounted on a suitable foundation to prevent the movement of the tapping plate during drilling operations.

5.7.5 Direct calculations regarding the scantlings of tapping plates are to be provided at the plan appraisal stage.

5.8 Fastenings

5.8.1 All fastenings are to be of a suitable marine grade. Sizes and specifications are to be indicated on the submitted plans.

5.8.2 In areas where localised crushing of a sandwich core is likely to occur, large diameter washers, compression tubes or inserts or a combination of these are to be adopted.

5.9 Secondary bonding and peel ply

5.9.1 Laminating is to proceed as a continuous process, as far as practicable, with the minimum of delay between successive plies. Where a secondary bond is to be made it is to be carried out in accordance with the resin manufacturer's recommendation, details of which are to be incorporated in the Builder's quality control documentation. This will, in general, take the form of the area being lightly abraded and wiped with a suitable solvent, which is to be allowed to dry prior to laminating.

5.9.2 Where other than epoxy resins are being used, the first reinforcement is to be of the chopped strand mat type.

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5.9.3 Consideration should be given, especially in highly stressed areas, to the application of peel ply materials to obviate contamination of the exposed surface, and thereby reducing the abrading required to obtain a good secondary bond.

5.10 Exposed edges

5.10.1 The exposed edges of all openings cut in single skin laminate panels are to be suitably sealed. Where such edges are in wet spaces or under water the edges of such openings are to have rounded edges and are to be sealed by two plies of 450 g/m^2 chopped strand mat (or equivalent) reinforcements, *see also* Ch 3,3.10.

5.10.2 Exposed edges of openings cut in sandwich panels are to be suitably sealed, *see* 5.6.2. The cut edges are, in general, to be sealed with a weight of reinforcement not less than that required for the outer skin of the sandwich. Where other than an epoxy resin system is used the first layer of such reinforcement is to be chopped strand mat with a weight not exceeding 450 g/m^2, *see also* Ch 3,3.10.

5.11 Joints

5.11.1 The details of all joints, the proposed jointing procedure and information regarding tolerancing are to be indicated on the submitted plans.

5.11.2 Joints may be bolted or adhesively bonded, or both. Where joints are bolted, full details of the bolt material, the proposed number and spacing are to be provided. Bolts are to be manufactured from a non-corrosive material or protected against corrosion.

5.12 Local reinforcement

5.12.1 Areas subject to local loads or increased stress are to be suitably reinforced, details of which are to be indicated on the submitted plans, *see* Ch 3,3.14.

5.12.2 The design of the structure, in way of the attachment of fittings or equipment in sandwich structures, is to be such that the induced loads can be transmitted into the surrounding structure by bending as opposed to shear. The areas are, in general, to take the form of suitably reinforced single skin areas, *see* Ch 3,3.14, with the additional layers of reinforcement staggered out onto the surrounding inner and outer skins as indicated in Fig. 3.3.1.

5.13 Hull to deck connections

5.13.1 Details of the hull to deck connection, the method of bonding and the tolerances are to be indicated on the submitted plans.

5.13.2 Hull to deck connections should, in general, be bolted and over-bonded. A suitable mastic or sealing compound is to be incorporated within the joint.

5.13.3 The bolting details should be reeled lines of bolts pitched as specified in Table 2.5.1. Suitable large diameter thick washers should be used under both the head and the nut.

5.13.4 Where a mastic is not used, sealing plies are to be applied on the inside of the hull.

5.13.5 The weight of the over-bonding reinforcement is, in general, not to be taken as less than equivalent to the lighter of the component members being connected, and in no case less than equivalent to three plies of 600 g/m^2 chopped strand mat.

5.13.6 Substantial beam knees are to be provided to maintain structural continuity between the transverse deck and hull stiffening.

5.13.7 The watertight integrity, continuity and strength of the connection is not to be impaired by the attachment of the hull fender.

5.13.8 For guidance details of scantlings required to resist impact loads at deck edge connections, *see* Ch 3,4.19 for side shell in way of fendering and Ch 3,3.6 for sheerstrakes.

5.14 Exhaust systems

5.14.1 Exhaust systems, manufactured from FRP, are to be of the water injected type with a normal operating temperature of 60° to 70°C and a maximum operating temperature of 120°C.

5.14.2 Exhaust pipes, silencers and water separators should be of a Type Approved design, installed strictly in accordance with the manufacturer's requirements.

5.14.3 Where a Type Approved system is not used, the arrangement will be considered on an individual basis. Resins used in the manufacture of exhaust systems are to be of a type approved by LR and are to have good heat and chemical resistance properties with a high deflection temperature under load. A vinylester resin should be used, but a fire retardant polyester resin, having a high heat distortion temperature, will be considered. Test samples may be required dependent upon the proposed arrangement, temperatures and materials.

5.14.4 It is recommended that pigments and additives are not used unless it can be demonstrated that the mechanical properties of the resin system remain unaffected. Resins used are not to show any embrittlement with age.

5.14.5 Special consideration is to be given to post curing of such systems to obtain optimal characteristics.

5.14.6 Due to the weight of water contained within the system, exhaust pipes and fittings are to be efficiently supported.

5.14.7 Exhaust boxes are to be lined with a minimum of two plies of 600 g/m^2 chopped strand mat (or equivalent) using a suitable fire retardant/high temperature resin.

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5.14.8 For engineering aspects of exhaust systems reference is to be made to Pt 10, Ch 1,8.6.

5.14.9 National Authority requirements take precedence over the requirements given in this Section.

5.15 Ballast

5.15.1 The provision of permanent ballast is not to adversely affect the surrounding structure.

5.15.2 Where a resin compound is to be poured into a void space, care is to be taken to minimise the generation of heat that may affect the mechanical and weathering characteristics of the structural laminate.

5.15.3 Details of all ballast materials and the proposed method of installation are to be indicated on the submitted plans.

5.16 Limber holes

5.16.1 Provision is to be made to drain areas likely to accumulate liquids, details of which are to be indicated on the submitted plans.

5.16.2 The size, shape and position of limber holes are not to affect the structural strength of the stiffening members in which they are fitted. Limber holes are, in general, to be positioned at the quarter span of the stiffener.

5.17 Integral tanks (requirements for coatings)

5.17.1 The surfaces of integral tanks are to be provided with a barrier to reduce the ingress of liquid. The details of the proposed system are to be indicated on the submitted plans.

5.17.2 Fresh water tanks are to be coated with a non-toxic and non-tainting coat of resin that is recommended by the resin manufacturer for potable water tanks.

5.17.3 The design and arrangement of oil fuel tanks is to be such that there is no exposed horizontal section at the bottom that could be exposed to a fire. Other fire protection arrangements for oil fuel tanks will be specially considered. For details of fire protection requirements, *see* Part 17.

5.17.4 Where plywood bulkheads form part of a tank boundary, the surface is to be completely protected against the ingress of moisture with a minimum of 4 mm thickness of laminate to provide an effective fluid barrier, regardless of resin and reinforcement type used.

5.17.5 Where outfit items are to be laminated to the tank surface, the heavy coating of resin is to be applied afterwards and the laminated brackets sealed to prevent the ingress of moisture.

5.17.6 The scantlings of integral oil fuel and water tanks are to be in accordance with Ch 3,7. Details regarding sub-division of integral tanks are given in Ch 3,7.11.1.

5.17.7 Integral tanks are to be tested in accordance with Ch 3,7.17.

5.18 Reserve buoyancy

5.18.1 Details of materials to be used and the method of installation of reserve buoyancy are to be indicated on the submitted plans.

5.18.2 Where necessary, buoyancy materials are to be over-laminated *in situ* to prevent the ingress of moisture.

5.19 Shear ties (stiffeners)

5.19.1 Where the total web depth to thickness ratio requirement in Ch 3,1.16 for buckling of stiffener webs is not complied with, cross linking of the stiffener webs at the Rule depth to thickness ratio is to be provided by the use of shear ties, as indicated in Fig. 2.5.1.

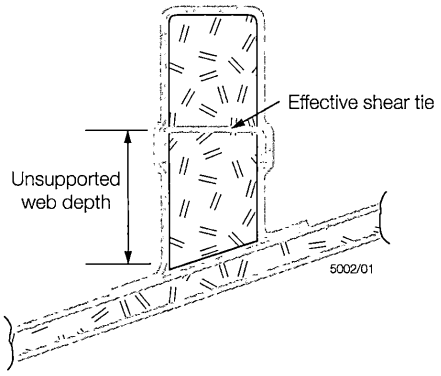

Fig. 2.5.1 Arrangement of shear ties (stiffeners)

5.19.2 Alternative arrangements will be subject to individual consideration in conjunction with submitted direct calculations.

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Section

1 **General**

2 **Minimum thickness requirements**

3 **Shell envelope laminate**

4 **Shell envelope framing**

5 **Single bottom structure and appendages**

6 **Double bottom structure**

7 **Bulkheads and deep tanks**

8 **Deck structures**

9 **Superstructures, deckhouses and bulwarks**

10 **Pillars and pillar bulkheads**

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull craft of composite construction as defined in Pt 1, Ch 1,1.

1.2 General

1.2.1 The scantlings of motor and sailing, mono-hull craft of conventional form and proportions are to be determined from the formulae contained within this Chapter.

1.2.2 The mechanical properties to be used for scantling calculation purposes are to be 90 per cent of the mean first ply/resin cracking failure values determined from accepted mechanical tests, or the mean values minus twice times the standard deviation for the five samples, whichever is the lesser. All test pieces are to be representative of the product to be manufactured and details submitted for consideration.

1.2.3 In the absence of suitable test data, the mechanical properties of the materials is to be estimated from the appropriate procedures and formulae contained within this Part. The acceptable design values for glass reinforced polyester resin laminates are, in general, not to be taken greater than those determined from Tables 3.1.1 to 3.1.3. Additional information on the application of the various formulae is given in Lloyd's Register's (hereinafter referred to as 'LR') *Guidance Notes for Calculation Procedures for Composite Construction*.

Table 3.1.1 Mechanical properties for chopped strand mat (CSM) glass reinforced polyester resin laminates

Mechanical property	N/mm^2
Ultimate tensile strength	$200f_c + 25$
Tensile modulus	$(15f_c + 2) \times 10^3$
Ultimate compressive strength	$150f_c + 72$
Compressive modulus	$(40f_c - 6) \times 10^3$
Ultimate shear strength	$80f_c + 38$
Shear modulus	$(1{,}7f_c + 2{,}24) \times 10^3$
Ultimate flexural strength	$502f_c^2 + 106{,}8$
Flexural modulus	$(33{,}4f_c^2 + 2{,}2) \times 10^3$

NOTE
f_c is as defined in 1.5.1.

Table 3.1.2 Mechanical properties for woven roving (WR) and cross plied (CP) glass reinforced polyester resin laminates at 0/90° degree orientation

Mechanical property	N/mm^2
Ultimate tensile strength	$400f_c - 10$
Tensile modulus	$(30f_c - 0{,}5) \times 10^3$
Ultimate compressive strength	$150f_c + 72$
Compressive modulus	$(40f_c - 6) \times 10^3$
Ultimate shear strength	$80f_c + 38$
Shear modulus	$(1{,}7f_c + 2{,}24) \times 10^3$
Ultimate flexural strength	$502f_c^2 + 106{,}8$
Flexural modulus	$(33{,}4f_c^2 + 2{,}2) \times 10^3$

NOTE
f_c is as defined in 1.5.1.

1.2.4 In the absence of suitable test data, the mechanical properties of aramid and carbon reinforced epoxy resin laminates are, in general, not to be taken greater than those determined from Tables 3.1.4 to 3.1.7.

1.2.5 The various formulae referred to in 1.2.3 and 1.2.4 require that sufficient input data be available which relates to each of the proposed materials. The designers and/or Builders are to, in general, agree the values for use in the scantling analysis with LR at the design stage and prior to the submission of plans and data for appraisal.

1.2.6 Typical acceptable values for the various fibre properties of materials commonly in use are given in Table 3.1.8.

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Table 3.1.3 Mechanical properties for uni-directional glass reinforced polyester resin laminates at 0/90° degree orientation

Mechanical property	N/mm^2
Longitudinal elastic modulus	$(50,5f_c - 6,87) \times 10^3$
Transverse elastic modulus	$(19,6f_c^2 - 15,7f_c + 6,6) \times 10^3$
In-plane shear modulus	$(7,3f_c^2 - 5,9f_c + 2,4) \times 10^3$
Longitudinal tensile strength	$656f_c - 89,3$
Longitudinal compressive strength	$530f_c - 72,1$
Transverse tensile strength	$68,4f_c^2 - 55f_c + 23$
Transverse compressive strength	$196f_c^2 - 157f_c + 65,6$
In-plane shear strength	$73,4f_c^2 - 59,2f_c + 24,5$

NOTES
1. f_c is as defined in 1.5.1.
2. Range of applicability: $0,4 < f_c < 0,7$. Laminates with fibre contents outside range of applicability will be specially considered.

Table 3.1.4 Mechanical properties for uni-directional aramid reinforced epoxy resin laminates at 0/90° degree orientation

Mechanical property	N/mm^2
Longitudinal elastic modulus	$(91,2f_c + 1,1) \times 10^3$
Transverse elastic modulus	$(1,5f_c + 2,4) \times 10^3$
In-plane shear modulus	$(8,6f_c^2 - 6,1f_c + 2,6) \times 10^3$
Longitudinal tensile strength	$1186f_c + 14,3$
Longitudinal compressive strength	$319f_c + 3,8$
Transverse tensile strength	$7,5f_c + 12,1$
Transverse compressive strength	$22,4f_c + 36,4$
In-plane shear strength	$129f_c^2 - 92f_c + 38,4$

NOTES
1. f_c is as defined in 1.5.1.
2. Range of applicability: $0,25 < f_c < 0,55$. Laminates with fibre contents outside range of applicability will be specially considered.

Table 3.1.5 Mechanical properties for woven roving (WR) and cross-plied (CP) aramid reinforced epoxy resin laminates at 0/90° degree orientation

Mechanical property	N/mm^2
Elastic modulus	$(46,4\ f_c + 1,76) \times 10^3$
In-plane shear modulus	$(8,6\ f_c^2 - 6,1\ f_c + 2,6) \times 10^3$
Tensile strength	$596\ f_c + 13,2$
Compressive strength	$171\ f_c + 20,1$
In-plane shear strength	$129\ f_c^2 - 92\ f_c + 38,4$

NOTES
1. f_c is as defined in 1.5.1.
2. Range of applicability: $0,25 < f_c < 0,55$. Laminates with fibre content outside range of applicability will be specially considered.

Table 3.1.6 Mechanical properties for uni-directional carbon reinforced epoxy resin laminates at 0/90° degree orientation

Mechanical property	N/mm^2
Longitudinal elastic modulus	$(153f_c - 9,80) \times 10^3$
Transverse elastic modulus	$(5,8f_c^2 - 2,6f_c + 3,5) \times 10^3$
In-plane shear modulus	$(8,9f_c^2 - 6,6f_c + 2,7) \times 10^3$
Longitudinal tensile strength	$1377f_c - 88,2$
Longitudinal compressive strength	$842f_c - 53,9$
Transverse tensile strength	$21,7f_c + 7,5$
Transverse compressive strength	$65,2f_c + 22,4$
In-plane shear strength	$132f_c^2 - 99,5f_c + 40$

NOTES
1. f_c is as defined in 1.5.1.
2. Range of applicability: $0,3 < f_c < 0,6$. Laminates with fibre content outside range of applicability will be specially considered.

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Table 3.1.7 Mechanical properties for woven roving (WR) and cross-plied (CP) carbon reinforced epoxy resin laminates at 0/90° degree orientation

Mechanical property	N/mm^2
Elastic modulus	$(78{,}7f_c - 4{,}15) \times 10^3$
In-plane shear modulus	$(8{,}8f_c^2 - 6{,}6f_c + 2{,}7) \times 10^3$
Tensile strength	$690f_c - 35{,}3$
Compressive strength	$453f_c - 15{,}7$
In-plane shear strength	$132f_c^2 - 99{,}5f_c + 40$

NOTES
1. f_c is as defined in 1.5.1.
2. Range of applicability: $0{,}3 < f_c < 0{,}6$. Laminates with fibre content outside range of applicability will be specially considered.

Table 3.1.8 Typical minimum fibre properties

	Specific gravity ζ_F	Tensile modulus N/mm^2	Shear modulus N/mm^2	Poisson's ratio μ_F
E glass	2,56	69000	28000	0,22
S glass	2,49	69000	— *see* Note 3	0,20
R glass	2,58	— *see* Note 3	— *see* Note 3	— *see* Note 3
Aramid	1,45	124000	2800	0,34
LM graphite *see* Note 1	1,80	230000	— *see* Note 3	— *see* Note 3
IM graphite *see* Note 1	1,80	270000	— *see* Note 3	— *see* Note 3
HM graphite *see* Note 1	1,8	300000	— *see* Note 3	— *see* Note 3
IM graphite *see* Note 2	1,9	160000	— *see* Note 3	— *see* Note 3
HM graphite *see* Note 2	2,0	380000	— *see* Note 3	— *see* Note 3
VHM graphite *see* Note 2	2,15	725000	— *see* Note 3	— *see* Note 3

NOTES
1. Polyacryonitrile type.
2. Mesophase pitch precursor type.
3. Actual values to be obtained from the material manufacturer and are to be agreed with LR prior to use.

1.2.7 Typical acceptable values for the various resin properties of materials commonly in use are given in Table 3.1.9.

1.3 Direct calculations

1.3.1 The scantlings are to be determined by direct calculation where the craft is of unusual design, form or proportions, or where the speed of the craft exceeds 60 knots.

1.3.2 The requirements of this Section may be modified where direct calculation procedures are adopted to analyse the stress distribution in the primary structure.

1.4 Equivalents

1.4.1 LR will consider direct calculations for the derivation of scantlings as an alternative and equivalent to those derived by Rule requirements in accordance with Ch 2,3 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

1.5 Symbols and definitions

1.5.1 The symbols used in this Chapter, unless specified otherwise, are defined as follows:

b = unsupported panel breadth, in mm
b_i = breadth of individual ply, i, in mm
e_f = flexural strain of plate laminate
B = moulded breadth of the craft, in metres
E_{ci} = compressive modulus of individual ply, i, in N/mm^2
E_{cp} = compressive modulus of plate laminate, in N/mm^2
E_i = E_{ti} or E_{ci} for the ply relative to its position above or below the neutral axis
E_F = tensile modulus of the fibres, in N/mm^2
E_R = tensile modulus of the resin, in N/mm^2
E_{ti} = tensile modulus of individual ply, i, in N/mm^2
E_{cps} = compressive modulus of the sandwich skin plate laminate as determined from 1.13.5, in N/mm^2
E_{tps} = tensile modulus of the sandwich skin plate laminate as determined from 1.13.4, in N/mm^2
E_{fp} = flexural modulus of plate laminate, in N/mm^2
E_{tp} = tensile modulus of the plate laminate, in N/mm^2
f_c = the fibre content, by weight, within the laminate
f_{ci} = fibre content, by weight, of individual ply, i
G = shear modulus of sandwich core material, in N/mm^2
I_i = second moment of area for a 1 cm length of the cross section of individual ply, i, in cm^4
I_P = second moment of area for a 1 cm length of the cross section of plate laminate, in cm^4
k_A = $85/\sigma_u$
k_s = sandwich laminate aspect ratio correction factor, as defined in 1.13.9
L_R = Rule length of craft, in metres
M = bending moment, as appropriate, in Nm
l_e = effective span length of stiffener, in metres
σ_u = ultimate tensile strength of the plate laminate, in N/mm^2

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Table 3.1.9 Typical minimum resin properties

	Type	Specific gravity ζ_R	Tensile modulus N/mm^2	Shear modulus N/mm^2	Poisson's ratio ν_R
Polyester	Thermosetting	1,20	3400	1300	0,36
Vinylester	Thermosetting	1,44	3500	— *see* Note	— *see* Note
Epoxy	Thermosetting	1,38	3500	— *see* Note	0,39
Phenolic	Thermosetting	1,30	1500~2500 *see* Note	— *see* Note	— *see* Note
NOTE Actual value to be obtained from the material manufacturer and is to be agreed with LR prior to use.					

p = design pressure in kN/m^2, as calculated in Part 5 for the appropriate item
s = stiffener spacing, in mm
t_c = core thickness, in mm
t_i = thickness of individual ply, i, in mm
t_p = thickness of plate laminate, in mm
t_s = mean skin thickness, in mm
ν_F = Poisson's ratio for the fibre
ν_R = Poisson's ratio for the resin
V_{Fi} = volume fraction of fibres of individual ply, i
W_{Fi} = weight fraction of the fibres of individual ply, i
m_{Fi} = mass of reinforcement in individual ply, i, in g/m^2
x_i = distance to the centre of individual ply, i, from the plate or sandwich laminate surface, in mm
x_L = distance of the neutral axis from the surface of the plate or sandwich laminate, in mm
x_S = the distance of the neutral axis, from the outer surface of the plate or sandwich laminate
y_i = distance from the neutral axis to the outer extremity of an individual ply, i, in mm
σ_{ci} = maximum compressive stress within ply, i, in N/mm^2
σ_{ti} = maximum tensile stress within ply, i, in N/mm^2
ζ_{Fi} = specific gravity of reinforcement in individual ply, i
ζ_{Ri} = specific gravity of resin in individual ply, i.

1.5.2 The side shell is defined as the portion of the hull between the bottom shell and the deck at side.

1.6 Material properties

1.6.1 The nominal thickness of an individual ply, t_i, may be determined from:

$$t_i = \frac{m_{Fi}\left[\frac{\zeta_{Fi}}{f_{ci}} - (\zeta_{Fi} - \zeta_{Ri})\right]}{1000\zeta_{Fi}\,\zeta_{Ri}} \text{ mm}$$

where

f_{ci}, t_i, m_{Fi}, ζ_{Fi} and ζ_{Ri} are as defined in 1.5.1.

1.7 Effective width of attached plating

1.7.1 The geometric properties of stiffening sections are to be calculated in accordance with 1.15 using an effective width, $2b_1$, of attached load bearing plating determined as follows:

(a) Single skin construction:

$b_1 = 0{,}5b_w + 10t_{ap}$

(b) Sandwich skin construction:

Generally:

$b_1 = 0{,}5b_w + 10(t_{outer} + t_{inner})$

Where a plywood core is used:

$b_1 = 0{,}5b_w + 10(t_{outer} + t_{inner} + 0{,}5t_{ply})$

where

b_1 = effective width of attached load bearing plating, in mm, and is not to be taken as greater than one half the spacing between the centres of adjacent stiffeners
b_w = base width of the stiffener section, in mm
t_{ap} = thickness, or mean thickness of attached plate laminate, in mm
t_{inner} = thickness, or mean thickness of inner skin laminate, in mm
t_{outer} = thickness, or mean thickness of outer skin laminate, in mm
t_{ply} = thickness of plywood core, in mm.

1.7.2 The geometric properties of primary support members (i.e. girders, stringers, web frames, etc.) are to be calculated in accordance with 1.15 using an effective area of attached load bearing plate laminate of nominal thickness, t mm, and of width equal to one-half the sum of spacings between parallel adjacent members or equivalent support.

1.8 Glass fibre and advanced fibre composites

1.8.1 Strength calculations for all advanced fibre composites are to be based on the results of testing of truly representative sections of the proposed design. In general the sections are to be manufactured under typical production conditions using the same materials, fibre contents, methods of lay-up and time delays.

1.8.2 Mechanical testing is, in general, to be based upon the requirements of Ch 14,3 of the Rules for Materials.

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1.8.3 Where test data is not available for standard glass fibre laminates, the following theoretical approach is to be used to estimate the tensile modulus and the shear modulus of a laminate:

The tensile modulus of a uni-directional reinforcement at angle θ to the axis of the fibres is to be determined from:

$$E_{\theta i} = \frac{E_{0i}}{\cos^4\theta_i + \frac{E_{0i}}{E_{90i}}\sin^4\theta_i + \frac{1}{4}\left(\frac{E_{0i}}{G_{0/90i}} - 2\nu_{0/90i}\right)\sin^2 2\theta_i} \text{ N/mm}^2$$

where

θ_i = angle of orientation of the fibre relative to the warp direction, and is not to be taken as less than seven degrees to allow for misalignment

E_{0i}, the longitudinal tensile modulus of individual ply, *i*, for an unfilled resin system is determined from:

$$E_{0i} = E_F V_F + E_R (1 - V_F) \text{ N/mm}^2$$

E_F, V_F and E_R are as defined in 1.5.1

V_F, the volume fraction of the fibres of individual ply, *i*, is determined from:

$$V_F = \frac{W_F \zeta_R}{W_F \zeta_R - W_F \zeta_F + \zeta_F}$$

W_F, ζ_F and ζ_R are as indicated in 1.5.1

E_{90i}, the transverse tensile modulus of individual ply, *i*, is determined from:

$$E_{90i} = \frac{E_F E_R}{E_R V_F + E_F - E_F V_F} \text{ N/mm}^2$$

E_F, E_R and V_F are as indicated in 1.5.1.

$G_{0/90i}$, the shear modulus of individual ply, *i*,is determined from:

$$G_{0/90i} = G_R \left\{ \frac{\frac{G_F}{G_R}(1 + V_F) + (1 - V_F)}{\frac{G_F}{G_R}(1 - V_F) + (1 + V_F)} \right\} \text{ N/mm}^2$$

Where the shear modulus of the resin, G_R is determined from:

$$G_R = \frac{E_R}{2(1 + \nu_R)} \text{ N/mm}^2$$

Where the shear modulus of the fibre, G_F is determined from:

$$G_F = \frac{E_F}{2(1 + \nu_F)} \text{ N/mm}^2$$

E_F, E_R, ν_R and ν_F are as indicated in 1.5.1.

The longitudinal Poisson's ratio, $\nu_{0/90}$, of individual ply, *i*, is determined as follows:

$$\nu_{0/90} = V_F(\nu_F - \nu_R) + \nu_R$$

V_F, ν_F and ν_R are as indicated in 1.5.1.

1.8.4 Where specific test data is not available for glass fibre reinforced polyester laminates, the mechanical properties for design are to be the values determined from the formulae given in Tables 3.1.1 and 3.1.2.

1.9 Plate and sandwich laminates

1.9.1 Unless otherwise specified in this Part, the bending moments, M_b and M_c, to be applied to a 1 cm length of panel, for both plate and sandwich laminates, subjected to lateral pressure are to be determined from:

(a) Bending moment at panel boundary and under base of stiffener, M_b:

$$M_b = \frac{k\,p\,b^2}{12} \times 10^{-5} \text{ Nm}$$

(b) Bending moment at centre of panel, M_c:

$$M_c = \frac{(1{,}5 - k)\,p\,b^2}{12} \times 10^{-5} \text{ Nm}$$

where

$$k = \frac{\gamma^3 + 1}{\gamma + 1}$$

$$\gamma = \frac{b_w}{b}$$

$b_w < b$ and is as defined below, *see* Fig. 3.1.1:

b = unsupported panel breadth, in mm

b_w = base width of stiffener, in mm

γ = ratio of base width of stiffener to panel breadth

k = bending moment influence coefficient

l_p = panel length, in mm

p = design pressure head as required by Part 5, for the element of plate laminate under consideration, in kN/m^2.

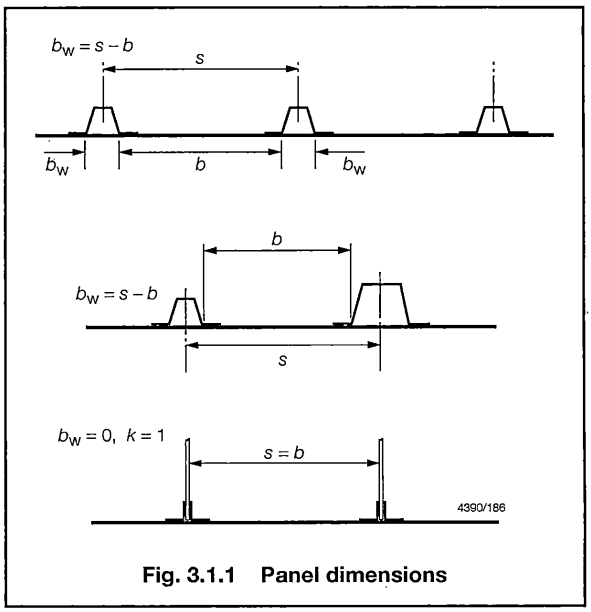

Fig. 3.1.1 Panel dimensions

1.10 Aspect ratio correction

1.10.1 The Rule bending moments, M_b and M_c, to be applied to plate laminates as determined by 1.9.1, may be reduced when the panel aspect ratio is taken into consideration. For panels with aspect ratio less than two the following factor, K_{AR}, may be applied:

$$K_{AR} = 0{,}56 + 0{,}63 \ln(A_R) \geq 0{,}56$$

where

A_R = panel aspect ratio
= panel length/panel breadth

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1.11 Convex curvature

1.11.1 The Rule bending moments, M_b and M_c, as determined by 1.9.1, may be reduced where significant curvature exists between the support members. For such panels the following factor, K_c, may be applied:

$$K_c = 1 - 1{,}76\,\frac{h}{s} \geq 0{,}56$$

where

h = the distance, in mm, measured perpendicularly from the chord length s (i.e. spacing) to the highest point of the curved plating arc between the two supports, *see* Fig. 3.1.2.

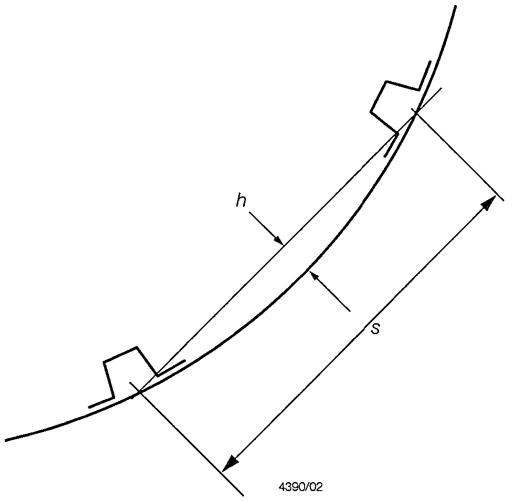

Fig. 3.1.2 Convex curvature

1.12 Determination of properties and stresses for single skin plate laminates

1.12.1 An estimate of the thickness of single skin plating required to carry the bending moment given in 1.9.1, is to be determined from:

$$t = 0{,}146b\sqrt[3]{\frac{p}{E_{tp}}} \text{ mm}$$

where

b, p and E_{tp} are as defined in 1.5.1.

1.12.2 The distance of the neutral axis, x_L, from the surface of the plate laminate is to be determined from the following:

$$x_L = \frac{\Sigma\,(E_i\,t_i\,x_i)}{\Sigma\,(E_i\,t_i)} \text{ mm}$$

where

E_i, t_i and x_i are as defined in 1.5.1.

1.12.3 The resultant tensile stress, σ_{ti}, at the extreme outer fibre of an individual ply, i, is to be determined from:

$$\sigma_{ti} = \frac{0{,}1E_{ti}\,y_i\,M}{\Sigma\,(E_i\,I_i)} \text{ N/mm}^2$$

where

σ_{ti}, E_{ti}, y_i, M, E_i and I_i are as defined in 1.5.1.

1.12.4 The resultant compressive stress, σ_{ci}, at the extreme outer fibre of an individual ply, i, is to be determined from:

$$\sigma_{ci} = \frac{0{,}1E_{ci}\,y_i\,M}{\Sigma\,(E_i\,I_i)} \text{ N/mm}^2$$

where

σ_{ci}, E_{ci}, y_i, M, E_i and I_i are as defined in 1.5.1.

1.12.5 The effective flexural modulus of elasticity in bending, E_{fp}, for the plate laminate is to be determined from:

$$E_{fp} = \frac{\Sigma\,(E_i\,I_i)}{I_p} \text{ N/mm}^2$$

where

E_{ti}, I_i and I_P are as defined in 1.5.1.

1.12.6 The apparent flexural strength, sf, of a plate laminate is to be determined from:

$$\sigma_f = E_{fp}\,e_f \text{ N/mm}^2$$

where

E_{fp} and e_f are as defined in 1.5.1.

1.13 Mechanical properties sandwich laminates

1.13.1 For the application of the various formulae relating to the use of sandwich construction, the following assumptions have been made:

(a) the sandwich skins carry the majority of the bending load,

(b) the core carries the majority of the shear load,

(c) the initial estimate of the skin thickness from 1.13.2 is based upon the limiting condition for thin skin theory:

$$\frac{\text{Core thickness}}{\text{Mean facing thickness}} \geq 5{,}77$$

(d) the sandwich skins are of approximately equal thickness (i.e. the panel is of balanced or approximately balanced construction), with the thickness of the outer sandwich facing not greater than:

t_{OUTER} = 1,33 t_{INNER} (excluding gel coat and non-structural materials).

1.13.2 An estimate of the thicknesses of the sandwich skins and core required to carry the Rule bending moment may be determined from the following formula. The subsequent design is then to be tested against the other criteria required by the Rules.

$$t_s = \phi_1\,k_S\,b\sqrt[3]{\frac{p}{E_{tps}}} \text{ mm}$$

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where

ϕ_1 = 0,0214 for inner skins
= 0,0286 for outer skins
= 0,1440 for core thickness

k_S, E_{tps}, b and p are as defined in 1.5.1.

1.13.3 Where it is proposed to use a thicker core than assumed in 1.13.2, the required skin thickness, t_s, is to be calculated from:

$$t_s = \frac{\phi^2 p b^3}{E_{tps} t_c^2} \times 10^{-3} \text{ mm}$$

where

ϕ_2 = 0,446 for inner skins
= 0,594 for outer skins

k_S, E_{tps}, b and p are as defined in 1.5.1.

1.13.4 The tensile modulus, E_{tp}, of a plate laminate which forms a skin of a sandwich laminate subject to tensile loading is to be determined from:

$$E_{tps} = \frac{\Sigma (E_{ti} t_i)}{\Sigma t_i} \text{ N/mm}^2$$

where

E_{tps}, E_{ti} and t_i are as defined in 1.5.1.

1.13.5 The compressive modulus, E_{cp}, of a plate laminate which forms a skin of a sandwich laminate subject to compressive loading is to be determined from:

$$E_{cps} = \frac{\Sigma (E_{ci} t_i)}{\Sigma t_i} \text{ N/mm}^2$$

where

E_{cps}, E_{ci} and t_i are as defined in 1.5.1.

1.13.6 The distance of the neutral axis, x_S, from the outer surface of the sandwich laminate is to be determined from:

$$x_S = \frac{\Sigma (E_i t_i x_i)}{\Sigma (E_{ti} t_i)} \text{ mm}$$

where

E_i, t_i and x_i are as defined in 1.5.1.

1.13.7 The resultant tensile stress, σ_{ti}, at the extreme outer fibre of an individual ply, *i*, is to be determined from:

$$\sigma_{ti} = \frac{0{,}1 E_{ti} y_i M}{\Sigma (E_i I_i)} \text{ N/mm}^2$$

where

σ_{ti}, E_{ti}, y_i, M, E_i and I_i are as defined in 1.5.1.

The allowable tensile stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

1.13.8 The resultant compressive stress, σ_{ci}, at the extreme outer fibre of an individual ply, *i*, is to be determined from:

$$\sigma_{ci} = \frac{0{,}1 E_{ci} y_i M}{\Sigma (E_i I_i)} \text{ N/mm}^2$$

where

σ_{ci}, E_{ci}, y_i, M, E_i and I_i are as defined in 1.5.1.

The allowable compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

1.13.9 The direct core shear stress, τ_c, at the edges of a sandwich panel subjected to lateral pressure is to be determined from:

$$\tau_c = \frac{p b k_S}{2(t_c + t_s)} \times 10^{-3} \text{ N/mm}^2$$

where

k_S = aspect ratio correction factor
= 0,32 A_R + 0,36 for $A_R \leq 2$
= 1,0 for $A_R > 2$

A_R = panel length/panel breadth

t_c and t_s are as defined in 1.5.1.

The allowable shear stress limits against core shear failure indicated in Ch 7,3.5.1. are to be complied with. For the purposes of this comparison it is assumed that the stated shear properties of the proposed core material have been determined by use of the four point sandwich beam bending test ASTM C393 or equivalent.

1.13.10 Where the core shear stress, τ_c, determined from 1.13.9 is in excess of the limiting stress for a particular core material, the effective shear strength of the core material in the direction of the panel breadth, may be increased by the addition of shear ties. The effective shear strength, τ_{eff}, of the core material is to be determined from:

$$\tau_{eff} = \tau_c + \left(\frac{t_t}{s_t} \times \tau_t \right) \text{ N/mm}^2$$

where

τ_{eff} = effective shear strength of the core material, in N/mm^2
τ_c = shear strength of basic core material, in N/mm^2
t_t = thickness of shear tie material, in mm
τ_t = ultimate shear strength of the shear tie material, in N/mm^2
s_t = spacing or mean spacing of the shear ties, in mm.

1.13.11 Where the Poisson's ratio, ν_f, for a particular facing laminate is known, the deflection, δ, of a flat sandwich panel with all edges assumed to be fully fixed, and subjected to a uniform lateral pressure is to be determined from:

$$\delta = \frac{p b^2}{8 t_c} \left(\frac{b^2 (1 - \nu_f^2)}{24 E_{ms} t_s t_c} + \frac{1}{G} \right) \times 10^{-3} \text{ mm}$$

where the mean skin modulus, E_{ms}, is given by:

$$E_{ms} = \frac{\Sigma (E_p t_s)}{\Sigma t_s} \text{ N/mm}^2$$

E_p is E_{tp} or E_{cp} whichever is the lesser.

where

ν_f, p, b, t_c, t_s, E_{tp}, E_{cp} and G are as defined in 1.5.1 and E_{ms} is the mean modulus of the total skin thicknesses.

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1.13.12 Where the Poisson's Ratio, v_f, for a particular facing laminate is not known, the deflection, δ, of a flat sandwich panel with all edges assumed to be fully fixed, and subjected to a uniform lateral pressure is to be estimated from:

$$\delta = \frac{p\,b^2}{8t_c}\left(\frac{b^2}{24E_{ms}\,t_s\,t_c} + \frac{1}{G}\right) \times 10^{-3} \text{ mm}$$

where

δ, p, b, t_c, t_s, and G, are as defined in 1.5.1

E_{ms} is as defined in 1.13.11.

1.13.13 The deflection determined from 1.13.11 or 1.13.12, as appropriate, is not to exceed the limiting deflection for the structural element under consideration, as indicated in Table 7.2.1 in Chapter 7.

1.14 Stiffeners general

1.14.1 Unless otherwise specified elsewhere in this Part, the Rule bending moment, M_s, to be applied to all stiffening members subjected to uniform lateral pressure is to be determined from:

$$M_s = \phi_M\, s\, l_e^2\, p \text{ Nm}$$

where

ϕ_M = bending moment coefficient as given in Table 3.1.10.

1.14.2 Unless otherwise specified elsewhere in this Part, the Rule shear force, F_s, to be applied to all stiffening members subjected to uniform lateral pressure is to be determined from:

$$F_s = \phi_s\, p\, s\, l_e \text{ N}$$

where

ϕ_S = shear force coefficient as given in Table 3.1.10.

1.14.3 The shear stress, τ_S, in the webs of stiffening members of 'top-hat' type section is to be determined from:

$$\tau_S = \frac{F_S}{2t_w\,d_W} \text{ N/mm}^2$$

where

F_S = shear force applied to the stiffening member, in *N*, as detailed in 1.14.2

t_W = stiffening member web thickness, in mm

d_W = stiffening member web depth, in mm. (Account is to be taken of the increased effective depth of web where the webs are inclined)

The maximum allowable shear stress is not to exceed that determined from Table 7.3.1 in Chapter 7, for the stiffener member under consideration.

1.14.4 The shear stress, τ_S, in the webs of stiffening members of inverted angle or 'T bar' type section is to be determined from:

$$\tau_S = \frac{F_S}{t_W\,d_W} \text{ N/mm}^2$$

where

F_S, t_W and d_W are as defined in 1.14.3.

The maximum allowable shear stress is not to exceed that determined from Table 7.3.1 in Chapter 7, for the stiffener member under consideration.

1.14.5 Unless otherwise specified elsewhere in this Part, the deflection, δ_s, of stiffening members, subjected to uniform lateral pressure is to be determined from:

$$\delta_s = \frac{\phi_\delta\, p\, s\, l_e^4}{(E\,I)_s} \times 10^5 \text{ mm}$$

where

$(EI)_s$ = total EI for the stiffener section including an effective width of attached plating as indicated in 1.7.1, in Ncm^4/mm^2

ϕ_δ = deflection coefficient as defined in Table 3.1.10

s, l_e, E, I and p are as defined in 1.5.1.

1.14.6 The maximum allowable deflection is not, in general, to exceed that determined from Table 7.2.1 in Chapter 7 for the stiffener member under consideration.

1.15 Geometric properties stiffener sections

1.15.1 The effective geometric properties of the stiffener sections are to be calculated directly from the dimensions of the section and associated effective width of attached plating in accordance with 1.7. Where the mean line of the stiffener webs is not normal to the attached laminate, and the angle exceeds 20°, the properties of the section are to be determined about an axis parallel to the attached plate laminate. Where plywood, solid timber, aluminium alloy, steel or other materials are integrated into a stiffening member, the effectiveness of the material is to be determined in accordance with 1.20.3. The stress in the individual material is to be limited to the allowable strain associated with the constituent material.

1.15.2 The distance of the neutral axis, x_S, from the outer surface of the plate laminate is to be determined from:

$$x_S = \frac{\Sigma\,(E_i\,t_i\,b_i\,x_i)}{\Sigma\,(E_i\,t_i\,b_i)} \text{ mm}$$

where

E_i, t_i, b_i and x_i are as defined in 1.5.1.

1.15.3 The resultant extreme fibre tensile stress for an individual ply, σ_{ti}, is to be determined from:

$$\sigma_{ti} = \frac{0{,}1E_{ti}\,y_i\,M}{\Sigma\,(EI)_s} \text{ N/mm}^2$$

where

σ_{ti}, E_{ti}, y_i, M, E_i and I_i are as defined in 1.5.1.

The term $(EI)_s$ refers to the whole stiffener section, i.e. including the attached plating in accordance with 1.7. *See also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*.

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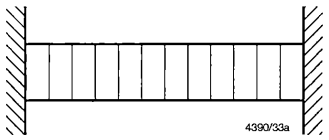
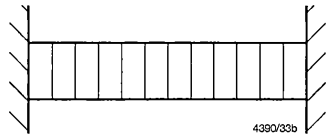
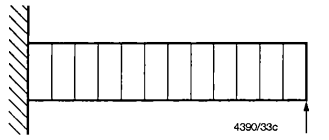
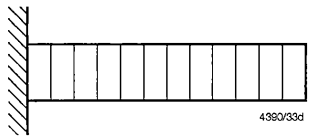
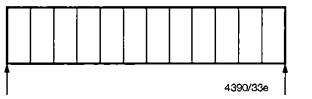
Table 3.1.10 Shear force, bending moment and deflection coefficients

Load model	Position 1	Position 2	Position 3	Position	Shear force, ϕ_S	Bending moment, ϕ_M	Deflection, ϕ_δ	Application
(a)	 4390/33a			1 2 3	1/2 — 1/2	1/12 1/24 1/12	— 1/384 —	Primary and other members where the end fixity is considered encastre
(b)	 4390/33b			1 2 3	1/2 — 1/2	1/10 1/10 1/10	— 1/288 —	Local, secondary and other members where the end fixity is considered to be partial
(c)	 4390/33c			1 2 3	5/8 — 3/8	1/8 9/128 —	— 1/185 —	Various
(d)	 4390/33d			1 2 3	1 — —	1/2 — —	— — 1/8	Various
(e)	 4390/33e			1 2 3	1/2 — 1/2	— 1/8 —	— 5/384 —	Hatch covers, glazing and other members where the ends are simply supported

1.15.4 The resultant extreme fibre compressive stress for an individual ply, σ_{ci}, is to be determined from:

$$\sigma_{ci} = \frac{0{,}1E_{ci}\, y_i\, M}{\Sigma\,(EI)_s}$$

where

σ_{ci}, E_{ci}, y_i, M, E_i and I_i are as defined in 1.5.1.

The term $(EI)_s$ refers to the whole stiffener section, i.e. including the attached plating in accordance with 1.7. *See also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*.

1.16 Stiffener proportions

1.16.1 From structural stability and local buckling considerations, the proportions of stiffening members are, in general, to be in accordance with the requirements of this Section.

1.16.2 The thickness of the web for 'top-hat' type stiffeners, t_w, is to be not less than that required to satisfy the web shear from 1.14.3 and 1.14.4, and in no case is to be taken as less than that determined from the following formula:

$$t_w = \frac{0{,}025d_w + 1{,}1}{1{,}3f_w + 0{,}61} \text{ mm}$$

where

d_w = unsupported web depth, in mm

f_w = fibre content, by weight, of the web laminate.

1.16.3 The thickness of the web of an inverted angle or 'T' bar stiffener section is to be twice the web thickness determined from 1.16.2.

1.17 Determination of span points

1.17.1 The effective span, l_e, of a stiffening member is generally less than the overall length, l, by an amount which depends on the design of the end connections. The span points, between which the value of l_e is measured, are to be determined from:

(a) For secondary stiffening members of top-hat type section as shown in Fig. 3.1.3(a) the span point is to be taken at the point where the depth of the end bracket, measured from the face of the secondary stiffening member is equal to the depth of the member. Where there is no end bracket, the span point is to be measured between primary member webs.

(b) For primary stiffening members of top-hat type section as shown in Fig. 3.1.3(b) the span point is to be taken at the point where the depth of the end bracket, measured from the face of the primary stiffening member is equal to the half depth of the member. Where there is no end bracket, the span point is to be measured between primary member webs.

1.17.2 Where the stiffener member is inclined to a vertical or horizontal axis and the inclination exceeds 10°, the span is to be measured along the member.

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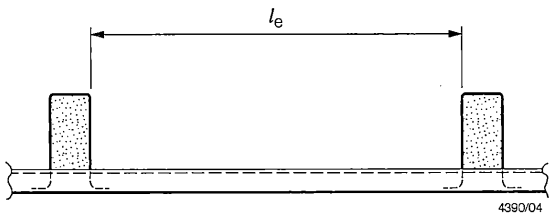

Fig. 3.1.3(a) Span points

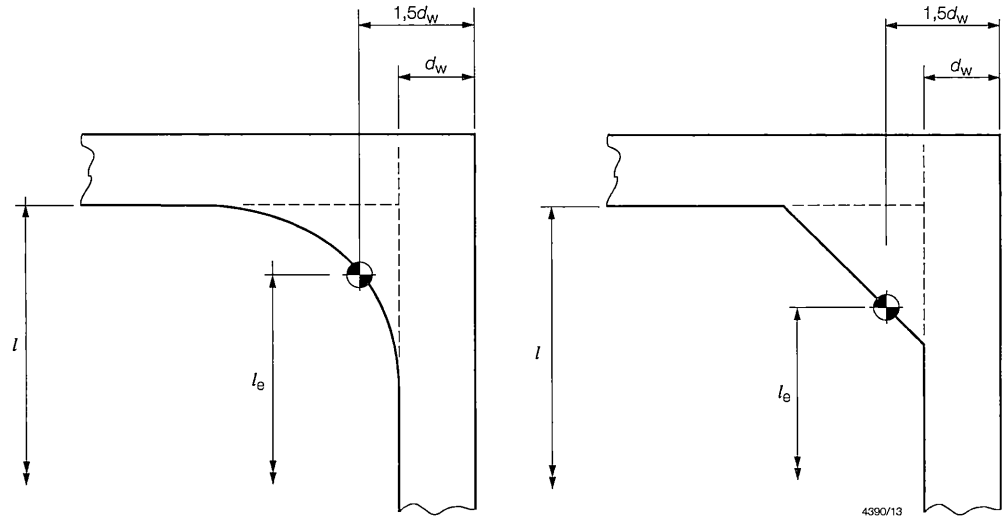

Fig. 3.1.3(b) Span points

1.17.3 Where the stiffening member is curved then the span is to be taken as the effective chord length.

1.17.4 Where there is a pronounced turn of bilge, chine or the structure is significantly pitched, the span is to be measured as in Fig. 3.1.3(c) to (f).

1.17.5 The determined effective span assumes that the ends of stiffening members are substantially fixed against rotation and displacement. If the arrangement of supporting structure is such that this condition is not achieved, the span is to be determined excluding any effect from the end brackets.

1.18 Boundary bonding

1.18.1 The connection of the various laminates into assemblies and the connection of units to the main structure is generally to be made by means of single or double angles of the type shown in Fig. 3.1.4.

1.18.2 These matting-in angles are to be formed by layers of reinforcements, laid-up *in situ*, and normally secondary bonded to the structure before the laminates are advanced in cure. Where the laminating schedule is such that this cannot be achieved then suitable peel plies and secondary bonding techniques, as recommended by the resin manufacturer, *see* Ch 2,5.9, are to be arranged in way of the surfaces to be connected.

1.18.3 All surfaces to be bonded are to be clean and suitably prepared prior to the application of the bonding angles. Suitable fillets of compliant resin are to be arranged as shown in Figs. 3.1.5 and 3.1.6.

1.18.4 Where floors, bulkheads, tank boundaries, etc., are manufactured from plate laminate the weight of the laminate forming each angle is to be not less than 50 per cent of the weight of the lighter member being connected, or 900g/m^2 chopped fibre reinforcement or equivalent, whichever is the greater.

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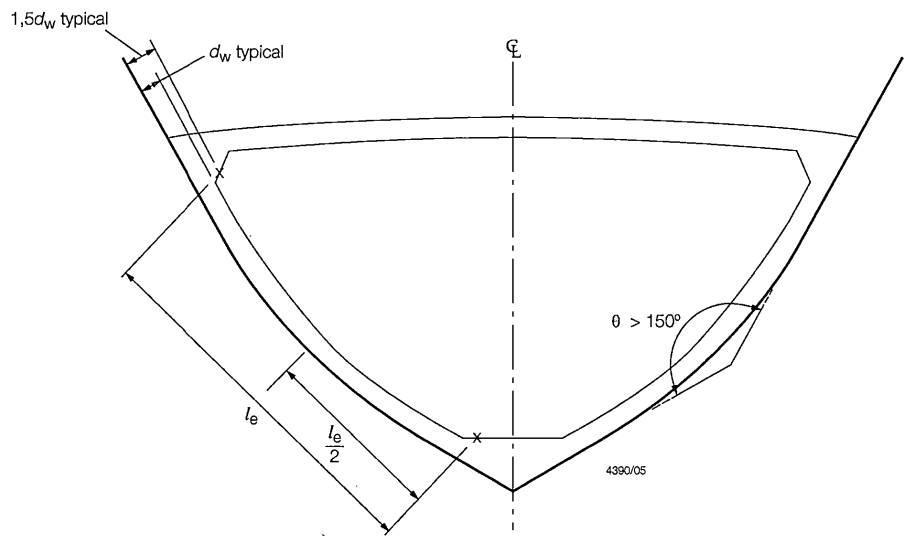

Fig. 3.1.3(c) Span points

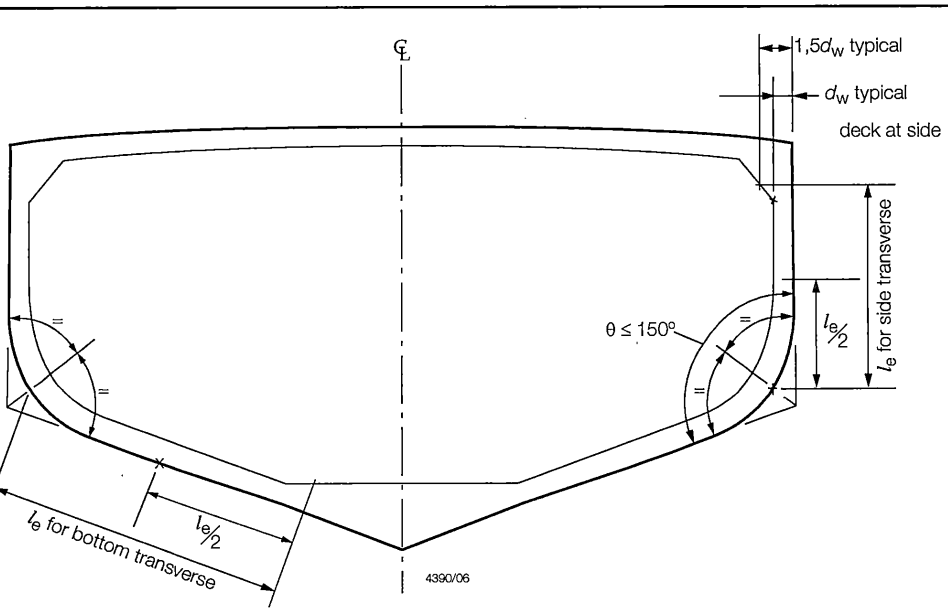

Fig. 3.1.3(d) Span points

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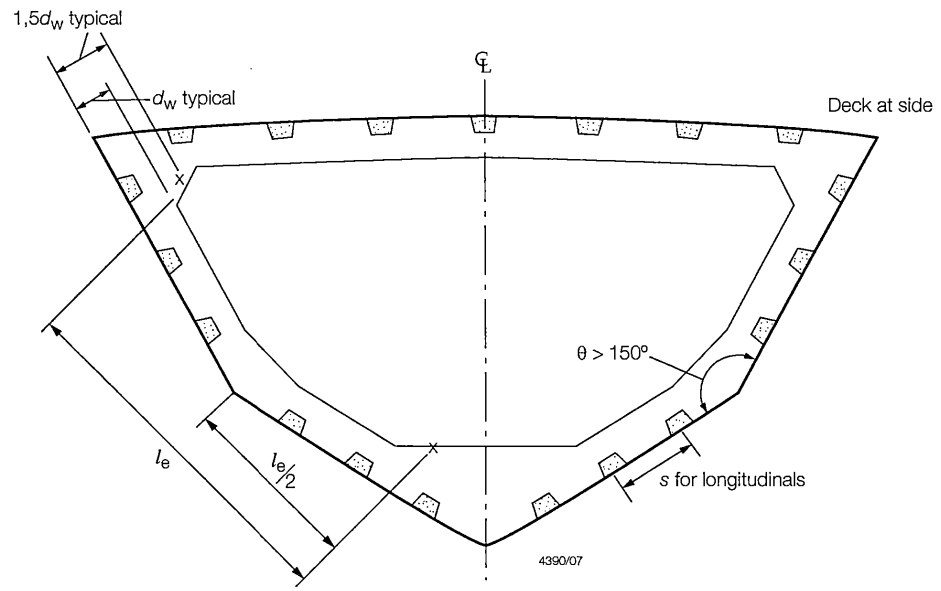

Fig. 3.1.3(e) Span points

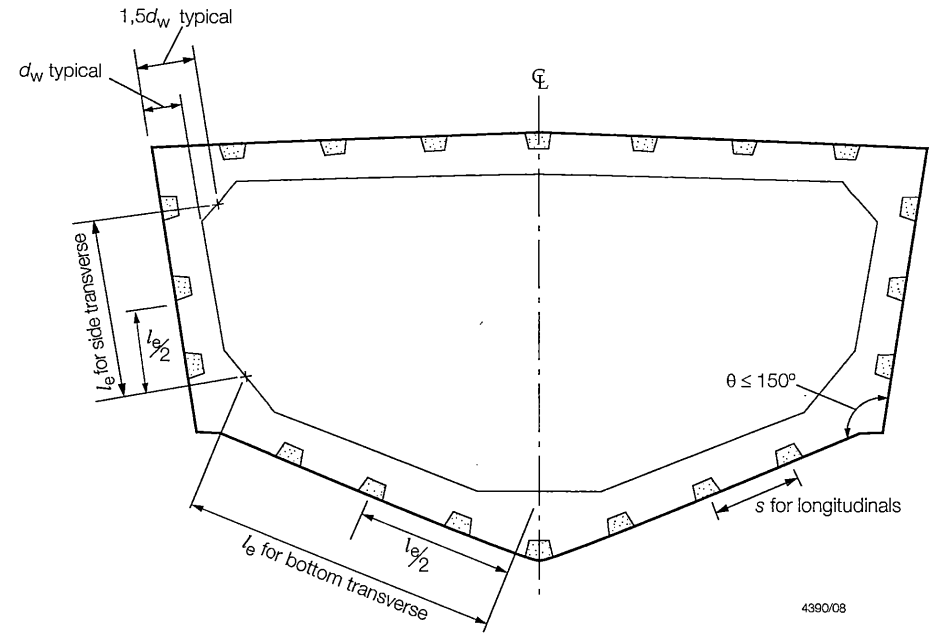

Fig. 3.1.3(f) Span points

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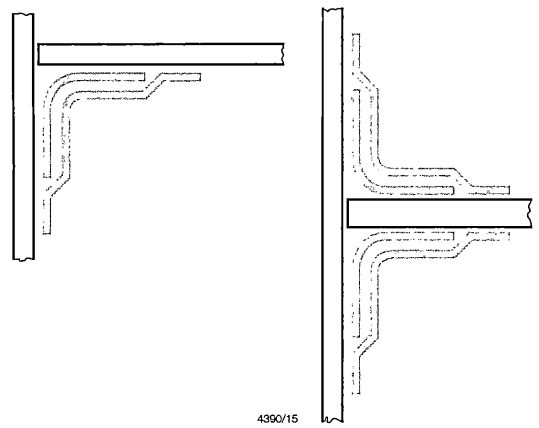

Fig. 3.1.4 Bonding angles

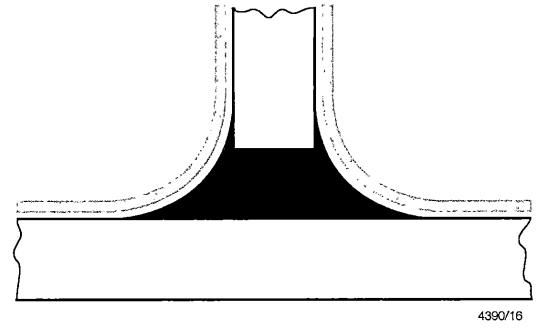

Fig. 3.1.5 Resin fillets

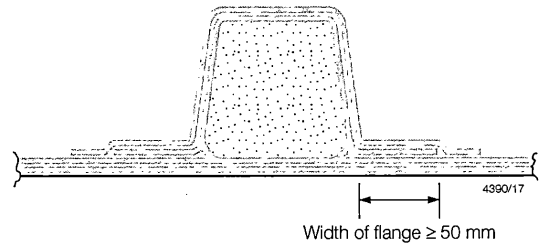

Fig. 3.1.6 Width of bonding angle

1.18.5 Double angles are normally to be used, but when this is not possible, such as where satisfactory access cannot be achieved on the reverse side, a single angle can be used provided it is suitably increased in width and weight. The weight of a single bonding angle is to be determined by direct calculation, and in no case to be taken as less than two thirds the weight of the lighter laminate being connected or 900 g/m^2 chopped fibre reinforcement or equivalent, whichever is the greater.

1.18.6 Where frames and stiffeners are of the 'top-hat' type, the width of the flange connection to the plate laminate is to be as shown in Fig. 3.1.6. The width of bonding angle is to be 25 mm for the first layer + 15 mm per each additional layer, but not less than 50 mm.

1.18.7 Where sandwich panels are to be connected the weight of bonding is to be not less than the weight of the appropriate skin. The inner and outer skins of primary sandwich structures such as bulkheads are to be effectively 'tied' by a suitable weight of reinforcement or by use of fillets and wedges of suitable compliant resin, as shown in Fig. 3.1.7.

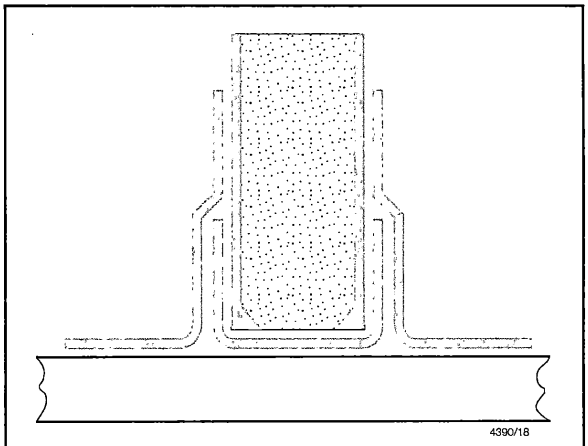

Fig. 3.1.7 Bonding ties

1.18.8 Where the floors, bulkheads, etc., are manufactured from plywood the weight of the laminate forming each angle is to be not less than 50 per cent of the weight of the equivalent thickness of bulkhead in the material used for the bonding angle or the lighter member being connected.

1.18.9 In no case is the thickness of the double bonding angle to be less than 2 mm at a glass content, by weight, of 0,5. Where a glass content is less than 0,5, the thickness is to be not less than that required to resist the same shear force using the formulae in Tables 3.1.1 and 3.1.2.

1.18.10 Alternative bonding arrangements incorporating epoxy fillets, bonded wedges, bolting, etc., may be specially considered. It is however the responsibility of the Builder to demonstrate their suitability and equivalence to the Rule requirements.

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Table 3.1.11 Mechanical properties for plywood panels

Mechanical property	N/mm^2
Flexural modulus parallel to face grain, $E_{//}$	$(34{,}1N^2 - 985N + 14800)\frac{\rho_{WD}}{1000}$
Flexural modulus perpendicular to face grain, $E_{\perp}$	$(-31{,}5N^2 + 909N - 633)\frac{\rho_{WD}}{1000}$
Flexural strength parallel to face grain, $\sigma_{//}$	$(0{,}15N^2 - 4{,}52N + 79{,}5)\frac{\rho_{WD}}{1000}$
Flexural strength perpendicular to face grain, $\sigma_{\perp}$	$(-0{,}1N^2 + 2{,}88N + 18{,}5)\frac{\rho_{WD}}{1000}$

NOTES
1. N is the number of plies and is an odd number between 3 and 15.
2. ρ_{WD} is the density of plywood in kg/m^3.

1.19 Timber

1.19.1 It is presumed that, in the selection of the species of timber for a particular application, the designers will relate the known characteristics, strength, density, bending and working capabilities of the particular species to the constructional design. The mechanical properties of timbers and assumptions used for design purposes are to be clearly indicated on the submitted construction plans, *see also* Ch 2,2.17 and 1.15.1.

1.19.2 All timbers are to be identified by their botanical name.

1.19.3 The moisture content of timber which is to be glued, bonded or overlaminated is to be about 15 per cent, *see also* Ch 2,2.17.

1.20 Plywood

1.20.1 Structural plywoods are to comply with Ch 2,2.17, *see also* Ch 2,2.16.3.

Table 3.1.12 Mechanical properties for plywood on edge

Mechanical property	N/mm^2
Flexural modulus parallel to face grain, $E_{//}$	$E_{//} = (15{,}6N^2 - 400N + 9850)\frac{\rho_{WD}}{1000}$
Flexural modulus perpendicular to face grain, $E_{\perp}$	$E_{\perp} = (-15{,}6N^2 + 400N + 3880)\frac{\rho_{WD}}{1000}$
Flexural modulus at any intermediate angle, E_{θ}	$E_{\theta} = E_{//}\cos^4\theta + 4G_{IP}\cos^2\theta\sin^2\theta + E_{\perp}\sin^4\theta$
Flexural strength parallel to face grain, $\sigma_{//}$	$\sigma_{//} = (0{,}093N^2 - 2{,}4N + 58{,}2)\frac{\rho_{WD}}{1000}$
Flexural strength perpendicular to face grain, $\sigma_{\perp}$	$\sigma_{\perp} = (-0{,}093N^2 + 2{,}4N + 22{,}4)\frac{\rho_{WD}}{1000}$
Flexural strength at any intermediate angle, σ_{θ}	$\sigma_{\theta} = \left(\frac{\cos^4\theta}{\sigma_{//}^2} + \frac{\cos^2\theta\sin^2\theta}{\sigma_{//}^2\tau^2}(\sigma_{//}^2 - \tau^2) + \frac{\sin^4\theta}{\sigma_{\perp}^2}\right)^{-1/2}$
In-plane shear modulus parallel/perpendicular to face grain, G_{IP}	$G_{IP} = 0{,}9\rho_{WD}$
In-plane shear modulus at any intermediate angle, G_{θ}	$G_{\theta} = (E_{//} + E_{\perp} - 2G_{IP})\cos^2\theta\sin^2\theta + G_{IP}(\cos^4\theta + \sin^4\theta)$
In-plane shear strength parallel/perpendicular to face grain, τ_{IP}	$\tau_{IP} = 0{,}015\rho_{WD}$
In-plane shear strength at any intermediate angle, τ_{θ}	$\tau_{\theta} = \left[\cos^2\theta\sin^2\theta\left(\frac{8}{\sigma_{//}^2} + \frac{4}{\sigma_{\perp}^2}\right) + \frac{(\cos^2\theta - \sin^2\theta)^2}{\tau_{IP}^2}\right]^{-1/2}$

NOTES
1. N is the number of plies and is an odd number between 3 and 15.
2. ρ_{WD} is the density of plywood in kg/m^3.

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1.20.2 The mechanical properties of the plywood proposed for use in structural applications is to be obtained from the plywood manufacturer and submitted for consideration. In the absence of such data the mechanical properties can be determined from Tables 3.1.11 and 3.1.12.

1.20.3 Where stiffeners incorporate encapsulated plywood structurally bonded to the plate laminate in accordance with 1.18.8, its effective $E_i I_i$ is to be incorporated into the $\Sigma (E_i I_i)$ as indicated in 1.15, with the basic thickness and tensile/compressive moduli of the plywood being taken as those corresponding to the least effective over the span of the stiffener. Directional considerations for structural plywood incorporated in stiffening members are to be indicated on construction plans submitted for appraisal.

1.21 Aluminium alloy

1.21.1 The use of aluminium alloy is permitted for craft in accordance with Part 7. Where this material is to be integrated structurally, with the fibre composite structure, *see* Ch 2,2.15 and 1.15.1.

1.22 Steel

1.22.1 The use of steel is permitted for craft in accordance with Part 6. Where this material is to be integrated structurally, with the fibre composite structure, *see* Ch 2,2.15 and 1.15.1.

1.23 Other materials

1.23.1 Special consideration will be given to the use of other types of materials. Details of the type of material, the specification to which it was manufactured and its mechanical properties are to be submitted for appraisal, *see also* 1.15.1.

1.24 Secondary member end connections

1.24.1 Secondary members, i.e. longitudinals, beams, frames and bulkhead stiffeners forming part of the hull structure are, in general, to be connected at their ends in accordance with the requirements of this Section. Where it is desired to adopt bracketless connections, the proposed arrangements will be individually considered on the basis of 1.17.5.

1.24.2 Where end connections are fitted in accordance with these requirements, they may be taken into account in determining the effective span of the member.

1.24.3 Where a longitudinal strength member is cut at a primary support and the continuity of strength is provided by brackets, the scantlings of the brackets are to be such that their section properties and effective cross-sectional area are not less than those of the member. Care is to be taken to ensure correct alignment of the brackets on each side of the primary member.

1.24.4 The thickness of the bracket webs is to be not less than that required for the webs of the stiffening member. *See* 1.14.

1.24.5 The arrangement of the connection between the stiffener and the bracket is to be such that at no point in the connection are the properties reduced to less than that of the stiffener with associated plating.

1.24.6 The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint.

1.24.7 Hard spots are to be avoided in way of end connections.

1.25 Scantlings of end brackets

1.25.1 Secondary members, i.e. longitudinals, beams, frames and bulkhead stiffeners forming part of the hull structure, are generally to be connected at their ends in accordance with the requirements of this Section. Where it is desired to adopt bracketless connections, the proposed arrangements will be individually considered.

1.25.2 Where end connections are fitted in accordance with these requirements, they may be taken into account in determining the effective span of the member.

1.25.3 The symbols used in this sub-Section are defined as follows:

t_w = the thickness of the bracket web, in mm

EI = section stiffness of the secondary member, in Ncm^4/mm^2

1.25.4 Typical arrangements of stiffener end brackets are shown diagrammatically in Fig. 3.1.8.

1.25.5 The section stiffness, (EI), in way of the bracket at the point to which the effective span of the stiffener, l_e, is measured is to be not less than two times the section stiffness of the basic stiffener.

1.25.6 The web thickness, t_w, and face width of end brackets are to be not less than that of the connecting stiffeners. Additionally the requirements of 1.16 are to be complied with.

1.25.7 Where brackets are of the inverted angle or 'T' bar stiffener section, their free edge is to be suitably stiffened by a flange or other equivalent means. The dimensions of the flange are to be such that the requirements of 1.16 are complied with.

1.25.8 Where the free edge of the bracket is hollowed out to form a 'soft-toe', the dimensions of the bracket arms and throat depth are to be increased such that the stiffness requirements of 1.16 are complied with.

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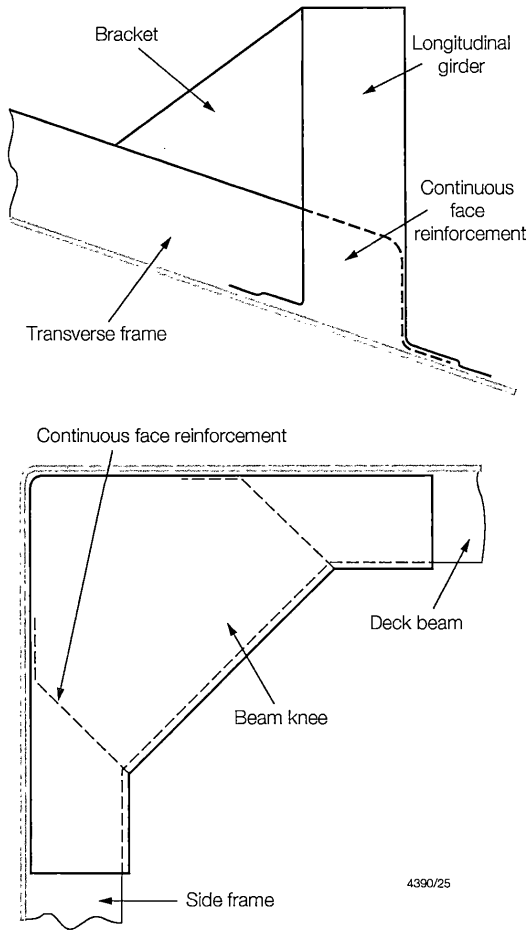

Fig. 3.1.8 Arrangement of end brackets

1.26 Primary member end connections

1.26.1 Primary members are to be so arranged as to ensure effective continuity of strength, and abrupt changes of depth or section are to be avoided. Where members abut on both sides of a bulkhead, or on other members, arrangements are to be made to ensure that they are in alignment. Primary members in tanks are to form a continuous line of support and wherever possible, a complete ring system.

1.26.2 The members are to have adequate lateral stability and web stiffening and the structure is to be so arranged as to minimise hard spots and other sources of stress concentration.

1.26.3 Primary members are to be provided with adequate end fixity by end brackets or equivalent structure. The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint and effective distribution of the load from the member.

1.26.4 Where the primary member is supported by structure which provides only a low degree of restraint against rotation, the member is generally to be extended for at least two frame spaces, or equivalent, beyond the point of support before being tapered.

1.26.5 Where primary members are subject to concentrated loads, particularly if these are out of line with the member web, additional strengthening will, in general, be required.

1.26.6 The thicknesses of the bracket webs are, in general, to be not less than those of the primary member webs. Where brackets are of the plate type, the free edge of the bracket is to be adequately stiffened and the plate positioned to limit any hard spot.

1.26.7 Where a deck girder or transverse is connected to a vertical member on the shell or bulkhead, the scantlings of the latter may be required to be increased to provide adequate stiffness to resist rotation of the joint.

1.26.8 Where a member is continued over a point of support, such as a pillar or pillar bulkhead stiffener, the design of the end connection is to be such as to ensure the effective distribution of the load into the support. Proposals to fit brackets of reduced scantlings, or alternative arrangements, will be considered.

1.26.9 Connections between primary members forming a ring system are to minimise stress concentrations at the junctions. Integral brackets are generally to be radiused or well rounded at their toes. The arm length of the bracket, measured from the face of the member, is to be not less than the depth of the smaller member forming the connection.

1.27 Arrangements and details

1.27.1 The arrangement of the connection between the stiffener and the bracket is to be such that at no point in the connection is the section stiffness (EI), reduced to less than that of the stiffener with associated plating.

1.27.2 The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint.

1.28 Web stability

1.28.1 Primary members of 'top-hat' or single plate laminate construction type section are to be supported by tripping brackets at, in general, four for top hat and alternate frame spacings for plate, of secondary stiffening members respectively.

1.29 Openings in the webs of stiffening members

1.29.1 Where openings are cut in the webs of stiffening members, the depth of the opening is not to exceed 50 per cent of the web depth, and the opening is to be so located that the edges are not less than 25 per cent of the web depth

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from the face laminate. The length of opening is not to exceed the web depth or 60 per cent of the secondary member spacing, whichever is the greater, and the ends of the openings are to be equidistant from the corners of cut-outs for secondary members. Where larger openings are proposed, the arrangements and compensation required will be specially considered.

1.29.2 Openings are to have smooth edges and well rounded corners. Exposed edges in way of cut-outs in single skin/plate laminate are to be suitably sealed with resin and/or be over laminated. Exposed edges in way of cut-outs in sandwich panels and top hat type stiffening members are to be overlaminated with a weight of laminate not less than the lower of the two skins which form the panel (or stiffener) or 2 mm in thickness whichever is the greater.

1.29.3 Cut-outs for the passage of secondary members are to be arranged so as to minimise the creation of stress concentrations. To avoid excessive use of filler material the breadth of cut-out is to be kept as small as necessary and the fit as accurate as practicable. Suitable fillets are to be arranged to ensure efficient bonding.

1.29.4 Consideration is to be given to the provision of adequate drainage and unimpeded flow of air and water when designing the cut-outs and connection details.

1.30 Continuity and alignment

1.30.1 The arrangement of material is to be such as will ensure structural continuity. Abrupt changes of shape or section, sharp corners and points of stress concentration are to be avoided.

1.30.2 Where members abut on both sides of a bulkhead or similar structure, care is to be taken to ensure good alignment.

1.30.3 Pillars and pillar bulkheads are to be fitted in the same vertical line wherever possible, and elsewhere arrangements are to be made to transmit the out of line forces satisfactorily. The load at head and heel of pillars is to be effectively distributed and arrangements are to be made to ensure the adequacy and lateral stability of the supporting members.

1.30.4 Continuity is to be maintained where primary members intersect and where the members are of the same depth, *see also* LR's *Guidance Notes for Structural Details*.

1.30.5 End connections of structural members are to provide adequate end fixity and effective distribution of the load into the supporting structure.

1.30.6 The toes of brackets, etc., are not to land on unstiffened panels of plating. Special care is to be taken to avoid notch effects at the toes of brackets, by making the toe concave or otherwise tapering it off in accordance with Fig. 3.4.1 in Chapter 3.

1.31 Arrangements at intersection of continuous secondary and primary members

1.31.1 Cut-outs for the passage of secondary members through the webs of primary members, and the related bonding arrangements, are to be so designed as to minimise stress concentrations around the perimeter of the opening and in the attached hull envelope or bulkhead plating. The critical shear buckling stress of the panel in which the cut-out is made is to be examined. Longitudinals will be required to have double bonding angles which may require to be locally increased in weight in areas of high stress, such as under bulkheads, machinery seating, mast steps, etc. The increased shear stresses in these areas are to be examined.

1.31.2 It is recommended that the web plate connection to the hull envelope, or bulkhead end in a smooth tapered 'soft toe'. Recommended shapes of cut-out are shown in Fig. 3.4.1, but consideration will be given to other shapes on the basis of maintaining equivalent strength and minimising stress concentration.

1.31.3 Alternative arrangements will be considered on the basis of their ability to transmit load with equivalent effectiveness. Details of the calculations made and testing procedures are to be submitted.

■ *Section 2*
Minimum thickness requirements

2.1 General

2.1.1 Structural laminates, used for both single skin and sandwich construction are, in general, to incorporate not less than 40 per cent, by weight, of woven or cross-ply reinforcement.

2.2 Single skin laminate

2.2.1 The minimum thicknesses of single skin laminates are as indicated in the appropriate Sections.

2.3 Sandwich skin laminate

2.3.1 The minimum amount of reinforcement in single skin laminates which form the inner and outer skins of sandwich panels are as indicated in 2.5.1. Where the structural requirements for thickness of either the bottom shell outer skin, or inner skin in way of an integral tank, is less than that required by 2.5.1, a 20 per cent reduction in the minimum amount of reinforcement will be acceptable, conditional upon a vacuum test to demonstrate the watertight integrity and also an impact test for impact resistance of the laminate, *see* 2.9.2.

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2.4 Laminate thickness of single skin laminates

2.4.1 The Rule minimum skin thicknesses for single skin laminates as determined from the appropriate Sections of the Rules are to be corrected for craft type irrespective of the reinforcement being used; the corrected minimum skin thickness of side, bottom, transom, wet-deck, vehicle deck and weather decks is to be determined from:

Single skin laminates:

$t_T = \omega\, t_{min}$

where

ω = Service Type Correction Factor given in Table 3.2.1

t_T = Rule minimum thickness corrected for craft type, in mm.

t_{min} = Rule basic minimum thickness, in mm.

2.4.2 All minimum thicknesses of laminate for both stiffener and single skin laminate components are based on an assumed fibre content, f_c, of 0,5. Where the fibre content by weight, f_c, is less than 0,5, the required minimum thicknesses are to be determined from:

$t_{fc} = t_{0,5}\,(1{,}65 - 1{,}3 f_c)$ mm

where

t_{fc} = minimum thickness at actual laminate fibre content, in mm

$t_{0,5}$ = Rule basic minimum laminate thickness at fibre content, by weight, of 0,5.

2.4.3 The equation in 2.4.2 relates to polyester 'E' glass laminates. Other laminates will be considered on an equivalence basis.

2.5 Minimum skin reinforcement in sandwich laminates

2.5.1 The minimum amount of reinforcement in single skin laminates, which form the inner and outer skins of sandwich laminates, is given in Table 3.2.2. The minimum amount of reinforcement is to be modified in accordance with 2.5.2 to 2.5.4.

2.5.2 The Rule minimum amount of reinforcement in 2.5.1 is to be corrected for craft type, irrespective of the reinforcement being used; the corrected minimum amount of reinforcement in the side, bottom, transom, wet-deck, vehicle deck and weather decks is to be determined from:

$W_T = \omega W_{min}$

where

W_T = Rule minimum amount of reinforcement corrected for craft type, in g/m^2

W_{min} = minimum amount of reinforcement given in Table 3.2.2

ω = Service Type Correction Factor given in Table 3.2.1.

Table 3.2.1 Service type correction factor (ω)

Service type notation	ω
Cargo	1,1
Passenger	1,00
Patrol	1,00
Pilot	1,1
Yacht	1,00
Workboat – Motor fishing vessel	1,2

2.5.3 The Rule minimum amount of reinforcement in Table 2.5.1 is to be corrected for craft length, irrespective of the reinforcement being used; the corrected amount of reinforcement is to be determined from:

$W_{Lc} = K_L\, W_{min}$

where

W_{Lc} = Rule minimum amount of reinforcement corrected for craft length

W_{min} = minimum amount of reinforcement given in Table 3.2.2

K_L = craft length correction factor

= $1{,}0 - f_{LS}$ for $L_R \le 15$ m

= 1,0 for $L_R \ge 35$ m

Intermediate values of K_L are to be determined by linear interpolation

f_{LS} = sandwich skin length factor given in Table 3.2.2 for mono-hull craft and Table 4.2.1 in Chapter 4 for multi-hull craft

= 0,0 for all sandwich panels in cargo, pilot and workboat crafts

L_R = Rule length, in metres, as defined in Pt 3, Ch 1,6.2.

2.5.4 The minimum amount of reinforcement is based on an assumed fibre content, f_c, of 0,5. Where the fibre content by weight, f_c, is greater than 0,5, the required minimum amount of reinforcement is to be determined from:

$W_{fc} = K_V\, W_{0,5}$

where

W_{fc} = minimum amount of reinforcement at actual laminate fibre content, in g/m^2

$W_{0,5}$ = Rule minimum amount of reinforcement laminate thickness at fibre content, by weight, of 0,5, in g/m^2

K_V = fibre volume correction factor for laminates with fibre content, by weight, greater than 0,5

$$= \left(\frac{1 + \frac{\zeta_F}{\zeta_R}}{1 + \left(\frac{\zeta_F}{\zeta_R}\right)\left(\frac{1 - f_c}{f_c}\right)} \right)^{0{,}67}$$

f_c, ζ_F and ζ_R are as defined in 1.5.1.

2.5.5 In areas where impact loads are not likely to occur, special consideration will be given to laminates with amount of reinforcement less than that required by 2.5.1, provided that all of the structural strength requirements of the Rules are complied with.

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Table 3.2.2 Minimum amount of reinforcement in sandwich laminate skins

Panel location	Minimum amount of reinforcement, W_{min} (g/m^2)		Sandwich skin length factor, f_{LS}
	Glass	Carbon/ Aramid	
Integral tanks, fluid barrier skin	3650	2700	0,0
Hull bottom, outer skin	3650	2700	0,33
Hull bottom, inner skin	2850	2100	0,33
Side shell, outer skin	3250	2400	0,33
Side shell, inner skin	2450	1950	0,33
Inner bottom, outer skin	3650	2700	0,33
Inner bottom, inner skin	2850	2100	0,33
Double bottom plate floor	1650	1300	0,0
Watertight bulkhead	1650	1300	0,0
Deep tanks, exterior skin	2450	1950	0,0
Deep tanks, fluid barrier skin	3250	2400	0,0
Strength/weather deck, outer skin	2450	1950	0,33
Strength/weather deck, inner skin	1650	1300	0,0
Lower deck/within deckhouse, accommodation decks	1650	1300	0,0
Cargo deck, outer skin	2450	1950	0,0
Cargo deck, inner skin	1650	1300	0,0
Superstructure sides	1650	1300	0,0
Superstructure front	2050	1500	0,0
Superstructure aft	1650	1300	0,0
Superstructure top	1650	1300	0,0
Coach roof	1650	1300	0,0
Machinery casings	2050	1500	0,0
Bulwarks	1650	1300	0,0

NOTE
The minimum amount of reinforcement in hybrid laminates will be individually considered on an equivalence basis. *See* 2.9.2.

2.6 Integral tank structure

2.6.1 The minimum thickness of laminate for all stiffening members passing through, or forming the boundary of integral oil fuel and water tanks is to be not less than 4,5 mm irrespective of fibre content.

2.6.2 Where the boundaries of integral oil fuel and water tanks are of sandwich skin construction the minimum amount of reinforcement in the laminate providing the fluid barrier, without satisfactory material testing, is to comply with the requirements of 2.5.1, *see* 2.3.1.

2.6.3 Where the boundaries of integral oil fuel and water tanks are of single skin construction, in no case is the tank laminate thickness, determined in accordance with 7.4, to be less than 5,0 mm irrespective of fibre content.

2.7 Novel features

2.7.1 Where the Rules do not specifically define the requirements for novel features, the scantlings and arrangements are to be determined by direct calculations. Such calculations are to be carried out on the basis of the Rules, Recognised Standards and good practice, and are to be submitted with the relevant construction plans for appraisal, *see also* Ch 1,2.6.

2.8 Impact considerations

2.8.1 Due consideration is to be given to the scantlings of all structures which may be subject to local impact loadings. Impact tests may be required to be carried out at the discretion of LR to demonstrate the suitability of the proposed scantlings for a particular application.

2.8.2 The minimum skin thickness requirements may, subject to the agreement of LR, be reduced provided that suitable impact tests are carried out to demonstrate that the proposed laminates have not less than the equivalent impact resistance to that of a laminate which satisfies the Rule minimum thickness. In addition it is assumed that this reduced laminate satisfies the structural strength and deflection requirements of the Rules.

2.9 Sheathing

2.9.1 Areas of shell and deck which are subject to additional wear by abrasion e.g., passenger routes, working areas of fishing craft, forefoot region, etc, are to be suitably protected by local reinforcement as given in 3.14 or sheathing. This sheathing may be of timber, rubber, steel, additional layers of reinforcement, etc., as appropriate. Details of such sheathing and the method of attachment are to be indicated on the relevant construction plans submitted for appraisal.

2.9.2 The attachment of sheathing by mechanical means such as bolting or other methods is not to impair the structural integrity of the laminate or the watertight integrity of the craft. Through bolting of the hull is to be kept to a minimum and avoided where practicable. The design arrangements in way of any through bolting is to be such that damage to the sheathing will not impair the watertight integrity of the attachment to the hull.

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Section 3
Shell envelope laminate

3.1 General

3.1.1 The requirements in respect of the general plating elements of the shell envelope, excluding the deck, are contained within this Section.

3.2 Keel plate

3.2.1 The width, b_K, and thickness, t_K, of plate keels are not to be taken as less than:

$$b_K = 7{,}0L_R + 340 \text{ mm}$$

$$t_K = \sqrt{k_t}\ (5{,}0L_R^{0{,}45}) \text{ mm}$$

where

$$k_t = \frac{152}{\sigma_f}$$

L_R = Rule length, in metres, as defined in 1.5.1

σ_f = ultimate flexural strength of the keel plate material, in N/mm^2, *see* 1.12.6.

3.2.2 In no case is the thickness of the keel to be less than that of the adjacent bottom shell plating.

3.2.3 The width and thickness of plate keels are to be maintained throughout the length of the craft from the transom to a point not less than 25 per cent of the freeboard measured at the forward perpendicular (FP), above the deepest load waterline on the stem. Thereafter the keel thickness may be reduced to that required by 3.3 for the stem. Laminate tapers are to be in accordance with Ch 2,3.9.

3.2.4 Where the bottom shell is of sandwich construction the keel is, in general, to be formed by locally returning to single skin construction for a width as required by 3.2.1. The Rule thickness of keel is to comprise both the inner and outer skins of the adjacent bottom shell sandwich plus additional reinforcement as required. The distribution of reinforcement in way of the plate keel and sandwich bottom structure is to be in accordance with Fig. 3.3.1.

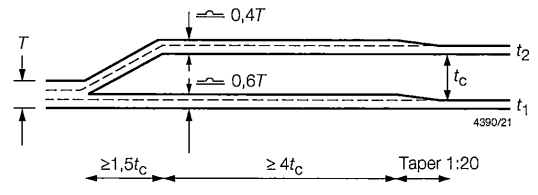

Fig. 3.3.1
Single skin/sandwich skin intersection detail

3.2.5 For large or novel craft, or yachts with externally attached ballast keels, or where it is proposed to incorporate keels of the 'bar' type the scantlings of the keel will be specially considered.

3.3 Stem plate

3.3.1 The thickness of the plate stem, t_s, is not to be taken as less than that given by the following expression:

$$t_s = \sqrt{k_t}\ (0{,}29L_R + 9) \text{ mm}$$

where

k_t = as defined in 3.2.1

L_R = Rule length, in metres, as defined in 1.5.1

σ_f = ultimate flexural strength of the stem plate material, in N/mm^2, *see* 1.12.6.

3.3.2 In no case is the thickness of the plate stem to be taken as less than the thickness of the adjacent side shell plating.

3.3.3 The width of the plate stem is to be not less than the width of keel as required by 3.2.1.

3.3.4 Plate stems are to be supported by horizontal diaphragms and, where the stem radius is large, a centreline stiffener or web may be required.

3.3.5 Where the side shell is of sandwich construction the stem is to be formed by locally returning to single skin construction for a width as required by 3.2.1. The Rule thickness of stem is to comprise both the inner and outer skins of the adjacent side shell sandwich plus additional reinforcement as required. The distribution of reinforcement in way of the plate stem and sandwich bottom structure is to be in accordance with Fig. 3.3.1.

3.3.6 For large or novel craft, the scantlings of the stem will be specially considered, *see also* 5.11.

3.4 Bottom

3.4.1 The bending moment assumed to be carried by the bottom shell plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for high speed or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 3.4.2 and 3.4.4 respectively.

3.4.2 An estimate of the thickness of **bottom single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

3.4.3 In no case is the minimum thickness of single skin plating to be taken as less than 5,5 mm.

3.4.4 An estimate of the stiffness EI, thickness of single skin plating for outer and inner skins of the **bottom sandwich panel** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and

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1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

3.4.5 The amount of reinforcement in laminates which form the skins of a sandwich laminate is to comply with the requirements of 2.5.1, *see* 2.3.1.

3.4.6 For all craft types, the minimum bottom shell thickness as required by 3.4.3 and 3.4.5 is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

3.4.7 Additionally, for high speed craft, the minimum thickness requirements for the bottom shell between the bilge tangential points or chines and the chine line or 150 mm above the static load waterline, whichever is the greater, is not to be less than determined for the side shell using the side shell impact pressure or the bottom shell hydrostatic or pitching pressures associated with a displacement or semi-displacement type craft whichever is the greater, *see* Fig. 3.3.2.

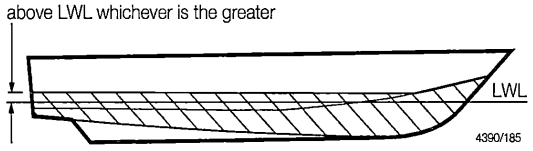

Fig. 3.3.2 Extent of bottom shell

3.4.8 Special consideration may be given to laminate thicknesses lesser than those required by 3.4.2 and 3.4.4, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided, *see* 2.3.1, and the equivalent impact resistance is demonstrated as required by 2.8.2.

3.5 Side

3.5.1 The bending moment assumed to be carried by the side shell plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 3.5.2 and 3.5.4 respectively.

3.5.2 An estimate of the thickness of **side single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

3.5.3 In no case is the minimum thickness of single skin plating to be taken as less than 5 mm.

3.5.4 An estimate of the stiffness *EI*, thickness of single skin plating for outer and inner skins of the **side sandwich panel** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

3.5.5 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of 2.5.1.

3.5.6 Special consideration may be given to laminate thicknesses lesser than that required by 3.5.3 and 3.5.5, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided, *see* 2.3.1, and the equivalent impact resistance is demonstrated as required by 2.8.2.

3.6 Sheerstrake

3.6.1 The sheerstrake, is in general, to be taken as the side shell, locally reinforced in way of deck/hull connection and fender attachment. The amount of local reinforcement will be dependent upon the arrangement of structure and the proposed service, but is not to be less than that required by 3.14.

3.6.2 The fendering arrangements for all craft types are the responsibility of the designers/Builders and are outside the scope of classification.

3.6.3 Where the pressure or impact loadings that a particular type of craft will experience in service are considered by the Builder, or subsequent Owner, to be not covered by, or be greater than, those indicated in Part 5 of the Rules, details of the loadings together with the calculations of how these will be satisfactorily distributed into the craft's structure, are to be submitted for consideration with the relevant construction plans.

3.6.4 The arrangements indicated in 3.6.5, 3.6.6, 4.19.5 and 4.19.6 for pilot and fishing craft are for the guidance of the Builder and subsequent Owners/operators of the craft. Where the intended service for either of these types of craft, or other types of craft which may be subject to loadings resulting from contact with other craft, jetties or similar loading or boarding facilities, is such that the loadings are greater than those that can be satisfactorily distributed into the craft's structure by the arrangements indicated, the strengthening arrangements are to be increased accordingly.

3.6.5 For **pilot craft** and other general workboats which may be subject to repeated impact loadings from contact with other craft, etc., the sheerstrake laminate and stiffening arrangements in way are to be increased locally. An increase in laminate weight of not less than 50 per cent of the side shell laminate weight is to be fitted, extending in general from the bow aft over a distance of $0{,}33L_R$ or 500 mm aft of the point at which the craft reaches its greatest breadth, whichever is the greater, and around the quarters. The additional weight is to extend forward of the quarter and over the transom for a

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distance of $0{,}075L_R$ or 1,0 m, whichever is the greater. This reinforcement is in general to extend from the deck edge to below the first longitudinal stiffener, or a vertical distance equivalent to 1/3 the freeboard height, whichever is the greater. The additional laminate weight is then to be tapered out to the side shell laminate weight in accordance with the Rules, *see* 3.14.2. For increase in stiffening arrangements, *see* 4.19. Where the side shell is of sandwich construction then in way of the sheerstrake the two skins of the sandwich are to combine and form a single skin. The weight of this single skin is to be the Rule single skin reinforced in accordance with the above or 1,5 times the total sandwich skin laminate weight whichever is the greater. The arrangement and distribution of this additional laminate between the skins in way of the taper is to be in accordance with 3.2.4. Where fendering can be considered to act as a chine/spray rail the extent of bottom shell laminate is, in general, to be to above the lower fender.

3.6.6 **Fishing craft** are, in general, to have their shell laminate as required to satisfy the Rule loadings, increased by 20 per cent. Additionally the side shell is not to be taken as less than the bottom shell weight, and where there are gallows, gantries, nets, or lines, etc., the laminate in way is to be further increased locally and/or suitably protected by sheathing in timber, steel or other means. Where the hull is of sandwich construction in way of the sheerstrake the laminate is to combine to form a single skin as indicated in 3.6.2.

3.6.7 Individual consideration will be given to lesser scantlings than those required by 3.6.3. for fishing craft used for pleasure, light duties, etc. Details of the service are to be submitted for appraisal.

3.7 Transom boundary reinforcement

3.7.1 Additional reinforcement is to be moulded into the transom boundary.

3.7.2 For single skin construction, the total weight of reinforcement is to be not less than twice the weight of the adjacent side shell plate laminate, but need not be greater than Rule keel weight as required by 3.2.

3.8 Chine reinforcement

3.8.1 Additional reinforcement is to be moulded into the chine line knuckle boundary, chines and other areas where there is a change of section.

3.8.2 The chine line knuckle is to be reinforced as required by 3.7 for the transom boundary.

3.8.3 Chine details are to be such that the continuity of structural strength across the panel is maintained. Details of all chines are to submitted for consideration, *see also* LR's *Guidance Notes for Structural Details*.

3.9 Skeg

3.9.1 The thickness of the skeg plating is, in general, to be not less than the thickness of the keel at bottom or 1,5 times the thickness of the bottom shell on the sides, whichever is the greater, *see also* 5.10.

3.10 Shell openings

3.10.1 Openings are to have smooth edges and well rounded corners. Exposed edges in way of cut-outs in single skin/plate laminate are, in general, to be suitably sealed over laminating with not less than 2 x 450 g/m^2 CSM (or equivalent) reinforcements. Alternative arrangements demonstrating the equivalent protection to the ingress of moisture into the laminate will be individually considered in association provided on the relevant plans.

3.10.2 The exposed edges of all openings cut in sandwich panels are to be suitably sealed. In general a high density foam core (or equivalent material) is to be used around the perimeter of such openings. Exposed edges in way of cut-outs in sandwich panels are to be overlaminated with a weight of laminate not less than that required for the outer skin of the sandwich panel.

3.10.3 Where other than an epoxy resin system is used the first layer of reinforcement, as required by 3.10.1 and 3.10.2, is, in general, to be CSM with a weight not exceeding 300 g/m^2.

3.10.4 Sea inlet boxes are to have well rounded corners and, so far as possible are to be kept clear of the bilge radius. Arrangements are to be made to maintain the continuity of structural strength in way of the openings.

3.11 Appendages

3.11.1 The scantlings of appendages will be subject to special consideration on the basis of the Rules and the design loadings anticipated, but are in no case to be taken as less than that of the surrounding structure.

3.12 Fin and tuck

3.12.1 Additional reinforcement is to be moulded into the fin and tuck areas of yachts which have either internal fixed ballast or external attached ballast keels, *see also* Part 16.

3.12.2 For single skin construction the total weight of reinforcement is not to be less than 1,50 times the weight of the adjacent bottom shell plate laminate, but need not be greater than the Rule keel weight as required by 3.2.

3.13 Transom

3.13.1 The thickness of the stern or transom is to be not less than that required by 3.4 and 3.5 as appropriate. Where water jet or sterndrive units are fitted, the scantlings of the plating in way of the nozzles and connections will be specially considered.

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3.14 Local reinforcement

3.14.1 The hull and deck are to be locally increased in thickness in way of fittings for rudder tubes, propeller brackets, passenger routes, vehicle lanes, etc. The amount of increase is to be not less than 50 per cent of the adjacent plate laminate. Details of such reinforcement are to be submitted.

3.14.2 Local reinforcement is in general to extend under the adjacent supporting structure and then be tapered gradually to the base laminate thickness over a distance of not less than 20 times the difference in thickness, *see* Fig. 3.3.3.

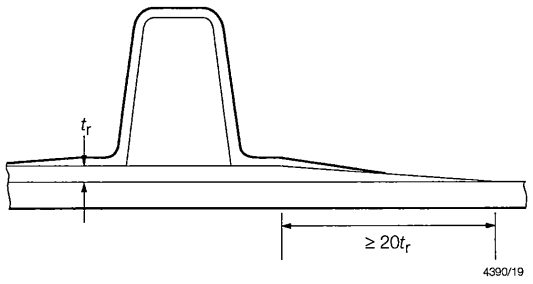

Fig. 3.3.3 Arrangement of local reinforcement

3.14.3 The amount of material laid 'wet on wet' is to be limited to avoid excessive heat generation.

3.15 Hull laminate arrangement

3.15.1 The hulls of all craft with a service speed of 25 knots or greater are to be moulded, such that following local impact, damage progressive stripping of surface reinforcements will not occur. This may be achieved by arranging all hull reinforcements as shown in Fig. 3.3.4.

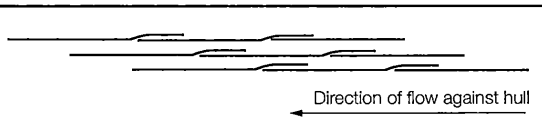

Fig. 3.3.4 Arrangement of hull reinforcement

3.15.2 Details of the laminate sequence and direction of orientation are to be indicated in the laminate schedule as required by Ch 2,3.3.7.

3.15.3 It is recommended that woven reinforcements be laid transversely to minimise the susceptibility to progressive stripping of hull laminates following local impact.

3.15.4 Special consideration is to be given to hull laminates where high glass content is proposed and where orthophthalic resins are used.

3.16 Novel features

3.16.1 Where the Rules do not specifically define the requirements for novel features then the scantlings and arrangements are to be determined by direct calculations. Such calculations are to be carried out on the basis of the Rules, recognised standards and good practice, and are to be submitted for appraisal.

Section 4
Shell envelope framing

4.1 Application

4.1.1 The requirements in this Section apply to longitudinally and transversely framed shell envelopes.

4.2 General

4.2.1 To determine the required scantlings, the formulae indicated in 1.14 are, in general, to be used in conjunction with the design loadings specified in Part 5.

4.3 Symbols and definitions

4.3.1 Symbols and definitions for use throughout this Chapter are as given in 1.5.1 or specified in the appropriate Section.

4.4 Bottom longitudinal stiffeners

4.4.1 The bottom longitudinals are to be supported by bottom transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.4.2 Bottom longitudinals are to be continuous through the supporting structures.

4.4.3 Where it is impracticable to comply with the requirements of 4.4.2, or where it is desired to terminate the bottom longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets.

4.4.4 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (b).

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4.4.5 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.5 Bottom longitudinal primary stiffeners

4.5.1 Bottom longitudinal primary stiffeners are to be supported by bottom deep transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 6 m apart.

4.5.2 Bottom longitudinal primary stiffeners are to maintain their continuity through the supporting structures.

4.5.3 Where it is impracticable to comply with the requirements of 4.5.2, or where it is desired to terminate the bottom longitudinal primary stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.5.4 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (a).

4.5.5 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.6 Bottom transverse stiffeners

4.6.1 Bottom transverse stiffeners are defined as local stiffening members which support the bottom shell, and which may be continuous or intercostal.

4.6.2 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (b).

4.6.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.7 Bottom transverse frames

4.7.1 Bottom transverse frames are defined as stiffening members which support the bottom shell, they are to be effectively continuous and be bracketed at their end connections to side frames and bottom floors as appropriate.

4.7.2 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (a).

4.7.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.8 Bottom transverse web frames

4.8.1 Bottom transverse web frames are defined as primary stiffening members which support bottom shell longitudinals, they are to be continuous and be substantially bracketed at their end connections to side web frames and bottom floors.

4.8.2 Where it is impracticable to comply with the requirements of 4.8.1, or where it is desired to terminate the bottom transverse web frames in way of bulkheads or integral tank boundaries, etc., they are to be bracketed in way of their end connections, to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed', *see* Fig. 3.4.1 and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.8.3 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (a).

4.8.4 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.9 Side longitudinal stiffeners

4.9.1 The side longitudinals are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.9.2 Side longitudinals are to be continuous through the supporting structures.

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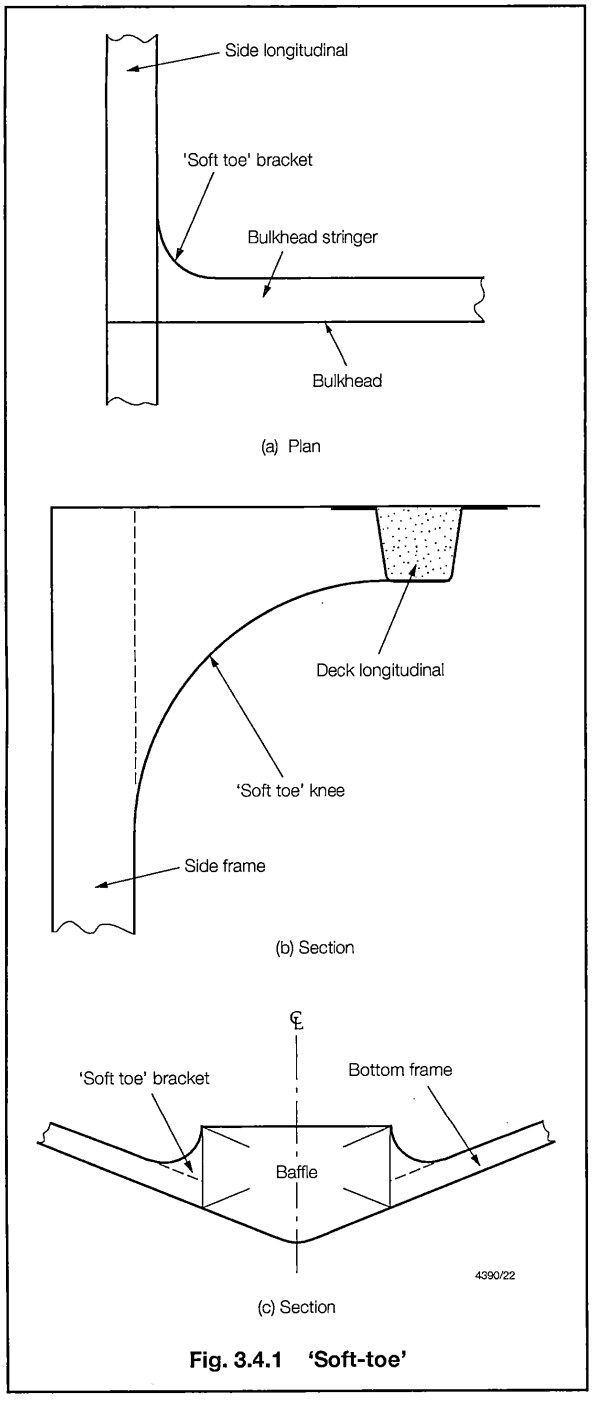

Fig. 3.4.1 'Soft-toe'

4.9.3 Where it is impracticable to comply with the requirements of 4.9.2, or where it is desired to terminate the side longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets.

4.9.4 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (b).

4.9.5 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.10 Side longitudinal primary stiffeners

4.10.1 Side longitudinal primary stiffeners are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 6 m apart.

4.10.2 Side longitudinal primary stiffeners are to maintain their continuity through the transverse bulkheads and other supporting structures.

4.10.3 Where it is impracticable to comply with the requirements of 4.10.2, or where it is desired to terminate the side longitudinal primary stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.10.4 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (a).

4.10.5 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.11 Side transverse stiffeners

4.11.1 Side transverse stiffeners are defined as local stiffening members which support the side shell, and which may be continuous or intercostal.

4.11.2 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (b).

4.11.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

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4.12 Side transverse frames

4.12.1 Side transverse frames are defined as stiffening members supporting the side shell and spanning continuously between bottom floors/frames and decks. They are to be effectively constrained against rotation at their end connections.

4.12.2 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (a).

4.12.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.13 Side transverse web frames

4.13.1 Side transverse web frames are defined as primary stiffening members which support side shell longitudinals, they are to be continuous and be substantially bracketed at their head and heel connections to deck beams and bottom web frames respectively.

4.13.2 Where it is impracticable to comply with the requirements of 4.13.1, or where it is desired to terminate the side transverse web frames in way of side longitudinal primary stiffeners, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections,to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.13.3 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (a).

4.13.4 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.14 Grouped frames

4.14.1 For the purposes of satisfying Rule requirements, frames may, subject to agreement by LR, be grouped. The number of frames in any group shall not in general exceed five. The summation of section stiffness, EI, for the group of frames is not to be less than the summation of the Rule requirements for the individual framing members. In addition, in no case is the proposed scantlings of an individual framing member within the group to be less than ninety per cent of the Rule value for that member.

4.15 Grillage structures

4.15.1 For complex girder systems, a complete structural analysis using numerical methods may have to be performed to demonstrate that the stress levels are acceptable when subjected to the most severe and realistic combination of loading conditions intended, *see also* 1.3.

4.15.2 General or special purpose computer programs or any other analytical techniques may be used provided that the effects of bending, shear, axial and torsion are properly accounted for and the theory and idealisation used can be justified.

4.15.3 In general, grillages consisting of slender girders may be idealised as frames based on beam theory provided proper account of the variations of geometric properties is taken. For cases where such an assumption is not applicable, finite element analysis or equivalent methods may have to be used.

4.16 Combined framing systems

4.16.1 Where longitudinal and transverse primary stiffeners form grillage structures the scantlings may be derived in accordance with 4.15.

4.17 Floating framing systems

4.17.1 Where the floating frame system is used, the effect of the plating attached to the stiffening members is to be ignored when calculating the required section stiffness, EI, of the primary stiffening members, i.e. the full section stiffness, EI, is to be provided by the primary stiffening member only.

4.18 Frame struts

4.18.1 Where struts are fitted to side shell transverse web frames or longitudinal primary stiffeners to carry axial loads the strut cross-sectional area is to be derived as for pillars in Section 10. If fitted at the stiffener half span point the stiffener section modulus may be taken as half the modulus derived from the general equations for the stiffening member being considered.

4.18.2 Design of end connections is to be such that the strut loads can be efficiently transmitted into the supporting structure.

4.19 Fenders and reinforcement in way

4.19.1 The design of and responsibility for the fendering on any craft rests with the designer and prospective Owner and are outside the scope of classification scantling approval requirements. The arrangement for fendering fitted should not be detrimental to the general working of the structure and therefore the requirements indicated in 4.19.2 to 4.19.6 are provided as recommendations of the areas requiring special consideration by the designer and Builder.

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4.19.2 Wood belting and fenders, which may be subject to considerable impact load, are to be bedded down on a flexible sealing compound or a neoprene type gasket to ensure watertightness. The bolts are to be both adequate in number and size and, where practicable, reeled to prevent perforation of the laminate. Substantial plate washers or, where practicable, a continuous backing plate are to be provided. The arrangement for the attachment of the fender should, in general, be arranged so that where sections of the fender are damaged or torn, the watertight integrity of the hull is not impaired.

4.19.3 The laminate in way of such fittings is to be substantially increased in thickness to prevent overloading, and depending on the position, a back-up block of wood, plastic or metal may be required.

4.19.4 For craft such as pilot craft, fishing craft, etc., which may be subject to repeated impact loadings from contact with other craft whilst in service, due consideration is to be given to increasing the scantlings of stiffening members in way of the fenders. Details of these increased scantlings, anticipated loadings and calculations, are to be indicated on the submitted plans, *see also* 3.6.3 and 3.6.4.

4.19.5 **Pilot craft** are, in general, to be fitted with large knees in way of the sheerstrake in areas as indicated in 3.6.5. The knees are to be aligned between the transverse frames and the deck beams. The thickness of the webs for these knees is to be twice that required by 1.16 or 6 mm at a fibre content by weight, of 0,5. Where the fibre content is less than 0,5 the minimum thickness is to be increased by the factor k_c as follows:

$$t_{min} = 6k_c$$

where

$k_c = 1{,}65 - 1{,}3f_c$

f_c is as defined in 1.5.1.

In the case of longitudinally framed craft, web frames with knees are to be fitted at a spacing of generally no greater than 500 mm. A side longitudinal with a section modulus of, in general, twice that of the Rule longitudinal for the web frame spacing is to be positioned just below the lower fendering to carry the load associated with the dynamic loading from pitching and rolling. Consideration is also to be given to the termination of such brackets by use of a 'soft-toe' in way of the deck.

4.19.6 **Fishing craft** engaged in pair trawling and other modes of fishing, and which may be subject to repeated impact loading from contact with the other craft, are to have additional stiffening fitted in way of the impact areas. This may be in the form of large knees, intermediate knees or substantial fendering/rubbing strakes. Additionally, the shell and deck in way of all working areas are to be suitably sheathed.

Section 5
Single bottom structure and appendages

5.1 General

5.1.1 The requirements of this Section provide for single bottom construction of mono-hull craft in association with either transverse or longitudinal framing.

5.1.2 All girders are to extend as far forward and aft as practicable and care is to be taken to avoid any abrupt discontinuity particularly in way of skegs. Where girders are cut at bulkheads, their longitudinal strength is to be maintained.

5.1.3 Particular attention is to be taken to ensure that the continuity of structural strength in way of the intersection of transverse floors and longitudinal girders is maintained. The face reinforcement of such stiffening members is to be effectively continuous.

5.1.4 The single bottom structure in way of the keel, skeg and girders is to be sufficient to withstand the forces imposed by dry-docking the craft.

5.1.5 The breadth and thickness of plate keels are to comply with the requirements detailed in 3.2. *See also* 3.9.1.

5.2 Centreline girder

5.2.1 In craft with single bottoms, a centreline girder is, in general, to be fitted in association with transverse frames, transverses supporting longitudinals or where the breadth of floors at the upper edge is greater than 1,5 m.

5.2.2 Centreline girders may be in the form of intercostal or continuous top hat or plate webs. Where the girder is intercostal, additional bracketing and local reinforcement as given in 3.14 is to be provided to maintain the continuity of structural strength. The face reinforcement in all cases is to be continuous.

5.2.3 The web depth of the centre girder in general is to be equal to the depth of the floors at the centreline as specified in 5.4.

5.2.4 The web thickness, t_w, for a centre girder of 'top-hat' type section is to be not less than that required by 1.16. or as determined as follows, whichever is the greater:

$$t_w = 1{,}28\sqrt{k_A}\ \left(\sqrt{L_R} + 1\right)\ \text{mm}$$

in no case is t_w to be taken less than 5,0 mm

where

k_A and L_R are as defined in 1.5.1.

5.2.5 The web thickness for a centre girder of single plate laminate construction is to be two times the thickness as required by 5.2.4.

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5.2.6 The face area of the centre girder, A_f, is to be not less than:

$$A_f = 1{,}18 L_R k_A \text{ cm}^2$$

where

k_A and L_R are as defined in 1.5.1.

5.2.7 The face area of the centre girder outside 0,5*L* about midships may be reduced to 80 per cent of the value given in 5.2.6.

5.2.8 The face thickness, t_f, is to be not less than the web thickness of the centre girder.

5.2.9 Additionally, the requirements of 4.5 for bottom longitudinal primary stiffeners are to be complied with.

5.3 Side girders

5.3.1 Where the floor breadth at the upper edge exceeds 6,0 m, side girders are to be fitted at each side of the centre girder such that the spacing between the side and centre girders or between the side girders themselves is not greater than 3 m. Side girders, where fitted, are to extend as far forward and aft as practicable and are, in general, to terminate in way of bulkheads, deep floors or other primary transverse structure.

5.3.2 In the engine room, additional side girders are generally to be fitted in way of the main machinery.

5.3.3 The face area of side girders, A_f, is not to be taken as less than:

$$A_f = 0{,}82 L_R k_A \text{ cm}^2$$

where

k_A and L_R are as defined in 1.5.1.

5.3.4 The face thickness, t_f, is not, in general, to be less than the web thickness of the side girder.

5.3.5 The web thickness, t_w, for side girders of 'top-hat' type section is to be not less than as required by 1.16 or as determined as follows, whichever is the greater:

$$t_w = 1{,}28 \sqrt{k_A L_R} \text{ mm}$$

where

k_A and L_R are as defined in 1.5.1

in no case is t_w to be taken less than 5,0 mm.

5.3.6 The web thickness for side girders of single plate laminate construction is to be two times the thickness as required by 5.3.5.

5.3.7 In addition, the requirements of 4.5 for bottom longitudinal primary stiffeners are to be complied with.

5.3.8 Watertight side girders, or side girders forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deep tanks as detailed in 7.3. and 7.4 respectively.

5.4 Floors, general

5.4.1 In transversely framed craft, floors are generally to be fitted at every frame and underneath each bulkhead.

5.4.2 In longitudinally framed craft, floors are to be fitted at every transverse web frame and bulkhead and generally at a spacing not exceeding 2 m. Additional transverse floors or webs are, in general, to be fitted at half web-frame spacing in way of engine seatings and thrust bearings, pillars, skegs, ballast/bilge keels and the bottom of the craft in the forefoot region.

5.4.3 The overall depth of transverse floors at the centre-line, d_f, is not to be taken as less than:

when $B < 10$ m $\quad d_f = 40\,(B + 0{,}85D)$ mm

when $B \geq 10$ m $\quad d_f = 40\,(1{,}5B + 0{,}85D) - 200$ mm

where

B is as defined in 1.5.1.

5.4.4 The web thickness, t_w, for transverse floors of 'top-hat' type section is to be not less than that required by 1.16 or as determined as follows, whichever is the greater:

$$t_w = \sqrt{k_A}\left(\frac{4{,}33 d_f}{1000} + 2{,}75\right)\left(\frac{s}{1000} + 0{,}5\right) \text{ mm}$$

where

d_f is as defined in 5.4.3.

k_A and s are defined in 1.5.1

In no case is t_w to be taken less than 5,0 mm.

5.4.5 The web thickness for transverse floors of single plate laminate construction is to be two times the thickness as required by 5.4.4.

5.4.6 If side frames are attached to the floors by brackets, the depth of floor may be reduced by 15 per cent and the floor thickness determined using the reduced depth. The brackets are to have the same thickness as the floors, and their arm lengths clear of the frame are to be the same as the reduced floor depth given above.

5.4.7 The face area of floors, A_f, is not to be taken as less than:

$$A_f = 0{,}82 L_R k_A \text{ cm}^2$$

where

k_A and L_R are as defined in 1.5.1.

5.4.8 The thickness of the face reinforcement, t_f, is to be not less than the web thickness.

5.4.9 In addition, the requirements of 4.8 for bottom transverse web frames are to be complied with.

5.4.10 Floors are generally to be continuous from side to side.

5.4.11 The tops of floors, in general, may be level from side to side. However, in craft having considerable rise of floor the depth of the floor plate may require to be increased to maintain the required mechanical properties of the section.

5.4.12 The floors in the aft peak are to extend over and provide efficient support to the stern tube where applicable.

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5.4.13 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for *watertight bulkheads or deep tanks* as detailed in 7.3 or 7.4 respectively.

5.5 Floors in machinery spaces

5.5.1 Floors within machinery spaces are to comply with the requirements of 5.4.

5.5.2 The depth and mechanical properties of floors between engine or gearbox girders is to be not less than that required to maintain continuity of structural integrity or 50 per cent of the depth given in 5.4.3. The web thickness and face reinforcement weight of such reduced height floors are to be increased appropriately in order to maintain the continuity of structural strength.

5.6 Machinery seating

5.6.1 The general requirements for machinery seating are given in Pt 3, Ch 2,6.9.

5.6.2 Main and auxiliary engines are to be effectively secured to the hull structure by seatings of adequate scantlings to resist the gravitational thrust, torque and vibration forces which may be imposed upon them.

5.6.3 The longitudinal girders forming the engine seating are to extend as far forward and aft as is practicable and are to be adequately supported by transverse floors or brackets.

5.6.4 Where stiffening is of plate construction, engine holding-down bolts are to be arranged as near as practicable to floors and longitudinal girders. When this cannot be achieved, bracket floors are to be fitted.

5.6.5 Machinery seatings are to be attached by means of primary bonding angles in accordance with 1.18.

5.7 Drainage arrangements

5.7.1 Suitable arrangements are to be made to provide free passage of air from all parts of the tanks to the air pipes, *see also* Pt 9, Ch 1,5.

5.7.2 Sufficient limber holes are to be positioned in the internal bottom structure to allow for the drainage of water from all parts of the bilge to the pump suctions.

5.7.3 Particular attention is to be given to the positioning of limbers to ensure adequate drainage and to avoid stress concentrations. *See* LR's *Guidance Notes for Calculation Procedures for Composite Construction*.

5.7.4 Openings in the webs of stiffening sections, baffle plates, etc., are, in general, to be formed by moulded-in preforms under top hat type stiffening. Edges of openings in plate laminates are to be suitably sealed in accordance with 1.29.

5.8 Rudder horns

5.8.1 The scantlings of the rudder horn will be specially considered and in the case of high aspect ratio or novel designs direct calculations will be required to be submitted in accordance with Pt 3, Ch 1,2.

5.9 Sternframes

5.9.1 Where it is proposed to mould a composite sternframe, the scantlings and arrangements will be specially considered on the basis of direct calculations and loadings submitted by the Builders and designers.

5.10 Skeg construction

5.10.1 Skegs are to be effectively integrated into the adjacent structure and their design is to be such as to facilitate this, *see also* 3.9.

5.10.2 The scantlings of skegs and the internal diaphragms at bulkheads and web frames are to be sufficient to withstand any docking forces to which they may be subjected.

5.11 Forefoot and stem

5.11.1 For craft of composite sandwich construction the forefoot region is to be so designed that in the event of local impact (*see also* 2.8) with floating debris, the resultant damage will be limited. This may be achieved by:

(a) Arranging the individual plies of the laminate such that any delamination will be directed to the outer surface of the laminate, *see* Fig. 3.5.1.
(b) The addition of a 'sacrificial nose', *see* Fig. 3.5.2.
(c) By the addition of suitable sheathing, in accordance with 2.9.
(d) For vessels where the operating high speed waterline results in the exposure of the forefoot region, the laminate sequence in the keel area will be specially considered.

5.12 Transom knee

5.12.1 Centre and side girders are to be bracketed to the transom framing members by means of substantial knees. The face flat area of the girders may be gradually reduced to that of the transom stiffening member in accordance with Fig. 3.5.3.

5.12.2 Hard spots are to be avoided in way of the end connection, and care taken to ensure that the stiffening member to which the transom knee is bracketed can satisfactorily carry the transmitted bending moment.

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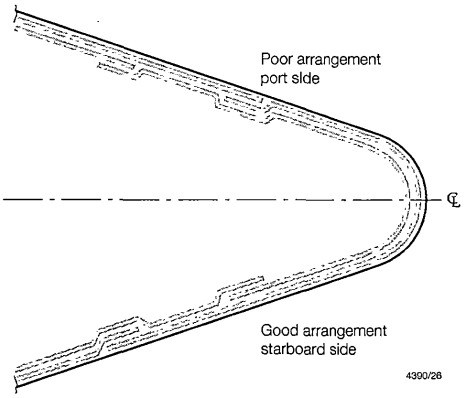

Fig. 3.5.1
Arrangement of laminate in way of forefoot and stem

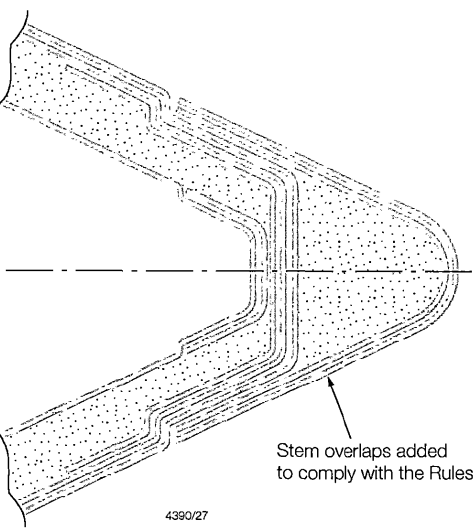

Fig. 3.5.2 'Sacrificial nose'

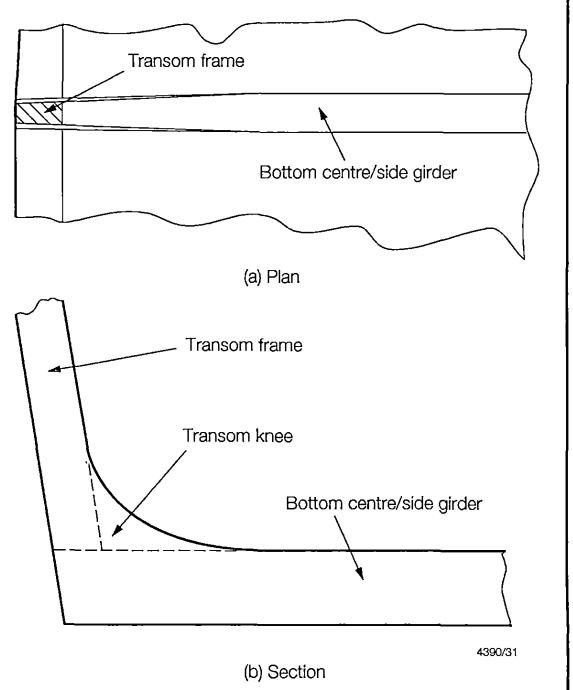

Fig. 3.5.3 Transom knee

■ *Section 6*
Double bottom structure

6.1 General

6.1.1 The requirements given in this Section provide for double bottom construction of mono-hull craft in association with either transverse or longitudinal framing.

6.1.2 Where required in accordance with Pt 3, Ch 2,6, double bottoms are generally to extend from the collision bulkhead to the after peak bulkhead, as far as this is practicable taking into account the design and proper working of the craft. In addition, the inner bottom is to be continued to the craft's side in such a manner as to protect the bottom to the turn of bilge or chine.

6.1.3 The double bottom structure in way of girders and duct keels is to be sufficient to withstand the forces imposed by dry-docking the craft.

6.1.4 The centreline girder and side girders are to extend as far forward and aft as practicable and care is to be taken to avoid any abrupt discontinuity. Where girders are cut at bulkheads, their longitudinal strength is to be maintained.

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6.2 Keel

6.2.1 The breadth and thickness of plate keels are to comply with the requirements of 3.2.

6.3 Centreline girder

6.3.1 A centreline girder is to be fitted throughout the length of the craft. The web thickness, t_w, of a centreline girder of 'top-hat' type section is to be not less than as required by 1.16 or as determined as follows, whichever is the greater and in no case is t_w to be taken less than 5 mm:

$$t_w = \sqrt{k_A}\left(\frac{L_R}{8} + 3{,}64\right) \geq 5 \text{ mm}$$

where

k_A and L_R are as defined in 1.5.1.

6.3.2 The web thickness of a centreline girder of single plate laminate construction is to be two times the thickness as required by 6.3.1.

6.3.3 The overall depth of the centre girder, d_{DB}, is not to be taken as less than 630 mm and is to be sufficient to give adequate access to all parts of the double bottom.

6.3.4 Additionally, the requirements of 4.5 for bottom longitudinal primary stiffeners are to be complied with.

6.4 Side girders

6.4.1 Where the breadth of the floor at the upper edge does not exceed 6,0 m, side girders are not required.

6.4.2 Where the breadth of the floor at the upper edge exceeds 6,0 m, side girders are to be fitted at each side of the centre girder such that the spacing between the side and centre girders or between the side girders themselves is not greater than 3 m. Side girders, where fitted, are to extend as far forward and aft as practicable and are, in general, to terminate in way of bulkheads, deep floors or other primary transverse structure.

6.4.3 Under the main engine, girders extending from the bottom to the top plate of the engine seating are to be fitted. The height of the girders is not to be less than the height of the floor. Engine holding-down bolts are to be arranged as near as practicable to the girders and floors. Where this cannot be achieved, bracket floors are to be fitted.

6.4.4 Side girders are to have a minimum web thickness, t_w, as required by 1.16 but not less than as determined as follows whichever is the greater and in no case is t_w to be taken less than 5,0 mm:

$$t_w = \sqrt{k_A}\ (0{,}064L_R + 4{,}32) \text{ mm}$$

where

k_A and L_R are as defined in 1.5.1.

6.4.5 The face area and face thickness of side girders are to comply with the requirements for plate floors as defined in 5.4.7 and 5.4.8 respectively.

6.4.6 Additionally, the requirements of 4.5 for bottom longitudinal primary stiffeners are to be complied with.

6.5 Bracket floors

6.5.1 Between plate floors, the shell inner bottom plating is to be supported by bracket floors. The brackets are to have the same thickness as plate floors and, where they are of single skin laminate construction, are to be stiffened on the unsupported edge.

6.5.2 In longitudinally framed craft, the brackets are to extend from the centre or side girder and margin plate to the adjacent longitudinal, but in no case is the breadth of the bracket to be taken less than 3/4 of the depth of centre girder. Brackets are to be fitted at every web frame at the margin plate, and those at the centre girder are to be spaced not more than 1,0 m apart.

6.5.3 In transversely framed craft, the breadth of the brackets attaching the bottom and inner bottom frames to the centre girder and margin plate is to be not less than 3/4 of the depth of the centre girder.

6.6 Plate floors

6.6.1 Plate floors may be of single skin, sandwich skin or 'top-hat' type construction.

6.6.2 The web thickness, t_w, for non-watertight plate floors of 'top-hat' type section is to be not less than as required by 1.16 or as determined as follows, whichever is the greater and in no case is t_w to be taken less than 5,0 mm.

$$t_w = \sqrt{k_A}\ (0{,}064L_R + 4{,}32) \text{ mm}$$

where

k_A and L_R are as defined in 1.5.1.

6.6.3 The web thickness for transverse floors of single plate laminate construction is to be two times the thickness as required by 6.6.2.

6.6.4 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of 2.5.1.

6.6.5 Additionally, the requirements of 4.8 for bottom transverse web frames are to be complied with.

6.6.6 Plate floors are generally to be continuous between the centre girder and the margin plate.

6.7 Watertight floors

6.7.1 The scantlings of watertight floors are to comply with the requirements for plate floors as detailed in 6.6.

6.7.2 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deep tanks as detailed in 7.3 or 7.4 respectively.

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6.8 Tankside brackets

6.8.1 The scantlings of tankside brackets are to comply with the requirements for plate floors as detailed in 6.6.

6.9 Inner bottom laminate

6.9.1 Inner bottom laminates forming boundaries of tank spaces, are also to comply with the requirements for water-tight bulkheads or deep tanks as detailed in 7.3 or 7.4 respectively and, where forming vehicle, passenger or other decks the requirements of Section 8 are to be complied with.

6.9.2 The bending moment assumed to be carried by the inner bottom plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 6.9.3 and 6.9.5 respectively.

6.9.3 An estimate of the thickness of the **inner bottom single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

6.9.4 In no case is the minimum thickness of single skin plating to be taken as less than 5 mm.

6.9.5 An estimate of the stiffness EI, the thickness of single skin plating for **outer and inner skins of the bottom sandwich panel** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

6.9.6 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of 2.5.1, *see* 2.3.1.

6.9.7 Special consideration may be given to laminate thicknesses lesser than that required by 6.9.4 and 6.9.6, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided, *see* 2.3.1, and the equivalent impact resistance is to be demonstrated as required by 2.8.2.

6.10 Inner bottom longitudinals

6.10.1 The inner bottom longitudinals are to be supported by inner bottom transverse web frames, floors, bulkheads, or other primary structures, generally spaced not more than 2 m apart.

6.10.2 Inner bottom longitudinals are to be continuous through the supporting structures.

6.10.3 Where it is impracticable to comply with the requirements of 6.10.2, or where it is desired to terminate the inner bottom longitudinals in way of bulkheads or integral tank boundaries, the longitudinals are to be bracketed in way of their end connections, to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets.

6.10.4 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (b).

6.10.5 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

6.11 Inner bottom transverse web framing

6.11.1 Inner bottom transverse web frames are defined as primary stiffening members which support inner bottom longitudinals. They are to be continuous and substantially bracketed at their end connections to bottom web frames, bottom floors and tankside brackets.

6.11.2 Where it is impracticable to comply with the requirements of 6.11.1, or where it is desired to terminate the inner bottom transverse web frames in way of centre or side girders, bulkheads or integral tank boundaries, etc., all web frames are to be bracketed in way of their end connections, to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

6.11.3 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (a).

6.11.4 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

6.12 Margin plates

6.12.1 A margin plate, if fitted, is to have a thickness as required for the inner bottom plating.

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6.13 Wells

6.13.1 Small wells constructed in the double bottom are not to extend in depth more than necessary. A well extending to the outer bottom may, however, be permitted at the after end of the shaft tunnel of the craft. Other well arrangements (e.g. for lubricating oil under main engines) may be considered provided they give protection equivalent to that afforded by the double bottom.

6.14 Transmission of pillar loads

6.14.1 In double bottoms under widely spaced pillars, the connections of the floors to the girders, and of the floors and girders to the inner bottom, are to be suitably increased. Where pillars are not directly above the intersection of plate floors and girders, partial floors and intercostals are to be fitted as necessary to support the pillars. Manholes are not to be cut in the floors and girders below the heels of pillars. Where longitudinal framing is adopted in the double bottom, equivalent stiffening under the heels of pillars is to be provided, and where the heels of pillars are carried on a tunnel, suitable arrangements are to be made to support the load.

6.15 Drainage arrangements

6.15.1 Suitable arrangements are to be made to provide free passage of air and water from all parts of the tanks to the air pipes and pump suctions.

6.15.2 Particular attention is to be given to the positioning of limbers to ensure adequate drainage and to avoid stress concentrations, *see also* 5.7.

6.15.3 Openings in the webs of stiffening sections, baffle plates, etc., are to be suitably sealed in accordance with 4.16.

6.16 Manholes

6.16.1 Sufficient manholes are to be cut in the inner bottom, floors and side girders to provide adequate access to and ventilation of all parts of the double bottom. The size of the manhole openings in plate laminates is not, in general, to exceed 50 per cent of the double bottom depth unless edge reinforcement is provided. Holes are, in general, not to be cut in the centre girder, except in tanks at the forward and after ends of the craft, and elsewhere where tank widths are reduced unless additional stiffening and/or compensation is fitted to maintain the structural integrity.

6.17 Pressure testing

6.17.1 Double bottoms are to be tested upon completion with a head of water representing the maximum internal pressure which could be experienced in service, but not less than a head of water equivalent to the level of the upper deck.

■ *Section 7*
Bulkheads and deep tanks

7.1 General

7.1.1 The requirements of this Section apply to craft with bulkheads of either sandwich or single skin composite construction.

7.1.2 Watertight and collision bulkheads are to be fitted in accordance with the requirements of Pt 3, Ch 2,4.

7.1.3 FRP composite bulkheads and plywood bulkheads are, where practicable, to be suitably attached to receiving frames, *see also* LR's *Guidance Notes for Structural Details*. The bulkheads are to be attached using double angles or equivalent, *see* 1.18. Proposals to fit bulkheads and tank boundaries on receiving strips in lieu of frames, will be individually considered.

7.1.4 Where bulkheads are of steel or aluminium construction, their scantlings and arrangements are to be in accordance with Pt 6, Ch 3 or Pt 7, Ch 3 respectively. The method of attachment to the framing will be specially considered.

7.1.5 For bulkheads in way of partially filled holds or tanks, sloshing forces may be required to be taken into account. Where such forces are likely to be significant, the scantlings will be required to be verified by additional calculations which are to be submitted with the plans.

7.1.6 In deep tanks which extend from side to side a centreline bulkhead is generally to be fitted. The bulkhead may be intact or perforated as desired. If intact the scantlings are to comply with the requirements of 7.4 and 7.11 for tank boundary bulkheads. If perforated, they are to comply with the requirements of 7.11 for washplates.

7.1.7 The scantlings of non-watertight or partial bulkheads are, in general, to be as required by 7.3 for watertight bulkheads. Non-watertight or partial bulkheads supporting hull framing are to have scantlings equivalent to frames or web frames, in the same position, as appropriate.

7.2 Symbols and definitions

7.2.1 The symbols and definitions for use within this Section are as given in 1.5.1.

7.3 Watertight bulkheads

7.3.1 Composite watertight bulkheads may be of sandwich construction, with or without stiffeners, or of single skin construction with closely spaced vertical or horizontal stiffeners. Where steel or aluminium alloy bulkheads are fitted, their scantlings and arrangements are to be in accordance with Pt 6, Ch 3 or Pt 7, Ch 3 respectively. Sandwich timber bulkheads, plywood bulkheads or other forms of bulkhead construction will be considered on the basis of equivalent strength and stiffness. Where bulkheads are of novel design they will be specially considered.

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7.3.2 The bending moment assumed to be carried by the watertight bulkhead plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 for both non-displacement or displacement type craft. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 7.3.3 and 7.3.5 respectively.

7.3.3 An estimate of the thickness of watertight **bulkhead single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

7.3.4 In no case is the minimum thickness of single skin plating to be taken as less than 2,5 mm.

7.3.5 An estimate of the stiffness *EI*, thickness of single skin plating for outer and inner skins of the **bulkhead sandwich panel** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

7.3.6 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of 2.5.1.

7.3.7 Special consideration may be given to laminate thicknesses lesser than that required by 7.3.4 and 7.3.6, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided, *see* 2.3.1, and the equivalent impact resistance is demonstrated as required by 2.8.2.

7.3.8 The Rule requirements for bending moment, shear force, shear stress and deflection for the bulkhead stiffeners are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 for both non displacement or displacement type craft, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the appropriate load model.

7.3.9 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

7.3.10 The geometric properties of stiffener sections are to be calculated in accordance with 1.15 using an effective width of attached plating as indicated in 1.7.

7.3.11 Bulkheads are to be suitably strengthened, if necessary, at the ends of deck girders and where subjected to concentrated loads.

7.3.12 Bulkheads in engine rooms that may be exposed to fuel oils are to be suitably protected against damage by fuel oil and by fire, *see* 7.15.

7.4 Deep tanks

7.4.1 Composite integral/deep tank bulkheads may be of sandwich construction with or without stiffeners, or of single skin with closely spaced vertical or horizontal stiffeners. Where steel or aluminium alloy integral/deep tank bulkheads are fitted, their scantlings and arrangements are to be in accordance with Pt 6, Ch 3 or Pt 7, Ch 3 respectively. Other forms of bulkhead construction will be considered on the basis of equivalent strength and stiffness. Where bulkheads are of novel design they will be specially considered.

7.4.2 The bending moment, M_b or M_c, as appropriate, assumed to be carried by the integral/deep tank bulkhead plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 for both non-displacement or displacement type craft. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 7.4.3 and 7.4.5 respectively.

7.4.3 An estimate of the thickness of **integral/deep tank bulkhead single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

7.4.4 In no case is the minimum thickness of single skin plating to be taken as less than 4,5 mm.

7.4.5 An estimate of the stiffness *EI*, thickness of single skin plating for outer and inner skins of **integral/deep tank bulkhead sandwich panels** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

7.4.6 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of 2.5.1, *see* 2.6.2.

7.4.7 Special consideration may be given to laminate thicknesses less than that required by 7.4.4 and 7.4.6, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided, *see* 2.3.1, and the equivalent impact resistance is demonstrated as required by 2.8.2.

7.4.8 The Rule requirements for bending moment, shear force, shear stress and deflection for the integral/deep tank stiffeners are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 for both non-displacement or displacement type craft, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (a).

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7.4.9 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

7.4.10 The geometric properties of stiffener sections are to be calculated in accordance with 1.15 using an effective width of attached plating as indicated in 1.7.

7.4.11 Integral/deep tank bulkheads are to be suitably strengthened, if necessary, at the ends of deck girders and where subjected to concentrated loads.

7.4.12 Integral/deep tank bulkheads in engine rooms that may be subjected to fuel oils are to be suitably protected against damage by fuel oil and by fire, *see* 7.15.

7.5 Double bottom tanks

7.5.1 The scantlings of double bottom tanks are to meet the structural requirements for deep tanks in accordance with 7.4.

7.5.2 Where the crown of a double bottom tank forms a vehicle, passenger or other deck, the requirements of Section 8 are also to be complied with.

7.6 Collision bulkheads

7.6.1 The scantlings of composite collision bulkheads are to meet the requirements of 7.3 but with allowable tensile, compressive and shear stress limits for collision bulkheads as indicated in Table 7.3.1 in Chapter 7.

7.6.2 If the collision bulkhead forms the boundary of a deep tank or cofferdam the requirements of 7.4 are to be complied with.

7.7 Gastight bulkheads

7.7.1 Where gastight bulkheads are fitted, in accordance with Pt 3, Ch 2,4, their scantlings are to be as required for watertight bulkheads.

7.7.2 Gastight bulkheads are to be fitted to protect accommodation spaces from gases and vapour fumes from machinery, exhaust and fuel systems.

7.8 Plywood bulkheads

7.8.1 Plywood used for bulkheads is to be high quality marine plywood, and is to be in accordance with the requirements of Ch 2,2.17.

7.8.2 The structural requirements of plywood watertight bulkheads are to be as required by 7.1.

7.9 Non-watertight or partial bulkheads

7.9.1 Where a bulkhead is structural but non-watertight, the scantlings are, in general, to be as required for watertight bulkheads or equivalent in strength to web frames in the same position. Partial bulkheads that are non-structural are outside the scope of LR classification.

7.10 Stiffeners passing through bulkheads

7.10.1 Primary longitudinal stiffening members are to be continuous through transverse bulkheads.

7.10.2 Where a stiffener passes through a watertight bulkhead the bonding of the stiffener and compensation in way is to be not less than the laminate weight of the bulkhead.

7.10.3 Where structural members pass through the boundaries of watertight bulkheads or integral/deep tanks, and leakage into the adjacent space could be hazardous or undesirable, suitable cofferdams are to be built into the cores of top-hat stiffeners on each side of the boundary. The minimum thickness of such cofferdams is 4,5 mm.

7.10.4 Pipe or cable runs through watertight bulkheads are to be fitted with suitable watertight glands.

7.11 Wash plates

7.11.1 Tanks are to be subdivided as necessary by internal baffles or wash plates and the minimum thickness of the laminate for any internal structure is not, in general, to be less than 4,5 mm at a fibre content of 0,5 or equivalent thickness. Baffles or wash plates which support hull framing are to have scantlings equivalent to web frames in the same position.

7.11.2 Wash plates and wash bulkheads are, in general, to have an area of perforation not less than 10 per cent of the total area of the bulkhead. The perforations are to be so arranged that the efficiency of the bulkhead as a support is not impaired.

7.11.3 The plate thickness is to be not less than the structural element from which the wash bulkhead is formed.

7.12 Cofferdams

7.12.1 A cofferdam is to be fitted between fresh water and oil fuel or sanitary tanks. The scantlings of cofferdams are to comply with the requirements for deep tank bulkheads given in 7.4.

7.13 Coatings

7.13.1 Fuel tanks are to incorporate a resin rich surface or be coated with an oil retardant resin on the internal exposed surfaces. Potable fresh water tanks are similarly to be coated with a suitable non-tainting resin.

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7.14 Air pipes

7.14.1 Air pipes sufficient in number and area are to be fitted to each tank in accordance with Pt 15, Ch 2,11.

7.15 Fire protection

7.15.1 Fire protection requirements as given in Part 17 are to be complied with.

7.16 Access

7.16.1 All compartments within the craft are to be accessible in order to facilitate proper maintenance and future structural surveys. Linings on craft-sides, deck-heads and bulkheads etc., must be capable of being removed. Similarly, sufficient space must be available below lower decks/soles to provide proper access to the bottom structure; an adequate number of manholes, removable panels, etc., are to be provided for this purpose.

7.16.2 Doors fitted through watertight bulkheads are to be of equivalent construction to the bulkhead in which they are fitted, permanently attached, capable of being closed watertight from both sides of the bulkhead and are to be tested watertight.

7.16.3 Doors or hatches are not to be fitted in collision bulkheads, except in craft of less than 21 m Rule length, L_R, or where it would be impracticable to arrange access to the forepeak other than through the collision bulkhead. Where fitted, such doors or hatches are to be watertight, as small as practicable and are to open into the forepeak compartment. Consideration will be given to operation from one side only. Doors or hatches in collision bulkheads are to be kept closed at all times while the craft is at sea.

7.16.4 Particular attention is to be given to the design and workmanship of adequate access manholes in tanks.

7.16.5 Where a manhole is fitted in a tank, the exposed edges of all openings cut in sandwich panels are to be suitably sealed. In general a high density foam core (or equivalent material) is to be used around the perimeter of such openings. Exposed edges in way of cut-outs in sandwich panels are to be overlaminated with a weight of laminate not less than that required for the skin of the sandwich panel exposed to the fluid or as required by 2.5.1, whichever is the greater, *see* 2.3.1.

7.16.6 Manhole covers are to be attached using bolts/studs spaced at not greater than six diameters. The cover is to be fitted on a suitable seal. Where studs or bolts used to attach the cover plate to the manhole pass through the laminate, they are to be suitably secured, sealed and over-laminated.

7.17 Testing

7.17.1 Integral/deep tanks are to be tested by air pressure or by a head of water. If tested by water, the head is to be either to 1,8 m above the crown of the tank or to the top of the air or overflow pipe, whichever is the greater. When tested by air, the pressure is not to exceed 0,014 N/mm^2. The head to which the tank will be subjected in service is to be indicated on the plans submitted.

■ *Section 8* Deck structures

8.1 General

8.1.1 The deck structure may be of either single skin or sandwich construction and is to be supported by transverse beams with fore and aft girders or by longitudinals with deep transverse beams.

8.1.2 Beams are to be fitted at each frame position and be bracketed to the side frames. Strong beams and deep transverse beams are to align with and be effectively connected to the side web frames. They are also to be fitted at the ends of large openings in the deck.

8.1.3 The ends of beams, longitudinals, girders and transverses are to be effectively built into the adjacent structure, or equivalent arrangements provided.

8.1.4 Primary stiffening members are to be continuous and substantially bracketed at their end connections to maintain continuity of structural strength.

8.1.5 Secondary stiffening members are to be effectively continuous and bracketed at their end connections as appropriate.

8.1.6 Deck structures subject to concentrated loads, such as pillars out of line, are to be suitably reinforced. Where concentrations of loading on one side of a stiffener may occur, the stiffener is to be adequately stiffened against torsion. Additional reinforcements may be required in way of localised areas of high stress.

8.1.7 Deck structures are to comply with the minimum thickness requirements of Section 2.

8.1.8 Tripping brackets are to be fitted on deep webs.

8.2 Symbols and definitions

8.2.1 The symbols defined in 1.5.1 apply, unless otherwise specified.

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8.3 Strength/weather deck laminate

8.3.1 The bending moment assumed to be carried by the strength/weather deck plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 8.3.2 and 8.3.4 respectively.

8.3.2 An estimate of the thickness of **strength/weather deck single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

8.3.3 In no case is the minimum thickness of single skin plating to be taken as less than 4 mm.

8.3.4 An estimate of the stiffness EI, thickness of single skin plating for outer and inner skins of the **strength/weather deck sandwich panels** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

8.3.5 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of 2.5.1.

8.3.6 Special consideration may be given to laminate thicknesses lesser than that required by 8.3.3 and 8.3.5, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided, *see* 2.3.1, and the equivalent impact resistance is demonstrated as required by 2.8.2.

8.3.7 The scantlings of watertight cockpits are to be of equivalent strength to those for the strength/weather deck, *see also* Part 4.

8.3.8 It is recommended that working areas of the weather deck have an anti-slip surface.

8.3.9 Where decks are sheathed with wood or other materials, details of the method of attachment are to be submitted, *see also* 2.9.

8.4 Lower deck/inside deckhouse deck laminate

8.4.1 The bending moment assumed to be carried by the lower deck/inside deckhouse deck plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 8.4.2 and 8.4.4 respectively.

8.4.2 An estimate of the thickness of the **lower deck/inside deckhouse deck single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

8.4.3 In no case is the minimum thickness of single skin plating to be taken as less than 3 mm.

8.4.4 An estimate of the stiffness EI, thickness of single skin plating for outer and inner skins of the **lower deck/inside deckhouse deck sandwich panels** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

8.4.5 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of 2.5.1.

8.4.6 Special consideration may be given to laminate thicknesses lesser than that required by 8.4.3 and 8.4.5, provided that all of the structural strength requirements of the Rules are complied with.

8.5 Accommodation deck laminate

8.5.1 Accommodation decks are, in general, to be treated as lower deck/inside deckhouse decks, with their scantling requirements determined in accordance with 8.4.

8.5.2 Sandwich timber, plywood or other forms of deck construction will be considered on the basis of equivalent strength and stiffness.

8.6 Cargo deck laminate

8.6.1 The bending moment assumed to be carried by the cargo deck plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 8.6.2 and 8.6.4 respectively.

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8.6.2 An estimate of the thickness of the **cargo deck single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

8.6.3 In no case is the minimum thickness of single skin plating to be taken as less than 4 mm.

8.6.4 An estimate of the stiffness EI, thickness of single skin plating for outer and inner skins of the **cargo deck sandwich panels** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

8.6.5 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of 2.5.1.

8.6.6 Special consideration may be given to laminate thicknesses lesser than that required by 8.6.3 and 8.6.5, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided, *see* 2.3.1, and the equivalent impact resistance is demonstrated as required by 2.8.2.

8.7 Decks forming crown of tanks

8.7.1 Decks forming the crowns of tanks are to comply with the requirements for the appropriate deck and, are to be additionally examined for compliance with the requirements for deep tanks given in 7.4.

8.8 Strength/weather deck stiffening

8.8.1 The Rule requirements for bending moment, shear force, shear stress and deflection for the **strength/weather deck primary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (a).

8.8.2 The Rule requirements for bending moment, shear force, shear stress and deflection for the **strength/weather deck secondary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.8.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

8.8.4 The geometric properties of stiffener sections are to be calculated in accordance with 1.15 using an effective width of attached plating as given in 1.7.

8.9 Lower deck/inside deckhouse stiffening

8.9.1 The Rule requirements for bending moment, shear force, shear stress and deflection for the lower deck/inside deckhouse stiffeners are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the appropriate load model. Primary members are assumed to be load model (a), secondary members are, in general, assumed to load model (b), however special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.9.2 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

8.9.3 The geometric properties of stiffener sections are to be calculated in accordance with 1.15 using an effective width of attached plating as given in 1.7.

8.10 Accommodation deck stiffening

8.10.1 Accommodation decks are, in general, to be treated as lower deck/inside deckhouse decks, with their scantling requirements determined in accordance with 8.9.

8.11 Cargo decks

8.11.1 The Rule requirements for bending moment, shear force, shear stress and deflection for cargo deck stiffeners are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the appropriate load model. Primary members are assumed to be load model (a), secondary members are, in general, assumed to be load model (b), however special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided. Additionally where the cargo comprises wheeled vehicles the requirements of Ch 5,3 are to be complied with.

8.11.2 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

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8.11.3 The geometric properties of stiffeners sections are to be calculated in accordance with 1.15 using an effective width of attached plating as given in 1.7.

8.12 Deck openings

8.12.1 All openings are to be supported by an adequate framing system, pillars or cantilevers. When cantilevers are used, stiffening requirements may be derived from direct calculations.

8.12.2 Where stiffening members are stopped in way of an opening, they are to be attached to carlings, girders, transverses or coamings.

8.12.3 The corners of large hatchways in the strength/weather deck within 0,5*L* amidships are to be elliptical, parabolic or rounded, with a radius generally not less than 1/24 of the breadth of the opening.

8.12.4 Where elliptical corners are arranged, the major axis is to be fore and aft, the ratio of the major to minor axis is to be not less than two to one, nor greater than 2,5 to 1, and the minimum half-length of the major axis is to be defined by l_1 in Fig. 3.8.1. Where parabolic corners are arranged, the dimensions are also to be as shown in Fig. 3.8.1.

8.12.5 Where the corners are parabolic or elliptical, increased thickness of laminate will, in general, not be required.

8.12.6 For other shapes of corner, reinforcement of the size and extent shown in Fig. 3.8.2 will, in general, be required. The required weight of reinforcement is to be not less than 25 per cent greater than the adjacent deck laminate.

8.12.7 For lower decks the corners of large openings are to be rounded, with a radius generally not less than 1/24 of the breadth of the opening.

8.12.8 Reinforcement as given in 8.12.6 will be required at lower decks in way of rapid change in hull form to compensate for loss of deck cross-sectional area. Otherwise, reinforcement will not normally be required.

8.12.9 Adequate transverse strength is to be provided in the deck area between large hatch openings subjected to transverse and buckling loads.

8.12.10 The requirements for closing arrangements and outfit are given in Pt 3, Ch 4.

8.13 Sheathing

8.13.1 The requirements for deck sheathing are given in 2.9.

8.14 Novel features

8.14.1 Novel features will be specially considered in accordance with 2.7.

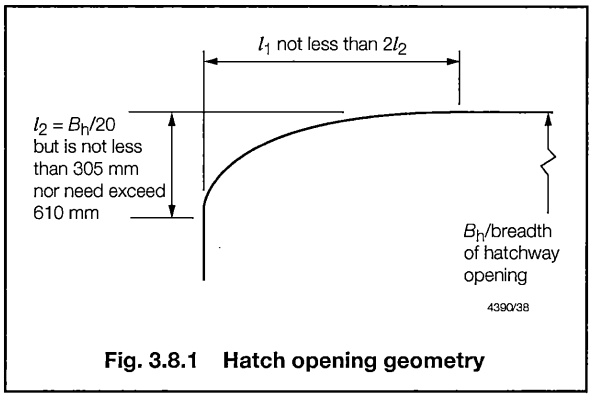

Fig. 3.8.1 Hatch opening geometry

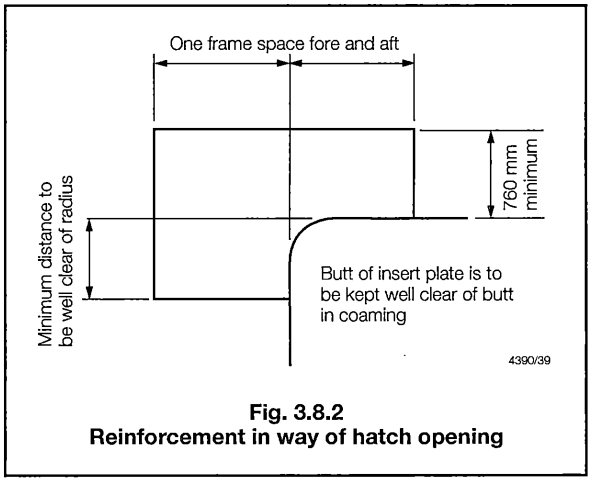

Fig. 3.8.2
Reinforcement in way of hatch opening

8.14.2 Where large or novel hatch openings are proposed, detailed calculations are to be submitted to demonstrate that the scantlings and arrangements in way of the openings are adequate to maintain continuity of structural strength.

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Section 9
Superstructures, deckhouses and bulwarks

9.1 General

9.1.1 Superstructures, deckhouses and bulwarks may be of single skin or sandwich construction or a combination of both.

9.1.2 Where practicable, superstructures and deckhouses are to be designed with well cambered decks and well radiused corners to build rigidity into the structure.

9.1.3 The laminate and supporting structure are to be suitably reinforced in way of stressed corners of openings, cranes, masts, derrick posts, machinery, fittings and other heavy or vibrating loads.

9.1.4 Primary stiffening members are to be continuous and substantially bracketed at their end connections to maintain continuity of structural strength.

9.1.5 Secondary stiffening members are, in general, to be continuous through supporting structures.

9.1.6 Structures subject to concentrated loads, such as pillars out of line, are to be suitably reinforced. Where concentrations of loading on one side of a stiffener may occur, the stiffener is to be adequately stiffened against torsion. Additional reinforcements may be required in way of localised areas of high stress.

9.1.7 Structures are to comply with the minimum thickness requirements of Section 2.

9.1.8 Where a superstructure is fitted, the side shell plating, in way of the end of the superstructure, may be required to be increased in thickness, *see* 3.14.

9.2 Symbols and definitions

9.2.1 The term 'house' is used in this Section to include both superstructures and deckhouses.

9.2.2 The symbols for use within this Section are as defined in 1.5.1 unless otherwise specified.

9.3 House side laminates

9.3.1 The bending moment assumed to be carried by the house side plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 9.3.2 and 9.3.4 respectively.

9.3.2 An estimate of the thickness of **house side single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.3.3 In no case is the minimum thickness of single skin plating to be taken as less than 2,5 mm.

9.3.4 An estimate of the stiffness EI, thickness of single skin plating for outer and inner skins of the **house side sandwich panels** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.3.5 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of 2.5.1.

9.4 House front laminates

9.4.1 The bending moment assumed to be carried by the house front plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 9.4.2 and 9.4.4 respectively.

9.4.2 An estimate of the thickness of **house front single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.4.3 In no case is the minimum thickness of single skin plating to be taken as less than 3,0 mm.

9.4.4 An estimate of the stiffness EI, the thickness of single skin plating for outer and inner skins of the **house front sandwich panels** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.4.5 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of 2.5.1.

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9.5 House aft end laminates

9.5.1 The bending moment assumed to be carried by the house aft end plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 9.5.2 and 9.5.4 respectively.

9.5.2 An estimate of the thickness of **house aft end single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.5.3 In no case is the minimum thickness of single skin plating to be taken as less than 2,5 mm.

9.5.4 An estimate of the stiffness EI, the thickness of single skin plating for outer and inner skins of the **house aft end sandwich panels** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.5.5 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of 2.5.1.

9.6 House top laminates

9.6.1 The bending moment assumed to be carried by the house top plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 9.6.3 and 9.6.5 respectively.

9.6.2 An estimate of the thickness of **house top single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.6.3 In no case is the minimum thickness of single skin plating to be taken as less than 2,5 mm.

9.6.4 An estimate of the stiffness EI, the thickness of single skin plating for outer and inner skins of the **house top sandwich panels** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.6.5 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of 2.5.1.

9.7 Coachroof laminates

9.7.1 The bending moment assumed to be carried by the coachroof plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 9.7.2 and 9.7.4 respectively.

9.7.2 An estimate of the thickness of **coachroof single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.7.3 In no case is the minimum thickness of single skin plating to be taken as less than 2,5 mm.

9.7.4 An estimate of the stiffness EI, thickness of single skin plating for outer and inner skins of the **coachroof sandwich panels** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.7.5 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of 2.5.1.

9.8 Machinery casing laminates

9.8.1 The bending moment assumed to be carried by the machinery casing plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 9.8.2 and 9.8.4 respectively.

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9.8.2 An estimate of the thickness of the **machinery casing single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits are indicated in Table 7.3.1 in Chapter 7 for house side plating.

9.8.3 In no case is the minimum thickness of single skin plating to be taken as less than 3,0 mm.

9.8.4 An estimate of the stiffness EI, the thickness of single skin plating for outer and inner skins of the **machinery casing sandwich panels** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.8.5 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of 2.5.1.

9.9 Forecastle requirements

9.9.1 The side laminate may be a continuation of the hull laminate, an integral part of the deck moulding or connected as a separate assembly. The laminate is to be the same weight as the side hull laminate at the deck edge position, and is to be increased along the connection, if fitted, to the top edge of the hull. Suitable scarfing arrangements are to be made to ensure the continuity of the effect of the sheerstrake at the break and at the upper edge of the forecastle side. The laminate is to be stiffened by sideframes carried up or they may be stopped short of the deck provided the ends are effectively built-in. Deep webs are to be fitted to ensure overall rigidity of the side laminate.

9.10 House side stiffeners

9.10.1 The Rule requirements for bending moment, shear force, shear stress and deflection for the **house side primary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (a).

9.10.2 The Rule requirements for bending moment, shear force, shear stress and deflection for the **house side secondary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.10.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

9.10.4 The geometric properties of stiffener sections are to be calculated in accordance with 1.15 using an effective width of attached plating as given in 1.7.

9.11 House front stiffeners

9.11.1 The Rule requirements for bending moment, shear force, shear stress and deflection for the **house front primary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (a).

9.11.2 The Rule requirements for bending moment, shear force, shear stress and deflection for the **house front secondary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.11.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

9.11.4 The geometric properties of stiffeners sections are to be calculated in accordance with 1.15 using an effective width of attached plating as given in 1.7.

9.12 House aft end stiffeners

9.12.1 The Rule requirements for bending moment, shear force, shear stress and deflection for the **house aft end primary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (a).

9.12.2 The Rule requirements for bending moment, shear force, shear stress and deflection for the **house aft end secondary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

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9.12.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

9.12.4 The geometric properties of stiffener sections are to be calculated in accordance with 1.15 using an effective width of attached plating as given in 1.7.

9.13 House top stiffeners

9.13.1 The house top is to be efficiently supported by a system of transverse or longitudinal beams and girders. The span of the beams is generally not to exceed 2,4 m and the beams are to be effectively built into the house upper coamings and girders.

9.13.2 The Rule requirements for bending moment, shear force, shear stress and deflection for the **house top primary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (a).

9.13.3 The Rule requirements for bending moment, shear force, shear stress and deflection for the **house top secondary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.13.4 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

9.13.5 The geometric properties of stiffeners sections are to be calculated in accordance with 1.15 using an effective width of attached plating as given in 1.7.

9.14 Coachroof stiffeners

9.14.1 The Rule requirements for bending moment, shear force, shear stress and deflection for the **coachroof primary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (a).

9.14.2 The Rule requirements for the bending moment, shear force, shear stress and deflection for the **coachroof secondary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.14.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

9.14.4 The geometric properties of stiffener sections are to be calculated in accordance with 1.15 using an effective width of attached plating as given in 1.7.

9.15 Machinery casing stiffeners

9.15.1 The Rule requirements for bending moment, shear force, shear stress and deflection for the **machinery casing primary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (a).

9.15.2 The Rule requirements for bending moment, shear force, shear stress and deflection for the **machinery casing secondary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.15.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

9.15.4 Where casing sides act as girders supporting decks over, care is to be taken that access openings do not seriously weaken the structure. Openings are to be effectively framed and reinforced if found necessary. Particular attention is to be paid to stiffening where the casing supports the funnel or exhaust uptakes.

9.15.5 Where casing stiffeners carry loads from deck transverses, girders, etc., or where they are in line with pillars below, they are to be suitably reinforced.

9.15.6 The geometric properties of stiffener sections are to be calculated in accordance with 1.15 using an effective width of attached plating as given in 1.7.

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9.16 Forecastle stiffeners

9.16.1 The Rule requirements for bending moment, shear force, shear stress and deflection for the **forecastle primary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (a).

9.16.2 The Rule requirements for bending moment, shear force, shear stress and deflection for the **forecastle secondary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.16.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

9.16.4 The geometric properties of stiffener sections are to be calculated in accordance with 1.15 using an effective width of attached plating as given in 1.7.

9.17 Superstructures formed by extending side structure

9.17.1 Superstructure first tier sides formed by extending the hull side structure are to be in accordance with the requirements for house fronts indicated in 9.4 and 9.11 for laminates and stiffeners respectively, but need not be taken as greater than the side structure requirements at the deck edge at the same longitudinal position.

9.18 Fire aspects

9.18.1 Fire detection, protection and extinction requirements are given in Part 17.

9.19 Openings

9.19.1 All openings are to be substantially framed and have well rounded corners. Arrangements are to be made to minimise the effect of discontinuities. Continuous coamings or girders are to be fitted below and above doors and similar openings.

9.19.2 Particular attention is to be paid to the effectiveness of end bulkheads when large openings for doors and windows are fitted, and also to the upper deck stiffening in way.

9.19.3 Special care is to be taken to minimise the size and number of openings in the side bulkheads in the region of the ends of houses within $0{,}5L_R$ amidships. Account is to be taken of the high vertical shear loading which may occur in these areas.

9.19.4 The requirements for closing arrangements and outfit are given in Pt 3, Ch 4.

9.20 Mullions

9.20.1 Window openings are to be suitably framed and mullions will in general be required.

9.20.2 The scantlings of mullions are to be not less than as required for a stiffener in the same position.

9.20.3 The geometric properties of stiffener sections are to be calculated in accordance with 1.15 using an effective width of attached plating as indicated in 1.7, in no case is the width of effective plating to be taken greater than the distance between adjacent window openings.

9.20.4 Where significant shear forces are to be transmitted by window frames, adequate shear rigidity requires to be verified.

9.21 Global strength

9.21.1 Transverse rigidity is to be maintained throughout the length of the house by means of web frames, bulkheads or partial bulkheads. Particular attention is to be paid when a superimposed tier is wider than its supporting tier and when significant loads are carried on the house top.

9.21.2 Where practicable, web frames are to be arranged in line with bulkheads below.

9.21.3 Internal bulkheads are to be fitted in line with bulkheads or deep primary stiffeners below.

9.22 House/deck connection

9.22.1 Adequate support under the ends of houses is to be provided in the form of webs, pillars, diaphragms or bulkheads in conjunction with reinforced deck beams.

9.22.2 Special attention is to be given to the connection of the house to the deck in order to provide an adequate load distribution and avoid stress concentrations.

9.22.3 Typical design details of house/deck connections are given in LR's *Guidance Notes for Structural Details*.

9.23 Sheathing

9.23.1 Sheathing arrangements are to comply with 2.9.

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9.24 Novel features

9.24.1 Laminate and stiffener requirements may need to be determined by direct calculation where the house is of unusual design, form or proportions, *see also* 2.7.

9.25 Bulwarks

9.25.1 General requirements for bulwarks are given in Pt 3, Ch 4.8.

9.25.2 The bending moment assumed to be carried by the bulwark plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 9.25.3 and 9.25.5 respectively.

9.25.3 An estimate of the thickness of the **bulwark single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.25.4 In no case is the minimum thickness of single skin plating to be taken as less than 2,5 mm.

9.25.5 An estimate of the stiffness *EI*, thickness of single skin plating for outer and inner skins of the **bulwark sandwich panels** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.25.6 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of 2.5.1.

9.25.7 The Rule requirements for bending moment, shear force, shear stress and deflection for the **bulwark stays** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (d).

9.25.8 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

9.25.9 The geometric properties of stiffener sections are to be calculated in accordance with 1.15 using an effective width of attached plating as given in 1.7.

9.25.10 Bulwarks should not be cut for gangway or other openings near the breaks of houses.

9.25.11 Attention is to be paid to avoid discontinuity of strength of the bulwark, particularly in way of local increases in stress and changes in height.

9.25.12 **Fishing craft** are to have bulwarks fitted. The bulwark may be formed as a continuation of the hull laminate, an integral part of the deck moulding or connected as a separate assembly. Where the bulwark is considered to be stressed and contributing to the global strength of the craft, the laminate weight of the bulwark is not to be less than the sheer laminate weight. In no case is the bulwark laminate weight to be taken as less than 80 per cent of the shell weight. The bulwark is to be supported by suitable stiffening which may be formed by a continuation of the side frames, or by top hat, or plate laminate stays of the same weight as the bulwark. These frames are not generally to be spaced more than two side frame spacings apart.

9.25.13 In way of gantries, trawl gallows, mooring pipes etc. the laminate in way is to be increased by 50 per cent.

9.25.14 **Pilot craft** are to be fitted with a suitable hand rail system adjacent to the exposed areas of the working decks and platforms and in addition these areas should have non skid surfaces. Where permitted by the Flag Administration, a suitable approved continuous safety rail system will be acceptable. Suitable operating procedures are to be in place for the trained crew.

9.26 Freeing arrangements

9.26.1 The requirements for freeing arrangements are given in Pt 3, Ch 4,9.

9.27 Free flow area

9.27.1 The requirements for free flow area are given in Pt 3, Ch 4,9.3.

9.28 Guard rails

9.28.1 The requirements for guard rails are given in Pt 3, Ch 4,8.4.

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Section 10
Pillars and pillar bulkheads

10.1 General

10.1.1 Pillars are to be arranged to transmit loads from decks and superstructures into the bottom structure. Pillars are to be constructed out of materials of adequate compressive strength and modulus, usually steel or aluminium and these are generally to be of solid, tubular or *I* beam form. A pillar may be a fabricated trunk or partial bulkhead.

10.2 Symbols and definitions

10.2.1 The symbols for use within this Section are as defined in 1.5.1, unless otherwise specified in the appropriate sub-Section.

10.3 Determination of spans

10.3.1 The effective span length of pillar, l_{ep}, is in general the distance between the head and heel of pillar. Where substantial brackets are fitted, the effective length of pillar, l_{ep}, may be reduced by 2/3 of the depth of the brackets at each end.

10.4 Head and heel connection

10.4.1 The structure in way of head and heel connections is to be suitably reinforced. The webs and face reinforcement of such supporting structure are to be locally increased as necessary with due account being taken of both the compression and bending moment in way.

10.4.2 Pillars are to be attached at their heads and heels to plates supported by efficient brackets. Where the attachment is through bolted, suitable inserts or compression tubes are to be incorporated within the deck and hull framing to prevent over-compression and damage to the laminate in way. Alternatively, tapping plates may be incorporated within the face reinforcement of the stiffener. Details of the proposed arrangement are to be indicated on the submitted plans.

10.5 Alignment and arrangement

10.5.1 Pillars are to be fitted on main structural members. They should be fitted below deckhouses, windlasses,winches, capstans and elsewhere where considered necessary.

10.5.2 Wherever possible, deck pillars are to be fitted in the same vertical line as pillars above and below, and effective arrangements are to be made to distribute the load at the heads and heels of all pillars.

10.5.3 Where pillars support eccentric loads, or are subjected to lateral pressures, they are to be suitably strengthened for the additional bending moment imposed upon them.

10.6 Minimum thickness

10.6.1 The minimum wall thickness of steel or aluminium pillars are to be as required by Pt 6, Ch 3 or Pt 7, Ch 3 respectively.

10.6.2 The minimum wall thickness of FRP pillars will be specially considered.

10.7 Pillar scantlings

10.7.1 The scantlings of steel or aluminium pillars, and pillar bulkheads, are to be as required by Pt 6, Ch 3 and Pt 7, Ch 3 respectively.

10.7.2 The scantlings of FRP pillars/pillar bulkheads are to be in accordance with 10.10.

10.7.3 Where a pillar is of unusual material, the scantlings will be specially considered.

10.8 Pillars in tanks

10.8.1 Pillars are in no circumstances to pass through tanks. Where loads are to be transmitted through the tank, pillars within the tanks are to be carefully aligned with the external pillars.

10.8.2 Pillars within tanks are, in general, to be of solid cross section. Proposals to use hollow section or tubular pillars will be subject to special consideration and the scantlings as determined from the Rules may be required to be increased dependent upon the material to be used, the fluid contained and the arrangement of the pillars. Hollow pillars are to be adequately drained and vented.

10.8.3 Pillars within tanks which may be subjected to tensile stresses due to hydrostatic pressure, are to be designed to provide sufficient connection to withstand the tension load imposed.

10.9 Pillar bulkheads

10.9.1 Where the pillar bulkhead is of steel or aluminium construction the method of attachment to the surrounding structure/framing will be specially considered.

10.9.2 Where a pillar bulkhead supports a concentrated load the structure in way is to be suitably reinforced to distribute the load into the adjacent stiffening.

10.10 Composite pillars and pillar bulkhead scantlings

10.10.1 The load P_p, assumed to be carried by a pillar is to be determined from:

$$P_p = S_{gt}\, b_{gt}\, P_c + P_a \quad \text{kN}$$

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where

P_p = design load supported by the pillar, which is to be taken as not less than 5 kN

P_c = basic deck girder design pressure as appropriate, plus any other loadings above the pillar, in kN/m^2

P_a = load, in kN, from pillar or pillars above, assumed zero if there are no pillars over

S_{gt} = spacing, or mean spacing, of girders or transverses, in metres

b_{gt} = distance between centres of two adjacent spans of girders or transverses supported by the pillars, in metres.

10.10.2 The load P_b, assumed to be carried by a pillar bulkhead is to be determined from:

$$P_{pb} = S_{bs}\, b_{pb}\, P_c + P_a \quad \text{kN}$$

where

P_{pb} = design load supported by the stiffener plate combination of the pillar bulkhead, in kN

P_c = basic deck girder design pressure, as appropriate, plus any other loadings directly above the pillar, in kN/m^2

S_{bs} = spacing, or mean spacing of bulkheads or effective transverses/longitudinal stiffeners, in metres

b_{pb} = distance between centres of two adjacent spans of girders or transverses supported by the pillar bulkhead, in metres, and can be taken as the distance between pillar bulkhead stiffeners where the stiffener at the top of the bulkhead effectively distributes the load evenly into the stiffeners.

10.10.3 The slenderness ratio (l_{ep}/r) of a pillar or plate stiffener combination is to be determined from:

$$r = \sqrt{\frac{\Sigma\,(E_i\, I_i)}{\Sigma\,(E_i\, A_i)}} \quad \text{cm}$$

where

r = least radius of gyration of pillar cross section, in cm

l_{ep} = effective length of pillar, in cm

E_i, I_i and A_i are as defined in 1.5.1.

Table 3.10.1 Pillar location factors

Location	f_p
Supporting weatherdeck	0,50
Supporting vehicle deck	0,25
Supporting passenger deck	0,50
Supporting lower/inner deck	0,75
Supporting coachroof	0,75
Supporting deckhouse top	1,00

10.10.4 The compressive loads P_p or P_{pb}, from 10.10.1 and 10.10.2 for pillars and pillar bulkheads respectively are not to exceed a function of the critical load P_{cr}, determined from 10.10.5:

$$P_p \text{ (or } P_{pb}) < f_p\, P_{cr} \quad \text{kN}$$

where

f_p is a factor dependent upon location and is as indicated in Table 3.10.1.

10.10.5 The critical compressive load, P_{cr}, for pillars and plate/stiffener combinations with a slenderness ratio (l_e/r) between 75 and 110 may be determined from:

$$P_{cr} = \frac{k\,\pi^2\,\Sigma\,(E_{ci}\, I_i)}{l_{ep}^2} \times 10^5 \quad \text{kN}$$

where

l_{ep} = effective span length of pillar or stiffener plate combination, in metres

E_{ci} = compressive modulus of plate laminate, in N/mm^2

k = end fixity factor

= 1,5 for full fixed/bracketed

= 0,75 for partially fixed

= 0,5 for free ended

Where the proposed slenderness ratio is below 75 the pillar will be specially considered. Slenderness ratios in excess of 110 are not to be contemplated.

10.10.6 The stiffener/plate combination used to determine the scantlings for pillar bulkheads is to be that of a stiffener with an effective width of attached plating carrying a load as determined from 1.7.

10.10.7 The scantlings of wooden pillar bulkheads will be specially considered on the basis of the Rules. Such pillar bulkheads are to be of equivalent strength, stiffness and load carrying capability.

10.11 Detail in way of sandwich structure

10.11.1 The attachment of pillars to sandwich structures should, in general, be through an area of single skin laminate, *see* Ch 2,4.3. Where this is not practicable and the attachment of the pillar has to be by bolting through a sandwich structure then a wood, or other suitable solid insert is to be fitted in the core in way.

10.12 Fire aspects

10.12.1 Pillars are to be suitably protected against fire, where necessary, be self extinguishing or be capable of resisting fire damage. All pillars are to comply with Part 17.

10.13 Novel features

10.13.1 Where pillars are of unusual design or constructed from novel material they will be specially considered in accordance with 2.7.

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Section

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2 **Minimum thickness requirements**

3 **Shell envelope laminate**

4 **Shell envelope framing**

5 **Single bottom structure and appendages**

6 **Double bottom structure**

7 **Bulkheads and deep tanks**

8 **Deck structures**

9 **Superstructures, deckhouses, bulwarks and pillars**

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to multi-hull craft of composite construction as defined in Pt 1, Ch 1,1.

1.2 General

1.2.1 Except as otherwise specified within this Chapter, the scantlings and arrangements of multi-hull craft are to be determined in accordance with the procedures described in, or as required by Chapter 3 for mono-hull craft, using the pressures from Part 5 appropriate to multi-hull craft.

1.3 Direct calculations

1.3.1 Where the craft is of unusual design, form or proportions, or where the speed of the craft exceeds 60 knots the scantlings are to be determined by direct calculation.

1.3.2 The requirements of this Chapter may be modified where direct calculation procedures are adopted to analyse the stress distribution in the primary structure.

1.4 Equivalents

1.4.1 Lloyd's Register (hereinafter referred to as 'LR') will consider direct calculations for the derivation of scantlings as an alternative and equivalent to those derived by Rule requirements in accordance with Pt 3, Ch 1,2.

1.5 Symbols and definitions

1.5.1 Unless otherwise specified the symbols and definitions for use within this Chapter are as defined in Ch 3,1.5.

1.5.2 **Bottom outboard.** For high speed craft, where the scantlings of the bottom shell are governed by impact pressure considerations, the bottom outboard shell is defined as the area of the hull between the outboard edge of the keel and the outer bilge tangential point. For displacement and semi displacement type craft where the scantlings of the bottom shell are governed by either hydrostatic or pitching pressures, the bottom outboard shell is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

1.5.3 **Bottom inboard.** For high speed craft, where the scantlings of the bottom shell are governed by impact pressure considerations, the bottom inboard shell is defined as the area of the hull between the inboard edge of the keel and the inner bilge tangential point. For displacement and semi displacement type craft where the scantlings of the bottom shell are governed by either hydrostatic or pitching pressures the bottom inboard shell is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

1.5.4 **Cross-deck.** The cross-deck is defined as the structure which forms the bridge connection between any two adjacent hulls.

1.5.5 **Haunch.** The haunch is defined as the transition area between the cross-deck and the side inboard shell laminate.

1.5.6 **Side inboard.** The side inboard is defined as the area between the bottom inboard shell and the wet-deck (or lower edge of the haunches, where fitted).

1.5.7 **Side outboard.** The side outboard is defined as the area between bottom outboard shell and the deck at side.

1.5.8 **Wet-deck.** The wet-deck is defined as the area between the upper edges of the side inboard laminate (or upper edges of the haunches, where fitted).

■ *Section 2* Minimum thickness requirements

2.1 General

2.1.1 The minimum thickness requirements for single skin laminates are to be in accordance with Ch 3,2.

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2.1.2 The minimum amount of reinforcement in single skin laminates which form the skins of sandwich laminate is to be in accordance with Ch 3,2. In addition, the minimum amount of reinforcement requirements of Table 4.2.1 are to be complied with. The amount of reinforcement is to be corrected for craft type, craft length and fibre content in accordance with Ch 3,2.5.

Table 4.2.1 Minimum amount of reinforcement in sandwich laminate skins

Panel location	Minimum amount of reinforcement, W_{min} (g/m^2)		Sandwich skin length factor, f_{LS}
	Glass	Carbon/ Aramid	
Bottom outboard, outer skin	3650	2700	0,33
Bottom outboard, inner skin	2850	2100	0,33
Side outboard, outer skin	3250	2400	0,33
Side outboard, inner skin	2450	1950	0,33
Wet-deck, outer skin	3250	2400	0,33
Wet-deck, inner skin	2450	1950	0,33
Cross-deck, outer skin	2450	1950	0,33
Cross-deck, inner skin	1650	1300	0,0

NOTE
The minimum amount of reinforcement in hybrid laminates will be individually considered on an equivalence basis. *See* Ch 3,2.9.2.

2.1.3 In addition, where laminates contribute to the global strength of the craft, the thickness is to be not less than that required to satisfy global strength requirements.

■ *Section 3* Shell envelope laminate

3.1 General

3.1.1 Except as otherwise specified within this Section, the scantlings and arrangements for the shell envelope laminate are to be determined in accordance with the procedures described in, or as required by Ch 3,3 for mono-hull craft, using the pressures from Part 5 appropriate to multi-hull craft.

3.2 Keel plates

3.2.1 The breadth, b_K, and thickness, t_K, of plate keels are not to be taken as less than:

$b_K = 5{,}0L_R + 250$ mm

$t_K = \sqrt{k_t}\ (5{,}0L_R^{0,45})$ mm

where

L_R = Rule length, in metres, as defined in Pt 3, Ch 2,6.1

k_t is as defined in Ch 3,2.1.

3.2.2 In no case is the thickness of the keel to be less than that of the adjacent bottom shell laminate.

3.2.3 The width and thickness of plate keels are to be maintained throughout the length of the craft from the transom to a point not less than 25 per cent of the freeboard measured at the forward perpendicular (FP) above the deepest load waterline on the stem. Thereafter the keel thickness may be reduced to that required by Ch 3,3.3.1 for the stem. Laminate tapers are to comply with Ch 3,3.14.2.

3.2.4 Where the bottom shell is of sandwich construction the keel is to be formed by locally returning to single skin construction for a width as required by 3.2.1. The Rule thickness of keel is to comprise both the inner and outer skins of the adjacent bottom shell sandwich plus additional reinforcement as required. The distribution of reinforcement in way of the plate keel and sandwich bottom structure is to be in accordance with Fig. 4.3.1. *See also* Ch 3,3.2.4.

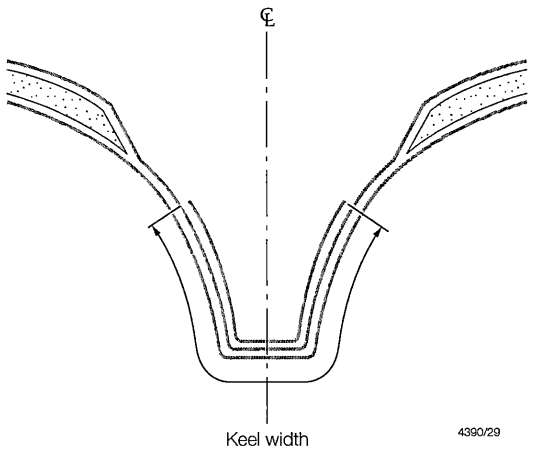

Fig. 4.3.1
Single skin/Sandwich skin intersection detail

3.2.5 For large, novel, asymmetric hull form craft, or yachts with externally attached ballast keels, or where it is proposed to incorporate keels of the 'bar' type the scantlings of the keel will be specially considered.

3.3 Bottom outboard

3.3.1 For all craft types, the minimum bottom outboard shell laminate thickness as required by the Rules is to be extended over the region as defined in 1.5.2 for displacement and semi-displacement craft.

3.3.2 The bending moment assumed to be carried by the bottom outboard shell laminate is to be not less than that determined by Ch 3,1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 3.3.3 and 3.3.5 respectively.

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3.3.3 An estimate of the thickness of **bottom outboard single skin laminate** is to be determined from Ch 3,1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using Ch 3,1.12.3 and Ch 3,1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

3.3.4 In no case is the minimum thickness of single skin laminate to be taken as less than 5,5 mm.

3.3.5 An estimate of the stiffness *EI*, the thickness of single skin laminate for outer and inner skins of the **bottom outboard sandwich panel** and the thickness of core material is to be determined from Ch 3,1.13.2 and Ch 3,1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using Ch 3,1.13.7 and Ch 3,1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

3.3.6 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of 2.1.2.

3.3.7 Special consideration may be given to laminate thicknesses lesser than those required by 3.3.4 and 3.3.6, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided, *see* Ch 3,2.3.1, and the equivalent impact resistance is demonstrated as required by Ch 3,2.8.2.

3.4 Bottom inboard

3.4.1 The scantlings and arrangements for bottom inboard shell laminate are to be determined in accordance with the procedures described in 3.3 using the bottom inboard shell design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.5 Side outboard

3.5.1 The side outboard shell is as defined in 1.5.7.

3.5.2 For all craft types, the minimum side outboard shell laminate thickness as required by the Rules is to be extended over the region as defined in 3.5.1 for displacement and semi-displacement craft.

3.5.3 The bending moment assumed to be carried by the side outboard shell laminate is to be not less than that determined by Ch 3,1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 3.5.4 and 3.5.6 respectively.

3.5.4 An estimate of the thickness of **side outboard single skin laminate** is to be determined from Ch 3,1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using Ch 3,1.12.3 and Ch 3,1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

3.5.5 In no case is the minimum thickness of single skin laminate to be taken as less than 5 mm.

3.5.6 An estimate of the stiffness *EI*, the thickness of single skin laminate for outer and inner skins of the **side outboard sandwich panel** and the thickness of core material is to be determined from Ch 3,1.13.2 and Ch 3,1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using Ch 3,1.13.7 and Ch 3,1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

3.5.7 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of 2.1.2.

3.5.8 Special consideration may be given to laminate thicknesses lesser than those required by 3.5.5 and 3.5.7, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided, *see* Ch 3,2.3.1, and the equivalent impact resistance is demonstrated as required by Ch 3,2.8.2.

3.6 Side inboard

3.6.1 The scantlings and arrangements for side inboard shell laminate are to be determined in accordance with the procedures described in 3.3 using the side inboard shell design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate.

3.7 Wet-deck

3.7.1 The wet-deck is as defined in 1.5.8.

3.7.2 The bending moment assumed to be carried by the wet-deck laminate is to be not less than that determined by Ch 3,1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 3.7.3 and 3.7.5 respectively.

3.7.3 An estimate of the thickness of wet-deck single skin laminate is to be determined from Ch 3,1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using Ch 3,1.12.3 and Ch 3,1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

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3.7.4 In no case is the minimum thickness of single skin laminate to be taken as less than 5 mm.

3.7.5 An estimate of the *EI*, the thickness of single skin laminate for outer and inner skins of the wet-deck sandwich panel and the thickness of core material is to be determined from Ch 3,1.13.2 and Ch 3,1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using Ch 3,1.13.7 and Ch 3,1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

3.7.6 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of 2.1.2.

3.7.7 Special consideration may be given to laminate thicknesses lesser than those required by 3.7.4 and 3.7.6, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided, *see* Ch 3,2.3.1, and the equivalent impact resistance is demonstrated as required by Ch 3,2.8.2.

3.7.8 The wet-deck laminate on the underside of the cross-deck structure may require to be additionally protected, particularly where the air gap is small and there is a high risk of localised impact due to collision with floating debris, ice, etc., in the service area. In such cases the requirements for sheathing, given in Ch 3,2.9, are to be complied with.

3.8 Transom

3.8.1 The scantlings and arrangements of transoms are to be not less than as required for the adjacent bottom inboard or side outboard structure as appropriate.

3.8.2 Where water jet or sterndrive units are fitted, the scantlings of the plating in way of the nozzles and connections will be specially considered.

3.9 Haunch reinforcement (SWATH)

3.9.1 For craft above 30 m in length, L_R, the stresses in the haunch area are to be derived using a two dimensional fine mesh finite element analysis. The model is to extend horizontally into the box structure and vertically into the strut structure. All discontinuities and cut-outs are to be modelled in order to determine shear stresses at critical locations and stresses for the determination of fatigue strength.

3.9.2 Due consideration is to be given to shear lag when calculating the effective breadth of the attached laminate.

3.10 Lower hull (SWATH)

3.10.1 Where the lower hull structure incorporates ring frames and attached shell laminate fitted between bulkheads or diaphragms, the thickness of the lower hull shell laminate may be derived from an established method for shell analysis or recognised standard for pressure vessels. Modes of failure to be considered are buckling, frame collapse, inter frame shell collapse and overall frame shell collapse between bulkheads. Copies of direct calculations are to be submitted for consideration.

3.10.2 In general the design load to be used is the pressure load given in Pt 5, Ch 4,3.1. If other loads are considered to be of significance for the scantling determination these are to be taken into account.

3.11 Novel features

3.11.1 Where the Rules do not specifically define the requirements for laminate elements with novel features then the scantlings and arrangements are to be determined by direct calculations. Such calculations are to be carried out on the basis of the Rules, recognised standards and good practice, and are to be submitted for consideration.

■ *Section 4* Shell envelope framing

4.1 General

4.1.1 Except as otherwise specified within this Section, the scantlings and arrangements for shell envelope framing are to be determined in accordance with the procedures described in, or as required by Ch 3,4 for mono-hull craft, using the pressures from Part 5 appropriate to multi-hull craft.

4.1.2 The requirements in this Section apply to longitudinally and transversely framed shell envelopes.

4.2 Bottom outboard longitudinal stiffeners

4.2.1 The bottom outboard longitudinal stiffeners are to be supported by bottom transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.2.2 Bottom outboard longitudinal stiffeners are to be continuous through the supporting structures.

4.2.3 Where it is impracticable to comply with the requirements of 4.2.2, or where it is desired to terminate the bottom outboard longitudinal stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.2.4 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1, or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 in Chapter 3 for the load model (b).

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4.2.5 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7 and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.3 Bottom outboard longitudinal primary stiffeners

4.3.1 The bottom outboard longitudinal primary stiffeners are to be supported by bottom transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 6 m apart.

4.3.2 Bottom outboard longitudinal primary stiffeners are to be continuous through the supporting structures.

4.3.3 Where it is impracticable to comply with the requirements of 4.3.2, or where it is desired to terminate the bottom outboard longitudinal primary stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.3.4 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 in Chapter 3 for the load model (a).

4.3.5 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.4 Bottom outboard transverse stiffeners

4.4.1 Bottom outboard transverse stiffeners are defined as local stiffening members which support the bottom shell, and which may be continuous or intercostal.

4.4.2 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 in Chapter 3 for the load model (b).

4.4.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.5 Bottom outboard transverse frames

4.5.1 Bottom outboard transverse frames are defined as stiffening members which support the bottom shell, they are to be effectively continuous and be bracketed at their end connections to side frames and bottom floors as appropriate.

4.5.2 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 in Chapter 3 for the load model (a).

4.5.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.6 Bottom outboard transverse web frames

4.6.1 Bottom outboard transverse web frames are defined as primary stiffening members which support bottom shell longitudinals, they are to be continuous and be substantially bracketed at their end connections to side web frames and bottom floors.

4.6.2 Where it is impracticable to comply with the requirements of 4.6.1, or where it is desired to terminate the bottom inboard transverse web frames in way of bulkheads or integral tank boundaries, etc., all web frames are to be bracketed in way of their end connections, to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' (*see* Fig. 3.4.1 in Chapter 3) and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.6.3 The Rule requirements for the bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 in Chapter 3 for the load model (a).

4.6.4 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.7 Bottom inboard longitudinal stiffeners

4.7.1 The scantlings and arrangements for bottom inboard longitudinal stiffeners are to be determined in accordance with the procedures described in 4.2 using the bottom inboard longitudinal stiffeners design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

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4.8 Bottom inboard longitudinal primary stiffeners

4.8.1 The scantlings and arrangements for bottom inboard longitudinal primary stiffeners are to be determined in accordance with the procedures described in 4.3 using the bottom inboard longitudinal primary stiffeners design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.9 Bottom inboard transverse stiffeners

4.9.1 The scantlings and arrangements for bottom inboard transverse stiffeners are to be determined in accordance with the procedures described in 4.4 using the bottom inboard transverse stiffeners design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.10 Bottom inboard transverse frames

4.10.1 The scantlings and arrangements for bottom inboard transverse frames are to be determined in accordance with the procedures described in 4.5 using the bottom inboard transverse frames design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.11 Bottom inboard transverse web frames

4.11.1 The scantlings and arrangements for bottom inboard transverse web frames are to be determined in accordance with the procedures described in 4.6 using the bottom inboard transverse web frames design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.12 Side outboard longitudinal stiffeners

4.12.1 The side outboard longitudinal stiffeners are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.12.2 Side outboard longitudinal stiffeners are to be continuous through the supporting structures.

4.12.3 Where it is impracticable to comply with the requirements of 4.12.2, or where it is desired to terminate the side outboard longitudinal stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.12.4 The Rule requirements for the bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 in Chapter 3 for the load model (b).

4.12.5 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.13 Side outboard longitudinal primary stiffeners

4.13.1 The side outboard longitudinal primary stiffeners are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 6 m apart.

4.13.2 Side outboard longitudinal primary stiffeners are to be continuous through the supporting structures.

4.13.3 Where it is impracticable to comply with the requirements of 4.13.2, or where it is desired to terminate the side outboard longitudinal primary stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.13.4 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 in Chapter 3 for the load model (a).

4.13.5 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.14 Side outboard transverse stiffeners

4.14.1 Side outboard transverse stiffeners are defined as local stiffening members which support the side shell, and which may be continuous or intercostal.

4.14.2 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 in Chapter 3 for the load model (b).

4.14.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.15 Side outboard transverse frames

4.15.1 Side outboard transverse frames are defined as stiffening members supporting the side shell and spanning continuously between bottom floors/frames and decks. They are to be effectively constrained against rotation at their end connections.

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4.15.2 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 in Chapter 3 for the load model (a).

4.15.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.16 Side outboard transverse web frames

4.16.1 Side outboard transverse web frames are defined as primary stiffening members which support side shell longitudinals, they are to be continuous and be substantially bracketed at their end connections to side web frames and side floors.

4.16.2 Where it is impracticable to comply with the requirements of 4.16.1, or where it is desired to terminate the side outboard transverse web frames in way of bulkheads or integral tank boundaries, etc., all web frames are to be bracketed in way of their end connections, to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed', *see* Fig. 3.4.1 in Chapter 3, and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.16.3 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 in Chapter 3 for the load model (a).

4.16.4 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.17 Side inboard longitudinal stiffeners

4.17.1 The scantlings and arrangements for side inboard longitudinal stiffeners are to be determined in accordance with the procedures described in 4.12 using the side inboard longitudinal stiffeners design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.18 Side inboard longitudinal primary stiffeners

4.18.1 The scantlings and arrangements for side inboard longitudinal primary stiffeners are to be determined in accordance with the procedures described in 4.8 using the side inboard longitudinal primary stiffeners design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.19 Side inboard transverse stiffeners

4.19.1 The scantlings and arrangements for side inboard transverse stiffeners are to be determined in accordance with the procedures described in 4.14 using the side inboard transverse stiffeners design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.20 Side inboard transverse frames

4.20.1 The scantlings and arrangements for side inboard transverse frames are to be determined in accordance with the procedures described in 4.15 using the side inboard transverse frames design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.21 Side inboard transverse web frames

4.21.1 The scantlings and arrangements for side inboard transverse web frames are to be determined in accordance with the procedures described in 4.16 using the side inboard transverse web frames design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.22 Wet-deck longitudinal stiffeners

4.22.1 The wet-deck longitudinal stiffeners are to be supported by transverse web frames, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.22.2 Wet-deck longitudinal stiffeners are to be continuous through the supporting structures.

4.22.3 Where it is impracticable to comply with the requirements of 4.22.2, or where it is desired to terminate the wet-deck longitudinal stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.22.4 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 in Chapter 3 for the load model (b).

4.22.5 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

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4.22.6 In no case are the scantlings and arrangements for the wet-deck longitudinal stiffeners to be taken less than as required for the side inboard longitudinal stiffeners indicated in 4.17.

4.23 Wet-deck longitudinal primary stiffeners

4.23.1 The wet-deck longitudinal primary stiffeners are to be supported by transverse web frames, bulkheads, or other primary structure, generally spaced not more than 6 m apart.

4.23.2 Wet-deck longitudinal primary stiffeners are to be continuous through the supporting structures.

4.23.3 Where it is impracticable to comply with the requirements of 4.23.2, or where it is desired to terminate the wet-deck longitudinal primary stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.23.4 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 in Chapter 3 for the load model (a).

4.23.5 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.23.6 In no case are the scantlings and arrangements for the wet-deck longitudinal primary stiffeners to be taken less than as required for the side inboard longitudinal primary stiffeners indicated in 4.18.

4.23.7 Additionally the requirements of Chapter 6, in respect of global strength are to be complied with.

4.24 Wet-deck transverse stiffeners

4.24.1 Wet-deck transverse stiffeners are defined as local stiffening members which support the wet-deck shell, and which may be continuous or intercostal.

4.24.2 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 in Chapter 3 for the load model (b).

4.24.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.24.4 In no case are the scantlings and arrangements for the wet-deck transverse stiffeners to be taken less than as required for the side inboard transverse stiffeners indicated in 4.19.

4.25 Wet-deck transverse frames

4.25.1 Wet-deck transverse frames are defined as stiffening members which support the wet-deck shell, they are to be effectively continuous and be bracketed at their end connections to side frames and side floors as appropriate.

4.25.2 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 in Chapter 3 for the load model (a).

4.25.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.25.4 In no case are the scantlings and arrangements for the wet-deck transverse frames to be taken less than as required for the side inboard transverse frames indicated in 4.20.

4.26 Wet-deck transverse web frames

4.26.1 Wet-deck transverse web frames are defined as primary stiffening members which support wet-deck longitudinals, they are to be continuous and be substantially bracketed at their end connections to side web frames and side floors.

4.26.2 Where it is impracticable to comply with the requirements of 4.26.1, or where it is desired to terminate the wet-deck transverse web frames in way of bulkheads or integral tank boundaries, etc., all web frames are to be bracketed in way of their end connections, to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed', *see* Fig. 3.4.1 in Chapter 3, and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.26.3 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 in Chapter 3 for the load model (a).

4.26.4 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

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4.26.5 In no case are the scantlings and arrangements for the wet-deck transverse web frames to be taken less than as required for the side inboard transverse web frames indicated in 4.21.

4.26.6 Primary transverse web frame members which link the strength deck to the wet-deck structure and which carry the transverse global loading, are additionally to comply with Ch 6,3.4.

4.26.7 Particular care is to be taken to ensure that the continuity of transverse structural strength is maintained. All primary transverse members are to be continuous through the side inboard structure and be integrated into transverse bulkheads or other primary structure within each hull, *see* Fig. 4.4.1. In the case of trimaran type craft the primary transverse members are to be continuous through the centre hull. Additionally the side inboard shell laminate in way of the intersection is to be locally increased in thickness by not less than 50 per cent. Copies of direct calculations are to be submitted for consideration.

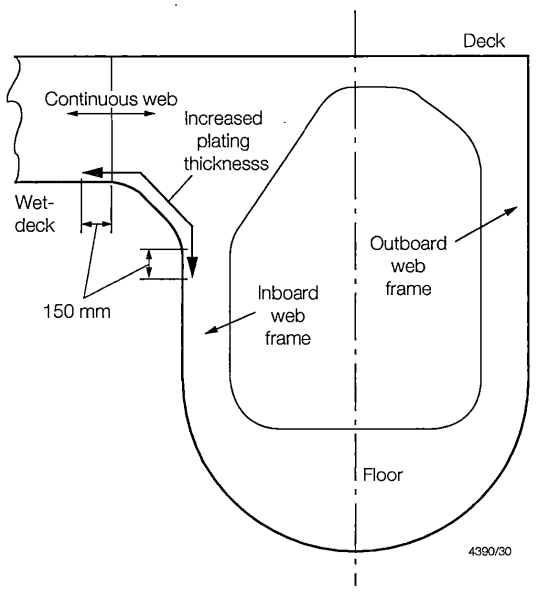

Fig. 4.4.1
End connection detail, wet-deck structure

4.27 Novel features

4.27.1 Where the Rules do not specifically define the requirements for novel features then the scantlings and arrangements are to be determined by direct calculations. Such calculations are to be carried out on the basis of the Rules, recognised standards and good practice, and are to be submitted for consideration.

Section 5
Single bottom structure and appendages

5.1 General

5.1.1 Except as otherwise specified within this Section, the scantlings and arrangements for single bottom structure and appendages are to be determined in accordance with the procedures described in, or as required by Ch 3,5 for mono-hull craft, using the pressures from Part 5 appropriate to multi-hull craft.

5.1.2 The minimum thickness requirements detailed in 2.1 are to be complied with as appropriate.

5.2 Keel

5.2.1 The scantlings and arrangements of plate keels are to be in accordance with 3.2. Where it is proposed to incorporate keels of the bar type such arrangements would require to be specially considered.

5.3 Centre girder

5.3.1 Centreline girders are to be fitted throughout the length of each hull and are generally to be fitted in association with transverse frames, transverses supporting longitudinals or where the breadth of floors at the upper edge is greater than 1,5 m.

5.3.2 Centreline girders may be formed with intercostal or continuous top hat or plate webs. Where girder webs are intercostal, additional bracketing and local reinforcement as given in Ch 3,3.14 are to be provided to maintain the continuity of structural strength. The face reinforcement in all cases is to be continuous.

5.3.3 The web depth of the centre girder in general is to be equal to the depth of the floors at the centreline as specified in 5.5.

5.3.4 The web thickness, t_w, for a centre girder of 'top-hat' type section is to be not less than that required by Ch 3,1.16. or as determined as follows whichever is the greater and in no case is t_w to be taken less than 5,0 mm:

$$t_w = \sqrt{k_A}\ (\sqrt{L_R} + 1{,}37)\ \text{mm}$$

where

k_A and L_R are as defined in Ch 3,1.5.1.

5.3.5 The web thickness for a centre girder of single plate laminate construction is to be two times the thickness as required by 5.3.4.

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5.3.6 The face area of the centre girder, A_f, is to be not less than:

$$A_f = 1{,}18 L_R k_A \text{ cm}^2$$

where

$$k_A = \frac{85}{\sigma_u}$$

σ_u = ultimate tensile strength of the face area laminate, in N/mm^2

L_R = as defined in Ch 3,1.5.1.

5.3.7 The face area of the centre girder outside $0{,}5L_R$ about midships may be reduced to 80 per cent of the value given in 5.3.6.

5.3.8 The face thickness, t_f, is to be not less than the web thickness of the centre girder.

5.3.9 Additionally, the requirements of 4.8 for bottom longitudinal primary stiffeners are to be complied with.

5.4 Side girder

5.4.1 Where the floor breadth at the upper edge exceeds 4,0 m side girders are to be fitted at each side of the centre girder such that the spacing between the side and centre girders or between the side girders themselves is not greater than 3 m. Side girders where fitted are to extend as far forward and aft as practicable and are in general to terminate in way of bulkheads, deep floors or other primary transverse structure.

5.4.2 In the engine room, additional side girders are generally to be fitted in way of the main machinery.

5.4.3 The face area of side girders, A_f, is not to be taken as less than:

$$A_f = 0{,}82 L_R k_A \text{ cm}^2$$

where

k_A and L_R are as defined in Ch 3,1.5.1.

5.4.4 The web thickness, t_w, for side girders of 'top-hat' type section is to be not less than as required by Ch 3,1.16. or as determined as follows whichever is the greater and in no case is t_w to be taken less than 5,0 mm:

$$t_w = \sqrt{0{,}66 k_A L_R} \text{ mm}$$

where

k_A and L_R are as defined in Ch 3,1.5.1.

5.4.5 The web thickness for side girders of single plate laminate construction is to be two times the thickness as required by 5.4.4.

5.4.6 Additionally, the requirements of 4.8 for bottom longitudinal primary stiffeners are to be complied with.

5.4.7 Watertight side girders, or side girders forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deeptanks as detailed in Ch 3,7.3. and Ch 3,7.4 respectively.

5.5 Floors

5.5.1 In transversely framed craft, floors are generally to be fitted at every frame and underneath each bulkhead.

5.5.2 In longitudinally framed craft, floors are to be fitted at every transverse web frame and bulkhead and generally at a spacing not exceeding 2 m. Additional transverse floors or webs are to be fitted at half web-frame spacing in way of engine seatings and thrust bearings, pillars, skegs, ballast/bilge keels and the bottom of the craft in the forefoot region.

5.5.3 The overall depth of transverse floors at the centre-line, d_W, is not to be taken as less than:

$$d_W = 6{,}2 L_R + 50 \text{ mm}$$

5.5.4 The web thickness, t_w, for transverse floors of 'top-hat' type section is to be not less than as required by Ch 3,1.16. or as determined as follows whichever is the greater and in no case is t_w to be taken less than 5,0 mm:

$$t_w = \sqrt{k_A}\left(\frac{4{,}33 d_W}{1000} + 2{,}75\right)\left(\frac{s}{1000} + 0{,}5\right) \text{ mm}$$

where

d_W = as defined in 5.5.3

k_A and s are as defined in 5.3.6.

5.5.5 The web thickness for transverse floors of single plate laminate construction is to be two times the thickness as required by 5.5.4.

5.5.6 If the side frames of the craft are attached to the floors by brackets, the depth of floor may be reduced by 15 per cent and the floor thickness determined using the reduced depth. The brackets are to have the same thickness as the floors, and their arm lengths clear of the frame are to be the same as the reduced floor depth given above.

5.5.7 The face area of floors, A_f, is not to be taken as less than:

$$A_f = 0{,}82 L_R k_A \text{ cm}^2$$

where

k_A and L_R are as defined in Ch 3,1.5.1.

5.5.8 The thickness of the face laminate, t_f, is to be not less than the web thickness.

5.5.9 In addition, the requirements of 4.11 for bottom inboard transverse web frames are to be complied with.

5.5.10 Floors are generally to be continuous from side to side.

5.5.11 The tops of floors, in general, may be level from side to side. However, in craft having considerable rise of floor the depth of the floor plate may require to be increased to maintain the required mechanical properties of the section.

5.5.12 The floors in the aft peak are to extend over and provide efficient support to the stern tube(s) where applicable.

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5.5.13 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deeptanks as detailed in Ch 3,7.3 or Ch 3,7.4 respectively.

5.6 Floors in machinery space

5.6.1 The depth and mechanical properties of floors between engine or gearbox girders is to be not less than that required to maintain continuity of structural integrity or 50 per cent of the depth given in 5.5.3. The web thickness and face reinforcement weight of such reduced height floors are to be increased appropriately in order to maintain the continuity of structural strength.

5.7 Lower hull (SWATH)

5.7.1 Where the lower hull structure incorporates ring frames and attached shell laminate fitted between bulkheads or diaphragms, the scantlings of the lower hull shell stiffening may be derived from an established method for stiffening analysis or recognised standard for pressure vessels. Modes of failure to be considered are buckling, frame collapse, inter frame shell collapse and overall frame shell collapse between bulkheads. Copies of detailed calculations are to be submitted for consideration.

5.7.2 In general, the design load used is to be the design pressure from Pt 5,Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate. If other loads are considered to be of significance for the scantling determination these are to be taken into account.

5.8 Forefoot and stem

5.8.1 The scantlings and arrangements for the forefoot and stem construction are to be in accordance with Ch 3,5.11.

5.9 Transom knee

5.9.1 Transom knees are to be fitted in each hull as necessary in accordance with Ch 3,5.12.

■ *Section 6* Double bottom structure

6.1 General

6.1.1 Except as otherwise specified within this Section, the scantlings and arrangements for double bottom structure are to be determined in accordance with the procedures described in, or as required by Ch 3,6 for mono-hull craft, using the pressures from Part 5 appropriate to multi-hull craft.

6.1.2 The minimum thickness requirements detailed in Ch 3,2.1 are to be complied with as appropriate.

6.2 Keel

6.2.1 The breadth and thickness of plate keels are to comply with the requirements of 3.2.

6.3 Centreline girder

6.3.1 A centreline girder is to be fitted throughout the length of each hull. The web thickness, t_w, of centre girders of 'top-hat' type section is to be not less than as required by Ch 3,1.16. or as determined as follows whichever is the greater and in no case is t_w to be taken less than 5,0 mm:

$t_w = \sqrt{k_A}\ (0{,}073L_R + 3{,}64)$ mm within $0{,}4L_R$ amidships

$= \sqrt{k_A}\ (0{,}073L_R + 2{,}73)$ mm at ends

where

k_A and L_R are as defined in Ch 3,1.5.1.

6.3.2 The web thickness for a centreline girder of single plate laminate construction is to be two times the thickness as required by 6.3.1.

6.3.3 The overall depth of the centreline girder, d_{DB}, is not to be taken as less than 630 mm and is to be sufficient to give adequate access to all parts of the double bottom.

6.3.4 Additionally, the requirements of 4.8 for bottom inboard longitudinal primary stiffeners are to be complied with.

6.4 Side girders

6.4.1 Where the breadth of the floor at the upper edge, within a single hull, does not exceed 4,0 m, side girders are not required. Vertical stiffeners are to be fitted to the floors on each side of the centreline girder, the number and positions of these stiffeners being dependent on the arrangement of the double bottom structure.

6.4.2 Where the breadth of the floor at the upper edge, within a single hull, exceeds 4,0 m, side girders are to be fitted at each side of the centre girder such that the spacing between the side and centre girders or between the side girders themselves is not greater than 3 m. Side girders, where fitted, are to extend as far forward and aft as practicable and are in general to terminate in way of bulkheads, deep floors or other primary transverse structure.

6.4.3 Under the main engine, girders extending from the bottom to the top plate of the engine seating are to be fitted. The height of the girders is not to be less than the height of the floor. Engine holding-down bolts are to be arranged as near as practicable to the girders and floors. Where this cannot be achieved, bracket floors are to be fitted.

6.4.4 Side girders are to have a minimum web thickness, t_w, as required by Ch 3,1.16 but not less than as determined as follows whichever is the greater and in no case is t_w to be taken less than 5,0 mm:

$t_w = \sqrt{k_A}\ (0{,}064L_R + 4{,}32)$ mm

where

k_A and L_R are as defined in Ch 3,1.5.1.

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6.4.5 Additionally, the requirements of 4.8 for bottom inboard longitudinal primary stiffeners are to be complied with.

6.5 Plate floors

6.5.1 Plate floors may be of single skin, sandwich skin or 'top-hat' type construction, and are to comply with the requirements of 5.5 where applicable.

6.5.2 The web thickness, t_w, of non-watertight plate floors of 'top-hat' type section is to be not less than as required by Ch 3,1.16 or as determined as follows whichever is the greater and in no case is t_w to be taken less than 5,0 mm:

$$t_w = \sqrt{k_A}\ (0{,}036L_R + 4)\ \text{mm}$$

where

k_A and L_R are as defined in Ch 3,1.5.1.

6.5.3 The web thickness for transverse floors of single plate laminate construction is to be two times the thickness as required by 6.5.2.

6.5.4 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of 2.1.2.

6.5.5 Additionally, the requirements of 4.11 for bottom inboard transverse web frames are to be complied with.

6.5.6 Plate floors are generally to be continuous between the centre girder and the margin plate.

■ *Section 7* Bulkheads and deep tanks

7.1 General

7.1.1 Except as otherwise specified within this Section, the scantlings and arrangements for bulkheads and deep tanks are to be determined in accordance with the procedures described in, or as required by Ch 3,7 for mono-hull craft, using the pressures from Part 5 appropriate to multi-hull craft.

7.1.2 The scantlings of non-watertight or partial bulkheads are in general to be as required for watertight bulkheads. Non-watertight or partial bulkheads supporting hull framing are to have scantlings equivalent to frames or web frames as appropriate, in the same position.

7.1.3 Sandwich wood bulkheads, plywood bulkheads or other forms of bulkhead construction will be considered on the basis of equivalent strength.

7.2 Longitudinal bulkheads within cross-deck structure

7.2.1 Longitudinal bulkheads are to be fitted within the cross-deck structure to prevent cross flooding and the spread of flame and smoke. The minimum number of such bulkheads is to be two for catamarans and four for trimarans. Quadrimarans and other craft of novel configuration will be specially considered.

7.2.2 The scantlings and arrangements of cross-deck longitudinal bulkheads are to be determined in accordance with the procedures described in Ch 3,7.3 and Ch 3,7.4 for bulkheads in mono-hull craft.

7.2.3 In addition the requirements of 7.4 in respect of global strength are to be complied with.

7.3 Transverse bulkheads within the cross-deck structure

7.3.1 The scantlings and arrangements of cross-deck transverse bulkheads are to be determined in accordance with the procedures described in Ch 3,7.3 and Ch 3,7.4 for bulkheads in mono-hull craft.

7.3.2 In addition the requirements of 7.4 in respect of global strength are to be complied with.

7.4 Additional strength required for global loadings

7.4.1 Where transverse bulkheads or deep tank bulkheads within the cross-deck structure are to assist in resisting torsional or bending loads between the hulls, then the watertight/deep tank bulkheads may be required to be additionally stiffened and the laminate or skin thicknesses may require to be increased. For hull girder strength requirements, *see* Ch 6,3.

7.4.2 Longitudinal bulkheads within the cross-deck structure that are to assist in maintaining the longitudinal strength of the vessel are to satisfy both bulkhead/deep tank and longitudinal strength requirements. This may require additional stiffening and increase in plate thickness requirements. For hull girder strength requirements, *see* Ch 6,3.

7.4.3 Where longitudinal or transverse cross-deck bulkheads/deep tanks are to carry global loads, detailed calculations are to be submitted.

7.4.4 For longitudinal or transverse cross-deck members carrying global loads, consideration is to be given to stiffener arrangement, alignment, and continuity in order to maximise the rigidity and stiffness of the structure, in resisting the torsional/bending loads. Due consideration is to be given to the wrinkling and buckling of the skins of sandwich plate laminates. Discontinuity of structural bulkheads is to be avoided.

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7.5 Access

7.5.1 Access through the cross-deck structure may be permitted, provided that the global strength requirements are satisfied. Cut-outs through the bulkhead are not to exceed 50 per cent of its depth. The edges of cut-out in sandwich panels are to be suitably reinforced while those of single skin construction are to be sealed.

7.5.2 Where the cross-deck structure acts as a watertight bulkhead pipe or cable runs through, the watertight bulkheads are to be fitted with suitable watertight glands.

7.6 Local strength

7.6.1 Bulkheads that form the cross-deck structure are to be suitably strengthened, if necessary, at the ends of deck girders and where subjected to concentrated loads.

7.7 Integral/deep tanks within cross-deck structure

7.7.1 Where the cross-deck structure forms the boundaries of deep tanks, the scantlings of these boundaries are to satisfy both deep tank and global strength requirements. For general and structural requirements for deep tanks, *see* Ch 3,7.4. For global considerations of strength, *see* Ch 6,3.

■ *Section 8*
Deck structures

8.1 General

8.1.1 Except as otherwise specified within this Section, the scantlings and arrangements for deck structures are to be determined in accordance with the procedures described in, or as required by Ch 3,8 for mono-hull craft, using the pressures from Part 5 appropriate to multi-hull craft.

8.1.2 Deck structures are to comply with the minimum thickness requirements of Section 2.

8.1.3 Special attention is to be given to the connections of primary transverse beams to hull side web frames in order to provide adequate load distribution and avoid stress concentrations.

8.1.4 Primary stiffening members are to be continuous and substantially bracketed at their end connections to maintain continuity of structural strength.

8.1.5 Secondary stiffening members are to be effectively continuous and bracketed at their end connections as appropriate.

8.1.6 Design loads to be applied for cross-deck scantling calculations are transverse vertical bending moment and shear force, twin hull torsional connecting moment, external pressure load and appropriate internal loads as defined in Part 5.

8.2 Arrangements

8.2.1 Deck structures are to comply with the longitudinal and transverse global strength requirements given in Chapter 6.

8.3 Symbols and definitions

8.3.1 The term 'cross-deck' is used in this Section for the bridging deck, connecting two or more hulls, carrying global transverse loads. *See also* 1.5.4.

8.4 Cross-deck laminate

8.4.1 The bending moment assumed to be carried by the cross-deck laminate is to be not less than that determined by Ch 3,1.9.1, using the design pressure from Pt 5, Ch 3,3.1, or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 8.4.2 and 8.4.4 respectively.

8.4.2 An estimate of the thickness of **strength/weather deck single skin laminate** is to be determined from Ch 3,1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using Ch 3,1.12.3 and Ch 3,1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

8.4.3 In no case is the minimum thickness of single skin laminate to be taken as less than 4 mm.

8.4.4 An estimate of the stiffness, *EI*, thickness of single skin laminate for outer and inner skins of the **strength/weather deck sandwich panels** and the thickness of core material is to be determined from Ch 3,1.13.2 and Ch 3,1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using Ch 3,1.13.7 and Ch 3,1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

8.4.5 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of 2.1.2.

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8.4.6 Special consideration may be given to laminate thicknesses lesser than those required by 8.4.3 and 8.4.5, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided and the equivalent impact resistance is demonstrated as required by Ch 3,2.8.2.

8.4.7 The scantlings of watertight cockpits are to be of equivalent strength to those for the strength/weather deck, *see also* Part 4.

8.4.8 It is recommended that working areas of the weather deck have an anti-slip surface.

8.4.9 Where decks are sheathed with wood or other materials, details of the method of attachment are to be submitted, *see also* Ch 3,2.9.

8.5 Cross-deck stiffening

8.5.1 The Rule requirements for bending moment, shear force, shear stress and deflection for the cross-deck primary stiffeners are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1, or Pt 5, Ch 4.3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 in Chapter 3 for the load model (a).

8.5.2 The Rule requirements for bending moment, shear force, shear stress and deflection for the cross-deck secondary stiffeners are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1, or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 in Chapter 3 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.5.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

8.5.4 The geometric properties of stiffener sections are to be calculated in accordance with Ch 3,1.15 using an effective width of attached laminate as given in Ch 3,1.7.

8.5.5 For cases where there may be excessive rotations or deflections at supports or where the lateral pressure distribution is non-uniform, the above scantlings may have to be increased appropriately.

8.5.6 Where stiffeners are subject to concentrated loads such as pillars, the concentrated loads are to be superimposed on the lateral pressure and strength calculations carried out to demonstrate compliance with the deflection and stress criteria given in Table 7.2.1 in Chapter 7 and Table 7.3.1 in Chapter 7.

8.5.7 Where the floating frame system is used, the effect of the plating attached to the stiffening members is to be ignored when calculating the required section stiffness, *EI*, of the primary stiffening members, i.e. the full stiffness, *EI*, is to be provided by the primary stiffening members only.

8.5.8 Openings in the cross-deck for hatches etc., are to comply with the requirements of Ch 3,8.12.

8.6 Novel features

8.6.1 Where the cross-deck structure is of unusual design, form or proportions, the scantlings are to be determined by direct calculation, *see* Ch 3,2.7.

■ *Section 9*
Superstructures, deckhouses, bulwarks and pillars

9.1 General

9.1.1 The scantlings and arrangements for superstructures, deckhouses and bulwarks are to be determined in accordance with the procedures described in, or as required for mono-hull craft indicated in Ch 3,9.

9.1.2 The scantlings and arrangements for pillars are to be determined in accordance with the procedures described in, or as required for mono-hull craft indicated in Ch 3,10.

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Section

1 **General**

2 **Special features**

3 **Vehicle decks**

4 **Movable decks**

5 **Helicopter landing areas**

6 **Strengthening requirements for navigation in ice conditions**

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to both mono-hull and multi-hull craft of composite construction.

1.2 Symbols and definitions

1.2.1 The symbols in this Section are as defined in Ch 3,1.5.1 and in the appropriate sub-Section.

■ *Section 2* Special features

2.1 Water jet propulsion systems – Construction

2.1.1 The requirements for the construction and installation of water jet units apply irrespective of rated power.

2.1.2 Water jet ducts may be fabricated as an integral part of the hull structure, or as a bolted-in unit. In either case, detailed plans indicating dimensions, scantlings and materials of construction of the following are to be submitted in triplicate:

(a) Arrangement of the system including intended method of attachment to the hull and building-in, geometry of tunnel, shell opening, method of stiffening, reinforcement, etc.
(b) Shaft sealing arrangements.
(c) Details of any shafting support or guide vanes used in the water jet system.
(d) Details and arrangements of inspection ports, their closing appliances and sealing arrangement, etc.
(e) Details and arrangements of protection gratings and their attachments.

2.1.3 When submitting the plans requested in 2.1.2, details of the designers' loadings and their positions of application in the hull are to be submitted and are to include maximum applied thrust, moments and tunnel pressures for which approval of the propulsion system is sought.

2.1.4 All materials used in construction are to be manufactured and tested in accordance with the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

2.1.5 Aluminium alloys, where used, are to be of suitable marine grades in accordance with the requirements of Part 7.

2.1.6 Irrespective of the material used, the strength and supporting structure of all tunnels are to be examined by direct calculation procedures which are to be submitted. In no case are the scantlings to be taken as less than the Rule requirements for the surrounding structure. The strength of the hull structure in way of tunnels is to be maintained. The structure is to be adequately reinforced and compensated as necessary. All openings are to be suitably reinforced and have radiused corners.

2.1.7 Consideration is to be given to providing the inlet to the tunnel with a suitable guard to prevent the ingress of large objects into the rotodynamic machinery. The dimensions of the guard are to strike a balance between undue efficiency loss due to flow restriction and viscous losses, the size of object allowed to pass and susceptibility to clog with weed and other flow restricting matter.

2.1.8 The inlet profile of the tunnel is to be so designed as to provide a smooth uptake of water over the range of craft operating trims and avoid significant separation of the flow into the rotating machinery.

2.1.9 The leading edges of FRP tunnels are to be additionally reinforced by suitable means. Proposals are to be submitted as required by 2.1.2.

2.1.10 Single or multiple water jet unit installations having a total rated power in excess of 500 kW are to be contained within their own watertight compartment. Other arrangements for maintaining watertight integrity may be specially considered depending on the size and installation layout.

2.1.11 For details of machinery requirements, *see* Pt 10, Ch 2, Machinery Requirements.

2.2 Water jet propulsion systems – Installation

2.2.1 Standard units built for 'off the shelf' supply and which include the duct are to be installed strictly in accordance with the manufacturer's instructions, *see also* 2.1.4.

2.2.2 Integral water jet ducts are to be constructed in accordance with the manufacturer's requirements and the relevant plans submitted as required by 2.1.2.

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2.2.3 Where load is transmitted into the transom and/or bottom shell, the thickness of the laminate adjacent to the jet unit is to be increased. The increase in thickness is to be not less than 50 per cent of the calculated transom and bottom laminate thicknesses respectively or 12 mm, whichever is the greater. Such reinforcement is to extend beyond the surrounding stiffening structure.

2.2.4 For 'bolted in' units, hull receiving rings are to be of a material compatible with the hull. Scantlings of the receiving rings are to be as required by the jet unit manufacturer and suitably edge prepared prior to bonding in place. The receiving ring is to be installed using an approved laminating procedure. Where a manufacturer's specification is not provided, full details are to be submitted.

2.2.5 Bolt sizes and spacings are to be specified by the manufacturer, and are to be of suitable marine grade, insulated as appropriate and locked by suitable means.

2.2.6 Where studs are proposed for the receiving ring(s), the remaining thickness below the depth of blind tap is to be not less than 0,2 times the thickness of the receiving ring or 5 mm whichever is the greater. Bottoms of all blind taps are to be free of sharp corners.

2.2.7 The use of approved alignment resins may be considered where accurate seating and faying surfaces are required. Details are to be submitted for consideration and approval.

2.2.8 Where a water jet unit forms an integral part of the hull structure, such units are to be installed using an approved laminating procedure and in accordance with the manufacturer's instructions. Materials to be laminated are to be of compatible specifications.

2.2.9 Water jet units transmitting thrust into the transom structure are to be supported by a system of radial, athwartship and vertical stiffening. Drawings are to be accompanied by a set of detailed structural calculations. Where complex installations are proposed, a finite element model may be submitted in lieu of direct calculations.

2.2.10 Water jet units transmitting thrust to a bottom shell connection or intermediate tunnel connection are to be supported by additional stiffening, the details and calculations for which are to be submitted.

2.2.11 In general, sandwich skin laminates in way of water jet installations are to be brought together to form single skins complying with 2.2.3. Proposals to use sandwich construction in way of installations will be specially considered, subject to the use of appropriate structural core materials and direct calculations being submitted in support.

2.2.12 Exposed edges of laminates subject to water flow are to be over laminated and protected by suitable means; proposals are to be submitted for consideration.

2.2.13 Where the jet-unit is an FRP premoulding of an approved type, the surface of the unit is to be suitably abraded and degreased prior to installation in the mould tool and subsequent over laminating of the main hull structure. Particular care is to be given to material compatibility of the resin system used for the premould and main hull laminate.

2.3 Foil support arrangements

2.3.1 The materials and construction of the lifting surface will be considered on a case by case basis.

2.3.2 The design and performance of the lifting surface is outside the scope of classification. However, when submitting structural plans for the hull connection installation, the designer/Builder is to define:

(a) Operating mode, i.e. fully submerged or surface piercing.
(b) Maximum operational speed for which approval is sought.
(c) Maximum, direct, bending, shear and torque loads generated by the foil at the point of attachment(s).
(d) The type of profile or section used, e.g. N.A.C.A.
(e) Supply of lift/drag profile.
(f) If the foil is fixed, movable or retractable.
(g) If the foil is fitted with control surfaces.
(h) If the vertical leg(s) act as a rudder(s).
(j) If shaft liners are carried to the foils at which support arrangements are provided.
(k) If water intakes/scoops are fitted.
(l) If propulsion units are fitted.

2.3.3 The scantlings and arrangements of foils and their supporting structure will be required to be specially considered in the following cases where:

(a) Propulsion units are incorporated within the foil.
(b) Foils carry shaft support arrangements.
(c) The foils are of novel design.

2.3.4 Where fully submerged foils are 'built-in' to the hull, the attachment area is to be contained within a watertight compartment. The structural arrangements of 2.4 are to be complied with as appropriate.

2.3.5 Where foils are to be bolted to the structural foundation and not 'built in', calculations are to be submitted. These are to demonstrate that the effect of loading arising from high speed impact, grounding, fouling, etc., is limited to failure of the bolted connection. In all cases the structural and watertight integrity of the craft is to be maintained.

2.3.6 Attachment points of foils are in all cases to be contained within a watertight compartment.

2.3.7 Foils attached by rivetted means are, in addition, to comply with Pt 7, Ch 2,4.25.

2.3.8 Bow fairing doors fitted on forward retracting bow foils are to be weathertight and are to comply with the requirements of Pt 3, Ch 4.

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2.3.9 Aft bulkheads of bow foil compartments are to comply with the requirements for collision bulkheads as detailed in Ch 3,7.6.

2.3.10 Hydraulically operated retracting systems are to be equipped with low pressure alarms, together with a manual system of operation in the event of system failure.

2.3.11 A mechanical locking system is to be provided on retracting systems when the system is in both the operational and 'stowed' conditions.

2.4 Surface drive mountings

2.4.1 Transoms through which surface drive systems pass and which are required to carry thrust, significant weight, torque, moment, etc., are to be adequately reinforced.

2.4.2 The thickness of transom laminate is to be not less than 50 per cent greater than the adjacent plating or as advised by the drive manufacturer, whichever is the greater.

2.4.3 Steering rams are to be mounted on suitably reinforced areas of laminate supported by additional internal stiffening; details are to be submitted for consideration.

2.5 Sea inlet scoops

2.5.1 Sea inlet scoops may be integral with or an appendage to the hull.

2.5.2 Scoops are to be suitably positioned to minimise ventilation.

2.5.3 Suitable protective arrangements are to be provided to minimise the ingress of debris. The net area through the proposed arrangement is to be not less than twice that of the valves connected to the scoop. Provision is to be made for clearing the scoops by the use of suitable means; proposals are to be submitted.

2.5.4 Scoops are to be contained within a watertight compartment.

2.5.5 The laminate thickness in way of integral scoops is to be not less than 50 per cent greater than that of the adjacent shell laminate, with additional reinforcement at the leading edge.

2.5.6 For all composite construction, scoops are to be fitted as bolted appendages.

2.5.7 For craft navigating in ice, the arrangements will be specially considered on an individual basis.

2.6 Crane support arrangements

2.6.1 Crane pedestals are to be efficiently supported and, in general, are to be carried through the deck and satisfactorily scarfed into the surrounding structure. Alternatively, crane pedestals may comprise of a foundation, in which case the foundation and its supporting structure are to be of substantial construction. Proposals for other support arrangements will be specially considered.

2.6.2 The pedestal or proposed arrangement is to be designed with respect to the worst possible combinations of loads resulting from the crane self weight, live load, wind and crane accelerations together with those resulting from the craft's heel and trim. The designer's calculations for loadings are to be indicated on the plans to be submitted.

2.6.3 Stowage arrangements are to be taken into account when calculating the loads applied to the pedestal.

2.6.4 When submitting plans for the proposed foundation, the designer is to include his design calculations covering the parameters indicated in 2.6.2.

2.6.5 The deck laminate is to be additionally reinforced in way of crane foundations. The thickness of reinforcement is to be that required by the designer's calculations but in no case less than 50 per cent the thickness of the adjacent plating.

2.6.6 Laminate tapers are to be in accordance with Ch 2,3.9.

2.7 Skirt attachment

2.7.1 The design and scantlings of the skirt are, in general, outside the scope of classification, however the designers/builders are to submit their proposals in respect of the attachment detail. The following supporting information is to be submitted:

(a) Cushion pressure,

(b) Calculations demonstrating that the effect of damage to the flexible membrane and/or the retaining section arising from high speed impact, grounding, fouling, etc., will not compromise the structural and watertight integrity of the craft.

2.7.2 The skirt is to be securely attached around its periphery. The supporting structure is to be suitably reinforced by the use of tapping plates incorporated into the laminate.

2.7.3 Where the skirt is retained by bolting the retaining bars are to be as long as practicable, with the fasteners being spaced not more than 50 mm apart.

2.7.4 Where the design of the skirt is such that the flexible edge is retained by the use of a pre-formed channel, only the bolted connection of the preform to the hull structure is to be considered.

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2.8 Trim tab arrangements

2.8.1 The shape, design and scantlings of the trim tab are outside the scope of classification, however Lloyd's Register (hereinafter referred to as 'LR') is concerned with their attachment to the hull structure.

2.8.2 The designer/Builder is to submit the following:

(a) Detailed calculations indicating the maximum lift force generated by the tab for which acceptance is sought together with the corresponding speed and displacement.

(b) Details of the hull attachment and loadings in way for the trim tab and actuation system.

(c) Details and calculations of the local internal reinforcement to resist the loading in way of the attachment.

2.8.3 Bearing materials used are to be of an approved type.

2.8.4 Fully submerged retractable trim tabs will be specially considered on a case by case basis.

2.9 Spray rails

2.9.1 Spray rails are, in general, to be integrated into the hull structure but may be added in the form of an appendage on completion of the hull shell.

2.9.2 Where spray rails are integrated, they are to have a laminate thickness not less than the adjacent bottom shell and additionally have section properties equivalent to that required for a longitudinal stiffener in the same position.

2.9.3 Where spray rails are added as an appendage, they are to be attached in accordance with an approved bonding/laminating procedure and are additionally to comply with the strength requirements of 2.9.2. Composite preforms bonded to the outer hull are to be manufactured and bonded using approved materials, compatible with the hull laminate.

2.9.4 Spray rails are to be supported by the internal stiffening arrangements and by additional local reinforcement as necessary, as given in Ch 3,3.14.

2.9.5 In no case are the toes of spray rails to terminate on unsupported shell laminate.

2.9.6 In sandwich construction the outer skin is to be a smooth continuous surface, with spray rails attached as required by 2.9.3.

2.10 Other lifting surfaces

2.10.1 Other lifting surfaces not specifically covered by the Rules will be individually considered on the basis of submitted direct calculations.

2.10.2 Structure or hull shapes above the running waterline designed to generate aerodynamic lift may be individually considered on a case by case basis.

2.10.3 Aerodynamic, hydrodynamic and aero-hydrodynamic stability are outside the scope of classification and are subject to the approval of the National Administration concerned.

2.11 Propeller ducting

2.11.1 Where propellers are fitted within ducts/tunnels the laminate weight in way of the blades is to be increased by 50 per cent.

2.11.2 The tunnel wall in way of the propeller blades is to be additionally stiffened.

2.12 Ride control ducting and installation for Surface Effect Ships (SES)

2.12.1 Ducts penetrating the side inboard shell plating are to comply with the scantling requirements for side inboard structures, over their entire length, in the appropriate material.

2.12.2 Ducts penetrating the wet-deck are to comply with the scantling requirements for wet-deck structures over their entire length, in the appropriate material.

2.12.3 Open ends of ducts are to be fitted with a suitable protective grille.

2.12.4 The vent assembly, its design, construction and operation is outside the scope of classification and is the responsibility of the ride control system designer.

2.12.5 Details of the installation and securing arrangements of the vent valve assembly into the duct are to be submitted for approval.

■ *Section 3* Vehicle decks

3.1 General

3.1.1 Where it is proposed to construct vehicle decks in FRP composite materials, each case will be subject to individual consideration. The scantlings are to be determined by direct calculation or on the basis of the requirements of Chapter 3, in conjunction with the procedures, loadings and general requirements for vehicle decks of aluminium alloy construction, as indicated in Pt 7, Ch 5.

3.1.2 It is recommended that single skin laminate construction incorporating longitudinal or transverse stiffening be adopted. Where it is proposed to use sandwich skin construction, particular care is to be given to the selection of the core material. Such proposals will require to be specially considered, and testing may be required to demonstrate the suitability of the panels.

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3.1.3 The deck and supporting structure are to be designed on the basis of the maximum loading to which they may be subjected in service. Where applicable, the hatch covers are to be similarly designed. In no case, however, are the scantlings to be less than would be required for a weather or cargo deck or hatch cover, as applicable.

3.1.4 Details of the deck loading resulting from the proposed stowage or operation of vehicles are to be supplied by the Builder. These details are to include axle and wheel spacing, the wheel load, type of tyre and tyre print dimensions for the vehicles. The vehicle types and wheel loads for which the vehicle decks, including hatch covers where applicable, have been approved are to be included in the craft's documentation and contained in a notice displayed on each deck. For design purposes, the wheel loading is to be taken as not less than 3,0 kN.

3.1.5 The scantling requirements are based on structural strength and limitations on stress and deflection, with no allowance made for wear and tear. Local reinforcement as given in Ch 3,3.14 is to be fitted as necessary, particularly in way of vehicle lanes and passenger routes.

3.1.6 Deck fittings in way of vehicle lanes are to be recessed.

3.2 Securing arrangements

3.2.1 Details of the loads and connections to the hull of vehicle securing arrangements are to be indicated on the plans submitted with the Designer's calculations.

3.3 Access

3.3.1 Where access to the vehicle deck is provided by bow, side and stern doors, these openings are to comply with the requirements of Pt 3, Ch 4,4.

3.3.2 Doors providing pedestrian access between vehicle decks and accommodation spaces are to be gastight, and have scantlings and fire restricting characteristics equivalent to the surrounding structure, *see also* Part 17.

3.4 Hatch covers

3.4.1 The scantlings and arrangements of hatch covers located within vehicle decks are to be not less than those required by the Rules for the supporting structure in which such hatches are fitted. In general, the end fixity of primary stiffening members is to be taken as simply supported. Local and secondary stiffening members may be either partially or fully fixed at their end connections dependent upon the proposed arrangement.

3.4.2 In no case, however, are the scantlings of plate or sandwich laminates and stiffeners to be less than would be required for a weather or cargo deck, or hatch cover, as applicable.

3.4.3 Where unusual arrangements of hatch cover stiffening are proposed, the scantlings of plating and stiffeners may be determined by direct calculations using a two-dimensional grillage determination.

3.5 Heavy and special loads

3.5.1 Where heavy or special loads are proposed to be carried, the scantlings and arrangements of the deck structure will be individually considered on the basis of submitted calculations.

3.5.2 Due account is to be taken of the acceleration levels due to craft motion applicable to particular items of heavy mass such as vehicles, containers, pallets, etc.

3.6 Direct calculations

3.6.1 LR will consider direct calculations for the derivation of vehicle deck scantlings as an alternative and equivalent to those derived by Rule requirements. The assumptions made and the calculation procedures used are to be submitted for appraisal in accordance with Pt 3, Ch 1,2.

■ *Section 4* Movable decks

4.1 Classification

4.1.1 Movable decks other than those described in 4.1.2 are not a classification item, although consideration is to be given to the associated supporting structure. Where movable decks are fitted, it is recommended that they are to be based on the requirements of this Section.

4.1.2 At the Owner's or Builder's request, however, movable decks will be included as a classification item, and the class notation **Removable decks** will be entered in the *Register Book*. In such cases, all movable decks on board the craft are to comply with the requirements of this Section.

4.2 Arrangements and designs

4.2.1 Movable decks are generally to be constructed as pontoons comprising a web structure with top decking. Other forms of construction will be individually considered.

4.2.2 Positive means of control are to be provided to secure decks in the lowered position.

4.2.3 The decks are to be efficiently supported, and hinges, pillars, chains or other means (or a combination of these) are to be designed on the basis of the imposed loads. Where supporting chains and fittings are required, they are to have a factor of safety of at least two on the proof load.

4.2.4 Plans showing the proposed scantlings and arrangements of the system are to be submitted.

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4.2.5 Where it is proposed to stow the pontoons on deck, when not in use, details of the proposals for racks, fittings, etc., are to be submitted for consideration.

4.3 Loading

4.3.1 The loading requirements for movable decks are to be in accordance with 3.1.

4.3.2 Where it is proposed also to use the decks for general cargo, the design loadings are to be submitted for consideration.

4.4 Scantling determination

4.4.1 The scantlings and arrangements of movable decks are to be not less than required by the Rules for the supporting structure in which they are fitted. In general the end fixity of primary stiffening members is to be taken as simply supported. Local and secondary stiffening members may be either partially or fully fixed at their end connections dependent upon the proposed arrangement.

4.5 Deflection

4.5.1 Where wheeled vehicles are to be used, the supporting arrangements are to be such that the movement at the edge of one pontoon relative to the next does not exceed 50 mm during loading or unloading operations.

4.6 Direct calculations

4.6.1 As an alternative to the requirements of 4.3 to 4.5, the structure may be designed on the basis of a direct calculation using a grillage idealisation. The method adopted and the stress levels proposed for the material of construction are to be submitted for consideration, *see also* Pt 3, Ch 1,2.

■ *Section 5* Helicopter landing areas

5.1 General

5.1.1 Where it is proposed to construct helicopter landing areas in FRP composite materials, each case will be subject to individual consideration.

5.1.2 Helicopter landing areas are to be designed to suit the largest helicopter type which it is intended to use. In general, the diameter of the landing area is to be not less than 1,25 times the rotor diameter.

5.1.3 Attention is drawn to the requirements of National and other Authorities concerning the construction of helicopter landing platforms and the operation of helicopters as they affect the craft.

5.1.4 Plans are to be submitted showing the proposed scantlings and arrangements of the structure. The type, size and weight of helicopters to be used are also to be indicated. Details of the helicopter types to be used are to be included in the craft's documentation, and be contained in a notice displayed on the helicopter landing deck.

5.1.5 Where the landing area forms part of a weather or erection deck, the scantlings are to be not less than those required for decks in the same position.

5.1.6 The requirements for fire protection, detection and extinction are to comply with Part 17. Special consideration is to be given to the insulation standard if the space below the helicopter deck is a high fire-risk space.

5.1.7 It is recommended that single skin laminate construction incorporating longitudinal or transverse stiffening is to be adopted. Where it is proposed to use sandwich skin construction, particular care is to be given to the selection of the core material; such proposals will require to be specially considered, and testing may be required to demonstrate the suitability of the panels.

5.2 Symbols

5.2.1 The symbols in this Section are as defined in Ch 3,1.5.1 and in the appropriate sub-Section.

5.3 Arrangements

5.3.1 The landing area is to be sufficiently large to allow for the landing and manoeuvring of the helicopter, and is to be approached by a clear landing and take-off sector complying in extent with the applicable regulations.

5.3.2 The landing area is to be free of any projections above the level of the deck. Projections in the zone surrounding the landing area are to be kept below the heights permitted by the regulations.

5.3.3 Suitable arrangements are to be made to minimise the risk of personnel or machinery sliding off the landing area. A non-slip surface and anchoring devices are to be provided.

5.3.4 Arrangements are to be made for drainage of the platform, including drainage of spilt fuel.

5.3.5 Details of the connections to the hull of helicopter securing arrangements are to be submitted for approval.

5.3.6 Engine uptake arrangements are to be sited such that exhaust gases cannot be drawn into helicopter engine intakes during helicopter take off or landing operations.

5.4 Loadings

5.4.1 The load cases to be investigated are to be not less than those required by Pt 7, Ch 5,6 for helicopter landing areas of aluminium alloy construction.

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5.4.2 The proposed loadings are to be agreed with LR prior to scantling analysis and submission of structural plans for appraisal.

5.4.3 Details of the deck loading resulting from the proposed stowage arrangements of helicopters are to be supplied by the Builder. These details are to include the axle and wheel spacing, the wheel load, type of tyre and tyre print dimensions for the helicopter. For design purposes the wheel loading is to be taken as not less than 3,0 kN (0,3 tonne-f).

5.4.4 Where it is proposed also to use the decks for general cargo or other alternative use, the design loadings are to be submitted for consideration.

5.5 Scantlings

5.5.1 The scantlings and arrangements of helicopter landing areas are to be not less than those required by the Rules for the supporting structure in which the helicopter landing areas are fitted. In general the end fixity of primary stiffening members is to be taken as simply supported. Local and secondary stiffening members may be either partially or fully fixed at their end connections dependent upon the proposed arrangement.

■ *Section 6* Strengthening requirements for navigation in ice conditions

6.1 General

6.1.1 Where an ice class notation is to be included in the class of a craft, the scantlings will require special consideration, *see* Pt 3, Ch 2,9.

6.2 Shell laminate

6.2.1 It is assumed that single skin laminate construction incorporating longitudinal or transverse stiffening will be adopted. Where it is proposed to use sandwich skin construction, particular care is to be given to the selection of the core material; such proposals will require to be specially considered, and testing may be required to demonstrate the suitability of the panels.

6.2.2 In way of the main ice belt zone, the thickness of the shell laminate is to be determined by direct calculation. A copy of these calculations is to be submitted for consideration.

6.2.3 Changes in laminate thicknesses are to take place gradually, and in no case is the length of taper to be less than 20 times the difference in thickness. Additionally individual plies of the laminate are to be arranged such that any delamination will be directed to the outer surface of the laminate.

6.3 Shell framing

6.3.1 The web thickness for ice framing members of top-hat or plate section is to be determined by direct calculation. A copy of these calculations is to be submitted for consideration.

6.3.2 Ice frames are to be attached to the shell plating by double primary bonding angles in accordance with Ch 3,1.18. The web area of ice frames is to be maintained; air and drain holes are to be kept to a minimum.

6.3.3 The bending moment assumed to be carried by the ice framing stiffening member is not to be taken as less than 50 per cent greater than that required by the appropriate Section of the Rules for the stiffening member subjected to hydrostatic or pitching pressure whichever is the greater.

6.4 Stem construction

6.4.1 The stem is to be additionally protected/reinforced by a metallic shoe or other equivalent arrangement. The shoe/reinforcement is to extend from the keel plate to 750 mm above the ice load waterline and is to be internally strengthened by closely spaced floors, brackets or webs. Details of such protection and the method of attachment are to be submitted for consideration.

6.4.2 Attachment by mechanical means such as bolting or other methods is not to impair the watertight integrity of the craft. Through bolting of the hull is to be kept to a minimum and avoided where practicable.

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Section

1 **General**

2 **Hull girder strength for mono-hull craft**

3 **Hull girder strength for multi-hull craft**

■ *Section 1* General

1.1 Application

1.1.1 The requirements for longitudinal and transverse global strength for both mono-hull and multi-hull craft of composite construction, are contained within this Chapter. Due consideration is taken of the dynamic effects, where appropriate, in both the crest and trough wave landing conditions.

1.2 Symbols and definitions

1.2.1 Unless specified otherwise the symbols used in this Chapter are defined as follows:

a_i = cross sectional area of the individual ply, *i*, in m^2

E_{ci} = compressive modulus of individual ply, *i*, in N/mm^2

E_i = E_{ti}, or E_{ci} of the individual ply *i*, relative to its position above or below the neutral axis, in N/mm^2

E_{ti} = tensile modulus of individual ply, *i*, in N/mm^2

I_i = inertia of the of individual ply, *i*, about the neutral axis, in mm^4

M_R = the appropriate Rule bending moment, as defined in Pt 5, Ch 5,5

Q_R = the appropriate Rule shear force, as defined in Pt 5, Ch 5,5

x_i = the distance to the centre of area of the individual ply, *i*, from the outer surface of the keel plate laminate, in metres

y_i = vertical distance from the hull transverse neutral axis to the centre of the individual ply, in metres

y_{NA} = the distance of the neutral axis, from the outer surface of the keel plate laminate, in metres.

$\Sigma(E_i I_i)_H$ = total $(EI)_H$ (stiffness) for the hull midship section, in Nm^4/mm^2

σ_{ci} = compressive stress within an individual element, *i*, in N/mm^2

σ_{ti} = tensile stress within an individual element, *i*, in N/mm^2

τ_H = shear stress at any position along the length of the craft, in N/mm^2

L_R and *B* are as defined in Pt 3, Ch 1,6.2.

1.2.2 The strength deck is to be taken as follows:

(a) Where there is a complete upper deck the strength deck is the upper deck.

(b) Where the upper deck is stepped, as in the case of raised quarterdeck craft, the strength deck is stepped as shown in Fig. 6.1.1.

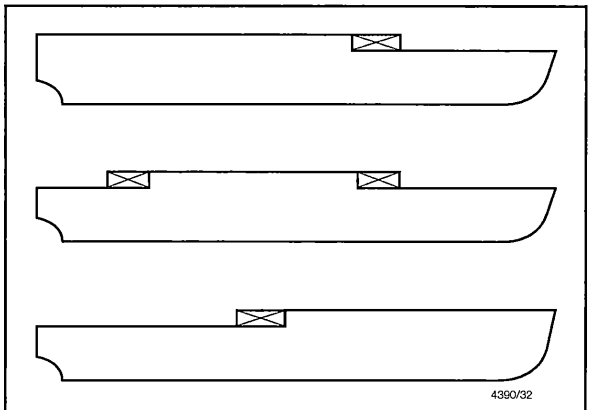

Fig. 6.1.1 Strength deck

1.3 General

1.3.1 The additional pressures arising from the influence of the global loading are considered in the determination of the longitudinal strength requirements for local and secondary stiffening and bottom shell laminate.

1.3.2 All continuous longitudinal structural material is to be included in the calculation of the stiffness, $(EI)_H$, of the hull midship section, and the lever, y_i, is to be measured vertically from the neutral axis to the centre of the individual ply, *i*. The inertia of an individual horizontal ply, *i*, about its own axes is to be ignored.

1.3.3 Structural members which contribute to the overall hull girder strength are to be carefully aligned so as to avoid discontinuities resulting in abrupt variations of stresses and are to be kept clear of any form of openings which may affect their structural performance.

1.3.4 In general, superstructures or deckhouses will not be accepted as contributing to the global longitudinal or transverse strength of the craft. However, where it is proposed to include substantial, continuous stiffening members, special consideration will be given to their inclusion on submission of the designer's/builder's calculations. Such calculations are to make due allowance for superstructure efficiency. *See also* Pt 7, Ch 6,2.5.

1.3.5 Where continuous deck longitudinals or deck girders are arranged above the strength deck, special consideration may be given to the inclusion of their sectional area in the calculation of the hull stiffness $(EI)_H$. The lever is to be taken to a position corresponding to the depth of the longitudinal member above the moulded deckline at side amidships. Each such case will be individually considered.

1.3.6 Adequate transition brackets are to be fitted at the ends of effective continuous longitudinal strength members in the deck and bottom structures.

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1.3.7 Scantlings of all continuous longitudinal members of the hull girder based on the minimum section stiffness requirements given in 2.2 are to be maintained within $0,4L_R$ amidships. However, in special cases, based on consideration of type of ship, hull form and loading conditions, the scantlings may be gradually reduced towards the ends of the $0,4L_R$ part, bearing in mind the desire not to inhibit the vessel's loading and operational flexibility. L_R is as defined in 1.2.1.

1.4 Openings

1.4.1 Deck openings having a length in the fore and aft directions exceeding $0,1B$ m or a breadth exceeding $0,05B$ m, are always to be deducted from the sectional areas used in the section stiffness calculation. B is as defined in 1.2.1.

1.4.2 Deck openings smaller than stated in 1.4.1 including manholes, need not be deducted provided they are isolated and the sum of their breadths or shadow area breadths (*see* 1.4.3), in one transverse section does not exceed $0,06(B_1 - \Sigma b_1)$. where

B_1 = breadth of craft at section considered

Σb_1 = sum of breadths of deductible openings.

Where a large number of deck openings are proposed in any transverse space, special consideration will be required.

1.4.3 Where calculating deduction-free openings, the openings are assumed to have longitudinal extensions as shown by the shaded areas in Fig. 6.1.2. The shadow area is obtained by drawing two tangent lines to an opening angle of 30°. The sections to be considered are to be perpendicular to the centreline of the ship and are to result in the maximum deduction in each transverse space.

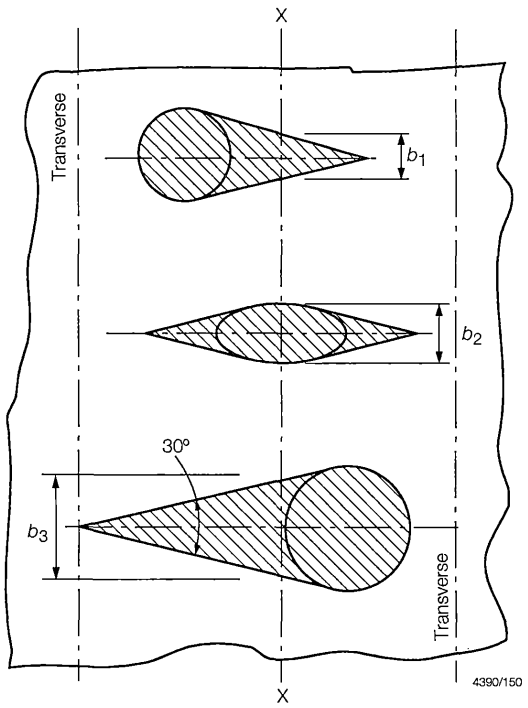
1.4.4 Isolated openings in longitudinals or longitudinal girders need not be deducted if their depth does not exceed 25 per cent of the web depth or 75 mm whichever is the lesser.

1.4.5 Openings are considered isolated if they are spaced not less than 1 m apart.

1.4.6 A reduction for drainage holes and scallops in beams and girders, etc., is not necessary so long as the original section stiffness at deck or keel is reduced by no more than three per cent.

1.5 Direct calculation procedure

1.5.1 In direct calculation procedures capable of deriving the wave induced loads on the ship, and hence the required modulus, account is to be taken of the ship's actual form and weight distribution.



Total equivalent breadth of small openings at XX = $b_1 + b_2 + b_3$

Fig. 6.1.2 Isolated openings

1.5.2 Lloyd's Register's (hereinafter referred to as 'LR') direct calculation method involves derivation of response to regular waves by strip theory, short-term response to irregular waves using the sea spectrum concept, and long-term response predictions using statistical distributions of sea states. Other direct calculation methods submitted for approval are normally to contain these three elements and produce similar and consistent results when compared with LR's methods.

1.6 Approved calculation systems

1.6.1 Where the assumptions, method and procedures of a longitudinal strength calculation system have received general approval from LR, calculations using the system for a particular ship may be submitted.

1.7 Information required

1.7.1 In order that an assessment of the longitudinal strength requirements can be made, the following information is to be submitted, in LR's standard format where appropriate:

(a) General arrangement and capacity plan or list, showing details of the volume and position of centre of gravity of all tanks and compartments.

(b) Bonjean data, in the form of tables or curves, for at least 21 equally spaced stations along the hull. A lines plan and/or Tables of offsets may also be required.

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(c) Details of the calculated lightweight and its distribution.
(d) Details of the weights and centres of gravity of all deadweight items for each of the main loading conditions. It is recommended that this information be submitted in the form of a preliminary Loading Manual, and that it includes the calculated still water and dynamic bending moments and shear forces.

1.8 Loading guidance information

1.8.1 Sufficient information is to be supplied to the Master of every craft to enable him to arrange loading in such a way as to avoid the creation of unacceptable stresses in the craft's structure.

■ *Section 2* Hull girder strength for mono-hull craft

2.1 General

2.1.1 Longitudinal strength calculations are to be submitted for all craft with a Rule length, L_R, exceeding 40 m, covering the range of load and ballast conditions proposed, in order to determine the required hull girder strength. Still water, static wave and dynamic bending moments and shear forces are to be calculated for both departure and arrival conditions.

2.1.2 For craft of ordinary hull form with a Rule length, L_R, less than 40 m, the minimum hull girder strength requirements are generally satisfied by scantlings obtained from local strength requirements. However longitudinal strength calculations may be required at LR's discretion dependent upon the hull form, constructional arrangement and proposed loading.

2.1.3 Where the Rule length, L_R, of the craft exceeds 65 m, or for new designs of large, structurally complicated craft, the design loads and scantling determination formulae in this Chapter are to be supplemented by direct calculation and structural analysis by 3-D finite element methods. These supplementary calculations are to include the results of model tests and full scale measurement where available or required by LR. Full details of such methods and all assumptions and calculations, which are to be based on generally accepted theories, are to be submitted for appraisal.

2.2 Bending strength

2.2.1 The effective geometric properties of the midship section are to be calculated directly from the dimensions of the section using only the effective material elements which contribute to the global longitudinal strength. For the purposes of this analysis an element may be a deck plating, longitudinal girder, inner bottom, etc., or other continuous member.

2.2.2 The distance of the neutral axis, y_{NA}, from the outer surface of the keel plate laminate may be determined from the following:

$$y_{NA} = \frac{\Sigma (E_i a_i x_i)}{\Sigma (E_i a_i)_H} \text{ m}$$

2.2.3 The resultant compressive stress within an individual ply, *i*, may be determined from the following:

$$\sigma_{ci} = \frac{E_{ci} y_i M_R}{\Sigma (E_i I_i)_H} \times 10^{-3} \text{ N/mm}^2$$

2.2.4 The resultant tensile stress within an individual ply, *i*, may be determined from the following:

$$\sigma_{ti} = \frac{E_{ti} y_i M_R}{\Sigma (E_i I_i)_H} \times 10^{-3} \text{ N/mm}^2$$

2.2.5 The ultimate tensile and compressive strengths of the laminate or face reinforcement which form an element, may be determined from suitable tests or alternatively may be predicted using classical stress/strain relationships with due account being taken of the amounts of different materials and their associated strain rates to failure. In this respect materials which are incompatible in terms of their strain rates to failure are not to be mixed. Where materials are mixed the requirements of 2.2.6 for reserve factors are to be complied with when a first ply failure analysis is carried out.

2.2.6 The allowable tensile and compressive stress limits indicated in Table 7.3.2 in Chapter 7 are to be complied with.

2.3 Shear strength

2.3.1 The shear strength of the craft at any position along the length is to be examined. The shear stress, τ_H, is determined from the following:

$$\tau_H = \frac{Q_R}{A_\tau} \times 10^{-3} \text{ N/mm}^2$$

where

A_τ = effective shear area of transverse section, in m^2, to be taken as the net sectional area of the side shell plating and the longitudinal bulkheads after deductions for openings, in m^2

Q_R is as defined in 1.2.1.

2.3.2 The allowable shear stress limits indicated in Table 7.3.2 in Chapter 7 are to be complied with.

2.4 Torsional strength

2.4.1 Torsional stresses are typically small for ordinary mono-hulls less than 65 m in Rule length, L_R, and can generally be ignored.

2.4.2 The calculation of torsional stresses and/or deflections may be required when considering craft with unusual form or proportions, or with large deck openings. In general, calculations may be required to be carried out using a direct calculation procedure. Such calculations are to be submitted in accordance with 1.5.

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Section 3
Hull girder strength for multi-hull craft

3.1 Application

3.1.1 Except as otherwise specified within this Section, the global strength requirements for multi-hull craft are to comply with Section 2.

3.1.2 Longitudinal strength calculations are to be submitted for all craft with a Rule length, L_R, exceeding 35 m, covering the range of load conditions proposed, in order to determine the required hull girder strength. Still water, static wave and dynamic bending moments and shear forces are to be calculated for both departure and arrival conditions and for any special mid-voyage conditions caused by changes in ballast distribution.

3.1.3 For craft of ordinary hull form with Rule length, L_R, less than 35 m, the minimum hull girder strength requirements are generally satisfied by scantlings obtained from local strength requirements. However longitudinal strength calculations may be required at LR's discretion dependent upon the hull form, constructional arrangement and proposed loading.

3.1.4 Where the Rule length, L_R, of the craft exceeds 50 m, or for new designs of large, structurally complicated craft, the design loads and scantling determination formulae in this Chapter are to be supplemented by direct calculation and structural analysis by 3-D finite element methods. These supplementary calculations are to include the results of model tests and full scale measurement where available or required by LR. Full details of such methods and all assumptions and calculations, which are to be based on generally accepted theories, are to be submitted for appraisal.

3.1.5 The strength deck plating in way of the cross-deck structure, the wet-deck plating, longitudinal bulkheads and girders, and other continuous members may be included in the determination of the midship section stiffness.

3.1.6 Special consideration will be given to the global strength requirements for craft with more than two hulls linked by cross-deck structure.

3.2 Hull longitudinal bending strength

3.2.1 The requirements of 2.2 are to be complied with, using the appropriate design bending moment applicable to multi-hull craft, as determined from Pt 5, Ch 5,5.

3.2.2 The allowable tensile and compressive stress limits indicated in Table 7.3.2 in Chapter 7 are to be complied with.

3.3 Hull shear strength

3.3.1 The requirements of 2.3 are to be complied with in so far as they are applicable.

3.3.2 The allowable shear stress limits indicated in Table 7.3.2 in Chapter 7 are to be complied with.

3.4 Torsional strength

3.4.1 At the discretion of LR or where a craft is of unusual form or novel construction, the torsional stress is to be determined by direct calculation methods using the twin hull torsional connecting moment as defined in Pt 5, Ch 5. Such calculations are to be submitted in accordance with 1.5.

3.5 Strength of cross-deck structures

3.5.1 Cross-deck structures are to have adequate transverse strength in relation to the design loads and moments. Generally the net areas with effective flange, after deductions of openings, are to be used for the calculations of the total stiffness of the longitudinal section of the cross-deck structures. The effective shear area of transverse strength members is the net web area after deduction of openings.

3.5.2 The twin hull transverse bending strength of the craft at any position along the length is to be examined.

3.5.3 The twin hull transverse bending stresses for both the compressive and tensile cases are to be determined by direct calculation methods, or on the basis of 2.2.3 and 2.2.4 respectively. The stresses are to be determined in conjunction with the twin hull transverse bending moment, M_R, as defined in Pt 5, Ch 5,5.

3.5.4 Due consideration is to be given to the increased bending moments which may arise due to local point loadings from pillars, fuel bunkers, heavy items of machinery, stores, etc.

3.5.5 The shear strength of the cross-deck structure is to be examined by applying the appropriate vertical shear force at the centreline of the cross-deck structure between the twin hulls. The shear stress, τ_V, is to be determined from:

$$\tau_V = \frac{Q_R}{A_\tau} \times 10^{-3} \quad N/mm^2$$

where

A_τ = the net cross sectional area of the primary transverse cross-deck structure, in m^2

Q_R is as defined in 1.2.1.

3.5.6 The allowable shear stress limits indicated in Table 7.3.2 in Chapter 7 are to be complied with.

3.6 Grillage structures

3.6.1 For complex girder systems, a complete structural analysis using numerical methods may be required to be performed to demonstrate that the stress levels are acceptable when subjected to the most severe and realistic combination of loading conditions intended, *see also* Ch 3,4.15.

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3.6.2 In general, the transverse and vertical girders, bottom and side structures, bridge structure, deck structures and any other parts of the craft which LR considers critical to the craft's structural integrity are to be included in the numerical modelling of the craft.

3.7 Analysis techniques

3.7.1 General or special purpose computer programs or any other analytical techniques may be used provided that the effects of bending, shear, axial and torsion are properly accounted for and the theory and idealisation used can be justified.

3.7.2 In general, grillages consisting of slender girders may be idealised as frames based on beam theory provided proper account of the variations of geometric properties is taken. For cases where such an assumption is not applicable, finite element analysis or equivalent methods may have to be used.

3.7.3 Analysis of the cross deck structures with regard to impact loads due to slamming may have to be carried out using advanced structural analysis techniques.

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Section

1 **General**

2 **Deflection control**

3 **Stress control**

4 **Buckling control**

5 **Impact control**

6 **Temperature control of cored sandwich structures**

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull and multi-hull craft of composite construction as defined in Ch 1,1.1.

1.2 General

1.2.1 The failure modes criteria contained within this Chapter are to be used in formulae from the preceding Chapters to determine the scantling requirements. In addition, they are to be used when direct calculations are proposed as an alternative.

1.3 Symbols and definitions

1.3.1 The symbols and definitions applicable to this Chapter are defined below or in the appropriate Section:

f_δ = span/deflection ratio.

1.4 Direct calculations

1.4.1 The requirements of this Section may be modified where direct calculation procedures are adopted to analyse the various failure modes.

1.5 Equivalents

1.5.1 Where direct calculations are proposed, the requirements of Pt 3, Ch 1,2 are to be complied with.

1.5.2 In addition, with the agreement of Lloyd's Register (hereinafter referred to as 'LR'), tests may be conducted to demonstrate the actual response of the structure and the results verified against the failure mode criteria in this Chapter.

■ *Section 2* Deflection control

2.1 General

2.1.1 The requirements in respect of limiting deflection for both panels and stiffening members are given in this Section. These limits are generally based on a span/deflection ratio, f_δ, as given in Table 7.2.1, in consistent units.

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Table 7.2.1 Limiting span/deflection ratio

Item	f_δ
Shell envelope:	
• sandwich construction	100
Bottom structure:	
• secondary stiffening	150
• primary girders and web frames	200
Side structure:	
• secondary stiffening	150
• primary girders and web frames	200
Main/strength deck structures:	
• sandwich construction	150
• secondary stiffening	200
• primary girders and web frames	250
• hatch covers	250
Superstructure/deckhouse laminates:	
(a) Generally: • sandwich construction	100
(b) Coachroof: • sandwich construction	150
(c) House top: • sandwich construction	100
(d) Lower/inner decks and house top subject to personnel loading:	
• sandwich construction	150
Superstructure/deckhouse stiffeners:	
(a) Generally: • secondary	100
• primary	150
(b) Coachroof: • secondary	150
• primary	200
(c) House top: • secondary	100
• primary	100
(d) Lower/inner decks and house top subject to personnel loading:	
• secondary members	150
• primary members	200
Deep tank structures:	
(a) Laminates: • sandwich construction	150
(b) Stiffeners: • secondary members	175
• primary members	200
Watertight bulkhead structures:	
(a) Laminates: • sandwich construction	100
(b) Stiffeners: • secondary members	125
• primary members	150
Multihull cross-deck structures:	
(a) Laminates: • sandwich construction	100
(b) Stiffeners: • secondary members	125
• primary members	150
Vehicle deck structures:	
(a) Laminates: • sandwich construction	150
(b) Stiffeners: • secondary members	200
• primary members	250
Helicopter/flight decks:	
(a) Laminates: • sandwich construction	150
(b) Stiffeners: • secondary members	200
• primary members	250
NOTE Where significant curvature exists over the span of the stiffener or breadth of the panel, the allowable deflections will be specially considered.	

■ *Section 3* Stress control

3.1 General

3.1.1 The nominal limiting stress for panels and primary and secondary stiffening members, subject to local and global loading conditions, are given in this Section.

3.2 Tensile and compressive stress

3.2.1 The limiting tensile and compressive stress criteria values for local and global loading conditions are given in Tables 7.3.1 and 7.3.2 respectively. These values are expressed as a fraction of the ultimate tensile and compressive strength of the laminate at first ply failure.

3.2.2 The ultimate compressive strength of the sandwich skin laminate shall not be taken greater than the critical skin buckling stress given by

$$\sigma_{cr} = 0{,}5\,(E_{cps}E_cG)^{1/3}$$

where

σ_{cr} = critical skin buckling stress, in N/mm^2

E_c = compressive modulus of the core material, in N/mm^2

E_{cps} and G are as defined in Ch 3,1.5.1

3.3 Shear stress

3.3.1 The limiting shear stress criteria values for local and global loadings are given in Tables 7.3.1 and 7.3.2 respectively. These values are expressed as a fraction of the ultimate shear strength of the laminate.

3.4 Interlaminar shear stress

3.4.1 The interlaminar shear strength of the proposed laminate is to be demonstrated to be not less than 13,8 N/mm^2.

3.5 Core shear stress

3.5.1 The limiting core shear stress criteria values are given in Table 7.3.3. These values are expressed as a fraction of the ultimate core shear strength of the core material, *see also* Ch 3,1.13.9.

3.5.2 The ultimate core shear strength of the core material is to be taken as 90 per cent of the mean ultimate shear strength determined from accepted mechanical tests, or the mean minus two standard deviations based on a minimum of five samples, whichever is less. All test pieces are to be representative of the product to be manufactured and details are to be submitted for consideration.

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Table 7.3.1 Limiting stress criteria for local loading (*see continuation*)

Item	Limiting stress fraction		
	Tensile	Compressive	Shear
Shell envelope:			
(a) Bottom shell laminate:			
• slamming zone	0,28	0,28	—
• elsewhere	0,25	0,25	—
(b) Side shell laminate:			
• slamming zone	0,33	0,33	—
• elsewhere	0,30	0,30	—
(c) Keel	0,25	0,25	—
Bottom structure:			
(a) Secondary stiffening:			
• slamming zone	0,33	0,33	0,33
• elsewhere	0,30	0,30	0,30
(b) Primary girders and web frames	0,33	0,33	0,33
(c) Engine girders	0,33	0,33	0,33
Side structure:			
(a) Secondary stiffening:			
• slamming zone	0,33	0,33	0,33
• elsewhere	0,30	0,30	0,30
(b) Primary girders and web frames	0,33	0,33	0,33
Main/strength deck laminate and stiffeners:			
(a) Laminate	0,30	0,30	—
(b) Secondary stiffening	0,30	0,30	0,30
(c) Primary girders and web frames	0,33	0,33	0,33
(d) Hatch covers	0,25	0,25	0,25
Superstructures/deckhouses:			
(a) Deckhouse front, 1st tier:			
• laminate	0,30	0,30	—
• stiffening	0,33	0,33	0,33
(b) Deckhouse front, upper tiers:			
• laminate	0,30	0,30	—
• stiffening	0,33	0,33	0,33
(c) Deckhouse, aft and sides:			
• laminate	0,30	0,30	—
• stiffening	0,33	0,33	0,33
(d) Coachroof:			
• laminate	0,30	0,30	—
• stiffening	0,33	0,33	0,33
(e) House top, not subject to personnel loading:			
• laminate	0,40	0,40	—
• stiffening	0,40	0,40	0,40
(f) Lower/inner decks and house top, subject to personnel loading:			
• laminate	0,33	0,33	—
• stiffening	0,30	0,30	0,30

3.5.3 In the absence of suitable test data, LR will consider basing the ultimate core shear strength on manufacturer recommended minimum design values based on mechanical tests performed by the core material manufacturer using accepted test methods.

Table 7.3.1 Limiting stress criteria for local loading (*conclusion*)

Item	Limiting stress fraction		
	Tensile	Compressive	Shear
Bulkheads:			
(a) Collision bulkhead:			
• laminate	0,26	0,26	—
• secondary stiffening	0,32	0,32	0,32
• primary stiffening	0,32	0,32	0,32
(b) Watertight bulkhead:			
• laminate	0,33	0,33	—
• secondary stiffening	0,40	0,40	0,40
• primary stiffening	0,40	0,40	0,40
(c) Watertight bulkhead doors:			
• in collision bulkhead	0,25	0,25	—
• in other bulkheads	0,33	0,33	—
(d) Structure supporting watertight doors:			
• in collision bulkhead	0,25	0,25	0,25
• in other bulkheads	0,33	0,33	0,33
(e) Minor bulkheads:			
• laminate	0,50	0,50	—
• secondary stiffening	0,50	0,50	0,50
• primary stiffening	0,50	0,50	0,50
(f) Deep tank bulkheads:			
• laminate	0,25	0,25	—
• secondary stiffening	0,33	0,33	0,33
• primary stiffening	0,33	0,33	0,33
Multihull cross-deck structure:			
(a) Laminate:			
• slamming zone	0,33	0,33	—
• elsewhere	0,30	0,30	—
(b) Secondary stiffening:			
• slamming zone	0,33	0,33	0,33
• elsewhere	0,30	0,30	0,30
(c) Primary stiffening	0,33	0,33	0,33
Vehicle deck:			
(a) Laminate	0,25	0,25	—
(b) Secondary stiffening	0,33	0,33	0,33
(c) Primary stiffening	0,33	0,33	0,33
Helicopter/flight decks:			
(a) Normal usage:			
• laminate	0,25	0,25	—
• secondary stiffening	0,33	0,33	0,33
• primary stiffening	0,33	0,33	0,33
(b) Emergency landing:			
• laminate	0,33	0,33	—
• secondary stiffening	0,43	0,43	0,43
• primary stiffening	0,43	0,43	0,43

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Table 7.3.2 Limiting stress criteria for global loading

Operational mode of craft	Limiting stress fraction			
	Tensile	Compressive	Shear *see* Note 1	Shear *see* Note 2
$\Gamma \geq 3,0$ or $\Delta \leq 0,04(L_R B)^{1,5}$	0,33	0,33	0,33	0,33
$\Gamma < 3,0$ and $\Delta > 0,04(L_R B)^{1,5}$	0,25	0,25	0,25	0,25

NOTES
1. Limiting stress fraction for the hull shear stress at any point along the craft length.
2. Limiting stress fraction for the vertical shear stress for the cross-deck structure.

Δ is the displacement as defined in Pt 5, Ch 2,2.
Γ is the Taylor Quotient as defined in Pt 5, Ch 2,2.1.16.
L_R and B are as defined in Pt 3, Ch 1,6.2.

Table 7.3.3 Limiting core shear stress criteria

Core Material	Limiting shear stress fraction
PVC	0,45
All other cores	0,35

■ *Section 4*

Buckling control

4.1 General

4.1.1 The requirements in respect of the control of buckling of single skin and sandwich panels, including global buckling of structures, pillars and pillar bulkheads are given in this Section.

4.2 Single skin laminate

4.2.1 Where single skin laminate panels are subject to compressive loading likely to cause axial buckling, design calculations are to be submitted indicating the margin against failure.

4.3 Sandwich skin laminate

4.3.1 Where sandwich panel skin laminates are subject to compressive loading likely to cause axial buckling, design calculations are to be submitted indicating the margin against failure.

4.3.2 Where sandwich panels subject to compressive loading have skin thicknesses which are less than the minimum required by Ch 3,2.3, design calculations are to be submitted indicating the margin against failure due to wrinkling of the sandwich skin laminates.

4.3.3 Where production methods or the craft design gives rise to local distortion or irregularity of the sandwich, the designer is to make due allowance for the reduction in critical wrinkling stress.

4.4 Pillars and pillar bulkheads

4.4.1 In general, the requirements in respect of the control of buckling of pillars and pillar bulkheads are given in Ch 3,10.

■ *Section 5*
Impact control

5.1 General

5.1.1 Skin thicknesses may be accepted which are below the stated Rule minima indicated throughout the Rules provided that acceptable stress levels are predicted for the in service condition and that equivalent impact strength can be demonstrated to the satisfaction of LR. In such cases due consideration is to be given to providing a satisfactory water barrier and ensuring suitability to resist abrasion, local point loadings, etc., *see* Ch 3,2.

5.2 Testing

5.2.1 All impact tests are to be comparative tests using the Rule basic laminate as the comparative standard. Original and tested samples of both the proposed laminate and the Rule comparison laminate are to be submitted for LR's consideration together with a detailed test report. Testing is to be carried out by the Builder and witnessed by the LR Surveyor or at an independent testing establishment, acceptable to LR. Comparison will be by visual inspection only and interpretation of the results will be at the sole discretion of LR.

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■ *Section 6*
Temperature control of cored sandwich structures

6.1 General

6.1.1 Where foam core materials are used in sandwich construction the properties at elevated temperature are to be considered. Where appropriate the mechanical properties are to be those at the maximum ambient temperature expected under normal operating conditions.

6.1.2 Alternatively other methods of controlling the temperature of the core may be considered, e.g. inserts, insulation.

6.2 Information required

6.2.1 The source of the mechanical properties data is to be shown on the Materials Data Sheet (Form 2075) when the plans are initially submitted for approval.

6.2.2 Test data is to be submitted for each grade of foam core in respect of:

- Core shear strength.
- Core shear modulus.
- Tensile strength
  (only for high density cores, i.e. > 100 kg/m^3).
- Tensile modulus
  (only for high density cores, i.e. > 100 kg/m^3).

6.3 Testing

6.3.1 Core materials are to be tested in accordance with the *Rules for the Manufacture, Testing and Certification of Materials*.

6.4 National Authority requirements

6.4.1 National Authority requirements are to be complied with as applicable.

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Rules and Regulations for the Classification of Special Service Craft

Volume 7
Part 9 to 16

July 2012

Lloyd's Register
LIFE MATTERS

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DIFFERENT TYPES OF HULL FORMS COVERED BY THE SPECIAL SERVICE CRAFT RULES

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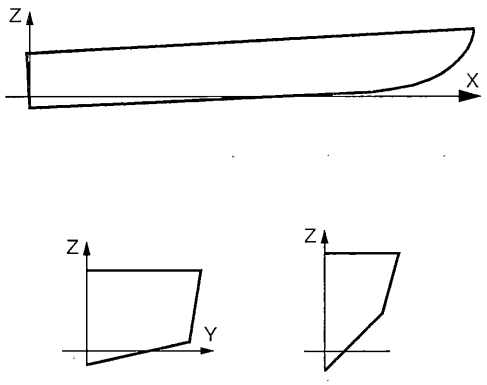
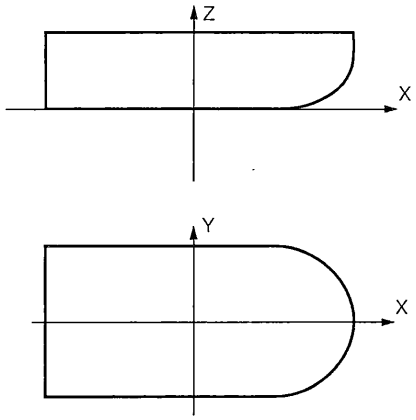


HOVERCRAFT



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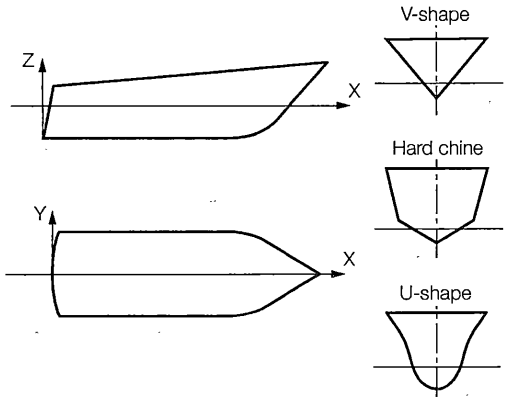
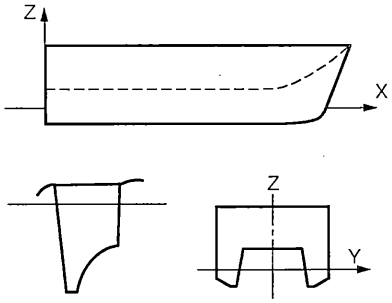
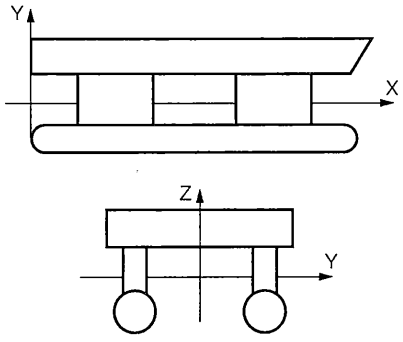


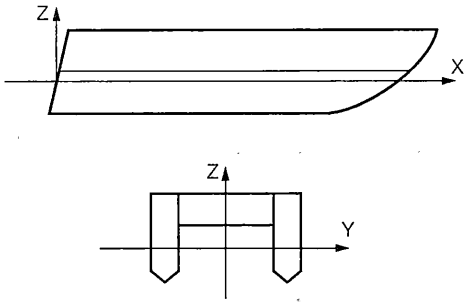
SURFACE EFFECT SHIP



SMALL WATERPLANE AREA TWIN HULL (SWATH)



CATAMARAN



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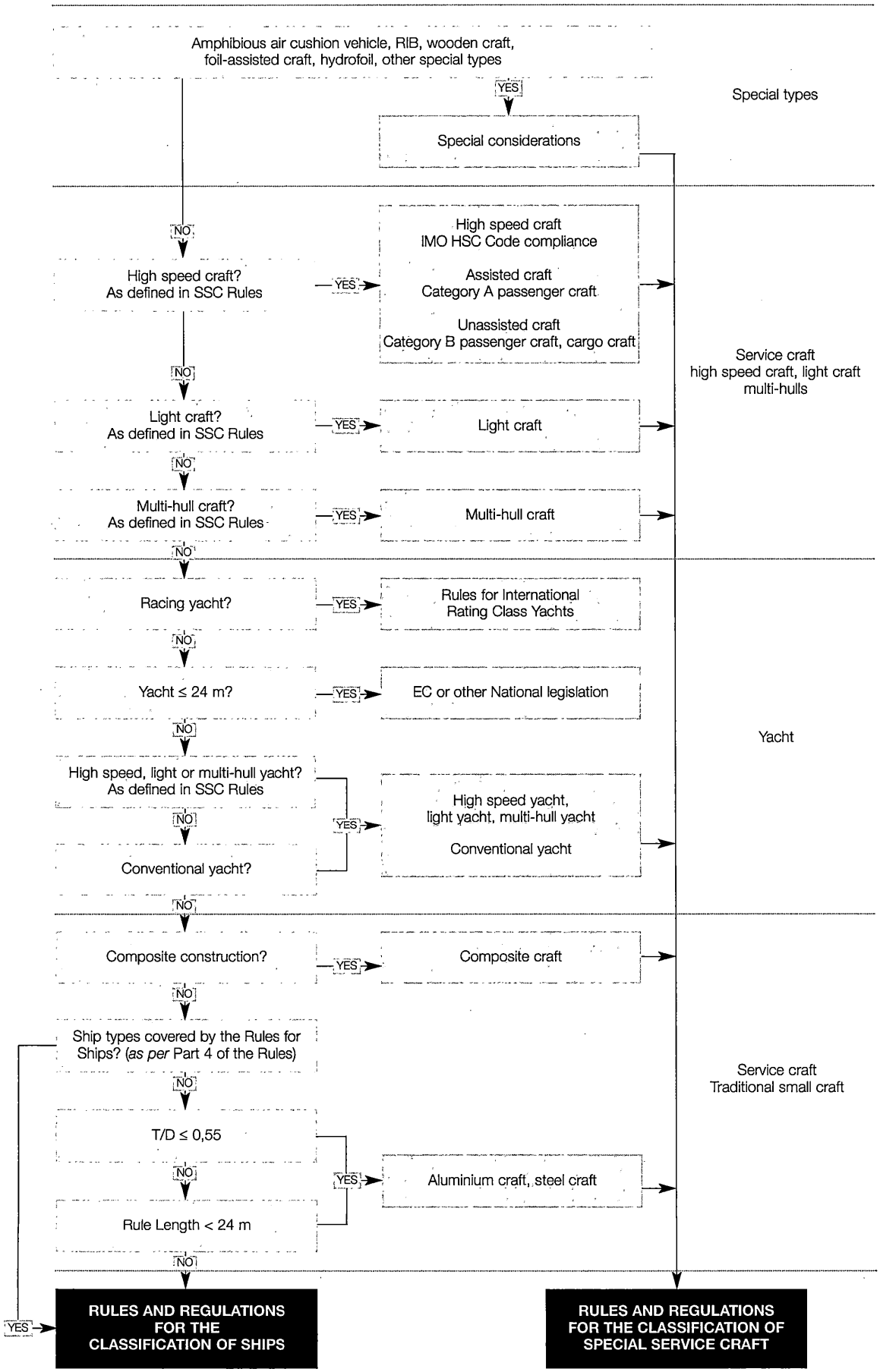
DIFFERENT TYPES OF CRAFT COVERED BY THE SPECIAL SERVICE CRAFT RULES



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Rules and Regulations for the Classification of Special Service Craft

Volume 7
Part 9
General Requirements for Machinery
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Section

1 **General requirements**

2 **Particulars to be submitted**

3 **Certification of materials**

4 **Operating conditions**

5 **Securing of machinery**

6 **Requirements for craft which are not required to comply with the HSC Code**

Section 1 General requirements

1.1 Application

1.1.1 Parts 9 to 16 apply to the design, construction, installation and testing of:

- Main propulsion machinery systems
- Essential auxiliary machinery systems, excluding the crankshaft for diesel engines intended for essential services where power does not exceed 110 kW
- Steering and manoeuvring systems

together with their associated equipment, pressure plant, piping systems, control engineering and electrical engineering systems for the craft types stated in Pt 1, Ch 2,1.

1.1.2 The Rules incorporate those requirements of the *International Convention for the Safety of Life at Sea, 1974* as amended (SOLAS 74) Chapter X – Safety Measures for High Speed Craft (*International Code of Safety for High Speed Craft*) hereinafter referred to as the HSC code, as applicable to the classification of such craft.

1.1.3 Requirements for craft which are not required to comply with the IMO Code for High Speed Craft are given at the end of each Chapter. Requirements for service craft, yachts of 24 m or greater and other craft types have been included in these requirements. For the purposes of Parts 9 to 16, small craft are service craft of less than 24 m in length.

1.1.4 Special requirements are included for main and auxiliary machinery, pumping and piping, electrical and control engineering and fire extinction for yachts that are 500 gt or more.

1.1.5 These Rules are applicable to machinery systems burning distillate fuels which do not require to be heated.

1.2 General

1.2.1 The units and formulae used in the Rules are in SI Units.

1.2.2 It is the responsibility of the Shipbuilder as main contractor to ensure that the information required is prepared and submitted.

1.2.3 Where the craft is defined as a Passenger (B) Craft (see Pt 1, Ch 2,3), sufficient redundancy is to be provided such that in the event of damage to any part of a main propulsion drive system, the craft is able to maintain sufficient seaway.

1.2.4 Sufficient astern power is to be provided to maintain control of the craft in all normal circumstances.

1.2.5 The main propulsion machinery will be approved for the maximum continuous power, and associated shaft speed, required to achieve the maximum craft velocity at the certified maximum operational weight in smooth water.

1.2.6 Main propulsion machinery will be considered for operation at a higher power rating than the classification rating for short time intervals (referred to as short term high power operation) in conjunction with the intended operation service profile.

1.2.7 Provision shall be made to facilitate cleaning, inspection and mantenance of main propulsion and auxiliary machinery including boilers and pressure vessels.

1.3 Fuel flash point

1.3.1 The flash point (closed cup test) of oil fuel is in general to be not less than 60°C. For emergency generator engines a flash point of not less than 43°C is permissible.

1.3.2 Oil fuel with a flash point lower than 60°C may be used where it can be shown that the temperature of the oil fuel will always be not less than 10°C below its flash point.

1.3.3 The use of fuel with a flash point below 43°C is not recommended. However, fuel with a lower flash point , but not lower than 35°C, may be used in gas turbines only, subject to compliance with the provisions in Section 4.

1.4 Exhaust

1.4.1 Where the surface temperature of the exhaust pipes and silencer may exceed 220°C, they are to be water cooled or efficiently lagged to minimise the risk of fire and to prevent damage by heat. Where lagging covering the exhaust piping system including flanges is oil-absorbing or may permit penetration of oil, the lagging is to be encased in sheet metal or equivalent. In locations where the Surveyor is satisfied that oil impingement could not occur, the lagging need not be encased.

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1.5 Bearings

1.5.1 Roller element bearings are to have an L10 design life of at least 30 000 hours, based upon the design operating conditions, including short term high power operation. An L10 design life of less than 30 000 hours would be accepted, provided it is proposed in conjunction with the manufacturer's design/maintenance manual.

1.6 Vibration of shaft systems

1.6.1 The Shipbuilders are to ensure that the systems are free from excessive vibrations, excessive bearing reactions and excessive bending moments under all design operating conditions.

1.6.2 Where changes are subsequently made to a dynamic system which has been approved by Lloyd's Register (hereinafter referred to as 'LR'), e.g. machining a shaft, fitting a propeller of a different design to the working propeller or fitting a different flexible coupling, full details of the changes are to be advised. Revised calculations may be required to be submitted.

1.6.3 Where there is experience of previous similar systems which have been approved, full details of these installations may be submitted for consideration in lieu of calculations.

1.7 Alternative system of survey

1.7.1 Where items of machinery are manufactured as individual or series produced units, LR will give consideration to the adoption of a survey procedure based upon an approved quality assurance system to ISO 9001 (or equivalent) utilising regular and systematic audits of the approved manufacturing and quality control processes and procedures as an alternative to the direct survey of individual components.

■ *Section 2* Particulars to be submitted

2.1 Submission of information

2.1.1 At least three copies of plans, information and specifications as listed are to be submitted before commencement of manufacture.

2.2 Plans

2.2.1 Plans are to indicate clearly the scantlings and materials of construction. Any design alteration to the plan is to be resubmitted for approval, indicating clearly the alteration.

2.2.2 Individual Chapters also list plans to be submitted for specific machinery systems or components.

2.2.3 Where machinery system components have been approved under LR's Type Approval System or Machinery General Design Appraisal for the proposed design conditions or service, plans of the components will not be required to be submitted for individual newbuildings. Full details of the components are to be advised.

2.2.4 Plans showing the arrangement of resiliently mounted machinery are to indicate the number, position, type, and design of mounts.

2.2.5 The plans of arrangement of resin chocks for machinery requiring accurate alignment are to be submitted.

2.3 Calculations and specifications

2.3.1 Relevant data covering the following topics is to be submitted.

2.3.2 **Service Profile.** The machinery power/speed operational envelope indicating all the intended operational points applicable to the class notation, and any short term high power operation.

2.3.3 **Classification rating:**

(a) The following operational parameters are to be taken, using the design conditions for the intended Class Notation:
- Total barometric pressure, in bar.
- Temperature of engine room, or suction air, in °C.
- The relative humidity, in per cent.
- Temperature of sea water, or charge air coolant inlet, in °C.

(b) For unrestricted service, the following operational parameters ambient reference conditions are to be taken:
- Total barometric pressure, at 1000 mb.
- Temperature of engine room or suction air, at 45°C.
- Relative humidity, at 60 per cent.
- Temperature of sea water or charge air coolant inlet, at 32°C.

2.3.4 **Short term high power operation**. Where the propulsion machinery is being considered for short term high power operation, full details of the power, speed and time intervals together with fatigue endurance calculations, and documentary evidence indicating the suitability of the component design under these conditions and for the intended class notation are required. The following are to be considered; prime mover, gearbox, flexible coupling, vibration dampers, shafting and propeller:

(a) The accrued number of load cycles and the percentage component overload are to be those recommended by the designers.

(b) Excessive overload may require the interval between surveys to be reduced.

(c) Machinery is to be maintained in accordance with the manufacturers' requirements.

2.3.5 **Damper and Flexible Coupling characteristics.** Documentary evidence that the characteristics have been verified.

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2.3.6 **Machinery Fastening.**

(a) Documentary evidence and calculations indicating that machinery is securely mounted for the accelerations to be expected during service.

(b) Calculations that mountings of large masses such as main engines, auxiliary engines, lift fans and electrical equipment can withstand the design collision acceleration according to 5.2.1 without fracturing.

(c) Natural frequency calculation of resilient mounted machinery.

(d) For non-metallic machinery chocks:
  (i) Resin type.
  (ii) The effective area and minimum thickness of the chocks.
  (iii) The total deadweight loading of machinery.
  (iv) The thrust load, where applicable, that will be applied to the chocked item.
  (v) The loading to be applied to the holding-down bolts.
  (vi) The material of the holding-down bolts.
  (vii) The number, thread size, and waisted shank diameter (where applicable) of the holding-down bolts.

2.3.7 **Manuals.** The operation and maintenance manuals.

2.3.8 **Failure Mode and Effect Analysis.** Where required for high speed craft, an FMEA is to be carried out covering the following systems:

(a) Main and auxiliary machinery systems, and their controls.

(b) Steering systems.

(c) Electrical systems.

2.3.9 **Fatigue Strength Analysis.** Where undertaken as an alternative to the requirements of the individual Chapters, fatigue strength analysis of components indicating a factor of safety of 1,5 at the design loads based on a suitable fatigue failure criteria. The effects of stress concentrations, material properties and operating environment are to be taken into account.

■ *Section 3* Certification of materials

3.1 Materials of construction

3.1.1 Materials used in the construction are to be in accordance with, or shown to be equivalent to *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials). Details of all materials included and not included in the Rules for Materials are to be forwarded as soon as possible (preferably at the design concept stage) and before commencement of manufacture.

3.1.2 Materials used in the construction of machinery and its installation are not to contain asbestos.

■ *Section 4* Operating conditions

4.1 Machinery control

4.1.1 The design and arrangement is to be such that the machinery can be started and controlled on board, without external aid, so that the operating conditions for which the craft is classed, can be maintained.

4.2 Inclinations of the craft

4.2.1 The main and auxiliary machinery is to be designed and installed such that it operates satisfactorily under the conditions as shown in Table 1.4.1.

Table 1.4.1 Inclinations

Installations, components	Angle of inclination, degrees, *see* Note 1			
	Athwartship		Fore-and-aft	
	Static	Dynamic	Static	Dynamic
Main and auxiliary machinery essential to the propulsion and safety of the craft	15	22,5	5 *see* Note 2	7,5
Emergency machinery and equipment fitted in accordance with Statutory Requirements	22,5	22,5	10	10

NOTES
1. Athwartships and fore-and-aft inclination may occur simultaneously.
2. Where the length of the craft exceeds 100 m, the fore-and-aft static angle of inclination may be taken as:

$$\frac{500}{L_{WL}} \text{ degrees}$$

where
L_{WL} = craft waterline length, in metres

4.2.2 The arrangements for lubricating bearings and for draining crankcase and other oil sumps of main and auxiliary engines, gearcases, electric generators, motors, and other running machinery are to be so designed that lubrication will remain efficient with the craft inclined under the conditions as shown in Table 1.4.1.

4.2.3 Deviations from these conditions may be accepted taking into consideration type and size of the craft and the class notation. The Shipbuilder is to ensure that the main and auxiliary machinery is capable of operating at the proposed angles of inclination.

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4.3 Power ratings

4.3.1 In the Chapters where the dimensions of any particular component are determined from shaft power, P, in kW (H, in shp), and revolutions per minute, R, the values to be used are to be derived from the following:

- For main propelling machinery, the maximum shaft power and corresponding revolutions per minute giving the maximum torque for which the machinery is to be classed.
- For auxiliary machinery, the maximum continuous shaft power and corresponding revolutions per minute which will be used in service.

4.4 Ambient operating conditions

4.4.1 Main and essential auxiliary machinery and equipment is to be capable of operating satisfactorily under the conditions shown in Table 1.4.2.

Table 1.4.2 Ambient operating conditions

Air		
Installations, Components	Location, arrangement	Temperature range (°C)
Machinery and electrical installations	In enclosed spaces	0 to +45, *see* Note 1
	On machinery components, boilers. In spaces subject to higher and lower temperatures	According to specific local conditions, *see* Note 2
	On the open deck	–25 to +45, *see* Note 1
Water		
Coolant		Temperature (°C)
Sea-water or charge air coolant inlet to charge air cooler		-2 to +32, *see* Notes 1 and 3

NOTES
1. For ships intended to be classed for restricted service, a deviation from the temperatures stated may be considered.
2. Details of local environmental conditions are stated in Annex B of IEC 60092: *Electrical installations in ships – Part 101: Definitions and general requirements.*
3. Charge air cooling arrangements utilising re-circulated cooling to maintain temperatures in a different range are accepted where the machinery and equipment operation is not degraded with a primary supply of cooling in the temperature range stated in this Table.

4.4.2 Where it is intended to allow for operation in ambient temperatures outside those shown in Table 1.4.2, the permissible temperatures and associated periods of time are to be specified and details are to be submitted for consideration. Propelling and essential auxiliary machinery, *see* Pt 1, Ch 2, 3.10.1, is to retain a continuous level of functional capability under these conditions and any level of degraded performance is to be defined. Operation under these circumstances is not to be the cause of damage to equipment in the system and is additionally to be acceptable to the National Authority of the country in which the craft is to be registered

■ *Section 5* Securing of machinery

5.1 Fastenings

5.1.1 Bedplates, thrust seatings and other fastenings are to be of robust construction. The machinery is to be securely fixed to the craft's structure, such that the arrangement is sufficient to restrain the dynamic forces arising from vertical and horizontal acceleration appropriate to the intended service.

5.2 Collision load

5.2.1 Unless an accurate analysis of the collision load is submitted and found acceptable by LR, the collision load is to be determined from:

$$g(\text{collision}) = 1{,}2\,\frac{P_{coll}}{\Delta g}$$

where the load P_{coll} is taken as the lesser of:

$$P_{coll} = 460\,(M\,C_L)^{2/3}\;\;(E\,C_H)^{1/3}\ \text{kN}$$

$$P_{coll} = 9000\,M\,C_L\,[C_H\,(T+2)]^{1/2}\ \text{kN}$$

where

C_H = a factor given in Table 1.5.1

$$C_L = \frac{(165 + L_{WL})}{245}\left(\frac{L_{WL}}{80}\right)^{0,4}$$

D = craft depth, in metres, from the underside of keel amidships to the top of effective hull girder

$E = 0{,}5\Delta\,V^2$ kNm

H_T = minimum height, in metres, from tunnel or wet-deck bottom to the top of effective hull girder for catamarans and surface effect ships
= D for air cushion vehicles

L_{WL} = craft waterline length, in metres

M = 1,3 for high tensile steel
= 1,0 for aluminium alloy
= 0,95 for mild steel
= 0,8 for fibre reinforced plastics

T = buoyancy tank clearance to skirt tip, in metres, (negative) for ACVs
= lifted clearance from keel to water surface, in metres, (negative) for hydrofoils
= craft draught to the underside of keel amidships, in metres, for all other craft

V = operational speed of craft, in m/s

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g = gravitational acceleration = 9,806 m/s^2
Δ = craft displacement, to be taken as the mean of the lightweight and maximum operational weight, in tonnes.

Table 1.5.1 Factor C_H

Factor, C_H	Catamarans, SES	Mono-hulls, H Foils	ACVs
C_H	$\frac{T + 2 + f(D/2)}{2D}$	$\frac{T + 2 + f(D/2)}{2D}$	$\frac{f}{4}$
where $f = 0$ for $f = 1$ for $f = 2$ for	 $T + 2 < D - H_T$ $D > T + 2 \geq D - H_T$ $T + 2 \geq DM$	 $T + 2 < D$ $T + 2 \geq D$ —	 — $H_T > 2$ $H_T \leq 2$

5.3 Resilient mounts

5.3.1 Creep of rubber mounts and the effects on the alignment are also to be considered.

5.3.2 Shafting, piping connections and electrical cable connections are to be provided with sufficient flexibility to accommodate such movements. Particular attention should be paid to exhaust bellows and the effectiveness of flexible couplings.

5.3.3 Limit stops are to be fitted as necessary to ensure that manufacturers' limits are not exceeded. Suitable means are to be provided to accommodate propeller thrust.

5.3.4 Mounts are to be shielded from the possible detrimental effects of oil.

5.4 Machinery mounted on resin chocks

5.4.1 These Rules relate to the application of synthetic resin compounds as materials for chocks under machinery components where accurate alignments are important, e.g. main engine, gearbox and auxiliary installations where the engine and generator do not share a common baseplate.

5.4.2 Resin compounds used in these applications are to be of a type accepted by LR.

5.4.3 The use of resin for chocking gas turbine casings or similar high temperature applications will not be considered.

■ *Section 6* Requirements for craft which are not required to comply with the HSC Code

6.1 Plans and particulars

6.1.1 At least three copies of the following plans are to be submitted for approval at the earliest opportunity:

- Crankshaft including details of the material specification.
- Gearing including details of the material specification.
- Arrangement and details of the propulsion shafting, couplings and bearing disposition, etc.
- Propeller where the diameter exceeds 1 m.
- Diagrammatic arrangements of the exhaust systems indicating the materials, methods of cooling, and if water spray is injected, the method of draining.
- Starting air system and receivers.
- Diagrammatic arrangements of pumping and piping systems including the air and sounding pipes for the tanks.
- Diagrammatic arrangements of bilge and fire water pumps and piping for craft having a Rules length of 12 m and over and which are subdivided into water-tight compartments.
- Diagrammatic arrangement of oil fuel piping.
- Construction arrangements of separate oil fuel tanks having a capacity exceeding 250 litres.
- Electrical equipment as detailed in Pt 16, Ch 2.
- Steering gear machinery and hydraulic circuit diagram if applicable.
- Fire extinction equipment as detailed in Part 17.
- Safety plan showing the position of all fire prevention controls, fixed and loose equipment and portable extinguishers, *see* Pt 17, Ch 1 to 4.
- Control circuits and alarm points as detailed in Pt 16, Ch 1.

6.1.2 The following particulars are to be submitted with the plans of crankshaft, gearbox or shafting as applicable:

- Name of manufacturer.
- Type designation.
- Particulars of engine cycle.
- Number of cylinders and vee angle where applicable.
- Maximum combustion pressure and mean indicated pressure.
- Span of bearings adjacent to a crank measured from centreline of the bearing to the centreline of the adjacent bearing.
- Proposed shaft power (kW) and revolutions per minute of the engine at each operating condition.
- Gear box reduction ratio.
- For engines over 500 kW, *see* Pt 10, Ch 1,3.

6.1.3 Where machinery system components or equipment have been approved under LR's Type Approval System or Machinery General Design Appraisal for the proposed design conditions or intended service, full details of the components should be advised to enable the validity of the approval to be checked. In cases where valid approvals are confirmed, plans are not required to be submitted for approval for individual craft.

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6.2 Calculations

6.2.1 Design calculations are to be submitted for the following systems and conditions:

(a) Direct calculation for design strength of machinery supports, such as engine mountings, on craft subjected to high accelerations, *see* Section 5.

(b) Calculations of torsional vibrations for main engines where the power exceeds 500 kW and for auxiliary engines for essential services where the power exceeds 110 kW.

6.3 Certification of materials

6.3.1 The requirements of 3.1 apply to all types of craft.

6.3.2 Where no provision is made in these Rules, materials may be accepted provided that they comply with an approved specification and such tests as may be considered necessary by the Surveyor.

6.3.3 The requirements for materials for machinery components are indicated in the relevant Part or Chapter of the Rules.

6.4 Operating conditions

6.4.1 The requirements of 4.2 do not apply to yachts or service craft less than 24 m.

6.4.2 For patrol craft and high speed craft of 24 m or greater, the main and auxiliary machinery is to be designed to operate under the conditions defined in Sections 4 and 5.

6.4.3 If operation under the required accelerations cannot be demonstrated on trials, alternative documentary evidence is to be presented to confirm that the machinery is capable of operating under such conditions.

6.4.4 Additional trials or conditions may be imposed to prove the machinery as considered necessary.

6.5 Securing of machinery

6.5.1 The requirements of 5.1, 5.3 and 5.4 apply.

6.5.2 Engines are to be installed so as to permit easy access to fittings, such as lubricating oil connections, bilge suctions and sea cocks.

6.5.3 Where the hull is constructed of FRP, wood or composites, and the hull surfaces are not adequately protected against oil contamination, drip trays are to be fitted under those parts of the engine and gearbox where leakage of oil fuel or lubricating oil might occur. Means are to be provided for removing any leakage easily.

6.5.4 Where resilient mounts are fitted, the name of the manufacturer and details of the type of mounting are to be indicated on the plan of the shafting.

6.5.5 Where inclinations beyond those defined in 4.2 might be experienced, such as yacht roll over, means are to be provided to prevent machinery becoming dislodged.

6.5.6 Satisfactory arrangements are to be made to transmit the propulsion thrust into the craft structure.

6.6 Ventilation of machinery spaces

6.6.1 For yachts and service craft of less than 24 m the ventilation of the machinery space is to be adequate for all conditions of the operation of the machinery and in no case is to be less than that required by the engine manufacturer.

6.6.2 The engine compartment is to be provided with inlet and outlet ventilating ducts. One or more inlet ducts are to extend down to a suitable low level.

6.6.3 Outlet ducts are to be connected near or at the top of the compartment and are to be arranged for natural or mechanical extraction as necessary.

6.6.4 Consideration will be given to equivalent alternative arrangements provided full details are submitted before construction is commenced.

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Surveys During Construction, Installation and Sea Trials

Section

1 **General requirements**

2 **Diesel engines**

3 **Turbo-chargers**

4 **Gas turbines**

5 **Gearing**

6 **Shafting systems**

7 **Propellers**

8 **Water jet units**

9 **Thrusters**

10 **Steering systems**

11 **Sea trials**

■ *Section 1* General requirements

1.1 Surveys during construction

1.1.1 Machinery is to be surveyed at the manufacturer's works from the commencement of work until the final test under working conditions. The Surveyors are to be satisfied that the materials, workmanship and arrangements are satisfactory and in accordance with the Rules.

1.1.2 Lloyd's Register's (hereinafter referred to as LR) requirements for the conditions of manufacture, survey and certification of materials used for the production of forged steel and castings used in the production of components are given in *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

1.2 Miscellaneous surveys

1.2.1 Resilient mounts are to be installed under survey and the machinery tested under full working conditions.

1.2.2 Alignment of machinery is to be checked after the first six months of operation.

■ *Section 2* Diesel engines

2.1 Construction and welding

2.1.1 Welding of engine structures is to be in accordance with the requirements specified in Chapter 13 of the Rules for Materials.

2.1.2 On completion of welding and stress relief heat treatment, welds are to be examined. Welds in transverse girder assemblies are to be crack detected by an approved method. Other joints are to be similarly tested if required by the Surveyors.

2.1.3 Forgings and castings are to be examined at the manufacturer's works.

2.2 Hydraulic testing

2.2.1 Items are to be tested by hydraulic pressure as indicated in Table 2.2.1.

2.3 Non-destructive testing

2.3.1 Non-destructive examination of welded construction is to be conducted in accordance with the requirements specified in Chapter 13 of the Rules for Materials.

2.4 Engine type testing

2.4.1 New engine types or developments of existing types are to be subjected to an agreed programme of type testing to complement the design appraisal and review of documentation. The programme will need to include short term high power operation where applicable.

2.4.2 Guidelines for type testing of engines will be supplied on application.

2.4.3 Wherever practical, type tests are to be conducted with the engine control systems operational in the approved configuration, *see* Pt 10, Ch 1,2.1.5 and 2.1.6. Configuration management documents are to be reviewed at testing for validity and referenced in the type test report.

2.4.4 An engine type is defined in terms of:
- Basic engine data, e.g. bore, stroke.
- Working cycle; 2 stroke, 4 stroke.
- Cylinder arrangement; in-line, vee.
- Cylinder rating.
- Fuel supply, e.g. direct or indirect injection.
- Gas exchange; natural aspiration, pressure charging arrangement.

2.4.5 Where an engine type has subsequently proved satisfactory in service with a number of applications a maximum uprating of 10 per cent may be considered without a further complete type test.

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Table 2.2.1 Test pressures

Item	Test pressure
Fuel injection system { Pump body, pressure side; Valve; Pipe }	The lesser of 1,5*p* or *p* + 295 bar
Cylinder cover, cooling space Cylinder liner, over the whole length of cooling space Piston crown, cooling space (where piston rod seals cooling space, test after assembly)	7,0 bar
Cylinder jacket, cooling space Exhaust valve, cooling space Turbo-charger, cooling space Exhaust pipe, cooling space Coolers, each side Engine driven pumps (oil, water, fuel, bilge)	The greater of 4,0 bar or 1,5*p*
Air compressor, including cylinders, covers, intercoolers and aftercoolers	Air side: 1,5*p* Water side: The greater of 4,0 bar or 1,5*p*
Scavenge pump cylinder	4,0 bar

NOTES
1. *p* is the maximum working pressure, in bar, in the item concerned.
2. Fuel pumps of the jerk or timed pump system are not included.
3. Turbo-charger air coolers need only be tested on the water side.
4. For forged steel cylinder covers alternative testing methods will be specially considered.

2.4.6 A type test will be considered to cover engines of a given design for a range of cylinder numbers in a given cylinder arrangement.

■ *Section 3* Turbo-chargers

3.1 Type testing

3.1.1 A type test is to consist of a hot gas running test of at least one hour duration at the maximum permissible speed and maximum permissible temperature. Following the test the turbo-charger is to be completely dismantled for examination of all parts.

3.1.2 Alternative arrangements will be considered.

3.2 Dynamic balancing

3.2.1 All rotors are to be dynamically balanced on final assembly to the Surveyor's satisfaction.

3.3 Overspeed tests

3.3.1 All fully bladed rotor sections and impeller/inducer wheels are to be overspeed tested for three minutes at either 20 per cent above the maximum permissible speed at room temperature or 10 per cent above the maximum permissible speed at the normal working temperature.

3.4 Mechanical running tests

3.4.1 Turbo-chargers are to be given a mechanical running test of 20 minutes duration at the maximum permissible speed.

3.4.2 Upon application, with details of an historical audit covering previous testing of turbo-chargers manufactured under an approved quality assurance scheme, consideration will be given to confining the test to a representative sample of turbo-chargers.

■ *Section 4* Gas turbines

4.1 Dynamic balancing

4.1.1 All rotors as finished-bladed and complete with half-coupling are to be dynamically balanced in accordance with the manufacturer's specification in a machine of sensitivity appropriate to the size of rotor.

4.2 Hydraulic testing

4.2.1 All casings are to be tested to a hydraulic pressure equal to 1,5 times the highest pressure in the casing during normal operation, or 1,5 times the pressure during starting, whichever is the higher. For test purposes, if necessary, the casings may be subdivided with temporary diaphragms for distribution of test pressure.

4.2.2 Where hydraulic tests cannot be carried out on the casing, alternative proposals will be considered.

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4.2.3 Intercoolers and heat exchangers are to be tested to 1,5 times the maximum working pressure on each side separately.

4.3 Overspeed tests

4.3.1 Before installation, the gas turbine is to be tested for five minutes at five per cent above the nominal setting of the overspeed protective device, or 15 per cent above the maximum design speed, whichever is the higher.

4.3.2 Where it is impracticable to overspeed the complete installation, each rotor, completely bladed and with all relevant parts such as half-couplings, is to be overspeed-tested individually at the appropriate speed.

■ *Section 5* Gearing

5.1 Construction and welding

5.1.1 Where castings are used for wheel centres, any radial slots in the periphery are to be fitted with permanent chocks before shrinking-on the rim.

5.1.2 Where welded construction is used for the manufacture of wheels and gearcases, welding is to be in accordance with the requirements specified in Chapter 13 of the Rules for Materials.

5.1.3 Welded constructions are to be stress relief heat treated on completion of welding.

5.1.4 Bolted attachments within the gear case are to be secured by locking wire or equivalent means.

5.2 Accuracy of gear cutting

5.2.1 The machining accuracy (Q grade) of pinions and wheels is to be demonstrated. For this purpose records of measurements are to be available for review.

5.3 Non-destructive testing

5.3.1 Magnetic particle or liquid penetrant testing is to be carried out on the teeth of all surface hardened forgings. This examination may also be requested on the finished machined teeth of through hardened gear forgings.

5.3.2 The manufacturer is to carry out an ultrasonic examination of all forgings where the finished diameter of the surfaces, where teeth will be cut, is in excess of 200 mm, and is to provide LR with a signed statement that such inspection has not revealed any significant internal defects.

5.3.3 On gear forgings where the teeth have been surface hardened, additional test pieces may be required to be processed with the forgings and subsequently sectioned to determine the depth of the hardened zone. These tests are to be carried out at the discretion of the Surveyor, and for induction or carburised gearing the depth of the hardened zone is to be in accordance with the approved specification. For nitrided gearing, the full depth of the hardened zone, i.e. depth to core hardness, is to be not less than 0,5 mm and the hardness at a depth of 0,25 mm is to be not less than 500 Hv.

5.4 Dynamic balancing

5.4.1 All rotating elements such as pinion and wheel shaft assemblies and coupling parts, are to be appropriately balanced.

5.4.2 The permissible residual unbalance, U, is defined as follows:

$$U = \frac{60m}{R} \times 10^3 \text{ g mm} \quad \text{for } R \leq 3000$$

$$U = \frac{24m}{R} \times 10^3 \text{ g mm} \quad \text{for } R > 3000$$

where

m = mass of rotating element, in kg

R = maximum service rev/min of the rotating element.

5.4.3 Where the size or geometry of a rotating element precludes measurement of the residual unbalance a full speed running test of the assembled gear unit at the manufacturer's works will normally be required to demonstrate satisfactory operation.

5.5 Meshing tests

5.5.1 Initially, meshing gears are to be carefully matched on the basis of the accuracy measurements taken. The alignment is to be demonstrated in the workshop by meshing in the gearbox without oil clearance in the bearings. Meshing is to be carried out with the gears locating in their light load positions and a load sufficient to overcome pinion weight and axial movement is to be imposed.

5.5.2 The gears are to be suitably coated to demonstrate the contact marking. The thickness of the coating to determine the contact marking is not to exceed 0,005 mm. The marking is to reflect the accuracy grade specified and end relief, crowning or helix correction, where these have been applied.

5.5.3 For gears without crowning or helix correction the marking is to be not less than shown in Table 2.5.1.

5.5.4 Where allowance has been given for end relief, crowning or helix correction, the normal shop meshing tests are to be supplemented by tooth alignment traces or other approved means to demonstrate the effectiveness of such modifications.

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Table 2.5.1 No load tooth contact marking

ISO accuracy grade	Contact marking area
$Q \leq 5$ $Q \geq 6$	50% b x 40% h_w + 40% b x 20% h_w 35% b x 40% h_w + 35% b x 20% h_w
NOTES 1. Where b is the face width and h_w is the working tooth depth. 2. For spur gears, the values of h_w should be increased by a further 10%.	

5.5.5 For gears with crowning or helix correction, the marking is to correspond to the designed no load contact pattern.

5.5.6 A permanent record is to be made of the meshing contact for the purpose of checking the alignment when installed on board the craft.

5.5.7 The full load tooth contact marking is to be not less than shown in Table 2.5.2.

Table 2.5.2 Full load tooth contact marking

ISO accuracy grade	Contact marking area
$Q \leq 5$ $Q \geq 6$	60% b x 70% h_w + 30% b x 50% h_w 45% b x 60% h_w + 35% b x 40% h_w
NOTES 1. Where b is the face width and h_w is the working tooth depth. 2. For spur gears, the values of h_w should be increased by a further 10%.	

5.5.8 Where, due to the compactness of the gear unit, meshing tests of individual units cannot be verified visually, consideration may be given to the gear manufacturer providing suitable evidence that the design meshing condition has been attained on units of the same design.

5.5.9 The normal backlash between any pair of gears should not be less than:

$$\frac{a\,\alpha_n}{90000} + 0{,}1 \text{ mm}$$

where

α_n = normal pressure angle, in degrees
a = centre distance, in mm.

■ *Section 6* Shafting systems

6.1 Construction and installation

6.1.1 Boring of the sternframe, fitting of the sterntube and bearings and aligning the shafting are to be carried out to a formal traceable procedure.

6.1.2 Before boring the sternframe the structure should be generally complete to the upper deck and to the engine-room forward bulkhead.

■ *Section 7* Propellers

7.1 Construction and welding

7.1.1 Castings are to be examined at the manufacturer's works.

7.1.2 All finished propellers are to be examined for material defects and finish, and measured for dimensional accuracy of diameter and pitch. Propeller repairs by welding, where proposed, are to be in accordance with the requirements of Ch 9,1 of the Rules for Materials.

7.2 Shop tests of keyless propellers

7.2.1 The bedding of the propeller with the shaft is to be demonstrated. Sufficient time is to be allowed for the temperature of the components to equalise before bedding. Alternative means for demonstrating the bedding of the propeller will be considered.

7.2.2 Means are to be provided to indicate the relative axial position of the propeller boss on the shaft taper.

7.3 Shop tests of controllable pitch propellers

7.3.1 The components of controllable pitch propellers are also subject to material tests, as in the case of solid propellers.

7.3.2 Examination of all the major components including dimensional checks, hydraulic pressure testing of the hub and cone assembly and the oil distribution box, where fitted, together with a full shop trial of the completed controllable pitch propeller assembly, is to be carried out.

7.4 Final fitting of keyless propellers

7.4.1 After verifying that the propeller and shaft are at the same temperature and the mating surfaces are clean and free from oil or grease, the propeller is to be fitted on the shaft under survey. The propeller nut is to be securely locked to the shaft.

7.4.2 Permanent reference marks are to be made on the propeller boss nut and shaft to indicate angular and axial positioning of the propeller. Care is to be taken in marking the inboard end of the shaft taper to minimise stress raising effects.

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7.4.3 The outside of the propeller boss is to be hard stamped with the following details:

- For oil injection method of fitting, the start point load, in Newtons, and the axial pull-up at 0°C and 35°C, in mm.
- For the dry fitting method, the push-up load at 0°C and 35°C, in Newtons.

7.4.4 A copy of the fitting curve relative to temperature and means for determining any subsequent movement of the propeller are to be placed on board.

7.5 Final fitting of keyed propellers

7.5.1 The fit of the screwshaft cone to both the working and any spare propeller is to be carried out under survey. Generally, a satisfactory fit for keyed type propellers should show a light, overall marking of the cone surface with a tendency towards heavier marking in way of the larger diameter of the cone face. The final fit to cone should be made with the key in place.

■ *Section 8* Water jet units

8.1 Construction and welding

8.1.1 The following components are to be inspected at the manufacturer's works:

- Steering nozzle.
- Reverse bucket.
- Stator impeller.
- Integral bearing.

8.1.2 Welded construction is to be in accordance with the requirements specified in Chapter 13 of the Rules for Materials.

8.1.3 Welded components are to comply with the requirements of Pt 15, Ch 4 and be subject to stress relief heat treatment upon completion. Where an impeller has welded blades, non-destructive testing is to be carried out to an approved procedure.

8.2 Testing

8.2.1 Testing of the first installation of a new type of water jet unit is required and is to demonstrate the adequacy of the steering and reversing mechanisms during the most arduous manoeuvres.

8.2.2 Upon completion, the impeller assembly is to be suitably balanced in accordance with ISO 940 Grade G6,3 or an equivalent Standard.

■ *Section 9* Thrusters

9.1 Azimuth thrusters

9.1.1 The performance specified for the craft is to be demonstrated.

9.1.2 The actual values of steering torque are to be verified during sea trials to confirm that the design maximum dynamic duty torque has not been exceeded.

9.2 Tunnel thrusters

9.2.1 It is to be demonstrated that the thruster unit meets the specified performance.

■ *Section 10* Steering systems

10.1 Construction

10.1.1 The requirements of the Rules relating to the testing of Class I pressure vessels, piping and related fittings including hydraulic testing apply.

10.2 Type testing

10.2.1 Each type of power unit pump is to be subjected to a type test. The type test is to be for a duration of not less than 100 hours, the test arrangements are to be such that the pump may run in idling conditions, and at maximum delivery capacity at maximum working pressure. During the test, idling periods are to be alternated with periods at maximum delivery capacity at maximum working pressure. The passage from one condition to another should occur at least as quickly as on board. During the whole test no abnormal heating, excessive vibration or other irregularities are permitted. After the test, the pump is to be opened out and inspected. Type tests may be waived for a power unit which has been proven to be reliable in marine service.

10.3 Testing

10.3.1 After installation on board the craft the steering unit is to be subjected to the applicable hydrostatic and running tests.

10.3.2 The steering system is to be demonstrated to show that the requirements of the Rules have been met. The trial is to include the operation of the following:

(a) The steering system, including demonstration of the functional performances.
(b) The steering power units, including transfer between steering power units.
(c) The isolation of one power actuating system, checking the time for regaining steering capability.

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(d) The hydraulic fluid recharging system (may be effected at the dockside).
(e) The emergency power supply.
(f) The steering controls, including transfer of control and local control.
(g) The means of communication between the steering compartment and the wheelhouse, also the engine room, if applicable (may be effected at the dockside).
(h) The alarms and indicators (may be effected at the dockside).
(j) Where the steering system is designed to avoid hydraulic locking this feature is to be demonstrated (may be effected at the dockside).

Section 11
Sea trials

11.1 Sea trials requirements

11.1.1 Sea trials are to be of sufficient duration and carried out under normal operating conditions applicable to the intended class notation. Individual Chapters give specific requirements.

11.2 Programme

11.2.1 Sea trials are to include the demonstration of:
(a) The adequacy of the starting arrangements of the main engines, auxiliary systems and emergency generators.
(b) The effectiveness of the steering gear control systems.
(c) Manoeuvring, to include:
- starting;
- normal and emergency stopping;
- reversing;
- governor testing;
- safety devices, and associated indicators and alarms.

(d) The redundancy arrangements for Category B craft.
(e) Tooth contact markings in geared installations using a recognised technique. The marking is to be as detailed in 5.5.
(f) For controllable pitch propellers, the pitch setting under failure conditions.

11.3 Performance testing

11.3.1 It is to be verified that the propeller performs satisfactorily under ahead and astern conditions. Where controllable pitch propellers are fitted, the free route astern trial is to be carried out with the propeller blades set in the full pitch astern condition.

11.3.2 It is to be verified that large movements of resiliently mounted machinery do not occur during start up and stop, or during normal operating conditions.

11.3.3 The installation should be tested to ensure that gas turbines cannot be continuously operated within any speed range where excessive vibration, stalling or surging may be encountered.

11.3.4 Overloading of machinery is not to occur under continuous astern power.

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Rules and Regulations for the Classification of Special Service Craft

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LIFE MATTERS

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■ *Section 1* General requirements

1.1 Application

1.1.1 This Chapter is to be read in conjunction with the General Requirements for Machinery in Part 9.

1.1.2 The requirements of Section 4 do not apply to diesel engines intended for essential services where power does not exceed 110 kW.

1.2 Power ratings

1.2.1 In this Chapter where the dimensions of any particular component are determined from shaft power, *P*, in kW, and revolutions per minute, *R*, the values to be used are those defined in Part 9.

1.3 Power conditions for generator sets

1.3.1 Auxiliary engines coupled to electrical generators are to be capable under service conditions of developing continuously the power to drive the generators at full rated output (kW) and of developing for a short period (15 minutes) an overload power of not less than 10 per cent, *see* Pt 16, Ch 2.

1.4 Inclination of craft

1.4.1 Main and essential auxiliary diesel engines are to operate satisfactorily under the conditions as shown in Table 1.4.1 in Pt 9, Ch 1.

1.5 Engine type testing

1.5.1 Engines are to be subjected to type testing in accordance with Pt 9, Ch 2,2.4.

■ *Section 2* Particulars to be submitted

2.1 Plans and information

2.1.1 At least three copies of the following plans are to be submitted for consideration:

- Crankshaft assembly plan (for each crank-throw).
- Crankshaft details plan (for each crank-throw).
- Thrust shaft or intermediate shaft (if integral with engine).
- Output shaft coupling bolts.
- Main engine securing arrangements where non-metallic chocks are used.
- Type and arrangement of crankcase explosion relief valves.
- Arrangement and welding specifications with details of the procedures for fabricated bedplate, thrust bearing bedplate, crankcases, frames and entablatures. Details of materials, welding consumables, fit-up conditions, fabrication sequence and heat treatments are to be included.
- Details of the securing and collision arrangements, *see also* Part 9.
- Schematic oil fuel system, including controls and safety devices.
- Lubricating oil system.
- Starting air system.
- Cooling water system.
- Control engineering aspects in accordance with Part 16.
- Shielding of high pressure fuel pipes.
- Crankshaft design data as outlined in Section 4.
- Combustion pressure-displacement relationship.
- High pressure parts for fuel oil injection system with specification of pressures, pipe dimensions and materials.
- For new engine types that have not been approved by LR, the proposed type test programme.
- The type test report on completion of type testing for a new engine type. For mass produced engines a separate report is to be submitted for each engine requiring approval, *see* 10.5.

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- Additionally, for mass produced engines:

(a) For consideration of an engine type to be approved:
  (i) Engine specification, *see* 11.1.4.
  (ii) Manufacturing processes and quality control information, *see* 11.2.3.
  (iii) List of sub-contractors for main parts.
  (iv) Procedures for configuring during commissioning.

(b) For engines of an approved type to be installed on a craft, a compliance and inspection certificate, *see* 11.4.

- For engine control, alarm monitoring and safety systems, the plans and information required by Pt 16, Ch 1,1.2.
- For electronically controlled engines, the plans and information required by 13.2.
- Schematic layouts showing details and arrangements of oil mist detection/monitoring and alarm systems.

2.1.2 The following information and calculations are to be submitted for information:

- Power/speed operational envelope.
- Calculations and information for short term high power operation where applicable.
- Longitudinal and transverse cross-section.
- Cast bedplate, thrust bearing bedplate, crankcase and frames.
- Cylinder head assembly.
- Cylinder liner.
- Piston assembly.
- Tie rod.
- Connecting rod, piston rod, and crosshead assemblies.
- Camshaft drive and camshaft general arrangement.
- Shielding and insulation of exhaust pipes.
- Operation and maintenance manuals.
- Vibration dampers/detuners and moment compensators.
- Details of turbochargers.
- Cross-sectional plans of the assembled turbo-charger with main dimensions.
- Fully dimensioned plans of the rotor.
- Material particulars with details of welding and surface treatments.
- Turbo-charger operating and test data.
- Manufacturer's burst test assessment.
- Material specifications covering the listed components together with details of any surface treatments, non-destructive testing and hydraulic tests.
- Arrangement of interior lighting, where provided.
- Engine Type test programme, where required including proposals for short term high power operation.
- Alternative proposals for hydraulic tests where design features are such that modifications to the test requirements are necessary.
- Thrust bearing assembly (if integral with engine and not integrated in the bedplate).
- Counterweights, where attached to crank-throw, including fastening.
- Main engine holding down arrangement (metal chocks).

2.1.3 Where it is proposed to use alloy castings, micro alloyed or alloy steel forgings or iron castings, details of the chemical composition, heat treatment and mechanical properties are to be submitted.

2.1.4 A Failure Mode and Effects Analysis (FMEA) as required by Part 9 is to be submitted. The FMEA is to include the following associated sub-systems:

- Starting and stopping.
- Oil fuel.
- Lubricating oil.
- Cooling water (fresh and sea).
- Air induction.
- Exhaust.
- Engine mounting.
- Control and monitoring.
- Electrical power supplies.
- Hydraulic oil (for valve lift).

2.1.5 Plans and details for dead craft condition starting arrangements are to be submitted for appraisal, *see* 7.1.

2.1.6 For engine types built under licence it is intended that the above documentation be submitted by the Licensor. Each Licensee is then to submit the following:

- A list, based on the above, of all documents required with the relevant drawing numbers and revision status from both Licensor and Licensee.
- The associated documents where the Licensee proposes design modifications to components. In such cases a statement is to be made confirming the Licensor's acceptance of the proposed changes.

In all cases a complete set of endorsed documents will be required by the Surveyor attending the Licensee's works.

2.1.7 Where considered necessary additional documentation may be required.

■ *Section 3* Materials

3.1 Materials test and inspections

3.1.1 Components for engines are to be tested as indicated in Table 1.3.1 and in accordance with the relevant requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

3.2 Crankshaft materials

3.2.1 The specified minimum tensile strength of castings and forgings for crankshafts is to be selected within the following general limits:

(a) Carbon-manganese steel castings – 400 to 550 N/mm^2.

(b) Carbon-manganese steel forgings (normalised and tempered) – 400 to 600 N/mm^2.

(c) Carbon-manganese steel forgings (quenched and tempered) – not exceeding 700 N/mm^2.

(d) Alloy steel castings – not exceeding 700 N/mm^2.

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Table 1.3.1 Material testing requirements

Component	Material tests	Non-destructive tests	
		Magnetic particle or Liquid penetrant	Ultrasonic
Crankshaft	all	all	all
Crankshaft coupling flange (non-integral) for main propulsion engines	above 400 mm bore	—	—
Crankshaft coupling bolts	above 400 mm bore	—	—
Steel piston crowns	above 400 mm bore	above 400 mm bore	all
Piston rods	above 400 mm bore	above 400 mm bore	above 400 mm bore
Connecting rods, including bearing caps	all	all	above 400 mm bore
Crosshead	above 400 mm bore	—	—
Cylinder liner	above 300 mm bore	—	—
Cylinder cover	above 300 mm bore	above 400 mm bore	all
Steel castings for welded bedplates	all	all	all
Steel forgings for welded bedplates	all	—	—
Plates for welded bedplates, frames and entablatures	all	—	—
Crankcases, welded or cast	all	—	—
Tie rods	all	above 400 mm bore	—
Turbo-charger, shaft and rotor	above 300 mm bore	—	—
Bolts and studs for cylinder covers, crossheads, main bearings, connecting rod bearings	above 300 mm bore	above 400 mm bore	—
Steel gear wheels for camshaft drives	above 400 mm bore	above 400 mm bore	—

NOTES
1. For closed-die forged crankshafts the ultrasonic examination may be confined to the initial production and to subsequent occasional checks.
2. Magnetic particle or liquid penetrant testing of tie rods may be confined to the threaded portions and the adjacent material over a length equal to that of the thread.
3. Cylinder covers and liners manufactured from spheroidal or nodular graphite iron castings may not be suitable for ultrasonic NDE, depending upon the grain size and geometry. An alternative NDE procedure is to be agreed with LR.
4. Bore dimensions refer to engine cylinder bores.
5. All required material tests are to be witnessed by the Surveyor unless alternative arrangements have been specifically agreed by LR.
6. For mass produced engines, *see* Section 10.

(e) Alloy steel forgings – not exceeding 1000 N/mm^2.
(f) Spheroidal or nodular graphite iron castings – 370 to 800 N/mm^2.

■ *Section 4* Crankshaft design

4.1 Application

4.1.1 The formulae given in this Section are applicable to solid or semi-built crankshafts, having a main support bearing adjacent to each crankpin, and are intended to be applied to a single crankthrow analysed by the static determinate method.

4.1.2 Alternative methods, including a fully documented stress analysis, will be considered.

4.1.3 Calculations are to be carried out for the maximum continuous power rating for all designed operating conditions. Calculations are to include short term high power operation where applicable.

4.1.4 Designs of crankshafts not included in this scope will be subject to special consideration.

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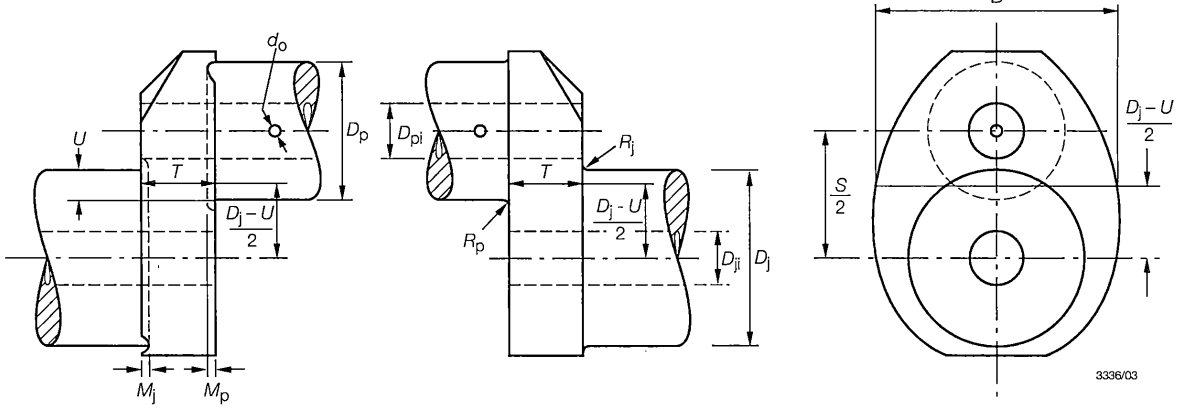
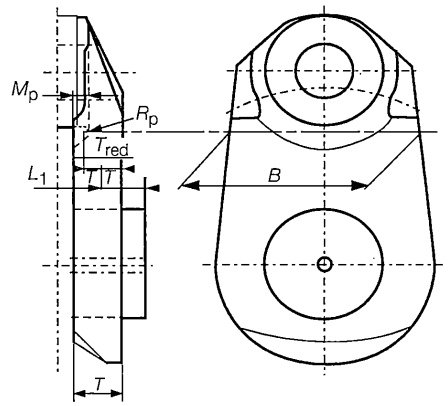


Fig. 1.4.1(a) Crank dimensions necessary for the calculation of stress concentration factors

4.2 Symbols

4.2.1 For the purposes of this Chapter the following symbols apply, *see also* Fig. 1.4.1:

h = radial thickness of web, in mm
k_e = bending stress factor
B = transverse breadth of web, in mm
D_p, D_j = outside diameter of pin or main journal, in mm
D_{pi}, D_{ji} = internal diameter of pin or main journal, in mm
D_s = shrink diameter of main journal in web, in mm
d_o = diameter of radial oil bore in crankpin, in mm
F = alternating force at the web centreline, in N
K_1 = fatigue enhancement factor due to manufacturing process
K_2 = fatigue enhancement factor due to surface treatment
M_b = alternating bending moment at web centreline, in N-mm (NOTE: alternating is taken to be 1/2 range value)
M_{BON} = alternating bending moment calculated at the outlet of crankpin oil bore
M_p, M_j = undercut of fillet radius into web measured from web face, in mm
R_p, R_j = fillet radius at junction of web and pin or journal, in mm
S = stroke, in mm
T = axial thickness of web, in mm
T_a = alternating torsional moment at crankpin or crank journal, in N-mm (NOTE: alternating is taken to be 1/2 range value)
U = pin overlap
α_B = bending stress concentration factor for crankpin
α_T = torsional stress concentration factor for crankpin
β_B = bending stress concentration factor for main journal
β_Q = direct shear stress concentration factor for main journal
β_T = torsional stress concentration factor for main journal
γ_B = bending stress concentration factor for radially drilled oil hole in the crankpin
γ_T = torsional stress concentration factor for radially drilled oil hole in the crankpin
σ_{ax} = alternating axial stress, in N/mm^2
σ_b = alternating bending stress, in N/mm^2
σ_{BON} = alternating bending stress in the outlet of the oil bore, in N/mm^2
σ_p,σ_j = maximum bending stress in pin and main journal taking into account stress raisers, in N/mm^2



Crankshaft without overlap

Fig 1.4.1(b)
Crank dimensions for crankshaft without overlap

σ_u = specified minimum UTS of material, in N/mm^2
σ_y = specified minimum yield stress of material, in N/mm^2
σ_{BO} = maximum bending stress in the outlet of the oil bore, in N/mm^2
σ_Q = alternating direct stress, in N/mm^2
τ_a = alternating torsional stress, in N/mm^2
τ_p, τ_j = maximum torsional stress in pin and main journals taking into account stress raisers, in N/mm^2
τ_{tob} = maximum torsional stress in outlet of crankpin oil bore taking into account stress raisers, in N/mm^2.

4.3 Stress concentration factors

4.3.1 Geometric factors. Crankshaft variables to be used in calculating the geometric stress concentrations together with their limits of applicability are shown in Table 1.4.1.

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Table 1.4.1 Crankshaft variables

Variable	Range	
	Lower	Upper
$b = B/D_p$	1,10	2,20
$d_j = D_{ji}/D_p$	0,00	0,80
$d_p = D_{pi}/D_p$	0,00	0,80
$m_j = M_j/D_p$	0,00	r_{jb}
$m_p = M_p/D_p$	0,00	r_p
$r_{jB} = R_j/D_p$	0,03	0,13
$r_{jT} = R_j/D_j$	0,03	0,13
$r_p = R_p/D_p$	0,03	0,13
$t = T/D_p$	0,20	0,80
$t = T_{red}/D_p$ *see* Note 3	0,20	0,80
$d = d_o/D_p$	0,00	0,20
$u = U/D_p$		0,50

NOTES
1. Where variables fall outside the range, alternative methods are to be used and full details submitted for consideration.
2. A lower limit of u can be extended down to large negative values provided that:
   (i) If calculated f(rec) < 1 then the factor f(rec) is not to be considered (f(rec) = 1)
   (ii) If $u < -0,5$ then f(ut) and f(ru) are to be evaluated replacing the actual value of u by –0,5.
3. For crankshafts without overlap *see also* 4.3.6.

4.3.2 Crankpin stress concentration factors:

Bending

$$\alpha_B = 2,70\, f(ut)\, f(t)\, f(b)\, f(r)\, f(dp)\, f(dj)\, f(rec)$$

where

$$f(ut) = 1,52 - 4,1t + 11,2t^2 - 13,6t^3 + 6,07t^4 - u\,(1,86 - 8,26t + 18,2t^2 - 18,5t^3 + 6,93t^4) - u^2\,(3,84 - 25,0t + 70,6t^2 - 87,0t^3 + 39,2t^4)$$

$$f(t) = 2,18t^{0,717}$$

$$f(b) = 0,684 - 0,0077b + 0,147b^2$$

$$f(r) = 0,208r_p^{(-0,523)}$$

$$f(dp) = 1 + 0,315(d_p) - 1,52(d_p)^2 + 2,41(d_p)^3$$

$$f(dj) = 1 + 0,27d_j - 1,02(d_j)^2 + 0,531(d_j)^3$$

$$f(rec) = 1 + (m_p + m_j)\,(1,8 + 3,2u)$$

valid only between $u = -0,5$ and 0,5

Torsion

$$\alpha_T = 0,8\, f(ru)\, f(b)\, f(t)$$

where

$$f(ru) = r_p^{-(0,22 + 0,1u)}$$

$$f(b) = 7,9 - 10,65b + 5,35b^2 - 0,857b^3$$

$$f(t) = t^{(-0,145)}$$

4.3.3 Crank journal stress concentration factors (not applicable to semi-built crankshafts)

Bending

$$\beta_B = 2,71 f_B(ut)\, f_B(t)\, f_B(b)\, f_B(r)\, f_B(dj)\, f_B(dp)\, f(rec)$$

where

$$f_B(ut) = 1,2 - 0,5t + 0,32t^2 - u\,(0,80 - 1,15t + 0,55t^2) - u^2\,(2,16 - 2,33t + 1,26t^2)$$

$$f_B(t) = 2,24t^{0,755}$$

$$f_B(b) = 0,562 + 0,12b + 0,118b^2$$

$$f_B(r) = 0,191r_{jB}^{(-0,557)}$$

$$f_B(dj) = 1 - 0,644d_j + 1,23(d_j)^2$$

$$f_B(dp) = 1 - 0,19d_p + 0,0073(d_p)^2$$

$$f(rec) = 1 + (m_p + m_j)\,(1,8 + 3,2u)$$

valid only between $u = -0,5$ and 0,5

Direct shear

$$\beta_Q = 3,01 f_Q(u)\, f_Q(t)\, f_Q(b)\, f_Q(r)\, f_Q(dp)\, f(rec)$$

where

$$f_Q(u) = 1,08 + 0,88u - 1,52(u)^2$$

$$f_Q(t) = \frac{t}{0,0637 + 0,937t}$$

$$f_Q(b) = b - 0,5$$

$$f_Q(r) = 0,533r_{jB}^{(-0,204)}$$

$$f_Q(dp) = 1 - 1,19d_p + 1,74(d_p)^2$$

$$f(rec) = 1 + (m_p + m_j)\,(1,8 + 3,2u)$$

valid only between $u = -0,5$ and 0,5

Torsion

$$\beta_T = 0,8 f(ru)\, f(b)\, f(t)$$

where

$$f(ru) = r_{jT}^{-(0,22 + 0,1u)}$$

$$f(b) = 7,9 - 10,65b + 5,35b^2 - 0,857b^3$$

$$f(t) = t^{(-0,145)}$$

4.3.4 Crankpin oil bore stress concentration factors for radially drilled oil holes:

- Bending

$$\gamma_B = 3 - 5,88 \bullet d_o + 34,6 \bullet d_o^2$$

- Torsion

$$\gamma_T = 4 - 6 \bullet d_o + 30 \bullet d_o^2$$

4.3.5 Where experimental measurements of the stress concentrations are available these may be used. The full documented analysis of the experimental measurements is to be submitted for consideration.

4.3.6 In the case of semi-built crankshafts when $M_p > R_p$ the web thickness is to be taken as:

$T_{red} = T - (M_p - R_p)$ and the web width B is to be taken in way of the crankpin fillet radius centre *see* Fig. 1.4.1(b).

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4.4 Nominal stresses

4.4.1 The nominal alternating bending stress, σ_b, is to be calculated from the maximum and minimum bending moment at the web centreline taking into account all forces being applied to the crank throw in one working cycle with the crank throw simply supported at the mid length of the main journals.

4.4.2 Nominal bending stresses are referred to the web bending modulus.

4.4.3 Nominal alternating bending stress:

$$\sigma_b = \pm \frac{M_b}{Z_{web}} k_e \text{ N/mm}^2$$

where

$$Z_{web} = \frac{BT^2}{6} \text{ mm}^3$$

k_e = 0,8 for crosshead engines
= 1,0 for trunk piston engines.

4.4.4 Nominal alternating bending stress in the outlet of the crankpin oil bore:

$$\sigma_{BON} = \pm \frac{M_{BON}}{Z_{crankpin}}$$

where

M_{BON} is taken as the ½ range value
$M_{BON} = \pm \frac{1}{2} (M_{BOmax} - M_{BOmin})$

and

$M_{BO} = (M_{BTO} \cos\psi + M_{BRO} \sin\psi)$, *see* Fig. 1.4.2

The two relevant bending moments are taken in the crankpin cross-section through the oil bore.

M_{BRO} = bending moment of the radial component of the connecting-rod force

M_{BTO} = bending moment of the tangential component of the connecting-rod force

$Z_{crankpin} = \frac{\pi}{32} \frac{D^4 - d^4}{D}$ $Z_{crankpin}$ related to the cross-section of axially bored crankpin.

4.4.5 The nominal direct shear stress in the web for the purpose of assessing the main journal is to be added algebraically to the bending stress, using the alternating forces which have been used in deriving M_b in 4.4.3.

4.4.6 Nominal stress is referred to the web cross-section area or the pin cross-section area as applicable.

4.4.7 Nominal alternating direct shear stress:

$$\sigma_Q = \pm \frac{F}{A_{web}} k_e \text{ N/mm}^2$$

where

$A_{web} = BT \text{ mm}^2$

4.4.8 The nominal alternating torsional stress, τ_a, is to be taken into consideration. The value is to be derived from forced-damped vibration calculations of the complete dynamic system. Alternative methods will be given consideration. The engine designer is to advise the maximum level of alternating vibratory stress that is permitted.

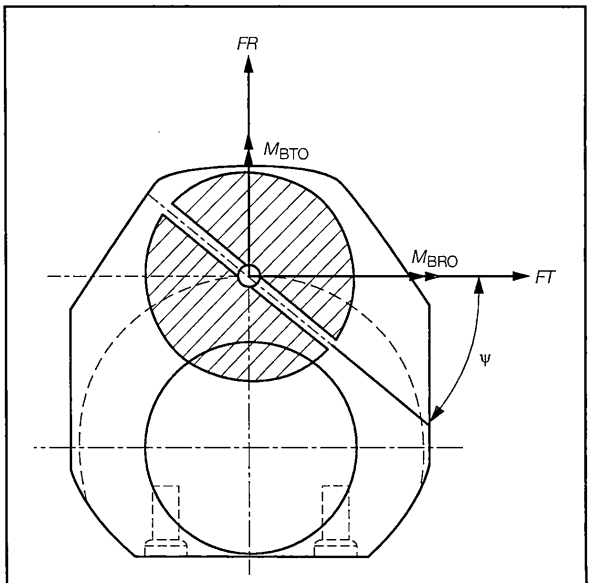

Fig. 1.4.2 Crankpin section through the oil bore

4.4.9 The results of torsional vibration calculations for the full dynamic system, carried out in accordance with Part 13 are to be submitted.

4.4.10 Nominal alternating torsional stress:

$$\tau_a = \pm \frac{T_a}{Z_T} \text{ N/mm}^2$$

where

Z_T = torsional modulus of crankpin and main journal

$$= \frac{\pi}{16} \left[\frac{(D^4 - d^4)}{D} \right] \text{ mm}^3$$

D = outside diameter of crankpin or main journal, in mm

d = inside diameter of crankpin or main journal, in mm

τ_a is to be ascertained from assessment of the torsional vibration calculations where the maximum and minimum torques are determined for every mass point of the complete dynamic system and for the entire speed range by means of a harmonic synthesis of the forced vibrations from the 1st order up to and including the 15th order for 2-stroke cycle engines and from the 0,5th order up to and including the 12th order for 4-stroke cycle engines. Whilst doing so, allowance must be made for the damping that exists in the system and for unfavourable conditions (misfiring [*] in one of the cylinders). The speed step calculation shall be selected in such a way that any resonance found in the operational speed range of the engine shall be detected.

If T_a is not known, a value can be calculated by the following formula as an approximation in the first instance:

$$T_a = \left((18,6 - 0,0132 D_e) \times \left(\frac{\sigma_u + 160}{560} \right) \right) \times Z_e \text{ N/mm}$$

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where

$$D_e = D_j \sqrt[3]{1 + \left(\frac{D_{ji}}{D_j}\right)^4}$$

or

$$D_p \sqrt[3]{1 - \left(\frac{D_{pi}}{D_p}\right)^4}$$

whichever is the smaller

Z_e = corresponding torsional modulus

$$= \pi \frac{(D_e^4 - d^4)}{16 D_e} \text{ mm}^3.$$

4.4.11 For the purpose of the crankshaft assessment, the nominal alternating torsional stress considered in calculations is to be the highest calculated value, according to the method described in 4.4.10, occurring at the most torsionally loaded mass point of the crankshaft system.

4.4.12 The approval of the crankshaft will be based on the installation having the largest nominal alternating torsional stress (but not exceeding the maximum figure specified by the engine manufacturer). For each installation it is to be ensured by calculation that the maximum approved nominal alternating tersional stress is not exceeded.

4.4.13 Reference should be made to Pt 13, Ch 1 on the calculations of torsional vibration characteristics.

4.4.14 In addition to the bending stress, σ_b, the axial vibratory stress, σ_{ax}, is to be taken into consideration, for crosshead type engines. For trunk piston engines, $\sigma_{ax} = 0$. The value is to be derived from forced-damped vibration calculations of the complete dynamic system. Alternative methods will be given consideration. The engine designer is to advise the maximum level of alternating vibratory stress that is permitted. The corresponding crankshaft free-end deflection is also to be stated.

4.5 Maximum stress levels

4.5.1 Crankpin fillet:

- Maximum alternating bending stress:

$\sigma_p = \alpha_B (\sigma_b + \sigma_{ax})$ N/mm²

where

α_B = bending stress concentration, *see* 4.3.2.

- Maximum alternating torsional stress:

$\tau_p = \alpha_T \tau_{ax}$ N/mm²

where

α_T = torsional stress concentration, *see* 4.3.2

τ_a = nominal alternating torsional stress in crankpin N/mm².

4.5.2 Outlet of crankpin oil bore

- Maximum alternating bending stress:

$\sigma_{BO} = \gamma_B (\sigma_{BON} + \sigma_{ax})$ N/mm²

where

γ_B = bending stress concentration factor, *see* 4.3.4

- Maximum alternating torsional stress:

$\tau_{tob} = \gamma_T \tau_a$ N/mm²

where

γ_T = torsional stress concentration factor, *see* 4.3.4

τ_a = nominal alternating torsional stress in crankpin N/mm².

4.5.3 Crank journal fillet (not applicable to semi-built crankshafts):

Maximum alternating bending stress:

$\sigma_j = \beta_B (\sigma_b + \sigma_{ax}) + \beta_Q \sigma_Q$ N/mm²

where

β_B = bending stress concentration, *see* 4.3.3

β_Q = direct stress concentration, *see* 4.3.3.

Maximum alternating torsional stress:

$\tau_j = \beta_T \tau_a$ N/mm²

where

β_T = torsional stress concentration, *see* 4.3.3

τ_a = nominal alternating torsional stress in main journal N/mm².

4.6 Equivalent alternating stress

4.6.1 Equivalent alternating stress of the crankpin, σ_{ep}, or crank journal σ_{ej}, is defined as:

$\sigma_{ep}, \sigma_{ej} = \sqrt{(\sigma + 10)^2 + 3\tau^2}$ N/mm²

where

σ = σ_p or σ_j N/mm²

τ = τ_p or τ_j N/mm²

4.6.2 Equivalent alternating stress for the outlet of the crankpin oil bore σ_{eob}, is defined as:

$$\sigma_{eob} = \pm \frac{1}{3} \sigma_{bo} \left[1 + 2 \sqrt{1 + \frac{9}{4} \left(\frac{\tau_{to}}{\sigma_{bo}}\right)^2}\right] \text{ N/mm}^2.$$

4.7 Fatigue strength

4.7.1 The fatigue strength of a crankshaft is based upon the crankpin and crank journal as follows:

$$\sigma_{fp} = K_1 K_2 (0{,}42\sigma_u + 39{,}3) \left(0{,}264 + 1{,}073 D_p^{-0,2} + \frac{785 - \sigma_u}{4900} + \frac{196}{\sigma_u} \sqrt{\frac{1}{R_p}}\right) \text{ N/mm}^2$$

To calculate the fatigue strength in the oil bore area, replace R_p with $\frac{1}{2}d_o$ and σ_{fp} with σ_{fob}.

$$\sigma_{fj} = K_1 K_2 (0{,}42\sigma_u + 39{,}3) \left(0{,}264 + 1{,}073 D_j^{-0,2} + \frac{785 - \sigma_u}{4900} + \frac{196}{\sigma_u} \sqrt{\frac{1}{R_j}}\right) \text{ N/mm}^2$$

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where

σ_u = UTS of crankpin or crank journal as appropriate, in N/mm^2

K_1 = fatigue endurance factor appropriate to the manufacturing process
= 1,05 for continuous grain-flow (CGF) or die-forged
= 1,0 for freedom forged (without CGF)
= 0,93 for cast steel manufactured using a LR approved cold rolling process

K_2 = fatigue enhancement factor for surface treatment. These treatments are to be applied to the fillet radii.

4.7.2 A value for K_2 will be assigned upon application by the engine designers. Full details of the process, together with the results of full scale fatigue tests will be required to be submitted for consideration. Alternatively, the following values may be taken (surface hardened zone to include fillet radii):

K_2 = 1,15 for induction hardened
= 1,25 for nitrided

Where a value of K_1 or K_2 greater than unity is to be applied then details of the manufacturing process are to be submitted.

4.8 Acceptability criteria

4.8.1 The acceptability factor, Q, is to be greater than 1,15:

$$Q = \frac{\sigma_f}{\sigma_e}$$ for crankpin, journal and the outlet of crankpin oil bore

where

$\sigma_f = \sigma_{fp}$, σ_{fj} or σ_{fob}

$\sigma_e = \sigma_{ep}$, σ_{ej} or σ_{eob}.

4.9 Crankshaft oil hole

4.9.1 The junction of the oil hole with the crankpin or main journal surface is to be formed with an adequate radius and smooth surface finish down to a minimum depth equal to 1,5 times the oil bore diameter.

4.9.2 Fatigue strength calculations or, alternatively, fatigue test results may be required to demonstrate acceptability.

4.9.3 When journal diameter is equal or larger than the crankpin diameter, the outlets of main journal oil bores are to be formed in a similar way to the crankpin oil bores, otherwise separate fatigue strength calculations or, alternatively, fatigue test results may be required.

4.10 Shrink fit of semi-built crankshafts

4.10.1 The maximum permissible internal diameter in the journal pin is to be calculated in accordance with the following formula:

$$D_{ji} = D_s \sqrt{1 - \frac{4000 FoS\, M_{max}}{\mu \pi D_s^2 L_s \sigma_{yj}}}$$

where the symbols are as defined in 4.10.7.

4.10.2 When 4.10.1 cannot be complied with, then 4.10.7 is not applicable. In such cases δ_{min} and δ_{max} are to be established from FEM calculations.

4.10.3 The following formulae are applicable to crankshafts assembled by shrinking main journals into the crankwebs.

4.10.4 In general, the radius of transition, R_j, between the main journal diameter, D_j, and the shrink diameter, D_s, is to be not less than $0{,}015D_j$ or $0{,}5(D_s - D_j)$.

4.10.5 The distance, y, between the underside of the pin and the shrink diameter should be greater than $0{,}05D_s$.

4.10.6 Deviations from these parameters will be specially considered.

4.10.7 The proposed diametral interference is to be within the following limits, *see also* Fig. 1.4.3:

The minimum required diametral interference is to be taken as the greater of:

$$\delta_{min} = \frac{12{,}156 \times 10^6 (FoS)}{T Ds\, \mu\, E} \frac{P}{R} (1 + C) \frac{k^2 - l^2}{(k^2 - 1)(1 - l^2)} \text{ mm}$$

or

$$\delta_{min} = \frac{\sigma_y D_s}{E} \text{ mm}$$

where

h = minimum radial thickness of the web around the diameter D_s, mm

$k = \frac{D_o}{D_s}$

$l = \frac{D_{ji}}{D_s}$

C = ratio of torsional vibratory torque to the mean transmitted torque at the P/R rating being considered

$D_o = D_s + 2h$, mm

D_s = shrink diameter, mm

E = Young's modulus of elasticity of crankshaft material, N/mm^2

FoS = Factor of Safety against rotational slippage to be taken as 2,0. A value less than 2,0 may be used where documented by experiments to demonstrate acceptability

P = output power, in kW

R = speed at associated power, in rpm

T = crankweb thickness, in mm

μ = coefficient of static friction to be taken as 0,2 for degreased surfaces. A value greater than 0,2 may be used where documented by experiments to demonstrate acceptability

σ_{yj} = minimum yield strength of material for journal pin

M_{max} = absolute maximum value of the torque taking Ch 8,2 into consideration

L_s = length of shrink fit, in mm

Maximum diametral interference, δ_{max}, is not to be greater than:

$$\delta_{max} = \frac{\sigma_y D_s}{E} + \frac{0{,}8D_s}{1000} \text{ mm}$$

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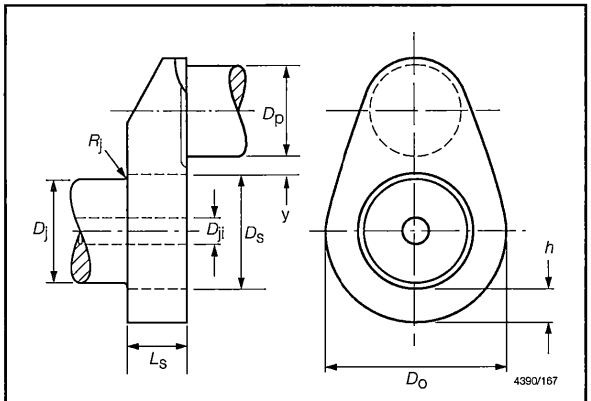

Fig. 1.4.3 Crankthrow of semi-built crankshaft

4.10.8 Reference marks are to be provided on the outer junction of the crankwebs with the journals.

■ *Section 5* Construction and welded structures

5.1 Crankcases

5.1.1 Crankcases and their doors are to be of robust construction to withstand anticipated crankcase pressures that may arise during a crankcase explosion, taking into account the installation of explosion relief valves required by Section 6, and the doors are to be securely fastened so that they will not be readily displaced by a crankcase explosion.

5.2 Welded joints

5.2.1 Bedplates and major components of engine structures are to be made with a minimum number of welded joints.

5.2.2 Double welded butt joints are to be adopted wherever possible in view of their superior fatigue strength.

5.2.3 Girder and frame assemblies should, so far as possible, be made from one plate or slab, shaped as necessary, rather than by welding together a number of small pieces.

5.2.4 Steel castings are to be used for parts which would otherwise require complicated weldments.

5.2.5 Care is to be taken to avoid stress concentrations such as sharp corners and abrupt changes in section.

5.2.6 Joints in parts of the engine structure which are stressed by the main gas or inertia loads are to be designed as continuous full strength welds and for complete fusion of the joint. They are to be so arranged that, in general, welds do not intersect, and that welding can be effected without difficulty and adequate inspection can be carried out. Abrupt changes in plate section are to be avoided and where plates of substantially unequal thickness are to be butt welded, the thickness of the heavier plate is to be gradually tapered to that of the thinner plate. Tee joints are to be made with full bevel or equivalent weld preparation to ensure full penetration.

5.2.7 In single plate transverse girders the castings for main bearing housings are to be formed with web extensions which can be butt welded to the flange and vertical web plates of the girder. Stiffeners in the transverse girder are to be attached to the flanges by full penetration welds.

5.3 Materials and construction

5.3.1 All welded construction is to be in accordance with the requirements specified in Chapter 13 of the Rules for Materials.

5.3.2 Plates, sections, forgings and castings are to be of welding quality in accordance with the requirements of the Rules for Materials, and with a carbon content generally not exceeding 0,23 per cent. Steels with higher carbon contents may be approved subject to satisfactory results from welding procedure tests.

■ *Section 6* Safety arrangements on engines

6.1 Cylinder relief valves

6.1.1 Scavenge spaces in open connection with cylinders are to be provided with explosion relief valves.

6.2 Crankcase relief valves

6.2.1 Crankcases are to be provided with lightweight spring-loaded valves or other quick-acting and self-closing devices to relieve the crankcases of pressure in the event of an internal explosion and to prevent any inrush of air thereafter. The valves are to be designed and constructed to open quickly and be fully open at a pressure not greater than 0,2 bar.

6.2.2 The valve lids are to be made of ductile material capable of withstanding the shock of contact with stoppers at the full open position.

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6.2.3 Each valve is to be fitted with a flame arrester that permits flow for crankcase pressure relief and prevents the passage of flame following a crankcase explosion. The valves are to be type tested in a configuration that represents the installation arrangements that will be used on an engine and in accordance with Section 15. The valves are to be positioned on engines to minimise the possibility of danger and damage arising from emission of the crankcase atmosphere. Where shielding from the emissions is fitted to a valve, the valve is to be type tested to demonstrate that the shielding does not adversely affect the operational effectiveness of the valve.

6.2.4 In engines having cylinders not exceeding 200 mm bore or having a crankcase gross volume not exceeding 0,6 m^3, relief valves may be omitted.

6.2.5 In engines having cylinders exceeding 200 mm but not exceeding 250 mm bore, at least two relief valves are to be fitted; each valve is to be located at or near the ends of the crankcase. Where the engine has more than eight crank throws an additional valve is to be fitted near the centre of the engine.

6.2.6 In engines having cylinders exceeding 250 mm but not exceeding 300 mm bore, at least one relief valve is to be fitted in way of each alternate crank throw with a minimum of two valves. For engines having 3, 5, 7, 9, etc., crank throws, the number of relief valves is not to be less than 2, 3, 4, 5, etc., respectively.

6.2.7 In engines having cylinders exceeding 300 mm bore at least one valve is to be fitted in way of each main crank throw.

6.2.8 Additional relief valves are to be fitted for separate spaces on the crankcase, such as gear or chaincases for camshaft or similar drives, when the gross volume of such spaces exceeds 0,6 m^3.

6.2.9 The combined free area of the crankcase relief valves fitted on an engine is to be not less than 115 cm^2/m^3 based on the volume of the crankcase.

6.2.10 The free area of each relief valve is to be not less than 45 cm^2.

6.2.11 The free area of the relief valve is the minimum flow area at any section through the valve when the valve is fully open.

6.2.12 In determining the volume of the crankcase for the purpose of calculating the combined free area of the crankcase relief valves, the volume of the stationary parts within the crankcase may be deducted from the total internal volume of the crankcase. No deduction shall be made for the volumes of the rotating and reciprocating components.

6.2.13 The valves are to be provided with a copy of the manufacturer's installation and maintenance manual for the size and type of valve being supplied for installation on a particular engine. The manual is to contain the following information:

- Description of valve with details of function and design limits.
- Copy of type test certification.
- Installation instructions.
- Maintenance and in-service instructions to include testing and renewal of any sealing arrangements.
- Actions required after a crankcase explosion.

6.2.14 A copy of the installation and maintenance manual required by 6.2.13 is to be provided on board the ship.

6.2.15 Plans showing details and arrangements of the relief valves are to be submitted for approval, *see* 2.1.

6.2.16 The valves are to be provided with suitable markings that include the following information:

- Name and address of manufacturer.
- Designation and size.
- Month/Year of manufacture.
- Approved installation orientation.

6.3 Vent pipes

6.3.1 Through ventilation, and any arrangement which could produce a flow of external air within the crankcase, is in principle not permitted except for trunk piston type dual fuel engines where crankcase ventilation is to be provided. Where crankcase vent or breather pipes are fitted, they are to be made as small as practicable and/or as long as possible to minimise the inrush of air after an explosion. Vent or breather pipes from crankcases of main engines are to be led to a safe position on deck or other approved position.

6.3.2 If provision is made for the extraction of gases from within the crankcase, e.g. for oil mist detection purposes, the vacuum within the crankcase is not to exceed 25 mm of water.

6.3.3 Lubricating oil drain pipes from engine sump to drain tank are to be submerged at their outlet ends. Where two or more engines are installed, vent pipes, if fitted, and lubrication oil drain pipes are to be independent to avoid intercommunication between crankcases.

6.4 Warning notice

6.4.1 A warning notice is to be fitted in a prominent position, preferably on a crankcase door on each side of the engine, or alternatively at the engine room control station. This warning notice is to specify that whenever overheating is suspected in the crankcase, the crankcase doors or sight holes are not to be opened until a reasonable time has elapsed after stopping the engine, sufficient to permit adequate cooling within the crankcase.

6.5 Crankcase access and lighting

6.5.1 Where access to crankcase spaces is necessary for inspection purposes, suitably positioned rungs or equivalent arrangements are to be provided as considered appropriate.

6.5.2 Interior lighting, where fitted, is to be flameproof.

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6.6 Oil mist detection

6.6.1 Where crankcase oil mist detection arrangements are fitted, they are to be of a type approved by LR, tested in accordance with Section 16 and comply with 6.6.2 to 6.6.15.

6.6.2 The oil mist detection system and arrangements are to be installed in accordance with the engine designer's and oil mist detection equipment manufacturer's instructions/ recommendations. The following particulars are to be included in the instructions:

(a) A schematic layout of the engine oil mist detection and alarm system showing locations of engine crankcase sample points and cabling/piping arrangements together with pipe dimensions to the detector.

(b) Evidence of study to justify the selected locations of sample points and sample extraction rate (if applicable) in consideration of the crankcase arrangements and geometry, and the predicted crankcase atmosphere where oil mist can accumulate.

(c) The manufacturer's maintenance and test manual.

(d) Information relating to type or in-service testing of the engine with engine protection system test arrangements having approved types of oil mist detection equipment.

6.6.3 A copy of the oil mist detection equipment maintenance and test manual required by 6.6.2 is to be provided on board the craft.

6.6.4 Oil mist detection and alarm information is to be capable of being read from a safe location away from the engine.

6.6.5 In the case of multi engine installations, each engine is to be provided with individual, dedicated oil mist detection arrangements and alarm(s).

6.6.6 Oil mist detection and alarm systems are to be capable of being tested on the test bed and on board when the engine is at a standstill and when the engine is running at normal operating conditions in accordance with test procedures that are acceptable to LR.

6.6.7 Alarms and safeguards for the oil mist detection system are to be in accordance with Pt 16, Ch 1 as applicable.

6.6.8 The oil mist detection arrangements are to provide an alarm indication in the event of a foreseeable functional failure in the equipment and installation arrangements.

6.6.9 The oil mist detection system is to provide an indication that any lenses fitted in the equipment and used in determination of the oil mist level have been partially obscured to a degree that will affect the reliability of the information and alarm indication.

6.6.10 Where oil mist detection equipment includes the use of programmable electronic systems, the arrangements are to be in accordance with Pt 16, Ch 1, as applicable.

6.6.11 Schematic layouts showing details and arrangements of oil mist detection and alarm systems are to be submitted. *See* 2.1.

6.6.12 The equipment together with detectors is to be tested when installed on the test bed and on board the craft to demonstrate that the detection and alarm system functions correctly. The testing arrangements are to be to the satisfaction of the Surveyor.

6.6.13 Where sequential oil mist detection arrangements are provided, the sampling frequency and time is to be as short as reasonably practicable.

6.6.14 Where alternative methods are provided for the prevention of the build-up of oil mist that may lead to a potentially explosive condition within the crankcase, detailed information is to be submitted for consideration. The information is to include:

(a) Engine particulars – type, power, speed, stroke, bore and crankcase volume.

(b) Details of arrangements designed to prevent the build up of potentially explosive conditions within the crankcase, e.g., bearing temperature monitoring, oil splash temperature monitoring, crankcase pressure monitoring, and recirculation arrangements.

(c) Evidence to demonstrate that the arrangements are effective in preventing the build up of potentially explosive conditions together with details of in-service experience.

(d) Operating instructions and the maintenance and test instructions.

6.6.15 Where it is proposed to use the introduction of inert gas into the crankcase to minimise a potential crankcase explosion, details of the arrangements are to be submitted for consideration.

■ *Section 7* Starting arrangements

7.1 Dead craft condition starting arrangements

7.1.1 Means are to be provided to ensure that machinery can be brought into operation from the dead craft condition without external aid.

7.1.2 Dead craft condition for the purpose of 7.1.1 is to be understood to mean a condition under which the main propulsion plant and auxiliaries are not in operation. In restoring propulsion, no stored energy for starting and operating the propulsion plant is assumed to be available. Additionally, neither the main source of electrical power nor other essential auxiliaries is assumed to be available for starting and operating the propulsion plant.

7.1.3 Where the emergency source of power is an emergency generator which fully complies with the requirements of Pt 16, Ch 2, this generator may be used for restoring operation of the main propulsion plant, boilers and auxiliaries where any power supplies necessary for engine operation are also protected to a similar level as the starting arrangements.

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7.1.4 Where there is no emergency generator installed or an emergency generator does not comply with Pt 16, Ch 2, the arrangements for bringing main and auxiliary machinery into operation are to be such that the initial charge of starting air or initial electrical power and any power supplies for engine operation can be developed on board the craft without external aid. If, for this purpose, an emergency air compressor or an electric generator is required, these units are to be powered by a hand-starting oil engine or a hand-operated compressor. The arrangements for bringing main and auxiliary machinery into operation are to have capacity such that the starting energy and any power supplies for engine operation are available within 30 minutes of a dead craft condition.

7.2 Starting arrangements – Air compressors

7.2.1 Two or more air compressors are to be fitted having a total capacity, together with a topping-up compressor where fitted, capable of charging the air receivers within one hour from atmospheric pressure, to the pressure sufficient for the number of starts required by 7.3. At least one of the air compressors is to be independent of the main propulsion unit and the capacity of the main air compressors is to be approximately equally divided between them. The capacity of an emergency compressor which may be installed to satisfy the requirements of 7.1 is to be ignored.

7.2.2 The compressors are to be so designed that the temperature of the air discharged to the starting air receivers will not substantially exceed 93°C in service. A small fusible plug or an alarm device operating at 121°C is to be provided on each compressor to give warning of excessive air temperature. The emergency air compressor is excepted from these requirements.

7.2.3 Each compressor is to be fitted with a safety valve so proportioned and adjusted that the accumulation with the outlet valve closed will not exceed 10 per cent of the maximum working pressure. The casings of the cooling water spaces are to be fitted with a safety valve or bursting disc so that ample relief will be provided in the event of the bursting of an air cooler tube.

7.2.4 Each compressor is to be fitted with an alarm for failure of the lubricating oil supply which will initiate an automatic shutdown.

7.3 Air receivers

7.3.1 Where the main engine is arranged for air starting the total air receiver capacity is to be sufficient to provide without replenishment, not less than 12 consecutive starts of the main engine, alternating between ahead and astern if of the reversible type and not less than six consecutive starts if of the non-reversible type. At least two air receivers of approximately equal capacity are to be provided. For scantlings and fittings of air receivers, *see* Pt 15, Ch 4.

7.3.2 For multi-engine installations, where more than one engine is driving each propulsion shaft line, the following requirements apply:

(a) Twin engine installations driving fixed pitch propeller, where one of the engines can be reversed, six consecutive starts per engine are required.

(b) For all other types of multi-engine installations three consecutive starts per engine are required.

7.3.3 Each air receiver is to be fitted with a drain arrangement at its lowest part, permitting oil and water to be blown out.

7.3.4 Each receiver which can be isolated from a relief valve is to be provided with a suitable fusible plug to discharge the contents in case of fire. The melting point of the fusible plug is to be approximately 150°C, *see also* Pt 15, Ch 4,9.2.

7.3.5 Receivers used for the storage of air for the control of remotely operated valves are to be fitted with relief valves and not fusible plugs.

7.4 Starting air pipe systems and safety fittings

7.4.1 Air start piping systems are in general to comply with the requirements of Part 15, due regard being paid to the particular type of installation.

7.4.2 In designing the compressed air installation, care is to be taken that the compressor air inlets will be located in an atmosphere reasonably free from oil vapour or, alternatively, an air duct from outside the machinery space is to be led to the compressors.

7.4.3 The air discharge pipe from the compressors is to be led direct to the starting air receivers. Provision is to be made for intercepting and draining oil and water in the air discharge for which purpose a separator or filter is to be fitted in the discharge pipe between compressors and receivers.

7.4.4 The starting air pipe system from receivers to main and auxiliary engines is to be entirely separate from the compressor discharge pipe system. Stop valves on the receivers are to permit slow opening to avoid sudden pressure rises in the piping system. Valve chests and fittings in the piping system are to be of ductile material.

7.4.5 Drain valves for removing accumulations of oil and water are to be fitted on compressors, separators, filters and receivers. In the case of any low-level pipelines, drain valves are to be fitted to suitably located drain pots or separators.

7.4.6 The starting air piping system is to be protected against the effects of explosions by providing an isolating non-return valve or equivalent at the starting air supply to each engine.

7.4.7 In direct reversing engines bursting discs or flame arresters are to be fitted at the starting valves on each cylinder; in non-reversing and auxiliary engines at least one such device is to be fitted at the supply inlet to the starting air manifold on each engine. The fitting of bursting discs or flame arresters may be waived in engines where the cylinder bore does not exceed 230 mm.

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7.4.8 Alternative safety arrangements may be submitted for consideration.

7.5 Electrical starting arrangements

7.5.1 Where main engines are fitted with electric starters, two batteries are to be fitted. Each battery is to be capable of starting the engines when cold and the combined capacity is to be sufficient without recharging to provide the number of starts of the main engines as required by 7.3.

7.5.2 Electric starting arrangements for auxiliary engines are to have two separate batteries or be supplied by separate circuits from the main engine batteries when such are provided. Where one of the auxiliary engines only is fitted with an electric starter one battery will be acceptable.

7.5.3 The combined capacity of the batteries for starting the auxiliary engines is to be sufficient for at least three starts for each engine.

7.5.4 Engine starting batteries are to be used only for the purposes of starting the engines and for the engines' own control, alarm, monitoring and safety arrangements. Means are to be provided to ensure that the stored energy in the batteries is maintained at a level required to start the engines as defined in 7.5.1 and 7.5.3.

7.5.5 Where engines are fitted with electric starting batteries, an alarm is to be provided for low battery level.

7.5.6 The requirements for battery installations are given in Pt 16, Ch 2.

7.6 Starting of the emergency source of power

7.6.1 Emergency generators are to be capable of being readily started in their cold conditions down to a temperature of 10°C. If this is impracticable, or if lower temperatures are likely to be encountered, consideration is to be given to the provision and maintenance of heating arrangements, so that ready starting will be assured.

7.6.2 Each emergency generator that is arranged to be automatically started is to be equipped with an approved starting system having two independent sources of stored energy, each of which is sufficient for at least three consecutive starts. When hand (manual) starting is demonstrated to be effective, only one source of stored energy need be provided. However, this source of stored energy is to be protected against depletion below the level required for starting.

7.6.3 Provision is to be made to maintain continuously the stored energy at all times, and for this purpose:

(a) Electrical and hydraulic starting systems are to be maintained from the emergency switchboard.

(b) Compressed air starting systems may be maintained by the main or auxiliary compressed air receivers, through a suitable non-return valve, or by an emergency air compressor energised by the emergency switchboard.

(c) All these starting, charging and energy storing devices are to be located in the emergency generator room. These devices are not to be used for any purpose other than the operation of the emergency generator.

7.6.4 When automatic starting is not required by the Rules and where it can be demonstrated as being effective, hand (manual) starting is permissible, such as manual cranking, inertial starters, manual hydraulic accumulators, powder charge cartridges.

7.6.5 When hand (manual) starting is not practicable, the provisions of 7.6.2 and 7.6.3 are to be complied with except that starting may be manually initiated.

7.6.6 Electric starting arrangements are to also satisfy 7.5.2 to 7.5.5.

7.7 Engine control, alarm monitoring and safety system power supplies

7.7.1 Power supplies are to be arranged so that power for electrically powered control, alarm monitoring and safety systems required for engine starting and operation will remain available in the event of a failure. Power is to remain available to permit starting attempts for the number of starts specified by this Section for each source of stored energy.

7.7.2 Where adequate battery and charging capacity exists, an engine starting battery may be used as one source of electrical power required by 8.6.1.

7.7.3 An alarm is to be activated in the event of failure of a power supply and, where applicable, low battery charge level. Manual power supply changeover facilities are permitted.

■ *Section 8* Piping systems

8.1 General

8.1.1 Diesel engine piping systems are, in general, to comply with the requirements of Pt 15, Ch 1 and Ch 3, due regard being paid to the particular type of installation.

8.1.2 Short lengths of synthetic rubber hoses that comply with the requirements of Pt 15, Ch 1,13 may be used in diesel engine piping systems to accommodate relative movement between machinery and fixed piping systems.

8.2 Oil fuel systems

8.2.1 Oil fuel arrangements are to comply with the requirements of Pt 15, Ch 3,3 and 3,4, as applicable.

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8.2.2 All external high pressure fuel delivery lines between the high pressure fuel pumps and fuel injectors are to be protected with a jacketed piping system capable of containing fuel from a high pressure line failure. If flexible hoses are used for shielding purposes, these arrangements are to be approved.

8.2.3 The protection is to prevent oil fuel or oil fuel mist from reaching a source of ignition on the engine or its surroundings. Suitable drainage arrangements are to be made for draining any oil fuel leakage and for preventing contamination of the lubricating oil by oil fuel.

8.3 Oil fuel filters and fittings

8.3.1 Two or more filters are to be fitted in the oil fuel supply lines to the main and auxiliary engines, and the arrangements are to be such that any filter can be cleaned without interrupting the supply of filtered oil fuel to the engines.

8.3.2 Drip trays are to be fitted under oil fuel filters and other fittings which are required to be opened up frequently for cleaning or adjustment or where there is the possibility of leakage. Alternative arrangements may be acceptable and full details should be submitted for consideration.

8.4 Lubricating oil systems

8.4.1 Lubricating oil arrangements are to comply with the requirements of Part 15 as applicable.

8.5 Engine cooling water systems

8.5.1 Cooling water arrangements are to comply with the requirements of Part 15, as applicable.

8.6 Inlet and exhaust systems

8.6.1 Engine inlets are to be arranged to provide sufficient air to the engines whilst minimising the ingestion of harmful particles.

8.6.2 Where the exhaust is led overboard near the waterline, means are to be provided to prevent water from being siphoned back to the engine. Where the exhaust is cooled by water spray, the exhaust pipes are to be self-draining overboard. Erosion/corrosion resistant shut-off flaps or other devices are to be fitted on the hull side shell or pipe end and acceptable arrangements made to prevent water flooding the space or entering the engine exhaust manifold.

8.6.3 Where the exhausts of two or more engines are led to a common silencer or exhaust gas-heated boiler or economiser, an isolating device is to be provided in each exhaust pipe.

8.6.4 The arrangement of the exhaust system is to be such as to prevent exhaust gases being drawn into the manned spaces, air conditioning systems and air intakes. They should not discharge into air cushion intakes.

8.6.5 Plastic pipes intended for exhaust systems are to be in accordance with a recognised Code or Standard suitable for the intended service conditions.

8.7 High pressure oil systems

8.7.1 Where flammable oils are used in high pressure systems, the oil pipe lines between the high pressure oil pump and actuating oil pistons are to be protected with a jacketed piping system capable of preventing oil spray from a high pressure line failure.

■ *Section 9* Control and monitoring

9.1 General

9.1.1 The Control and Monitoring systems are to comply with the requirements of Part 16.

9.1.2 While it is recommended that oil mist detection, engine bearing temperature monitors or alternative methods for crankcase protection be fitted, they are in any case to be provided:

(a) When arrangements are fitted to override the automatic stop for excessive reduction of the lubricating oil supply pressure.

(b) For engines of 2,250 kW and above or having cylinders of more than 300 mm bore.

Notes:

1. For medium and high speed engines automatic shutdown of the engine is to occur, *see also* 9.7.2.
2. Where arrangements are made to override the automatic shutdown due to high oil mist or bearing temperature, the override is to be independent of other overrides.
3. Where engine bearing temperature monitors or alternative methods are provided for the prevention of the build-up of oil mist that may lead to a potentially explosive condition within the crankcase, details are to be submitted for consideration. The submission is to demonstrate that the arrangements are equivalent to those provided by oil mist detection, *see* 6.6.14.

9.1.3 All main and auxiliary engines intended for essential services are to be provided with means of indicating the lubricating oil pressure supply to them. Where such engines are of more than 220 kW, audible and visual alarms are to be fitted to give warning of an appreciable reduction in pressure of the lubricating oil supply. Further, these alarms are to be actuated from the outlet side of any restrictions, such as filters, coolers, etc.

9.2 Main engine governors

9.2.1 An efficient governor is to be fitted to each main engine so adjusted that the speed does not exceed that for which the engine is to be classed by more than 15 per cent.

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9.3 Auxiliary engine governors

9.3.1 Auxiliary engines intended for driving electric generators are to be fitted with governors which, with fixed setting, are to control the speed within 10 per cent momentary variation and 5 per cent permanent variation under the following conditions:

(a) Full load is suddenly taken off.

(b) Full load is suddenly applied following a minimum of 15 minutes no load. If the BMEP is greater than 8 bar the load may be applied as follows:

$$\frac{800}{BMEP}\ \%\ \left(\text{but not less than } \frac{1}{3} \text{ full load}\right)$$, then full load being attained in not more than two equal stages as rapidly as possible.

9.3.2 Emergency engines are to comply with 9.3.1 except that the initial load required by 9.3.1(b) is to be not less than the total connected emergency statutory load.

9.3.3 For alternating current installations, the permanent speed variation of the machines intended for parallel operation are to be equal within a tolerance of ±0,5 per cent. Momentary speed variations with load changes in accordance with 9.5.1 are to return to and remain within one per cent of the final steady state speed in not more than eight seconds.

9.4 Overspeed protective devices

9.4.1 Each main engine developing 220 kW or over which can be declutched or which drives a controllable (reversible) pitch propeller, also each auxiliary engine developing 220 kW and over for driving an electric generator, is to be fitted with an approved overspeed protective device.

9.4.2 The overspeed protective device, including its driving mechanism, is to be independent of the governor required by 9.4 or 9.5 and is to be so adjusted that the speed does not exceed that for which the engine and its driven machinery are to be classed by more than 20 per cent for main engines and 15 per cent for auxiliary engines.

9.5 Engine stopping

9.5.1 At least two independent means of stopping the engines quickly from the control station under any conditions are to be available.

9.6 Unattended machinery

9.6.1 Where machinery is fitted with automatic or remote controls so that under normal operating conditions it does not require any manual intervention by the operators, it is to be provided with the alarms and safety arrangements required by 9.1 to 9.8 as appropriate. Alternative arrangements which provide equivalent safeguards will be considered.

9.6.2 Where a first stage alarm together with a second stage alarm and automatic shutdown of machinery are required by Tables 1.9.1 and 1.9.2, the sensors and circuits utilised for the second stage alarm and automatic shutdown are to be independent of those required for the first stage alarm.

9.6.3 Means are to be provided to prevent leaks from high pressure oil fuel injection piping for main and auxiliary engines dripping or spraying onto hot surfaces or into machinery air inlets. Such leakage is to be collected and, where practicable, led to a collector tank(s) fitted in a safe position. An alarm is to be provided to indicate that leakage is taking place. These requirements may also be applicable to high pressure hydraulic oil piping depending upon the location.

9.6.4 Where machinery specified in this Section is required to be provided with a standby pump, the standby pump is to start automatically if the discharge pressure from the working pumps falls below a predetermined value.

9.7 Diesel engines for propulsion purposes

9.7.1 Alarms and safeguards are indicated in 9.7.2 to 9.7.8 and Table 1.9.1, *see also* 9.1.2 and 9.6.3.

9.7.2 Alarms are to operate, and indication is to be given at the relevant control stations that the speed or power of the main propulsion engine(s) is to be reduced for the following fault conditions:

(a) Oil mist in crankcase or high bearing temperature (if detection is fitted, *see* 9.1.2).
(b) Low piston coolant pressure or flow.
(c) High piston coolant outlet temperature.
(d) Low cylinder coolant pressure or flow.
(e) High cylinder coolant temperature.
(f) High exhaust gas temperature per cylinder or deviation from average temperature (high).
(g) High thrust bearing temperature.
(h) Low cylinder lubricator flow.

NOTES:

1. For medium and high speed engines automatic slowdown is required for items (d), (e), (f) and (h). However, an automatic shutdown is required for (a).
2. Common sensors are acceptable for alarms and slowdown functions.

9.7.3 Reduction of speed or power may be effected by either manual or automatic control.

9.7.4 The following engine services are to be fitted with automatic temperature controls so as to maintain steady state conditions throughout the normal operating range of the propulsion engine(s):

(a) Lubricating oil supply.
(b) Piston coolant supply, where applicable.
(c) Cylinder coolant supply, where applicable.
(d) Fuel valve coolant supply, where applicable.

9.7.5 Indication of the starting air pressure is to be provided at each control station from which it is possible to start the main propulsion engine(s).

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Table 1.9.1 Oil engines for propulsion purposes alarms and safeguards (*see continuation*)

Item	Alarm	Note
Lubricating oil sump level	Low	Engines (and gearing if fitted)
Lubricating oil inlet pressure*+++	1st stage Low++	Engines (and gearing if fitted)
	2nd stage Low	Automatic shutdown engines (and gearing if fitted), *see* 9.6.2
Lubricating oil inlet temperature*	High	Engines (and gearing if fitted)
Lubricating oil filters differential pressure	High	—
Cylinder lubricator flow	Low unit	One sensor per lubricator
Piston coolant inlet pressure	Low	If a separate system
Piston coolant outlet temperature*	High	Per cylinder (if a separate system)
Piston coolant outlet flow*	Low	Per cylinder (if a separate system)
Cylinder coolant inlet pressure or flow*++	Low	—
Cylinder coolant outlet temperature*+++	1st stage High++	Per cylinder (if a separate system) or manifold++
	2nd stage High	Automatic shutdown medium and high speed engines, *see* 9.6.2
Sea-water cooling pressure	Low	—
Thrust bearing temperature*	High	—
Common rail servo oil pressure	Low	—
Fuel valve coolant pressure	Low	If a separate system
Fuel valve coolant temperature	High	If a separate system
Oil fuel pressure from booster pump	Low	—
Oil fuel temperature or viscosity*	High and Low	Heavy oil only
Common rail fuel oil pressure	Low	—
Charge air cooler outlet temperature	High and Low	4 stroke medium and high speed engines
Scavenge air temperature	High	Per cylinder, (fire detection, 2 stroke engines)
Exhaust gas temperature*	High	Per cylinder (or deviation from average temperature)

Table 1.9.1 Oil engines for propulsion purposes alarms and safeguards (*conclusion*)

Item	Alarm	Note
Turbo-charger exhaust gas outlet temperature*	High	—
Turbo-charger lubricating oil inlet pressure	Low	If system not integral with turbo-charger
Turbo-charger lubricating oil outlet temperature	High	Each bearing, if system not integral with turbo-charger. *See* Note 4
Starting air pressure*	Low	Before engine manoeuvring valve
Overspeed*	High	Automatic shutdown of engine, *see also* 9.4. Details of alternative proposals in accordance with the manufacturer's instructions may be submitted for consideration
Automatic start of engine	Failure	*See* 9.7.6
Electrical starting battery charge level	Low	—

NOTES
1. Where 'per cylinder' appears in this Table, suitable alarms may be situated on manifold outlets for medium and high speed engines.
2. For engines and gearing of 1500 kW or less, only the items marked* are required.
3. For service craft with engines of 500 kW or less, only the items marked ++ are required.
4. Where the outlet temperature for each bearing cannot be measured due to the design, details of alternative proposals in accordance with the turbocharger manufacturer's instructions may be submitted for consideration.

9.7.6 The number of automatic consecutive attempts which fail to produce a start is to be limited to three attempts. For reversible engines which are started and stopped for manoeuvring purposes, means are to be provided to maintain sufficient starting air in the air receivers. For electric starting, *see* 7.5.

9.7.7 Prolonged running in a restricted speed range is to be prevented automatically or, alternatively, an indication of restricted speed ranges is to be provided at each control station.

9.8 Auxiliary and other engines

9.8.1 Alarms and safeguards are indicated in Table 1.9.2, *see also* 9.1.2 and 9.6.3.

9.8.2 For engines operating on heavy oil fuel, automatic temperature of viscosity controls is to be provided.

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Table 1.9.2 Auxiliary engine alarms and safeguards

Item	Alarm	Note
Lubricating oil inlet temperature	High	—
Lubricating oil inlet pressure	1st stage Low	—
	2nd stage Low	Automatic shutdown of engine, *see* 9.6.2
Coolant outlet temperature	1st stage High	For engines over 220 kW
	2nd stage High	For engines over 220 kW Automatic shutdown of engine, *see* 9.6.2
Coolant pressure or flow	Low	—
Overspeed	High	Automatic shutdown of engine, *see also* 9.4. Details of alternative proposals in accordance with the manufacturer's instructions may be submitted for consideration
Starting air pressure	Low	—
Electrical starting battery charge level	Low	—
Oil fuel inlet temperature or viscosity	High and low	Heavy oil only
Common rail servo oil pressure	Low	—
Common rail fuel oil pressure	Low	—

9.9 Alarms and safeguards for emergency diesel engines

9.9.1 These requirements apply to emergency diesel engines required to be immediately available in an emergency and capable of being controlled remotely or automatically.

9.9.2 Alarms and safeguards are indicated in Table 1.9.3. *See also* 9.1.2 and 9.6.3.

9.9.3 The safety and alarm systems are to be designed to 'fail safe'. The characteristics of the 'fail safe' operation are to be evaluated on the basis not only of the system and its associated machinery, but also the complete installation, as well as the craft.

9.9.4 Regardless of the engine output, if shutdowns additional to those specified in Table 1.9.3 are provided except for the overspeed shutdown, they are to be automatically overridden when the engine is in automatic or remote control mode during navigation.

Table 1.9.3 Alarms and safeguards for emergency diesel engines

Item	Alarm	Alarm	Note
Emergency diesel engine	≥ 220 kW	<220 kW	
Fuel oil leakage from pressure pipes	Leakage	Leakage	*See* 9.6.3
Lubricating oil temperature	High	—	—
Lubricating oil pressure	Low	Low	—
Oil mist concentration in crankcase	High	—	*See* Note
Coolant pressure or flow	Low	—	—
Coolant temperature (can be air)	High	High	—
Overspeed	High	—	Automatic shutdown

NOTE
For engines having a power of more than 2250 kW or a cylinder bore of more than 300 mm.

9.9.5 Grouped alarms of at least those items listed in Table 1.9.3 are to be arranged on the bridge.

9.9.6 In addition to the fuel oil control from outside the space, a local means of engine shutdown is to be provided.

9.9.7 Local indications of at least those items listed in Table 1.9.3 are to be provided within the same space as the diesel engines and are to remain operational in the event of failure of the alarm and safety systems.

■ *Section 10* Requirements for craft which are not required to comply with the HSC Code

10.1 General

10.1.1 The requirements of Sections 1 to 9 apply to craft which are not required to comply with the HSC code, unless specifically exempted by the contents of this Section.

10.1.2 The requirements of 1.4.1 do not apply to yachts or service craft less than 24 m.

10.1.3 The requirements of 1.5.1 do not apply to service craft less than 24 m.

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10.2 Details to be submitted

10.2.1 The requirements of 2.1.1 do not apply to yachts or service craft less than 24 m, *see* Pt 9, Ch 1,6.1.

10.2.2 The requirements of 2.1.4 (FMEA as detailed in Part 9) do not apply to yachts or to service craft less than 24 m unless used for passenger carrying duties.

10.3 Materials

10.3.1 Materials for which no provision is made in this Part of the Rules may be accepted provided that they comply with an approved specification and such tests as may be considered necessary.

10.4 Crankshaft design

10.4.1 The requirements of Section 4 do not apply to the following types of craft having main or auxiliary diesel engines with a power output not exceeding 110 kW:
(a) service craft of less than 24 m,
(b) yachts,
(c) ACVs.

■ *Section 11*
Mass produced engines

11.1 Definition

11.1.1 Mass produced engines, for main and auxiliary purposes, are defined as those which are produced under the following criteria:
(a) In quantity under strict quality control of material and parts, according to a quality assurance scheme acceptable to LR.
(b) By the use of jigs and automatic machine tools designed to machine parts to specified tolerances for interchangeability, and which are verified on a regular inspection basis.
(c) By assembly with parts taken from stock and requiring little or no fitting.
(d) With bench tests carried out on individual assembled engines according to a specified programme.
(e) With appraisal by final examination of engines selected at random after workshop testing.

11.1.2 Castings, forgings and other parts for use in mass produced engines are also to be produced by methods similar to those given in 11.1.1(a), (b) and (c), with appropriate inspection.

11.1.3 Pressure testing of components is to comply with Pt 9, Ch 2,2.2.

11.1.4 The specification of a mass produced engine is to define the limits of manufacture of all component parts. The total production output is to be certified by the manufacturer and verified as may be required, by LR in accordance with the agreed manufacturer's quality assurance scheme, *see* 11.1.1(a).

11.2 Procedure for approval of mass produced engines

11.2.1 The procedure outlined in 11.2.2 to 11.2.5 applies to the inspection and certification of mass produced oil engines having a bore not exceeding 300 mm.

11.2.2 For the approval of a mass produced engine type, the manufacturer is to submit:
(a) The plans and particulars required by 2.1 for assessment;
(b) As necessary, information to assess compliance with Section 4;
(c) A list of subcontractors for main parts; and
(d) Control, alarm monitoring and safety system configuration procedures, *see* 11.4.2.

11.2.3 The manufacturer is to supply full information regarding the manufacturing processes and quality control procedures applied in the workshops. The information is to address the following:
(a) Organisation of quality control systems.
(b) Recording of quality control operations.
(c) Qualification and independence of personnel in charge of quality control.

11.2.4 A running type test of at least 100 hours duration is to be carried out on an engine chosen from the production line. The type testing is to comply with 11.5.

11.2.5 LR reserves the right to limit the duration of validity of approval of a mass produced engine. LR is to be informed, without delay, of any change in the design of the engine, including changes to the software and control, alarm monitoring or safety systems, in the manufacturing or quality, control processes, in the selection of materials or in the list of subcontractors for main parts.

11.3 Continuous review of production

11.3.1 LR Surveyors are to be provided free access to the manufacturer's workshops and to the quality control files.

11.3.2 The control of production, which is subject to survey, is to include the following:
(a) Inspection and testing records are to be maintained to the satisfaction of the Surveyor.
(b) The system for identification of parts is to be in accordance with recognised practice, and acceptable to LR.

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(c) The manufacturer is to provide full information about the quality control of the parts supplied by subcontractors for which certification may be required. LR reserves the right to apply direct and individual inspection procedures for parts supplied by subcontractors when deemed necessary.
(d) At the request of an attending LR surveyor, a workshop test may be required for an individual engine.

11.4 Compliance and inspection certificate

11.4.1 Each engine which is to be installed on a ship classed by LR is to be supplied with a statement certifying that the engine is identical to the one which underwent the tests specified in 11.2.4, and state the test and inspection results. The statement is to be made on a form agreed with LR. Each statement is to include the identification number which appears on the engine. A copy of this statement is to be submitted to LR.

11.4.2 The certificate is to include reference to the manufacturer's procedures to be followed during commissioning for configuring control, alarm monitoring and safety systems for multi-purpose engines or other engine types that require parameters and settings to be adjusted for the intended application.

11.5 Type test conditions

11.5.1 The requirements in this Section are applicable to the type testing of mass produced internal combustion engines where the manufacturer has requested approval. Omission or simplification of the type test requirements will be considered by LR for engines of an established type on application by the manufacturer.

11.5.2 The engine to be tested is to be selected from the production line and agreed by LR.

11.5.3 The type tests are to be conducted with the engine control systems operational in the approved configuration, *see* 2.1.5 and 2.1.6. Configuration management documents are to be reviewed at testing for validity and referenced in the type test report.

11.5.4 The duration and programme of type tests is to include the following:
(a) 80 h at rated output.
(b) 8 h at 110 per cent overload.
(c) 10 h at varying partial loads (25 per cent, 50 per cent, 75 per cent and 90 per cent of rated output).
(d) 2 h at maximum intermittent loads.
(e) Starting tests.
(f) Reverse running of direct reversing engines.
(g) Testing of speed governor.
(h) Testing of over-speed device.
(j) Testing of lubricating oil system failure alarm device.
(k) Testing of the engine with turbocharger out of action when applicable.
(l) Testing of minimum speed for main propulsion engines and the idling speed for auxiliary engines.

11.5.5 The type tests in 11.5.4 at the required outputs are to be combined together in working cycles for the whole duration within the limits indicated. *See also* 11.5.11 and 11.5.12.

11.5.6 The overload testing required by 11.5.4 is to be carried out with the following conditons:
(a) 110 per cent of rated power at 103 per cent revolutions per minute for engines directly driving propellers.
(b) 110 per cent of rated power at 100 per cent revolutions per minute for engines driving electrical generators or for other auxiliary purposes.

11.5.7 For prototype engines, the duration and programme of tests are to be specially agreed between the manufacturer and LR.

11.5.8 As far as practicable during type testing, the following particulars are to be continuously recorded:
(a) Ambient air temperature.
(b) Ambient air pressure.
(c) Atmospheric humidity.
(d) External cooling water temperature.
(e) Fuel and lubrication oil characteristics.

11.5.9 In addition to the particulars stated in 11.5.8 and as far as practicable, the following are also to be continuously measured and recorded:
(a) Engine revolutions per minute.
(b) Brake power.
(c) Torque.
(d) Maximum combustion pressure.
(e) Indicator pressure diagrams where practicable.
(f) Exhaust smoke (with an approved smoke meter).
(g) Lubricating oil pressure and temperature.
(h) Exhaust gas temperature in exhaust manifold, and, where facilities are available, from each cylinder.
(j) For turbocharged engines:
- Turbocharger revolutions per minute.
- Air temperature and pressures before and after turbo-blower and charge cooler.
- Exhaust gas temperature and pressures before and after the turbine.
- The cooling water inlet temperature to the charge air cooler.

11.5.10 After the type test, the main parts and especially those subject to wear are to be dismantled for examination by LR Surveyors.

11.5.11 For engines that are required to be approved for different purposes (multi-purpose engines), and that have different performance profiles and control, alarm, monitoring and safety systems configurations for each purpose, the programme and duration of test is to be modified to cover the whole range of the engine performance, taking into account the most severe conditions and intended purpose(s).

11.5.12 The rated output for which the engine is to be tested is the output corresponding to that declared by the manufacturer and agreed by LR, i.e. actual maximum power which the engine is capable of delivering continuously between the normal maintenance intervals stated by the manufacturer at the rated speed and under the stated ambient conditions.

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Section 12
Mass produced turbo-chargers

12.1 Application

12.1.1 The following procedure applies to the inspection of exhaust driven turbo chargers which are manufactured on the basis of mass production methods similar to 11.1 as applicable and for which the maker has requested the approval.

12.2 Procedure for approval of mass produced turbo-chargers

12.2.1 The procedure outlined in 12.2.2 to 12.2.5 applies to the inspection and certification of mass produced turbo-chargers when a simplified method of inspection has been requested by the manufacturers.

12.2.2 For the approval of a mass produced turbo-charger, the manufacturer is to submit, in addition to the plans and particulars required by Chapter 1, as applicable, a list of main current suppliers and subcontractors for rotating parts and an operation and maintenance manual.

12.2.3 The manufacturer will supply full information regarding the material and quality control system used in the organisation as well as the inspection methods, the way of recording and proposed frequency, and the method of material testing of important parts.

12.2.4 A Type test, *see* Pt 9, Ch 2,3.1, is to be carried out on a standard unit taken from the assembly line and is to be witnessed by the Surveyor. The performance data which may have to be verified are to be made available at the time of the type test. For manufacturers who have facilities for testing the turbo-charger unit on an engine for which the turbo-charger is intended, substitution of the hot running test by a test run of one hour's duration at overload (110 per cent of the rated output) may be considered.

12.2.5 LR reserves the right to limit the duration of validity of approval of a mass produced turbo-charger. LR is to be informed, without delay, of any change in the design of the turbo-charger, in the manufacturing or control processes, in the selection of materials or in the list of subcontractors for main parts.

12.3 Continuous inspection of individual units

12.3.1 LR Surveyors are to be provided with free access to the manufacturer's workshop to inspect at random the quality control measures and to witness the tests required by 12.3.3 to 12.3.7 as deemed necessary, and to have free access to all control records and subcontractor's certificates.

12.3.2 Each individual unit is to be tested in accordance with 12.3.4 to 12.3.7 by the maker who is to issue a final certificate.

12.3.3 Rotating parts of the turbo-charger blower are to be marked for easy identification with the appropriate certificate.

12.3.4 Material tests of the rotating parts are to be carried out by the maker or his subcontractor in accordance with the requirements of the Rules for Materials as applicable. The relevant certificate is to be produced and filed to the satisfaction of the Surveyor.

12.3.5 Pressure tests are to be carried out in accordance with Table 2.2.1. Special consideration will be given where design or testing features may require modification of the test requirements.

12.3.6 Dynamic balancing and overspeed tests are to be carried out, *see* Pt 9, Ch 2,3.2 and 3.3, in accordance with the approved procedure for quality control. If each forged wheel is individually controlled by an approved non-destructive examination method, then no overspeed test may be required except for wheels of the test unit.

12.3.7 A mechanical running test, *see* Pt 9, Ch 2,3.4, is to be carried out. The duration of the running test may be reduced to 10 minutes provided that the manufacturer is able to verify the distribution of defects established during the running tests on the basis of a sufficient number of tested turbo-chargers. For manufacturers who have facilities in their works for testing the turbo-chargers on an engine for which the turbo-chargers are intended, the bench test may be replaced by a test run of 20 minutes at overload (110 per cent of the rated output) on this engine.

12.4 Compliance and certificate

12.4.1 For every turbo-charger unit liable to be installed on an engine intended for a ship classed by LR, the manufacturer is to supply a statement certifying that the turbo-charger is identical with one that underwent the tests specified in 12.2.4 and that prescribed tests were carried out. Results of these tests are also to be stated. This statement is to be made on a form agreed with LR and a copy is to be sent to LR. Each statement must have a number which is to appear on the turbo-charger.

Section 13
Electronically controlled engines

13.1 Scope

13.1.1 The requirements of this Section are applicable to engines for propulsion, auxiliary or emergency power purposes with programmable electronic systems implemented and used to control fuel injection timing and duration, and which may also control combustion air or exhaust systems. The requirements of this Section also apply to programmable electronic systems used to control other functions (e.g. starting and control air, cylinder lubrication, etc.) where essential for the operation of the engine.

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13.1.2 These engines may be of the slow, medium or high-speed type. They generally have no direct camshaft driven fuel systems, but have common rail fuel/hydraulic arrangements and may have hydraulic actuating systems for the functioning of the exhaust systems.

13.1.3 The operation of these engines relies on the effective monitoring of a number of parameters such as crank angle, engine speed, temperatures and pressures using programmable electronic systems to provide the services essential for the operation of the engine such as fuel injection, air inlet, exhaust and speed control.

13.1.4 Details of proposals to deviate from the requirements of this Section are to be submitted and will be considered on the basis of a technical justification produced by the Enginebuilder.

13.1.5 Each engine is to be configured for the specified performance and is to satisfy the relevant requirements for propulsion, auxiliary or emergency engines.

13.1.6 During the life of the engine details of any proposed changes to control, alarm, monitoring or safety systems which may affect safety and the reliable operation of the engine are to be submitted to LR for approval.

13.2 Plans and particulars

13.2.1 In addition to the plans and particulars required by Section 2 the following information is to be submitted:

(a) A general overview of the operating principles, supported by schematics explaining the functionality of individual systems and sub-systems. The information is to relate to the engine capability and functionality under defined operating and emergency conditions such as recovery from a failure or malfunction, with particular reference to the functioning of programmable electronic systems and any sub-systems. The information is also to indicate if the engine has different modes of operation, such as to limit exhaust gas emissions and/or to run under an economic fuel consumption mode or any other mode that is electronically controlled.

(b) Operating manuals which describe the particulars of each system and, together with maintenance instructions, include reference to the functioning of sub-systems.

(c) A risk-based analysis of the mechanical, pressure containing, electrical, electronic and programmable electronic systems and arrangements that support the operation of the engine. The analysis is to demonstrate that suitable risk mitigation has been achieved in accordance with 13.3.

(d) Details of hydraulic systems for actuation of subsystems (fuel injection or exhaust), to include details of the design/construction of pipes, pumps, valves, accumulators and the control of valves/pumps. Details of pump drive arrangements are also to be included.

(e) Quality plan for sourcing, design, installation and testing of all components used in the oil fuel and hydraulic oil systems installed with the engine for engine operation.

(f) Fatigue analysis for all high pressure oil fuel and hydraulic oil piping arrangements required for engine operation where failure of the pipe or its connection or a component would be the cause of engine unavailability. The analysis is to concentrate on high pressure components and sub-systems and recognise the pressures and fluctuating stresses that the pipe system may be subject to in normal service.

(g) Evidence of type testing of the engine with the programmable electronic system, or a proposed test plan at the Enginebuilders with the programmable electronic system functioning, to verify the functionality and behaviour under all operating and fault conditions of the programmable electronic system.

(h) Schedule of testing at Enginebuilders, pre-sea trial commissioning and sea trials. The test schedules are to identify all modes of engine operation and the sea trials are to include typical port manoeuvres under the intended engine operating modes. The schedule is to include:
(i) testing and trials to demonstrate that the engine is capable of operating as described in (a);
(ii) tests to verify that the response of the complete mechanical, hydraulic, electrical and electronic system is as predicted for the intended operational modes; and
(iii) testing required to verify the conclusions of the risk-based analysis.

The scope of these tests is to be agreed with LR.

13.2.2 In addition to the applicable plans and particulars required by Pt 16, Ch 1,1.2.3 to 1.2.6 the following information for control, alarm, monitoring and safety systems relating to the operation of an electronically controlled engine is to be submitted:

(a) Engine configuration details, *see* 13.5.2;
(b) Software quality plans, including configuration management documents;
(c) Software safety evidence; and
(d) Software assessment inspection report.

13.3 Risk-based analysis

13.3.1 An analysis is to be carried out in accordance with relevant standards acceptable to LR to demonstrate compliance with the applicable requirements of this sub-Section appropriate to the engine application. The analysis is to be a risk-based consideration of engine operation and craft and personnel safety, and is to demonstrate adequate risk mitigation through fault tolerance and/or reliability in accordance with the specified criteria in 13.3.2 to 13.3.4 relevant to the engine application.

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13.3.2 For craft with a single main propulsion engine, a Failure Mode and Effects Analysis (FMEA), or alternative recognised analysis of system reliability, is to be carried out and is to demonstrate that an electronic control system failure:

(a) will not result in the loss of the ability to provide the services essential for the operation of the engine, *see* Pt 16, Ch 1,2.5.11 and 2.12.2;

(b) will not affect the normal operation of the services essential for the operation of the engine other than those services dependent upon the failed part, *see* Pt 16, Ch 1,2.13.4 and 2.13.5; and

(c) will not leave either the engine, or any equipment or machinery associated with the engine, or the craft in an unsafe condition, *see* Pt 16, Ch 1,2.3.14, 2.4.6, 2.5.5, 2.10.3, 2.10.4 and 2.13.5.

13.3.3 A risk-based analysis is to be carried out for:

(a) main engines on craft with multiple main engines or other means of providing propulsion power; and/or

(b) auxiliary engines intended to drive electric generators forming the craft's main source of electrical power or otherwise providing power for essential services.

The analysis is to demonstrate that adequate hazard mitigation has been incorporated in electronically controlled engine systems or the overall craft installation with respect to personnel safety and providing propulsion power and/or power for essential services for the safety of the craft. Arrangements satisfying the criteria of 13.3.2(a) to (c) will also be acceptable.

13.3.4 For engines for emergency power purposes, a risk-based analysis is to be carried out to demonstrate that the design incorporates adequate hazard mitigation, such that the likelihood of an electronic control system failure, resulting in the loss of the ability to provide emergency power when required, has been reduced to a level considered acceptable by LR, and that means are provided to detect failures and permit personnel to restore engine availability to operate on demand. Failures which would result in engine failure and/or damage or loss of availability are to be identified, and the report is to include documentation of:

(a) component reliability evidence;

(b) failure detection and alarms; and

(c) failure response required to restore engine availability and maintain personnel safety.

13.3.5 The risk-based analysis report is to:

(a) Identify the standards used for analysis and system design;

(b) Identify the engine, its purpose and the associated objectives of the analysis;

(c) Identify any assumptions made in the analysis.;

(d) Identify the equipment, system or sub-system, mode of operation and the equipment;

(e) Identify potential failure modes and their causes.

(f) Evaluate the local effects (e.g. fuel injection failure) and the effects on the system as a whole (e.g. loss of propulsion power) of each failure mode;

(g) Identify measures for reducing the risks associated with each failure mode (e.g. system design, failure detection and alarms, redundancy, quality control procedures for sourcing, manufacture and testing, etc.); and

(h) Identify trials and testing necessary to prove conclusions.

13.3.6 At sub-system level, it is acceptable to consider failure of equipment items and their functions, e.g. failure of a pump to produce flow or pressure head. It is not required that the failure of components within that pump be analysed, and failure need only be dealt with as a cause of failure of the pump.

13.4 Oil fuel and hydraulic oil systems

13.4.1 Oil fuel and hydraulic oil piping system arrangements are to comply with Part 15 as applicable.

13.4.2 Where pumps are essential for engine operation, no fewer than two oil fuel and two hydraulic oil pressure pumps are to be provided for their respective service and arranged such that failure of one pump does not render the other inoperative. Each oil fuel pump and hydraulic oil pump is to be capable of supplying the quantity of oil for engine operation at its maximum continuous rating and arranged ready for immediate use.

13.4.3 The oil fuel pressure piping between the oil fuel high pressure pumps and the fuel injectors is to be protected with a jacketed piping system capable of containing oil fuel leakage from a high pressure pipe failure.

13.4.4 The hydraulic oil pressure piping between the high pressure hydraulic pumps and hydraulic actuators is to be protected with a jacketed piping system capable of containing hydraulic oil leakage from a high pressure pipe failure.

13.4.5 Accumulators and associated high pressure piping are to be designed, manufactured and tested in accordance with a standard applicable to the maximum pressure and temperature rating of the system.

13.4.6 All valves, cocks and screwed connections are to be of a type-tested type applicable to the maximum service conditions anticipated in normal service.

13.4.7 Isolating valves and cocks are to be located as near as practicable to the equipment to be isolated. All valves forming part of the oil fuel and hydraulic oil installation are to be capable of being controlled from readily accessible positions above the working platform.

13.4.8 High pressure oil fuel and high pressure hydraulic oil piping systems are to be provided with high pressure alarms with set points that do not exceed the system design pressures.

13.4.9 High pressure oil fuel and high pressure hydraulic piping systems are to be provided with suitable relief valves on any part of the system that can be isolated and in which pressure can be generated. The settings of the relief valves are not to exceed the design pressures. The valves are to be of adequate size and so arranged as to avoid an undue rise in pressure above the design pressures.

13.4.10 Equipment fitted for monitoring pressures and temperatures in the high pressure oil fuel and high pressure hydraulic oil systems is to comply with a recognised standard suitable to the anticipated vibration and temperature conditions.

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13.4.11 A fatigue analysis is to be carried out in accordance with a standard applicable to the system under consideration and all anticipated pressure, pulsation and vibration loads are to be addressed. The analysis is to demonstrate that the design and arrangements are such that the likelihood of failure is as low as reasonably practicable. The analysis is to identify all assumptions made and standards to be applied during manufacture and testing of the system. Any potential weak points which may develop due to incorrect construction or assembly are also to be identified.

13.4.12 For high pressure oil containing and mechanical power transmission systems, the quality plan for sourcing, design, installation and testing of components is to address the following issues:

(a) Design and manufacturing standard(s) applied.
(b) Materials used for construction of key components and their sources.
(c) Details of the quality control system applied during manufacture and testing.
(d) Details of type approval, type testing or approved type status assigned to the machinery or equipment.
(e) Details of installation and testing recommendations for the machinery or equipment.

13.5 Control engineering systems

13.5.1 Control, alarm, monitoring, safety and programmable electronic systems are to comply with Pt 16, Ch 1 as applicable.

13.5.2 The engine control, alarm monitoring and safety systems are to be configured to comply with the relevant requirements (e.g. operating profile, alarms, shutdowns, etc.) of this Chapter and Pt 16, Ch 1 for an engine for main, auxiliary or emergency power purposes. Details of the engine configuration are to be submitted for consideration, identifying:

(a) Local and remote means to carry out system configuration.
(b) Enginebuilder procedures for undertaking configuring.
(c) Roles and responsibilities for configuration (e.g. Enginebuilder, engine packager, system integrator or other nominated party) with accompanying schedule.
(d) Configurable settings and parameters (including those not to be modified from a default value).
(e) Configuration for propulsion, auxiliary or emergency engine application.

Configuration records are to be maintained and are to be made available to the Surveyor at testing and trials and on request in accordance with Pt 16, Ch 1,1.4 and 7.1.3.

13.6 Software

13.6.1 Software lifecycle activities are to be carried out in accordance with an acceptable quality management system, *see* Pt 16, Ch 1,2.12.2 and 2.12.7.

13.6.2 Appropriate safety related processes, methods, techniques and tools are to be applied to software development and maintenance by the Enginebuilder. Selection and application of techniques and measures in accordance with Annex A of IEC 61508-3, *Functional safety of electrical/electronic/programmable electronic systems: Software requirements*, or other relevant standards or codes acceptable to LR, will generally be acceptable.

13.6.3 To demonstrate compliance with 13.6.1 and 13.6.2:

(a) software quality plans and safety evidence are to be submitted for consideration, *see* 13.2.2(b) and (c); and
(b) an assessment inspection of the Enginebuilder's completed development is to be carried out by LR. The inspection is to be tailored to verify application of the standards and codes used in software safety assurance accepted by LR.

■ *Section 14* Programme for trials of diesel engines to assess operational capability

14.1 Works trials (acceptance test)

14.1.1 Diesel engines which are to be subjected to trials on the test bed at the manufacturer's works and under attendance by the Surveyor(s) are to be tested in accordance with the scope of works trials specified in 14.1.2 to 14.1.10. The scope of the trials is to be agreed between the LR Surveyor and the manufacturer prior to testing. At the discretion of the Surveyor, the scope of the trials may be extended depending on the engine application.

14.1.2 For electronically controlled engines:

(a) works tests in accordance with 13.2.1(h); and
(b) verification of engine configuration, *see* 13.5.2, and that the approved software quality plans, including the software configuration management process, are being applied.

14.1.3 For all stages of the works trials, the pertaining operation values are to be measured and recorded by the engine manufacturer. All results are to be compiled in an acceptance protocol to be issued by the engine manufacturer.

14.1.4 In each case given in Table 1.14.1, all measurements conducted at the various load points shall be carried out at steady operating conditions. The readings for 100 per cent power (rated power at rated speed) are to be taken twice at an interval of at least 30 minutes.

14.1.5 The data to be measured and recorded, when testing the engine at various load points, are to include all necessary parameters for the engine operation. The crankshaft deflection is to be checked when this check is required by the manufacturer during the operating life of the engine. Crankshaft deflection measurements are to be taken before (cold condition) and after (hot condition) works acceptance trials.

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Table 1.14.1 Scope of works trials for diesel engines

Main engines driving propellers and waterjets		
Trial condition	Duration	Note
100 per cent power (rated power) at rated engine speed, *R*	≥ 60 minutes	After having reached steady conditions
110 per cent power at engine speed corresponding to 1,032**R*	30–45 minutes	After having reached steady conditions (1)
90 per cent (or maximum continuous power), 75 per cent, 50 per cent and 25 per cent	—	Powers in accordance with the nominal propeller curve
Starting and reversing manoeuvres	—	—
Testing of governor and independent overspeed protective device	—	*See* 9.2
Shut-down device	—	*See* 9.4
Engines driving generators		
Trial condition	Duration	Note
100 per cent power (rated power) at rated engine speed, *R*	≥ 50 minutes	After having reached steady conditions (2)
110 per cent power	15 minutes	After having reached steady conditions (2) (3)
75 per cent, 50 per cent and 25 per cent power and idle run	—	(2)
Start-up tests	—	—
Testing of governor and independent overspeed protective device	—	*See* 9.3
Shut-down device	—	*See* 9.4

NOTES
1. After running on the test bed, the fuel delivery system of main engines is normally to be so adjusted that overload power cannot be given in service.
2. The test is to be performed at rated speed with a constant governor setting.
3. After running on the test bed, the fuel delivery system of diesel engines driving generators must be adjusted such that overload (110 per cent) power can be given in service after installation on board, so that the governing characteristics including the activation of generator protective devices can be fulfilled at all times.

14.1.6 Checks of components to be presented for inspection after the works trials are left to the discretion of the Surveyor.

14.1.7 The Surveyor may require that after the trials the fuel delivery system is restricted so as to limit the engines to run at not more than 100 per cent power. The setting of the restriction is to be made as applicable to the intended fuel. Any restriction settings, and other changes to the engine's fuel injection equipment required for operation on special fuels, are to be recorded and included by the engine manufacturer.

14.1.8 For the duration of the acceptance test, no interventions or adjustments will be made to the machinery under test.

14.1.9 The testing of exhaust gas emissions is to comply with MARPOL as applicable.

14.1.10 For all stages that the engine is to be tested and where no duration is specified in Table 1.14.1, the load point is to be maintained for a sufficient period to allow pertaining values to be measured and recorded when the engine has achieved a steady operating condition.

14.2 On board trials

14.2.1 After the conclusion of the running-in programme prescribed by the engine manufacturer, engines are to undergo on board trials as specified in Table 1.14.2. The scope of the trials is to be agreed between the LR Surveyor and the Builder prior to testing.

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Table 1.14.2 Scope of shipboard trials for diesel engines

Main engines driving fixed-pitch propellers (1) (2)		
Trial condition	Duration	Note
At rated engine speed, *R*	≥ 4 hours	—
At engine speed corresponding to normal continuous power	≥ 2 hours	—
At engine speed corresponding to 1,032**R*	30 minutes	Where the engine adjustment permits, *see* 14.1.7
At minimum on-load speed	—	—
Starting and reversing manoeuvres	—	*See* Ch 1,7
In reverse direction of propeller rotation during the dock or sea trials at a minimum engine speed of 0,7**R*	10 minutes	—
Control, monitoring, alarms and safety systems	—	Operation to be demonstrated
Where imposed, test to ensure engine can pass safely through barred speed range	—	—
Single engine driving generator for propulsion only		
Trial condition	Duration	Note
100% power (rated propulsion power), *see* 14.2.3	≥ 4 hours	(3) (4)
At normal continuous propulsion power	≥ 2 hours	(3) (4)
110% power (rated propulsion power)	30 minutes	
In reverse direction of propeller rotation at a minimum speed of 70% of the nominal propeller speed	10 minutes	(3) (4)
Starting manoeuvres	—	—
Control, monitoring, alarm and safety systems	—	Operation to be demonstrated

NOTES
1. For main propulsion engines driving controllable pitch propellers, waterjets or reversing gears, the tests for main engines driving fixed-pitch propellers apply as appropriate.
2. Controllable pitch propellers are to be tested with various propeller pitches.
3. The tests to be performed at rated speed with a constant governor setting.
4. Tests are to be based on the rated electrical powers of the electric propulsion motors.

14.2.2 Engines driving generators or important auxiliaries are to be subjected to an operational test for at least 4 hours. During the test, the set concerned is required to operate at its rated power for an extended period. It is to be demonstrated that the engine is capable of supplying 100 per cent of its rated power, and in the case of on board generating sets, account shall be taken of the times needed to actuate the generator's overload protection system

14.2.3 In addition to 14.2.2, for engines driving generators for electric propulsion motors as well as auxiliaries, an operational test is to be carried out of at least 4 hours duration at a load which corresponds to 100 per cent of the electric propulsion motor(s) rated power. The astern/ahead manoeuvring capability of the propulsion system is to be demonstrated.

14.2.4 Trials are to include demonstration of engine control, monitoring, alarm and safety system operation to confirm that they have been provided, installed and configured as intended and in accordance with the relevant requirements for main, auxiliary or emergency engines.

14.2.5 For electronically controlled engines:
(a) On board tests in accordance with 13.2.1(h); and
(b) verification of engine configuration, *see* 13.5.2, and that the approved software quality plans, including the software configuration management process, are being applied.

14.2.6 The suitability of an engine to burn residual or other special fuels is to be demonstrated, if the machinery installation is arranged to burn such fuels in service. *See also* Pt 16, Ch 1,7.2.1.

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14.2.7 At the discretion of the attending Surveyor, the scope of the trials may be expanded in consideration of special operating conditions, such as towing, trawling, etc.

■ *Section 15*
Type testing procedure for crankcase explosion relief valves

15.1 Scope

15.1.1 To specify type tests and identify standard test conditions using methane gas and air mixture to demonstrate that LR requirements are satisfied for crankcase explosion relief valves intended to be fitted to engines and gear cases.

15.1.2 The test procedure is only applicable to explosion relief valves fitted with flame arresters. Where internal oil wetting of a flame arrester is a design feature of an explosion relief valve, alternative testing arrangements that demonstrate compliance with these requirements may be proposed by the manufacturer. The alternative testing arrangements are to be submitted to LR for approval.

15.2 Purpose

15.2.1 The purpose of type testing crankcase explosion relief valves is fourfold:

(a) To verify the effectiveness of the flame arrester.
(b) To verify that the valve closes after an explosion.
(c) To verify that the valve is gas/air tight after an explosion.
(d) To establish the level of over-pressure protection provided by the valve.

15.3 Test facilities

15.3.1 Test houses for carrying out type testing of crankcase explosion relief valves are to meet the following requirements:

(a) The test houses where testing is carried out are to be accredited to a National or International Standard for the testing of explosion protection devices, such as ISO/IEC 17025.
(b) The test facilities are to be acceptable to LR.
(c) The test facilities are to be equipped so that they can perform and record explosion testing in accordance with this procedure.
(d) The test facilities are to have equipment for controlling and measuring a methane gas in air concentration within a test vessel to an accuracy of ±0,1 per cent.
(e) The test facilities are to be capable of effective point-located ignition of a methane gas in air mixture.
(f) The pressure measuring equipment is to be capable of measuring the pressure in the test vessel in at least two positions, one at the valve and the other at the test vessel centre. The measuring arrangements are to be capable of measuring and recording the pressure changes throughout an explosion test at a frequency recognising the speed of events during an explosion. The result of each test is to be documented by video recording and by recording with a heat sensitive camera.
(g) The test vessel for explosion testing is to have documented dimensions. The dimensions are to be such that the vessel is not pipe-like with the distance between dished ends being not more than 2,5 times the diameter. The internal volume of the test vessel is to include any standpipe arrangements.
(h) The test vessel is to be provided with a flange, located centrally at one end at 90° to the vessel longitudinal axis for mounting the explosion relief valve. The test vessel is to be arranged in an orientation consistent with how the valve will be installed in service, i.e., in the vertical plane or the horizontal plane.
(j) A circular flat plate is to be provided for fitting between the pressure vessel flange and valve to be tested with the following dimensions:
    1. Outside diameter of 2 times the outer diameter of the valve top cover.
    2. Internal bore having the same internal diameter as the valve is to be tested.
(k) The test vessel is to have connections for measuring the methane in air mixture at the top and bottom.
(l) The test vessel is to be provided with a means of fitting an ignition source at a position as specified in 15.4.3.
(m) The test vessel volume is to be as far as practicable, related to the size and capability of the relief valve to be tested. In general, the volume is to correspond to the requirement in 6.3.1 for the free area of explosion relief valve to be not less than 115 cm^2/m^3 of crankcase gross volume, e.g., the testing of a valve having 1150 cm^2 of free area, would require a test vessel with a volume of 10 m^3. The following is to apply:
    (i) Where the free area of relief valves is greater than 115 cm^2/m^3 of the crankcase gross volume, the volume of the test vessel is to be consistent with the design ratio.
    (ii) In no case is the volume of the test vessel to vary by more than ±15 per cent from the design cm^2/m^3 volume ratio.

15.4 Explosion test process

15.4.1 All explosion tests to verify the functionality of crankcase explosion relief valves are to be carried out using an air and methane mixture with a volumetric methane concentration of 9,5 per cent ±0,5 per cent. The pressure in the test vessel is to be not less than atmospheric and is not to exceed the opening pressure of the relief valve.

15.4.2 The concentration of methane in the test vessel is to be measured at the top and bottom of the vessel and these concentrations are not to differ by more than 0,5 per cent.

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15.4.3 The ignition of the methane and air mixture is to be made at the centreline of the test vessel at a position approximately one third of the height or length of the test vessel opposite to where the valve is mounted.

15.4.4 The ignition is to be made using a maximum 100 joule explosive charge.

15.5 Valves to be tested

15.5.1 The valves used for type testing (including the testing specified in 15.5.3) are to be selected from the manufacturer's normal production line for such valves by the LR Surveyor witnessing the tests.

15.5.2 For approval of a specific valve size, three valves are to be tested in accordance with 15.5.3 and 15.6. For a series of valves, *see* 15.8.

15.5.3 The valves selected for type testing are to have been previously tested at the manufacturer's works to demonstrate that the opening pressure is in accordance with the specification within a tolerance of ±20 per cent and that the valve is air tight at a pressure below the opening pressure for at least 30 seconds. This test is to verify that the valve is air tight following assembly at the manufacturer's works and that the valve begins to open at the required pressure demonstrating that the correct spring has been fitted.

15.5.4 The type testing of valves is to recognise the orientation in which they are intended to be installed on the engine or gear case. Three valves of each size are to be tested for each intended installation orientation, i.e. in the vertical and/or horizontal positions.

15.6 Method

15.6.1 The following requirements are to be satisfied at explosion testing:

(a) The explosion testing is to be witnessed by a LR surveyor.

(b) Where valves are to be installed on an engine or gear case with shielding arrangements to deflect the emission of explosion combustion products, the valves are to be tested with the shielding arrangements fitted.

(c) Successive explosion testing to establish a valve's functionality is to be carried out as quickly as possible during stable weather conditions.

(d) The pressure rise and decay during all explosion testing is to be recorded.

(e) The external condition of the valves is to be monitored during each test for indication of any flame release by video and heat sensitive camera.

15.6.2 The explosion testing is to be in three stages for each valve that is required to be approved as being type tested.

15.6.3 **Stage 1.** Two explosion tests are to be carried out in the test vessel with the circular plate as specified in 15.3.1(j) fitted and the opening in the plate covered by a 0,05 mm thick polythene film. These tests establish a reference pressure level for determination of the capability of a relief valve in terms of pressure rise in the test vessel, *see* 15.7.1(f).

15.6.4 **Stage 2.**

(a) Two explosion tests are to be carried out on three different valves of the same size. Each valve is to be mounted in the orientation for which approval is sought, i.e., in the vertical or horizontal position with the circular plate described in 15.3.1(j) located between the valve and pressure vessel mounting flange.

(b) The first of the two tests on each valve is to be carried out with a 0,05 mm thick polythene bag, having a minimum diameter of three times the diameter of the circular plate and volume not less than 30 per cent of the test vessel, enclosing the valve and circular plate. Before carrying out the explosion test the polythene bag is to be empty of air. The polythene bag is required to provide a readily visible means of assessing whether there is flame transmission through the relief valve following an explosion. During the test, the explosion pressure will open the valve and some unburned methane/air mixture will be collected in the polythene bag. When the flame reaches the flame arrester and if there is flame transmission through the flame arrester, the methane/air mixture in the bag will be ignited and this will be visible.

(c) Provided that the first explosion test successfully demonstrated that there was no indication of combustion outside the flame arrester and there are no signs of damage to the flame arrester or valve, a second explosion test without the polythene bag arrangement is to be carried out as quickly as possible after the first test. During the second explosion test, the valve is to be visually monitored for any indication of combustion outside the flame arrester and video records are to be kept for subsequent analysis. The second test is required to demonstrate that the valve can still function in the event of a secondary crankcase explosion.

(d) After each explosion, the test vessel is to be maintained in the closed condition for at least 10 seconds to enable the tightness of the valve to be ascertained. The tightness of the valve can be verified during the test from the pressure/time records or by a separate test after completing the second explosion test.

15.6.5 **Stage 3.** Carry out two further explosion tests as described in Stage 1. These further tests are required to provide an average baseline value for assessment of pressure rise, recognising that the test vessel ambient conditions may have changed during the testing of the explosion relief valves in Stage 2.

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15.7 Assessment and records

15.7.1 For the purposes of verifying compliance with the requirements of this Section, the assessment and records of the valves used for explosion testing is to address the following:

(a) The valves to be tested are to have evidence of appraisal/approval by LR, *see also* 15.5.1.

(b) The designation, dimensions and characteristics of the valves to be tested are to be recorded. This is to include the free area of the valve and of the flame arrester, and the amount of valve lift at 0,2 bar.

(c) The test vessel volume is to be determined and recorded.

(d) For acceptance of the functioning of the flame arrester there is not to be any indication of flame or combustion outside the valve during an explosion test.

(e) The pressure rise and decay during an explosion is to be recorded, with indication of the pressure variation showing the maximum overpressure and steady under-pressure in the test vessel during testing. The pressure variation is to be recorded at two points in the pressure vessel.

(f) The effect of an explosion relief valve in terms of pressure rise following an explosion is ascertained from maximum pressures recorded at the centre of the test vessel during the three stages. The pressure rise within the test vessel due to the installation of a relief valve is the difference between average pressure of the four explosions from Stages 1 and 3 and the average of the first tests on the three valves in Stage 2. The pressure rise is not to exceed the limit specified by the manufacturer.

(g) The valve tightness is to be ascertained by verifying from the records at the time of testing that an under-pressure of at least 0,3 bar is held by the test vessel for at least 10 seconds following an explosion. This test is to verify that the valve has effectively closed and is reasonably gas-tight following dynamic operation during an explosion.

(h) After each explosion test in Stage 2, the external condition of the flame arrester is to be examined for signs of serious damage and/or deformation that may affect the operation of the valve.

(j) After completing the explosion tests, the valves are to be dismantled and the condition of all components ascertained and documented. In particular, any indication of valve sticking or uneven opening that may affect the operation of the valve is to be noted. Photographic records of the valve condition are to be taken and included in the report.

15.8 Design series qualification

15.8.1 The qualification of quenching devices to prevent the passage of flame can be evaluated for other similar devices of identical type where one device has been tested and found satisfactory.

15.8.2 The quenching ability of a flame arrester depends on the total mass of quenching lamellas/mesh. Provided the materials, thickness of materials, length of lamellas/thickness of mesh layer and the quenching gaps are the same, then the same quenching ability can be qualified for different sizes of flame arresters subject to (a) and (b) being satisfied.

(a) $$\frac{n_1}{n_2} = \sqrt{\frac{S_1}{S_2}}$$

(a) $$\frac{A_1}{A_2} = \frac{S_1}{S_2}$$

where

n_1 = total depth of flame arrester corresponding to the number of lamellas of size 1 quenching device for a valve with a relief area equal to S_1

n_2 = total depth of flame arrester corresponding to the number of lamellas of size 2 quenching device for a valve with a relief area equal to S_2

A_1 = free area of quenching device for a valve with a relief area equal to S_1

A_2 = free area of quenching device for a valve with a relief area equal to S_2.

15.8.3 The qualification of explosion relief valves of larger sizes than that which has been previously satisfactorily tested in accordance with 15.6 and 15.7 can be evaluated where valves are of identical type and have identical features of construction subject to the following:

(a) The free area of a larger valve does not exceed three times + 5 per cent that of the valve that has been satisfactorily tested.

(b) One valve of the largest size, subject to (a), requiring qualification is subject to satisfactory testing required by 15.5.3 and 15.6.4 except that a single valve will be accepted in 15.6.4(a) and the volume of the test vessel is not to be less than one third of the volume required by 15.3.1(m).

(c) The assessment and records are to be in accordance with 15.7, noting that 15.7.1(f) will only be applicable to Stage 2 for a single valve.

15.8.4 The qualification of explosion relief valves of smaller sizes than that which has been previously satisfactorily tested in accordance with 15.6 and 15.7 can be evaluated where valves are of identical type and have identical features of construction subject to the following:

(a) The free area of a smaller valve is not less than one third of that of the valve that has been satisfactorily tested.

(b) One valve of the smallest size, subject to (a), requiring qualification is subject to satisfactory testing required by 15.5.3 and 15.6.4 except that a single valve will be accepted in 15.6.4(a) and the volume of the test vessel is not to be more than the volume required by 15.3.1(m).

(c) The assessment and records are to be in accordance with 15.7, noting that 15.7.1(f) will only be applicable to Stage 2 for a single valve.

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15.9 The report

15.9.1 The test house is to deliver a full report that includes the following information and documents:

(a) Test specification.
(b) Details of test pressure vessel and valves tested.
(c) The orientation in which the valve was tested (vertical or horizontal position).
(d) Methane in air concentration for each test.
(e) Ignition source.
(f) Pressure curves for each test.
(g) Video recordings of each valve test.
(h) The assessment and records stated in 15.7.

15.10 Approval

15.10.1 The approval of an explosion relief valve is at the discretion of LR, based on the appraisal of plans and particulars and the test facility's report of the results of type testing.

■ *Section 16*
Type testing procedure for crankcase oil mist detection and alarm equipment

16.1 Scope

16.1.1 To specify the tests required to demonstrate that crankcase oil mist detection and alarm equipment intended to be fitted to diesel engines satisfy LR requirements.

16.1.2 This test procedure is also applicable to oil mist detection and alarm arrangements intended for gear cases.

16.2 Purpose

16.2.1 The purpose of type testing crankcase oil mist detection and alarm equipment is sevenfold:

(a) To verify the functionality of the system.
(b) To verify the effectiveness of the oil mist detectors.
(c) To verify the accuracy of the oil mist detectors.
(d) To verify the alarm set points.
(e) To verify time delays between oil mist leaving the source and alarm activation.
(f) To verify functional failure detection.
(g) To verify the influence of optical obscuration on detection.

16.3 Test facilities

16.3.1 Test houses carrying out type testing of crankcase oil mist detection and alarm equipment are to satisfy the following criteria:

(a) A full range of facilities for carrying out the environmental and functionality tests required by this procedure shall be available and be acceptable to LR.
(b) The test house that verifies the functionality of the equipment is to be equipped so that it can control, measure and record oil mist concentration levels in terms of mg/l to an accuracy of ±10 per cent in accordance with this procedure.

16.4 Equipment testing

16.4.1 The range of tests is to include the following for the alarm/monitoring panel:

(a) Functional tests described in 16.5.
(b) Electrical power supply failure test.
(c) Power supply variation test.
(d) Dry heat test.
(e) Damp heat test.
(f) Vibration test.
(g) EMC test.
(h) Insulation resistance test.
(j) High voltage test.
(k) Static and dynamic inclinations, if moving parts are contained.

16.4.2 The range of tests is to include the following for the detectors:

(a) Functional tests described in 16.5.
(b) Electrical power supply failure test.
(c) Power supply variation test.
(d) Dry heat test.
(e) Damp heat test.
(f) Vibration test.
(g) EMC test.
(h) Insulation resistance test.
(j) High voltage test.
(k) Static and dynamic inclinations.

16.5 Functional tests

16.5.1 All tests to verify the functionality of crankcase oil mist detection and alarm equipment are to be carried out in accordance with 16.5.2 to 16.5.6 with an oil mist concentration in air, known in terms of mg/l to an accuracy of ±10 per cent.

16.5.2 The concentration of oil mist in the test chamber is to be measured in the top and bottom of the chamber and these concentrations are not to differ by more than 10 per cent. *See* 16.7.2(a).

16.5.3 The oil mist monitoring arrangements are to be capable of detecting oil mist in air concentrations of between 0 and 10 per cent of the lower explosive limit (LEL), which corresponds to an oil mist concentration of approximately 50 mg/l (15 per cent oil-air mixture) or between 0 and a percentage corresponding to a level not less than twice the maximum oil mist concentration alarm set point.

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16.5.4 The alarm set point for oil mist concentration in air is to provide an alarm at a maximum setting corresponding to not more than 5 per cent of the LEL or approximately 2,5mg/l.

16.5.5 Where alarm set points can be altered, the means of adjustment and indication of set points are to be verified against the equipment manufacturer's instructions.

16.5.6 Where oil mist is drawn into a detector via piping arrangements, the time delay between the sample leaving the crankcase and operation of the alarm is to be determined for the longest and shortest lengths of pipes recommended by the manufacturer. The pipe arrangements are to be in accordance with the manufacturer's instructions/recommendations.

16.5.7 Detector equipment that is in contact with the crankcase atmosphere and may be exposed to oil splash and spray from engine lubricating oil is to be tested to demonstrate that openings do not occlude or become blocked under continuous oil splash or spray conditions. Testing is to be in accordance with arrangements proposed by the manufacturer and agreed by LR.

16.5.8 Detector equipment may be exposed to water vapour from the crankcase atmosphere which may affect the sensitivity of the equipment. It is to be demonstrated that exposure to such conditions will not affect the functional operation of the detector equipment. Where exposure to water vapour and/or water condensation has been identified as a possible source of equipment malfunctioning, testing is to demonstrate that any mitigating arrangements such as heating are effective. Testing is to be in accordance with arrangements proposed by the manufacturer and agreed by LR. This testing is in addition to that required by 16.4.2(e) and is concerned with the effects of condensation caused by the detection equipment being at a lower temperature than the crankcase atmosphere.

16.6 Detectors and alarm equipment to be tested

16.6.1 The detectors and alarm equipment selected for the type testing are to be selected from the manufacturer's normal production line by the LR Surveyor witnessing the tests.

16.6.2 Two detectors are to be tested. One is to be tested in the clean condition and the other in a condition representing the maximum level of lens obscuration specified by the manufacturer.

16.7 Method

16.7.1 The requirements of 16.7 are to be satisfied at type testing.

16.7.2 Oil mist generation is to satisfy the following:

(a) Oil mist is to be generated with suitable equipment using an SAE 80 monograde mineral oil or equivalent and supplied to a test chamber having a volume of not less than 1 m^3. The oil mist produced is to have a maximum droplet size of 5 µm. The oil droplet size is to be checked using the sedimentation method.

(b) The oil mist concentrations used are to be ascertained by the gravimetric deterministic method or equivalent. For this test, the gravimetric deterministic method is a process where the difference in weight of a 0,8 µm pore size membrane filter is ascertained from weighing the filter before and after drawing 1 litre of oil mist through the filter from the oil mist test chamber. The oil mist chamber is to be fitted with a recirculating fan.

(c) Samples of oil mist are to be taken at regular intervals and the results plotted against the oil mist detector output. The oil mist detector is to be located adjacent to where the oil mist samples are drawn off.

(d) The results of a gravimetric analysis are considered invalid and are to be rejected if the resultant calibration curve has an increasing gradient with respect to the oil mist detection reading. This situation occurs when insufficient time has been allowed for the oil mist to become homogeneous. Single results that are more than 10 per cent below the calibration curve are to be rejected. This situation occurs when the integrity of the filter unit has been compromised and not all of the oil is collected on the filter paper.

(e) The filters require to be weighed to a precision of 0,1 mg and the volume of air/oil mist sampled to 10 ml.

16.7.3 The testing is to be witnessed by an LR Surveyor where type testing approval is required by LR.

16.7.4 Oil mist detection equipment is to be tested in the orientation (vertical, horizontal or inclined) in which it is intended to be installed on an engine or gear case as specified by the equipment manufacturer.

16.7.5 Type testing is to be carried out for each type of oil mist detection and alarm equipment for which a manufacturer seeks LR approval. Where sensitivity levels can be adjusted, testing is to be carried out at the extreme and mid-point level settings.

16.8 Assessment

16.8.1 Assessment of oil mist detection equipment after testing is to address the following:

(a) The equipment to be tested is to have evidence of design appraisal/approval by LR, *see also* 16.6.1.

(b) Details of the detection equipment to be tested are to be recorded such as name of manufacturer, type designation, oil mist concentration assessment capability and alarm settings.

(c) After completing the tests, the detection equipment is to be examined and the condition of all components ascertained and documented. Photographic records of the monitoring equipment condition are to be taken and included in the report.

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16.9 Design series qualification

16.9.1 The approval of one type of detection equipment may be used to qualify other devices having identical construction details. Proposals are to be submitted for consideration.

16.10 The report

16.10.1 The test house is to provide a full report which includes the following information and documents:

(a) Test specification.
(b) Details of equipment tested.
(c) Results of tests.

16.11 Acceptance

16.11.1 Acceptance of crankcase oil mist detection equipment is at the discretion of LR, based on the appraisal of plans and particulars and the test house report of the results of type testing.

16.11.2 The following information is to be submitted to LR for acceptance of oil mist detection equipment and alarm arrangements:

(a) Description of oil mist detection equipment and system including alarms.
(b) Copy of the test house report identified in 16.10.
(c) Schematic layout of engine oil mist detection arrangements showing location of detectors/sensors and piping arrangements and dimensions.
(d) Maintenance and test manual which is to include the following information:
    - Intended use of equipment and its operation.
    - Functionality tests to demonstrate that the equipment is operational and that any faults can be identified and corrective actions notified.
    - Maintenance routines and spare parts recommendations.
    - Limit setting and instructions for safe limit levels.
    - Where necessary, details of configurations in which the equipment is and is not to be used.

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Section

1 **General requirements**

2 **Particulars to be submitted**

3 **Materials**

4 **Design**

5 **Construction**

6 **Starting arrangements**

7 **Piping systems**

8 **Control and monitoring**

9 **Requirements for craft which are not required to comply with the HSC Code**

■ *Section 1* General requirements

1.1 Application

1.1.1 This Chapter is to be read in conjunction with the General Requirements for Machinery in Part 9.

1.1.2 The requirements of this Chapter are applicable to gas turbines for main propulsion and essential auxiliary services.

1.2 Power ratings

1.2.1 In this Chapter, where the dimensions of any particular component are determined from shaft power, *P*, in kW, and revolutions per minute, *R*, the values to be used are those defined in Part 9.

1.3 Power conditions for generator sets

1.3.1 Auxiliary gas turbines coupled to electrical generators are to be capable under service conditions of developing continuously the power to drive the generators at full rated output and of developing for a short period (15 minutes) an overload power of not less than 10 per cent, *see* Pt 16, Ch 2.

1.4 Inclination of craft

1.4.1 Main and essential auxiliary gas turbines are to operate satisfactorily under the conditions as shown in Table 1.4.1 in Pt 9, Ch 1.

■ *Section 2* Particulars to be submitted

2.1 Plans and information

2.1.1 At least three copies of the following plans are to be submitted:

- Sectional assembly.
- Casings.
- Combustion chambers and heat exchangers.
- Rotors, bearings and couplings.
- Blades and blade attachments.
- Inlet and exhaust ducting.
- Securing arrangement (including details of resilient mounts where applicable).
- Control engineering aspects in accordance with Pt 16, Ch 1.
- Fuel oil system schematic, including controls and safety devices.
- Lubricating oil system schematic.
- Starting system schematic.
- Cooling water system schematic, where applicable.

2.1.2 The following information and calculations are to be submitted:

(a) Details of the acoustic enclosure fire detection and extinguishing system, where applicable.

(b) Power/speed operational envelope.
Calculations and information for short term high power operation, where applicable.
Operation and Maintenance Manuals.

(c) Calculations of the critical speeds of blade and rotor vibration, giving full details of the basic assumptions.
An analysis of the effect of a rotor blade failure and any details of service experience, *see* 4.3.

(d) High temperature characteristics of the materials, where applicable, including (at the working temperatures) the associated creep rate and rupture strength for the designed service life, fatigue strength, corrosion resistance and scaling properties.
Particulars of heat treatment, including stress relief, where applicable.
Material specifications covering the listed components together with details of any surface treatments, non-destructive testing and hydraulic tests.

2.1.3 The most onerous pressures and temperatures to which each component may be subjected are to be indicated on plans or provided as part of the design specification.

2.1.4 Calculations of the steady state stresses, including the effect of stress raisers, etc., in the turbine and compressor rotors and blading at the maximum speed and temperature in service are to be submitted. Such calculations should indicate the designed service life and be accompanied, where possible, by test results substantiating the limiting criteria.

2.1.5 Details of calculations and tests to establish the service life of other stressed parts, including gearing (where applicable), bearings, seals, etc., are also to be submitted. All calculations and tests should take account of all relevant environmental factors including particular type of service and fuel intended to be used.

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2.1.6 Components fabricated by means of welding will be considered for acceptance if constructed by firms whose works are properly equipped to undertake welding of the standards appropriate to the components. Details are to be submitted for consideration.

2.1.7 Before work is commenced, manufacturers are to submit for consideration details of proposed welding procedures and their proposals for routine examination of joints by non-destructive means.

2.1.8 The manufacturer's proposals for testing the gas turbine are to be submitted for consideration.

2.1.9 A Failure Mode and Effects Analysis (FMEA) is to be submitted as detailed in Part 9.

■ *Section 3* Materials

3.1 Materials for forgings

3.1.1 Rotors and discs are to be of forged steel. For carbon and carbon-manganese steel forgings, the specified minimum tensile strength is to be selected within the limits of 400 and 600 N/mm^2. For alloy steel rotor forgings, the specified minimum tensile strength is to be selected within the limits of 500 and 800 N/mm^2. For discs and other alloy steel forgings, the specified minimum tensile strength is to be selected within the limits of 500 and 1000 N/mm^2. *See also Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

3.1.2 For alloy steels, specifications giving the proposed chemical composition and heat treatment are to be submitted for approval.

3.1.3 When it is proposed to use a material of higher tensile strength, full details are to be submitted for approval.

3.1.4 Components of non-ferrous construction should be submitted for consideration, together with full details of materials to be used and method of fabrication.

3.2 Material tests and inspection

3.2.1 Components are to be tested in accordance with the relevant requirements of the Rules for Materials.

3.2.2 For components of novel design special consideration will be given to the material test and non-destructive testing requirements.

■ *Section 4* Design

4.1 General

4.1.1 All parts of turbines, compressors, etc., are to have clearances and fits consistent with adequate provision for the relative thermal expansion of the various components. Special attention is to be given to minimising casing and rotor distortion under all operating conditions.

4.1.2 Turbine bearings are to be so disposed and supported that lubrication is not adversely affected by heat flow from adjacent hot parts. Effective means are to be provided for intercepting oil leakage and preventing oil from reaching high temperature glands and casings.

4.2 Vibration

4.2.1 Care is to be taken in the design and manufacture of turbine and compressor rotors, rotor discs and rotor blades to ensure freedom from undue vibration within the operating speed range. Where critical speeds are found by calculation to occur within the operating speed range, vibration measurements may be requested in order to verify the calculations, *see* Part 13.

4.3 Containment

4.3.1 Gas turbines are to be designed and installed so as to contain debris in the event of an internal failure.

4.3.2 The gas turbine is to be located such that any flying debris resulting from a failure will not endanger the craft, other machinery, occupants of the craft or any other persons.

4.3.3 Where an acoustic enclosure is fitted which completely surrounds the gas generator and the high pressure oil pipes, a fire detection and extinguishing system is to be provided for the acoustic enclosure.

4.4 External influences

4.4.1 Pipes and ducting connected to casings are to be so designed that no excessive thrust loads or moments are applied by them to the compressors and turbines.

4.4.2 Platform gratings and fittings in way of the supports are to be so arranged that casing expansion is not restricted.

4.4.3 Where main turbine seatings incorporating a tank structure are proposed, consideration is to be given to the temperature variation of the tank in service to ensure that turbine alignment will not be adversely affected.

4.4.4 For securing arrangements, including resilient mounting, *see* Pt 9, Ch 1.

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Section 5
Construction

5.1 Welded components

5.1.1 All welded construction is to be in accordance with the requirements specified in Chapter 13 of the Rules for Materials.

5.1.2 Major joints are to be designed as full-strength welds and for complete fusion of the joint.

5.1.3 Stress relief heat treatment is to be applied to all cylinders, rotors and associated components on completion of the welding of all joints and attached structures, *see* Part 15.

Section 6
Starting arrangements

6.1 Initial starting arrangements

6.1.1 Equipment for starting main and auxiliary turbines is to be provided and arranged such that the necessary initial charge of starting air or initial electric power can be developed on board the craft without external aid. If for this purpose an emergency air compressor or electric generator is required, these units are to be power driven by manually started oil engines except in the case of small installations where a hand operated compressor of approved capacity may be accepted. Alternatively, other devices of approved type may be accepted as a means of providing the initial start, *see also* Pt 16, Ch 2,2.4.2.

6.2 Purging before ignition

6.2.1 Means are to be provided, preferably automatic or interlocked, to clear all parts of the gas turbine of the accumulation of oil fuel or for purging gaseous fuel before ignition commences on starting, or recommences after failure to start. The purge is to be of sufficient duration to displace at least three times the volume of the exhaust system.

6.3 Air starting

6.3.1 Where the gas turbine is arranged for air starting the total air receiver capacity is to be sufficient to provide, without replenishment, not less than six consecutive starts. At least two air receivers of approximately equal capacity are to be provided. For scantlings and fittings of air receivers, *see* Part 15.

6.3.2 For multi-engine installations three consecutive starts per engine are required.

6.4 Electric starting

6.4.1 Where main turbines are fitted with electric starters, two batteries are to be fitted. Each battery is to be capable of starting the turbines when cold and the combined capacity is to be sufficient without recharging to provide the number of starts of the main turbines as required by 6.3.

6.4.2 Electric starting arrangements for auxiliary turbines are to have two separate batteries or be supplied by separate circuits from the main turbine batteries when such are provided. Where one of the auxiliary turbines only is fitted with an electric starter one battery will be acceptable.

6.4.3 The combined capacity of the batteries for starting the auxiliary turbines is to be sufficient for at least three starts for each turbine.

6.4.4 The requirements for battery installations are given in Pt 16, Ch 2.

Section 7
Piping systems

7.1 General

7.1.1 Gas turbine piping systems are, in general, to comply with the requirements given in Pt 15, Ch 1 and Ch 3, due regard being paid to the particular type of installation.

7.1.2 Synthetic rubber hoses, with single or double closely woven integral wire braid reinforcement, or convoluted metal pipes with wire braid protection, may be used in compressed air, fresh water, sea-water, oil fuel and lubricating oil systems. Where synthetic rubber hoses are used for fuel or supply to burners, the hoses are to have external wire braid protection in addition to the integral wire braid.

7.2 Oil fuel systems

7.2.1 Oil fuel arrangements are to comply with the requirements of Pt 15, Ch 3.

7.2.2 Two or more filters are to be fitted in the oil fuel supply lines to the main and auxiliary turbines, and the arrangements are to be such that any filter can be cleaned without interrupting the supply of filtered oil fuel to the turbines.

7.3 Lubricating oil systems

7.3.1 Lubricating oil arrangements are to comply with the requirements of Pt 15, Ch 3.

7.3.2 Where the lubricating oil for main propelling gas turbines is circulated under pressure, provision is to be made for the efficient filtration of the oil. The filters are to be capable of being cleaned without stopping the turbine or reducing the supply of filtered oil to the turbine.

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7.4 Cooling systems

7.4.1 Cooling water arrangements are to comply with the requirements of Pt 15, Ch 3, as applicable.

7.5 Inlet and exhaust systems

7.5.1 The air-inlet system is to be designed to minimise the ingestion of harmful particles. Icing up of air intakes is to be prevented.

7.5.2 Means for preventing the accumulation of salt deposits in the compressors and turbines, e.g. water washing, are to be provided.

7.5.3 The arrangement of the exhaust system is to be such as to prevent exhaust gases being drawn into manned spaces, air conditioning systems and air intakes. They should not discharge into air cushion intakes.

7.5.4 Where the exhaust is led overboard near the waterline, means are to be provided to prevent water from being siphoned back to the turbine. Where the exhaust is cooled by water spray, the exhaust pipes are to be self draining overboard. Erosion/corrosion resistant shut off flaps or other devices are to be fitted on the hull side shell or pipe end and acceptable arrangements made to prevent water flooding the space.

7.5.5 Where two or more turbines have a common exhaust, an isolating device is to be provided in each exhaust pipe.

7.5.6 The exhaust system is to be arranged so that hot exhaust gases are directed away from areas to which personnel have access, either on board or in the vicinity of where the craft is berthed.

■ *Section 8* Control and monitoring

8.1 General

8.1.1 Control engineering systems are to comply with the requirements of Part 16.

8.2 Overspeed protective devices

8.2.1 An overspeed protective device is to be provided for each shaft of main and auxiliary turbines to automatically shut off the fuel, near the burners, to prevent a dangerous overspeed condition of the shaft, unless it can be established that such a condition cannot arise.

8.2.2 The overspeed device is to be set to operate before the speed of the line exceeds the rated maximum speed by 10 per cent. For auxiliary turbines driving electric generators this setting may be increased to 15 per cent.

8.3 Speed governors

8.3.1 Where a main propulsion installation incorporates a reverse gear, electric transmission or controllable (reversible) pitch propeller, a speed governor, independent of the overspeed protective device, is to be fitted and is to be capable of controlling the speed of the unloaded power turbine without bringing the overspeed protective device into action.

8.3.2 Where an auxiliary turbine is intended for driving an electric generator, a speed governor, independent of the overspeed protective device, is to be fitted which, with fixed setting, is to control the speed within 10 per cent momentary variation and five per cent permanent variation when full load is suddenly taken off or put on. The permanent speed variations of a.c. machines intended for parallel operations are to be equal within a tolerance of ±0,5 per cent.

8.4 Lubricating oil failure

8.4.1 Main turbines are to have an arrangement whereby fuel is automatically shut off, near the burners, in the event of failure of the lubrication system.

8.5 Indication of temperature

8.5.1 Means are to be provided for indicating the temperature of power turbine exhaust gases.

8.6 Automatic and remote controls

8.6.1 Where gas turbines are fitted with automatic or remote controls so that under normal operating conditions they do not require any manual intervention by the operators, they are to be provided with the alarm and safety arrangements required by 8.6.2 and Table 2.8.1 as appropriate. Alternative arrangements which provide equivalent safeguards will be considered.

8.6.2 The following turbine services are to be fitted with automatic temperature controls so as to maintain steady state conditions throughout the normal operating range of the turbine:

(a) Lubricating oil supply.
(b) Oil fuel supply, *see also* 8.6.3.
(c) Exhaust gas.

8.6.3 The oil fuel supply may be fitted with an automatic control for viscosity instead of the temperature control required by 8.6.2.

8.6.4 A means of manually shutting off the fuel in an emergency is to be provided at the manoeuvring station.

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Table 2.8.1 Alarms and safeguards

Item	Alarm	Note
Overspeed	High	Automatic shut down
Lubricating oil pressure for turbine and gearing	1st stage low 2nd stage low	 Automatic shut down
Lubricating oil temperature	High	
Lubricating oil filter differential pressure	High	
Oil fuel supply pressure	Low	
Oil fuel supply temperature	High	
Bearing temperature	High	
Exhaust gas temperature	1st stage high 2nd stage high	 Automatic shut down
Turbine vibration	1st stage high 2nd stage high	 Automatic shut down
Rotor axial displacement	High	Automatic shut down, *see* Note 2
Flame and ignition	Failure	Automatic shut down
Automatic starting	Failure	Automatic shut down
Compressor inlet vacuum	1st stage high 2nd stage high	 Automatic shut down
Control system	Failure	

NOTES
1. Automatic or interlocked means are to be provided for clearing all parts of the main gas turbine of the accumulation of liquid fuel or for purging gaseous fuel, before ignition commences on starting or recommences after failure to start.
2. Except for gas turbines with rolling element bearings.

■ *Section 9* Requirements for craft which are not required to comply with the HSC Code

9.1 General

9.1.1 The requirements of Sections 1 to 8 apply to craft which are not required to comply with the HSC Code, unless specifically exempted by the contents of this Section.

9.1.2 The requirements of 1.4.1 do not apply to yachts or service craft less than 24 m.

9.2 Information and calculations

9.2.1 Gas turbines for craft with a power output not exceeding 110 kW do not have to comply with 2.1.2(c) and (d) or 2.1.4 to 2.1.7 inclusive and 2.1.9.

9.3 Starting arrangements

9.3.1 Craft with a Service Group notation of G1 or G2 do not have to comply with 6.1.1.

9.4 Piping systems

9.4.1 Soft solder is not to be used for attaching pipe fittings forming part of oil fuel systems.

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CHAPTER 2 SHAFTING SYSTEMS

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7 **Requirements for craft which are not required to comply with the HSC Code**

■ *Section 1* General requirements

1.1 Application

1.1.1 This Chapter is to be read in conjunction with the General Requirements for Machinery in Part 9.

1.1.2 The requirements of this Chapter, except where otherwise stated are applicable to electric motor, gas turbine and diesel engine gearing for driving:

(a) Conventional, totally submerged propeller(s)/impeller(s) for main propulsion purposes, for transmitted powers greater than 220 kW.

(b) Auxiliary machinery which is essential for the safety of the craft or for safety of persons on board where the transmitted powers exceed 110 kW.

NOTE

Alternatively calculations using the methods defined in ISO 6336 – *Calculation of load capacity of spur and helical gears* will be considered.

1.1.3 Gear designs for applications other than those specified in 1.1.2 will be specially considered.

1.1.4 In any mesh, the terms pinion and wheel refer to the smaller and larger gear respectively.

1.1.5 Bevel gears will be specially considered on the basis of a conversion to equivalent cylindrical gears.

1.1.6 For vibration and alignment requirements, *see* Part 13.

1.2 Power ratings

1.2.1 In this Chapter where the dimensions of any particular components are determined from shaft power, P, in kW, and revolutions per minute, R, the values to be used are those defined in Part 9.

1.3 Inclination of craft

1.3.1 Main and auxiliary gear units are to operate satisfactorily under the conditions as shown in Table 1.4.1 in Pt 9, Ch 1.

■ *Section 2* Particulars to be submitted

2.1 Submission of information

2.1.1 At least three copies of the following plans and information as detailed in 2.2 to 2.3 are to be submitted.

2.2 Plans

2.2.1 **Gearing:**

(a) Cross sectional views indicating general arrangement.

(b) Detailed plans of elements.

2.2.2 **Shafting and auxiliary systems:**

(a) Mass elastic schematic showing gear unit torsional data.

(b) Arrangements plan indicating bearing positions.

(c) Detailed plans indicating scantlings of shafts, couplings and bolting.

(d) Schematic plans of the lubricating oil system, together with pipe material, relief valve and working pressures.

(e) Schematic of the control and electrical system.

2.3 Information

2.3.1 **Gearing:**

(a) Operational power/speed envelope for each pinion.

(b) Number of teeth in each gear.

(c) Reference diameters.

(d) Helix angles at reference diameters.

(e) Normal pitches of teeth at reference diameters.

(f) Tip diameters.

(g) Root diameters.

(h) Face widths and gaps, where applicable.

(j) Pressure angles of teeth (normal or transverse) at reference diameters.

(k) Accuracy grade Q in accordance with ISO 1328 or an equivalent Standard.

(l) Surface texture of tooth flanks and roots.

(m) Minimum backlash.

(n) Centre distance.

(o) Basic rack tooth form.

(p) Protuberance and final machining allowance.

(q) Details of post hobbing processes, if any.

(r) Details of tooth flank corrections, if adopted.

(s) Case depth for surface-hardened teeth.

(t) Shrinkage allowance for shrunk-on rims and hubs.

(u) Type of coupling proposed for oil engine applications.

(v) Details of surface treatment.

(w) Additional measures, not covered by the Rules, taken during manufacture of the gear elements, to improve the load capacity of the gear teeth.

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(x) Calculations for short term high power operation, where applicable, *see* Part 9.
(y) Failure mode effects analysis as required by Part 9.
(z) Specifications for carbon-manganese and alloy steel forging materials of pinions, pinion sleeves, wheel rims, gear wheels, couplings, bolting and all transmission shafting, giving chemical composition, heat treatment and mechanical properties.

2.3.2 **Shafting and auxiliary systems:**
(a) Details of clutch units, where fitted.
(b) Details of alarms and control systems, where fitted.
(c) Schematic plans of the lubricating oil system, together with pipe material, relief valve and working pressures.

■ *Section 3* Materials

3.1 Requirements and specifications

3.1.1 Components for gearboxes are to be in accordance with the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

3.1.2 Manufacturers' certificates for forgings may be accepted where the transmitted power does not exceed 220 kW, *see* Ch 1,3.1.3(b) of the Rules for Materials.

3.1.3 In the selection of materials for pinions and wheels, consideration is to be given to their compatibility in operation. Except in the case of low reduction ratios, for gears of through-hardened steels, provision is also to be made for a hardness differential between pinion teeth and wheel teeth. For this purpose, the specified minimum tensile strength of the wheel rim material is not to be more than 85 per cent of that of the pinion.

3.1.4 Gear wheel and rim forgings with a specified minimum tensile strength not in excess of 760 N/mm^2 may be made in carbon-manganese steel. Gear wheel or rim forgings where the specified minimum tensile strength is in excess of 760 N/mm^2, and all pinion or pinion sleeve forgings are to be made in a suitable alloy steel.

3.1.5 Forgings for couplings, quill shafts and gear wheel shafts are to comply with the requirements of Chapter 2.

■ *Section 4* Design of gearing

4.1 Symbols

4.1.1 The following symbols apply:

a = centre distance, in mm
b = face width, in mm
NOTE: unless otherwise specified, b is to be taken as the lesser value of b_1 or b_2
In the case of double helical gears $b = 2b_B$ where b_B is the width of one helix
d = reference diameter, in mm
d_a = tip diameter, in mm
d_{an} = virtual tip diameter, in mm
d_b = base diameter, in mm
d_{bn} = virtual base diameter, in mm
d_{en} = virtual diameter to the highest point of single tooth pair contact, in mm
d_f = root diameter, in mm
d_{fn} = virtual root diameter, in mm
d_n = virtual reference diameter, in mm
d_s = shrink diameter, in mm
d_w = pitch circle diameter, in mm
f_{ma} = tooth flank misalignment due to manufacturing errors, in μm
f_{pb} = maximum base pitch deviation of wheel, in μm
f_{Sh} = tooth flank misalignment due to wheel and pinion deflections, in μm
f_{Sho} = intermediary factor for the determination of f_{Sh}
g_α = length of line of action for external gears, in mm:

$$= 0{,}5\sqrt{(d_{a1}^2 - d_{b1}^2)} + 0{,}5\sqrt{(d_{a2}^2 - d_{b2}^2)} - a\sin\alpha_{tw}$$

for internal gears:

$$= 0{,}5\sqrt{(d_{a1}^2 - d_{b1}^2)} - 0{,}5\sqrt{(d_{a2}^2 - d_{b2}^2)} + a\sin\alpha_{tw}$$

h = total depth of tooth, in mm
h_{ao} = basic rack addendum of tool, in mm
h_F = bending moment arm for root stress, in mm
h_W = sum of actual tooth addenda of pinion and wheel, in mm
m_n = normal module, in mm
n = rev/min of pinion
q = machining allowances, in mm
q_s = notch parameter
q' = intermediary factor for the determination of C_γ

$$u = \text{gear ratio} = \frac{\text{Number of teeth in wheel}}{\text{Number of teeth in pinion}} \geq 1$$

v = linear speed at pitch circle, in m/s
x = addendum modification coefficient
y_α = running in allowance, in μm
y_β = running in allowance, in μm
z = number of teeth

$$z_n = \text{virtual number of teeth} = \frac{z}{\cos^2\beta_0\cos\beta}$$

C_γ = tooth mesh stiffness (mean total mesh stiffness per unit face width), in N/mm μm
F_t = nominal tangential tooth load, in N

$$= \frac{P}{nd}\,19{,}098 \times 10^6$$

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F_β = total tooth alignment deviation (maximum value specified), in μm
$F_{\beta x}$ = actual longitudinal tooth flank deviation before running in, in μm
$F_{\beta y}$ = actual longitudinal tooth flank deviation after running in, in μm
HV = Vickers hardness number
K_A = application factor
$K_{F\alpha}$ = transverse load distribution factor
$K_{F\beta}$ = longitudinal load distribution factor
$K_{H\alpha}$ = transverse load distribution factor
$K_{H\beta}$ = longitudinal load distribution factor
K_v = dynamic factor
$K_{v\alpha}$ = dynamic factor for spur gears
$K_{v\beta}$ = dynamic factor for helical gears
K_γ = load sharing factor
P = transmitted power, in kW
P_r = radial pressure at shrinkage surface, in N/mm^2
P_{ro} = protuberance of tool, in mm
Q = accuracy grade derived from ISO 1328 – *Cylindrical gears – ISO system of accuracy*
R_a = surface roughness – arithmetical mean deviation (C.L.A.) as determined by an instrument having a minimum wavelength cut-off of 0,8 mm and for a sampling length of 2,5 mm, in μm
S_{pr} = residual undercut left by protuberance in mm
$S_{F\,min}$ = minimum factor of safety for bending stress
S_{Fn} = tooth root chord in the critical section, in mm
$S_{H\,min}$ = minimum factor of safety for Hertzian contact stress
Y_D = design factor
Y_F = tooth form factor
$Y_{R\,rel\,T}$ = relative surface finish factor
Y_S = stress concentration factor
Y_{ST} = stress correction factor
Y_X = size factor
Y_β = helix angle factor
$Y_{\delta\,rel\,T}$ = relative notch sensitivity factor
Z_E = material elasticity factor
Z_H = zone factor
Z_R = surface finish factor
Z_V = velocity factor
Z_X = size factor
Z_β = helix angle factor
Z_ε = contact ratio factor
α_{en} = pressure angle at the highest point of single tooth contact, in degrees
α_n = normal pressure angle at reference diameter, in degrees
α_t = transverse pressure angle at reference diameter, in degrees
α_{tw} = transverse pressure angle at pitch circle diameter, in degrees
$\alpha_{F\,en}$ = angle for application of load at the highest point of single tooth contact, in degrees
β = helix angle at reference diameter, in degrees
β_b = helix angle at base diameter, in degrees
γ = intermediary factor for the determination of f_{Sh}
ε_α = transverse contact ratio

$$= \frac{g\alpha \cos\beta}{\pi\, m_n \cos\alpha_t}$$

$\varepsilon_{\alpha n}$ = virtual transverse contact ratio
ε_β = overlap ratio

$$= \frac{b \sin\beta}{\pi\, m_n}$$

ε_γ = total contact ratio
ρ_{ao} = tip radius of tool, in mm
ρ_c = relative radius of curvature at pitch point, in mm

$$= \frac{a \sin\alpha_{tw}\, u}{\cos\beta_b\,(1+u)^2}$$

ρ_F = tooth root fillet radius at the contact of the 30° tangent, in mm
σ_y = yield or 0,2 per cent proof stress, in N/mm^2
σ_B = ultimate tensile strength, in N/mm^2
σ_F = bending stress at tooth root, N/mm^2
$\sigma_{F\,lim}$ = endurance limit for bending stress in N/mm^2
σ_{FP} = allowable bending stress at the tooth root, in N/mm^2
σ_H = Hertzian contact stress at the pitch circle, in N/mm^2
$\sigma_{H\,lim}$ = endurance limit for Hertzian contact stress, in N/mm^2
σ_{HP} = allowable Hertzian contact stress, in N/mm^2

Subscript: $_1$ = pinion
$_2$ = wheel
$_0$ = tool

NOTE
a and *z* are considered positive for both external and internal gearing for the purposes of these calculations.

4.2 Tooth form

4.2.1 The tooth profile in the transverse section is to be of involute shape, and the roots of the teeth are to be formed with smooth fillets of radii not less than $0{,}25m_n$.

4.2.2 All sharp edges left on the tips and ends of pinion and wheel teeth after hobbing and finishing are to be removed.

4.3 Tooth loading factors

4.3.1 For values of application factor, K_A, *see* Table 1.4.1.

Table 1.4.1 Values of K_A

Main and auxiliary gears	K_A
Main propulsion – electric motor or gas turbine, reduction gears	1,15
Main propulsion – diesel engine reduction gears:	
Hydraulic coupling or equivalent on input	1,10
High elastic coupling on input	1,30
Other coupling	1,50
Auxiliary Gears:	
Electric, gas turbine and diesel engine drives with hydraulic coupling or equivalent on input	1,00
Diesel engine drives with high elastic coupling on input	1,20
Diesel engine drives with other couplings	1,40

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4.3.2 Load sharing factor, K_γ. When a gear drives two or more mating gears where the total transmitted load is not evenly distributed between the individual meshes, K_γ is to be taken as 1,15, otherwise K_γ is to be taken as 1,0. Alternatively, where measured data exists, a derived value will be considered.

4.3.3 **Dynamic factor, K_v:**

For helical gears with $\varepsilon_\beta \geq 1$:

$$K_v = 1 + Q^2 v z_1 10^{-5} = K_{VB}$$

For helical gears with $\varepsilon_\beta \leq 1$:

$$K_v = K_{va} - \varepsilon_\beta (K_{va} - K_{v\beta})$$

For spur gears:

$$K_v = 1 + 1{,}8\, Q^2 v z_1 10^{-5} = K_{va}$$

where $\dfrac{v z_1}{100} > 14$ for helical gears, and

where $\dfrac{v z_1}{100} > 10$ for spur gears, the value of K_v will be specially considered

NOTE

Q is to be taken as the larger value of Q_1 or Q_2.

4.3.4 **Longitudinal load distribution factors, $K_{H\beta}$ and $K_{F\beta}$:**

$$K_{H\beta} = 1 + \frac{b F_{\beta y} C\gamma}{2F_t K_A K_\gamma K_v}$$

Calculated values of $K_{H\beta} > 2$ are to be reduced by improved accuracy and helix correction as necessary:

where

$F_{\beta y} = F_{\beta x} - y_\beta$ and

$F_{\beta x} = 1{,}33 f_{Sh} + f_{ma}$

$f_{ma} = \dfrac{2}{3} F_\beta$ at the design stage, or

$f_{ma} = \dfrac{2}{3} F_\beta$ where helix correction has been applied

$f_{Sh} = f_{Sho} \dfrac{F_t K_A K_\gamma K_v}{b}$ where

$f_{Sho} = 23\gamma\ 10^{-3}$ µm mm/N for gears without helix correction or crowning and without end relief, or

$= 12\gamma\ 10^{-3}$ µm mm/N for gears without helix correction but with crowning, *see* Note 1

$= 16\gamma\ 10^{-3}$ µm mm/N for gears without helix correction or crowning but with end relief, where

$\gamma = \left(\dfrac{b}{d_1}\right)$ for single helical and spur gears

$= 3\left(\dfrac{b}{2d_1}\right)^2$ for double helical gears

The following minimum values are applicable, these also being the values where helix correction has been applied:

$f_{Sho} = 10 \times 10^{-3}$ µm mm/N for helical gears, or

$= 5 \times 10^{-3}$ µm mm/N for spur gears

For through-hardened steels and surface hardened steels running on through-hardened steels:

$y_\beta = \dfrac{320}{\sigma_{H\,lim}} F_{\beta x}$ up to an upper limit value of

$y_\beta = \dfrac{12800}{\sigma_{H\,lim}}$ m, and

For surface hardened steels, when

$y_\beta = 0{,}15 F_{\beta x}$ up to an upper limit value of

$y_\beta = 6$ m

$F_{F\beta} = K_{H\beta} n$

where

$$n = \frac{\left(\dfrac{b}{h}\right)^2}{1 + \dfrac{b}{h} + \left(\dfrac{b}{h}\right)^2}$$

NOTES

1. $\dfrac{b}{h}$ is to be taken as the smaller of $\dfrac{b_1}{h_1}$ or $\dfrac{b_2}{h_2}$

2. For double helical gears $\dfrac{b}{2}$ is to be substituted for b in the equation for n.

4.3.5 **Transverse load distribution factors, $K_{H\alpha}$ and $K_{F\alpha}$**

$K_{H\alpha} = K_{F\alpha} \geq 1{,}000$

where

$\varepsilon\gamma \leq 2$

$$K_{H\alpha} = \frac{\varepsilon\gamma}{2}\left(0{,}9 + \frac{0{,}4C\gamma\,(f_{pb} - Y_\alpha)\,b}{F_t K_A K_\gamma K_v K_{H\beta}}\right)$$

where

$\varepsilon\gamma \leq 2$

$$K_{H\alpha} = 0{,}9 + 0{,}4\sqrt{\frac{2(\varepsilon_\gamma - 1)}{\varepsilon_\gamma}}\left(\frac{C_\gamma\,(f_{pb} - y_\alpha)\,b}{F_t K_A K_\gamma K_v K_{H\beta}}\right), \text{ but}$$

$K_{H\alpha} \leq \dfrac{\varepsilon_\gamma}{\varepsilon_a Z_\varepsilon^2}$ and

$K_{F\alpha} \leq \dfrac{\varepsilon_\gamma}{0{,}25\varepsilon_\gamma + 0{,}75}$

When tip relief is applied, f_{pb} is to be half of the maximum specified value:

$y_\alpha = \dfrac{160}{\sigma_{H\,lim}} f_{pb}$ for through-hardened steels, when

$y_\alpha \leq \dfrac{6400}{\sigma_{H\,lim}}$ µm and

$y_\alpha = 0{,}075 f_{pb}$ for surface hardened steels, when

$y_\alpha \leq 3$ µm

When pinion and wheel are manufactured from different materials:

$$y_\alpha = \frac{y_{\alpha 1} + y_{\alpha 2}}{2}$$

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NOTE
Tip relief is to take the form of either tip and root relief on the pinion, or tip relief on pinion and wheel.

4.3.6 **Tooth mesh stiffness, C_γ:**

$$C_\gamma = \frac{0,8}{q^1} \cos\beta\,(0,75\varepsilon_\alpha + 0,25) \quad \text{N/mm}\,\mu\text{m}$$

where

$$q^1 = 0,04723 + \frac{0,1551}{z_{n1}} + \frac{0,25791}{z_{n2}} - 0,00635x_1 - \frac{0,11654x_1}{z_{n1}} - 0,00193x_2 - \frac{0,24188x_2}{z_{n2}} + 0,00529x_1^2 + 0,00182x_2^2$$

For internals gears $z_{n2} = \infty$
Other calculation methods for C_γ will be specially considered.

4.4 Tooth loading for surface stress

4.4.1 The Hertzian contact stress, σ_H, at the pitch circle is not to exceed the allowable Hertzian contact stress, σ_{HP}:

$$\sigma_H = Z_H Z_E Z_\varepsilon Z_\beta \sqrt{\frac{F_t\,(u+1)}{d_1\,bu} K_A K_\gamma K_v K_{H\beta} K_{Ha}}$$

and

$$\sigma_{HP} = \frac{\sigma_{H\,lim} Z_R Z_v Z_X}{S_{H\,min}} \text{ for the pinion/wheel combination}$$

where

$$Z_H = \sqrt{\frac{2\cos\beta_b \cos\alpha_{tw}}{\cos^2\alpha_t \sin\alpha_{tw}}}$$

$$Z_E = 189,8 \text{ for steel}$$

$$Z_\varepsilon = \sqrt{\frac{4-\varepsilon_\alpha}{3}(1-\varepsilon_\beta) + \frac{\varepsilon_\beta}{\varepsilon_\alpha}} \quad \text{for } \varepsilon_\beta < 1 \text{ and}$$

$$Z_\varepsilon = \sqrt{\frac{1}{\varepsilon_\alpha}} \quad \text{for } \varepsilon_\beta \geq 1$$

$$Z_\beta = \sqrt{\cos\beta}$$

$$Z_R = \left(\frac{1}{R_a}\right)^{0,11} \quad \text{but } Z_R \leq 1,14$$

Where R_a is the surface roughness value of the tooth flanks. When pinion and wheel tooth flanks differ then the larger value of R_a is to be taken:

$$Z_v = 0,88 + 0,23\left(0,8 + \frac{32}{v}\right)^{-0,5}$$

For values of Z_x, *see* Table 1.4.2
$\sigma_{H\,lim}$, *see* Table 1.4.3
$S_{H\,min}$, *see* Table 1.4.4.

Table 1.4.2 Values of Z_x

Pinion heat treatment		Z_x
Carburised and induction-hardened	$m_n \leq 10$ $10 < m_n < 30$ $30 \leq m_n$	1,00 1,05 – 0,005 m_n 0,9
Nitrided	$m_n < 7,5$ $7,5 < m_n < 30$ $30 \leq m_n$	1,00 1,08 – 0,005 m_n 0,75
Through-hardened	All modules	1,00

Table 1.4.3 Values of endurance limit for Hertzian contact stress, $\sigma_{H\,lim}$

Heat treatment		
Pinion	Wheel	
Through-hardened	Through-hardened	$0,46\sigma_{B2} + 255$
Surface-hardened	Through-hardened	$0,42\sigma_{B2} + 415$
Carburised, nitrided or induction-hardened	Soft bath nitrided (tufftrided)	1000
Carburised, nitrided or induction-hardened	Induction-hardened	$0,88HV_2 + 675$
Carburised or nitrided	Nitrided	1300
Carburised	Carburised	1500

Table 1.4.4 Factors of safety

	$S_{H\,min}$	$S_{F\,min}$
Main propulsion gears	1,40	1,80
Auxiliary gears	1,15	1,40

4.5 Tooth loading for bending stress

4.5.1 The bending stress at the tooth root, σ_F is not to exceed the allowable tooth root bending stress σ_{FP}:

$$\sigma_F = \frac{F_t}{b\,m_n} Y_F Y_S Y_\beta K_A K_\gamma K_v K_{F\beta} K_{F\alpha} \quad \text{N/mm}^2$$

$$\sigma_{FP} = \frac{\sigma_{F\,lim} Y_{ST} Y_{d\,rel\,T} Y_{R\,rel\,T} Y_x}{S_{F\,min} Y_D} \quad \text{N/mm}^2$$

NOTE
If b_1 and b_2 are not equal the load bearing width of the wider face taken is not to exceed that of the smaller plus $2m_n$.

For values of $S_{F\,min}$, *see* Table 1.4.4
$\sigma_{F\,lim}$, *see* Table 1.4.5
Stress correction factor $Y_{ST} = 2$.

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Table 1.4.5 Values of endurance limit for bending stress, $\sigma_{F\,lim}$

Heat treatment	$\sigma_{F\,lim}$ N/mm^2
Through-hardened carbon steel	$0{,}09\sigma_B + 150$
Through-hardened alloy steel	$0{,}1\sigma_B + 185$
Soft bath nitrided (Tufftrided)	330
Induction hardened	$0{,}35\,HV + 125$
Gas nitrided	390
Carburised A	450
Carburised B	410

NOTES
1. A is applicable for Cr Ni Mo carburising steels.
2. B is applicable for other carburising steels.

4.5.2 **Tooth form factor, Y_F:**

$$Y_F = \frac{6\,\frac{h_F}{m_n}\cos\alpha_{Fen}}{\left(\frac{S_{Fn}}{m_n}\right)^2\cos\alpha_n}$$

where

h_F, α_{Fen} and S_{Fn} are shown in Fig. 1.4.1.

$$\frac{S_{Fn}}{m_n} = z_n\sin\left(\frac{\pi}{3} - \nu\right) + \sqrt{3}\left(\frac{G}{\cos\nu} - \frac{\rho_{ao}}{m_n}\right)$$

where

$$\nu = \frac{2G}{z_n}\tan\nu - H$$

$$G = \frac{\rho_{ao}}{m_n} - \frac{h_{ao}}{m_n} + x$$

$$H = \frac{2}{z_n}\left(\frac{\pi}{2} - \frac{E}{m_n}\right) - \frac{\pi}{3}$$

$$E = \frac{\pi}{4}m_n - h_{ao}\tan\alpha_n + \frac{S_{pr}}{\cos\alpha_n} - (1-\sin\alpha_n)\frac{\rho_{ao}}{\cos\alpha_n}$$

E, h_{ao}, α_n, S_{pr} and ρ_{ao} are shown in Fig. 1.4.2.

$$\frac{\rho_F}{m_n} = \frac{\rho_{ao}}{m_n} + \frac{2G^2}{\cos\nu\,(z_n\cos^2\nu - 2G)}$$

$$d_{en} = \frac{2z}{|z|}\left\{\left[\sqrt{\left(\frac{d_n}{2}\right)^2 - \left(\frac{d_{bn}}{2}\right)^2} - \frac{\pi d\cos\beta\cos\alpha_n}{|z|}(\varepsilon_{\alpha n} - 1)\right]^2 + \left(\frac{d_{bn}}{2}\right)^2\right\}^{1/2}$$

where

$$d_{an} = d_n + d_a - d$$

$$d_n = \frac{d}{\cos^2\beta_b}$$

$$d_{bn} = d_n\cos\alpha_n$$

$$\varepsilon_{\alpha n} = \frac{d}{\cos^2\beta_b}$$

$$\gamma_e = \frac{\frac{\zeta\pi}{2} + 2x\tan\alpha_n}{z_n} + \text{inv.}\,\alpha_n - \text{inv.}\,\alpha_{en}$$

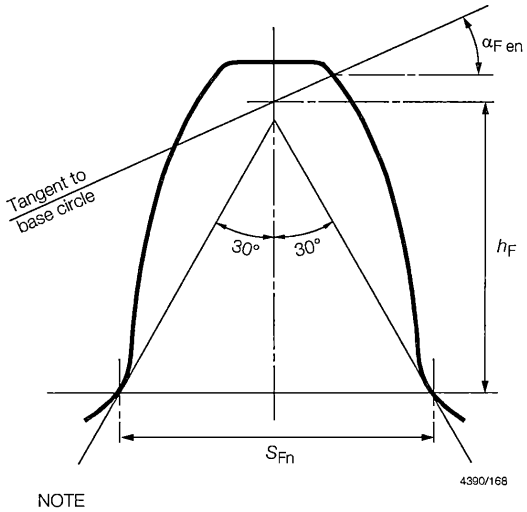
where

$$\alpha_{en} = \arccos\frac{d_{bn}}{d_{en}}$$

$$\frac{h_F}{m_n} = \frac{1}{2}\left[(\cos\gamma_e - \sin\gamma_e\tan\alpha_{F\,en})\frac{d_{en}}{m_n} - z_n\cos\left(\frac{\pi}{3} - \nu\right) - \frac{G}{\cos\nu} + \frac{\rho_{ao}}{m_n}\right]$$

where

$$\alpha_{F\,en} = \alpha_{en} - \gamma_e.$$



NOTE
For helical gears the normal section is taken with the virtual number of teeth

Fig. 1.4.1 Normal tooth section

4.5.3 For internal tooth forms the form factor is calculated, as an approximation, for a substitute gear rack with the form of the basic rack in the normal section, but having the same tooth depth as the internal gear:

$$\frac{S_{Fn2}}{m_n} = 2\left[\frac{\pi}{4} + \tan\alpha\left(\frac{h_{ao2} - \rho_{ao2}}{m_n}\right) + \left(\frac{\rho_{ao2} - S_{pr}}{m_n}\right) - \frac{\rho_{ao2}}{m_n}\cos\frac{\pi}{6}\right], \text{ and}$$

$$\frac{h_{F2}}{m_n} = \frac{d_{en2} - d_{fn2}}{2m_n} - \left[\frac{\pi}{4} + \left(\frac{h_{ao2}}{m_n} - \frac{d_{en2} - d_{fn2}}{2m_n}\right)\tan\alpha_n\right]\tan\alpha_n - \frac{\rho_{ao2}}{m_n}\left(1 - \sin\frac{\pi}{6}\right)$$

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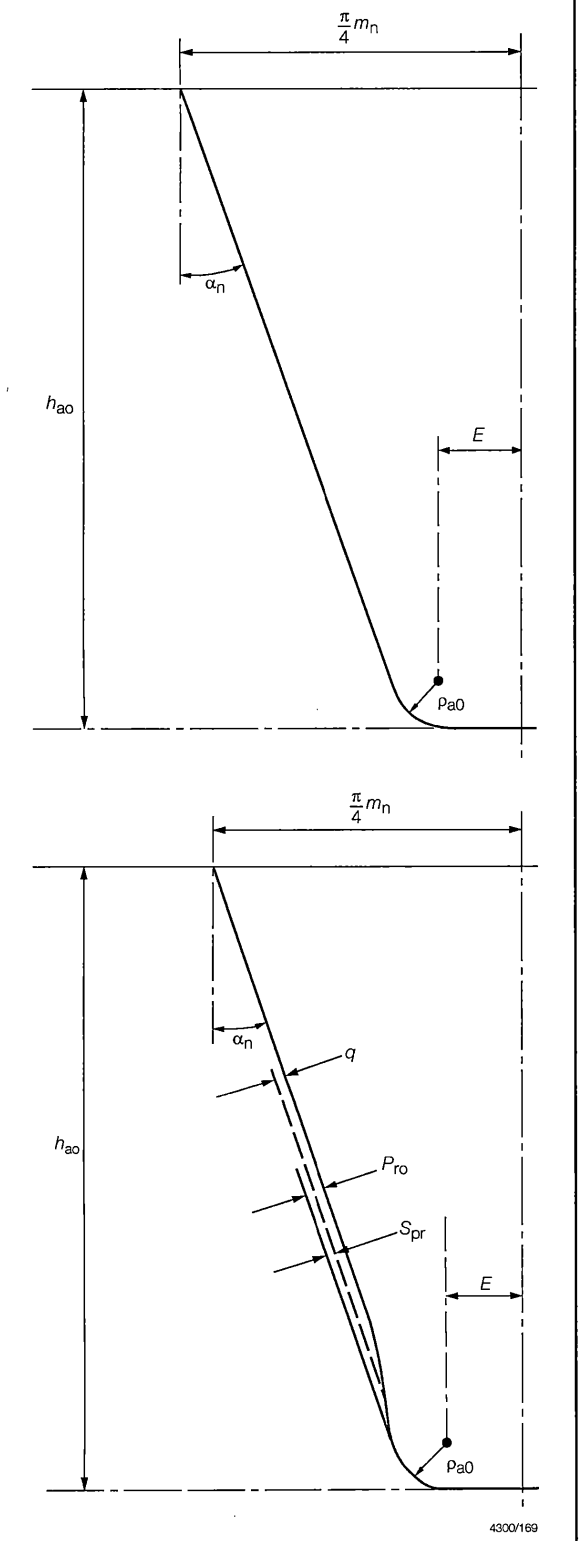

NOTES
1. Dimensions shown in rack profile of tooth
2. $S_{pr} = P_{ro} - q$

Fig. 1.4.2 External tooth forms

where

$\alpha_{F\,en}$ is taken as being equal to α_n

$$\rho_{F2} = \frac{\rho_{ao2}}{2}$$

d_{en2} is calculated as d_{en} for external gears, and

$$d_{fn} = d - d_f - d_n$$

4.5.4 Stress concentration factor, Y_s

$$Y_s = (1{,}2 + 0{,}13L)\, q_s^{\left(\frac{1}{1{,}21 + 2.3/L}\right)}$$

where

$$L = \frac{S_{Fn}}{h_F}$$

$$q_S = \frac{S_{Fn}}{2\rho_F}$$

when

$q_s < 1$ the value of Y_s is to be specially considered.

The formula for Y_s is applicable to external gears with $\alpha_n = 20°$ but may be used as an approximation for other pressure angles and internal gears.

4.5.5 Helix angle factor Y_β

$$Y_\beta = 1 - \left(\varepsilon_\beta \frac{\beta}{120}\right), \text{ if } \varepsilon_\beta > 1 \text{ let } \varepsilon_\beta = 1$$

but

$$Y_b \geq 1 - 0{,}25\varepsilon_\beta \geq 0{,}75$$

4.5.6 Relative notch sensitivity factor, $Y_{\delta\,rel\,T}$

$Y_{\delta\,rel\,T} = 1 + 0{,}036\,(q_s - 2{,}5)\left(1 - \frac{\sigma_y}{1200}\right)$ for through-hardened steels

$= 1 + 0{,}008\,(q_s - 2{,}5)$ for carburised and induction-hardened steels, and

$= 1 + 0{,}04\,(q_s - 2{,}5)$ for nitrided steels.

4.5.7 Relative surface finish factor, $Y_{R\,rel\,T}$

$Y_{R\,rel\,T} = 1{,}674 - 0{,}529\,(6R_a + 1)^{0{,}1}$ for through-hardened, carburised and induction hardened steels, and

$= 4{,}299 - 3{,}259\,(6R_a + 1)^{0{,}005}$ for nitrided steels.

4.5.8 Size factor, Y_x

$Y_x = 1{,}00$, when $m_n \leq 5$

$= 1{,}03 - 0{,}006m_n$ for through-hardened steels

$= 0{,}85$, when $m_n \geq 30$

$= 1{,}05 - 0{,}01\,m_n$ for surface-hardened steels

$= 0{,}80$, when $m_n \geq 25$.

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4.5.9 **Design factor, Y_D**

Y_D = 0,83 for gears treated with a controlled shot peening process

= 1,5 for idler gears

= 1,25 for shrunk on gears, or

$$= 1 + \frac{0{,}2 d_s^2\, d\, P_r\, b}{F_t\, \sigma_{F\,lim}\, (d_f^2 - d_s^2)}, \text{ otherwise}$$

= 1,00, or any combination of the above – e.g. Y_D = (0,83 x 1,5) for an idler gear treated with a controlled shot peening process.

4.6 Factors of safety

4.6.1 Factors of safety are shown in Table 1.4.4.

4.7 Design of enclosed gear shafting

4.7.1 The following symbols apply:

P in kW and *R* in rpm, *see* 1.2.1.

L = span between shaft bearing centres, in mm

α_n = normal pressure angle at the gear reference diameter, in degrees

β = helix angle at the gear reference diameter, in degrees

d_w = pitch circle diameter of the gear teeth, in mm

σ_u = specified minimum tensile strength of the shaft material, in N/mm^2

NOTE

Numerical value used for σ_u is not to exceed 800 N/mm^2 for gear and thrust shafts and 1100 N/mm^2 for quill shafts.

4.7.2 This sub-Section is applicable to the main and ancillary transmission shafting, enclosed within the gearcase.

4.7.3 The diameter of the enclosed gear shafting adjacent to the pinion or wheel is to be not less than the greater of d_b or d_t, where:

$$d_b = 365 \left(\frac{P\,L}{R\, d_w\, S_b} \right)^{1/3} \left(1 + \left(\frac{\tan \alpha_n}{\cos\beta} + \frac{\tan\beta\; d_w}{L} \right)^2 \right)^{1/6}$$

$$d_t = 365 \left(\frac{P}{R\, S_s} \right)^{1/3}$$

where

S_b = 45 + 0,24 (σ_u – 400) and

S_s = 42 + 0,09 (σ_u – 400).

4.7.4 For the purposes of the above it is assumed that the pinion or wheel is mounted symmetrically spaced between bearings.

4.7.5 Outside a length equal to the required diameter at the pinion or wheel, the diameter may be reduced, if applicable, to that required for d_t.

4.7.6 For bevel gear shafts, where a bearing is located adjacent to the gear section, the diameter of the shaft is to be not less than d_t. Where a bearing is not located adjacent to the gear the diameter of the shaft will be specially considered.

4.7.7 The diameter of quill shaft (not axially constrained and subject only to external torsional loading) is to be not less than given by the following formula:

$$\text{Diameter of quill shaft} = 101 \sqrt[3]{\frac{P400}{R\,\sigma_u}} \text{ mm.}$$

4.7.8 Where a shaft, located within the gearcase, is subject to the main propulsion thrust, the diameter at the collars of the shaft transmitting torque, or in way of the axial bearing where a roller bearing is used as a thrust bearing, is to be not less than 1,1d_t. For thrust bearings located outside the gearcase, *see* Chapter 2.

4.8 Gear wheels

4.8.1 In general, arrangements are to be made so that the interior structure of the wheel may be examined. Alternative proposals will be specially considered.

4.9 External shafting and components

4.9.1 For shafting external to the gearbox and other components ancillaries, *see* Pt 11, Ch 2.

4.10 Clutch actuation

4.10.1 Where a clutch is fitted in the transmission, normal engagement shall not cause excessive stresses in the transmission or the driven machinery. Inadvertent operation of any clutch is not to produce dangerously high stresses in the transmission or driven machinery.

4.11 Gearcases

4.11.1 Gearcases and their supports are to be designed sufficiently stiff such that misalignment at the mesh due to movements of the external foundations and the thermal effects under all conditions of service do not disturb the overall tooth contact.

4.11.2 Inspection openings are to be provided at the peripheries of gearcases to enable the teeth of pinions and wheels to be readily examined. Where the construction of gearcases is such that sections of the structure cannot be readily be moved for inspection purposes, access openings of adequate size are also to be provided at the ends of the gearcases to permit examination of the structure of the wheels. Their attachment to the shafts is to be capable of being examined by removal of bearing caps or by equivalent means.

4.11.3 For gearcases fabricated by fusion welding the carbon content of the steels should generally not exceed 0,23 per cent. Steels with higher carbon content may be approved subject to satisfactory results from weld procedure tests.

4.11.4 Gearcases are to be stress relieved upon completion of all welding.

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4.11.5 Gearcases manufactured from material other than steel will be considered upon full details being submitted.

4.12 Backlash

4.12.1 The normal backlash between any pair of gears should not be less than:

$$\frac{a\alpha_n}{90\,000} + 0{,}1 \text{ mm}$$

4.12.2 The normal backlash is not to exceed three times the value calculated in 4.12.1.

4.13 Alignment

4.13.1 Reduction gears with sleeve bearings, for main and auxiliary purposes are to be provided with means for checking the internal alignment of the various elements in the gearcases.

4.13.2 In the case of separately mounted reduction gearing for main propulsion, means are to be provided by the gear manufacturer to enable the Surveyors to verify that no distortion of the gearcase has taken place, when chocked and secured to its seating on board the craft.

■ *Section 5* Piping systems for gearing

5.1 General

5.1.1 Piping systems for gearing are to comply with the general design requirements given in Part 15.

5.1.2 The specific requirements for lubricating/hydraulic oil systems and standby arrangements are given in Part 15.

5.1.3 Lubricating oil lines are to be screened, or otherwise suitably protected, to avoid oil spray or oil leakages onto hot surfaces, into machinery air intakes or other sources of ignition. The number of joints in such piping systems should be kept to a minimum. Flexible pipes are to be of an approved type.

5.2 Pumps

5.2.1 Where lubricating oil for the reduction gearing is circulated under pressure, pump standby arrangements are to be provided in accordance with Part 15.

5.3 Filters

5.3.1 Where the lubricating oil for the reduction gearing is circulated under pressure, provision is to be made for the efficient filtration of the oil. The filters are to be capable of being cleaned without stopping the gear set or reducing the supply of filtered oil to the gearing.

■ *Section 6* Control and monitoring

6.1 General

6.1.1 Control engineering systems are to be in accordance with Part 16.

6.1.2 All main and auxiliary gear units, intended for essential services, are to be provided with means of indicating the lubricating oil supply pressure. Audible and visual alarms are to be fitted to give warning of an appreciable reduction in pressure of the lubricating oil supply. These alarms are to be actuated from the outlet side of any restrictions, such as filters, coolers, etc.

6.2 Unattended machinery

6.2.1 Where the machinery is fitted with automatic or remote controls so that under normal operating conditions it does not require any manual intervention by the operators, gear units are to be provided with the alarms and safety arrangements required by 6.2.2 and Table 1.6.1. The sensors and circuits utilised for the second stage alarm and automatic shut down in Table 1.6.1 are to be independent of those required for the first stage alarm.

Table 1.6.1 Alarms and safeguards

Item	Alarm	Note
Lubricating oil sump level	Low	
Lubricating oil inlet pressure*	1st Stage Low	
	2nd Stage Low	Automatic shutdown of engine
Lubricating oil inlet temperature*	High	
Thrust bearing temperature*	High	
NOTE For transmitted powers of 1500 kW or less, only the items marked * are required.		

6.2.2 Where the gear unit is required to be provided with a standby pump, the standby pump is to start automatically if the discharge pressure from the working pump falls below a predetermined value.

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Section 7
Requirements for craft which are not required to comply with the HSC Code

7.1 Details to be submitted

7.1.1 Failure mode effect analysis is not required for craft which do not require to comply with the HSC Code.

7.1.2 Mass elastic schematic showing gear unit torsional data is only required for gears with an input power greater than 500 kW, *see* 2.2.2 and Part 13.

7.2 Design of gearing

7.2.1 Where they are not intended for passenger carrying duties, the gearing factors of safety for yachts, service craft less than 24 m and ACVs are to satisfy Table 1.7.1.

Table 1.7.1 Factors of safety

	$S_{H\,min}$	$S_{F\,min}$
Main propulsion gears for yachts, etc., single screw	1,25	1,50
Main propulsion gears for yachts, etc., multiple screw	1,20	1,45

7.3 Piping systems

7.3.1 For service craft less than 24 m and for yachts the requirements of 5.2.1 and 5.3.1 do not apply. These craft are to have gearing provided with an efficient lubricating oil pump, a cooler where necessary, and a filter arrangement which can be cleaned.

7.4 Control and monitoring

7.4.1 For service craft less than 24 m the alarms required by 6.2.1 are not required.

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Section

1 **General requirements**

2 **Particulars to be submitted**

3 **Materials**

4 **Design and construction**

5 **Control and monitoring**

6 **Requirements for craft which are not required to comply with the HSC Code**

■ *Section 1* General requirements

1.1 Application

1.1.1 This Chapter is to be read in conjunction with the General Requirements for Machinery in Part 9.

1.1.2 This Chapter gives the requirements for the dimensions of transmission shafts, couplings, coupling bolts, keys, keyways, sternbushes and other associated components of main propulsion shafting.

1.1.3 The diameters may require to be modified as a result of alignment considerations and vibration characteristics (*see* Part 13), or the inclusion of stress raisers, other than those contained in this Chapter.

1.1.4 For shafting enclosed within an gearbox, *see* Ch 1,4.7.

1.1.5 For diesel engine crankshaft and turbine rotor shafting, *see* Part 10.

1.2 Power ratings

1.2.1 In this Chapter, the dimensions of main propulsion component are determined from shaft power, *P*, in kW, and revolutions per minute, *R*, and general requirements defined in Pt 9, Ch 1,1.

1.2.2 For auxiliary machinery, the maximum continuous shaft power and corresponding revolutions per minute which will be used in service are to be stated.

1.3 Clutches

1.3.1 Clutches for single engine propulsion plants are to be provided with a suitable means for emergency operation in the event of loss of operating fluid systems. Their suitability for short term high power operation is to be demonstrated.

1.4 Safety

1.4.1 Means are to be provided such that in the event of a failure to a shaft or coupling the occupants of the craft are not endangered, either directly or by damaging the craft or its systems. Where necessary, guards may be fitted to achieve compliance with these requirements.

■ *Section 2* Particulars to be submitted

2.1 Plans

2.1.1 At least three copies of the following plans are to be submitted:

- Shafting arrangement.
- Thrust shaft.
- Intermediate shafting.
- Tube shaft, where applicable.
- Screwshaft.
- Screwshaft oil gland.
- Screwshaft protection.
- Sternbush and arrangement in housing.
- Couplings.
- Coupling bolts.
- Flexible coupling.
- Cardan shafts.

2.1.2 The shafting arrangement plan is to indicate the relative position of the main engine(s), flywheel, flexible coupling(s), gearing, thrust block, line shafting and bearing(s), sterntube, 'A' bracket and propulsion device, as applicable.

2.2 Calculations and specifications

2.2.1 The following calculations and specifications are to be submitted:

- Calculations, or relevant documentation indicating the suitability of all components for short term high power operation, where applicable.
- Where undertaken as an alternative to the requirements of this Chapter, fatigue endurance calculations of all components according to Part 9.
- Vibration analysis and alignment analysis as required by Part 13.
- The material specifications, including the minimum specified tensile strength of each shaft and coupling component are to be stated. Where corrosion resistant material not included in Table 2.4.1 is used for unprotected screwshafts the corrosion fatigue strength in sea-water is to be stated together with the chemical composition and mechanical properties.
- Where it is proposed to use composite (non-metallic) shafts, details of materials, resin, lay-up procedure and documentary evidence of fatigue endurance strength.

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■ *Section 3* Materials

3.1 Materials for shafts

3.1.1 Components are to be manufactured and tested in accordance with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

3.1.2 Where it is proposed to use alloy steel forgings, particulars of the chemical composition, mechanical properties and heat treatment are to be submitted for approval. For main propulsion shafting, not exposed to sea water, in alloy steels, the specified minimum tensile strength is not to exceed 800 N/mm^2 and for other forgings is not to exceed 1100 N/mm^2.

3.1.3 Unprotected screwshafts and tubeshafts exposed to sea-water are in general to be manufactured, from corrosion resistant ferrous or non-ferrous material, such as those indicated in Table 2.4.1.

3.1.4 In the selection of materials for shafts, keys, locking nuts etc., consideration is to be given to their compatibility with the proposed propeller material.

3.1.5 Where shafts are manufactured from composite material the process is to be approved.

■ *Section 4* Design and construction

4.1 Fatigue strength analysis

4.1.1 As an alternative to the following requirements, a fatigue strength analysis of components can be submitted indicating a factor of safety of 1,5 at the design loads, based on a suitable fatigue failure criteria. The effects of stress concentrations, material properties and operating environment are to be taken into account.

4.2 Intermediate shafts

4.2.1 The diameter, d, of the intermediate shaft is to be not less than:

$$d = Fk \sqrt[3]{\frac{P}{R}\left(\frac{560}{\sigma_u + 160}\right)} \quad \text{mm}$$

where

k = 1,0 for shafts with integral coupling flanges complying with 4.8 or shrink fit couplings
= 1,10 for shafts with keyways, where the fillet radii in the transverse section of the bottom of the keyway are not less than 0,0125d
= 1,10 for shafts with transverse or radial holes where the diameter of the hole does not exceed 0,3d
= 1,20 for shafts with longitudinal slots having a length of not more than 1,4d and a width of not more than 0,2d where d, is determined with k = 1,0

F = 95 for turbine installations, electric propulsion installations and diesel engine installations with slip type couplings
= 100 for other diesel engine installations

P and R are as defined in Part 9

σ_u = specified minimum tensile strength of the shaft material, in N/mm^2.

4.2.2 Beyond a length of 0,2d from the end of a keyway, transverse hole or radial hole and 0,3d from the end of a longitudinal slot, the diameter of the shaft may be gradually reduced to that determined with k = 1,0.

4.2.3 For shafts with design features other than stated as above, the value of k will be specially considered.

4.2.4 The Rule diameter of the intermediate shaft for diesel engines, turbines and electric propelling motors may be reduced by 3,5 per cent for craft classed G1 (Service Group 1), *see* Pt 1, Ch 2,3.5.

4.3 Thrust shafts

4.3.1 The diameter at the collars of the thrust shaft transmitting torque or in way of the axial bearing where a roller bearing is used as a thrust bearing is to be not less than that required for the intermediate shaft in accordance with 4.2 with a k value of 1,10. Beyond a length equal to the thrust shaft diameter from the collars, the diameter may be tapered down to that required for the intermediate shaft with a k value of 1,0. For the purpose of the foregoing calculations, σ_u is to be taken as the minimum tensile strength of the thrust shaft material, in N/mm^2.

4.4 Screwshafts and tube shafts

4.4.1 Screwshafts and tube shafts, (i.e the shaft which passes through the sterntube, but does not carry the propeller), made from carbon manganese steel are to be protected by a continuous bronze liner, where exposed to sea water. Alternatively, the liner may be omitted provided the shaft is arranged to run in an oil lubricated bush with an approved oil sealing gland at the after end. Lengths of shafting between sterntubes and brackets, which are readily visible when the craft is slipped, may be protected by coatings of an approved type.

4.4.2 Means for the protection of screwshafts and tube-shafts are not required when the shafts are made of corrosion resistant material.

4.4.3 The diameter, d_p of the protected forged steel screwshaft immediately forward of the forward face of the propeller boss or, if applicable, the forward face of the screw-shaft flange, is to be not less than:

$$d_p = 100k \sqrt[3]{\frac{P}{R}\left(\frac{560}{\sigma_u + 160}\right)} \quad \text{mm}$$

where

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k = 1,22 for a shaft carrying a keyless propeller, or where the propeller is attached to an integral flange, and where the shaft is fitted with a continuous liner, a coating of an approved type, or is oil lubricated and provided with an approved type of oil sealing gland

= 1,26 for a shaft carrying a keyed propeller and where the shaft is fitted with a continuous liner, a coating of an approved type, or is oil lubricated and provided with an approved type of oil sealing gland

P and R are as defined in Part 9

σ_u = specified minimum tensile strength of the shaft material, in N/mm^2 but is not to be taken as greater than 600 N/mm^2.

4.4.4 The diameter, d_p of the screwshaft determined in accordance with 4.4.3 is to extend over a length not less than that to the forward edge of the bearing immediately forward of the propeller or 2,5d_p whichever is the greater.

4.4.5 The diameter of the portion of the screwshaft and tube shaft forward of the length required by 4.4.4 to the forward end of the stern tube seal is to be determined in accordance with 4.4.3 with a k value of 1,15. The change of diameter from that determined with k = 1,22 or 1,26 to that determined with k = 1,15 should be gradual.

4.4.6 Screwshafts which run in sterntubes and tube shafts may have the diameter forward of the forward stern tube seal gradually reduced to the diameter of the intermediate shaft. Abrupt changes in shaft section at the screwshaft/tube shaft to intermediate shaft couplings are to be avoided.

4.4.7 The diameter of unprotected screwshafts and tube shafts of materials having properties as shown in Table 2.4.1 is to be not less than:

$$d_{up} = 128A \sqrt[3]{\frac{P}{R}}$$

where

'A' is taken from Table 2.4.1 and

P and R are as defined in Part 9.

Table 2.4.1 Provisional 'A' Value for use in unprotected screwshaft formula

Material	'A' Value
Stainless steel type 316 (austenitic)	0,71
Stainless steel type 431 (martensitic)	0,69
Manganese bronze	0,8
Aluminium bronze	0,65
Nickel copper alloy – monel 400	0,65
Nickel copper alloy – monel K 500	0,55
Duplex steels	0,49

4.4.8 The diameter of unprotected screwshafts of materials having properties as shown in Table 2.4.1 forward of the forward stern tube seal is to be determined in accordance with 4.4.7 or 4.4.3, whichever is less.

4.5 Hollow shafts

4.5.1 Where the thrust, intermediate, tube shafts and screwshafts have central holes having a diameter greater than 0,4 times the outside diameter, the equivalent diameter, d_e, of a solid shaft is not to be less than the Rule size, d, (of a solid shaft), where d_e is given by:

$$d_e = d_o \sqrt[3]{1 - \left(\frac{d_i}{d_o}\right)^4}$$

where

d_o = proposed outside diameter, in mm

d_i = diameter of central hole, in mm.

4.5.2 Where the diameter of the central hole does not exceed 0,4 times the outside diameter, the diameter is to be calculated in accordance with the appropriate requirements for a solid shaft.

4.6 Cardan shafts

4.6.1 Cardan shafts, used in installations having more than one propulsion shaftline, are to be of an approved design, suitable for the designed operating conditions including short term high power operation. Consideration will be given to accepting the use of approved cardan shafts in single propulsion unit applications if a complete spare interchangeable end joint is provided on board.

4.6.2 Cardan shaft ends are to be contained within substantial tubular guards that also permit ready access for inspection and maintenance.

4.7 Coupling bolts

4.7.1 Close tolerance fitted bolts transmitting shear are to have a diameter, d_b, at the flange joining faces of the couplings not less than:

$$d_b = \sqrt{\frac{240}{nD} \frac{10^6}{\sigma_u} \frac{P}{R}} \text{ mm}$$

where

n = number of bolts in the coupling

D = pitch circle diameter of bolts, in mm

σ_u = specified minimum tensile strength of bolts, in N/mm^2

P and R are as defined in Part 9.

4.7.2 At the joining faces of couplings, other than within the crankshaft and at the thrust shaft/crankshaft coupling, the Rule diameter of the coupling bolts may be reduced by 5,2 per cent for craft classed exclusively for smooth water service.

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4.7.3 Where dowels or expansion bolts are fitted to transmit torque in shear they are to comply with the requirements of 4.7.1. The expansion bolts are to be installed, and the bolt holes in the flanges are to be correctly aligned in accordance with manufacturer's instructions.

4.7.4 The minimum diameter of tap bolts or of bolts in clearance holes at the joining faces of coupling flanges, pretensioned to 70 per cent of the bolt material yield strength value, is not to be less than:

$$d_R = 1{,}348 \sqrt{\left(\frac{120\ 10^6 F P (1 + C)}{R D} + Q\right) \frac{1}{n \sigma_y}}$$

where d_R is taken as the lesser of:

(a) Mean of effective (pitch) and minor diameters of the threads.

(b) Bolt shank diameter away from threads. (Not for waisted bolts which will be specially considered.)

P and R are defined in Part 9.

F = 2,5 where the flange connection is not accessible from within the craft
= 2,0 where the flange connection is accessible from within the craft

C = ratio of vibratory/mean torque values at the rotational speed being considered

D = pitch circle diameter of bolt holes, in mm

Q = external load on bolt in N (+ve tensile load tending to separate flange, –ve)

n = number of tap or clearance bolts

σ_y = bolt material yield stress in N/mm^2.

4.7.5 Consideration will be given to those arrangements where the bolts are pretensioned to loads other than 70 per cent of the material yield strength.

4.7.6 Where clamp bolts are fitted they are to comply with the requirements of 4.7.4 and are to be installed, and the bolt holes in the flanges correctly aligned, in accordance with manufacturer's instructions.

4.8 Flange connections of couplings

4.8.1 The minimum thicknesses of the coupling flanges are to be equal to the diameters of the coupling bolts at the face of the couplings as required by 4.7.1, and for this purpose the minimum tensile strength of the bolts is to be taken as equivalent to that of the shafts. For intermediate, thrust shafts, and the inboard end of of the screwshaft, the thickness of the coupling flange is in no case to be less than 0,20 of the diameter of the intermediate shaft as required by 4.2.1.

4.8.2 The fillet radius at the base of the coupling flange, integral with the shaft, is to be not less than 0,08 of the diameter of the shaft at the coupling. The fillets are to have a smooth finish and are not to be recessed in way of nut and bolt heads.

4.8.3 Where the propeller is attached by means of a flange, the thickness of the flange is to be not less than 0,25 of the actual diameter of the adjacent part of the screwshaft. The fillet radius at the base of the coupling flange is to be not less than 0,125 of the diameter of the shaft at the coupling.

4.8.4 All couplings which transmit torque are to be of approved dimensions.

4.8.5 Where couplings are separate from the shafts, provision is to be made to resist the astern pull.

4.8.6 Where a coupling is shrunk on to the parallel portion of a shaft or is mounted on a slight taper, e.g. by means of the oil pressure injection method, the assembly is to meet the requirements of 4.11.

4.9 Tooth couplings

4.9.1 The contact stress, S_c, at the flanks of mating teeth of a gear coupling is not to exceed that given in Table 2.4.2, where

$$S_c = \frac{24{,}10^6 P}{R d_p bhz} \text{ N/mm}^2$$

where

P and R are defined in Part 9.

d_p = pitch circle diameter of coupling teeth, in mm

b = tooth facewidth, in mm

h = tooth height, in mm

z = number of teeth (per coupling half).

Table 2.4.2 Allowable S_c values

Tooth material surface treatment	Allowable S_c Value N/mm^2
Surface hardened teeth	19
Through hardened teeth	11

4.9.2 Where experience has shown that under similar operating and alignment conditions, a higher tooth loading can be accommodated full details are to be submitted for consideration.

4.10 Flexible couplings

4.10.1 Details of flexible couplings are to be submitted together with the manufacturer's rating capacity, for the designed operating conditions including short term high power operation. Verification of coupling characteristics will be required.

4.10.2 In determining the allowable mean, maximum and vibratory torque ratings consideration of the mechanical properties of the selected elastic element type in compression, shear and fatigue loading together with heat absorption/ generation is to be given.

4.10.3 In determining the allowable torque ratings of the steel spring couplings, consideration of the material mechanical properties to withstand fatigue loading and overheating is to be given.

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4.11 Interference fit assemblies

4.11.1 The interference fit assembly is to have a capacity to transmit a torque of $S.T_{max}$ without slippage.

NOTE

For guidance purposes only $T_{max} = T_{mean}\ (1 + C)$

where

C is to be taken from Table 2.4.3

S = 2,0 for assemblies accessible from within the vessel

= 2,5 for assemblies not accessible from within the vessel.

Table 2.4.3 'C' values for guidance purposes

Coupling location	C
High Speed Shafting — I.C engine driven	0,3
High Speed Shafting — Electric Motor or Turbine driven	0,1
Low Speed Shafting — main or PTO stage gearing	0,1

4.11.2 The effect of any axial load acting on the assembly is to be considered.

4.11.3 The resulting equivalent von Mises stress in the assembly is not to be greater than the yield strength of the component material.

4.11.4 Reference marks are to be provided on the adjacent surfaces of parts secured by shrinkage alone.

4.12 Keys and keyways for propeller connections

4.12.1 Round ended or sled-runner ended keys are to be used, and the keyways in the propeller boss and cone of the screwshaft are to be provided with a smooth fillet at the bottom of the keyways. The radius of the fillet is to be at least 0,0125 of the diameter of the screwshaft at the top of the cone. The sharp edges at the top of the keyways are to be removed.

4.12.2 Two screwed pins are to be provided for securing the key in the keyway, and the forward pin is to be placed at least one-third of the length of the key from the end. The depth of the tapped holes for the screwed pins is not to exceed the pin diameter, and the edges of the holes are to be slightly bevelled. The omission of pins for keys for small diameter shafts will be specially considered.

4.12.3 The distance between the top of the cone and the forward end of the keyway is to be not less than 0,2 of the diameter of the screwshaft at the top of the cone.

4.12.4 The effective sectional area of the key in shear, is to be not less than:

$$\frac{155d^3}{\sigma_u d_1}\ \text{mm}^2$$

where

d = diameter, in mm, required for the intermediate shaft determined in accordance with 4.2, based on material having a specified minimum tensile strength of 400 N/mm^2 and $k = 1$

d_1 = diameter of shaft at mid-length of the key, in mm

σ_u = specified minimum tensile strength (UTS) of the key material, N/mm^2.

4.12.5 The effective area in crushing of key, shaft or boss is to be not less than:

$$\frac{24d^3}{\sigma_y d_1}\ \text{mm}^2$$

where

σ_y = yield strength of key, shaft or boss material as appropriate, N/mm^2.

4.13 Keys and keyways for inboard shaft connections

4.13.1 Round ended keys are to be used and the keyways are to be provided with a smooth fillet at the bottom of the keyways. The radius of the fillet is to be at least 0,0125 of the diameter of the shaft at the coupling. The sharp edges at the top of the keyways are to be removed.

4.13.2 The effective area of the key in shear, A, is to be not less than:

$$A = \frac{126d^3}{\sigma_u d_1}\ \text{mm}^2$$

where

d = diameter, in mm, required for the intermediate shaft determined in accordance with 4.2, based on material having a specified minimum tensile strength of 400 N/mm^2 and $k = 1$

d_1 = diameter of shaft at mid-length of the key, in mm

σ_u = specified minimum tensile strength (UTS) of the key material, N/mm^2

Alternatively, consideration will be given to keys conforming to the design requirements of a recognised National Standard.

4.14 Corrosion resistant liners on shafts

4.14.1 Liners may be bronze, gunmetal, stainless steel or other approved alloy.

4.14.2 The thickness, t, of liners fitted on screwshafts or on tube shafts, in way of the bushes, is to be not less, when new, than given by the following formula:

$$t = \frac{D + 230}{32}\ \text{mm}$$

where

t = thickness of the liner, in mm

D = diameter of the screwshaft or tube shaft under the liner, in mm.

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4.14.3 The thickness of a continuous liner between the bushes is to be not less than 0,75*t*.

4.14.4 Continuous liners are to be fabricated or cast in one piece.

4.14.5 Where liners consist of two or more lengths, these are to be butt welded together. In general, the lead content of the gunmetal of each length forming a butt welded liner is not to exceed 0,5 per cent. The composition of the electrodes or filler rods is to be substantially lead-free.

4.14.6 The circumferential butt welds are to be of multi-run, full penetration type. Provision is to be made for contraction of the weld by arranging for a suitable length of the liner containing the weld, if possible about three times the shaft diameter, to be free of the shaft. To prevent damage to the surface of the shaft during welding, a strip of heat resisting material covered by a copper strip should be inserted between the shaft and the liner in way of the joint. Other methods for welding this joint may be accepted if approved. The welding is to be carried out by an approved method and to the Surveyor's satisfaction.

4.14.7 Each continuous liner or length of liner is to be tested by hydraulic pressure to 2,0 bar after rough machining.

4.14.8 Liners are to be carefully shrunk onto the shafts by hydraulic pressure. Pins are not to be used to secure the liners.

4.14.9 Effective means are to be provided for preventing water from reaching the shaft at the part between the after end of the liner and the propeller boss.

4.15 Intermediate bearings

4.15.1 Long unsupported lengths of shafting are to be avoided by the fitting of steady bearings at suitable positions, *see* Part 13.

4.16 Sternbushes and sterntube arrangement

4.16.1 Where the sterntube or sternbushes are to be installed using a resin, of an approved type, the following requirements are to be met:

(a) Pouring and venting holes are to be provided at opposite ends with the vent hole at the highest point.

(b) The minimum radial gap occupied by the resin is to be not less than 6 mm at any one point with a nominal resin thickness of 12 mm.

(c) In the case of oil lubricated sterntube bearings, the arrangement of the oil grooves is to be such as to promote a positive circulation of oil in the bearing.

(d) Provision is to be made for the remote measurement of the temperature at the aft end of the aft bearing, with indication and alarms at the control stations.

4.16.2 The length of the bearing in the sternbush next to and supporting the propeller is to be as follows:

(a) For water lubricated bearings which are lined with rubber composition or staves of approved plastics material, the length is to be not less than four times the diameter required for the screwshaft under the liner.

(b) For water lubricated bearings lined with two or more circumferentially spaced sectors, of an approved plastics material, without axial grooves in the lower half, the length of the bearing is to be such that the nominal bearing pressure will not exceed 0,55 N/mm^2. The length of the bearing is to be not less than twice its diameter.

(c) For bearings which are white-metal lined, oil lubricated and provided with an approved type of oil sealing gland, the length of the bearing is to be approximately twice the diameter required for the screwshaft and is to be such that the nominal bearing pressure will not exceed 0,8 N/mm^2. The length of the bearing is to be not less than 1,5 times its diameter.

(d) For bearings of cast iron and bronze which are oil lubricated and fitted with an approved oil sealing gland, the length of the bearing is, in general, to be not less than four times the diameter required for the screwshaft.

(e) Oil lubricated non-metallic bearings are to be manufactured from an approved material. The length of the bearing is to be such that the maximum approved bearing pressure is not exceeded for any limiting length to diameter ratio.

4.16.3 Sternbushes are to be adequately secured in housings.

4.16.4 Forced water lubrication is to be provided for all bearings lined with rubber or plastics. The supply of water may come from a circulating pump or other pressure source. Flow indicators are to be provided for the water service to plastics and rubber bearings. The water grooves in the bearings are to be of ample section and of a shape which will be little affected by weardown, particularly for bearings of the plastics type.

4.16.5 The shut-off valve or cock controlling the supply of water is to be fitted directly to the after peak bulkhead, or to the sterntube where the water supply enters the sterntube forward of the bulkhead.

4.16.6 Oil sealing glands must be capable of accommodating the effects of differential expansion between hull and line of shafting for all sea temperatures in the proposed area of operation. This requirement applies particularly to those glands which span the gap and maintain oiltightness between the sterntube and the propeller boss.

4.16.7 Where a tank supplying lubricating oil to the sternbush is fitted, it is to be located above the load waterline and is to be provided with a low level alarm device in the machinery space, *see also* 5.1.1.

4.16.8 Where sternbush bearings are oil lubricated, provision is to be made for cooling the oil by maintaining water in the after peak tank above the level of the sterntube or by other approved means. Means for ascertaining the temperature of the oil in the sterntube are also to be provided.

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4.16.9 Where an ***IWS** (In-water Survey) notation is to be assigned, means are to be provided for ascertaining the clearance in the sternbush with the vessel afloat.

4.17 Vibration and alignment

4.17.1 For the requirements for torsional, axial and lateral vibration, and for alignment of the shafting, *see* Part 13.

■ *Section 5* Control and monitoring

5.1 Unattended machinery

5.1.1 Where sterntube lubrication oil systems are fitted with automatic or remote controls so that under normal operating conditions they do not require any manual intervention by the operators, they are to be provided with the alarms indicated in Table 2.5.1.

Table 2.5.1 Alarms

Item	Alarm
Sterntube lubricating oil tank level	Low
Sterntube bearing temperature (oil lubricated)	High

■ *Section 6* Requirements for craft which are not required to comply with the HSC Code

6.1 General

6.1.1 Service craft of less than 24 m do not have to comply with 1.3.1 in respect of emergency operation of clutches on single screw installations.

6.2 Details to be submitted

6.2.1 The corrosion fatigue strength of corrosion resistant shaft material need not be submitted if the material is as shown in Table 2.4.1, *see also* 2.2.

6.3 Materials

6.3.1 The proposals to use extruded non-ferrous or composite materials will receive special consideration.

6.3.2 For the survey and testing of shaft material, *see* the Rules for Materials.

6.4 Sternbushes and sterntube arrangement

6.4.1 For service craft less than 24 m, the requirements of 4.16.1 do not apply. Sterntube bearings of approved plastics materials are to be installed so as to ensure a supply of water for lubrication in accordance with the bearing manufacturer's recommendations.

6.4.2 The aftermost propeller shaft bearing in the sterntube is to be secured to prevent rotational and axial movement.

6.4.3 For service craft less than 24 m, the requirements of 4.16.8 do not apply.

6.4.4 The lubrication of propulsion shafting bearings on SES craft less than 24 m will be considered.

6.5 Alarms

6.5.1 The requirements of 5.1.1 do not apply to service craft less than 24 m.

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4 **Propeller design**

5 **Piping systems**

6 **Control and monitoring**

7 **Requirements for craft which are not required to comply with the HSC Code**

■ *Section 1* General requirements

1.1 Application

1.1.1 This Chapter is to be read in conjunction with the General Requirements for Machinery in Part 9.

1.2 Power ratings

1.2.1 In this Chapter where the dimensions of main propulsion components are determined from shaft power, P, in kW, and revolutions per minute, R, the values to be used are those defined in Part 9.

1.3 Highly skewed propellers

1.3.1 The maximum skew angle of a propeller blade is defined as the angle, in projected view of the blade, between a line drawn through the blade tip and the shaft centreline and a second line through the shaft centreline which acts as a tangent to the locus of the mid-points of the helical blade sections, *see* Fig. 1.1.1.

1.4 Supercavitating propellers

1.4.1 A supercavitating propeller is defined as one in which the sheet cavity is designed to cover the entire blade width over at least the outer 50 per cent of the blade span.

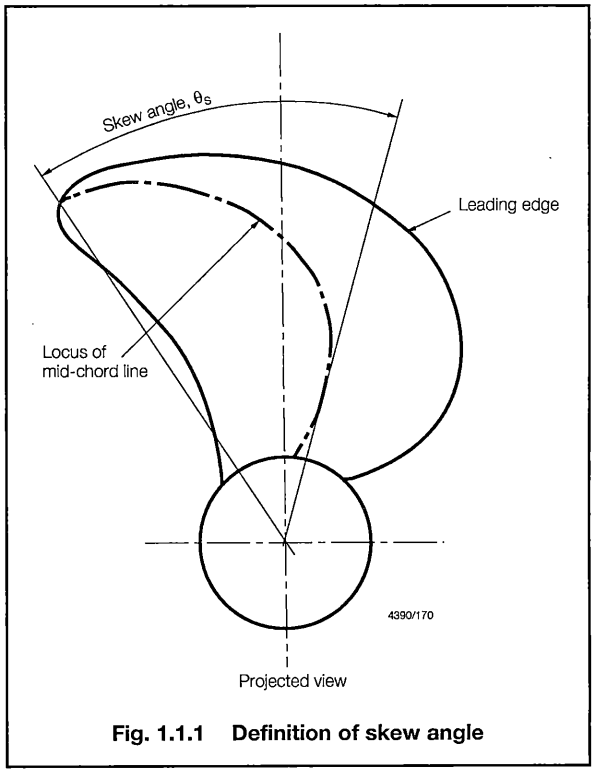

Fig. 1.1.1 Definition of skew angle

■ *Section 2* Plans and particulars

2.1 Particulars to be submitted

2.1.1 At least three copies of the following plans and information are to be submitted.

2.2 Plans

2.2.1 A plan of the propeller, together with the following particulars is to be submitted:

(a) Maximum blade thickness of the expanded cylindrical section considered, in mm, excluding any allowance for fillet, T, in mm.
(b) Maximum shaft power, P, in kW, *see* Part 9.
(c) Estimated craft speed at design loaded draught in the free running condition at maximum shaft power and corresponding revolutions per minute (*see* (b) and (d)).
(d) Revolutions per minute of the propeller at maximum power, R.
(e) Propeller diameter, D, in metres.
(f) Pitch at 25 per cent radius (for solid propellers only), $P_{0,25}$, in metres.
(g) Pitch at 35 per cent radius (for controllable pitch propellers only), $P_{0,35}$, in metres.
(h) Pitch at 60 per cent radius, $P_{0,6}$, in metres.
(j) Pitch at 70 per cent radius, $P_{0,7}$, in metres.

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(k) Length of blade section of the expanded cylindrical section at 25 per cent radius (for solid propellers only), $L_{0,25}$, in mm.
(l) Length of blade section of the expanded cylindrical section at 35 per cent radius (for controllable pitch propellers only), $L_{0,35}$, in mm.
(m) Length of blade section of the expanding cylindrical section at 60 per cent radius, $L_{0,6}$, in mm.
(n) Rake at blade tip measured at shaft axis (backward rake positive, forward rake negative), A, in mm.
(o) Number of blades, N.
(p) Developed area ratio, B.
(q) Material: type and specified minimum tensile strength.
(r) Skew angle, θ_s, in degrees, *see* Fig. 1.1.1.
(s) Connection of propeller to shaft- details of fit, push up and securing.
(t) Keyed connection details.
(u) Details of control/hydraulic system and pressures for CP Propellers actuating mechanisms.
(v) Inertia of propeller assembly, kgm^2.
(w) Total mass of propeller assembly, kg.

2.2.2 For propellers having a skew angle equal or greater than 50° in addition to the particulars detailed in 2.2.1 details are to be submitted of:
(a) Full blade section details at each radial station defined for manufacture.
(b) A detailed blade stress computation supported by the following hydrodynamic data for the ahead mean wake condition and when absorbing full power:
  (i) Radial distribution of lift and drag coefficients, section inflow velocities and hydrodynamic pitch angles.
  (ii) Section pressure distributions calculated by either an advised viscid or viscous procedure.

2.3 Calculations and information

2.3.1 In cases where the craft has been the subject of model wake field tests a copy of the results is to be submitted.

2.3.2 The following information is to be submitted as applicable:
- For controllable pitch propellers plans (in diagrammatic form) of the hydraulic systems together with pipe material and working pressures.
- Details of control engineering aspects in accordance with Part 16.
- Calculations, or relevant documentation indicating the suitability of all components for short term high power operation.
- Where undertaken, fatigue strength analysis of components indicating a factor of safety of 1,5 at the design loads.
- For cases where the propeller material is not specified in Table 1.3.1, details of the chemical composition, mechanical properties and density are to be provided, together with results of fatigue tests in sea water in order to assign a value for U.

■ *Section 3* Materials

3.1 Castings for propellers

3.1.1 Castings for propellers and propeller blades are to comply with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials). The chemical composition and mechanical properties of steel castings are given in Ch 4,5 of the Rules for Materials and those of the copper alloys are given in Ch 9,1 of the Rules for Materials.

3.1.2 The specified minimum tensile strength of the castings is to be not less than stated in Table 1.3.1.

Table 1.3.1 Materials for propellers

Material	Specified minimum tensile strength N/mm^2	*G* Density g/cm^3	*U* Allowable stress N/mm^2
Carbon steels	400	7,9	20,6
Low alloy steels	440	7,9	20,6
13% chromium stainless steels	540	7,7	41
Chromium – nickel austenitic stainless steel	450	7,9	41
Duplex stainless steels	590	7,8	41
Grade Cu 1 Manganese bronze (high tensile brass)	440	8,3	39
Grade Cu 2 Ni-Manganese bronze (high tensile brass)	440	8,3	39
Grade Cu 3 Ni-Aluminium bronze	590	7,6	56
Grade Cu 4 Mn-Aluminium bronze	630	7,5	46

3.1.3 Where propellers of carbon and low alloy steels shown in Table 1.3.1 are provided with an approved method of cathodic protection, special consideration will be given to the value of U.

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■ *Section 4* Propeller design

4.1 Minimum blade thickness

4.1.1 For propellers having a skew angle of less than 25° as defined in 1.3.1, the minimum blade thickness, T, of the propeller blades at 25 per cent radius for solid propellers, 35 per cent radius for controllable pitch propellers, neglecting any increase due to fillets, and at 60 per cent radius, is to be not less than:

$$T = \frac{KCA}{EFULN} + 100\sqrt{\frac{3150MP}{EFRULN}} \text{ mm}$$

where

L = $L_{0,25}$, $L_{0,35}$, or $L_{0,6}$, as appropriate

$K = \frac{GBD^3R^2}{675}$

G = density, in g/cm^3, *see* Table 1.3.1

U = allowable stress, in N/mm^2, *see* 4.1.2, 4.1.3, 4.1.4 and Table 1.3.1.

$E = \frac{\text{actual face modulus}}{0{,}09T^2L}$

For aerofoil sections with and without trailing edge washback, E may be taken as 1,0 and 1,25 respectively.

For solid propellers at 25 per cent radius

C = 1,0

$F = \frac{P_{0,25}}{D} + 0{,}8$

$M = 1{,}0 + \frac{3{,}75D}{P_{0,7}} + 2{,}8\frac{P_{0,25}}{D}$

For controllable pitch propellers at 35 per cent radius

C = 1,4

$F = \frac{P_{0,35}}{D} + 1{,}6$

$M = 1{,}35 + \frac{5D}{P_{0,7}} + 2{,}6\frac{P_{0,35}}{D}$

For all propellers at 60 per cent radius

C = 1,6

$F = \frac{P_{0,6}}{D} + 4{,}5$

$M = 1{,}35 + \frac{5D}{P_{0,7}} + 1{,}35\frac{P_{0,6}}{D}$

4.1.2 The fillet radius between the root of a blade and the boss of a propeller is to be not less than the Rule thickness of the blade or equivalent at this location. Composite radiused fillets or elliptical fillets which provide a greater effective radius to the blade are acceptable and are to be preferred. Where fillet radii of the required size cannot be provided, the value of U is to be multiplied by

$$\left(\frac{r}{T}\right)^{0,2}$$

where

r = proposed fillet radius at the root, in mm

T = Rule thickness of the blade at the root, in mm.

Where a propeller has bolted-on blades, consideration is also to be given to the distribution of stress in the palms of the blades. In particular, the fillets of recessed bolt holes and the lands between bolt holes are not to induce stresses which exceed those permitted at the outer end of the fillet radius between the blade and the palm. Counterbored bolt holes in blade flanges are to be provided with adequate fillet radii at the bottom of the counter bore.

4.1.3 The value U may be increased by 10 per cent for twin screw and outboard propellers of triple screw craft.

4.1.4 For propellers having skew angles of 25° or greater, but less than 50°, the mid chord thickness, $T_{sk0,6}$, at the 60 per cent radius is to be not less than:

$$T_{sk0,6} = 0{,}54T_{0,6}\sqrt{(1 + 0{,}1\theta_s)} \text{ mm}$$

The mid chord thickness, $T_{sk\,root}$, at 25 or 35 per cent radius, neglecting any increase due to fillets, is to be not less than:

$$T_{sk\,root} = 0{,}75T_{root}\sqrt[4]{(1 + 0{,}1\theta_s)} \text{ mm}$$

where

θ_s = proposed skew angle as defined in 1.3.1

$T_{0,6}$ = thickness at 60 per cent radius, calculated by 4.1.1

$T_{sk\,root}$ = thickness at 25 per cent radius or 35 per cent radius, calculated by 4.1.1

The thickness at the remaining radii are to be joined by a fair curve and the sections are to be of suitable aerofoil section.

4.1.5 Results of detailed calculations where carried out, are to be submitted.

4.1.6 Where the design of a propeller has been based on analysis of reliable wake survey data in conjunction with a detailed fatigue analysis and is deemed to permit scantlings less than required by 5.1.1, a detailed stress analysis for the blades is to be submitted for consideration.

4.2 Interference fit of keyless propellers

4.2.1 The symbols used in 4.2.2 are defined as follows:

d_1 = diameter of the screwshaft cone at the mid-length of the boss or sleeve, in mm

d_3 = outside diameter of the boss at its mid-length, in mm

d_i = bore diameter of screwshaft, in mm

$k_3 = \frac{d_3}{d_1}$

$l = \frac{d_i}{d_1}$

$p_1 = \frac{2M}{A_1\theta_1 V_1}\left(-1 + \sqrt{1 + V_1\left(\frac{F_1^2}{M^2} + 1\right)}\right)$

A_1 = contact area fitting at screwshaft, in mm^2

$B_3 = \frac{1}{E_3}\left(\frac{k_3^2 + 1}{k_3^2 - 1} + \nu_3\right) + \frac{1}{E_1}\left(\frac{1 + l^2}{1 - l^2} - \nu 1\right)$

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C = 0 for turbine installations or electric propulsion

$= \frac{\text{vibratory torque at the service speed}}{\text{mean torque at the service speed}}$ for oil engine installations

E_1 = modulus of elasticity of screwshaft material, in N/mm^2

E_3 = modulus of elasticity of propeller material, in N/mm^2

$F_1 = \frac{2000Q}{d_1}(1 + C)$

M = propeller thrust, in N

Q = mean torque corresponding to P and R as defined in Part 9, in Nm

T_1 = temperature at time of fitting propeller on shaft, in °C

$V_1 = 0{,}51\left(\frac{\mu_1}{\theta_1}\right)^2 - 1$

α_1 = coefficient of linear expansion of screwshaft material, in mm/mm/°C

α_3 = coefficient of linear expansion of propeller material, in mm/mm/°C

θ_1 = taper of the screwshaft cone, but is not to exceed $\frac{1}{15}$ on the diameter, i.e. $\theta_1 \leq \frac{1}{15}$

μ_1 = coefficient of friction for fitting of boss assembly on shaft
= 0,13 for oil injection method of fitting

ν_1 = Poisson's ratio for screwshaft material

ν_3 = Poisson's ratio for propeller material.

4.2.2 Where it is proposed to fit a keyless propeller by the oil shrink method, the pull-up, δ on the screwshaft is to be not less than:

$$\delta = \frac{d_1}{\theta_1}\left(p_1 B_3 + (\alpha_3 - \alpha_1)(35 - T_1)\right) \text{ mm}$$

The yield stress or 0,2 per cent proof stress, σ_0, of the propeller material is to be not less than:

$$\sigma_0 = \frac{1{,}4}{B_3}\left(\frac{\theta_1 \delta_p}{d_1} + T_1(\alpha_3 - \alpha_1)\right)\frac{\sqrt{3k_3^4 + 1}}{k_3^2 - 1} \text{ N/mm}^2$$

where

δ_p = proposed pull-up at the fitting temperature.
The start point load, W, to determine the actual pull-up is to be not less than:

$$W = A_1\left(0{,}002 + \frac{\theta_1}{20}\right)\left(p_1 + \frac{18}{B_3}(\alpha_3 - \alpha_1)\right) \text{ N.}$$

4.3 Keyed propellers pushed up by an hydraulic nut

4.3.1 Calculations are to be undertaken to show that the proof stress of the boss material is not exceeded in way of the keyway root fillet radius. In order to reduce the likelihood of frettage a grip stress of not less than 20 N/mm^2 between boss and shaft is to be achieved.

4.4 Propeller boss

4.4.1 The forward edge of the bore of the propeller boss is to be rounded to a 6 mm radius. In the case of keyed propellers, the length of the forward fitting surface is to be about one diameter.

4.4.2 Drilling holes through propeller bosses is to be avoided, except where it is essential to the design.

4.5 Fixed and steering nozzles

4.5.1 The requirements for scantlings for fixed and steering nozzles are given in Pt 3, Ch 3,4.

■ *Section 5* Piping systems

5.1 General

5.1.1 The piping system for a controllable pitch propeller is to comply with the general design requirements given in Part 15.

5.1.2 The specific requirements for lubricating hydraulic oil systems and standby arrangements are given in Part 15.

5.1.3 The hydraulic power operating systems are to be provided with arrangements to maintain the cleanliness of the hydraulic fluid, taking into consideration the type and design of the hydraulic system.

■ *Section 6* Control and monitoring

6.1 General

6.1.1 Control and monitoring is to comply with the requirements of Pt 16, Ch 1.

6.2 Automatic and remote controls

6.2.1 Where controllable pitch propellers are fitted with automatic or remote controls so that under normal operating conditions they do not require any manual intervention by the operators, they are to be provided with the alarms and safety arrangements required by 6.2.2, 6.2.3 and Table 1.6.1.

6.2.2 For controllable pitch propellers for main propulsion, a standby or alternative power source of actuating medium for controlling the pitch of the propeller blades is to be provided. Automatic start of the standby pump supplying hydraulic power for pitch control is to be provided.

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Table 1.6.1 Alarms

Item	Alarm	Note
Hydraulic system pressure	Low	—
Hydraulic oil supply tank level	Low	—
Hydraulic oil temperature	High	Where an oil cooler is fitted
Power supply to the control system between the remote control station and hydraulic actuator	Failure	Failure of any power supply to a control system is to operate an audible and visual alarm
Propulsion motor	Overload	*See* Part 16

6.2.3 For controllable pitch propellers, a shaft speed indicator and a pitch indicator which shows the degree of pitch as a measure of the propeller blade or actuator movement are to be provided at each station from which it is possible to control shaft speed or propeller pitch.

■ *Section 7* Requirements for craft which are not required to comply with the HSC Code

7.1 Propellers not exceeding one metre in diameter

7.1.1 The materials and the scantlings need not comply with Sections 1 to 3 inclusive or 4.1 to 4.3 inclusive.

7.1.2 Propellers for service craft less than 24 m and main engine power output not exceeding 500 kW are to be manufactured from materials in accordance with the Rules for Materials at a works recognised for the quality of its casting and machining, and be free from defects.

7.1.3 Certificates of construction are not required.

7.1.4 Specific requirements for the piping systems are given in Part 15.

7.1.5 The alarm and monitoring arrangements, and for controllable pitch propellers, the safety arrangements and standby power sources, will be specially considered, *see also* Part 16.

7.2 Alternative materials and design

7.2.1 Propellers made from materials not listed in the Rules for Materials or of unusual form or design will be specially considered.

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Waterjet Systems

Section

1 **Scope**

2 **General requirements**

3 **Design requirements**

4 **Piping systems**

5 **Control and monitoring**

6 **Electrical systems**

7 **Inspection testing and fitting of waterjets**

8 **Installation, maintenance and replacement**

■ *Section 1* Scope

1.1 General

1.1.1 For the purposes of these Rules, a waterjet propulsion unit is described as a machine which takes in water, by means of a suitable inlet and conduit, and accelerates the mass of water using an impeller and nozzle to form a jet propulsion system. The waterjet system comprises the unit and its associated actuation and control devices. The detail of the prime mover is excluded but not its effect on the waterjet system.

1.1.2 This Chapter defines the requirements for the design and service life of marine waterjet propulsion systems and is to be read in conjunction with the General Requirements for the Design and Construction of Machinery in Chapter 1.

1.1.3 The requirements for a fixed or steerable waterjet propulsion system rated at 500 kW and above, which is integral with the ship's hull structure and forms a means of main propulsion, are detailed in this Chapter. This includes support arrangements, controls and the systems necessary to maintain operation and functionality of the waterjet unit.

1.1.4 These requirements relate to waterjets driven by axial or mixed flow pumps. Where units driven by radial flow pumps or inducers are proposed, details are to be submitted for consideration.

■ *Section 2* General requirements

2.1 Waterjet arrangement

2.1.1 In general, for a ship to be assigned an unrestricted service notation, a minimum of two waterjet systems is to be provided where these form the sole means of propulsion. For ships where a single waterjet system is the sole means of propulsion, a detailed engineering and safety justification is to be evaluated by LR, *see* 2.3.22. This evaluation process will include a risk analysis, using a recognised technique to verify that sufficient levels of redundancy and monitoring are incorporated in the waterjet unit's essential support systems and operating equipment.

2.1.2 Waterjet propulsion units are to be capable of continuous operation between their maximum and minimum output power rating at specified operating conditions, *see* Ch 1,3 and within the operational service profiles defined by 2.3.11 and 2.3.12.

2.1.3 It is the Shipbuilder's responsibility to ensure that all of the installed equipment is suitable for operation in the location and under the environmental conditions defined in Chapter 1. Where anticipated environmental conditions are outside these limits or where additional conditions are to be considered, such as vibration and impulsive accelerations, requirements and details of compliance are to be submitted to LR.

2.2 Plans to be submitted

2.2.1 Plans, in triplicate, and information as detailed below and in 2.3 and 2.4 are to be submitted for consideration.

2.2.2 General arrangement plans showing details of the following:

(a) Shafting assembly indicating bearing positions.
(b) Steering assembly.
(c) Reversing assembly.
(d) Shaft sealing arrangement assembly.
(e) Longitudinal section of the complete waterjet unit.

2.2.3 Detailed and dimensioned plans indicating scantlings, materials of construction and, where applicable, surface finish of the following:

(a) Arrangement of the system, including the intended method of attachment to the hull and building-in, tunnel geometry, shell openings, method of stiffening, reinforcement, etc.
(b) All torque transmitting components, including the shafting system, impeller and stator if fitted.
(c) Steering components, together with a description and line diagram of the control circuit. This is to include steerable exit waterjet nozzles where fitted.
(d) Components of the retractable buckets where these are used for providing astern thrust.
(e) The bearing or bearings absorbing the thrust and supporting the impeller, together with the method of lubrication.

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(f) Details of any shafting support or guide vanes used in the waterjet system.

2.2.4 Schematic plans of the lubrication and hydraulics required for steering/reversing systems, together with pipe material, relief valves and the working pressures required.

2.3 Calculations and information

2.3.1 Strength calculations based on fatigue considerations incorporating the maximum continuous torque rating and the most 'onerous' operating condition, *see* 2.3.12, including any short-term high power operation, and including the effects of mean and fluctuating loads, transitory loadings, residual stress allowances, and stress raisers, for the following components:

(a) Impeller, stator and any bolting arrangements supporting propulsion or steering loads.
(b) Shaft supports and coupling arrangements.
(c) Inlet guide vanes, if fitted.
(d) Steering components, including the lugs of steerable nozzles where fitted.
(e) Retractable buckets and associated mechanisms which are used to provide astern thrust. A calculation of the hydrodynamic transient loads is to be made for each design and is to include the full ahead to full astern condition. The calculation procedure used is to be supported, where possible, with full scale or model test data, or satisfactory service experience, to validate the design method.

2.3.2 Calculations supporting the connection method of the impeller to the shaft including details of the fit, push-up, securing, bolting arrangements, etc. In addition, where lengths of shafts are joined using couplings of the shrunk element type, full particulars of the method of achieving the grip force.

2.3.3 Calculations relating to the design of the shaftline as evidence of compliance with Pt 11, Ch 2.

2.3.4 Torsional vibration calculations of the complete dynamic system in accordance with the relevant requirements included in Pt 13, Ch 1.

2.3.5 Shaft lateral vibration calculations where required by Pt 13, Ch 3.

2.3.6 Calculations of the tunnel strength and supporting structure.

2.3.7 A calculation to determine the stresses within the impeller blade.

2.3.8 A calculation of the blade natural frequency for the impeller blades.

2.3.9 A calculation of the relative blade passing frequency between the rotor and stator blades.

2.3.10 The value of the fluctuating stresses during one revolution of the impeller and from transient loadings.

2.3.11 Details of the power/speed range of operation, indicating the maximum continuous torque rating, together with the associated thrusts; this information may be presented in the form of a characteristic curve for the waterjet.

2.3.12 The waterjet thrust for the assessment of the strength condition being considered is to be as follows:

(a) For ships which are intended to operate predominantly in a free-running condition and at steady service conditions, the waterjet thrust is to correspond to the absorption of the maximum continuous shaft power and corresponding revolutions per minute, giving the maximum torque for which the shaft system is approved.
(b) For ships which are designed for several operating conditions, the maximum thrust associated with these conditions and the absorption of the corresponding power, in addition to the maximum continuous powering condition, are to be used in the calculation.
(c) The justification for the thrust selected is to be submitted for consideration in the approval process and this is to include the ship type and the ship speed at the conditions considered.

2.3.13 A justification that the waterjet system will meet the self-priming criteria, *see* 3.1.6.

2.3.14 Specifications of materials and NDE procedures for components essential for propulsion and steering operation and, in the case of the impeller and stator, the yield strength and the fatigue characteristics of the material intended for their manufacture.

2.3.15 A detailed weld specification where an impeller has welded blades.

2.3.16 Full details of the means of corrosion protection in the case of carbon or carbon manganese steel shafts. Alternatively, where it is proposed to use composite shafts, details of the connections at flanges, materials, resin, lay-up procedures, quality control procedures and documentary evidence of fatigue endurance strength is to be provided.

2.3.17 Dry impeller mass and polar moment of inertia.

2.3.18 The prime mover type and designation.

2.3.19 Details of the control engineering aspects of the system design in accordance with Pt 16, Ch 1.

2.3.20 The tolerance specification, agreed between the manufacturer and the Shipbuilder or Owner, to which the components of the unit are to be manufactured is to be defined together with a justification.

2.3.21 Details of the waterjet's loading reactions together with the positions of application within the hull and is to include the maximum applied thrust, tunnel pressures, moments and forces imposed on the ship.

2.3.22 The waterjet unit's rated flow and head.

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2.3.23 Where an engineering and safety justification report is required, the following supporting information is to be submitted:

- A Failure Mode and Effects Analysis report (FMEA), *see* 2.4.
- Design standards and assumptions.
- Limiting operating parameters.
- A statement and evidence in respect of the anticipated reliability of any non-duplicated components.

2.3.24 Recommended installation, inspection, maintenance and component replacement procedures. This is to include any in-water engineering procedures where recommended by the waterjet manufacturer.

2.3.25 All transient loads which the steering unit is likely to experience from manoeuvring, accelerating, decelerating and the sea conditions.

2.4 Failure Mode and Effects Analysis (FMEA)

2.4.1 An FMEA is to be carried out where a single waterjet system is the ship's sole means of propulsion, *see* 2.2.3. The FMEA is to identify components where a single failure could cause the loss of all propulsion and/or steering capability and the proposed arrangements for preventing and mitigating the effects of such a failure.

2.4.2 The FMEA is to be carried out using the format presented in Table 22.2.1 in Chapter 22 of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships) or an equivalent format that addresses the same reliability issues. Analyses in accordance with IEC 60812 *Analysis for System Reliability – Procedure for Failure Mode and Effects Analysis*, or the IMO Code of Safety for High Speed Craft, 2000, Annex 4 – *Procedures for Failure Mode and Effects Analysis*, would be acceptable.

2.4.3 The FMEA is to be organised in terms of equipment and function. The effects of item failures at a stated level and at higher levels are to be analysed to determine these effects on the system as a whole. Actions for mitigation of the effects of failure are to be determined, *see* 2.4.1.

2.4.4 The FMEA is to:

(a) identify the equipment or sub-system and mode of operation;
(b) identify potential failure modes and their causes;
(c) evaluate the effects on the system of each failure mode;
(d) identify measures for reducing the risks associated with each failure mode;
(e) identify measures for preventing failure; and
(f) identify trials and testing necessary to prove conclusions.

2.4.5 At sub-system level it is acceptable, for the purposes of these Rules, to consider failure of equipment items and their functions. It is not required that the failure of components within that equipment item be analysed, *see* Ch 22,2.1.5 of the Rules for Ships.

2.4.6 Where a FMEA is used for consideration of systems that depend on software-based functions for control or co-ordination, the analysis is to investigate failure of the functions rather than a specific analysis of the software code itself.

■ *Section 3* Design requirements

3.1 General

3.1.1 The arrangement of waterjet units is to be such that the ship can be satisfactorily manoeuvred to a declared performance capability. The operating conditions covered are to include the following:

(a) Maximum continuous shaft power/speed to the impeller in the ahead condition at the declared steering angles and conditions.
(b) Manoeuvring speeds of the impeller shaft and/or reversing mechanism in the ahead and astern direction at the declared steering angles and sea conditions.
(c) The stopping manoeuvre described in Pt 9, Ch 2,8.2.
(d) Astern running conditions for the craft.

3.1.2 The mean loadings are those loadings induced by the waterjet absorbing the mean torque supplied by the prime mover.

3.1.3 Fluctuating loads are defined as those loads which occur during one revolution of the impeller due to cyclic variations. For example, the spatial flow variations and torsional vibration at nominally steady state operating conditions.

3.1.4 Transient loads are defined as those loadings resulting from acceleration and deceleration of the ship, manoeuvring, seaway conditions and other similar forms of loading. This also includes any significant back-pressure effects developed from the operation of the reversing bucket, if fitted.

3.1.5 To ensure self-priming of the waterjet unit, the shaft centreline of the unit is to be lower than the light draught static waterline of the ship. In cases where this is either impracticable or undesirable, the distance of the impeller shaft centreline above the ship's light draught waterline is to be less than or equal to 10 per cent of the pump inlet diameter.

3.1.6 Provision is to be made to allow for the in-service visual inspection of the complete blade surfaces of both the impeller and stator blades using either a direct visual or borescope inspection technique.

3.2 Shaftline

3.2.1 The diameter of the shaftline components are to comply with Pt 11, Ch 2. For calculation purposes the shaft carrying the impeller is to be taken as equivalent to a screw-shaft.

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3.2.2 Where it is proposed to use carbon or carbon manganese steel shafts which may be in contact with seawater, these are to be protected.

3.2.3 The diameter of unprotected screwshafts of corrosion-resistant material is not to be less than that given in Pt 11, Ch 2,4.4.7.

3.2.4 The use of composite shafts is permitted, *see* 2.3.16.

3.2.5 Where lengths of shafts are joined using couplings of the shrunk element type, a factor of safety, based upon the mean plus the vibratory and transient torques, against slippage of 2,0 is to be achieved for couplings which are located inboard and 2,5 for couplings which are located outboard.

3.2.6 Where shaftline components are bolted together, the design of the bolted connection should demonstrate a factor of safety of 1,5 when considered in the context of the mean, fluctuating and transitory loadings.

3.2.7 If a keyed fitting of the impeller to the shaft is contemplated, then the requirements of Pt 11, Ch 2,4.12 are to be satisfied.

3.2.8 Where it is proposed to fit a keyless impeller, the fitting is to comply with the requirements of Ch 1,4.2, as applicable, excluding the requirements for Ice Class. Use of the words 'propeller' and 'screwshaft' are to be taken as meaning 'impeller' and 'impellershaft' respectively.

3.3 Shaft support system and guide vanes

3.3.1 In cases where the shaft requires support from the tunnel walls ahead of the impeller or, alternatively, where guide vanes are required to assist the flow around a bend in the ducting system, the supports or guide vanes are to be suitably aligned to the flow and have suitably rounded leading and trailing edges or be of an aerofoil section.

3.3.2 In general, the fillet radius should be greater than or equal to the maximum thickness of the vane or support at that location. Smaller radii may be considered, for which the results of an approved measurement programme or calculation procedure are to be submitted. In all cases, a factor of safety of at least 1,5 is to be demonstrated for the maximum designed operating conditions.

3.3.3 A facility for the inspection of the supports or guide vanes is to be provided, which will allow either direct visual or borescope inspection of these components and their transition to other members.

3.4 Impeller

3.4.1 A calculation to determine the stresses within the impeller blades is to be carried out which takes into account the mean blade loading, fluctuating loadings, transient loads and centrifugal force. The computations may be accomplished by either classical methods or numerical analysis. Designs of waterjet systems which have been based on a combination of computational fluid dynamics and finite element methods will be considered. However, it will be necessary to demonstrate to the satisfaction of LR that the formulation of the methods used has been correlated with previous full scale measurement or other calculation experience.

3.4.2 For the purposes of the calculation required by this sub-Section, the fluctuating stresses during one revolution of the impeller is to be taken as 20 per cent of the maximum mean stress, and the stresses from transient loadings are to be taken as 15 per cent of the hydrodynamic mean stress, unless otherwise specified by the designer.

3.4.3 The fatigue assessment of the impeller blades is to be based on the stress in the root sections, excluding the influence of the blade root fillets. This assessment is to include the following components:

- the maximum stresses derived from the mean loading, including both the hydrodynamic and centrifugal components;
- the amplitude of the fluctuating stresses during one revolution of the impeller;
- the stresses derived from transient loading and an allowance for any residual stresses in the material.

It is permissible to combine the variable components of stress in a linear fatigue damage accumulation assessment procedure. A factor of safety of at least 1,5 against fatigue failure is to be demonstrated for the maximum continuous rating condition or any other more onerous condition, *see* 3.1.1.

3.4.4 In general, the fillet radius is to be greater than the maximum thickness of the impeller blade at that location. Composite radiused fillets or elliptical fillets which provide an improved stress concentration factor are preferred.

3.4.5 Where an impeller has bolted-on blades, consideration is to be given to the distribution of stress in the palms of the blade and in the hub and bolting arrangements.

3.4.6 Where an impeller has welded blades, the welds are to be of the full penetration type or of equivalent strength. Where laser welding is to be used, details are to be submitted for consideration.

3.4.7 The blades are to be provided with hydrodynamically faired leading and trailing edges which may be either of simple radius or of a more complex aerofoil edge form. The tip clearance, whilst being kept to a minimum for hydrodynamic purposes, is to be sufficient to allow for any transient vibrational behaviour, axial shaft movement or differential thermal expansion.

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3.4.8 A calculation of the blade natural frequency for the impeller blades is to be undertaken. The fundamental natural frequency in water of the blade is to be shown to lie outside any expected excitation frequencies within a speed range of the waterjet unit and up to 10 per cent above the maximum impeller speed.

3.5 Stator

3.5.1 The stator blades, where fitted, are to be designed to be capable of withstanding the combined hydrodynamic mean, fluctuating, transient and mechanical loads, including any loads transmitted via shaft bearings, developed by the unit and reacted through the blades when the impeller is absorbing full power. Consideration is to be given to situations when the vessel is either free running or in a condition specified by 3.1.1 or undergoing stopping, accelerating or decelerating manoeuvres. A factor of safety against mechanical failure by yielding of the blades of 1,5 is to be demonstrated.

3.5.2 In general, the fillet radius is to be greater than the maximum thickness of the blade at that location. Composite radiused fillets or elliptical fillets which provide improved stress concentration factors are preferred.

3.5.3 If the stator ring comprises a segmented assembly, then consideration is also to be given to the distribution of stress in the various adjacent members of the overall assembly.

3.5.4 A calculation of the relative blade passing frequency between the rotor and stator blades is to demonstrate that this does not coincide with the natural frequency of the stator blades over the speed range of the waterjet unit and up to 10 per cent above maximum impeller speed.

3.5.5 The stator blades are to be provided with hydrodynamically faired leading edges which may have either a simple radius or a more complex aerofoil edge form.

3.5.6 Where the stator blading assembly forms part of the nozzle, the requirements of 3.7 are to be considered in association with those for the stator assembly.

3.6 Tunnel and securing arrangements

3.6.1 The tunnel is to be adequately supported, framed and fully integrated into the hull structure. The critical locations and integrity of the supports and framing are to be as specified in the FMEA and agreed by the Shipbuilder and LR.

3.6.2 The tunnel and supporting structure scantlings are to be not less than the Rule requirements for the surrounding structure. The strength of the hull structure in way of tunnel(s) is to be maintained. The structure is to be adequately reinforced and compensated as necessary. All openings are to be suitably reinforced and have radiused corners.

3.6.3 Consideration is to be given to providing the inlet to the tunnel with a suitable guard to prevent the ingress of large objects into the rotodynamic machinery. The dimensions of this guard, if fitted, are to strike a balance between undue efficiency loss due to flow restriction and viscous losses, the size of object allowed to pass and the susceptibility to clog with weed and other flow-restricting matter.

3.6.4 The inlet profile of the tunnel is to be designed so as to provide a smooth uptake of the water over the range of vessel operating trims and avoid significant separation and/or cavitation of the flow which may then pass downstream into the rotating machinery.

3.6.5 Design consideration is to take account of pressures which could develop as a result of a duct blockage as well as in relation to the axial location of rotating parts.

3.6.6 The strength of the tunnel and supporting structure are to be examined by direct calculation procedures.

3.7 Nozzle/steering arrangements

3.7.1 In general, the steering systems and components are to comply with the requirements of Pt 14, Ch 1.

3.7.2 Nozzles can be either of a fixed or steerable form. The design of the nozzle is to take into account fully the change in pressure distribution along its inner surface together with the other mechanical loads (e.g. stator assembly loads) and transient loads caused by the flow directing attachments which may be reacted through the body of the nozzle. In this analysis, the changes to the pressure distribution caused by transient manoeuvres are to be considered.

3.7.3 In addition to the requirements of Pt 14, Ch 1, the steering mechanism and bucket are to be capable of maintaining the manoeuvrability of the ship in terms of turning circle, zig-zag and stopping requirements within the limits defined by IMO Resolution MSC.137(76), Standards for Ship Manoeuvrability.

3.7.4 Consideration is to be given to all transient loads which the steering unit is likely to experience from manoeuvring, accelerating, decelerating and the sea conditions.

3.7.5 The nozzle/bucket is to be given mechanical protection by the Shipbuilder from other impact damage such as collision.

3.8 Bolts

3.8.1 Detailed consideration and analysis is to be given to essential bolting arrangements in critical locations as specified in the FMEA and where indicated by the Manufacturer or Shipbuilder and agreed by LR. These are to include bolts used in the securing of blades or guide vanes, assembly of the unit in the ship and any conduit components.

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■ *Section 4* Piping systems

4.1 General

4.1.1 The piping systems for a waterjet unit are to comply with the general requirements of Pt 15, Ch 3.

4.1.2 Lubricating and hydraulic oil systems and standby arrangements are to comply with the requirements of Pt 15, Ch 3; in addition, steering hydraulic systems are to comply with the applicable requirements of Pt 14, Ch 1.

■ *Section 5* Control and monitoring

5.1 General

5.1.1 In addition to this Section, the control engineering systems are to comply with Pt 16, Ch 1.

5.1.2 Steering control for the waterjet is to be provided at the ship's normal conning stations.

5.1.3 For waterjets used as the only means of propulsion and steering, a standby or alternative power source for the actuating device, that controls the angular position and/or the reversing angle, is to be provided. Automatic start of the standby pump supplying hydraulic power for steering and reversing is to be provided.

5.1.4 Means are to be provided at each control station to stop each waterjet.

5.2 Monitoring and Alarms

5.2.1 In addition to the requirements of Pt 14, Ch 1, alarms and monitoring requirements are indicated in 5.2.2 to 5.2.4 and Table 12.5.1.

5.2.2 An indication of the angular position of the nozzle is to be provided at each station from which it is possible to control the direction of thrust from the units.

5.2.3 An indication of both the required and actual reversing bucket position is to be provided at each station from which it is possible to control the reversal of thrust.

5.2.4 All alarms associated with waterjet unit faults are to be indicated individually at the control stations and in accordance with the alarm system specified by Pt 16, Ch 1.

■ *Section 6* Electrical systems

6.1 Installation and distribution arrangements

6.1.1 The electrical installation is to comply with the relevant sections of Pt 16, Ch 2.

6.1.2 Waterjet auxiliaries and controls are to be served by individual circuits. Services that are duplicated are to be separated throughout their length as widely as practicable and without the use of common feeders, transformers, converters, protective devices or control circuits.

■ *Section 7* Inspection, testing and fitting of waterjets

7.1 General

7.1.1 The finished impeller is to be statically balanced on completion of the manufacturing process and meet the requirements of ISO 1940 or an alternative standard acceptable to LR. In the case where the blade tip speed is greater than 60 m/s, dynamic balancing is required unless otherwise agreed by the Manufacturer and LR.

Table 12.5.1 Alarms

Item	Alarm	Note
Hydraulic system pressure	Low	–
Hydraulic oil supply tank level	Low	–
Hydraulic oil temperature	High	Where an oil cooler is fitted
Lubricating oil temperature	High	
Lubricating oil pressure	Low	In forced lubrication systems
Lubricating oil tank level	Low	Where a tank is provided
Ratio of jet rpm/vessel speed	High	Only if installed power per jet > 4 MW
Control system failure	Fault	Includes follow-up failure of steering or reversng system
Control system power supply	Failure	

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7.1.2 The following tests, markings and inspections are to be carried out in the presence of the Surveyor:

(a) The balancing of the impeller or the blades.

(b) Non-destructive examination of the impeller blades and the principal component parts of the propulsion system: for austenitic stainless steels, *see* Ch 4,8, and for aluminium alloys, *see* Ch 8,3, of the Rules for Materials.

(c) The quality of the fit of the impeller boss on the shaft taper.

(d) The fitting of the impeller to the shaft and its subsequent functional testing.

(e) The finished surfaces of the impeller boss, hub, conical bores, fillets, cones and blade surfaces are to be shown to conform to the tolerances specified on the impeller drawing.

7.1.3 Bolts and nuts in critical locations, as specified in the FMEA and where indicated by the Manufacturer or Shipbuilder and agreed by LR, are to be equipped with adequate securing arrangements to the satisfaction of the LR Surveyor.

7.2 Shop tests and installation of waterjet systems

7.2.1 The completed waterjet unit is to undergo a tightness test in which an internal hydrostatic pressure of 1,5 bar above the maximum working pressure of the unit is to be applied.

7.2.2 In cases where the impeller is fitted to the shaft using an interference fit, the bedding of the impeller with the shaft is to be demonstrated in the shop to the satisfaction of the LR Surveyor. Sufficient time is to be allowed for the temperature of the components to equalise before bedding. A contact marking between the bore of the impeller boss and the shaft surface of better than 80 per cent is to be demonstrated when the contact marking ink is spread thinly on the surface of the shaft. Alternative means for demonstrating the bedding of the impeller will be considered.

7.2.3 Means are to be provided to indicate the relative axial position of the impeller boss on the shaft. Permanent reference marks are to be made on the impeller boss, shaft and any nut to indicate angular and axial positioning of the impeller. Care is to be taken in marking the inboard end of the shaft taper to minimise stress-raising effects.

7.2.4 A copy of the fitting curve relative to temperature and means for determining any subsequent movement are to be placed on board.

7.2.5 The impeller running clearances are to be checked following the installation of the unit in the ship.

7.2.6 The thrust bearing clearances in the waterjet system are to be verified against the required design values. This is to be done following the installation of the unit in the ship.

7.2.7 The piping systems are to be adequately flushed in accordance with the Manufacturer's recommendations and the final levels of contamination recorded. Similarly, pressure testing of the piping systems is to comply with Pt 15, Ch 1.

7.3 Sea trial requirements

7.3.1 The following requirements are to be complied with:

- Pt 9, Ch 2,8.2 for sea trials.
- Pt 14, Ch 1,4.4 for steering trials.

In addition, the general design capability specified in 3.1.1 is to be demonstrated to the Surveyor's satisfaction.

7.3.2 The control systems relating to the correct functioning of the waterjet is to be the subject of harbour and then sea trials. Demonstration of the requirements of Pt 16, Ch 1 is required and the design combinations of control functions are to be undertaken during the trials programme.

7.3.3 On sea trials and under free running conditions, the relationship between ship speed and impeller rotational speed is to be verified against the waterjet's design basis.

7.3.4 Any trials and testing identified from the FMEA report, *see* 2.4, are to be carried out.

■ *Section 8* Installation, maintenance and replacement

8.1 General

8.1.1 All waterjet system propulsion units are to be provided with a copy of the Manufacturer's installation and maintenance manual that is pertinent to the actual equipment. *See* 2.3.24.

8.1.2 The manual required by 8.1.1 is to be placed on board and is to contain the following information:

(a) Description of the waterjet propulsion system with details of function and design operating limits. This is also to include details of support systems such as lubrication, cooling and condition monitoring arrangements.

(b) Identification of all components together with details of any that have a defined maximum operating life.

(c) Instructions for installation of the system on board ship with details of any required specialised equipment.

(d) Instructions for commissioning at initial installation and following maintenance.

(e) Maintenance and service instructions to include inspection/renewal of bearings and sealing arrangements. This is also to include component fitting procedures, clearance measurements and lubricating oil treatment where applicable.

(f) Actions required in the event of fault/failure conditions being detected.

(g) Precautions to be taken by personnel working during installation and maintenance.

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Section

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5 **Piping systems**

6 **Control and monitoring**

7 **Electrical systems**

8 **Requirements for craft which are not required to comply with the HSC Code**

■ *Section 1* General requirements

1.1 Application

1.1.1 This Chapter is to be read in conjunction with the General Requirements for Machinery in Part 9.

1.1.2 This Chapter gives requirements for fixed or steerable thruster units (azimuth thrusters) which are used for propulsion and steering, and also applies to transverse propulsion (tunnel) thrusters which are an aid to manoeuvring.

1.1.3 In this Chapter where the dimensions of any particular component are determined from shaft power, *P*, in kW, and revolutions per minute, *R*, the values to be used are those defined in Part 9.

1.2 Redundancy

1.2.1 A minimum of two azimuth thruster units are to be provided where these form the sole means of propulsion. Where a single azimuth thruster installation is proposed, it will be subject to consideration, taking into account the proposed restricted area notation.

1.2.2 The failure of one azimuth thruster unit or its control system is not to render any other thruster inoperative.

1.3 Inclination of craft

1.3.1 Thruster units are to operate satisfactorily under the conditions as shown in Part 9.

■ *Section 2* Particulars to be submitted

2.1 Submission of information

2.1.1 At least three copies of the following plans are to be submitted.

2.1.2 **Fixed/Azimuth propulsion thrusters**

(a) A general arrangement sectional assembly plan showing all the connections of the torque transmitting components from the prime mover to the propeller, together with the azimuthing mechanism and, if a nozzle is provided, the nozzle ring structure and nozzle support struts.

(b) Detailed and dimensional plans of the individual torque transmitting components.

(c) Schematic plans of lubricating and hydraulic systems, together with pipe material, relief valves and working pressures.

2.1.3 **Tunnel thrusters.**
Structural assembly plan including connections to tunnel.

2.2 Calculations and specifications

2.2.1 At least three copies of the following information are to be submitted.

2.2.2 **Fixed/Azimuth propulsion thrusters**

(a) Thruster prime mover type and operational power/speed envelope.

(b) Rating and type of motor for the azimuthing mechanism (e.g. type – hydraulic or electric).

(c) Gearing calculations for the azimuthing mechanism which is to be designed to a recognised National Standard.

(d) Bearing specifications.

(e) Details of control engineering aspects in accordance with Pt 16, Ch 1.

(f) Calculations indicating suitability of components for short term high power operation, where applicable. *See* Part 9.

(g) Where carried out in accordance with Part 9, a fatigue strength analysis of components indicating a factor of safety of 1,5 at the design loads, based on a suitable fatigue failure criteria.

2.2.3 **Tunnel thrusters.** Specification for materials of gears, shafts, couplings and propeller, stock and struts.

■ *Section 3* Materials

3.1 Azimuth thrusters

3.1.1 The materials used in the construction are to be manufactured and tested in accordance with the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

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■ *Section 4* Design and construction

4.1 General

4.1.1 The arrangement of all types of thrusters is to be such that the craft can be manoeuvred in accordance with the design specifications.

4.1.2 The requirements associated with the structural and watertight integrity and the installation arrangement are to be in accordance with Pt 3, Ch 3.

4.1.3 In addition to the requirements of this Section reference is to be made to:

(a) Main transmission gearing (Pt 11, Ch 1).
(b) Main transmission shafting (Pt 11, Ch 2).
(c) Propeller (Chapter 1).
(d) Torsional vibration (Pt 13, Ch 1).
(e) Lateral vibration for shafting systems which include cardan shafts (Pt 13, Ch 3).

4.2 Azimuth thrusters

4.2.1 The following requirements are to be complied with:

(a) The azimuthing mechanism is to be capable of a maximum rotational speed of not less than 1,5 rev/min.
(b) Gearing for the azimuthing mechanism is to be designed to a recognised National Standard.
The design is to consider both static ($<10^3$ cycles) and dynamic loading conditions.
(c) Under dynamic operating conditions, the gear is to be considered for
  (i) design maximum dynamic duty steering torque,
  (ii) variable loading, where applicable. A spectrum (duty) factor may be used. The load spectrum value is to be derived using load measurements of similar units, where possible.
(d) Under a static duty ($<10^3$ load cycles) steering torque, which should be not less than M_T, as defined in 4.3.1.
(e) The following minimum factor of safety values are to be achieved:
Surface Stress $S_{Hmin} = 1,0$.
Bending Stress $S_{Fmin} = 1,5$.
(f) For hydraulic pressure retaining parts and load bearing components, *see also* Part 14.

4.3 Azimuth thrusters with a nozzle

4.3.1 Where the propeller is contained within a nozzle, the equivalent rudder stock diameter in way of tiller, used in Table 1.4.1 in Pt 14, Ch 1 is to be determined as follows:

$$d_{SU} = 26,03 \sqrt[3]{(V+3)^2 A_N X_{PF}} \quad \text{mm}$$

where

V = maximum service speed, in knots, which the craft is designed to maintain under thruster operation

A_N = projected nozzle area, in m^2, and is equal to the length of the nozzle multiplied by the mean external vertical height of the nozzle

X_{PF} = horizontal distance from the centreline of the steering tube to the centre of pressure, in metres. The position of the centre of pressure is determined from Table 3.2.6 in Pt 3, Ch 3.

The corresponding maximum turning moment, M_T, is to be determined as follows:

$$M_T = 11,1 \times d_{SU}^3 \quad \text{Nmm}$$

4.3.2 In addition to the requirements of Part 3 the scantlings of the nozzle stock or steering tube are to be such that the section modulus Z against transverse bending at any section x–x is not less than:

$$Z = 1,73 \sqrt{(V+3)^4 A_N^2 X_{PF}^2 + \frac{a^2}{4} T_M^2 10^4} \quad \text{cm}^3$$

where

a = dimension, in metres, as shown in Fig. 3.4.1

T_M = maximum thrust of the thruster unit, in tonnes.

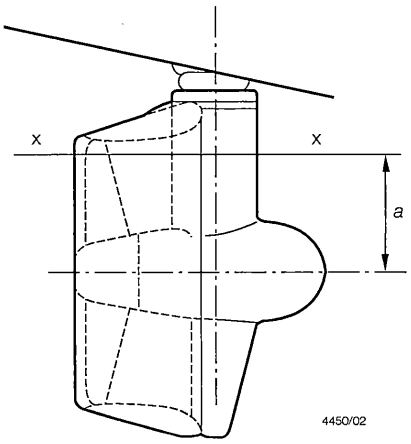

Fig. 3.4.1 Azimuth thruster

4.3.3 The scantlings of nozzle connections or struts will be specially considered. In the case of certain high powered craft, direct calculation may be required.

4.3.4 Where the propeller is not contained in a nozzle, the scantlings in way of the tiller will be subject to special consideration.

■ *Section 5* Piping systems

5.1 General

5.1.1 The piping system for azimuth thrusters is to comply with the general design requirements given in Pt 15, Ch 1.

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5.1.2 The specific requirements for lubricating/hydraulic oil systems and standby arrangements are given in Pt 15, Ch 3.

5.2 Azimuth thruster

5.2.1 The hydraulic power operating systems for each azimuth thruster are to be provided with the following:

(a) arrangements to maintain the cleanliness of the hydraulic fluid, taking into consideration the type and design of the hydraulic system,

(b) a fixed storage tank having sufficient capacity to recharge at least one azimuth power actuating system including the reservoir. The piping from the storage tank is to be permanent and arranged in such a manner as to allow recharging from within the thruster space.

5.2.2 Where the lubricating oil for the azimuth thrusters is circulated under pressure, provision is to be made for the efficient filtration of the oil. The filters are to be capable of being cleaned without stopping the thruster or reducing the supply of filtered oil.

■ *Section 6* Control and monitoring

6.1 General

6.1.1 Except where indicated in this Section the control engineering systems are to be in accordance with Pt 16, Ch 1.

6.1.2 Azimuthing control for azimuth thruster(s) and propeller pitch control for azimuth and/or tunnel thruster(s) are to be provided from the navigating bridge, the main machinery control station and locally.

6.1.3 Means are to be provided at the remote control station(s) to stop each azimuth or tunnel thruster unit.

6.2 Monitoring and alarms

6.2.1 Alarms and monitoring requirements are indicated in 6.2.2, 6.2.3 and Table 3.6.1.

6.2.2 An indication of the angular position of the azimuth thruster(s) and the propeller pitch position for azimuth and/or tunnel thruster(s) are to be provided at each station from which it is possible to control the direction of thrust or the pitch.

6.2.3 All alarms associated with thruster unit faults are to be indicated individually on the navigating bridge and in accordance with the alarm system specified by Part 16.

Table 3.6.1 Alarms

Item	Alarm	Note
Thruster, azimuth or tunnel	—	Indicators, *see* 6.2.2
Azimuthing motor	Power failure, single phase	Also running indication on bridge and at machinery control station
Propeller pitch motor	Power failure	Also running indication on bridge and at machinery control station
Propulsion motor	Overload, power failure	Also running indication on bridge and at machinery control station
Control system	Failure	
Hydraulic oil supply tank level	Low	
Hydraulic oil system pressure	Low	
Hydraulic oil system temperature	High	Where oil cooler is fitted
Hydraulic oil filters differential pressure	High	Where oil filters are fitted
Lubricating oil supply pressure	Low	If separate forced lubrication

■ *Section 7* Electrical systems

7.1 General

7.1.1 The electrical installation is to be designed, constructed and installed in accordance with the requirements of Part 16.

7.2 Emergency power for steering systems and drives

7.2.1 For high speed craft, in the event of total power failure, either:

(a) emergency power for steering systems/drives is to be restored automatically within five seconds. To achieve this an interim fast acting system may be required to come into operation until such time as the auxiliary/emergency power source comes on line. (Note: starting arrangements are to comply with the requirements relating to starting arrangements of emergency generators), or

(b) means are to be provided to bring the craft to a safe condition.

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7.3 Circuits

7.3.1 Azimuth thruster auxiliaries and controls are to be served by individual circuits. Services that are duplicated are to be separated throughout their length as widely as is practicable and without the use of common feeders, transformers, converters, protective devices or control circuits.

■ *Section 8*
Requirements for craft which are not required to comply with the HSC Code

8.1 Design and installation

8.1.1 Tunnel thrusters on service craft less than 24 m and yachts which are not essential for steering and manoeuvring do not have to comply with the design requirements of this Chapter.

8.1.2 The installation of such thrusters is to be such as to maintain the structural and watertight integrity of the craft.

8.2 Control and monitoring

8.2.1 Alarms and monitoring requirements of Table 3.6.1 are not required for service craft of less than 24 m.

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Rules and Regulations for the Classification of Special Service Craft

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Section

1 **General requirements**

2 **Details to be submitted**

3 **Design**

4 **Measurements**

5 **Requirements for craft which are not required to comply with the HSC Code**

■ *Section 1* General requirements

1.1 Application

1.1.1 This Section is to be read in conjunction with the requirements of Parts 9, 10, 11 and 12.

1.1.2 Unless otherwise advised, it is the responsibility of the Builder as main contractor to ensure, in co-operation with the Enginebuilders, that the information required by this Chapter is prepared and submitted.

1.1.3 The requirements of this Chapter are applicable to the following systems:

(a) Main propulsion systems formed by oil engines, turbines or electric motors, directly driven or geared to the shafting.

(b) Machinery driven at constant speed by oil engines, developing 110 kW and over, for essential auxiliary services including generator sets which are the source of power for main electric propulsion motors.

1.2 Power ratings

1.2.1 In this Chapter where shaft power, P, in kW, and revolutions per minute, R, are referred to, the values to be used are those defined in Part 9.

1.3 Basic requirements

1.3.1 System designs are to take account of the potential effects of engine and component malfunction and variability in characteristic values.

1.3.2 Where torques, stresses or amplitudes are found to exceed the limits for continuous operation, restrictions in speed and/or power will be imposed.

■ *Section 2* Details to be submitted

2.1 Particulars to be submitted

2.1.1 Torsional vibration calculations, including an analysis of the vibratory torques and stresses for the full dynamic system.

2.1.2 Particulars of the division of power and utilisation, throughout the speed range, for turbines, multi-engine or other combined power installations, and those with power take-off systems. For multi-engined installations, special considerations associated with the possible variations in the mode of operation and phasing of engines.

2.1.3 Details of operating conditions encountered in service for prolonged periods, e.g. idling speed, combinator characteristics for installations equipped with controllable pitch propellers.

2.1.4 Details, obtained from the manufacturers, of the principal characteristics of machinery components such as dampers and couplings, confirming their capability to withstand the effects of vibratory loading including, where appropriate, heat dissipation. Evidence that the data which is used to represent the characteristics of components, which has been quoted from other sources, is supported by a programme of physical measurement and control.

2.1.5 Where installations include electric motors, generators or non-integral pumps, drawings showing the principal dimensions of the shaft, together with the manufacturer's estimates of mass moment of inertia for the rotating parts.

2.1.6 Details of vibration or performance monitoring proposals where required.

2.2 Scope of calculations

2.2.1 Calculations are to be carried out, by recognised techniques, for the full dynamic system formed by the oil engines, turbines, motors, generators, flexible couplings, gearing, shafting and propeller, where applicable, including all branches.

2.2.2 Calculations are to give due consideration to the potential deviation in values used to represent component characteristics due to manufacturing/service variability.

2.2.3 The calculations carried out on oil engine systems are to be based on the Enginebuilders' harmonic torque data. (On request, Lloyd's Register (hereinafter referred to as 'LR') can provide a table of generalised harmonic torque components for use where appropriate.) The calculations are to take account of the effects of engine malfunction commonly experienced in service, such as a cylinder not firing. Calculations are also to take account of a degree of imbalance between cylinders, characteristic of the normal operation of an engine under service conditions.

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2.2.4 Whilst limits for torsional vibration stress in crankshafts are no longer stated explicitly, calculations are to include estimates of crankshaft stress at all designated operating/service speeds, as well as at any major critical speed.

2.2.5 Calculations are to take into account the possible effects of excitation from propeller rotation. Where the system shows some sensitivity to this phenomenon, propeller makers' data should be used as a basis for calculation, and submitted.

2.2.6 Where the torsional stiffness of flexible couplings varies with torque, frequency or speed, calculations should be representative of the appropriate range of effective dynamic stiffness.

■ *Section 3* Design

3.1 Symbols and definitions

3.1.1 The symbols used in this Section are defined as follows:

d = minimum diameter of shaft considered, in mm
r = ratio N/N_s or N_c/N_s whichever is applicable
N = engine speed, in rev/min
N_c = critical speed, in rev/min
N_s = maximum continuous engine speed, in rev/min, or, in the case of constant speed generating sets, the full load speed, in rev/min
Q_s = rated full load mean torque
τ_c = maximum value of the vibration stress for continuous running at or below the maximum speed, in N/mm^2
τ_t = permissible stress due to torsional vibrations for transient operation, in N/mm^2
σ_u = specified minimum tensile strength of the shaft material, in N/mm^2
C_k = a factor for different shaft design features, *see* Table 1.3.1
C_d = a size factor defined as $0,35 + 0,93d^{-0,2}$
k = the factor used in determining minimum shaft diameter, defined in Pt 11, Ch 2,4.2.1 and 4.4.3.

Table 1.3.1 C_k factors

For intermediate shafts with			For thrust shafts external to engines		For propeller shafts
Integral coupling flanges	Shrink fit couplings	Keyways	On both sides of thrust collar	In way of axial bearing where a roller bearing is used as a thrust bearing	For which k = 1,22 and = 1,26
1,0	1,0	0,60	0,85	0,85	0,55

NOTE
The determination of C_k – factors for shafts other than shown in this Table is at the discretion of LR.

3.1.2 Alternating torsional vibration stresses are to be based on half-range amplitudes of stress resulting from the alternating torque (which is superimposed on the mean torque) representing the synthesis of all harmonic orders present.

3.1.3 All vibration stress limits relate to the synthesis or measurement of total nominal torsional stress and are to be based on the plain section of the shafting neglecting stress raisers.

3.2 Limiting stress in propulsion shafting

3.2.1 The following stress limits apply to intermediate shafts, thrust shafts and to screwshafts fully protected from seawater. For screwshafts, the limits apply to the minimum section between the forward end of the propeller boss and the forward stern gland.

3.2.2 In the case of unprotected screwshafts, special consideration will be given.

3.2.3 In no part of the propulsion shafting system may the alternating torsional vibration stresses exceed the values of τ_c for continuous operation, and τ_t for transient running, given by the following formulae:

$$\tau_c = \frac{\sigma_u + 160}{18} C_k C_d (3 - 2r^2) \text{ for } r < 0,9 \quad \text{N/mm}^2$$

$$\tau_c = \frac{\sigma_u + 160}{18} C_k C_d \, 1,38 \text{ for } 0,9 \le r \le 1,05 \quad \text{N/mm}^2$$

$$\tau_t = \pm 1,7\tau_c \frac{1}{\sqrt{C_k}} \text{ for } r \le 0,8$$

3.2.4 In general, the tensile strength of the steel used is to comply with the requirements of Pt 11, Ch 2. For the calculation of the permissible limits of stresses due to torsional vibration, σ_u is not to be taken as more than 800 N/mm^2 in the case of intermediate shafts and 600 N/mm^2 in the case of thrust and propeller shafts.

3.2.5 Where the scantlings of coupling bolts and straight shafting differ from the minimum required by the Rules, special consideration will be given.

3.3 Generator sets

3.3.1 Natural frequencies of the complete set are to be sufficiently removed from the firing impulse frequency at the full load speed, particularly where flexible couplings are interposed between the engine and generator.

3.3.2 Within the speed limits of $0,95N_s$ and $1,05N_s$ the vibration stresses in the transmission shafting are not to exceed the values given by the following formula:

$\tau_c = \pm (21 - 0,014d)$ N/mm^2.

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3.3.3 Vibration stresses in the transmission shafting due to critical speeds which have to be passed through in starting and stopping, are not to exceed the values given by the following formula:

$\tau_t = 5{,}5\tau_c$.

3.3.4 The amplitudes of total vibratory inertia torques imposed on the generator rotors are to be limited to $\pm 2{,}0Q_s$ in general, or to $\pm 2{,}5Q_s$ for close-coupled revolving field alternating current generators, over the speed range from $0{,}95N_s$ to $1{,}05N_s$. Below $0{,}95N_s$ the amplitudes are to be limited to $\pm 6{,}0Q_s$. Where two or more generators are driven from one engine, each generator is to be considered separately in relation to its own rated torque.

3.3.5 The rotor shaft and structure are to be designed to withstand these magnitudes of vibratory torque. Where it can be shown that they are capable of withstanding a higher vibratory torque, special consideration will be given.

3.3.6 In addition to withstanding the vibratory conditions over the speed range from $0{,}95N_s$ to $1{,}05N_s$ flexible couplings, if fitted, are to be capable of withstanding the vibratory torques and twists arising from transient criticals and short-circuit currents.

3.3.7 In the case of alternating current generators, resultant vibratory amplitudes at the rotor are not to exceed ±3,5 electrical degrees under both full load working conditions and the malfunction condition mentioned in 2.2.3.

3.4 Other auxiliary machinery systems

3.4.1 The relevant requirements of 3.3.1, 3.3.2 and 3.3.3 are also applicable to other machinery installations such as pumps or compressors.

3.5 Other machinery components

3.5.1 **Torsional vibration dampers.** The use of dampers or detuners to limit vibratory stress due to resonances which occur within the range between $0{,}85N_s$ and $1{,}05N_s$ are to be considered. If fitted, these should be of a type which makes adequate provision for dissipation of heat. Where necessary, performance monitoring may be required.

3.5.2 **Flexible couplings:**

(a) Flexible couplings included in an installation are to be capable of transmitting the mean and vibratory loads without exceeding the makers' recommended limits for angular amplitude or heat dissipation.

(b) Where calculations indicate that the limits recommended by the manufacturer may be exceeded under misfiring conditions, a suitable means is to be provided for detecting and indicating misfiring. Under these circumstances power and/or speed restriction may be required. Where machinery is non-essential, disconnection of the branch containing the coupling would be an acceptable action in the event of misfiring.

3.5.3 **Gearing:**

(a) The torsional vibration characteristics are to comply with the requirements of 2.2. The vibratory torque should not exceed one-third of the full transmission torque throughout the speed range. In cases where the proposed transmission torque loading on the gear teeth is less than the maximum allowable, special consideration will be given the acceptance of additional vibratory loading on the gears.

(b) Where calculations indicate the possibility of torque reversal, the operating speed range is to be determined on the basis of observations during sea trials.

3.6 Restricted speed and/or power ranges

3.6.1 Restricted speed and/or power ranges will be imposed where the stresses exceed the limiting values, τ_c, for continuous running. Similar restrictions will be imposed, or other protective measures required to be taken, where vibratory torques or amplitudes are considered to be excessive for particular machinery items.

3.6.2 Critical responses which give rise to speed restrictions are to be arranged sufficiently removed from the maximum revolutions per minute to ensure that, in general, at $r = 0{,}8$ the stress due to the upper flank does not exceed τ_c.

3.6.3 Where shafting stresses due to a torsional critical response exceed the limiting values, τ_c, for continuous running, the speed restriction will be from:

$$= \frac{16}{18-r} N_c \text{ to } \frac{18-r}{16} N_c \text{ inclusive.}$$

3.6.4 Where calculated vibration stresses due to criticals below $0{,}8N_s$ marginally exceed τ_c or where the critical speeds are sharply tuned, the range of revolutions restricted for continuous operation may be reduced.

3.6.5 In cases where the resonance curve of a critical speed has been derived from measurements, the range of revolutions to be avoided for continuous running may be taken as that over which the measured stresses are in excess of τ_c, having regard to tachometer accuracy.

3.6.6 Where restricted speed ranges under normal operating conditions are imposed, notice boards are to be fitted at the control stations stating that the engine is not to be run continuously between the speed limits obtained as above, and the engine tachometers are to be marked accordingly.

3.6.7 Where vibration stresses approach the limiting value, τ_t, the range of revolutions restricted for continuous operation may be extended. The notice boards are to indicate that this range must be passed through rapidly.

3.6.8 For excessive vibratory torque, stress or amplitude in other components, based on 3.6.1 to 3.6.3, the limits of any speed/power restriction are to be such as to maintain acceptable levels during continuous operation.

3.6.9 Where the restrictions are imposed for the contingency of an engine malfunction or component failure, the limits are to be entered in the machinery operating manual.

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3.6.10 There are to be no restricted speed ranges imposed above a speed ratio of $r \geq 0,8$ under normal operating conditions.

3.7 Tachometer accuracy

3.7.1 Where restricted speed ranges are imposed as a condition of approval, the tachometer accuracy is to be checked against the counter readings, or by equivalent means, in the presence of the Surveyors to verify that it reads correctly within ±2 per cent in way of the restricted range of revolutions.

3.8 Governor control

3.8.1 Where there is significant critical response above and close to the service speed, consideration will be given to the effect of temporary overspeed.

■ *Section 4* Measurements

4.1 General requirements

4.1.1 Where calculations indicate that the limits for torsional vibration within the range of working speeds are exceeded, measurements, using an appropriate technique, may be taken from the machinery installation for the purpose of approval of torsional vibration characteristics, or determining the need for restricted speed ranges and the confirmation of their limits.

4.1.2 Where differences between calculated and measured levels of stress, torque or angular amplitude arise, the stress limits are to be applied to the stresses measured on the completed installation.

4.1.3 The method of measurement is to be appropriate to the machinery components and the parameters which are of concern. Where shaft stresses have been estimated from angular amplitude measurements, and are found to be close to limits, strain gauge techniques may be required. When measurements are required, detailed proposals are to be submitted.

4.2 Vibration monitoring

4.2.1 Where calculations and/or measurements have indicated the possibility of excessive vibratory stresses, torques or angular amplitudes in the event of a malfunction, vibration or performance monitoring, directly or indirectly, may be required.

■ *Section 5* Requirements for craft which are not required to comply with the HSC Code

5.1 General requirements

5.1.1 The requirements of this Chapter do not apply to the following types of vessel having main engines not exceeding 500 kW power output or auxiliary engines not exceeding 110 kW output for essential services:

(a) Service craft of less than 24 m.
(b) Yachts.
(c) ACVs.

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Section

1 **General requirements**

2 **Details to be submitted**

3 **Design**

4 **Measurements**

5 **Requirements for craft which are not required to comply with the HSC Code**

■ *Section 1* General requirements

1.1 Application

1.1.1 This Section is to be read in conjunction with the requirements of Parts 9, 10, 11 and 12.

1.1.2 Unless otherwise advised, it is the responsibility of the Builder as main contractor to ensure, in co-operation with the Enginebuilders, that the information required by this Chapter is prepared and submitted.

1.1.3 The requirements of this Chapter are applicable to the following systems:

- Main propulsion systems formed by oil engines, turbines or electric motors, directly driven or geared to the shafting.

1.2 Power ratings

1.2.1 In this Chapter where shaft power, P, in kW, and revolutions per minute, R, are referred to, the values to be used are those defined in Part 9.

1.3 Basic requirements

1.3.1 For all main propulsion systems, the Builders are to ensure that axial vibration amplitudes are satisfactory throughout the speed range. Where natural frequency calculations indicate significant axial vibration responses, sufficiently wide restricted speed ranges will be imposed. Alternatively, measurements may be used to determine the speed ranges at which amplitudes are excessive for continuous running.

■ *Section 2* Details to be submitted

2.1 Particulars to be submitted

2.1.1 The results of calculations, together with recommendations for any speed restrictions found necessary.

2.1.2 The Enginebuilder's recommendation for axial vibration amplitude limits.

2.1.3 Estimate of flexibility of the thrust bearing and its supporting structure.

2.2 Scope of calculations

2.2.1 Calculations of axial vibration natural frequency are to be carried out using appropriate techniques, taking into account the effects of flexibility of the thrust bearing, for shaft systems where the propeller is:

(a) Driven directly by a reciprocating internal combustion engine.

(b) Driven via gears, or directly by an electric motor, and where the total length of shaft between propeller and thrust bearing is in excess of 60 times the intermediate shaft diameter.

2.2.2 Where an axial vibration damper is fitted, the calculations are to consider the effect of a malfunction of the damper.

■ *Section 3* Design

3.1 Symbols

3.1.1 The symbols used in this Section are as follows:

D = outside diameter of shaft, taken as an average over length l, in mm

d = internal diameter of shaft, in mm

l = length of shaft line between propeller and thrust bearing, in mm

m = mass of shaft line considered, in kg
= $0{,}785\,(D^2 - d^2)\,G\,l$

M = dry mass of propeller, in kg

$A = \dfrac{m}{M}$

$M_e = M\,(A + 2)$

n = number of propeller blades

k = estimated stiffness at thrust block bearing, in N/m

E = modulus of elasticity of shaft material, in N/mm^2

G = density of shaft material, in kg/mm^3

N_c = critical speed, in rev/min.

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3.2 Critical frequency of axial vibration

3.2.1 For those systems as defined in 2.2.1(b) the propeller speed at which the critical frequency occurs may be estimated using the following formula:

$$N_c = \frac{0,98}{n}\left(\frac{ab}{a+b}\right)^{1/2} \text{ rev/min}$$

where

$$a = \frac{E}{G\,l^2}(66,2 + 97,5A - 8,88A^2)^2 \text{ c/min}^2$$

$$b = 91,2\,\frac{k}{M_e} \text{ c/min}^2.$$

3.2.2 Where the results of this method indicate the possibility of an axial vibration resonance in the vicinity of the service speed, calculations using a more accurate method will be required.

3.3 Restricted speed ranges

3.3.1 The limits of any speed restriction are to be such as to maintain axial amplitudes within recommended levels during continuous operation.

3.3.2 Limits of a speed restriction, where required, may be determined from calculation or on the basis of measurement.

3.3.3 Where a speed restriction is imposed for the contingency of a damper malfunction, the speed limits are to be entered in the operating manual and regular monitoring of the axial vibration amplitude is required. Details of proposals for monitoring are to be submitted.

■ *Section 4* Measurements

4.1 General requirements

4.1.1 Where calculations indicate the possibility of excessive axial vibration amplitudes within the range of working speeds under normal or malfunction conditions, measurements are required to be taken from the shafting system for the purpose of determining the need for restricted speed ranges.

4.2 Vibration monitoring

4.2.1 Where a vibration monitoring system is to be specified, details of proposals are to be submitted.

■ *Section 5* Requirements for craft which are not required to comply with the HSC Code

5.1 General requirements

5.1.1 The requirements of this Chapter do not apply to the following types of vessel having main engines not exceeding 500 kW power output or auxiliary engines not exceeding 110 kW output for essential services:

(a) Service craft of less than 24 m.
(b) Yachts.
(c) ACVs.

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Section

1 **General requirements**

2 **Details to be submitted**

3 **Measurements**

4 **Requirements for craft which are not required to comply with the HSC Code**

■ *Section 1* General requirements

1.1 Application

1.1.1 This Section is to be read in conjunction with the requirements of Parts 9, 10, 11 and 12.

1.1.2 Unless otherwise advised, it is the responsibility of the Builder as main contractor to ensure, in co-operation with the Enginebuilders, that the information required by this Chapter is prepared and submitted.

1.1.3 The requirements of this Chapter are applicable to the following systems:

- Main propulsion systems formed by oil engines, turbines or electric motors, directly driven or geared to the shafting.

1.2 Power ratings

1.2.1 In this Chapter where shaft power, *P*, in kW, and revolutions per minute, *R*, are referred to, the values to be used are those defined in Part 9.

1.3 Basic requirements

1.3.1 For all main propulsion shafting systems, the Builders are to ensure that lateral vibration characteristics are satisfactory throughout the speed range.

■ *Section 2* Details to be submitted

2.1 Particulars to be submitted

2.1.1 Calculations of the lateral vibration characteristics of shafting systems having supports outboard of the hull or incorporating cardan shafts are to be submitted.

2.2 Calculations

2.2.1 The calculations in 2.1.1, taking account of bearing, oil-film (where applicable) and structural dynamic stiffnesses, are to investigate the excitation frequencies which may result in significant amplitudes within the speed range, and are to indicate relative deflections and bending moments throughout the shafting system.

■ *Section 3* Measurements

3.1 General requirements

3.1.1 Where calculations indicate the possibility of significant lateral vibration responses within the range of working speeds, measurements using an appropriate recognised technique may be required to be taken from the shafting system for the purpose of determining that hazardous whirling or excessive vibration does not occur.

3.1.2 The method of measurement is to be appropriate to the machinery arrangement and the modes of vibration which are of concern. When measurements are required, detailed proposals are to be submitted in advance.

■ *Section 4* Requirements for craft which are not required to comply with the HSC Code

4.1 General requirements

4.1.1 The requirements of this Chapter do not apply to the following types of vessel having main engines not exceeding 500 kW power output unless the spacing of bearings on the propulsion shafting exceeds 30 diameters or cardan shafts are used in the propulsion shafting system:

(a) Service craft of less than 24 m.
(b) Yachts.
(c) ACVs.

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Section

1 **Shaft alignment**

2 **Requirements for craft which are not required to comply with the HSC Code**

Section 1 Shaft alignment

1.1 General

1.1.1 The Builder is to carry out shaft alignment calculations for all installations and to prepare alignment procedures detailing the proposed alignment method and the alignment checks.

1.2 Particulars to be submitted for approval – Shaft alignment calculations

1.2.1 Shaft alignment calculations are to be submitted to Lloyd's Register (hereinafter referred to as 'LR') for approval for the following shafting systems:

(a) All geared installations where the screwshaft has a diameter of 300 mm or greater in way of the aftmost bearing.

(b) All direct drive installations which incorporate three or fewer bearings supporting the intermediate and screwshaft aft of the prime mover.

(c) Where prime movers or shaftline bearings are installed on resilient mountings.

1.2.2 The shaft alignment calculations are to take into account the:

(a) thermal displacements of the bearings between cold static and hot dynamic machinery conditions;

(b) buoyancy effect of the propeller immersion due to the craft's operating draughts;

(c) effect of predicted hull deformations over the range of the craft's operating draughts, where known;

(d) gear forces, where appropriate;

(e) for multi-engined installations, possible contributions in the mode of operation;

(f) propeller offset thrust effects, where applicable;

(g) bearing loading in the horizontal plane, where appropriate; and

(h) bearing weardown, where applicable, and its effect on the bearing loads.

1.2.3 The shaft alignment calculations are to state the:

(a) expected bearing loads at light and normal ballast, fully loaded and any other draughts deemed to be part of the craft's operating profile, for the machinery in cold and hot, static and dynamic conditions;

(b) bearing influence coefficients and the deflection, slope, bending moment and shear force along the shaftline;

(c) details of propeller offset thrust effects, where employed in calculation;

(d) details of proposed slope-bore of the aftermost sterntube bearing, where applicable;

(e) manufacturer's specified limits for bending moment and shear force at the shaft couplings of the gearbox/prime movers;

(f) estimated bearing weardown rates for water or grease-lubricated sterntube bearings;

(g) origin of findings where the effect of hull deformation has been considered, *viz.* whether finite element calculations or measured results from sister or similar craft have been used;

(h) anticipated thermal rise of prime movers and gearing units between cold static and hot running conditions; and

(j) manufacturer's allowable bearing loads.

1.3 Particulars to be submitted for review – Shaft alignment procedure

1.3.1 A shaft alignment procedure is to be submitted for all main propulsion installations detailing, as a minimum, the:

(a) expected bearing loads at light and normal ballast, fully loaded and any other draughts deemed to be part of the craft's operating profile, for the machinery in cold and hot, static and dynamic conditions;

(b) maximum permissible loads for the proposed bearing designs;

(c) design bearing offsets from the straight line;

(d) design gaps and sags;

(e) location and loads for the temporary shaft supports;

(f) expected relative slope of the shaft and the bearing in the aftermost sterntube bearing;

(g) details of slope-bore of the aftermost sterntube bearing, where applied;

(h) expected shear forces and bending moments at the forward end flange of the shafting system connecting to the gear output shaft or, for direct-drive installations, to the prime mover output flange;

(j) proposed bearing load measurement technique and its estimated accuracy;

(k) jack correction factors for each bearing where the bearing load is measured using a specified jacking technique;

(l) proposed shaft alignment acceptance criteria, including the tolerances; and

(m) flexible coupling alignment criteria.

1.4 Design and installation criteria

1.4.1 For main propulsion installations, the shafting is to be aligned to give, in all conditions of craft loading and machinery operation, bearing load distribution satisfying the requirements of 1.4.2.

1.4.2 Design and installation of the shafting is to satisfy the following criteria:

(a) The Builder is to position the bearings and construct the bearing seatings to minimise the effects of hull deflections under any of the craft's operating conditions.

(b) Relative slope between the propeller shaft and the aftermost sterntube bearing is, in general, not to exceed 3×10^{-4} rad.

(c) Sterntube bearing loads are to satisfy the requirements of Pt 11, Ch 2,4.16.2.

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(d) Intermediate shaft bearings' loads are not to exceed 80 per cent of the bearing manufacturer's allowable maximum load, for plain journal bearings, based on the bearing projected area.
(e) Main gear wheel bearing loads are to be within the gear-box manufacturer's specified limits.
(f) Resulting shear forces and bending moments are to meet the equipment manufacturer's specified coupling conditions throughout the shafting system.
(g) The manufacturer's radial, axial and angular alignment limits for the flexible couplings are to be maintained.

1.5 Measurements

1.5.1 Where calculations indicate that the system is sensitive to changes in alignment under different service conditions, the optimised shaft alignment is to be verified by measurements during sea trials using an approved strain gauge technique.

1.6 Flexible couplings

1.6.1 Where the shafting system incorporates flexible couplings, the effects of such couplings on the various modes of vibration are to be considered, *see* Section 2.

■ *Section 2*
Requirements for craft which are not required to comply with the HSC Code

2.1 General requirements

2.1.1 The requirements of Section 1 do not apply to the following types of vessel where the main engine does not exceed 500 kW power output:
(a) Service craft of less than 24 m.
(b) Yachts.
(c) ACVs.

2.1.2 The engines, shafting, sterntubes and propeller brackets are to be carefully fitted and well secured to the hull of the craft so that satisfactory alignment of the shafting will be maintained in service.

2.1.3 The alignment of the sterntube and propeller brackets is to be demonstrated before launching and the shafting and engine alignment verified when afloat.

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Rules and Regulations for the Classification of Special Service Craft

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Section

1 **General requirements**

2 **Particulars to be submitted**

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5 **Piping systems**

6 **Control, monitoring and electrical equipment**

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Section 1 General requirements

1.1 Application

1.1.1 This Chapter is to be read in conjunction with the General Requirements for Machinery in Part 9.

1.1.2 The requirements of this Chapter apply to the design and construction of steering systems.

(a) A steering system includes:
- all steering devices;
- all mechanical, electrical, and hydraulic linkages;
- all power devices, including manual devices;
- all controls and all actuating systems.

(b) Steering may be achieved by means of:
- air or water rudders;
- foils, flaps, steerable propellers or jets;
- yaw control ports or transverse thrusters;
- differential propulsive thrust;
- variable geometry of the craft or its lift system components; or
- by a combination of these devices.

1.2 Provision of steering gear

1.2.1 Craft are to be provided with a means for steering which is to be of adequate strength and suitable design to enable the craft's heading and direction of travel to be effectively controlled at all designed operating conditions.

1.2.2 Craft are to be provided with a main steering system and an independent auxiliary steering unit. The main and the auxiliary steering units are to be so arranged that the failure of one of them will not render the other one inoperative or unable to bring the craft to a safe situation.

1.2.3 An auxiliary steering system is not a requirement provided the craft is fitted with two independent and identical steering systems, one of which is capable of steering the craft when the second system becomes inoperative.

1.3 Definitions

1.3.1 **Main steering system** means the machinery, the actuator(s), the power units, if any, ancillary equipment, and the means of applying the steering torque, if applicable, necessary for the purpose of steering the craft under design conditions.

1.3.2 **Auxiliary steering system** means the equipment other than any part of the main steering unit necessary to steer the craft in the event of failure of the main steering system.

1.3.3 **Steering power system** means:

(a) In the case of electric steering system, an electric motor and its associated electrical parts.

(b) In the case of electrohydraulic steering system, an electric motor and its associated electrical parts and connected pump.

(c) In the case of other hydraulic steering system units, a driving engine and connected pump.

1.3.4 **Steering control system** means the equipment by which orders are transmitted from the control station to the steering power units. Steering control systems comprise transmitters, receivers, hydraulic control pumps and their associated motors, motor controllers, piping and cables.

1.3.5 **Maximum working pressure** means the expected pressure in the system when the steering unit is operated under the most onerous design condition.

Section 2 Particulars to be submitted

2.1 Submission of information

2.1.1 At least three copies of the plans and information as detailed in 2.2 and 2.3 are to be submitted.

2.2 Plans

2.2.1 Detailed plans of all load bearing, and torque transmitting components and hydraulic pressure retaining parts of the steering system together with proposed rated torque, all relief valve settings, and scantlings.

2.2.2 Schematic of the hydraulic systems, together with pipe material, relief valve and working pressures.

2.2.3 Details of control engineering aspects in accordance with Pt 16, Ch 1.

2.3 Calculations and information

2.3.1 The manoeuvring characteristics for which the craft has been designed.

2.3.2 Material specifications.

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Section 3
Materials

3.1 General

3.1.1 All components are to be in accordance with the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

3.1.2 All steering unit components transmitting mechanical forces are to be of steel or other approved ductile material. In general, such material is to have an elongation of not less than 12 per cent nor a tensile strength in excess of 650 N/mm^2. Special consideration will be given to the acceptance of grey cast iron for low pressure valve bodies and mechanical parts with low stress levels.

3.1.3 Consideration will be given to the acceptance of non-ferrous materials as applicable.

Section 4
Design and performance

4.1 General

4.1.1 Power-operated steering units are to be provided with positive arrangements, such as limit switches, for stopping the unit before the mechanical stops are reached. These arrangements are to be synchronised with the unit itself and not with the steering unit control mechanism.

4.1.2 The steering unit is to be secured to the seating by fitted bolts, and suitable chocking arrangements are to be provided. The seating is to be of substantial construction.

4.1.3 All welded joints within the pressure boundary of an actuator or connecting parts transmitting mechanical loads are to be of full penetration type or of equivalent strength.

4.1.4 Steering devices involving variable geometry of the craft or its lift system components are to be so constructed that any failure of the drive linkage or actuating system will not significantly hazard the craft.

4.2 Actuating systems

4.2.1 Actuators are to be designed in accordance with the relevant requirements of Part 15 for Class I pressure vessels (notwithstanding any exemptions for hydraulic cylinders).

4.2.2 Accumulators, if fitted, are to comply with the relevant requirements of Part 15.

4.2.3 The design pressure for calculations to determine the scantlings of piping and other steering components subjected to internal hydraulic pressure shall be at least 1,25 times the maximum working pressure to be expected under the operational conditions specified taking into account any pressure which may exist in the low pressure side of the system. Fatigue criteria may be applied for the design of piping and components, taking into account pulsating pressures due to dynamic loads.

4.2.4 The permissible primary general membrane stress is not to exceed the lower of the following values:

$$\frac{\sigma_B}{A} \text{ or } \frac{\sigma_y}{B}$$

where

σ_B = specified minimum tensile strength of material at ambient temperature

σ_y = specified minimum yield stress or 0,2 per cent proof stress of the material, at ambient temperature.

A and *B* are given by the following Table:

	Wrought steel	Cast steel	Nodular cast iron
A	3,5	4	5
B	1,7	2	3

4.2.5 Oil seals between non-moving parts, forming part of the external pressure boundary, should be of the metal upon metal type or of an equivalent type.

4.2.6 Hydraulic power operated steering units are to be provided with the following:

(a) Arrangements to maintain the cleanliness of the hydraulic fluid taking into consideration the type and design of the hydraulic system;

(b) A fixed storage tank having sufficient capacity to recharge at least one power actuating system including the reservoir. The storage tank is to be provided with a contents gauge and be permanently connected by piping in such a manner that the hydraulic systems can be readily recharged from a position within the steering unit compartment, if applicable.

4.3 Rudder systems

4.3.1 For the requirements of rudder and rudder stock, *see* Pt 3, Ch 3.

4.3.2 Tillers and quadrants are to comply with the requirements of Table 1.4.1.

4.3.3 On double rudder installations, where the two tillers are connected by mechanical means (tie-bar), the strength and stability of the tie-bar is to be assessed using the maximum steering torque applied to the stock.

4.3.4 Where higher tensile steel bolts are used on bolted tillers and quadrants, the yield and ultimate tensile stresses of the bolt material are to be stated on plans submitted for approval, together with full details of the methods to be adopted to obtain the required setting-up stress. Where proprietary nuts or systems are used, the manufacturer's instructions for assembly are to be adhered to.

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Table 1.4.1 Connection of tiller to stock

(1) Dry fit – tiller to stock for M_T (*see* Notes)	(a) For keyed connection, factor of safety against slippage = 1,1 (b) For keyless connection, factor of safety against slippage = 2,2 (c) Coefficient of friction = 0,17 (d) Grip stress not to be less than 20 N/mm^2
(2) Hydraulic fit – tiller to stock for M_T (*see* Notes)	(a) For keyed connection, factor of safety against slippage = 1,1 (b) For keyless connection, factor of safety against slippage = 2,2 (c) Coefficient of friction = 0,12 (d) Grip stress not to be less than 20 N/mm^2
(3) Bolted tiller and quadrant (*see* Symbols and Notes)	Shim to be fitted between two halves before machining to take rudder stock, then removed prior to fitting Minimum thickness of shim: For 4 connecting bolts: $t_s = 0{,}0014d_{SU}$ mm For 6 connecting bolts: $t_s = 0{,}0012d_{SU}$ mm Key to be fitted Diameter of bolts, $\delta_T = \frac{0{,}60d_{SU}}{\sqrt{n_T}}$ mm Distance from centre of stock to centre of bolts should generally be equal to $d_{SU}\left(1{,}0 + \frac{0{,}30}{\sqrt{n_T}}\right)$ mm Thickness of flange on each half of the bolted tiller $\frac{0{,}66d_{SU}}{\sqrt{n_T}}$ mm
(4) Key (*see* Symbols and Notes)	Effective sectional area in shear $\geq 0{,}25d_{SU}^2$ mm^2 Key thickness $\geq 0{,}17d_{SU}$ mm Keyway is to extend over full depth of tiller and is to have a rounded end. Corners are to be provided with suitable radii to avoid high stress at the keyway root.
(5) Section modulus – tiller arm (at any point within its length about vertical axis) (*see* Symbols and Notes)	To be not less than the greater of: (a) $Z_{TA} = \frac{0{,}15d_{SU}^3(b_T - b_s)}{1000b_T}$ cm^3 (b) $Z_{TA} = \frac{0{,}06d_{SU}^3(b_T - 0{,}9d_{SU})}{1000b_T}$ cm^3 If more than one arm is fitted, combined modulus is not to be less than the greater of (a) or (b). For solid tillers, the breadth to depth ratio is not to exceed 2.
(6) Boss (*see* Symbols and Notes)	Depth of boss $\geq d_{SU}$ Thickness of boss in way of tiller $\geq 0{,}4d_{SU}$

Symbols

b_s = distance between the section of the tiller arm under consideration and the centre of the rudder stock, in mm
NOTE: b_T and b_s are to be measured with zero rudder angle

b_T = distance from the point of application of the load on the tiller to the rudder stock, in mm

n_T = number of bolts in coupling, but generally not to be taken greater than six

t_s = thickness of shim for machining bolted tillers and quadrants, in mm

Z_{TA} = section modulus of tiller arm, in cm^3

d_{SU} = *see* Pt 3, Ch 3

δ_T = diameter of bolts securing bolted tillers and quadrants, in mm

σ_o = minimum yield stress or 0,5 per cent proof stress of the tiller bolt material, in N/mm^2

NOTES
1. If $d_{SU} > 400$ mm, higher tensile steel bolts are to be used for bolted tillers. A predetermined setting-up load equivalent to a stress of approximately $0{,}7\sigma_o$ should be applied to each bolt assembly. A lower stress may be accepted provided that two keys, complying with item (4) are fitted.
2. Where M_T, the maximum turning moment applied to the stock, is to be taken as the greater of the following:
   (a) $11{,}1d_{SU}^3$ Nmm where d_{SU} is to be determined from Table 3.2.7 in Pt 3, Ch 3 with σ_o taken as 235 N/mm^2 and $N = 0$.
   (b) The torque generated by the steering gear at the maximum working pressure, *see* 1.3.5.

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4.3.5 All steering components transmitting mechanical forces to the rudder stock, which are not protected against overload by structural rudder stops or mechanical buffers, are to have a strength at least equivalent to that of the rudder stock in way of the tiller.

4.3.6 In bow rudders having a vertical locking pin operated from the deck above, positive means are to be provided to ensure that the pin can be lowered only when the rudder is exactly central. In addition, an indicator is to be fitted at the deck to show when the rudder is exactly central.

4.4 Performance

4.4.1 The main steering system is to be:

(a) Of adequate strength and capable of steering the craft at all speeds and conditions for which the craft is designed and this shall be demonstrated during trials;

(b) operated by power where necessary to meet the requirements of (a) and in any case when the Rules require a rudder stock over 120 mm diameter in way of the tiller; and

(c) so designed that it will not be damaged at maximum astern speed.

4.4.2 The auxiliary steering system is to be:

(a) Of adequate strength and capable of steering the craft at navigable speed and of being brought speedily into action in an emergency.

(b) Operated by power where necessary to meet the requirements of (a) and in any case when the Rules, require a rudder stock over 230 mm diameter in way of the tiller.

(c) Where manual operated steering units are proposed, these are acceptable when the operation does not require an effort exceeding 160N under normal conditions.

4.4.3 Main and auxiliary steering power units are to be:

(a) Arranged to re-start automatically when power is restored after power failure.

(b) Capable of being brought into operation from a position at the control station. In the event of a power failure to any one of the steering power units, an audible and visual alarm is to be given on the control station.

(c) Arranged so that transfer between units can be readily effected.

4.4.4 For high speed craft, in the event of total power failure, either:

(a) emergency power for steering systems/drives is to be restored automatically within five seconds. To achieve this an interim fast acting system may be required to come into operation until such time as auxiliary/ emergency power source comes on line. (Note: starting arrangements are to comply with the requirements relating to starting arrangements of emergency generators); or

(b) means are to be provided to bring the craft to a safe condition.

4.4.5 Where the steering unit is so interconnected that more than one power system, or control system, can be simultaneously operated, the design is to be such that hydraulic locking caused by a single failure cannot occur.

4.4.6 Steering systems, other than of the hydraulic type, will be accepted provided the standards are considered equivalent to the requirements of this Section.

■ *Section 5* Piping systems

5.1 Components

5.1.1 Piping, joints, valves, flanges and other fittings are to comply within the requirements of Pt 15, Ch 1 for Class 1 piping system components. The design pressure is to be in accordance with 4.2.3.

5.2 Valve and relief valve arrangements

5.2.1 For vessels with non-duplicated actuators, isolating valves are to be fitted at the connection of pipes to the actuator, and are to be directly fitted on the actuator.

5.2.2 Arrangements for bleeding air from the hydraulic system are to be provided, where necessary.

5.2.3 Relief valves are to be fitted to any part of the hydraulic system which can be isolated and in which pressure can be generated from the power source or from external forces. The settings of the relief valves is not to exceed the design pressure. The valves are to be of adequate size and so arranged as to avoid an undue rise in pressure above the design pressure.

5.2.4 Relief valves for protecting any part of the hydraulic system which can be isolated, as required by 5.2.3 are to comply with the following:

(a) The setting pressure is not to be less than 1,25 times the maximum working pressure.

(b) The minimum discharge capacity of the relief valve(s) is not to be less than 110 per cent of the total capacity of the pumps which can deliver through it (them).
Under such conditions the rise in pressure is not to exceed 10 per cent of the setting pressure. In this regard, due consideration is to be given to extreme foreseen ambient conditions in respect of oil viscosity.

5.3 Flexible hoses

5.3.1 Flexible hoses are to be of approved type, *see* Pt 15, Ch 1,13.

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Section 6
Control, monitoring and electrical equipment

6.1 Control

6.1.1 All steering systems are to be be operated from the craft's control station.

6.1.2 If steering systems can also be operated from other positions, then two-way communication is to be arranged between the control station and these other positions.

6.1.3 Steering control is to be provided:

(a) For the main steering unit, both at the control station and in the steering unit compartment, where applicable;

(b) Where the main steering unit is arranged by two independent control systems, both operable from the control station. This does not require duplication of the steering wheel or steering lever. Where the control system consists of a hydraulic telemotor, a second independent system need not be fitted.

(c) For the auxiliary steering unit, in the steering unit compartment and, if power operated, it is also to be operable from the control station and is to be independent of the control system for the main steering system.

6.1.4 Electrical control systems are to be independent and separated as far as is practicable throughout their length.

6.1.5 Any main and auxiliary steering unit control system operable from the control station is to comply with the following:

(a) Means are to be provided in the steering unit compartment, if applicable, for disconnecting any control system operable at the control station from the steering unit it serves;

(b) The system is to be capable of being brought into operation from a position on the control station.

6.1.6 Appropriate operating instructions with a block diagram showing the change-over procedures for steering unit control systems and steering unit actuating systems are to be permanently displayed at the control station and in the steering unit compartment, if applicable.

6.1.7 Where the system failure alarms for hydraulic lock, *see* Table 1.6.1, are provided, appropriate instructions are to be placed on the control station to shut down the system at fault.

6.2 Monitoring

6.2.1 Alarms and monitoring requirements are indicated in 6.2.2, 6.2.3 and Table 1.6.1.

Table 1.6.1 Alarms

Item	Alarm	Note
Angular position of the Steering Mechanism	—	Indication, *see* 6.1.6
	Failure	*See* 6.2.4
Steering power units, power	Failure	—
Steering motors	Overload Single phase	For alarm and running indication locations. *see* 6.3.2 and 6.3.3
Control system	Failure	*See* 6.2.4
Control system power	Failure	—
Steering gear hydraulic oil level	Low	Each reservoir to be be monitored. For Alarm locations, *see* 6.3.4.
Auto pilot	Failure	Running indication
Hydraulic oil temperature	High	Where oil cooler is fitted
Hydraulic lock	Fault	Where more than one system (either power or control) can be operated simultaneously each each system is to be monitored, *see* Note
Hydraulic oil filter differential pressure	High	When oil filters are fitted

NOTE
This alarm is to identify the system at fault and is to be activated when (for example):
- position of the variable displacement pump control system does not correspond with given order; or
- incorrect position of 3-way full flow valve or similar in constant delivery pump system is detected.

6.2.2 The angular position of the steering mechanism is to:

(a) Where the main steering unit is power operated, be indicated at the control station, and other positions as applicable. The angular indication is to be independent of the steering unit control system; and is to indicate any abnormal responses or malfunctions. The logic of such feedback and indications are to be consistent with the other alarms and indications so that in an emergency operators are unlikely to be confused.

(b) Be recognisable in the steering unit compartment, if applicable.

6.2.3 The alarms described in Table 1.6.1 are to be indicated on the navigating bridge and the additional locations described and are to be in accordance with the alarm system specified by Pt 16, Ch 1,2.3.

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6.2.4 Steering control systems are to be monitored and an audible and visual alarm is to be initiated on the navigation bridge in the event of:

- failure of the control system, including command and fee back circuits; or
- unacceptable deviation between the rudder order and actual rudder position and/or unacceptable delay in response to changes in the rudder order.

6.3 Electrical equipment

6.3.1 Short circuit protection, and overload alarm and, in the case of polyphase circuits, an alarm to indicate failure of any one of the phases is to be provided for each main and auxiliary motor circuit. Protective devices are to operate at not less than twice the full load current of the motor or circuit protected and are to allow excess current to pass during the normal accelerating period of the motors.

6.3.2 The alarms required by 6.3.1 are to be provided on the bridge and in the main machinery space or control room from which the main machinery is normally controlled.

6.3.3 Indicators for running indication of each main and auxiliary motor are to be installed on the control station and at a suitable main machinery control position.

6.3.4 A low-level alarm is to be provided for each steering system hydraulic fluid reservoir to give the earliest practicable indication of hydraulic fluid leakage. Alarms are to be given on the navigation bridge and in the machinery space where they can be readily observed.

6.3.5 Two exclusive circuits are to be provided for each electric or electrohydraulic steering unit arrangement consisting of one or more electric motors.

6.3.6 Each of these circuits is to be fed from the main switchboard. One of these circuits may pass through the emergency switchboard.

6.3.7 One of these circuits may be connected to the motor of an associated auxiliary electric or electrohydraulic power unit.

6.3.8 Each of these circuits is to have adequate capacity to supply all the motors which can be connected to it and which can operate simultaneously.

6.3.9 These circuits are to be separated throughout their length as widely as is practicable.

6.3.10 Each main and auxiliary electric control system which is to be operated from the control station is to comply with the following:

(a) It is to be served with electric power by a separate circuit supplied from the associated steering unit power circuit, from a point within the steering unit compartment, or directly from the same section of switchboard busbars, main or emergency, to which the associated steering unit power circuit is connected.

(b) Each separate circuit is to be provided with short circuit protection only.

■ *Section 7*
Requirements for craft which are not required to comply with the HSC Code

7.1 Introduction

7.1.1 The requirements of Sections 1 to 6 of this Chapter apply, except where modified by this Section.

7.2 Design and performance

7.2.1 In craft over 50 m in length, the main steering system is to be power operated.

7.2.2 Service craft of length 50 m or less, or sailing yachts of length 50 m or less, may have manual steering. Where wheel steering is fitted, an alternative means of steering (which may be a hand tiller) is to be readily available, and the performance of both systems is to be in accordance with 7.2.6.

7.2.3 The main steering gear is to be capable of steering the craft at the maximum ahead speed and turning the rudder from hardover to hardover in 30 seconds.

7.2.4 Where wire rope steering leads are fitted, they are to be of suitable construction. Wire rope is to be stainless steel or suitably protected against corrosion and the strength of the rope is to be as follows:

$$\text{Breaking load} = \frac{d_{SU}^3}{100R} \text{ kN}$$

where

d_{SU} is the basic stock diameter at quadrant or tiller given by Table 3.2.7 in Pt 3, Ch 3, in mm.

R = radius of quadrant, or length of tiller arm, in mm.

7.2.5 Steering leads are to be as direct as possible, and sharp bends are to be avoided. Sheaves are to be of adequate diameter and designed to prevent the steering leads from jumping or jamming.

7.2.6 Means are to be provided for adjusting the tension in the steering leads.

7.2.7 Where considered necessary, an efficient locking or brake arrangement is to be fitted to keep the rudder steady when a change from one type of steering to the other is required.

7.2.8 Where manually operated steering is permitted, the effort required to operate the tiller or steering wheel is to be not more than 160 N under normal conditions.

7.3 Control and monitoring

7.3.1 The alarms and safeguards for yachts and service craft less than 24 m are to be adequate for the type of steering system employed, *see* Table 1.7.1.

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Table 1.7.1 Alarms

Item	Alarm	Note
Angular position of the Steering Mechanism	—	Indication
Steering power units, power	Failure	—
Steering motors	Overload, single phase	Also running indication on bridge
Control system power	Failure	—
Steering gear hydraulic oil level	Low	—
Auto pilot	Failure	Running indication
Hydraulic oil temperature	High	Where oil cooler is fitted

7.3.2 The requirements of 6.3.5 do not apply to service craft less than 24 m.

7.4 Electrical equipment

7.4.1 Consideration will be given to the electrical control equipment of simple steering systems on service craft less than 24 m or yachts, *see* Pt 16, Ch 2.

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Rules and Regulations for the Classification of Special Service Craft

Volume 7
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Piping Systems and Pressure Plant
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■ *Section 1* Application

1.1 General

1.1.1 The requirements of this Chapter apply to the design and construction of piping systems including pipe fittings forming part of such systems.

■ *Section 2* Details to be submitted

2.1 Plans and information

2.1.1 At least three copies of the following plans and information are to be submitted.

2.1.2 Venting, sounding and drainage arrangements for all watertight compartments.

2.1.3 The following diagrammatic plans including details of the material and pipe dimensions/thickness:

- Bilge and ballast system including the capacities of the pumps on bilge service.
- Lubricating oil systems.
- Flammable liquids used for control and heating systems.
- Power transmission systems for services essential for safety or for the operation of the craft at sea.
- Cooling water systems for main and auxiliary services.
- Compressed air systems for main and auxiliary services.
- Steam systems with a design pressure above 7 bar.

2.1.4 Arrangement of oil fuel storage tanks with a capacity of over 0,5 m^3 where these do not form part of the structure of the craft.

2.1.5 Where it is intended to use plastic pipes for Class I, Class II and any Class III systems for which there are requirements in these Rules, details of the following:

(a) Properties of the materials.
(b) Operating conditions.
(c) Intended service and location.
(d) Pipes, fittings and joints.

2.1.6 Design details of the following components:

(a) Flexible hoses.
(b) Sounding devices.
(c) Resiliently seated valves.
(d) Expansion joints.
(e) Components of an unusual or novel nature.

2.1.7 The requirements for plans and information for the fire-fighting systems are given in Pt 17, Ch 1,1.2.3.

■ *Section 3* Class of pipes

3.1 General

3.1.1 Pipework systems are divided into three classes depending on the internal fluid and design temperature and pressure of the system.

3.1.2 Material test requirements for the different classes of pipe are detailed in the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

3.1.3 Acceptable jointing methods for the different classes of pipe are given in the appropriate Section of this Chapter. Material certificate requirements are given in Section 11.

3.1.4 The maximum design pressure and temperature for Class II and III systems is given in Table 1.3.1. To illustrate, *see* Fig. 1.3.1.

3.1.5 Class I pipes are to be used where either the maximum design pressure or design temperature exceeds that applicable to Class II pipes.

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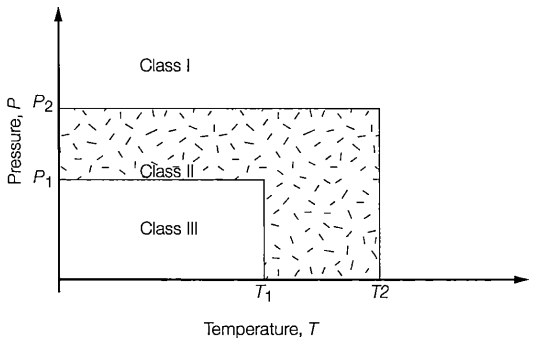
Table 1.3.1 Maximum pressure and temperature conditions for Class II and III piping systems

Piping system	Class II		Class III	
	p	*T*	*p*	*T*
	bar	°C	bar	°C
Steam	16,0	300	7,0	170
Flammable liquids (*see* Note)	16,0	150	7,0	60
Other media	40,0	300	16,0	200

NOTE
Flammable liquids include: oil fuel, thermal oil and lubricating oil.



NOTE
T_1 and P_1 correspond to the maximum temperatures and pressures for a Class III piping system and T_2 and P_2 to those for a Class II piping system depending on the service.

Fig. 1.3.1 Classes of piping system

3.1.6 Class III pipes may also be used for open ended piping, e.g. overflows, vents, boiler waste steam pipes, open-ended drains, sounding pipes, etc.

■ *Section 4* Design symbols and definitions

4.1 Design symbols

4.1.1 The symbols used in this Chapter are defined as follows:

- a = percentage negative manufacturing tolerance on thickness
- c = corrosion allowance, in mm
- d = inside diameter of pipe, in mm, *see* 4.1.3
- e = weld efficiency factor, *see* 4.1.4
- p = design pressure, in bar, *see* 4.2
- p_t = hydraulic test pressure, in bar
- t = the minimum thickness of a straight pipe, in mm, including corrosion allowance and negative tolerance, where applicable
- t_b = the minimum thickness of a straight pipe to be used for a pipe bend, in mm, including bending allowance, corrosion allowance and negative tolerance, where applicable
- D = outside diameter of pipe, in mm, *see* 4.1.2
- R = radius of curvature of a pipe bend at the centre line of the pipe, in mm
- T = design temperature, in °C, *see* 4.3.1
- σ = maximum permissible design stress, in N/mm^2.

4.1.2 The outside diameter, D, is subject to manufacturing tolerances, but these are not to be used in the evaluation of formulae.

4.1.3 The inside diameter, d, is not to be confused with nominal pipe size, which is an accepted designation associated with outside diameters of standard rolling sizes.

4.1.4 The weld efficiency factor, e, is to be taken as 1,0 for seamless and electric resistance or induction welded steel pipes.

4.2 Design pressure

4.2.1 The design pressure, p, is the maximum permissible working pressure and is to be not less than the highest set pressure of the safety valve or relief valve. In systems which have no safety valve or relief valve, the design pressure is to to be taken as 1,1 times the maximum working pressure.

4.2.2 The design pressure of piping on the discharge from pumps is to be taken as the pump pressure at full rated speed against a shut valve. Where a safety valve or other protective device is fitted to restrict the pressure to a lower value than the shut valve load, the design pressure is to be the highest set pressure of the device.

4.2.3 For design pressure of steering system components and piping, *see* Part 14.

4.3 Design temperature

4.3.1 The design temperature is to be taken as the maximum temperature of the internal fluid, but in no case is it to be less than 50°C.

■ *Section 5* Carbon and low alloy steels

5.1 General

5.1.1 The minimum thickness of steel pipes is to be determined by the formulae given in 5.1.2 and 5.1.3 except that in no case is it to be less than that shown in Table 1.5.1.

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Table 1.5.1 Minimum thickness for steel pipes

External diameter *D* mm	Minimum pipe thickness mm
10,2–12	1,6
13,5–19	1,8
20–44,5	2,0
48,3–63,5	2,3
70–82,5	2,6
88,9–108	2,9
114,3–127	3,2
133–139,7	3,6
152,4–168,3	4,0
177,8 and over	4,5

NOTES
1. The thickness of air, overflow and sounding pipes for structural tanks is to be not less than 4,5 mm.
2. The thickness of bilge, ballast and general sea water pipes is to be not less than 4,0 mm.
3. The thickness of bilge, air, overflow and sounding pipes through ballast and oil fuel tanks, ballast lines through oil fuel tanks and oil fuel lines through ballast tanks is to be not less than 6,3 mm.
4. For air, bilge, ballast, oil fuel, overflow, sounding, and venting pipes as mentioned in Notes 1 to 3, where the pipes are efficiently protected against corrosion the thickness may be reduced by not more than 1 mm.
5. For air and sounding pipes the minimum thickness applies to the part of the pipe outside the tank but not exposed to weather. The section of pipe exposed to weather may be required to be suitably increased in thickness in accordance with statutory and loadline requirements as applicable.

5.1.2 The minimum thickness, t, of straight steel pressure pipes is to be determined by the following formula:

$$t = \left(\frac{pD}{20\sigma e + p} + c\right)\frac{100}{100 - a} \text{ mm}$$

where
symbols are as defined in 4.1.1
c is obtained from Table 1.5.2, *see also* 5.1.4
σ may be obtained directly from Table 1.5.3 or from the formula given in 5.1.6.

Table 1.5.2 Values of corrosion allowance (*c*) for steel pipes

Piping service	*c*, in mm
Saturated steam systems	0,8
Compressed air systems	1,0
Hydraulic oil systems	0,3
Lubricating oil systems	0,3
Fuel oil systems	1,0
Refrigerating plants	0,3
Fresh water systems	0,8
Sea-water systems in general	3,0

5.1.3 The minimum thickness, t_b, of a straight steel pipe to be used for a pipe bend is to be determined by the following formula, except where it can be demonstrated that the use of a thickness less than t_b would not reduce the thickness below t at any point after bending:

$$t_b = \left[\left(\frac{pD}{20\sigma e + p}\right)\left(1 + \frac{D}{2{,}5R}\right) + c\right]\frac{100}{100 - a} \text{ mm}$$

where
symbols are as defined in 4.1.1
c and σ are obtained as in 5.1.2
in general, R is to be not less than $3D$.

5.1.4 For pipes passing through tanks, where the thickness has been calculated in accordance with 5.1.2 or 5.1.3, an additional corrosion allowance is to be added to take account of external corrosion; the addition will depend on the external medium and the value is to be in accordance with Table 1.5.2.

5.1.5 Where the pipes are efficiently protected against corrosion, the corrosion allowance, c, may be reduced by not more than 50 per cent.

Table 1.5.3 Carbon and carbon-manganese steel pipes

Specified minimum tensile strength, N/mm²	Maximum permissible design stress, N/mm²												
	Maximum design temperature, °C												
	50	100	150	200	250	300	350	400	410	420	430	440	450
320	107	105	99	92	78	62	57	55	55	54	54	54	49
360	120	117	110	103	91	76	69	68	68	68	64	56	49
410	136	131	124	117	106	93	86	84	79	71	64	56	49
460	151	146	139	132	122	111	101	99	98	85	73	62	53
490	160	156	148	141	131	121	111	109	98	85	73	62	53

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5.1.6 The maximum permissible design stress, σ, is to be taken as the lowest of the following values:

$$\sigma = \frac{E_t}{1,6}$$

$$\sigma = \frac{R_{20}}{2,7}$$

$$\sigma = \frac{S_R}{1,6}$$

where

E_t = specified minimum lower yield or 0,2 per cent proof stress at the design temperature

R_{20} = specified minimum tensile strength at ambient temperature

S_R = average stress to produce rupture in 100 000 hours at the design temperature

Values of E_t, R_{20} and S_R may be obtained from Chapter 6 of the Rules for Materials. Intermediate values may be obtained by interpolation.

5.1.7 Steel stub pipes between the shell plating and the sea valve are to be of short rigid construction, adequately supported and of substantial thickness.

5.2 Steel pipe joints

5.2.1 Joints in steel pipelines may be made by:

- Screwed on or welded on bolted flanges.
- Butt welds between pipes or between pipes and valve chests.
- Socket welded joints (up to 60,3 mm outside diameter).
- Threaded sleeve joints (parallel thread), *see also* 5.5.
- Special types of approved joints that have been shown to be suitable for the design conditions, *see also* 5.4.

5.2.2 All welding of pipes is to be in accordance with the requirements specified in Chapter 13 of the Rules for Materials.

5.2.3 Where pipes are joined by welding a suitable number of flanged joints are to be provided at suitable positions to facilitate installation and removal for maintenance.

5.2.4 Where welded pipes are protected against corrosion then the corrosion protection is to be applied after welding or the corrosion protection is to be made good in way of the weld damaged area.

5.2.5 Where it is not possible to make good the corrosion protection of the weld damaged area, then the pipe is to be considered to have no corrosion protection.

5.2.6 Where backing rings are used for welding pipes, then the effect of the flow obstruction of the backing ring and erosion/crevice corrosion of the backing ring is to be taken into account.

5.3 Welded-on flanges, butt welded joints and fabricated branch pieces

5.3.1 The dimensions and material of flanges and bolting, and the pressure-temperature rating of bolted flanges in pressure pipelines, in accordance with National or other established standards will be accepted.

5.3.2 The types of welded-on flanges are to be suitable for the pressure, temperature and service for which the pipes are intended.

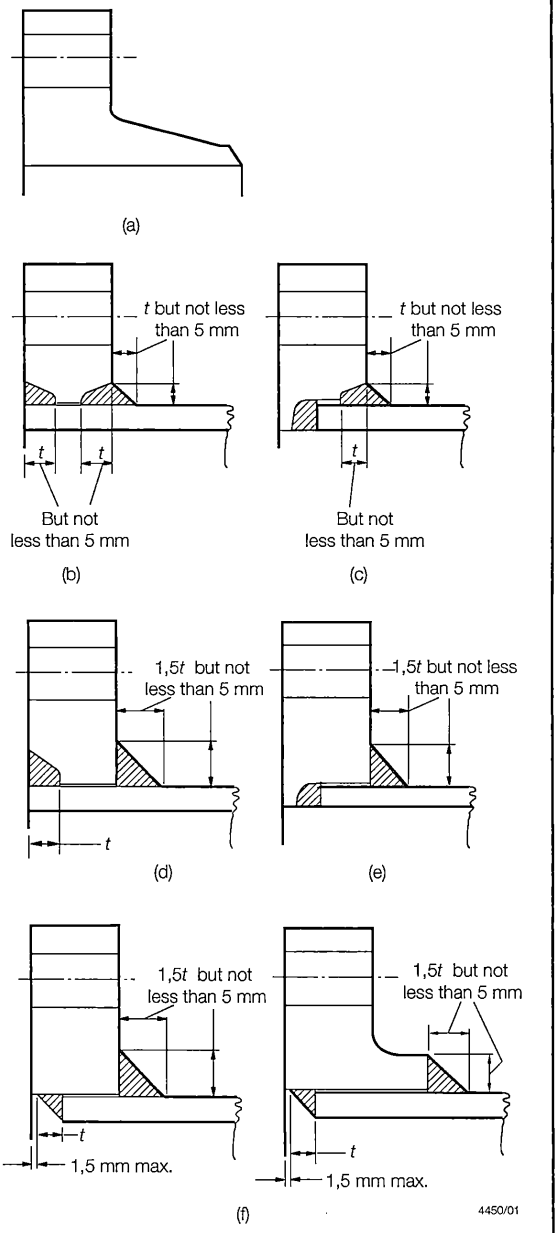

Fig. 1.5.1
Typical examples of welded flange connections

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Table 1.5.4 Limiting design conditions for flange types

Flange type	Maximum pressure	Maximum temperature	Maximum pipe o.d.	Minimum pipe bore
		°C	mm	mm
(a)	Pressure-temperature ratings to be in accordance with a recognised standard	No restriction	No restriction	No restriction
(b)		No restriction	168,3 for alloy steels*	No restriction
(c)		No restriction	168,3 for alloy steels*	75
(d)		425	No restriction	No restriction
(e)		425	No restriction	75
(f)		425	No restriction	No restriction

* No restriction for carbon steels

5.3.3 Typical examples of welded-on flange attachments are shown in Fig. 1.5.1, and limiting design conditions for flange types (a) to (f) are shown in Table 1.5.4.

5.3.4 Welded-on flanges are not to be a tight fit on the pipes. The maximum clearance between the bore of the flange and the outside diameter of the pipe is to be 3 mm at any point, and the sum of the clearances diametrically opposite is not to exceed 5 mm.

5.3.5 Where butt welds are employed in the attachment of flange type (a), in pipe-to-pipe joints or in the construction of branch pieces, the adjacent pieces are to be matched at the bores. This may be effected by drifting, roller expanding or machining, provided that the pipe wall is not reduced below the designed thickness. If the parts to be joined differ in wall thickness, the thicker wall is to be gradually tapered to the thickness of the thinner at the butt joint. The welding necks of valve chests are to be sufficiently long to ensure that the valves are not distorted as the result of welding and subsequent heat treatment of the joints.

5.3.6 Where backing rings are used with flange type (a) they are to fit closely to the bore of the pipe and should be removed after welding. The rings are to be made of the same material as the pipes or of mild steel having a sulphur content not greater than 0,05 per cent.

5.3.7 Branches may be attached to pressure pipes by means of welding provided that the pipe is reinforced at the branch by a compensating plate or collar or other approved means, or alternatively that the thickness of pipe and branch are increased to maintain the strength of the pipe. These requirements also apply to fabricated branch pieces.

5.4 Screwed fittings

5.4.1 Screwed fittings including compression fittings may be used in piping systems not exceeding 41 mm outside diameter. Where the fittings are not in accordance with an acceptable standard then Lloyd's Register (hereinafter referred to as 'LR') may require the fittings to be subjected to special tests to demonstrate their suitability.

5.5 Threaded sleeve joints (parallel thread)

5.5.1 Threaded sleeve joints in accordance with National or other established standards may be used within the limits given in Table 1.5.5. They are not to be used in piping systems conveying flammable liquids.

Table 1.5.5 Limiting design conditions for threaded sleeve joints

Nominal bore	Maximum pressure	Maximum temperature
mm	bar (kgf/cm^2)	°C
≤ 25	12,0 (12,2)	260
> 25 ≤ 40	10,0 (10,2)	260
> 40 ≤ 80	8,5 (8,7)	260
> 80 ≤ 100	7,0 (7,1)	260

5.6 Socket weld joints

5.6.1 Socket weld joints may be used with carbon steel pipes not exceeding 60,3 mm outside diameter. Socket weld fittings are to be of forged steel and the material is to be compatible with the associated piping. Such joints are not to be used where fatigue, severe erosion or crevice corrosion is expected to occur. *See also* Ch 4,7.3.9.

5.6.2 The thickness of the socket weld fittings is to meet the requirements of 5.1.3 but is to be not less than 1,25 times the nominal thickness of the pipe or tube. The diametrical clearance between the outside diameter of the pipe and the bore of the fitting is not to exceed 0,8 mm, and a gap of approximately 1,5 mm is to be provided between the end of the pipe and the bottom of the socket.

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5.6.3 The leg lengths of the fillet weld connecting the pipe to the socket weld fitting are to be such that the throat dimension of the weld is not less than the nominal thickness of the pipe or tube.

5.7 Welded sleeve joints

5.7.1 Welded sleeve joints may be used in Class III systems only, subject to the restrictions and general dimensional requirements given in 5.6 for socket weld joints.

5.7.2 The pipe ends are to be located in the centre of the sleeve with a 1,5 to 2,0 mm gap.

5.8 Other mechanical couplings

5.8.1 Pipe unions, compression couplings, or slip-on joints, as shown in Fig. 1.5.2, may be used if type approved for the service conditions and the intended application. The type approval is to be based on the results of testing of the actual joints. The acceptable use for each service is indicated in Table 1.5.6 and dependence upon the Class of piping, with limiting pipe dimensions, is indicated in Table 1.5.7.

5.8.2 Where the application of mechanical joints results in a reduction in pipe wall thickness due to the use of bite type rings or other structural elements, this is to be taken into account in determining the minimum wall thickness of the pipe to withstand the design pressure.

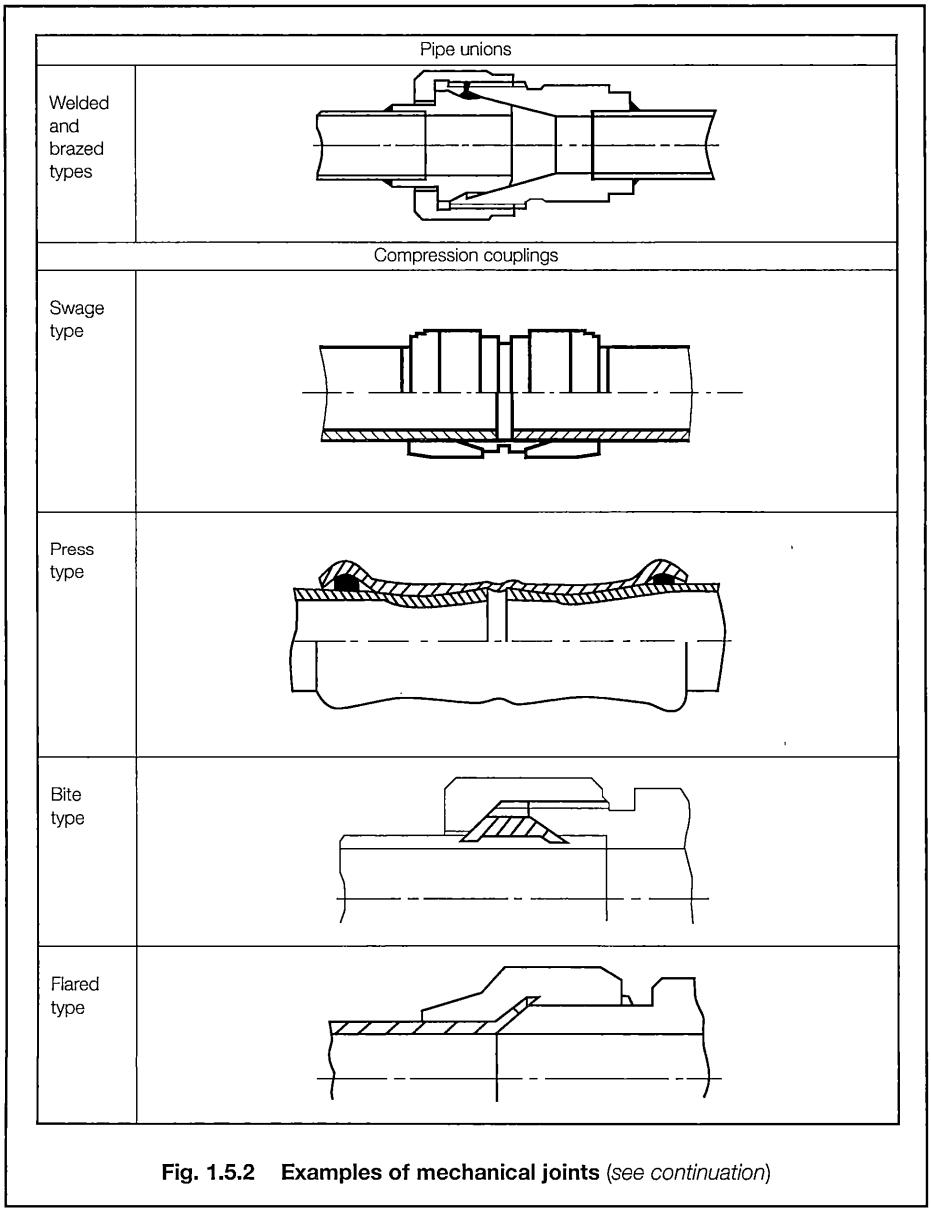

Fig. 1.5.2 Examples of mechanical joints *(see continuation)*

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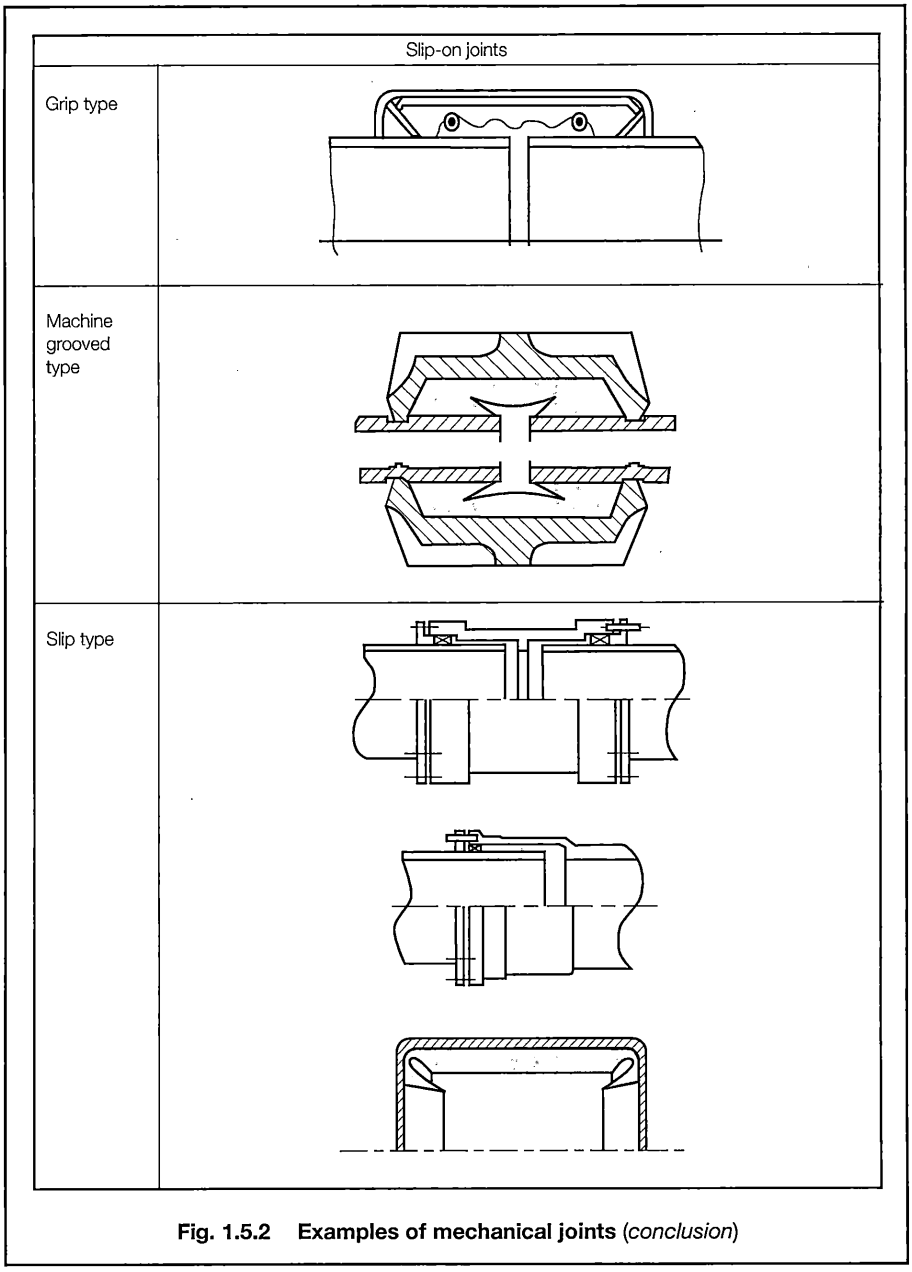

Fig. 1.5.2 Examples of mechanical joints (*conclusion*)

5.8.3 Construction of mechanical joints is to prevent the possibility of tightness failure affected by pressure pulsation, piping vibration, temperature variation and other similar adverse effects occurring during operation on board.

5.8.4 Materials of mechanical joints are to be compatible with the piping material and internal and external media.

5.8.5 Mechanical joints for pressure pipes are to be tested to a burst pressure of 4 times the design pressure. For design pressures above 200 bar the required burst pressure will be specially considered.

5.8.6 In general, mechanical joints are to be of fire-resistant type where required by Table 1.5.6.

5.8.7 Mechanical joints, which in the event of damage could cause fire or flooding, are not to be used in piping sections directly connected to the sea openings or tanks containing flammable fluids.

5.8.8 Mechanical joints are to be designed to withstand internal and external pressure as applicable and where used in suction lines are to be capable of operating under vacuum.

5.8.9 Generally, slip-on joints are not to be used in pipelines in cargo holds, tanks, and other spaces which are not easily accessible. Application of these joints inside tanks may only be accepted where the medium conveyed is the same as that in the tanks.

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Table 1.5.6 Application of mechanical joints

Systems	Kind of connections		
	Pipe unions	Compression couplings (6)	Slip-on joints
Flammable fluids (Flash point <60°)			
Cargo oil lines	+	+	+5
Crude oil washing lines	+	+	+5
Vent lines	+	+	+3
Inert gas			
Water seal effluent lines	+	+	+
Scrubber effluent lines	+	+	+
Main lines	+	+	+2,5
Distribution lines	+	+	+5
Flammable fluids (Flash point > 60°)			
Cargo oil lines	+	+	+5
Fuel oil lines	+	+	+2,3
Lubricating oil lines	+	+	+2,3
Hydraulic oil	+	+	+2,3
Thermal oil	+	+	+2,3
Sea-water			
Bilge lines	+	+	+1
Fire main and water spray	+	+	+3
Foam system	+	+	+3
Sprinkler system	+	+	+3
Ballast system	+	+	+1
Cooling water system	+	+	+1
Tank cleaning services	+	+	+
Non-essential systems	+	+	+
Fresh water			
Cooling water system	+	+	+1
Condensate return	+	+	+1
Non-essential system	+	+	+
Sanitary/Drains/Scuppers			
Deck drains (internal)	+	+	+4
Sanitary drains	+	+	+
Scuppers and discharge (overboard)	+	+	—
Sounding/vent			
Water tanks/Dry spaces	+	+	+
Oil tanks (f.p.> 60°C)	+	+	+2,3
Miscellaneous			
Starting/Control air (1)	+	+	—
Service air (non-essential)	+	+	+
Brine	+	+	+
CO_2 system	+	+	—
Steam	+	+	—

KEY
+ Application is allowed
— Application is not allowed

NOTES
1. Inside machinery spaces of Category A – only approved fire resistant types.
2. Not inside machinery spaces of Category A or accommodation spaces. May be accepted in other machinery spaces provided the joints are located in easily visible and accessible positions.
3. Approved fire resistant types.
4. Above freeboard deck only.
5. In pump rooms and open decks – only approved fire resistant types.
6. If compression couplings include any components which are sensitive to heat, they are to be of approved fire resistant type as required for slip-on joints.

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Table 1.5.7 Application of mechanical joints depending on class of piping

Types of joints	Classes of piping systems		
	Class I	Class II	Class III
Pipe unions			
Welded and brazed type	+(OD ≤ 60,3 mm)	+(OD ≤ 60,3 mm)	+
Compression couplings			
Swage type	–	–	+
Bite type	+(OD ≤ 60,3 mm)	+(OD ≤ 60,3 mm)	+
Flared type	+(OD ≤ 60,3 mm)	+(OD ≤ 60,3 mm)	+
Press type	–	–	+
Slip-on joints			
Machine grooved type	+	+	+
Grip type	–	+	+
Slip type	–	+	+

KEY
+ Application is allowed
– Application is not allowed

5.8.10 Unrestrained slip-on joints are only to be used in cases where compensation of lateral pipe deformation is necessary. Usage of these joints as the main means of pipe connection is not permitted.

■ *Section 6* Copper and copper alloys

6.1 General

6.1.1 Copper and copper alloy pipes are acceptable for a wide range of services, including bilge pipework and where non heat-sensitive material is required.

6.1.2 The maximum permissible service temperature of copper and copper alloy pipes, valves and fittings is not to exceed 200°C for copper and aluminium brass, and 300°C for copper-nickel. Cast bronze valves and fittings complying with the requirements of Chapter 9 of the Rules for Materials may be accepted up to 260°C.

6.1.3 The minimum thickness, t, of straight copper and copper alloy pipes is to be determined by the following formula but is not to be less than that shown in Table 1.6.1:

$$t = \left(\frac{pD}{20\sigma + p} + c\right)\frac{100}{100 - a} \text{ mm}$$

where

symbols are as defined in 4.1.1

c = 0,8 mm for copper, aluminium brass, and copper-nickel alloys where the nickel content is less than 10 per cent

= 0,5 mm for copper-nickel alloys where the nickel content is 10 per cent or greater

= 0 where the media are non-corrosive relative to the pipe material

σ may be obtained from Table 1.6.2.

Intermediate values may be obtained by linear interpolation.

Table 1.6.1 Minimum thickness for copper and copper alloy pipes

Standard pipe sizes (outside diameter)			Minimum overriding nominal thickness	
			Copper	Copper alloy
8	to	10	1,0	0,8
12	to	20	1,2	1,0
25	to	44,5	1,5	1,2
50	to	76,1	2,0	1,5
88,9	to	108	2,5	2,0
133	to	159	3,0	2,5
193,7	to	267	3,5	3,0
273	to	457,2	4,0	3,5
508	and	over	4,5	4,0

6.1.4 The minimum thickness t_b, of a straight seamless copper or copper alloy pipe to be used for a pipe bend is to be determined by the formula below, except where it can be demonstrated that the use of a thickness less than t_b would not reduce the thickness below t at any point after bending:

$$t_b = \left[\left(\frac{pD}{20\sigma + p}\right)\left(1 + \frac{D}{2{,}5R}\right) + c\right]\frac{100}{100 - a} \text{ mm}$$

where

symbols are as defined in 4.1.1

c and σ are obtained as in 6.1.3

in general, R is to be not less than $3D$.

6.1.5 Pipes are to be seamless, and branches are to be provided by cast or stamped fittings, pipe pressing or other approved fabrications.

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Table 1.6.2 Copper and copper alloy pipes

Pipe material	Condition of supply	Specified minimum tensile strength, N/mm^2	Permissible stress, N/mm^2										
			Maximum design temperature, °C										
			50	75	100	125	150	175	200	225	250	275	300
Copper	Annealed	220	41,2	41,2	40,2	40,2	34,3	27,5	18,6	—	—	—	—
Aluminium brass	Annealed	320	78,5	78,5	78,5	78,5	78,5	51,0	24,5	—	—	—	—
90/19 Copper-nickel iron	Annealed	270	68,6	68,6	67,7	65,7	63,7	61,8	58,8	55,9	52,0	48,1	44,1
70/30 Copper-nickel	Annealed	360	81,4	79,4	77,5	75,5	73,5	71,6	69,6	67,7	65,7	63,7	61,8

6.1.6 Brazing and welding materials are to be suitable for the operating temperature and for the medium being carried.

6.1.7 Where silver brazing is used, strength is to be obtained by means of the bond in a capillary space over the whole area of the mating surfaces. A fillet braze at the back of the flange or at the face is undesirable. The alloy used for silver brazing is to contain not less than 49 per cent silver.

6.1.8 The use of copper-zinc brazing alloy is not permitted.

6.2 Heat treatment

6.2.1 Pipes which have been hardened by cold bending are to be suitably heat treated on completion of manufacture and prior to being tested by hydraulic pressure. Copper pipes are to be annealed and copper alloy pipes are to be either annealed or stress relief heat treated.

■ *Section 7* Cast iron

7.1 General

7.1.1 Grey cast iron valves and fittings will, in general, be accepted in Class III piping systems except as stated in 7.1.5. Grey cast iron valves and fittings may be accepted in the Class II steam systems referred to in Table 1.3.1 but the design pressure or temperature is not to exceed 13 bar or 220°C, respectively.

7.1.2 Spheroidal or nodular graphite iron castings for valves and fittings in Class II and Class III piping systems are to be made in a grade having a specified minimum elongation not less than 12 per cent on a gauge length of $5{,}65\sqrt{S_o}$, where S_o is the actual cross-sectional area of the test piece.

7.1.3 Proposals for the use of this material in Class I piping systems will be specially considered, but in no case is the material to be used in systems where the design temperature exceeds 350°C.

7.1.4 Where the elongation is less than the minimum required by 7.1.2, the material is, in general, to be subject to the same limitations as grey cast iron.

7.1.5 Grey cast iron is not to be used for the following:

- Valves and fittings for boiler blow-down systems and other piping systems subject to shock or vibration.
- Shell valves and fittings, *see* Ch 2,3.1.
- Valves fitted on the collision bulkhead.

■ *Section 8* Plastics

8.1 General

8.1.1 Proposals to use plastics pipes will be considered in relation to the properties of the materials, the operating conditions and the intended service and location. Special consideration will be given to any proposed service for plastics pipes not mentioned in these Rules.

8.1.2 Attention is also to be given to *Guidelines for the Application of Plastics Pipes on Ships* contained in IMO Resolution A.753(18).

8.1.3 Plastics pipes and fittings will, in general, be accepted in Class III piping systems.

8.1.4 Plastics pipes are not acceptable for oil fuel, lubricating oil or other flammable liquid systems in machinery spaces, cargo holds and other spaces of high fire risk.

8.1.5 For Class I, Class II and any Class III piping systems for which there are Rule requirements, the pipes are to be of a type which has been approved by LR.

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8.1.6 For domestic and similar services where there are no Rule requirements, the pipes need not be of a type which has been approved by LR. However, the fire safety aspects as referenced in 8.4, are to be taken into account.

8.1.7 The use of plastics pipes may be restricted by statutory requirements of the National Authority of the country in which the craft is to be registered.

8.2 Design and performance criteria

8.2.1 Pipes and fittings are to be of robust construction and are to comply with a national or other established standard, consistent with the intended use. Particulars of pipes, fittings and joints are to be submitted for consideration.

8.2.2 The design and performance criteria of all piping systems, independent of service or location, are to meet the requirements of 8.3.

8.2.3 Depending on the service and location, the fire safety aspects such as fire endurance, and fire protection coatings, are to meet the requirements of 8.4.

8.2.4 Plastics piping is to be electrically conductive when:

(a) Carrying fluids capable of generating electrostatic charges.

(b) Passing through hazardous zones and spaces, regardless of the fluid being conveyed.

Suitable precautions against the build up of electrostatic charges are to be provided in accordance with the requirements of 8.5, *see also* Pt 16, Ch 2,1.13.

8.3 Design strength

8.3.1 The strength of pipes is to be determined by hydrostatic pressure tests to failure on representative sizes of pipe. The strength of fittings is to be not less than the strength of the pipes.

8.3.2 In service, the pipe is not to be subjected to a pressure greater than the nominal internal pressure pN_i.

8.3.3 The nominal internal pressure, pN_i, of the pipe is to be determined by the lesser of the following:

$$pN_i \leq \frac{P_{st}}{4}$$

$$pN_i \leq \frac{P_{lt}}{2,5}$$

where

p_{st} = short term hydrostatic test failure pressure, in bar

p_{lt} = long term hydrostatic test failure pressure (100 000 hours), in bar.

Due to the length of time stipulated for the long term test, testing may be carried out over a reduced period of time and the results extrapolated using a suitable standard such as ASTM D2837 and ASTM D1598.

8.3.4 The nominal external pressure, pN_e of the pipe, defined as the maximum total of internal vacuum and external static pressure head to which the pipe may be subjected, is to be determined by the following:

$$pN_e \leq \frac{P_{col}}{3}$$

where

p_{col} = pipe collapse pressure in bar

The pipe collapse pressure is to be not less than 3 bar.

8.3.5 Piping is to meet the design requirements of 8.3.2 and 8.3.4 over the range of service temperature it will experience.

8.3.6 High temperature limits and pressure reductions relative to nominal pressures are to be in accordance with a recognised standard, but in each case the maximum working temperature is to be at least 20°C lower than the minimum temperature of deflection under load of the resin or plastics material without reinforcement. The minimum temperature of deflection under load is not to be less than 80°C, *see also* Ch 14,4 of the Rules for Materials.

8.3.7 Where it is proposed to use plastics piping in low temperature services, design strength testing is to be made at a temperature 10°C lower than the minimum working temperature.

8.3.8 For guidance, typical temperature and pressure limits are indicated in Tables 1.8.1 and 1.8.2. The Tables are related to water service only.

8.3.9 The selection of plastics materials for piping is to take account of other factors such as impact resistance, ageing, fatigue, erosion resistance, fluid absorption and material compatibility such that the design strength of the piping is not reduced below that required by these Rules.

8.3.10 Design strength values may be verified experimentally or by a combination of testing and calculation methods.

8.4 Fire performance criteria

8.4.1 Where plastics pipes are used in systems essential for the safe operation of the craft, or for containing combustible fluids or sea-water where leakage or failure could result in fire or in the flooding of watertight compartments, the pipes and fittings are to be of a type which have been fire endurance tested, *see also* 8.2.3.

8.4.2 Where a fire protective coating of pipes and fittings is necessary for achieving the fire endurance standards required, the coating is to be resistant to products likely to come into contact with the piping and be suitable for the intended application.

8.5 Electrical conductivity

8.5.1 Where a piping system is required to be electrically conductive for the control of static electricity, the resistance per unit length of the pipe, bends, elbows, fabricated branch pieces, etc., is not to exceed 0,1 MΩ/m, *see also* 8.2.4.

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Table 1.8.1 Typical temperature and pressure limits for thermoplastic pipes

Material	Nominal pressure, bar	Maximum permissible working pressure, bar						
		–20°C to 0°C	30°C	40°C	50°C	60°C	70°C	80°C
PVC	10		7,5	6				
	16		12	9	6			
ABS	10	7,5	7,5	7	6			
	16	12	12	10,5	9	7,5	6	
HDPE	10	7,5	6					
	16	12	9,5	6				

Abbreviations:

PVC Polyvinyl chloride
ABS Acrylonitrile – butadiene – styrene
HDPE High density polyethylene

Table 1.8.2 Typical temperature and pressure limits for glass fibre reinforced epoxy (GRE) and glass fibre reinforced polyester (GRP) pipes

Min. temperature of deflection under load of resin	Nominal pressure, bar	Maximum permissible working pressure, bar							
		–50°C to 30°C	40°C	50°C	60°C	70°C	80°C	90°C	95°C
80°C	10	10	9	7,5	6				
	16	16	14	12	9,5				
	25	16	16	16	15				
100°C	10	10	10	9,5	8,5	7	6		
	16	16	16	15	13,5	11	9,5		
	25	16	16	16	16	16	15		
135°C	10	10	10	10	10	9,5	8,5	7	6
	16	16	16	16	16	15	13,5	11	9,5
	25	16	16	16	16	16	16	16	15

8.6 Installation and construction

8.6.1 All pipes are to be adequately but freely supported. Suitable provision is to be made for expansion and contraction to take place without unduly straining the pipes.

8.6.2 Pipes may be joined by mechanical couplings or by bonding methods such as welding, laminating, adhesive bonding or other approved means.

8.6.3 Sufficient mechanical joints are to be provided to enable the pipes to be readily removed.

8.6.4 The required fire endurance level of the pipe is to be maintained in way of pipe supports, joints and fittings, including those between plastics and metallic pipes.

8.6.5 Where piping systems are arranged to pass through watertight bulkheads or decks, provision is to be made for maintaining the integrity of the bulkhead or deck by means of metallic bulkhead pieces. The bulkhead pieces are to be protected against corrosion and so constructed to be of a strength equivalent to the intact bulkhead; attention is drawn to 8.6.1. Details of the arrangements are to be submitted for approval.

8.6.6 Where a piping system is required to be electrically conductive, for the control of static electricity, continuity is to be maintained across the joints and fittings, and the system is to be earthed, *see also* Pt 16, Ch 2,1.13.

8.7 Testing

8.7.1 The hydraulic testing of pipes and fittings is to be in accordance with 14.1.2. For pipes and fittings not employing hand lay up techniques, the hydrostatic pressure test required by Ch 14,4.9 of the Rules for Materials may be replaced by testing carried out in accordance with the requirements stipulated in a National or International Standard, consistent with the intended use for which the pipe or fittings are manufactured, provided there is an effective quality system in place complying with the requirements of Ch 14,4.4 of the Rules for Materials and the testing is completed to the satisfaction of the LR Surveyor.

8.7.2 Where a piping system is required to be electrically conductive, tests are to be carried out to verify that the resistance to earth from any point in the system does not exceed 1 MΩ.

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■ *Section 9* Austenitic stainless steel

9.1 General

9.1.1 Stainless steels may be used for a wide range of services and are particularly suitable for use at elevated temperatures. For guidance on the use of austenitic steels in sea water systems, *see* 16.3.4.

9.1.2 The minimum thickness of stainless steel pipes is to be determined from the formula given in 5.1.2 or 5.1.3 using a corrosion allowance of 0,8 mm. Values of the 1,0 per cent proof stress and tensile strength of the material for use in the formula in 5.1.6 may be obtained from Table 6.5.2 in Chapter 6 of the Rules for Materials.

9.1.3 Where stainless steel is used in lubricating oil and hydraulic oil systems, the corrosion allowance may be reduced to 0 mm.

9.1.4 In no case is the thickness of stainless steel pipes to be less than that shown in Table 1.9.1.

Table 1.9.1 Minimum thickness for austenitic stainless steel pipes

Standard pipe sizes (outside diameter)			Minimum nominal thickness
mm		mm	mm
10,2	to	17,2	1,0
21,3	to	48,3	1,6
60,3	to	88,9	2,0
114,3	to	168,3	2,3
219,1			2,6
273,0			2,9
323,9	to	406,4	3,6
over	406,4		4,0

NOTE
The external diameters and thicknesses have been selected from ISO-Standard 1127:1980. Diameters and thicknesses according to other National or International Standards may be accepted.

9.1.5 Joints in stainless steel pipework may be made by any of the techniques described in 5.2 to 5.7.

9.1.6 Where pipework is butt welded, this should preferably be accomplished without the use of backing rings, in order to eliminate the possibility of crevice corrosion between the backing ring and pipe.

■ *Section 10* Aluminium alloy

10.1 General

10.1.1 The use of aluminium alloy material in Class III piping systems will be considered in relation to the fluid being conveyed and operating conditions of temperature and pressure.

10.1.2 In general, aluminium alloy may be used for air and sounding pipes for water tanks and dry spaces providing it can be shown that pipe failure will not cause a loss of integrity across watertight divisions. In craft of aluminium construction, aluminium alloy may also be used for air and sounding pipes for oil fuel, lubricating oil and other flammable liquid tanks provided the pipes are suitably protected against the effects of fire.

10.1.3 Aluminium alloy pipes are not to be used in machinery spaces or cargo holds for conveying oil fuel, lubricating oil or other flammable liquids, or for bilge suction pipework within machinery spaces.

Table 1.10.1 Minimum thickness of aluminium pipes

Nominal pipe size (mm)	Minimum wall thickness (mm)
10	1,7
15	2,1
20	2,1
25	2,8
40	2,8
50	2,8
80	3,0
100	3,0
150	3,4
200	3,8
250 and over	4,2

10.1.4 Aluminium alloy pipes are not acceptable for fire extinguishing pipes unless they are suitably protected against the effect of heat. The use of aluminium alloy with appropriate insulation will be considered when it has been demonstrated that the arrangements provide equivalent structural and integrity properties compared to steel. In open and exposed locations, where the insulation material is likely to suffer from mechanical damage, suitable protection is to be provided.

10.1.5 The minimum thickness of aluminium alloy pipes is to be not less than that shown in Table 1.10.1.

10.1.6 Design requirements for aluminium pressure pipes for design pressures greater than 7 bar will be specially considered.

10.1.7 Attention is drawn to the susceptibility of aluminium to corrosion in the region of welded connections.

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Section 11
Material certificates

11.1 Metallic materials

11.1.1 Materials for Class I and II piping systems and components as defined in Table 1.3.1, also for shell valves and fittings and fittings on the collision bulkhead are to be manufactured and tested in accordance with the Rules for Materials.

11.1.2 Ferrous castings and forgings for Class I and II piping systems are to be produced at a works approved by LR.

11.1.3 Materials for Class III piping systems are to be manufactured and tested in accordance with the requirements of acceptable National Standards.

11.1.4 The Manufacturer's materials test certificate will be accepted for all classes of piping and components in lieu of an LR materials certificate where the maximum design conditions are less than shown in Table 1.11.1.

Table 1.11.1 Maximum conditions for pipes, valves and fittings for which Manufacturer's materials test certificate is acceptable

Material	Working temperature °C	*DN* = Nominal Diameter, mm P_W = Working Pressure, bar
Carbon and low alloy steel. Stainless steel. Spheroidal or nodular cast iron.	< 300	*DN* < 50 or P_W x *DN* < 2500
Copper alloy	< 200	*DN* < 50 or P_W x *DN* < 1500

11.2 Non-metallic materials

11.2.1 Pipes and fittings intended for applications in Class I, Class II and Class III systems for which there are Rule requirements are to be manufactured in accordance with Chapter 14 of the Rules for Materials.

Section 12
Requirements for valves

12.1 General

12.1.1 The design, construction and operational capability of valves are to be in accordance with an acceptable National or International Standard appropriate for the piping system. Where valves are not in accordance with an acceptable Standard, details are to be submitted for consideration.

12.1.2 Valves are to be made of steel, cast iron, copper alloy, or other approved material suitable for the intended purpose.

12.1.3 Valves having isolation or sealing components sensitive to heat are not to be used in spaces where leakage or failure caused by fire could result in fire spread, flooding or the loss of an essential service.

12.1.4 Where valves are required to be capable of being closed remotely in the event of fire, the valves, including their control gear, are to be of steel construction or of an acceptable fire tested design.

12.1.5 Valves are to be arranged for clockwise closing and are to be provided with indicators showing whether they are open or shut unless this is readily obvious.

12.1.6 Valves are to be so constructed as to prevent the possibility of valve covers or glands being slackened back or loosened when the valves are operated.

12.1.7 Valves and cocks are to be fitted with legible nameplates, and, unless otherwise specifically mentioned in the Rules, the valves and cocks are to be fitted in places where they are at all times readily accessible.

12.1.8 Valves are to be used within their specified pressure and temperature rating for all normal operating conditions, and are to be suitable for the intended purpose.

12.1.9 Valves intended for submerged installation are to be suitable for both internal and external media. Spindle sealing is to prevent ingress of external media at the maximum external pressure head expected in service.

12.1.10 Additional requirements for shell valves are given in Ch 2,3.

12.2 Valves with remote control

12.2.1 All valves which are provided with remote control are to be arranged for local manual operation, independent of the remote operating mechanism.

12.2.2 In the case of valves which are required by the Rules to be provided with remote control, opening and/or closing of the valves by local manual means is not to render the remote control system inoperable.

12.3 Resiliently seated valves

12.3.1 Valves, having isolation or sealing components sensitive to heat, are not to be used in spaces where leakage or failure caused by fire could result in fire spread, flooding or loss of an essential service.

12.3.2 Where the valves are of the diaphragm type, they are not acceptable as shut off valves at the shell plating.

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12.3.3 Resiliently seated valves are not to be used in main or auxiliary machinery spaces as branch or direct bilge suction valves or as pump suction valves from the main bilge line (except where the valve is located in the immediate vicinity of the pump and in series with a metal seated non-return valve. The non-return valve is to be fitted on the bilge main side of the resiliently seated valve). Where they are used in other locations and within auxiliary machinery spaces having little or no fire risk they should be of an approved fire safe type and used in conjunction with a metal seated non-return valve.

12.3.4 Resiliently seated valves are not acceptable for use in fire water mains unless they have been satisfactorily fire tested.

Section 13
Requirements for flexible hoses

13.1 General

13.1.1 A flexible hose assembly is a short length of metallic or non-metallic hose normally with prefabricated end fittings ready for installation.

13.1.2 For the purpose of approval for the applications in 13.2, details of the materials and construction of the hoses, and the method of attaching the end fittings together with evidence of satisfactory prototype testing, are to be submitted for consideration.

13.1.3 The use of hose clamps and similar types of end attachments are not be used for flexible hoses in piping systems for steam, flammable media, starting air systems or for sea water systems where failure may result in flooding. In other piping systems, the use of hose clamps may be accepted where the working pressure is less than 5 bar and provided that there are two clamps at each end connection.

13.1.4 Flexible hoses are to be limited to a length necessary to provide for relative movement between fixed and flexibly mounted items of machinery/equipment or systems.

13.1.5 Flexible hoses are not to be used to compensate for misalignment between sections of piping.

13.1.6 Flexible hose assemblies are not to be installed where they may be subjected to torsional deformation (twisting) under normal operating conditions.

13.1.7 The number of flexible hoses in piping systems mentioned in this Section is to be kept to a minimum and to be limited for the purpose stated in 13.2.1.

13.1.8 Where flexible hoses are intended for conveying flammable fluids in piping systems that are in close proximity to hot surfaces, electrical installation or other sources of ignition, the risk of ignition due to failure of the hose assembly and subsequent release of fluids is to be mitigated as far as practicable by the use of screens or other suitable protection.

13.1.9 Flexible hoses are to be installed in clearly visible and readily accessible locations.

13.1.10 The installation of flexible hose assemblies is to be in accordance with the manufacturer's instructions and use limitations with particular attention to the following:

(a) Orientation.
(b) End connection support (where necessary).
(c) Avoidance of hose contact that could cause rubbing and abrasion.
(d) Minimum bend radii.

13.1.11 Flexible hoses are to be permanently marked by the manufacturer with the following details:

(a) Hose manufacturer's name or trademark.
(b) Date of manufacture (month/year).
(c) Designation type reference.
(d) Nominal diameter.
(e) Pressure rating.
(f) Temperature rating.

Where a flexible hose assembly is made up of items from different manufacturers, the components are to be clearly identified and traceable to evidence of prototype testing.

13.2 Applications for rubber hoses

13.2.1 Short joining lengths of flexible hoses complying with the requirements of this Section may be used, where necessary, to accommodate relative movement between various items of machinery connected to permanent piping systems. The requirements of this Section may also be applied to temporarily-connected flexible hoses or hoses of portable equipment.

13.2.2 Rubber or plastics hoses, with integral cotton or similar braid reinforcement, may be used in fresh and sea-water cooling systems. In the case of sea-water systems, where failure of the hoses could give rise to the danger of flooding, the hoses are to be suitably enclosed.

13.2.3 Rubber hoses, with single, double or more closely woven integral wire braid or other suitable material reinforcement, or convoluted metal pipes with wire braid protection, may be used in bilge, ballast, compressed air, fresh water, sea-water, oil fuel, lubricating oil, Class III steam, hydraulic and thermal oil systems. Flexible hoses of plastics materials for the same purposes, such as Teflon or Nylon, which are unable to be reinforced by incorporating closely woven integral wire braid are to have suitable material reinforcement as far as practicable. Where rubber or plastics hoses are used for oil fuel supply to burners, the hoses are to have external wire braid protection in addition to the integral wire braid. Flexible hoses for use in steam systems are to be of metallic construction.

13.2.4 Flexible hoses are not to be used in high pressure fuel oil injection systems.

13.2.5 The requirements in this Section for flexible hose assemblies are not applicable to hoses intended to be used in fixed fire extinguishing systems.

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13.3 Design requirements

13.3.1 Flexible hose assemblies are to be designed and constructed in accordance with recognised National or International Standards acceptable to LR.

13.3.2 Flexible hoses are to be complete with approved end fittings in accordance with manufacturer's specification. End connections which do not have flanges are to comply with 5.8 as applicable and each type of hose/fitting combination is to be subject to prototype testing to the same standard as that required by the hose with particular reference to pressure and impulse tests.

13.3.3 Flexible hose assemblies intended for installation in piping systems where pressure pulses and/or high levels of vibration are expected to occur in service, are to be designed for the maximum expected impulse peak pressure and forces due to vibration. The tests required by 13.4 are to take into consideration the maximum anticipated in-service pressures, vibration frequencies and forces due to installation.

13.3.4 Flexible hose assemblies constructed of non-metallic materials intended for installation in piping systems for flammable media, and sea-water systems where failure may result in flooding, are to be of fire-resistant type. Fire resistance is to be demonstrated by testing to ISO 15540 and ISO 15541.

13.3.5 Flexible hose assemblies are to be suitable for the intended location and application, taking into consideration ambient conditions, compatibility with fluids under working pressure and temperature conditions consistent with the manufacturer's instructions and any other applicable requirements in the Rules.

13.4 Testing

13.4.1 Acceptance of flexible hose assemblies is subject to satisfactory prototype testing. Prototype test programmes for flexible hose assemblies are to be submitted by the manufacturer and are to be sufficiently detailed to demonstrate performance in accordance with the specified standards.

13.4.2 For a particular hose type complete with end fittings, the tests, as applicable, are to be carried out on different nominal diameters for pressure, burst, impulse and fire resistance in accordance with the requirements of the relevant standard. The following standards are to be used as applicable:

- ISO 6802 – *Rubber and plastics hoses and hose assemblies – Hydraulic pressure impulse test without flexing*.
- ISO 6803 – *Rubber and plastics hoses and hose assemblies – Hydraulic pressure impulse test with flexing*.
- ISO 15540 – *Ships and marine technology – Fire resistance of hose assemblies – Test methods*.
- ISO 15541 – *Ships and marine technology – Fire resistance of hose assemblies – Requirements for test bench*.
- ISO 10380 – *Pipework – Corrugated metal hoses and hose assemblies*.

Other Standards may be accepted where agreed by LR.

13.4.3 All flexible hose assemblies are to be satisfactorily prototype burst tested to an international standard (*see* Note) to demonstrate they are able to withstand a pressure of not less than four times the design pressure without indication of failure or leakage.

NOTE:
The International Standards, e.g. EN or SAE for burst testing of non-metallic hoses, require the pressure to be increased until burst without any holding period at 4 x Maximum Working Pressure.

■ *Section 14* Hydraulic tests on pipes and fittings

14.1 Hydraulic tests before installation on board

14.1.1 All Class I and II pipes and their associated fittings are to be tested by hydraulic pressure. Further, all steam, feed, compressed air and oil fuel pipes, together with their fittings, are to be similarly tested where the design pressure is greater than 7 bar. The test is to be carried out after completion of manufacture and before installation on board and, where applicable, before insulating and coating.

14.1.2 The test pressure is to be 1,5 times the design pressure, as defined in 4.2.

14.1.3 Shell valves and valves on the collision bulkhead are to be tested by hydraulic pressure to 1,5 times the nominal pressure rating of the valve at ambient temperature.

14.2 Testing after assembly on board

14.2.1 Oil fuel piping is to be tested by hydraulic pressure, after installation on board, to 1,5 times the design pressure but in no case to less than 3,5 bar.

14.2.2 Where pipes specified in 14.1.1 are butt welded together during assembly on board, they are to be tested by hydraulic pressure in accordance with the requirements of 14.2.1 after welding. The pipe lengths may be insulated, except in way of the joints made during installation and before the hydraulic test is carried out.

14.2.3 The hydraulic test required by 14.2.2 may be omitted provided non–destructive tests by ultrasonic or radiographic methods are carried out on the entire circumference of all butt welds with satisfactory results.

14.2.4 Where ultrasonic tests have been carried out, the manufacturer is to provide the Surveyor with a signed statement confirming that ultrasonic examination has been carried out by an approved operator and that there were no indications of defects which could be expected to have prejudicial effect on the service performance of the piping.

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■ *Cross-reference*

See also Ch 2,2.4 for testing after installation.

■ *Section 15* Requirements for small craft which are not required to comply with the HSC Code

15.1 General

15.1.1 The requirements of Sections 1 to 13 apply, except where modified by this Section.

15.2 Details to be submitted

15.2.1 Details of oil fuel storage tanks over 0,25 m^3, where these do not form part of the structure of the craft, are to be submitted.

15.2.2 Design details of the components listed in 2.1.6 are not required.

15.3 Materials

15.3.1 Materials for which no provision is made in this Chapter may be accepted provided that they comply with an acceptable National or International Standard and are satisfactorily tested as may be considered necessary. Manufacturer's material test certificates are not required unless the material is of unusual or special specification.

15.3.2 Shell valves and cocks, inlet chests, distance pieces and other sea connections are to be of approved ductile material. Due attention is to be paid to the compatibility of the material with that of the shell. Ordinary grey cast iron is not acceptable.

15.4 Aluminium alloy

15.4.1 Proposals for the use of aluminium alloy pipes in bilge systems in machinery spaces will be considered, provided that a single failure in any section of the pipe does not render the whole system inoperable.

15.4.2 Aluminium alloy pipes may be used for fire-fighting systems outside machinery spaces in locations of low fire risk.

15.5 Plastics pipes

15.5.1 IMO Resolution A.753(18) *Guidelines for the Application of Plastics Pipes on Ships* does not apply.

15.5.2 The requirements of 8.1.5 do not apply but where plastics pipes are used for bilge and cooling water services they are to be of a type which has been approved by LR. However, fire endurance testing is not required.

15.5.3 Where plastics pipes are used in bilge systems in machinery spaces, a single failure in any section of the pipe is not to render the whole system inoperable.

15.6 Copper and copper alloys

15.6.1 Where copper and copper alloy pipes are in accordance with an acceptable National Standard/ Specification which is applicable to the intended service or media, Table 1.6.1 need not be applied.

■ *Section 16* Guidance notes on metal pipes for water services

16.1 General

16.1.1 These guidance notes, except where it is specifically stated, apply to sea-water piping systems.

16.1.2 In addition to the selection of suitable materials, careful attention should be given to the design details of the piping system and the workmanship in fabrication, construction and installation of the pipework in order to obtain maximum life in service.

16.2 Materials

16.2.1 Materials used in sea water piping systems include:

- Galvanised steel.
- Stainless and duplex steel, *see also* 16.3.4.
- Steel pipes lined with rubber, plastics or stoved coatings.
- Copper.
- 90/10 copper-nickel-iron.
- 70/30 copper-nickel.
- Aluminium alloy.
- Aluminium brass.
- Bronze.
- Approved plastics.

16.2.2 Selection of materials should be based on:

- The ability to resist general and localised corrosion, such as pitting, impingement attack and cavitation throughout all the flow velocities likely to be encountered;
- Compatibility with the other materials in the system, such as valve bodies and casings, in order to minimise bimetallic corrosion;
- The ability to resist selective corrosion, e.g. dezincification of brass, dealuminification of aluminium brass and graphitisation of cast iron;
- The ability to resist stress corrosion and corrosion fatigue, and;
- The amenability to fabrication by normal practices.

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16.3 Steel pipes

16.3.1 Steel pipes should be protected against corrosion and protective coatings should be applied on completion of all fabrication, i.e. bending, forming and welding of the steel pipes.

16.3.2 Welds should be free from lack of fusion and crevices. The surfaces should be dressed to remove slag and spatter and this should be done before coating. The coating should be continuous around the ends of the pipes and on the faces of flanges.

16.3.3 Galvanising the bores and flanges of steel pipes as protection against corrosion is common practice, and is recommended as the minimum protection for pipes in sea-water systems, including those for bilge and ballast service.

16.3.4 Austenitic stainless steel pipes are not recommended for salt water services in polluted waters or where stagnant conditions exist. Steel of specification 316L or better may give satisfactory service in water circulating systems for clean sea water.

16.3.5 Rubber lined pipes are effective against corrosion and suitable for higher water velocities. The rubber lining should be free from defects, e.g. discontinuities, pinholes, etc., and it is essential that the bonding of the rubber to the bore of the pipe and flange face is sound. Rubber linings should be applied by firms specialising in this form of protection.

16.3.6 The foregoing comments on rubber lined pipes also apply to pipes lined with plastics.

16.3.7 Stove coating of pipes as protection against corrosion should only be used where the pipes will be efficiently protected against mechanical damage.

16.4 Copper and copper alloy pipes

16.4.1 Copper pipes are particularly susceptible to perforation by corrosion/erosion and should only be used for low water velocities and where there is no excessive local turbulence.

16.4.2 Aluminium brass and copper-nickel-iron alloy pipes give good service in reasonably clean sea-water. For service with polluted river or harbour waters, copper-nickel-iron alloy pipes with at least 10 per cent nickel are preferable. Alpha-brasses, i.e. those containing 70 per cent or more copper, must be inhibited effectively against dezincification by suitable additions to the composition. Alpha beta-brasses, i.e. those containing less than 70 per cent copper, should not be used for pipes and fittings.

16.4.3 New copper alloy pipes should not be exposed initially to polluted water. Clean sea-water should be used at first to allow the metals to develop protective films. If this is not available the system should be filled with inhibited town mains water.

16.5 Flanges

16.5.1 Where pipes are exposed to sea-water on both external and internal surfaces, flanges should be made, preferably, of the same material. Where sea-water is confined to the bores of pipes, flanges may be of the same material or of less noble metal than that of the pipe.

16.5.2 Fixed or loose type flanges may be used. The fixed flanges should be attached to the pipes by fillet welds or by capillary silver brazing. Where welding is used, the fillet weld at the back should be a strength weld and that in the face, a seal weld.

16.5.3 Inert gas shielded arc welding is the preferred process but metal arc welding may be used on copper-nickel-iron alloy pipes.

16.5.4 Mild steel flanges may be attached by argon arc welding to copper-nickel-iron pipes and give satisfactory service, provided that no part of the steel is exposed to the sea-water.

16.5.5 Where silver brazing is used, strength should be obtained by means of the bond in a capillary space over the whole area of the mating surfaces. A fillet braze at the back of the flange or at the face is undesirable. The alloy used for silver brazing should contain not less than 49 per cent silver.

16.5.6 The use of a copper-zinc brazing alloy is not permitted.

16.6 Water velocity

16.6.1 Water velocities should be carefully assessed at the design stage and the materials of pipes, valves, etc., selected to suit the conditions.

16.6.2 The water velocity in copper pipes should not exceed 1 m/s.

16.6.3 The water velocity in the pipes of the materials below should normally be not less than about 1 m/s in order to avoid fouling and subsequent pitting, but should not be greater than the following:

Galvanised steel	3,0 m/s
Aluminium brass	3,0 m/s
90/10 copper-nickel-iron	3,5 m/s
70/30 copper-nickel	5,0 m/s.

16.7 Fabrication and installation

16.7.1 Attention should be given to ensuring streamlined flow and reducing entrained air in the system to a minimum. Abrupt changes in the direction of flow, protrusions in the bores of pipes and other restrictions of flow should be avoided. Branches in continuous flow lines should be set at a shallow angle to the main pipe, and the junction should be smooth.

16.7.2 Pipe bores should be smooth and clean.

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16.7.3 Jointing should be flush with the bore surfaces of pipes and misalignment of adjacent flange faces should be reduced to a minimum.

16.7.4 Pipe bends should be of as large a radius as possible, and the bore surfaces should be smooth and free from puckering at these positions. Any carbonaceous films or deposits formed on the bore surfaces during the bending processes should be carefully removed. Organic substances are not recommended for the filling of pipes for bending purposes.

16.7.5 The position of supports should be given special consideration in order to minimise vibration and ensure that excessive bending moments are not imposed on the pipes.

16.7.6 Systems should not be left idle for long periods, especially where the water is polluted.

16.7.7 Strainers should be provided at the inlet to sea-water systems.

16.8 Metal pipes for fresh water services

16.8.1 Mild steel or copper pipes are normally satisfactory for service in fresh water applications. Hot fresh water, however, may promote corrosion in mild steel pipes unless the hardness and pH of the water are controlled.

16.8.2 Water with a slight salt content should not be left stagnant for long periods in mild steel pipes. Low salinity and the limited supply of oxygen in such conditions promote the formation of black iron oxide, and this may give rise to severe pitting. Where stagnant conditions are unavoidable, steel pipes should be galvanised, or pipes of suitable non-ferrous material used.

16.8.3 Copper alloy pipes should be treated to remove any carbonaceous films or deposits before the tubes are put into service.

16.8.4 Brass fittings and flanges in contact with water should be made of an alpha-brass effectively inhibited against dezincification by suitable additions to the composition.

16.8.5 Aluminium brass has been widely used as material for heat exchanger and condenser tubes, but its use in 'once through' systems is not recommended since, under certain conditions, it is prone to pitting and cracking.

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Section

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■ *Section 1* General

1.1 Application

1.1.1 The requirements of Sections 1 to 11 of this Chapter apply to all craft which are required to satisfy the relevant design and construction regulations of the HSC Code.

1.1.2 Special requirements for multi-hull craft are given in Section 12.

1.1.3 Additional requirements for Passenger (B) Craft are given in Section 13.

1.1.4 Requirements for craft of less than 24 m not required to comply with the HSC Code are given in Section 14.

1.1.5 Requirements for craft of 24 m or more not required to comply with the HSC Code are given in Section 15.

1.1.6 Additional requirements for yachts that are 500 gt or more are given in Section 16.

1.1.7 The requirements for air cushion vehicles are given in Section 17.

1.1.8 In addition to the requirements of this Chapter, attention should be given to any relevant statutory requirements of the National Authority of the country in which the craft is to be registered.

1.1.9 Consideration will be given to special cases or to arrangements which are equivalent to those required by these Rules.

1.2 Details to be submitted

1.2.1 The plans and information detailed in Chapter 1 are to be submitted before commencement of work.

1.3 Watertight and non-watertight decks

1.3.1 For the purpose of this Section, a non-watertight deck covered by a weathertight structure may be taken as equivalent to a watertight deck. For definitions of the terms watertight and weathertight, *see* Pt 3, Ch 1.

■ *Section 2* Construction and installation

2.1 Installation

2.1.1 All pipes for essential services are to be secured in position to prevent chafing or lateral movement.

2.1.2 Long or heavy lengths of pipe are to be supported by bearers so that no undue load is carried by pipe connections or pumps and fittings to which they are attached.

2.2 Provision for expansion

2.2.1 Suitable provision for expansion is to be made, where necessary, in each range of pipes.

2.2.2 Where expansion pieces are fitted, arrangements are to be provided to protect against over extension and compression. The adjoining pipes are to be suitably aligned, supported, guided and anchored. Where necessary, expansion pieces of the bellows type are to be protected against mechanical damage.

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2.3 Miscellaneous requirements

2.3.1 All pipes situated in cargo spaces, chain lockers or other positions where they are liable to mechanical damage are to be efficiently protected.

2.3.2 So far as practicable, pipelines, including exhaust pipes from engines, are not to be routed in the vicinity of switchboards or other electrical appliances in positions where the drip or escape of fluids, gas or steam from joints or fittings could cause damage to the electrical installation. Where it is not practicable to comply with these requirements, drip trays or shields are to be provided as found necessary.

2.4 Testing after installation

2.4.1 After installation on board, all steam, hydraulic, compressed air and other piping systems covered by Ch 1,2.1.3 together with associated fittings which are under internal pressure, are to be subjected to a running test at the intended maximum working pressure.

■ *Section 3* Shell valves and fittings (other than those on scuppers and sanitary discharges)

3.1 Construction

3.1.1 All sea inlet and overboard discharge pipes are to be fitted with valves or cocks secured direct to the shell or to fabricated water boxes attached to the shell.

3.1.2 Distance pieces of short rigid construction and made of approved material may be fitted between the valve and shell. The thickness of such pipes is to be equivalent to shell thickness.

3.1.3 The arrangements are to be such that the section of pipe immediately inboard of the shell valve may be removed without affecting the watertight integrity of the hull.

3.1.4 The valves are to be in accordance with the general requirements for valves given in Ch 1,12.

3.1.5 Shell valves are to be manufactured from non-heat sensitive materials and tested in accordance with the appropriate requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials). Special consideration will be given to the use of other materials on craft of aluminium or composite construction. Where the valves are manufactured from spheroidal or nodular graphite cast iron they are to be produced at a works approved by Lloyd's Register (hereinafter referred to as 'LR'). Grey cast iron is not acceptable.

3.1.6 Shell valves are to be fitted in accessible positions and are to be capable of being operated from positions which are readily accessible in case of influx of water to the compartment.

3.1.7 Valve hand wheels and cock handles are to be suitably retained on the spindles. Means are to be provided to indicate whether the valve or cock is open or closed.

3.1.8 The scantlings of valves and valve stools fitted with steam or compressed air clearing connections are to be suitable for the maximum pressure to which the valves and stools may be subjected.

3.1.9 Shell valves are to be hydraulically tested before installation in accordance with Ch 1,14.

■ *Section 4* Bilge pumping and drainage systems

4.1 General

4.1.1 Arrangements are to be made for draining all watertight compartments other than those intended for permanent storage of fluids. Where drainage is not considered necessary, drainage arrangements may be omitted provided the safety of the craft is not impaired.

4.1.2 Pumping arrangements are to be provided having suctions and means of drainage so arranged that any water within any watertight compartment of the craft or any watertight section of any compartment, can be pumped out through at least one suction under all possible conditions of list and trim in the maximum assumed damage condition.

4.1.3 The bilge pumping system is to be designed to prevent water flowing from one watertight compartment to another.

4.1.4 The necessary valves for controlling the bilge suctions are to be capable of being operated from above the watertight deck.

4.1.5 Where a bilge main is not fitted and a compartment is served by a fixed submersible pump in accordance with Section 10, then an additional emergency means of pumping out the compartment is to be provided, *see* Section 6.

4.1.6 Small compartments may be drained by individual hand pump suctions.

4.1.7 The intactness of watertight bulkheads is not to be impaired by the fitting of scuppers discharging to machinery spaces or tunnels from adjacent compartments situated below the highest watertight deck.

4.1.8 Any unattended space for which bilge pumping arrangements are required is to be provided with a bilge level alarm.

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4.1.9 Where it is intended to carry flammable or toxic liquids in enclosed spaces, the bilge system shall be designed to prevent pumping of such liquids through piping and pumps in machinery or other spaces where a source of ignition may exist.

■ *Section 5* Bilge drainage of machinery spaces with a propulsion prime mover

5.1 General

5.1.1 The bilge drainage arrangements are to comply with Section 4, except that the arrangements are to be such that any water which may enter this compartment can be pumped out through at least two bilge suctions under all possible conditions of list and trim in the maximum assumed damage condition.

5.1.2 Where a bilge main is fitted, one of the suctions referred to in 5.1.1 is to be a branch bilge suction i.e. a suction connected to the bilge main. The second bilge suction is to be a direct bilge suction as detailed in 8.6.

5.1.3 Where a bilge main is not fitted, the branch bilge suction referred to in 5.1.2 may be replaced by a suction from a submersible bilge pump. The second bilge suction is to be either a second submersible bilge pump or a direct bilge suction as detailed in 8.6.

5.1.4 The emergency bilge drainage arrangements detailed in Section 6 are to be provided where either 5.1.2 or 5.1.3 applies.

5.2 Additional bilge suctions

5.2.1 Additional bilge suctions may be required for the drainage of wells or other recesses.

■ *Section 6* Emergency bilge drainage

6.1 Emergency bilge drainage

6.1.1 In machinery spaces the emergency bilge suction required by 4.1.5 and 5.1.4 is to be led to the largest available power pump, which is not a bilge, propulsion or oil pump, from a suitable low level in the machinery space and is to be fitted with a screw-down non-return valve with an extended spindle and hand wheel situated above the floor plating.

6.1.2 As an alternative to 6.1.1, or in compartments other than machinery spaces, the emergency bilge pumping arrangements may be provided by a portable submersible self-priming pump of capacity not less than that required by 8.3.5.

6.1.3 The pump referred to in 6.1.2 together with its suction and delivery hoses is to be stored in a locker marked 'For emergency use only' and is to be available for immediate use. Arrangements to facilitate safe handling under adverse conditions are to be provided. If the pump is electrically driven it is to be supplied from the emergency switchboard.

■ *Section 7* Size of bilge suction pipes

7.1 Bilge main

7.1.1 Where a bilge main is fitted, its internal diameter d_m is to be not less than that required by the following formula:

$$d_m = 1{,}68\sqrt{L\,(B + D)} + 25 \text{ mm}$$

where

B = breadth of craft, in metres

D = moulded depth to the watertight deck, in metres

L = length of craft, in metres

The actual internal diameter of the bilge main may be rounded off to the nearest pipe size of a recognised standard, but d_m is in no case to be less than 50 mm.

7.2 Branch bilge suctions

7.2.1 The diameter d_b of branch bilge suction pipes is to be not less than that required by the following formula:

$$d_b = 2{,}15\sqrt{C\,(B + D)} + 12{,}5 \text{ mm}$$

where

B and D are as defined in 7.1.1

C = length of compartment, in metres.

The actual internal diameter of branch bilge suction pipes may be rounded off to the nearest pipe size of a recognised standard, but d_b is in no case to be less than 25 mm.

■ *Section 8* Pumps on bilge service

8.1 Number of pumps

8.1.1 For craft fitted with a bilge main, at least two power bilge pumping units are to be provided. One of these units may be worked from the main engines and the other is to be independently driven.

8.1.2 Each unit may consist of one or more pumps connected to the main bilge line, provided that their combined capacity is not less than that required by 8.3.2.

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8.1.3 A bilge ejector in combination with a high pressure sea-water pump may be accepted as a substitute for an independent bilge pump as required by 8.1.1.

8.1.4 For craft fitted with fixed submersible bilge pumps, one pump is to be provided for each watertight compartment.

8.1.5 For the bilge pumping requirements for multi-hull craft, *see* Section 12.

8.2 General service pumps

8.2.1 The bilge pumping units or pumps required by 8.1 may also be used for ballast, fire or general service duties of an intermittent nature, but not for pumping fuel or other flammable liquids. These pumps are to be immediately available for bilge duty when required. For the use of bilge pumping units for fire-extinguishing duties, *see* Part 17.

8.3 Capacity of pumps

8.3.1 Each bilge pumping unit is to be connected to the bilge main and is to be capable of giving a speed of water through the Rule size of bilge main of not less than 2 m/s.

8.3.2 To achieve the flow velocity required by 8.3.1, the capacity Q of each bilge pumping unit or bilge pump is to be not less than that required by the following formula:

$$Q = \frac{5{,}75}{10^3} d_m^2 \text{ m}^3\text{/hour}$$

where

d_m is as defined in 7.1.1.

Q = Rule minimum capacity, in m^3/hour.

8.3.3 Where one bilge pumping unit is of slightly less than Rule capacity, the deficiency may be made good by an excess capacity of the other unit. In general, the deficiency is to be limited to 30 per cent.

8.3.4 Where fixed submersible bilge pumps are fitted, the total capacity Q_t of the pumps is to be not less than that required by the following formula:

$$Q_t = \frac{13{,}8}{10^3} d_m^2 \text{ m}^3\text{/hour}$$

where

d_m is as defined in 7.1.1.

Q_t = Rule minimum total capacity, in m^3/hour.

8.3.5 The capacity Q_n of each submersible bilge pump is to be not less than that required by the following formula:

$$Q_n = \frac{Q_t}{(N-1)} \text{ m}^3\text{/hour}$$

where

N = number of fixed submersible pumps

Q_t is as defined in 8.3.4

Q_n = Rule minimum submersible pump capacity, in m^3/hour

Q_n is in no case to be less than 8 m^3/hour.

8.4 Self-priming pumps

8.4.1 All power pumps which are essential for bilge services are to be of the self-priming type, unless an approved central priming system is provided for these pumps.

8.5 Pump connections

8.5.1 The connections at the bilge pumps are to be such that one unit may continue in operation when the other unit is being opened up for overhaul.

8.5.2 Pumps required for essential services are not to be connected to a common suction or discharge chest or pipe unless the arrangements are such that the working of any pumps so connected is unaffected by the other pumps being in operation at the same time.

8.6 Direct bilge suctions

8.6.1 The direct bilge suction in the machinery space required by 5.1.2 and referred to in 5.1.3 is to be led to an independent power pump, and the arrangements are to be such that the direct suction can be used independently of the main bilge line suctions.

8.6.2 The machinery space direct bilge suction is not to be of a diameter less than that required for the machinery space branch bilge suction and arranged as detailed in 8.6.1.

■ *Section 9* Bilge main arrangements and materials

9.1 General

9.1.1 Bilge mains, branch bilge suctions and bilge overboard discharge arrangements within machinery spaces are to be of steel or other equivalent material.

9.1.2 Where bilge suction pipework outside machinery spaces is manufactured from material sensitive to heat then the arrangements are to be such that pipe failure in one compartment will not render the bilge suction pipework in another compartment inoperable.

9.1.3 Bilge pipework is to be mounted inboard such that in the event of the maximum assumed damage the pipework will remain intact.

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9.2 Prevention of communication between compartments

9.2.1 The arrangement of valves, cocks and their connections is to be such as to prevent the possibility of one watertight compartment being placed in communication with another, or of dry cargo spaces, machinery spaces or other dry compartments being placed in communication with the sea or with tanks. For this purpose, screw-down non-return valves are to be provided in the following fittings:

- Bilge valve distribution chests
- Bilge suction hose connections, whether fitted direct to the pump or on the main bilge line.
- Direct bilge suctions and bilge pump connections to the main bilge line.

9.3 Isolation of bilge system

9.3.1 Bilge suction pipes are to be entirely separate from sea inlet pipes or from pipes which may be used for filling or emptying spaces where water or oil is carried.

9.4 Bilge suction strainers

9.4.1 The open ends of bilge suctions are to be enclosed in strum boxes having perforations of not more than 10 mm diameter, whose combined area is not less than twice that required for the suction pipe. The boxes are to be so constructed that they can be cleared without breaking any joint of the suction pipe.

■ *Section 10*
Submersible bilge pump arrangements

10.1 General

10.1.1 Arrangements are to be such that at least two automatic non-return devices are fitted between the overboard discharge and the watertight space being served by the pump.

10.1.2 One of these devices is to be an automatic non-return valve situated at or near the shell and the other may be a pipework loop taken up to the highest practicable point below the watertight deck. The arrangements are to be effective in the maximum assumed damaged condition.

■ *Section 11*
Air, overflow and sounding pipes

11.1 Air pipes

11.1.1 Air pipes are to be fitted to all tanks, cofferdams, tunnels and other compartments which are not fitted with alternative ventilation arrangements.

11.1.2 Air pipes are to be fitted at the opposite end of the tank to that which the filling pipes are placed and/or at the highest part of the tank. Where the tank top is of unusual or irregular profile, special consideration will be given to the number and position of the air pipes.

11.1.3 Air pipes to oil fuel, lubricating oil and other tanks containing flammable liquids which are located in or pass through compartments of high fire risk or on open deck are to be of steel or other equivalent material.

11.2 Termination of air pipes

11.2.1 Air pipes to double bottom tanks, deep tanks extending to the shell plating, or tanks which can be run up from the sea are to be led to above the watertight deck. Air pipes to oil fuel tanks, cofferdams and all tanks which can be pumped up are to be led to the open.

11.2.2 Air pipes from storage tanks containing lubricating or hydraulic oil may terminate in the machinery space, provided that the open ends are so situated that issuing oil cannot come into contact with electrical equipment or heated surfaces.

11.2.3 The open ends of air pipes to oil fuel tanks are to be situated where no danger will be incurred from issuing oil vapour when the tank is being filled.

11.2.4 The location and arrangement of air pipes for oil fuel service, settling and lubricating oil tanks are to be such that in the event of a broken vent pipe, this does not directly lead to the risk of ingress of sea-water or rainwater.

11.3 Gauze diaphragms

11.3.1 The open ends of air pipes to oil fuel tanks are to be fitted with a wire gauze diaphragm of non-corrodible material which can be readily removed for cleaning or renewal.

11.3.2 Where wire gauze diaphragms are fitted at air pipe openings, the area of the opening through the gauze is to be not less than the cross-sectional area required for the pipe, *see* 11.6.

11.4 Air pipe closing appliances

11.4.1 Closing appliances fitted to tank air pipes are to be of an automatic opening type which will allow the free passage of air or liquid to prevent the tanks being subjected to a pressure or vacuum greater than that for which they are designed, *see also* Pt 3, Ch 4,12.3.

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11.4.2 Air pipe closing devices are to be of a type acceptable to LR and are to be tested in accordance with a National or International Standard recognised by LR. The flow characteristic of the closing device is to be determined using water, *see* 11.6.1.

11.4.3 Wood plugs and other devices which can be secured closed are not to be fitted at the outlets.

11.4.4 Air pipe automatic closing devices shall be so designed that they will withstand both ambient conditions as indicated in Pt 9, Ch 1, 4.4 and designed working conditions, and be suitable for use at inclinations up to and including ± 40°.

11.4.5 Air pipe automatic closing devices shall be constructed to allow inspection of the closure and the inside of the casing, as well as changing the seals.

11.4.6 Efficient ball or float seating arrangements are to be provided for the closures. Bars, cages or other devices are to be provided to prevent the ball or float from contacting the inner chamber in its normal state, and made in such a way that the ball or float is not damaged when subjected to liquid impact due to a tank being overfilled.

11.4.7 Air pipe automatic closing devices are to be self-draining.

11.4.8 The clear area through an air pipe closing device in the open position shall be at least equal to the area of the inlet.

11.4.9 In the case of air pipe closing devices of the float type, suitable guides are to be provided to ensure unobstructed operation under all working conditions of heel and trim.

11.4.10 The maximum allowable tolerances for wall thickness of floats should not exceed ±10 per cent of thickness.

11.4.11 The inner and the outer chambers of an automatic air pipe head are to be of a minimum thickness of 6 mm.

11.4.12 Casings of air pipe closing devices are to be of approved metallic materials adequately protected against corrosion.

11.4.13 For galvanised steel air pipe heads, the zinc coating is to be applied by the hot method and the thickness is to be 70 to 100 microns.

11.4.14 For areas of the head susceptible to erosion (e.g. those parts directly subjected to ballast water impact when the tank is being pressed up, for example the inner chamber area above the air pipe, plus an overlap of 10° or more either side) an additional harder coating should be applied. This is to be an aluminium bearing epoxy, or other equivalent coating, applied over the zinc.

11.5 Nameplates

11.5.1 Nameplates are to be affixed to the upper ends of all air and sounding pipes.

11.6 Size of air pipes

11.6.1 For every tank which can be filled by on-board pumps, the total cross-sectional area of the air pipes and the air pipe closing devices is to be such that when the tank is overflowing at the maximum pumping capacity available for the tank, it will not be subjected to a pressure greater than that for which it is designed.

11.6.2 In all cases, whether a tank is filled by on-board pumps or other means, the total cross-sectional area of the pipes is to be not less than 25 per cent greater than the effective area of the respective filling pipe.

11.6.3 Air pipes are to be generally not less than 38 mm bore. In the case of small gravity filled tanks smaller bore pipes may be accepted but in no case is the bore to be less than 25 mm.

11.7 Overflow pipes

11.7.1 For all tanks which can be pumped up, overflow pipes are to be fitted where:

(a) The total cross-sectional area of the air pipes is less than that required by 11.6.

(b) The pressure head corresponding to the height of the air pipe is greater than that for which the tank is designed.

11.7.2 In the case of oil fuel tanks, lubricating oil tanks and other tanks containing flammable liquids, the overflow pipe is to be led to an overflow tank of adequate capacity or to a storage tank having a space reserved for overflow purposes. Suitable means is to be provided to indicate when overflowing is occurring.

11.7.3 Overflow pipes are to be self draining under normal conditions of trim.

11.7.4 Where overflow sight glasses are provided, they are to be in a vertical dropping line and designed such that the oil does not impinge on the glass. The glass is to be of heat resisting quality and be adequately protected from mechanical damage. Overflow sight glasses are not permitted in oil fuel systems for craft required to comply with the HSC Code.

11.8 Combined air and overflow systems

11.8.1 Where a combined air or overflow system is fitted, the arrangement is to be such that in the event of any one of the tanks being bilged, the other tanks cannot be flooded from the sea through combined air pipes or the overflow main. For this purpose, it will normally be necessary to lead the overflow pipe to a point above the waterline in the maximum assumed damage condition.

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11.8.2 Where a common overflow main is provided, the main is to be sized to allow any two tanks connected to that main to overflow simultaneously.

11.9 Sounding arrangements

11.9.1 Provision is to be made for sounding all tanks and the bilges of those compartments which are not at all times readily accessible. The soundings are to be taken as near the suction pipes as practicable.

11.9.2 Sounding devices of an approved type (i.e. level gauge or remote reading level device) may be used in lieu of sounding pipes.

11.9.3 Bilges of compartments which are not at all times readily accessible are to be provided with sounding pipes.

11.9.4 Where fitted, sounding pipes are to be as straight as practicable, and if curved to suit the structure of the craft, the curvature is to be sufficiently easy to permit the ready passage of the sounding rod or chain.

11.9.5 Striking plates of adequate thickness and size are to be fitted under open ended sounding pipes.

11.9.6 Where slotted sounding pipes having closed ends are employed, the closing plugs are to be of substantial construction.

11.9.7 Sounding pipes are to be not less than 32 mm bore.

11.10 Termination of sounding pipes

11.10.1 Except as permitted by 11.11, sounding pipes are to be led to positions above the bulkhead deck which are at all times accessible and, in the case of oil fuel tanks, cargo oil tanks and lubricating oil tanks, the sounding pipes are to be led to safe positions on the open deck.

11.10.2 For closing requirements, *see also* Pt 3, Ch 4,12.3.1.

11.11 Short sounding pipes

11.11.1 In machinery spaces, where it is not practicable to extend sounding pipes as mentioned in 11.10 short sounding pipes extending to readily accessible positions above the platform may be fitted.

11.11.2 Short sounding pipes are not permitted in machinery spaces for tanks containing oil fuel or other flammable oils used in power transmission systems, control and activating systems and heating systems, except as permitted by 11.13.6.

11.11.3 Short sounding pipes may be fitted to tanks used for the storage, distribution and utilisation of lubricating oil in machinery spaces. These sounding pipes are to be fitted with cocks having parallel plugs with permanently attached handles located such that, on being released, they automatically close the cocks.

11.12 Elbow sounding pipes

11.12.1 In passenger craft, elbow sounding pipes are not permitted.

11.12.2 Elbow sounding pipes are not to be used for deep tanks, unless the elbows and pipes are situated within closed cofferdams or within tanks containing similar liquids. They may, however, be fitted to other tanks and may be used for sounding bilges, provided that it is not practicable to lead them direct to the tanks or compartments, and subject to any subdivision and damage stability requirements that may apply.

11.12.3 The elbows are to be of heavy construction and adequately supported.

11.13 Sounding arrangements for oil fuel, lubricating oil and other flammable liquids

11.13.1 Safe and efficient means of ascertaining the amount of oil in any storage tank are to be provided.

11.13.2 For oil fuel, lubricating oil and other flammable liquids, closed sounding devices are preferred. Design details of such devices are to be submitted and they are to be tested after fitting on board, to the satisfaction of the Surveyors.

11.13.3 If closed sounding devices are fitted, failure of the device or over filling of the tank is not to result in the release of tank contents. In passenger craft and yachts that are 500 gt or more, such means are not to require penetration below the top of the tank.

11.13.4 Where sounding pipes are used they are not to terminate in any space where risk of ignition or spillage from the sounding pipe might arise. In particular they are not to terminate in public spaces or crew accommodation. Additionally for oil fuel tanks they are not to terminate in machinery spaces. Terminations are to be provided with a suitable means of closure and provision to prevent spillage during refuelling/refilling operations.

11.13.5 Where gauge glasses are used they are to be of the flat type of heat resisting quality, adequately protected from mechanical damage and fitted with self closing valves at the lower ends and at the top ends if these are connected to the tanks below the maximum liquid level.

11.13.6 In yachts and service craft which are not required to comply with the HSC Code, short sounding pipes extending to well-lighted, readily accessible positions above the platform may be fitted in machinery spaces and tunnels. Sounding pipes are to be fitted with cocks having parallel plugs with permanently attached handles located such that, on being released, they automatically close the cocks.

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11.13.7 For yachts that are 500 gt or more, where short sounding pipes serve tanks containing oil fuel, an additional sounding device of approved type is to be fitted. In addition, a small diameter self-closing test cock is to be fitted below the cock mentioned in 11.13.6, in order to ensure that the sounding pipe is not under pressure from oil fuel before opening up the sounding pipe.

Section 12
Requirements for multi-hull craft

12.1 General

12.1.1 The requirements of Sections 2 to 11 apply to multi-hull craft except where modified by the requirements of this Section.

12.2 Drainage of raft void spaces

12.2.1 Arrangements are to be provided for venting, sounding and draining raft void spaces generally as required by Sections 1 to 11.

12.2.2 Where the raft void space is located above the water line in the maximum assumed damage condition then it may be drained directly overboard through scuppers fitted with non-return valves.

12.2.3 Raft void spaces which are not located above the water line in the worst expected damage condition are to be provided with pumping arrangements in accordance with Section 4.

12.3 Size of bilge suction pipes

12.3.1 Where a bilge main is fitted in each hull, its internal diameter d_m is to be not less than that required by the following formula:

$$d_m = 1{,}68\sqrt{L\,(B + D)} + 25 \text{ mm}$$

where

B = breadth of a hull in metres

D = moulded depth to the watertight deck, in metres

L = length of craft, in metres

The actual internal diameter of the bilge main may be rounded off to the nearest pipe size of a recognised standard, but d_m is in no case to be less than 50 mm.

12.3.2 The diameter d_b of branch bilge suction pipes is to be not less than that required by the following formula:

$$d_b = 2{,}15\sqrt{C\,(B + D)} + 12{,}5 \text{ mm}$$

where

C = length of compartment, in metres

B and D are as defined in 12.3.1

The actual internal diameter of branch bilge suction pipes may be rounded off to the nearest pipe size of a recognised standard, but d_b is in no case to be less than 25 mm.

12.4 Capacity and number of pumps on bilge main services

12.4.1 Each power bilge pump should be capable of pumping water through the required size of bilge main at a speed of not less than 2 m/s.

12.4.2 To achieve the flow velocity required by 12.4.1, the capacity Q of each bilge pumping unit or bilge pump is to be not less than that required by the following formula:

$$Q = \frac{5{,}75}{10^3} d_m^2 \text{ m}^3\text{/hour}$$

where

d_m is as defined in 12.3.1.

12.4.3 Not less than two power bilge pumping units taking suction from the bilge main in each hull are to be provided.

12.4.4 Where the bilge system in each hull is entirely separate then two bilge pumping units in each hull are to be provided.

12.4.5 Where fixed submersible bilge pumps are fitted, the total capacity Q_t of the pumps in each hull is to be not less than that required by the following formula:

$$Q_t = \frac{13{,}8}{10^3} d_m^2 \text{ m}^3\text{/hour}$$

where

d_m is as defined in 12.3.1.

12.4.6 The capacity Q_n of each submersible pump is to be not less than that required by the following formula:

$$Q_n = \frac{Q_t}{(N - 1)} \text{ m}^3\text{/hour}$$

where

N = number of fixed submersible pumps in each hull

Q_t is as defined in 12.4.5

Q_n is in no case to be less than 8 m^3/hour.

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Section 13
Additional requirements for Passenger (B) Craft

13.1 Bilge pumping arrangements

13.1.1 At least three power bilge pumping units are to be fitted connected to the bilge main, one of which may be driven by the propulsion machinery.

13.1.2 For multi-hull craft the bilge pumping units are to be capable of taking suction from the bilge main in any hull of the craft.

13.1.3 The arrangements are to be such that at least one power bilge pump is to be available for use in all flooding conditions which the craft is required to withstand as follows:

(a) one of the required bilge pumps is to be an emergency pump of a reliable submersible type having a source of power located above the waterline after the craft has sustained the maximum assumed damage; or

(b) the bilge pumps and their sources of power are to be so distributed throughout the length of the craft that at least one pump in an undamaged compartment will be available.

13.1.4 Alternatively fixed submersible bilge pumps may be provided in accordance with the requirements of 8.3.4 for monohull craft or 12.4.5 for multihull craft.

13.1.5 Distribution boxes, cocks and valves in connection with the bilge pumping system are to be so arranged that, in the event of flooding, one of the bilge pumps may take suction from any compartment.

13.1.6 Damage to a pump or its pipe connecting to the bilge main is not to put the bilge system out of action.

13.1.7 When in addition to the main bilge pumping system an emergency bilge pumping system is provided, it is to be independent of the main system and so arranged that a pump is capable of operating in any compartment under the maximum assumed flooding conditions. In that case only the valves necessary for the operation of the emergency system need be capable of remote operation.

13.1.8 All cocks and valves referred to in 13.1.5 which can be remotely operated are to have their controls at their place of operation clearly marked and are to be provided with means to indicate whether they are open or closed.

Section 14
Requirements for small craft which are not required to comply with the HSC Code

14.1 General

14.1.1 These requirements replace Sections 1 to 10, 12 and 13 of this Chapter. In general the requirements of Section 11 are to be complied with, however 11.4.1 and 11.9.3 do not apply.

14.1.2 Bilge and cooling water pipework systems are to be of an approved material, *see* Ch 1,15.

14.2 Shell valves and fittings

14.2.1 All sea inlet and overboard discharges are to be provided with shut off valves or cocks arranged in positions where they are readily accessible at all times.

14.2.2 Where valves, cocks, inlet chests, distance pieces and other sea connections are made of steel or other approved materials of low corrosion resistance, they are to be suitably protected against wastage.

14.3 Fittings for steel and aluminium hulls

14.3.1 All suction and discharge valves and cocks secured direct to the plating are to be fitted with spigots passing through the plating, but spigots on the valves and cocks may be omitted if these fittings are attached to pads or distance pieces which themselves form spigots in way of the plating.

14.4 Fittings for wood and glass reinforced plastics hulls

14.4.1 The openings in the shell or planking are to have suitably reinforced areas or pads into which the attached fittings are to be spigoted.

14.4.2 Valves or fittings are to be secured with an external ring under the bolt heads. The ring is to be of copper nickel alloy, bronze, dezincification resistant brass or other material approved for use in sea-water.

14.4.3 Valves or cocks up to 50 mm bore may be attached to spigot pieces or hull fittings having an external collar and internal nut.

14.4.4 Valves or cocks over 50 mm bore are to be flanged and attached as per 14.4.2.

14.5 Bilge pumping arrangements

14.5.1 An efficient bilge pumping system is to be fitted having suctions and means of drainage so arranged that any water which may enter any compartment can be pumped overboard.

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14.5.2 The system is to be tested on completion of the craft to ensure that all limber holes are free and that under normal conditions of trim any bilge water can drain to an appropriate suction.

14.5.3 The arrangement of pumps, valves, cocks, pipes and sea connections is to be such as to prevent water entering the craft accidentally or the possibility of one water-tight compartment being placed in communication with another.

14.5.4 Readily accessible strum boxes are to be fitted at the open ends of tail pipes.

14.5.5 The perforations in the strum boxes are to be not greater than 10 mm diameter and the combined area is to be not less than twice that required for the bilge suction pipe.

14.5.6 Where a collision bulkhead is fitted, the fore peak dry space is to be drained either by a branch suction to the main bilge line or by a manual pump. Alternatively, it may be drained to the adjacent compartment by means of a self closing drain cock which is to be readily accessible under all conditions.

14.5.7 Where a bilge main is fitted, the internal diameter d of the main and the branch suction pipes is to be not less than that required by the following formula:

$$d = \frac{L}{1,2} + 25 \text{ mm}$$

where

L = length of craft, in metres.

14.6 Pumps on bilge service and their connections

14.6.1 Not less than one power pump and one manual bilge pump are to be provided. Both pumps are to be arranged to take suction from the bilge main or suction valve chest as applicable.

14.6.2 The power driven pumps may be used for other services such as deck washing, fire extinguishing or standby cooling water duty but not for pumping oil fuel or other flammable liquids.

14.6.3 The total capacity Q_t of the bilge pumps is to be not less than required by the following formula:

$$Q_t = 1,5\,(d - 25) - 6,7 \text{ m}^3\text{/hour}$$

where

d is as defined in 14.5.7

Q_t is in no case to be less than 3 m^3/hour.

14.6.4 A reduction in capacity of one pump may be permitted provided the deficiency is made good by an excess capacity of the other pump or by an additional pump. In no case is this deficiency to be more than 40 per cent of the Rule capacity.

14.6.5 Pumps on bilge service are to be of the self-priming type.

14.6.6 The bilge pumps are to be connected to a common bilge line provided with a branch connection to each compartment.

14.6.7 A non-return valve is to be fitted between each bilge pump and the bilge main.

14.6.8 Non-return valves are to be fitted in each branch bilge suction from the main bilge line.

14.6.9 Power pumps may be driven by the main engine, an auxiliary engine or by an electric motor.

14.6.10 The power pump is to be provided with a suction enabling it to pump directly from the engine space in addition to the suction from the main bilge line. This direct bilge suction is to be controlled by a screw down non-return valve or equivalent.

14.6.11 Manual bilge pumps are to be capable of being operated from readily accessible positions above the waterline.

14.6.12 As an alternative to fitting a bilge main, individual submersible pumps may be fitted. In this case the arrangements are to be in accordance with the requirements of Sections 8, 10 and 12 of this Chapter, as applicable.

■ *Section 15*
Requirements for yachts and service craft of 24 m or greater in length, which are not required to comply with the HSC Code

15.1 General

15.1.1 The requirements of Sections 1, 2, 3, 11 and 12 of this Chapter are generally applicable. The remaining Sections 4 to 10 of this Chapter concerning the requirements for bilge pumping and drainage systems are replaced by the requirements given in 15.2 to 15.28.

15.2 Bilge systems and pumping

15.2.1 Where it is intended to carry vehicles with fuel in their tanks having a flashpoint less than 60°C for their own propulsion and having re-fuelling facilities for such vehicles or when only providing re-fuelling facilities, a separate bilge system is to be provided.

15.2.2 The bilge system is to be designed to prevent pumping of flammable liquids through piping and pumps in machinery, accommodation or any other spaces where a source of ignition may exist.

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15.3 Drainage of compartments, other than machinery spaces

15.3.1 All craft are to be provided with efficient pumping plant having the suctions and means for drainage so arranged that any water within any compartment of the craft, or any watertight section of any compartment, can be pumped out through at least one suction when the craft is on an even keel and is either upright or has a list of not more than 5°. For this purpose, wing suctions will generally be necessary, except in short, narrow compartments where one suction can provide effective drainage under the above conditions.

15.3.2 In the case of dry compartments, the suctions required by 15.3.1 are, except where otherwise stated, to be branch bilge suctions, i.e. suctions connected to a main bilge line.

15.4 Tanks and cofferdams

15.4.1 All tanks (including double bottom tanks), whether used for water ballast, oil fuel or liquid cargoes, are to be provided with suction pipes, led to suitable power pumps, from the after end of each tank.

15.4.2 In general, the drainage arrangements are to be in accordance with 15.3. However, where the tanks are divided by longitudinal watertight bulkheads or girders into two or more tanks, a single suction pipe, led to the after end of each tank, will normally be acceptable.

15.4.3 Similar drainage arrangements are to be provided for cofferdams, except that the suctions may be led to the main bilge line.

15.5 Fore and after peaks

15.5.1 Where the peaks are used as tanks, a power pump suction is to be led to each tank, except in the case of small tanks used for the carriage of domestic fresh water, where hand pumps may be used.

15.5.2 Where the peaks are not used as tanks, and main bilge line suctions are not fitted, drainage of both peaks may be effected by hand pump suctions, provided that the suction lift is well within the capacity of the pumps. Drainage of the after peak may be effected by means of a self-closing cock fitted in a well lighted and readily accessible position.

15.5.3 Pipes piercing the collision bulkhead are to be fitted with suitable valves secured to the bulkhead. The valves are to be operable from above the freeboard deck.

15.6 Spaces above fore peaks, after peaks and machinery spaces

15.6.1 Provision is to be made for the drainage of the chain locker and watertight compartments above the fore peak tank by hand or power pump suctions.

15.6.2 Steering gear compartments or other small enclosed spaces situated above the after peak tank are to be provided with suitable means of drainage, either by hand or power pump bilge suctions.

15.6.3 The compartments referred to in 15.6.2 may be drained by scuppers of not less than 38 mm bore, discharging to the tunnel or machinery space and fitted with self-closing cocks situated in well lighted and visible positions.

15.7 Maintenance of integrity of bulkheads

15.7.1 The intactness of the machinery space bulkheads, and of tunnel plating required to be of watertight construction, is not to be impaired by the fitting of scuppers discharging to machinery space or tunnels from adjacent compartments which are situated below the bulkhead deck.

15.7.2 No drain valve or cock is to be fitted to the collision bulkhead. Drain valves or cocks are not to be fitted to other watertight bulkheads if alternative means of drainage are practicable.

15.8 Bilge drainage of machinery space

15.8.1 The bilge drainage arrangements in the machinery space are to comply with 15.3 except that the arrangements are to be such that any water which may enter this compartment can be pumped out through at least two bilge suctions when the craft is on an even keel, and is either upright or has a list of not more than 5°. One of these suctions is to be a branch bilge suction, i.e. a suction connected to the main bilge line, and the other is to be a direct bilge suction, i.e. a suction led direct to an independent power pump.

15.9 Separate machinery spaces

15.9.1 Where the machinery space is divided by watertight bulkheads to separate the auxiliary engine room(s) from the main engine room, the bilge drainage arrangements for the auxiliary engine room(s) are to be the same as for compartments, other than machinery spaces, referred to in 15.3.1.

15.9.2 In addition to the requirements of 15.9.1, at least one direct suction, led to an independent power pump, is to be fitted in each compartment.

15.10 Machinery space with double bottom

15.10.1 Where the double bottom extends the full length of the machinery space and forms bilges at the wings, it will be necessary to provide one branch and one direct bilge suction at each side.

15.10.2 Where the double bottom plating extends the full length and breadth of the compartment, one branch bilge suction and one direct bilge suction are to be led to each of two bilge wells, situated one at each side.

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15.10.3 Where there is no double bottom and the rise of floor is not less than 5°, one branch and one direct bilge suction are to be led to accessible positions as near to the centreline as practicable.

15.11 Machinery space – Emergency bilge drainage

15.11.1 In addition to the bilge suctions detailed in 15.8 and 15.9, an emergency bilge suction is to be provided in each main machinery space. This suction is to be led to the main cooling water pump from a suitable low level in the machinery space and is to be fitted with a screw-down non-return valve having the spindle so extended that the hand wheel is not less than 460 mm above the bottom platform.

15.11.2 Where two or more cooling water pumps are provided, each capable of supplying cooling water for normal power, only one pump need be fitted with an emergency bilge suction.

15.11.3 Where main cooling water pumps are not suitable for bilge pumping duties, the emergency bilge suction is to be led to the largest available power pump, which is not a bilge pump.

15.11.4 Emergency bilge suction valve nameplates are to be marked 'For emergency use only'.

15.12 Sizes of bilge suction pipes

15.12.1 The diameter, d_m, of the main bilge line is to be not less than that required by the following formula, to the nearest 5 mm, but in no case is the diameter to be less than that required for any branch bilge suction:

$$d_m = 1{,}68\sqrt{L\,(B + D)} + 25 \text{ mm}$$

where

d_m = internal diameter of main bilge line, in mm
B = greatest moulded breadth of craft, in metres
D = moulded depth to bulkhead deck, in metres
L = Rule length of craft in metres.

15.12.2 The diameter d_b, of branch bilge suction pipes to cargo and machinery spaces is to be not less than required by the following formula, to the nearest 5 mm, but in no case is the diameter of any suction to be less than 50 mm:

$$d_b = 2{,}15\sqrt{C\,(B + D)} + 25 \text{ mm}$$

where

d_b = internal diameter of branch bilge suction, in mm
C = length of compartment, in metres
B and D are as defined in 15.12.1.

15.12.3 The direct bilge suctions in the machinery space are not to be of a diameter less than that required for the main bilge line.

15.12.4 For sizes of emergency bilge suctions, *see* 15.11.

15.13 Distribution chest branch pipes

15.13.1 The area of each branch pipe connecting the bilge main to a distribution chest is to be not less than the sum of the areas required by the Rules for the two largest branch bilge suction pipes connected to that chest, but need not be greater than that required for the main bilge line.

15.14 Pumps on bilge service and their connections

15.14.1 At least two power bilge pumping units are to be provided in the machinery space. One of these units may be worked from the main engines and the other is to be independently driven.

15.14.2 Each unit may consist of one or more pumps connected to the main bilge line, provided that their combined capacity is adequate.

15.14.3 A bilge ejector in combination with a high pressure sea-water pump may be accepted as a substitute for an independent bilge pump as required by 15.14.1.

15.14.4 Special consideration will be given to the number of pumps for small craft and, in general, if there is a class notation restricting a small craft to harbour or river service, a hand pump may be accepted in lieu of one of the bilge pumping units.

15.15 General service pumps

15.15.1 The bilge pumping units, or pumps, required by 15.14 may also be used for ballast, fire or general service duties of an intermittent nature, but they are to be immediately available for bilge duty when required.

15.16 Capacity of pumps

15.16.1 Each bilge pumping unit is to be connected to the main bilge line and is to be capable of giving a speed of water through the Rule size of main bilge pipe of not less than 122 m/min.

15.16.2 The capacity of each bilge pumping unit or bilge pump is to be not less than required by the following formula:

$$Q = \frac{5{,}75}{10^3} d_m^2$$

where

d_m = Rule internal diameter of main bilge line, in mm
Q = capacity, in m^3/hour.

15.16.3 Where one bilge pumping unit is of slightly less than Rule capacity, the deficiency may be made good by an excess capacity of the other unit. In general, the deficiency is to be limited to 30 per cent.

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15.17 Self-priming pumps

15.17.1 All power pumps which are essential for bilge services are to be of the self-priming type, unless an approved central priming system is provided for these pumps. Details of this system are to be submitted.

15.17.2 Cooling water pumps having emergency bilge suctions need not be of the self-priming type.

15.18 Pump connections

15.18.1 The connections at the bilge pumps are to be such that one unit may continue in operation when the other unit is being opened up for overhaul.

15.18.2 Pumps required for essential services are not to be connected to a common suction or discharge chest or pipe unless the arrangements are such that the working of any pumps so connected is unaffected by the other pumps being in operation at the same time.

15.19 Direct bilge suctions

15.19.1 The direct bilge suctions in the machinery space are to be led to independent power pumps, and the arrangements are to be such that these direct suctions can be used independently of the main bilge line suctions.

15.20 Main bilge line suctions

15.20.1 Suctions from the main bilge line, i.e. branch bilge suctions, are to be arranged to draw water from any hold or machinery compartment within the craft, excepting small spaces such as those mentioned in 15.5 and 15.6 where manual pump suctions are accepted, and are not to be of smaller diameter than that required by the formula in 15.12.2.

15.21 Prevention of communication between compartments

15.21.1 The arrangement of valves, cocks and their connections is to be such as to prevent the possibility of one watertight compartment being placed in communication with another, or of dry cargo spaces, machinery spaces or other dry compartments being placed in communication with the sea or with tanks. For this purpose, screw-down non-return valves are to be provided in the following fittings:

- Bilge valve distribution chests.
- Bilge suction hose connections, whether fitted directly to the pump or on the main bilge line.
- Direct bilge suctions and bilge pump connections to main bilge line.

15.22 Isolation of bilge system

15.22.1 Bilge pipes which are required for draining cargo or machinery spaces are to be entirely distinct from sea inlet pipes or from pipes which may be used for filling or emptying spaces where water or oil is carried. This does not, however, exclude a bilge ejection connection, a connecting pipe from a pump to its suction valve chest, or a deep tank suction pipe suitably connected through a change-over device to a bilge, ballast or oil line.

15.23 Machinery space suctions – Mud boxes

15.23.1 Suctions for bilge drainage in machinery spaces and tunnels, other than emergency suctions, are to be led from easily accessible mud boxes fitted with straight tail pipes to the bilges and having covers secured in such a manner as to permit their being expeditiously opened or closed. Strum boxes are not to be fitted to the lower ends of these tail pipes or to the emergency bilge suctions.

15.24 Hold suctions – Strum boxes

15.24.1 The open ends of bilge suctions in holds and other compartments outside machinery spaces and tunnels are to be enclosed in strum boxes having perforations of not more than 10 mm diameter, whose combined area is not less than twice that required for the suction pipe. The boxes are to be so constructed that they can be cleared without breaking any joint of the suction pipe.

15.25 Tail pipes

15.25.1 The distance between the foot of all bilge tail pipes and the bottom of the bilge well is to be adequate to allow a full flow of water and to facilitate cleaning.

15.26 Location of fittings

15.26.1 Bilge valves, cocks and mud boxes are to be fitted at, or above, the machinery space platforms.

15.26.2 Where relief valves are fitted to pumps having sea connections, these valves are to be fitted in readily visible positions above the platform. The arrangements are to be such that any discharge from the relief valves will also be readily visible.

15.27 Bilge pipes in way of double bottom tanks

15.27.1 Bilge suction pipes are not to be led through double bottom tanks if it is possible to avoid doing so.

15.27.2 Bilge pipes which have to pass through these tanks are to have a minimum wall thickness of 6,3 mm. The thickness of pipes made from material other than steel will be specially considered.

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15.27.3 Expansion bends, not glands, are to be fitted to these pipes within the tanks, and the pipes are to be tested, after installation, to the same pressure as the tanks through which they pass.

15.28 Hold bilge non-return valves

15.28.1 Where non-return valves are fitted to the open ends of bilge suction pipes in cargo holds in order to decrease the risk of flooding, they are to be of an approved type which does not offer undue obstruction to the flow of water.

Section 16
Additional requirements for yachts that are 500 gt or more

16.1 General

16.1.1 Yachts that are 500 gt or more are to comply with Section 15 of this Chapter and in addition the following requirements.

16.2 Location of bilge pumps and bilge main

16.2.1 At least three power bilge pumps are to be provided, one of which may be operated from the main engines. Wherever practicable they are to be located in separate watertight compartments which will not readily be flooded by the same damage. If the engines are in two or more watertight compartments, the bilge pumps are to be distributed throughout these compartments so far as possible.

16.2.2 Where compliance with 16.2.1 is impractical, two independently driven bilge pumps may be accepted provided they are located in separate watertight compartments. If both pumps are necessarily located in the machinery space then one is to be of the submersible type with its source of power located above the bulkhead deck.

16.2.3 The bilge main is to be so arranged that no part is situated nearer the side of the craft than *B*/5, measured at right angles to the centreline at the level of the deepest sub-division load line, where *B* is the breadth of the craft.

16.2.4 Where any bilge pump or its pipe connection to the bilge main is situated outboard of the *B*/5 line, then a non-return valve is to be provided in the pipe connection at the junction with the bilge main.

16.2.5 Each independent bilge pump is to have a direct bilge suction from the space in which it is situated, but not more than two such suctions are required in any one space. The suctions are to be arranged such that each side of the space is fitted with at least one suction.

16.3 Prevention of communication between compartments in the event of damage

16.3.1 Provision is to be made to prevent the compartment served by any bilge suction pipe being flooded, in the event of the pipe being severed, or otherwise damaged by collision or grounding in any other compartment. For this purpose, where any part of a branch bilge pipe is situated outboard of the *B*/5 line or in a duct keel, a non-return valve is to be fitted to the pipe in the compartment containing the open end.

16.4 Arrangement and control of bilge valves

16.4.1 Distribution boxes, valves and cocks in connection with the bilge pumping arrangements are to be so arranged that, in the event of flooding, one of the bilge pumps may be operative on any compartment.

16.4.2 Where there is only one system of pipes common to all pumps, the arrangements are to be such that if the machinery space or other compartment is flooded then it is possible to operate the necessary valves and cocks in order to take suction from that compartment. For this purpose it may be necessary to arrange for remote control of the bilge suction valves from above the bulkhead deck.

16.4.3 Where, in addition to the main bilge pumping system, an emergency bilge pumping system is provided, it is to be independent of the main system and so arranged that a pump is capable of operating on any compartment under flooding conditions. In this case, only the valves and cocks necessary for the operation of the emergency system need to be capable of being operated from above the bulkhead deck.

16.4.4 All valves and cocks mentioned in 16.4.2 which can be operated from above the bulkhead deck are to have their controls at their place of operation clearly marked and provided with means to indicate whether they are open or closed.

16.5 Cross flooding arrangements

16.5.1 Where divided deep tanks or side tanks are provided with cross flooding arrangements to limit the angle of heel after side damage, the arrangements are to be self-acting where practicable. In any case, where controls to cross flooding fittings are provided, they are to be operable from above the bulkhead deck.

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■ *Section 17* Requirements for Air Cushion Vehicles

17.1 General

17.1.1 At least three copies of the following diagrammatic plans are to be submitted together with a general description of each system, indicating operating pressures and temperatures, etc., safety devices incorporated and means of protection against corrosion and contamination:

- Oil fuel.
- Lubricating oil.
- Hydraulic and pneumatic systems.
- Pumping arrangements for draining and trimming.
- Air filtering to power units.

17.1.2 Reference is to be made to the *Guidance Notes and Requirements for the Classification of Air Cushion Vehicles (ACV) 1970*.

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Section

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11 **Requirements for small craft which are not required to comply with the HSC Code**

■ *Section 1* Application

1.1 Applicability of requirements

1.1.1 The requirements of Sections 2 to 8 of this Chapter apply to piping systems on mono-hull and multi-hull craft except where modified by Sections 9 to 11 as applicable.

1.1.2 Special requirements for multi-hull craft are given in Section 9.

1.1.3 These requirements satisfy the relevant design and construction requirements of the HSC Code. They are also applicable to yachts and service craft of more than 24 m not required to comply with the Code.

1.1.4 Requirements for Passenger (A) Craft are given in Section 10.

1.1.5 Requirements for small craft not required to comply with the HSC Code are given in Section 11.

1.1.6 In addition to the requirements of this Chapter, attention is to be given to any relevant statutory requirements of the National Authority of the country in which the craft is to be registered.

■ *Section 2* General requirements

2.1 General

2.1.1 The maximum working pressure in any part of a fluid system is not to be greater than the design pressure.

2.1.2 Where the design pressure of a system component, such as a valve or a fitting, is less than that for the pipe or tubing, the system pressure is to be limited to the lowest of the component design pressures. Every system which may be exposed to pressures higher than the design pressure is to be safeguarded by appropriate relief devices.

2.1.3 Materials used in piping systems are to be compatible with the fluid conveyed and due regard given to the risk of fire. Non-metallic piping material may be permitted in certain systems, provided the integrity of the hull and watertight decks and bulkheads is maintained.

2.1.4 The design of pipework systems is to be in accordance with the requirements of Chapter 1.

■ *Section 3* Oil fuel storage

3.1 Flash point

3.1.1 The flash point (closed cup test) of oil fuel for use in craft classed for unrestricted service is in general to be not less than 60°C. For emergency generator engines, a flash point of not less than 43°C is permissible.

3.1.2 Oil fuel with a flash point lower than 60°C may be used in craft intended for restricted service where it can be demonstrated that the temperature of machinery spaces will always be 10°C below the flash point of the oil fuel.

3.1.3 The use of oil fuel with a flash point below 43°C is not recommended. However, oil fuel with a lower flash point, but not lower than 35°C, may be used in gas turbines only subject to compliance with the provisions specified in Section 5.

3.1.4 Proposals for the use or carriage of oil fuel with a lower flash point will be specially considered.

3.2 Oil fuel storage arrangements

3.2.1 Tanks containing oil fuel are to be separated from passenger, crew and baggage compartments by vapour-proof enclosures or cofferdams which are suitably ventilated and drained.

3.2.2 Oil fuel tanks are not to be located in or adjacent to major fire hazard areas.

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3.2.3 Oil fuel is not to be carried forward of the area for which public spaces or crew accommodation are permitted.

3.2.4 No oil fuel tank is to be situated where spillage or leakage therefrom can constitute a hazard by falling on heated surfaces.

3.2.5 Safe and efficient means of ascertaining the amount of oil fuel contained in any oil fuel tank is to be provided, *see also* Ch 2,11.9 to 11.12.

3.2.6 Oil fuel tanks are to be provided with self-closing valves or cocks for draining water from the bottom of the tanks.

3.2.7 As far as practicable, all parts of the oil fuel system containing heated oil under pressure exceeding 2 bar are not to be placed in a concealed position such that defects and leakage cannot be readily observed. The machinery spaces in way of such parts of the oil fuel system are to be adequately illuminated.

3.2.8 Oil fuel tanks are to be provided with oil-tight drip trays of sufficient capacity having suitable drainage arrangements.

3.2.9 In general oil fuel tanks are not to be used for carriage of water ballast. Where this is unavoidable the fuel transfer system is to be isolated from the ballast system and either oily water separating equipment is to be installed, or discharge to shore facilities provided, in accordance with the requirements of the *International Convention for the Prevention of Pollution from Ships* in force.

3.3 Oil fuel storage arrangements for yachts and service craft of 24 m or greater in length, which are not required to comply with the HSC Code

3.3.1 Oil fuel tanks are normally to be located outside machinery spaces and other areas of major fire hazard.

3.3.2 Where structural tanks are located adjacent to machinery spaces they are to be arranged such that the area of the tank common with the machinery space is kept to a minimum. In craft constructed of aluminium or other heat sensitive material the tanks are to be suitably protected against the effect of fire in the machinery space.

3.3.3 Where free standing tanks are fitted in machinery spaces they are to be of steel or equivalent material and positioned in an oil tight drip tray of ample size having suitable drainage arrangements to a spill oil tank.

3.3.4 For yachts that are 500 gt or more, free standing oil fuel tanks are not to be fitted in machinery spaces, *see* Pt 17, Ch 3,3.17.3.

3.3.5 The requirements of 3.2.4 to 3.2.8 are to be complied with. Where free standing tanks are fitted they are to comply with the requirements of 11.3.1 to 11.3.3.

3.4 Unattended machinery

3.4.1 Where machinery is fitted with automatic or remote controls so that under normal operating conditions it does not require any manual intervention by the operators, the requirements of 3.4.2 to 3.4.5 apply.

3.4.2 Where daily service tanks are filled automatically or by remote control, means are to be provided to prevent overflow spillages.

3.4.3 Other equipment which treats flammable liquid automatically, such as oil fuel purifiers, are to have arrangements to prevent spillage of the liquid through overflow or malfunction of seals.

3.4.4 Alarms are to be provided for purifier broken water seal and high oil inlet temperature.

3.4.5 Where daily service oil fuel tanks or settling tanks are fitted with heating arrangements, a high temperature alarm is to be provided if the flash point of the oil can be exceeded. This alarm is to be separate from the temperature control system.

3.4.6 Oil fuel service tanks are to be provided with high and low level alarms. Where a common overflow tank is fitted, a high level alarm in the common overflow tank may be accepted.

3.4.7 Oil and gas dual-fired systems for boilers and engines are to be provided with indication to show which fuel is in use.

■ *Section 4* Oil fuel systems

4.1 Oil fuel supply to main and auxiliary engines

4.1.1 Two or more filters are to be fitted in the oil fuel supply lines to the main and auxiliary engines, and the arrangements are to be such that any filter can be cleaned without interrupting the supply of filtered oil fuel to the engines.

4.2 Booster pumps

4.2.1 Where an oil fuel booster pump is fitted, which is essential to the operation of the main engine, a standby pump is to be provided.

4.2.2 The standby pump is to be connected ready for immediate use, but where two or more main engines are fitted, each with its own pump, a complete spare pump may be accepted provided that it is readily accessible and can easily be installed.

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4.3 Fuel valve cooling pumps

4.3.1 Where pumps are provided for fuel valve cooling, the arrangements are to be in accordance with 4.2.1 and 4.2.2.

4.4 Transfer pumps

4.4.1 Where a power driven pump is necessary for transferring oil fuel, a standby pump is to be provided and connected ready for use. The standby pump may be a manual pump. Alternatively, emergency connections may be made to another suitable power driven pump.

4.5 Control of pumps

4.5.1 All independently driven oil fuel transfer and pressure pumps are to be capable of being stopped locally and from a position outside of the space in which they are located. The remote stop position is always to be accessible in the event of fire occurring in the space in which these pumps are located.

4.6 Relief valves on pumps

4.6.1 All pumps which are capable of developing a pressure exceeding the design pressure of the system are to be provided with relief valves. Each relief valve is to be in closed circuit, i.e. arranged to discharge back to the suction side of the pump and to effectively limit the pump discharge pressure to the design pressure of the system.

4.7 Pump connections

4.7.1 Valves or cocks are to be interposed between the pumps and the suction and discharge pipes, in order that any pump may be shut off for opening up and overhauling.

4.8 Low pressure pipes

4.8.1 Transfer, suction and other low pressure oil pipes and all pipes passing through oil storage tanks are to be suitable for a working pressure of not less than 7 bar.

4.9 Valves on deep tanks and their control arrangements

4.9.1 Every oil fuel suction pipe from a storage, settling or daily service tank situated above the double bottom, and every oil fuel levelling pipe, is to be fitted with a valve or cock secured to the tank.

4.9.2 In machinery spaces such valves and cocks are to be capable of being closed locally and from positions outside these spaces which will always be accessible in the event of fire occurring in these spaces. Instructions for closing the valves or cocks are to be indicated at the valves and cocks and at the remote control positions.

4.9.3 In the case of tanks of less than 0,5 m^3, consideration will be given to the omission of remote controls for craft not required to comply with the HSC Code.

4.9.4 Every oil fuel suction pipe which is led into the machinery spaces, from a deep tank outside these spaces, is to be fitted in the machinery space with a valve controlled as in 4.9.2 except where the valve on the tank is already capable of being closed from an accessible position above the bulkhead deck.

4.9.5 Where the filling pipes to deep oil tanks are not connected to the tanks near the top, they are to be provided with non-return valves at the tanks or with valves or cocks fitted and controlled as in 4.9.2.

4.10 Filling arrangements

4.10.1 Filling stations are to be isolated from other spaces and are to be efficiently drained and ventilated.

4.10.2 Provision is to be made against over-pressure in the filling pipelines. Any relief valve fitted for this purpose is to discharge to an overflow tank or other safe position.

4.11 Precautions against fire

4.11.1 Pipes, valves and couplings conveying flammable fluids are to be installed, screened or otherwise suitably protected, to avoid spray or leakages onto hot surfaces, into machinery air intakes, or other sources of ignition such as electrical equipment. The number of joints in such systems is to be kept to a minimum.

■ *Section 5* Low flash point fuels

5.1 General

5.1.1 For craft having oil fuel with a flash point below 43°C the arrangements for the storage, distribution and utilisation of the oil fuel are to be such that the safety of the craft and persons on board is preserved, having regard to fire and explosion hazards. The arrangements are to comply with Sections 3, 4 and 5.1.2 to 5.1.6.

5.1.2 Tanks for the storage of such oil fuel are to be located outside any machinery space and at a distance of not less than 760 mm inboard from the shell and bottom plating, and from decks and bulkheads.

5.1.3 The spaces in which oil fuel tanks are located are to be mechanically ventilated using exhaust fans providing not less than six air changes per hour. The fans are to be such as to avoid the possibility of ignition of flammable gas air mixtures. Suitable wire mesh guards are to be fitted over inlet and outlet ventilation openings. The outlets for such exhausts are to discharge to a safe position.

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5.1.4 A fixed vapour detection system is to be installed in each space through which oil fuel lines pass, with alarms provided at a continuously manned control station.

5.1.5 Safe and efficient means of ascertaining the amount of oil fuel contained in any tank is to be provided. Gauge glasses are not to be used. Other means of ascertaining the amount of oil fuel contained in any tank may be permitted if such means do not require penetration below the top of the tank, and providing their failure or overfilling of the tanks will not permit the release of oil fuel.

5.1.6 Vessel to shore oil fuel connections are to be of closed type and suitably grounded during bunkering operations.

5.1.7 Air pipes shall discharge to a safe position and terminate with flame arresters in accordance with MSC/Circ. 677.

■ *Section 6* Lubricating/hydraulic oil systems

6.1 Lubricating oil arrangements

6.1.1 The arrangements for the storage, distribution and utilisation of oil used in pressure lubrication systems in machinery spaces and, whenever practicable, in auxiliary machinery spaces are to comply with the provisions of 3.2 (except 3.2.2), 3.4 and 4.9 (except 4.9.3).

6.1.2 Tanks containing lubricating oil located within major fire hazard areas are to be of steel or other equivalent material.

6.1.3 Where lubricating oil tanks have a capacity of less than 0,5 m^3, consideration will be given to relaxing the requirements for remote controls to be fitted.

6.1.4 Where the lubricating oil for main propelling engines is circulated under pressure, provision is to be made for the efficient filtration of the oil. The filters are to be capable of being cleaned without stopping the engine or reducing supply of filtered oil to the engine. Proposals for an automatic by-pass for emergency purposes in high speed engines are to be submiited for consideration.

6.1.5 In addition, craft of 24 m or greater in length are to comply with the requirements of 4.5 to 4.7.

6.2 Arrangements for hydraulic and flammable oils

6.2.1 The requirements of this Section are applicable to flammable oils employed under pressure in power transmission, control, actuating and heating systems, and hydraulic media in systems which are providing essential services.

6.2.2 The arrangements for storage, distribution and utilisation of hydraulic and flammable oils employed in the systems defined in this sub-Section are to comply with the provisions of 6.1.

6.3 Lubricating/hydraulic oil standby arrangements

6.3.1 Where lubricating oil for the main engine(s) is circulated under pressure, a standby lubricating oil pump is to be provided where the following conditions apply:

(a) The lubricating oil pump is independently driven and the total output of the main engine(s) exceeds 500 kW.

(b) One main engine with its own pump is fitted and the output of the engine exceeds 500 kW.

(c) More than one engine each with its own lubricating oil pump is fitted and the output of each engine exceeds 500 kW.

6.3.2 The standby pump is to be of sufficient capacity to maintain the supply of oil for normal conditions with any one pump out of action. The pump is to be fitted and connected ready for immediate use, except that where the conditions referred to in 6.3.1(c) apply, a complete spare pump may be accepted. In all cases, satisfactory lubrication of the engines is to be ensured while starting and manoeuvring.

6.3.3 Similar provisions to those of 6.3.1 and 6.3.2 are to be made where separate lubricating/hydraulic oil systems are employed for piston cooling, reduction gears, oil operated couplings controllable pitch propellers and steering systems etc., unless approved alternative arrangements are provided.

6.3.4 Independently driven pumps of rotary type are to be fitted with a non-return valve on the discharge side of the pump.

6.4 Lubricating oil contamination

6.4.1 The materials used in the storage and distribution of lubricating oil are to be selected such that they do not introduce or modify the properties of the oil. The use of cadmium or zinc in lubricating oil systems where they may come into contact with the oil is not permitted.

6.4.2 Arrangements are to be made for each forced lubrication system, renovation system, ready to use tank(s) and their associated rundown lines to drain tanks to be flushed after system installation and prior to running of machinery. The flushing arrangements are to be in accordance with the equipment manufacturer's procedures and recommendations.

6.4.3 The design and construction of engine and gear box piping arrangements are to prevent as far as practicable, contamination of engine lubricating oil systems by leakage of cooling water or from bilge water where engines or gearboxes are partly installed below the lower platform.

6.4.4 Where a lubricating oil filling pipe and cap are provided for engines and other machinery, provision is to be made for the topping up oil to pass through a gauze strainer. The caps are to be capable of being secured in the closed position.

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6.4.5 Sampling points are to be provided that enable samples of lubricating oil to be taken in a safe manner. The sampling arrangements are to have the capability to provide samples when machinery is running and are to be provided with valves and cocks of the self-closing type and located in positions as far removed as possible from any heated surface or electrical equipment.

■ *Section 7*
Engine cooling water systems

7.1 General

7.1.1 The cooling arrangements provided are to be adequate to maintain all lubricating and hydraulic fluid temperatures within the manufacturer's recommended limits.

7.2 Main supply

7.2.1 Provision is to be made for an adequate supply of cooling water to the main propelling machinery and essential auxiliary engines, also to the lubricating oil and fresh water coolers and air coolers for electric propelling machinery, where these coolers are fitted. The cooling water pump(s) may be worked from the engines or be driven independently.

7.3 Standby supply

7.3.1 Provision is also to be made for a separate supply of cooling water from a suitable independent pump of adequate capacity.

7.3.2 The following arrangements are acceptable depending on the purpose for which the cooling water is intended:

(a) Where only one main engine is fitted, the standby pump is to be connected ready for immediate use.

(b) Where more than one main engine is fitted, each with its own pump, a complete spare pump of each type may be accepted.

(c) Where fresh water cooling is employed for main and/or auxiliary engines, a standby fresh water pump need not be fitted if there are suitable emergency connections from a salt water system.

(d) Where each auxiliary engine is fitted with a cooling water pump, standby means of cooling need not be provided. Where, however, a group auxiliary engine is supplied with cooling water from a common system, a standby cooling water pump is to be provided for this system.

This pump is to be connected ready for immediate use and may be a suitable general service pump.

7.4 Selection of standby pumps

7.4.1 When selecting a pump for standby purposes, consideration is to be given to the maximum pressure which it can develop if the overboard discharge valve is partly or fully closed. Where necessary, water boxes, etc., are to be protected against inadvertent over-pressure by an approved device.

7.5 Relief valves on main cooling water pumps

7.5.1 Where cooling water pumps can develop a pressure head greater than the design pressure of the system, they are to be provided with relief valves on the pump discharge to effectively limit the pump discharge pressure to the design pressure of the system.

7.6 Sea inlets

7.6.1 Not less than two sea inlets are to be provided for the pumps supplying the sea water cooling system, one for the main pump and one for the standby pump. Alternatively, the sea inlets may be connected to a suction line available to main and standby pumps.

7.6.2 Where standby pumps are not connected ready for immediate use (*see* 7.3.2(b) and (d)), the main pump is to be connected to both sea inlets.

7.6.3 The auxiliary cooling water sea inlets are to be located one on each side of the craft.

7.7 Strainers

7.7.1 Where sea water is used for the direct cooling of the main engines and essential auxiliary engines, the cooling water suction pipes are to be provided with strainers which can be cleaned without interruption to the cooling water supply.

■ *Section 8*
Miscellaneous machinery

8.1 General

8.1.1 Alarms and safeguards are indicated in Table 1.8.1.

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Table 1.8.1 Miscellaneous machinery: Alarms and safeguards

Item	Alarm	Note
Coolant tanks level	Low	–
Sludge tanks level	High	–
Feed water tanks level	Low	Service tank only
Hydraulic control system pressure	Low	–
Pneumatic control system pressure	Low	–

■ *Section 9* Special requirements for multi-hull craft

9.1 General

9.1.1 The requirements of Sections 1 to 8 are generally applicable to multi-hull craft except where these are modified by the requirements of this Section.

9.1.2 Where the machinery piping arrangements in each hull of a multi-hull craft are separate, the machinery piping and standby requirements for each hull are to be as detailed in 6.3.1(c) and 7.3.2(b), i.e. the requirements for a twin-engined mono-hull craft apply.

9.1.3 Where a multi-hull craft cannot navigate safely with the main propulsion machinery in one hull out of action, the machinery piping and standby requirements are to be as detailed in 6.3.1(a) or (b), and 7.3.2(a), i.e. the requirements for a single-engined mono-hull craft apply to the machinery in each hull.

■ *Section 10* Requirements for Passenger (A) Craft

10.1 General

10.1.1 The requirements of Sections 1 to 9 apply except that the standby machinery arrangements detailed in Sections 6 and 7 are not required.

■ *Section 11* Requirements for small craft which are not required to comply with the HSC Code

11.1 General

11.1.1 The requirements of this Section replace Sections 3.2 to 3.4 and 4, 5, 6 and 7 of this Chapter, *see also* Ch 1,15.

11.2 Oil fuel system

11.2.1 Where a power driven oil fuel transfer pump is fitted, it is to be capable of being stopped from a position outside the space which will always be accessible in the event of fire occurring in the compartment in which the pump is situated, as well as from the compartment itself.

11.2.2 Where a power driven pump is necessary for transferring oil fuel, a standby pump is to be provided and connected ready for use.

11.3 Separate oil fuel tanks

11.3.1 Except for very small tanks separate oil fuel tanks are to be not less than 3 mm in thickness. The seams are to be welded or brazed. Steel tanks are to be protected from corrosion.

11.3.2 Before installation, all tanks are to be tested by a head of water equal to the maximum to which the tanks may be subjected, but not less than 2,5 m above the crown of the tank.

11.3.3 Separate oil fuel tanks are to be securely fixed in position, and located as remote as practicable from exhaust manifolds and exhaust pipes or other hot surfaces and not above any electrical apparatus. Where this cannot be avoided, a drip tray is to be fitted under the tank and extended sufficiently to catch any drips from fittings attached to the tank.

11.3.4 Oil fuel tanks are not to be fitted above or adjacent to oil fired heaters, cooking stoves, equipment using naked flames or electrical equipment unless this is suitably constructed or enclosed.

11.4 Oil fuel filling

11.4.1 The filling pipe is to be of metallic construction and is to be a permanent fixture led from the deck and secured to the tank by an approved connection. A screwed cap and name plate inscribed 'Oil Fuel' is to be provided at the filling point.

11.4.2 Flexible hoses are not permitted as filling pipes. In wood or composite craft short lengths may be employed at the deck connection to accommodate any movement between the tank and the deck fitting.

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11.5 Oil fuel supply

11.5.1 Provision is to be made for efficient filtration of the oil fuel supply to the engine.

11.6 Oil fuel valves and cocks

11.6.1 Outlet valves or cocks are to be fitted to all deep tanks. The valves are to be fitted directly to the tank plating and are to be capable of being closed locally and from positions which will always be readily accessible in the event of fire.

11.6.2 Valve covers are to be so constructed that they will not become slack when the valves are operated.

11.6.3 Heat sensitive materials are not to be used in the construction of valves and cocks.

11.6.4 Where drain cocks or valves are fitted to oil fuel tanks they are to be of the self-closing type and suitable provision is to be made for collecting the oil discharge.

11.7 Flexible hoses for oil fuel systems

11.7.1 Where necessary, flexible pipes of approved type may be used as short joining lengths to the engine.

11.8 Pipe joints for oil fuel systems

11.8.1 Where flanged joints are used the jointing material is to be impervious to oil. Cone type joints and approved types of compression fittings may be permitted for pipes having a bore not exceeding 40 mm.

11.8.2 Soft solder is not to be used for attaching pipe fittings.

11.9 Engine cooling system

11.9.1 Where sea water is used for the direct cooling of the engine, an efficient strainer which can be cleared from inside the craft is to be fitted between the sea inlet valve and the pump.

11.9.2 Means are to be provided for cleaning the strainer without interruption to the cooling water supply, where necessary.

11.9.3 Means are to be provided for indicating the temperature of the engine cooling media.

11.9.4 Alarms for the engine cooling water system are to be provided in accordance with Part 10.

11.10 Lubricating oil system

11.10.1 Where the lubricating oil for main propelling engines is circulated under pressure, provision is to be made for the efficient filtration of the oil.

11.10.2 Where necessary, flexible pipes of approved type may be used as short joining lengths to the engine.

11.10.3 In general, joints are to be of the flanged type with jointing materials which are impervious to oil. Cone type joints and approved types of compression fittings may be permitted for pipes having a bore not exceeding 40 mm.

11.10.4 Soft solder is not to be used for attaching pipe fittings.

11.10.5 Means are to be provided for indicating the lubricating oil pressure.

11.10.6 Alarms for the lubricating oil systems are to be provided in accordance with Part 10.

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Section

1 **General requirements**

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3 **Spherical shells subject to internal pressure**

4 **Dished ends subject to internal pressure**

5 **Standpipes and branches**

6 **Unstayed circular flat end plates**

7 **Construction**

8 **Requirements for fusion welded pressure vessels**

9 **Mountings and fittings for pressure vessels**

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11 **Fibre reinforced plastics pressure vessels**

12 **Requirements for craft which are not required to comply with the HSC Code**

■ *Section 1* General requirements

1.1 Application

1.1.1 The requirements of this Chapter are applicable to fusion welded pressure vessels and their mountings and fittings, where plans have to be submitted in accordance with 1.2.

1.1.2 Seamless pressure vessels are to be manufactured in accordance with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials) where applicable.

1.1.3 Steam raising plant and associated pressure vessels should be designed and constructed in accordance with Pt 5, Ch 10 of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships).

1.2 Details to be submitted

1.2.1 Plans of pressure vessels are to be submitted in triplicate for consideration where all the conditions in (a) or (b) are satisfied:

(a) The vessel contains vapours or gases, e.g. air receivers, hydrophore or similar vessels and gaseous CO_2 vessels for fire-fighting, and
$pV > 600$
$p > 1$
$V > 100$
V = volume (litres) of gas or vapour space

(b) The vessel contains liquefied gases for fire-fighting, or flammable liquids, and
$p > 7$
$V > 100$
V = volume (litres)
p = design pressure (bar).

1.3 Materials

1.3.1 Materials used in the construction of Class 1, 2/1 and 2/2 pressure vessels are to be manufactured, tested and certified in accordance with the requirements of the Rules for Materials. Materials used in the construction of Class 3 pressure vessels may be in accordance with the requirements of an acceptable National or International Standard. The manufacturer's certificate will be accepted in lieu of LR's material certificate for such materials.

1.3.2 The specified minimum tensile strength of carbon and carbon-manganese steel plates, pipes, forgings and castings is to be within the following general limits:

(a) For seamless and Class 1 and Class 2/1 fusion welded pressure vessels:
340 to 520 N/mm^2.

(b) For Class 2/2 and where required Class 3 fusion welded pressure vessels:
340 to 430 N/mm^2.

1.3.3 Where it is proposed to use materials other than those specified in the Rules for Materials, details of the chemical compositions, heat treatment and mechanical properties are to be submitted for approval. In such cases, the values of the mechanical properties used for deriving the allowable stress are to be subject to agreement by Lloyd's Register (hereinafter referred to as 'LR').

1.4 Classification of fusion welded pressure vessels

1.4.1 Fusion welded pressure vessels are graded as Class 1 where the shell thickness exceeds 38 mm.

1.4.2 Fusion welded pressure vessels are graded as Class 2/1 and Class 2/2 if they comply with the following conditions:

(a) where the design pressure exceeds 17,2 bar, or
(b) where the metal temperature exceeds 150°C, or
(c) where the design pressure, in bar, multiplied by the actual thickness of the shell, in mm exceeds 157, or
(d) where the shell thickness does not exceed 38 mm.

1.4.3 For Rule purposes, Class 3 pressure vessels are to have a maximum shell thickness of 16 mm, and are pressure vessels not included in Classes 1, 2/1 or 2/2.

1.5 Design pressure

1.5.1 The design pressure is the maximum permissible working pressure and is to be not less than the highest set pressure of any safety valve.

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1.6 Metal temperature

1.6.1 The metal temperature, T, used to evaluate the allowable stress, σ, is to be taken as the actual mean wall metal temperature expected under operating conditions for the pressure part concerned, and is to be stated by the manufacturer when plans of the pressure parts are submitted for consideration.

1.6.2 For fusion welded pressure vessels the minimum design temperature, T, is not to be less than 50°C.

1.7 Definition of symbols

1.7.1 The symbols used in the various formulae in Sections 2 to 6, unless otherwise stated, are defined as follows and are applicable to the specific part of the pressure vessel under consideration:

p = design pressure, in bar, *see* 1.5
r_i = inside knuckle radius, in mm
r_o = outside knuckle radius, in mm
t = minimum thickness, in mm
D_i = inside diameter, in mm
D_o = outside diameter, in mm
J = joint factor applicable to welded seams
R_i = inside radius, in mm
R_o = outside radius, in mm
T = design temperature, in °C
σ = allowable stress, in N/mm^2, *see* 1.8.

1.7.2 Where reference is made to calculated or actual plate thickness for the derivation of other values, these thicknesses are to be minus the standard Rule corrosion allowance of 0,75 mm, if not so stated.

1.8 Allowable stress

1.8.1 The term 'allowable stress', σ, is the stress to be used in the formulae for the calculation of scantlings of pressure parts.

1.8.2 The allowable stress, σ, is to be the lowest of the following values:

$$\sigma = \frac{E_t}{1,5}$$

$$\sigma = \frac{R_{20}}{2,7}$$

$$\sigma = \frac{S_R}{1,5}$$

where

E_t = specified minimum lower yield stress or 0,2 per cent proof stress at temperature, T, for carbon and carbon-manganese steels. In the case of austenitic steels, the 1,0 per cent proof stress at temperature, T, is to be used
R_{20} = specified minimum tensile strength at room temperature
S_R = average stress to produce rupture in 100 000 hours at temperature, T
T = metal temperature, *see* 1.6.

1.8.3 The allowable stress for steel castings is to be taken as 80 per cent of the value determined by the method indicated in 1.8.2, using the appropriate values for cast steel.

1.8.4 Where steels castings, which have been tested in accordance with the Rules for Materials, are also subjected to non-destructive tests, consideration will be given to increasing the allowable stress using a factor up to 90 per cent in lieu of the 80 per cent referred to in 1.8.3. Particulars of the non-destructive test proposals are to be submitted for consideration.

1.9 Joint factors

1.9.1 The following joint factors are to be used in the equations in Sections 2 to 6, where applicable. Fusion welded pressure parts are to be made in accordance with Section 8.

Class of pressure vessel	Joint factor
Class 1	1,0
Class 2/1	0,85
Class 2/2	0,75
Class 3	0,6

1.9.2 The longitudinal joints for all Classes of vessels are to be butt joints. Circumferential joints for Class 1 vessels and all classes of vessel for the production and storage of steam are also to be butt welds. Circumferential joints for Class 2/1, 2/2 and 3 vessels should also be butt joints with the following exceptions:

(a) Circumferential joints for Class 2/1, 2/2 and 3 vessels may be of the joggle type provided neither plate at the joints exceeds 16 mm thickness.
(b) Circumferential joints for Class 3 vessels may be of the lap type provided neither plate at the joint exceeds 16 mm thickness nor the internal diameter of the vessel exceeds 610 mm.

For typical acceptable methods of attaching dished ends, *see* Fig. 4.6.1.

1.10 Pressure parts of irregular shape

1.10.1 Where pressure parts are of such irregular shape that it is impracticable to design their scantlings by the application of formulae in this Chapter, the suitability of their construction is to be determined by hydraulic proof test of a prototype or by agreed alternative method.

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Section 2
Cylindrical shells subject to internal pressure

2.1 Minimum thickness

2.1.1 Minimum thickness, t, of a cylindrical shell is to be determined by the following formula:

$$t = \frac{p R_i}{10\sigma J - 0{,}5p} + 0{,}75 \text{ mm}$$

where

t, p, R_i and σ are defined in 1.7

J = the joint factor of the longitudinal joints (expressed as a fraction), *see* 1.9.1. In the case of seamless shells clear of openings, $J = 1{,}0$.

2.1.2 The formula in 2.1.1 is applicable only where the resulting thickness does not exceed half the internal radius, i.e. where R_o is not greater than $1{,}5R_i$.

2.1.3 For fusion welded pressure vessels, t, is to be not less than $3 + \frac{D_i}{1500}$ mm,

where

D_i is as defined in 1.7.

2.1.4 The minimum thickness of vessels manufactured of corrosion resistant steels will be the subject of special consideration.

2.2 Unreinforced openings

2.2.1 The maximum diameter, d, of any unreinforced isolated openings is to be determined by the following formula:

$$d = 8{,}08\,[D_o\, t\,(1 - K)]^{1/3} \text{ in mm}$$

The value of K to be used is calculated from the following formula:

$$K = \frac{p D_o}{18{,}2\sigma t} \text{ but is not to be taken as greater than } 0{,}99$$

where

p, D_o and σ are as defined in 1.7

t = actual thickness of shell, in mm.

2.2.2 For elliptical or oval holes, d, for the purposes of 2.2.1, refers to the major axis when this lies longitudinally or to the mean of the major and minor axes when the minor axis lies longitudinally.

2.2.3 No unreinforced opening is to exceed 200 mm in diameter.

2.2.4 Holes may be considered isolated if the centre distance between two holes on the longitudinal axis of a cylindrical shell is not less than:

$$d + 1{,}1\sqrt{D\,t} \text{ with a minimum } 5d$$

where

d = diameter of openings in shell (mean diameter if dissimilarly sized holes are involved)

D = mean diameter of shell

t = actual thickness of shell

Where the centre distance is less than so derived, the holes are to be fully compensated.

2.3 Reinforced openings

2.3.1 Openings larger than those permitted by 2.2 are to be compensated in accordance with Fig. 4.2.1(a) or (b). The following symbols are used in Fig. 4.2.1(a) and (b):

t_s = calculated thickness of a shell without joint or opening or corrosion allowance, in mm

t_d = thickness calculated in accordance with 3.1 without corrosion allowance, in mm

t_a = actual thickness of shell plate without corrosion allowance, in mm

t_b = actual thickness of standpipe without minus tolerances and corrosion allowance, in mm

t_r = thickness of added reinforcement, in mm

D_i = internal diameter of cylindrical shell, in mm

d_o = diameter of hole in shell, in mm

L = width of added reinforcement not exceeding D, in mm

$C = \sqrt{d_o\, t_b}$ in mm

$D = \sqrt{D_i\, t_a}$ and is not to exceed $0{,}5d_o$, in mm

σ = shell plate allowable stress, N/mm^2

σ_p = standpipe allowable stress, N/mm^2

σ_r = added reinforcement allowable stress, N/mm^2

σ_w = weld metal allowable stress, N/mm^2

NOTE

σ_p, σ_r and σ_w are not to be taken as greater than σ.

2.3.2 For elliptical or oval holes, the dimension on the meridian of the shell is to be used for d_o in 2.3.1.

2.3.3 The welds attaching standpipes and reinforcing plates to the shell are to be of sufficient size to transmit the full strength of the reinforcing areas and all other loadings to which they may be subjected.

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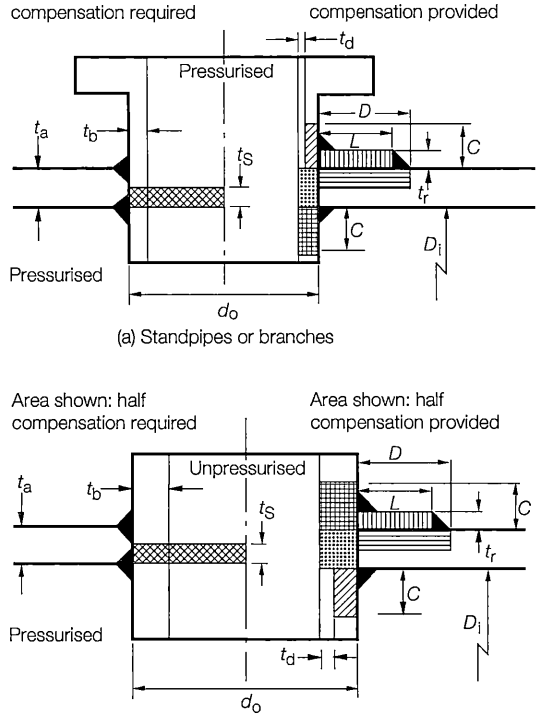

(a) Standpipes or branches

(b) Insert pieces for internal doors

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Compensation required:

A_1 = $= d_o\, t_S$ mm²

Compensation provided:

A_2 = $= 2D\,(t_a - t_S)$ mm²

A_3 = $= 2\, t_b\, t_a \frac{\sigma_p}{\sigma}$ mm²

A_4 = $= 2C\, t_b \frac{\sigma_p}{\sigma}$ mm²

A_5 = $= 2C\,(t_b - t_d) \frac{\sigma_p}{\sigma}$ mm²

A_6 = $= 2L\, t_r \frac{\sigma_r}{\sigma}$ mm²

A_7 = (Area of fillet welds) $\frac{\sigma_w}{\sigma}$ mm²

$A_2 + A_3 + A_4 + A_5 + A_6 + A_7 \geq A_1$

Fig. 4.2.1
Compensation for welded standpipes or branches in cylindrical shells

Section 3
Spherical shells subject to internal pressure

3.1 Minimum thickness

3.1.1 The minimum thickness, t, of a spherical shell is to be determined by the following formula:

$$t = \frac{p\,R_i}{20\sigma\,J - 0{,}5p} + 0{,}75 \text{ mm}$$

where

t, p, R_i, σ and J are as defined in 1.7.

3.1.2 The formula in 3.1.1 is applicable only where the resulting thickness does not exceed half the internal radius.

3.1.3 Irrespective of the thickness determined by the formula in 3.1.1, t is to be not less than $\frac{D_i}{1500} + 3$ mm for other pressure vessels, where D_i is as defined in 1.7.

3.1.4 The minimum thickness permitted for vessels manufactured in corrosion resistant steels will be the subject of special consideration.

3.1.5 Openings in spherical shells requiring compensation are to comply, in general, with 2.3, using the calculated and actual thicknesses of the spherical shell as applicable.

Section 4
Dished ends subject to internal pressure

4.1 Minimum thickness

4.1.1 The thickness, t, of semi-ellipsoidal and hemispherical unstayed ends, and the knuckle section of torispherical ends, dished from plate, having pressure on the concave side and satisfying the conditions listed below, is to be determined by the following formula:

$$t = \frac{p\,D_o\,K}{20\sigma\,J} + 0{,}75 \text{ mm}$$

where

t, p, D_o, σ and J are as defined in 1.7

K = a shape factor, *see* 4.2 and Fig. 4.4.1.

4.1.2 For semi-ellipsoidal ends:

the external height, $H \geq 0{,}18D_o$

where

D_o = the external diameter of the parallel portion of the end, in mm.

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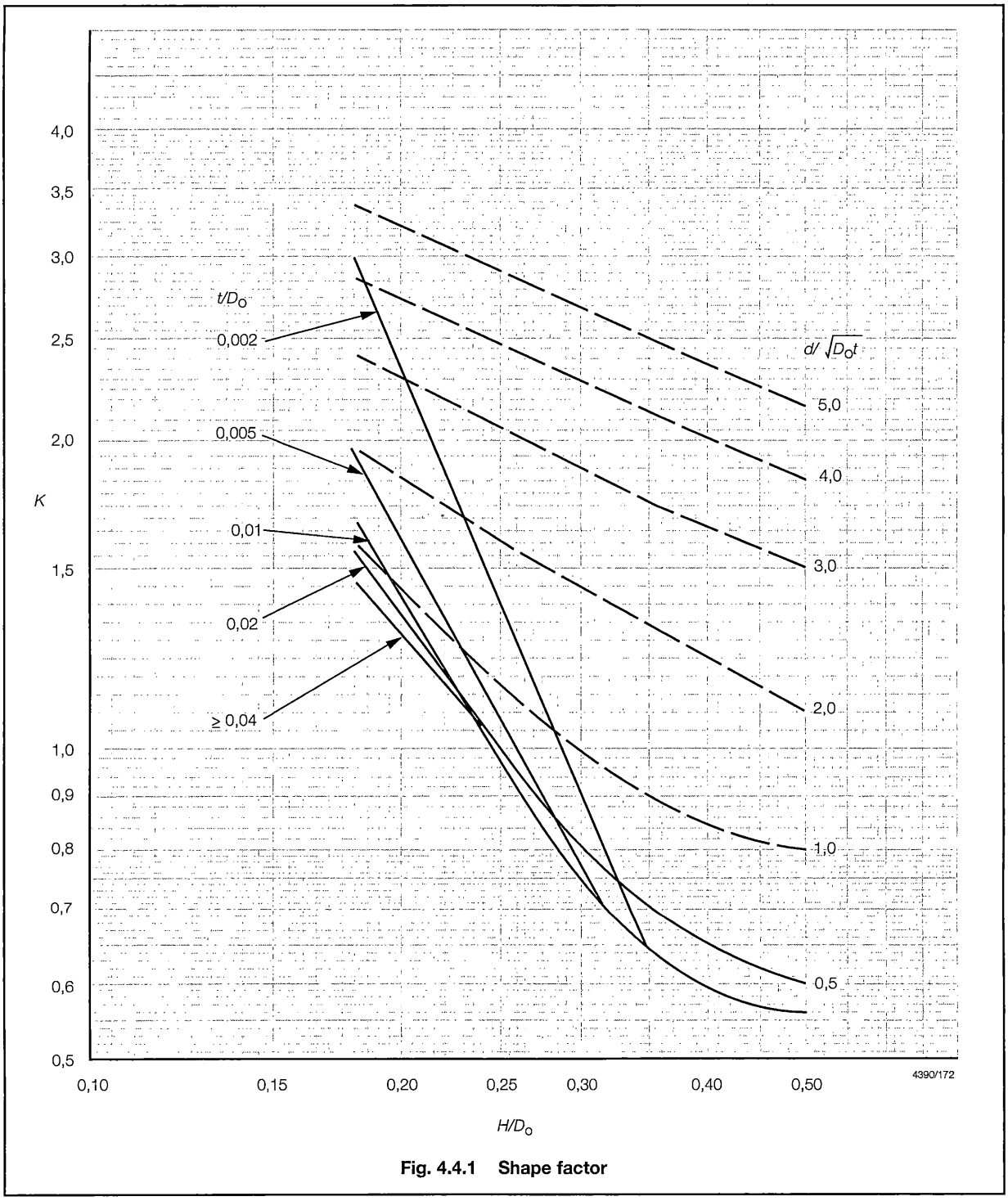

Fig. 4.4.1 Shape factor

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4.1.3 For torispherical ends:

- the internal radius, $R_i \leq D_o$
- the internal knuckle radius, $r_i \geq 0{,}1D_o$
- the internal knuckle radius, $r_i \geq 3t$
- the external height, $H \geq 0{,}18D_o$ and is determined as follows:

$$H = R_o - \sqrt{(R_o - 0{,}5D_o)\,(R_o + 0{,}5D_o - 2r_o)}$$

4.1.4 In addition to the formula in 4.1.1 the thickness, t, of a torispherical head, made from more than one plate, in the crown section is to be not less than that determined by the following formula:

$$t = \frac{p\,R_i}{20\sigma\,J - 0{,}5p} + 0{,}75 \quad \text{mm}$$

where

t, p, R_i, σ and J are as defined in 1.7.

4.1.5 The thickness required by 4.1.1 for the knuckle section of a torispherical head is to extend past the common tangent point of the knuckle and crown radii into the crown section for a distance not less than $0{,}5\sqrt{R_i\,t}$ mm, before reducing to the crown thickness permitted by 4.1.4,

where

t = the required thickness from 4.1.1.

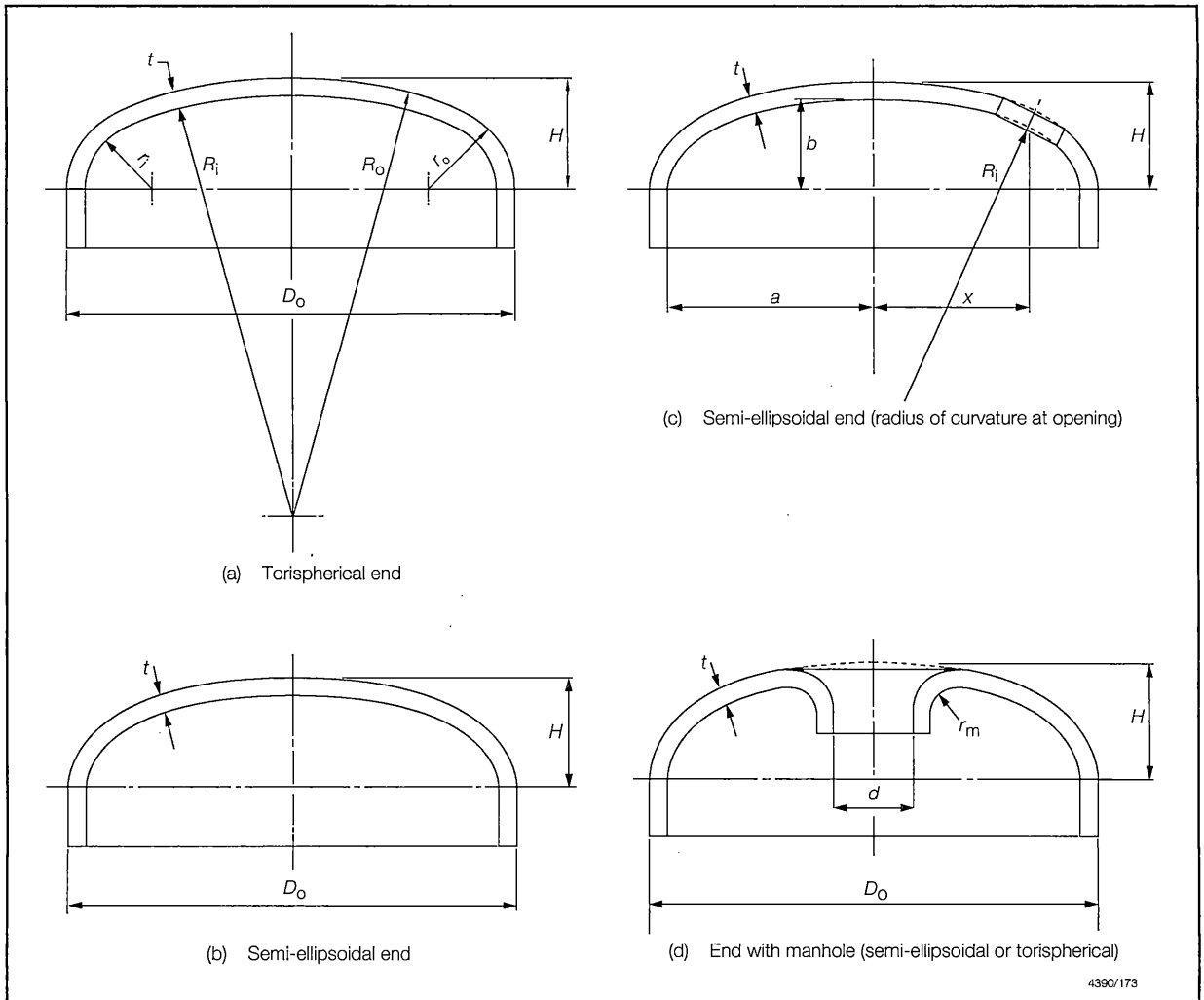
4.1.6 In all cases, H, is to be measured from the commencement of curvature, *see* Fig. 4.4.2.

4.1.7 For fusion welded pressure vessels the minimum thickness of the head, t, is to be not less than $3 + \frac{D_i}{1500}$ mm

where

D_i is as defined in 1.7.

4.1.8 For ends which are butt welded to the shell the thickness of the edge of the flange for connection to the shell is to be not less than the thickness of an unpierced seamless or welded shell, whichever is applicable, of the same diameter and material and determined by 2.1.



(a) Torispherical end

(b) Semi-ellipsoidal end

(c) Semi-ellipsoidal end (radius of curvature at opening)

(d) End with manhole (semi-ellipsoidal or torispherical)

Fig. 4.4.2 Typical dished ends

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4.2 Shape factors for dished ends

4.2.1 The shape factor, K, to be used in 4.1.1 is to be obtained from the curves in Fig. 4.4.1, and depends on the ratio of height to diameter $\frac{H}{D_o}$.

4.2.2 The lowest curve in the series provides the factor, K, for plain (i.e. unpierced) ends. For lower values of $\frac{H}{D_o}$, K depends upon the ratio of thickness to diameter, $\frac{t}{D_o}$, aswell as on the ratio $\frac{H}{D_o}$, and a trial calculation may be necessary to arrive at the correct value of K.

4.3 Dished ends with unreinforced openings

4.3.1 Openings in dished ends may be circular, obround or approximately elliptical.

4.3.2 The upper curves in Fig. 4.4.1 provide values of K, to be used in 4.1.1, for ends with unreinforced openings. The selection of the correct curve depends on the value of $\frac{d}{\sqrt{D_o t}}$ and a trial calculation is necessary to select the correct curve,
where

d = the diameter of the largest opening in the end plate, in mm (in the case of an elliptical opening, the larger axis of the ellipse)
t = minimum thickness, after dishing, in mm
D_o = outside diameter of dished end, in mm.

4.3.3 The following requirements must in any case be satisfied:

$$\frac{t}{D_o} \leq 0{,}1$$

$$\frac{d}{D_o} \leq 0{,}7$$

4.3.4 From Fig. 4.4.1 for any selected ratio of $\frac{H}{D_o}$ the curve for unpierced ends gives a value for $\frac{d}{\sqrt{D_o t}}$ as well as for K. Openings giving a value of $\frac{d}{\sqrt{D_o t}}$ not greater than the value so obtained may thus be pierced through an end designed as unpierced without any increase in thickness.

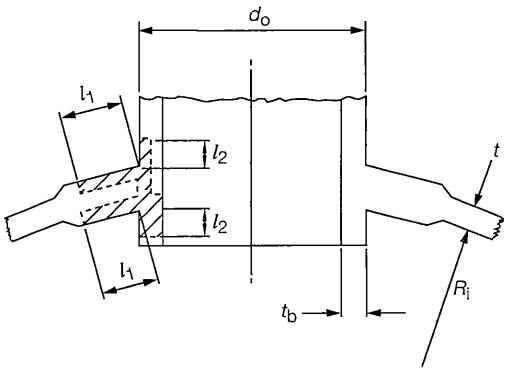
4.4 Flanged openings in dished ends

4.4.1 The requirements in 4.3 apply equally to flanged openings and to unflanged openings cut in the plate of an end. No reduction may be made in end plate thickness on account of flanging.

4.4.2 Where openings are flanged, the radius, r_m of the flanging is to be not less than 25 mm, *see* Fig. 4.4.2(d). The thickness of the flanged portion may be less than the calculated thickness.

4.5 Location of unreinforced and flanged openings in dished ends

4.5.1 Unreinforced and flanged openings in dished ends are to be so arranged that the distance from the edge of the hole to the outside edge of the plate and the distance between openings are not less than those shown in Fig. 4.4.3.



$l_1 = \sqrt{2R_i t}$ or $0{,}5d_o$ whichever is the lesser
l_2 is not to exceed $\sqrt{d_o t_b}$ 4390/179

Fig. 4.4.3 Limits for reinforcement

4.6 Dished ends with reinforced openings

4.6.1 Where it is desired to use a large opening in a dished end of less thickness than would be required by 4.3, the end is to be reinforced. This reinforcement may consist of a ring or standpipe welded into the hole, or of reinforcing plates welded to the outside and/or inside of the end in the vicinity of the hole, or a combination of both methods, *see* Fig. 4.4.4. Forged reinforcements may be used.

4.6.2 Reinforcing material with the following limits may be taken as effective reinforcement:

(a) The effective width, l_1 of reinforcement is not to exceed $\sqrt{2R_i t}$ or $0{,}5d_o$ whichever is the lesser.

(b) The effective length, l_2 of a reinforcing ring is not to exceed $\sqrt{d_o t_b}$

where

R_i = the internal radius of the spherical part of a torispherical end, in mm, or

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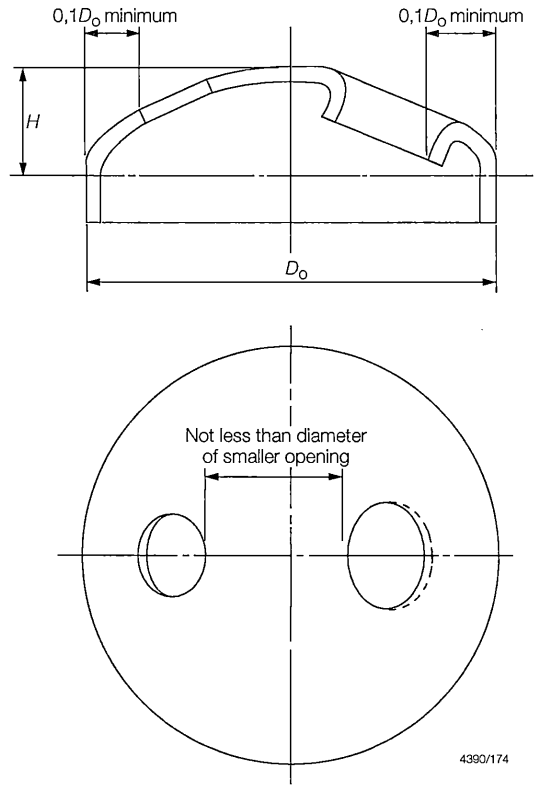

Fig. 4.4.4 Opening in dished ends

R_i = internal radius of the meridian of the ellipse at the centre of the opening, of a semi-ellipsoidal end, in mm, and is given by the following formula:

$$\frac{[a^4 - x^2(a^2 - b^2)]^{3/2}}{a^4 b}$$

where

a, b and x are shown in Fig. 4.4.2(c)

d_o = external diameter of ring or standpipe, in mm

l_1 and l_2 are shown in Fig. 4.4.3

t_b = actual thickness of ring or standpipe, in mm.

4.6.3 The shape factor, K, for a dished end having a reinforced opening can be read from Fig. 4.4.1 using the value obtained from:

$$\frac{d_o - \frac{A}{t}}{\sqrt{D_o t}} \text{ instead of from } \frac{d}{\sqrt{D_o t}}$$

where

A = the effective cross-sectional area of reinforcement and is to be twice the area shown shaded on Fig. 4.4.3

As in 4.3, a trial calculation is necessary in order to select the correct curve.

4.6.4 The area shown in Fig. 4.4.3 is to be obtained as follows:

- Calculate the cross-sectional area of reinforcement both inside and outside the end plate within the length, l_1, plus the full cross-sectional area of that part of the ring or standpipe which projects inside the end plate up to a distance, l_2, plus the full cross-sectional area of that part of the ring or standpipe which projects outside the internal surface of the end plate up to a distance, l_2, and deduct the sectional area which the ring or standpipe would have if its thickness were as calculated in accordance with 5.1.

4.6.5 If the material of the ring or the reinforcing plates has an allowable stress value lower than that of the end plate, then the effective cross-sectional area, A, is to be multiplied by the ratio:

$$\frac{\text{allowable stress of reinforcing plate at design temperature}}{\text{allowable stress of end plate at design temperature}}$$

4.7 Torispherical dished ends with reinforced openings

4.7.1 If an opening and its reinforcement are positioned entirely within the crown section, the compensation requirements are to be as for a spherical shell, using the crown radius as the spherical shell radius. Otherwise, the requirements of 4.6 are to be applied.

■ *Section 5* Standpipes and branches

5.1 Minimum thickness

5.1.1 The minimum wall thickness, t, of standpipes and branches is to be not less than the greater of the two values determined by the following formulae, making such additions as may be necessary on account of bending, static loads and vibrations:

$$t = \frac{p D_o}{20\sigma + p} + 0{,}75 \text{ mm}$$

$$t = 0{,}015 D_o + 3{,}2 \text{ mm}$$

where

t, p, D_o and σ are defined in 1.7.

If the second formula applies, the thickness need only be maintained for a length, L, from the outside surface of the vessel, but need not extend past the first connection, butt weld or flange, where:

$$L = 3{,}5\sqrt{D_o t} \text{ mm}$$

5.1.2 In no case does the wall thickness need to exceed that of the shell as required by 2.1, 3.1 or 4.1 as applicable.

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Section 6
Unstayed circular flat end plates

6.1 Minimum thickness

6.1.1 Ends attached by welding are to be designed such that the minimum thickness of flat end plates is to be determined by the following formula:

$$t = d_i \sqrt{\frac{pC}{\sigma}} + 0{,}75 \text{ mm}$$

where

p and σ are as defined in 1.7.

t = minimum thickness of end plate, in mm

d_i = internal diameter of circular shell, in mm

C = a constant depending on method of end attachment, *see* Fig. 4.6.1

(a) For end plates welded as shown in Fig. 4.6.1(a):

C = 0,019 for circular shells.

(b) For end plates welded as shown in Figs. 4.6.1(b) and (c):

C = 0,028 for circular shells.

6.1.2 Where flat end plates are bolted to flanges attached to the ends of headers, the flanges and end plates are to be in accordance with recognised pipe flange standards.

6.1.3 Openings in flat plates are to be compensated in accordance with Fig. 4.2.1(a) or (b) with the value of A_1, the compensation required, calculated as follows:

$$A_1 = \frac{d_o}{2{,}4} t_f \text{ mm}^2$$

where

d_o = diameter of hole in flat plate, in mm

t_f = required thickness of the flat plate in the area under consideration, in mm, calculated in accordance with 6.1.1, as applicable, without corrosion allowance

Limit D = $0{,}5d_o$.

Section 7
Construction

7.1 Access arrangements

7.1.1 Pressure vessels are to be so made that the internal surfaces may be examined. Wherever practicable, the openings for this purpose are to be sufficiently large for access and for cleaning the inner surfaces.

7.1.2 Manholes in cylindrical shells should preferably have their shorter axes arranged longitudinally.

7.1.3 Doors for manholes and sightholes are to be formed from the steel plate or of other approved construction, and all jointing surfaces are to be machined.

7.1.4 Doors of the internal type are to be provided with spigots which have a clearance of not more than 1,5 mm all round, i.e. the axes of opening are not to exceed those of the door by more than 3 mm. The width of the manhole gasket seat is not to be less than 16 mm.

7.1.5 Doors of the internal type for openings not larger than 230 x 180 mm need be fitted with only one stud, which may be forged integral with the door. Doors for openings larger than 230 mm x 180 mm are to be fitted with two studs or bolts. The strength of the attachment to the door is not to be less than the strength of the stud or bolt.

7.1.6 The crossbars or dogs for doors are to be of steel.

7.1.7 External circular flat cover plates are to be in accordance with a recognised standard.

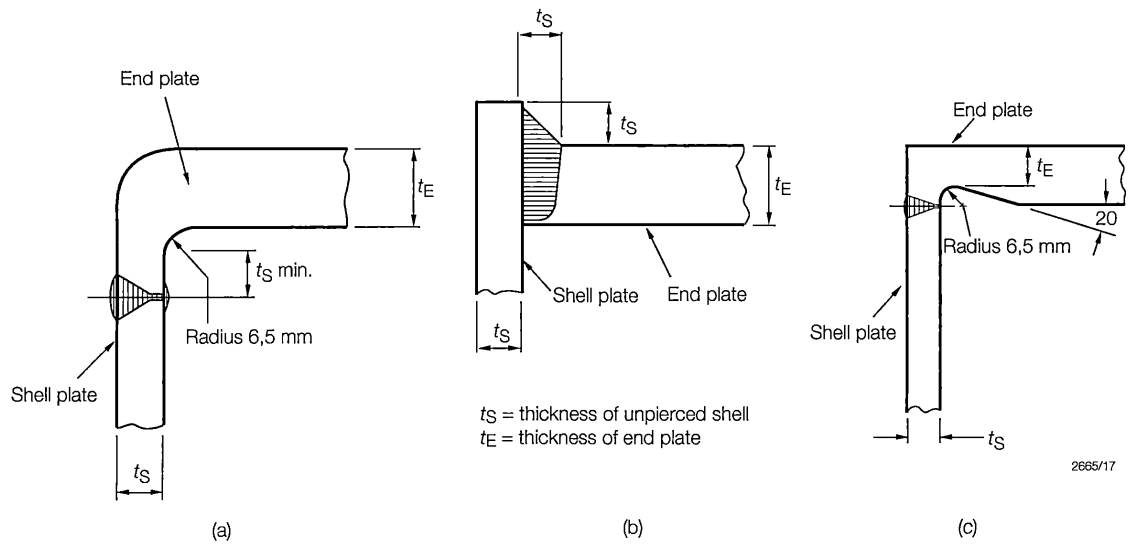

Fig. 4.6.1 Typical methods of attachment of unstayed circular flat end plates

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7.2 Torispherical and semi-ellipsoidal ends

7.2.1 For typically acceptable types of attachment for dished ends to cylindrical shells, *see* Fig. 4.7.1. Types (d) and (e) are to be made a tight fit in the cylindrical shell.

7.2.2 Where the difference in thickness is the same throughout the circumference, the thicker plate is to be reduced in thickness by machining to a taper for a distance not less than four times the offset, so that the two plates are of equal thickness at the position of the circumferential weld. A parallel portion may be provided between the end of the taper and the weld edge preparation; alternatively, if so desired, the width of the weld may be included as part of the smooth taper of the thicker plate.

7.2.3 The thickness of the plates at the position of the circumferential weld is to be not less than that of an unpierced cylindrical shell of seamless or welded construction, whichever is applicable, of the same diameter and material, *see* 2.1.

7.3 Welded-on flanges, butt welded joints and fabricated branch pieces

7.3.1 Flanges may be cut from plates or may be forged or cast. Hubbed flanges are not to be machined from plate. Flanges are to be attached to branches by welding. Alternative methods of flange attachment will be subject to special consideration.

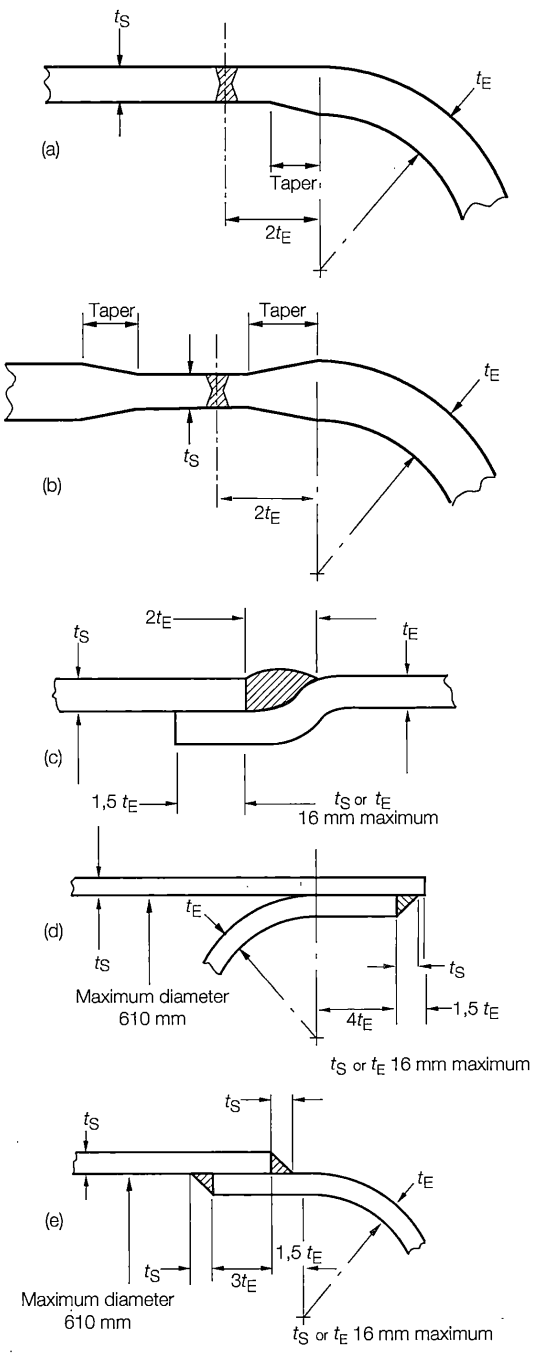
7.3.2 The types of welded-on flanges are to be suitable for the pressure, temperature and service for which the branches are intended.

7.3.3 Flange attachments and pressure-temperature ratings in accordance with materials and design of recognised standards will be accepted.

7.3.4 Typical examples of welded-on flange connections are shown in Fig. 4.7.2(a) to (f), and limiting design conditions for the flange types are shown in Table 4.7.1. In Fig. 4.7.2, t is the minimum Rule thickness of the standpipe or branch.

7.3.5 Welded-on flanges are not to be a tight fit on the branch. The maximum clearance between the bore of the flange and the outside diameter of the branch is to be 3 mm at any point, and the sum of the clearances diametrically opposite is not to exceed 5 mm.

7.3.6 Where butt welds are employed in the attachment of flange type (a), or in the construction of standpipes or branch pieces, the adjacent pieces are to be matched at the bores. This may be effected by drifting, roller expanding or machining, provided the pipe wall is not reduced below the designed thickness. If the parts to be joined differ in wall thickness, the thicker wall is to be gradually tapered to that of the thinner at the butt joint.



Type of end attachment	Acceptable for
(a) and (b)	All classes
(c)	2/1, 2/2 and 3
(d) and (e)	Class 3 only

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Fig. 4.7.1
Typical attachment of dished ends to cylindrical shell

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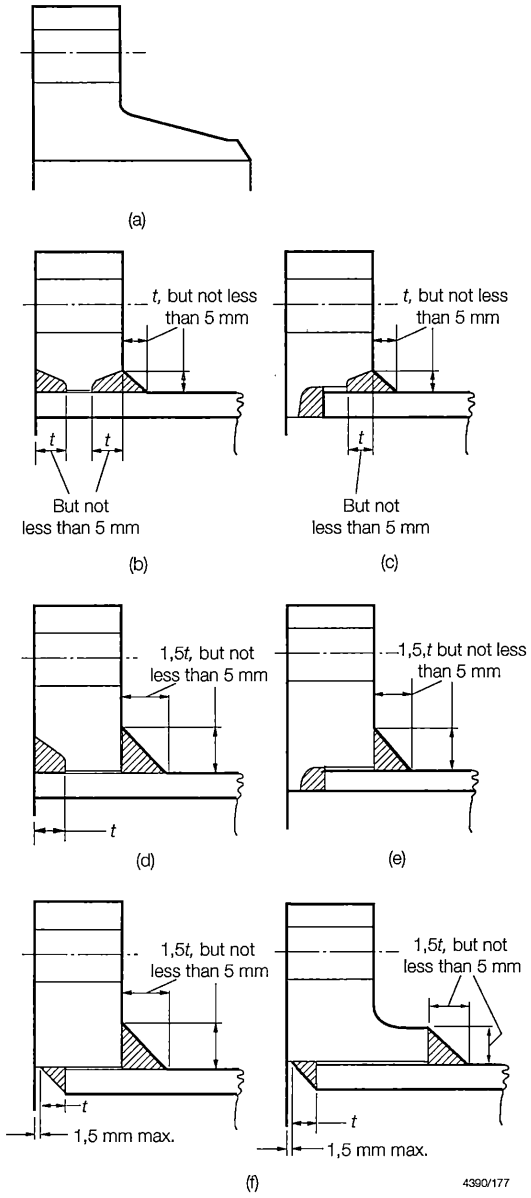

't' is the minimum Rule thickness of standpipe or branch

Fig. 4.7.2
Typical example of welded flange connections

7.3.7 Welding may be carried out by means of the shielded metal arc, inert gas metal arc, oxy-acetylene or other approved process, but in general, oxy-acetylene welding is suitable only for flange type (a) and is not to be applied to branches exceeding 100 mm diameter or 9,5 mm thick.

7.3.8 Threaded sleeve joints complying with Ch 1,5.5.1 may be used on the steam and water piping of small oil fired package boilers of the once through coil type, used for auxiliary or domestic purposes, where the feed pump capacity limits the output.

7.3.9 Socket weld joints are not to be used where fatigue, severe erosion, crevice corrosion or stress corrosion are expected to occur, for example, blow down, drain, scum and chemical dosing connections.

7.4 Welded attachments to pressure vessels

7.4.1 Unless the actual thickness of the shell or end is at least twice that required by calculation for a seamless shell or end, whichever is applicable, doubling plates with well rounded corners are to be fitted in way of attachments such as lifting lugs, supporting brackets and feet, to minimise load concentrations on pressure shells and ends. Compensating plates, pads, brackets and supporting feet are to be bedded closely to the surface before being welded, and are to be provided with a 'tell-tale' hole not greater than 9,5 mm in diameter, open to the atmosphere to provide for the release of entrapped air during heat treatment of the vessel, or as a means of indicating any leakage during hydraulic testing and in service.

7.4.2 For acceptable methods of attaching standpipes, branches, compensating plates and pads, *see* Fig. 4.7.3. Alternative methods of attachment may be accepted provided details are submitted for consideration.

7.4.3 Where fillet welds are used to attach standpipes, there are to be equal sized welds both inside and outside the vessel shell, *see* Fig. 4.7.3(a) and (l). The leg length of each of the fillet welds is to be not less than the actual thickness of the thinner of the parts being joined.

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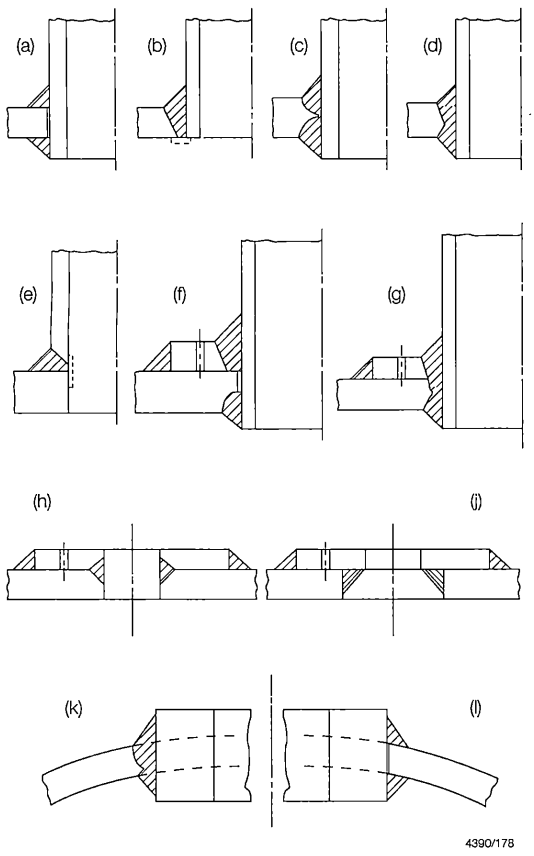
Table 4.7.1 Limiting design conditions for flanges

Flange type	Maximum pressure	Maximum temperature	Maximum pipe o.d.	Minimum pipe bore
		°C	mm	mm
(a)	Pressure temperature ratings to be in accordance with a recognised Standard	No restriction	No restriction	No restriction
(b)		No restriction	168,3 for alloy steels*	No restriction
(c)		No restriction	168,3 for alloy steels*	75
(d)		425	No restriction	No restriction
(e)		425	No restriction	75
(f)		425	No restriction	No restriction

NOTE
* No restriction for carbon steels



Type (a) and (l) attachments are not to be used for openings which require to be compensated. Backing rings may be used with types (b) and (e).

Fig. 4.7.3
Typical acceptable methods of attaching branches and pads

Section 8
Requirements for fusion welded pressure vessels

8.1 General requirements

8.1.1 Welded construction of pressure vessels is to be in accordance with the requirements specified in Ch 13,1 and 4 of the Rules for Materials.

8.1.2 Fusion welded pressure vessels constructed to Class 1 and Class 2/1 requirements will be accepted only if manufactured by firms equipped and competent to undertake high quality welding. In order that firms may be approved for this purpose, it will be necessary for the Surveyors to visit the works for the purpose of inspecting the welding plant equipment and procedures, and to arrange for the carrying out of preliminary tests as stated in Ch 13,4 of the Rules for Materials.

Section 9
Mountings and fittings for pressure vessels

9.1 General

9.1.1 Each pressure vessel or system is to be fitted with a stop valve situated as close as possible to the shell.

9.1.2 Adequate arrangements are to be provided to prevent over-pressure of any part of a pressure vessel which can be isolated. Pressure gauges are to be fitted in positions where they can be easily read.

9.1.3 Adequate arrangements are to be provided for draining and venting the separate parts of each pressure vessel.

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9.2 Receivers containing pressurised gases

9.2.1 Each air receiver is to be fitted with a drain arrangement at its lowest part, permitting oil and water to be blown out.

9.2.2 Each receiver which can be isolated from a relief valve is to be provided with a suitable fusible plug to discharge the contents in case of fire. The melting point of the fusible plug is to be approximately 150°C. *See also* 9.2.3 and 9.2.4.

9.2.3 Where a fixed system utilising fire-extinguishing gas is fitted, to protect a machinery space containing an air receiver(s), fitted with a fusible plug, it is recommended that the discharge from the fusible plug be piped to the open deck.

9.2.4 Receivers used for the storage of air for the control of remotely operated valves are to be fitted with relief valves and not fusible plugs.

■ *Section 10* Hydraulic tests

10.1 Fusion welded pressure vessels

10.1.1 Fusion welded pressure vessels are to be tested on completion to a pressure, p_T, determined by the following formula, without showing signs of weakness or defect:

$$p_T = 1{,}3 \frac{\sigma_{50}}{\sigma_t} \frac{t}{(t - 0{,}75)} p$$

but in no case is to exceed

$$1{,}5 \frac{t}{(t - 0{,}75)} p$$

where

p = design pressure, in bar
p_T = test pressure, in bar
t = nominal thickness of shell as indicated on the plan, in mm
σ_T = allowable stress at design temperature, in N/mm^2
σ_{50} = allowable stress at 50°C, in N/mm^2.

10.2 Mountings

10.2.1 Mountings are to be subjected to a hydraulic test of twice the approved design pressure.

■ *Section 11* Fibre reinforced plastics pressure vessels

11.1 General

11.1.1 Pressure vessels may be constructed in fibre reinforced plastics provided the manufacturer is competent and suitably equipped for this purpose.

11.1.2 Pressure vessels are to be of standard design whose suitability has been established by fatigue and burst tests on a prototype.

11.2 Prototype testing

11.2.1 For the fatigue test the pressure shall be cycled from atmospheric to design pressure 100 000 times at the design temperature.

11.2.2 For the burst test the minimum bursting pressure shall be six times the design pressure.

11.3 Production hydraulic test

11.3.1 Vessels subject to internal pressure shall be hydraulically tested to not less than 1,5 times the design pressure.

■ *Section 12* Requirements for craft which are not required to comply with the HSC Code

12.1 Fibre reinforced plastics pressure vessels

12.1.1 Fibre reinforced plastics pressure vessels, where the product of the design pressure in bar and volume in litres exceeds 600, are not to be situated in machinery spaces or high risk areas on yachts and service craft less than 24 m.

12.1.2 Small fibre reinforced plastics pressure vessels will receive special consideration in relation to their intended duty and service conditions.

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Rules and Regulations for the Classification of Special Service Craft

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Section 1
General requirements

1.1 General

1.1.1 This Chapter applies to control engineering systems on special service craft.

1.1.2 Section 2 states requirements for alarm systems, safety systems and automatic or remote controls where fitted.

1.1.3 Section 4 states requirements which shall apply where it is intended to operate the craft with machinery spaces unattended. In general, craft complying with the requirements of Section 4 will be eligible for the class notation **UMS**.

1.1.4 Section 5 states requirements which shall apply where it is intended to operate the craft with machinery spaces under continuous supervision from a centralised control station. In general, craft complying with the requirements of Section 5 will be eligible for the class notation **CCS**.

1.1.5 Lloyd's Register (hereinafter referred to as 'LR') will be prepared to give consideration to special cases or to arrangements which are equivalent to the Rules.

1.2 Plans and information

1.2.1 Plans and information as detailed in 1.2.2 to 1.2.7 are to be submitted in triplicate.

1.2.2 A description of operation with explanatory diagrams together with line diagrams of control circuits, list of monitored, control and alarm points is required for the following machinery or equipment:

- Fixed water-based local application fire-fighting systems, *see* 2.9.
- Air compressors.
- Bilge systems.
- Controllable pitch propellers.
- Electric generating plant.
- Oil fuel transfer and storage systems.
- Propulsion machinery including essential auxiliaries.
- Steam raising plant (boilers and their ancillary equipment).
- Steering systems.
- Thermal fluid heaters.
- Thrust units.
- Valve position indicating systems.
- Waterjets for propulsion purposes.
- Windlasses.

1.2.3 **Test schedules** (for both works testing and sea trials), which should include methods of testing and test facilities, *see* 7.4.1.

1.2.4 **Alarm systems.** Details of the overall alarm system linking the main control station, subsidiary control stations, the bridge area and accommodation. Details of alarms and warnings presented by the user interface including: an approach to category assignment which is in accordance with the IMO *Code on Alerts and Indicators, 2009*; and for alarms required by these Rules, the intended operator response and the message is to be presented.

1.2.5 **Programmable electronic systems.** In addition to the documentation required by 1.2.2, the following is to be submitted:

(a) System requirements specification.
(b) System integration plan, *see* 2.14.2.
(c) Failure Mode and Effects Analysis (FMEA), *see* 2.14.5.
(d) Details of the hardware configuration in the form of a system block diagram, including input/output schedules.
(e) Hardware certification details, *see* 2.10.5 and 2.13.3.
(f) Software quality plans, including applicable procedures, *see* 2.10.25.
(g) Factory acceptance, integration and sea trial test schedules for hardware and software.
(h) Details of data storage arrangements, *see* 2.10.10 and 2.13.6.

1.2.6 For wireless data communication equipment:

(a) Details of manufacturer's installation and maintenance recommendations;
(b) network plan with arrangement and type of aerials and identification of location;
(c) specification of wireless communication system protocols and management functions, *see* 2.12.4; and
(d) details of radio frequency and power levels, including details of those permitted by the National Administration.

1.2.7 **Control station.** Plans showing the location and details of control stations, e.g., control panels and consoles. Location and details of controls and displays on each panel. Details of user interface specifications. A general arrangement plan of control rooms showing the position of consoles, handrails, operator area, lighting, door and window arrangements. Drawing of HVAC systems including vent arrangements.

1.2.8 **Fire detection systems.** Plans showing the system operation and the type and location of all machinery space fire detector heads, manual call points and the fire detector indicator panel(s). The plans are to indicate the position of the fire detectors in relation to significant items of machinery, ventilation and extraction openings.

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1.2.9 **Cables.** For details of instrumentation and control system cabling requirements, *see* Ch 2,11.

1.3 Control, alarm and safety equipment

1.3.1 Major units of equipment associated with control, alarm and safety systems as defined in 1.2 are to be surveyed at the manufacturers' works and the inspection and testing is to be to the Surveyor's satisfaction, *see also* 1.2.2.

1.3.2 Equipment used in control, alarm and safety systems is to be suitable for its intended purpose, and accordingly, whenever practicable, be selected from the *List of Lloyd's Register Type Approved Products* published by LR.

1.3.3 Where equipment requires a controlled environment, an alternative means is to be provided to maintain the required environment in the event of a failure of the normal air conditioning system. Failure of the air conditioning system is to initiate an alarm.

1.3.4 Assessment of performance parameters, such as accuracy, repeatability, etc., are to be in accordance with an acceptable National or International Standard, e.g., IEC 60051, *Direct acting indicating analogue electrical measuring instruments and their accessories*.

1.4 Alterations and additions

1.4.1 When an alteration or addition to the approved system(s) is proposed, plans are to be submitted for approval. The alterations or additions are to be carried out under survey and the installation and testing are to be to the Surveyor's satisfaction.

1.4.2 Details of proposed software modifications are to be submitted for consideration. Where the modification may affect compliance with these Rules, proposals for verification and validation are also to be submitted.

1.4.3 Software versions are to be uniquely identified by number, date or other appropriate means. Modifications are not to be made without also changing the version identifier. A record of changes to the system since the original issue (and their identification) is to be maintained and made available to the LR Surveyor on request.

■ *Section 2* Essential features for control, alarm and safety systems

2.1 General

2.1.1 Where it is proposed to install control, alarm and safety systems to the machinery and equipment listed in 1.2.2 the applicable features contained in this Section are to be incorporated in the system design.

2.1.2 Systems complying with ISO 17894, *Ships and marine technology – Computer applications – General principles for the development and use of programmable electronic systems in marine applications*, may be accepted as meeting the requirements of this Section in which case evidence of compliance is to be submitted for consideration.

2.2 Control stations for machinery

2.2.1 A system of alarm and warning displays and controls is to be provided which readily ensures identification of faults in the machinery and satisfactory supervision of related equipment by duty personnel. This may be provided at a main control station or, alternatively at subsidiary control stations. In the latter case, a master alarm display is to be provided at the main control station showing which of the subsidiary control stations is indicating a fault condition.

2.2.2 At the main control station (if provided) or close to the subsidiary stations (if fitted) means of two way voice communication with the bridge area, the accommodation for engineering personnel and, if necessary, the machinery spaces are to be provided.

2.2.3 Where operator interfaces are installed in the wheelhouse, illumination should not interfere with night vision. All illumination and lighting of instruments, keyboards and controls are to be adjustable to zero illumination, except for lighting for visual indication of alarms and the controls of dimmers, which are to remain readable.

2.2.4 Provision is to be made at the main control station, or subsidiary control stations as appropriate, for the operation of an engineers' alarm which is to be clearly audible in the engineers' accommodation.

2.2.5 Provision is to be made at the main control station and any other subsidiary control station from which the main propulsion and auxiliary machinery or associated equipment may be controlled to indicate which station is in control.

2.2.6 Control of machinery and associated equipment is to be possible only from one station at a time.

2.2.7 Changeover between control stations is to be arranged so that it may only be effected with the acceptance of the station taking control. The system is to be provided with interlocks or other suitable means to ensure effective transfer of control.

2.2.8 For additional requirements where control stations incorporate visual display units and keyboard input facilities, *see* 2.10.

2.3 Alarm systems

2.3.1 Where an alarm system, which will alert relevant personnel to faults, abnormal situations and other conditions requiring attention in the machinery and the safety and control systems required by this Chapter or other Sections of the Rules, is to be installed, the requirements of 2.3.2 to 2.3.20 are to be satisfied.

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2.3.2 Machinery, safety and control system faults are to be indicated at the relevant control stations to advise duty personnel of a fault condition. The presence of unrectified faults is to be clearly indicated at all times.

2.3.3 Alarms and warnings associated with machinery and equipment required to satisfy this sub-Section are to be categorised according to the urgency and type of response required by the crew, as described in the IMO *Code on Alerts and Indicators, 2009*. The assignment of the category to each alert is to be evaluated on the basis not only of the machinery or equipment being monitored, but also the complete installation. Categories not included in an alarm system may be omitted from the system design. Details of alternative alert management proposals supported with evidence of service experience, may be submitted for consideration by LR.

2.3.4 Where the facility to provide messages in association with alarms and warnings exists, messages accompanying alarms and warnings are to describe the condition and indicate the intended response required by the crew.

2.3.5 Where the facility to provide messages in association with alarms and warnings exists, messages of different categories are to be clearly distinguishable from each other.

2.3.6 Where alarms are displayed as group alarms, provision is to be made to identify individual alarms at the main control station (if fitted) or alternatively at subsidiary control stations.

2.3.7 All alarms are to be both audible and visual. If arrangements are made to silence audible signals they are not to extinguish visual indications.

2.3.8 Acknowledgement of visual alarms is to be clearly indicated.

2.3.9 Acknowledgement of alarms at positions outside a machinery space is not to silence the audible signal or extinguish the visual indication in that machinery space.

2.3.10 If an alarm has been acknowledged and a second fault occurs prior to the first being rectified, audible signals and visual indications are again to operate. Where alarms are displayed at a local panel adjacent to the machinery and with arrangements to provide a group or common fault alarm in the control room then the occurrence of a second fault prior to the first alarm being rectified need only be displayed at the local panel, however the group alarm is to be reinitiated. Unacknowledged alarms on monitors are to be distinguished by either flashing text or a flashing marker adjacent to the text. A change of colour will not in itself be sufficient to distinguish between acknowledged and unacknowledged alarms.

2.3.11 For the detection of transient faults which are subsequently self-correcting, alarms are required to lock in until accepted.

2.3.12 The alarm system is to be arranged with automatic changeover to a standby power supply in the event of a failure of the normal power supply. Where an alarm system could be adversely affected by an interruption in power supply, changeover to the standby power supply is to be achieved without a break.

2.3.13 Failure of any power supply to the alarm system is to operate an audible and visual alarm.

2.3.14 The alarm system should be designed with self-monitoring properties. Insofar as practicable, any fault in the alarm system should cause it to fail to the alarm condition.

2.3.15 The alarm system is to be capable of being tested during normal machinery operation, *see* 7.1.2.

2.3.16 The alarm system is to be designed as far as practicable to function independently of control and safety systems such that a failure or malfunction in these systems will not prevent the alarm system from operating.

2.3.17 Disconnection or manual overriding of any part of the alarm system is to be clearly indicated.

2.3.18 When alarm systems are provided with means to adjust their set point, the arrangements are to be such that the final settings can be readily identified.

2.3.19 Where monitors are provided at the station in control and, if fitted, in the duty engineer's accommodation, they are to provide immediate display of new alarm information regardless of the information display page currently selected. This may be achieved by provision of a dedicated alarm monitor, a dedicated area of screen for alarms or other suitable means.

2.3.20 Where practicable, alarms displayed on monitors are to be displayed in the order in which they occur. Alarms requiring shutdown or slowdown action are to be given visual prominence.

2.4 Safety systems, general requirements

2.4.1 Where safety systems are provided, the requirements of 2.4.2 to 2.4.12 are to be satisfied. The requirements of this sub-Section apply, where relevant, to the safety systems installed on the equipment defined in 1.2.3, including those provided in addition to those safeguards required by other Sections of the Rules.

2.4.2 Safety systems are to operate automatically in case of serious faults endangering the machinery, so that:

(a) normal operating conditions are restored, e.g., by the starting of standby machinery, or

(b) the operation of the machinery is temporarily adjusted to the prevailing conditions, e.g., by reducing the output of the machinery, or

(c) the machinery is protected from critical conditions by shutting off the fuel or power supplies thereby stopping the machinery.

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2.4.3 The safety system required by 2.4.2(c) is to be designed as far as practicable to operate independently of the control and alarm systems, such that a failure or malfunction in the control and alarm systems will not prevent the safety system from operating.

2.4.4 For safety systems required by 2.4.2(a) and (b) complete independence from other control systems is not necessary.

2.4.5 Safety systems for different items of the machinery plant are to be arranged so that failure of the safety system of one part of the plant will not interfere with the operation of the safety system in another part of the plant.

2.4.6 The safety system is to be designed to 'fail safe'. The characteristics of the 'fail safe' operation are to be evaluated on the basis not only of the safety system and its associated machinery, but also the complete installation.

2.4.7 When a safety system is activated, an audible and visual alarm is to be provided to indicate the cause of the safety action.

2.4.8 The safety system is to be manually reset before the relevant machinery can be restarted.

2.4.9 Where arrangements are provided for overriding a safety system, they are to be such that inadvertent operation is prevented. Visual indication is to be given at the relevant control station(s) when a safety override is operated. High speed craft are to be provided with arrangements for overriding automatic shutdown systems except in cases where there is a risk of complete breakdown or explosion.

2.4.10 The safety system is to be arranged with automatic changeover to a standby power supply in the event of a failure of the normal power supply.

2.4.11 Failure of any power supply to a safety system is to operate an audible and visual alarm.

2.4.12 When safety systems are provided with means to adjust their set point, the arrangements are to be such that the final settings can be readily identified.

2.5 Control systems

2.5.1 Where control systems are provided, the requirements of 2.5.2 to 2.5.11 are to be satisfied.

2.5.2 Control systems for machinery operations are to be stable throughout their operating range.

2.5.3 The control system is to be designed such that normal operation of the controls cannot induce detrimental mechanical or thermal overloads in the machinery.

2.5.4 When control systems are provided with means to adjust their sensitivity or set point, the arrangements are to be such that the final settings can be readily identified.

2.5.5 Control systems are to be designed to 'fail safe'. The characteristics of the 'fail safe' operation are to be evaluated on the basis not only of the control system and its associated machinery, but also the complete installation.

2.5.6 Failure of any power supply to a control system is to operate an audible and visual alarm.

2.5.7 Where machinery is fitted with automatic or remote controls so that under normal operating conditions it does not require any manual intervention by the operators, it is to be provided with the alarms and safety arrangements required by the appropriate Chapter(s). Alternative arrangements which provide equivalent safeguards will be considered.

2.5.8 Remote or automatic controls are to be provided with sufficient instrumentation at the relevant control stations to ensure effective control by duty personnel and to indicate that the system is functioning correctly.

2.5.9 Where machinery is arranged to start automatically or from a remote control station, interlocks are to be provided to prevent start-up under conditions which could hazard the machinery.

2.5.10 Where machinery, controlled in accordance with 2.5.7, is required to be provided with a standby pump, the standby pump is to start automatically if the discharge pressure from the working pumps falls below a predetermined value.

2.5.11 Failure of a control system is not to result in the loss of ability to provide essential services by alternative means. This may be achieved by manual control or redundancy within the control system or redundancy in machinery and equipment, *see also* 2.13.2. Instrumentation is to be provided at local manual control stations to ensure effective operation of the machinery by duty personnel.

2.6 Bridge control for propulsion machinery

2.6.1 Where a bridge control system for propulsion machinery is to be fitted, the requirements of 2.6.2 to 2.6.8 are to be satisfied.

2.6.2 Means are to be provided to ensure satisfactory control of propulsion from the bridge in both the ahead and astern directions.

2.6.3 Two independent means are to be provided on the bridge to enable the watchkeeper to stop the propulsion machinery in an emergency.

2.6.4 Audible and visual alarms are to operate on the bridge and in the machinery alarm system if any power supply to the bridge control system fails. Where practicable the preset speed and direction of thrust are to be maintained until corrective action is taken.

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2.6.5 Cargo (B) high speed craft are to be provided with a standby system for controlling propulsion machinery. A standby system controllable from an engine control space such as an engine control room outside the bridge is acceptable.

2.6.6 Passenger (B) high speed craft are to be provided with a standby system for controlling propulsion machinery from the bridge.

2.6.7 Passenger (B) high speed craft are to be provided with additional control of propulsion and manoeuvring at the same location as the emergency functions referred to in Ch 2,16.6.12. Such stations are to have direct communication with the bridge area.

2.6.8 For high speed craft, failure of the operating propulsion control system or of transfer of control is to bring the craft to low speed without hazarding passengers or craft.

2.7 Valve control systems

2.7.1 Where cargo, bilge, ballast, oil fuel transfer and sea valves for engine services are operated by remote or automatic control, the requirements of 2.7.2 to 2.7.5 are to be satisfied.

2.7.2 Failure of actuator power is not to permit a valve to move to an unsafe condition.

2.7.3 Positive indication is to be provided at the remote control station for the service to show the actual valve position or alternatively that the valve is fully open or closed.

2.7.4 Equipment located in places which may be flooded is to be capable of operating when submerged.

2.7.5 A secondary means of operating the valves, which may be by local manual control, is to be provided.

2.7.6 For requirements applicable to closing appliances on scuppers and sanitary discharges, *see* Pt 3, Ch 4,9.4. For power supplies on passenger craft, *see* Ch 2,3.2.

2.8 Fire detection alarm systems

2.8.1 Where an automatic fire detection system is to be fitted in a machinery space the requirements of 2.8.2 to 2.8.14 are to be satisfied.

2.8.2 A fire detection control unit is to be located in the navigating bridge area, the fire control station, or in some other position such that a fire in the machinery spaces will not render it inoperable.

2.8.3 Fire detection indicating panels are to denote the section in which a detector or manually operated call point has operated. At least one indicating panel is to be so located that it is easily accessible to responsible members of the crew at all times. An indicating panel is to be located on the navigating bridge, together with TV monitoring in the case of high speed craft.

2.8.4 An audible fire-alarm signal is to be provided having a characteristic which distinguishes it from the alarm signal required by 2.3 or any other alarm system. The audible fire-alarm signal is to be immediately audible on all parts of the navigating bridge, at the fire control station and the machinery control stations, and throughout the crew accommodation areas and the machinery spaces.

2.8.5 Facilities are to be provided in the fire detection system to manually initiate the fire alarm from the following locations:

(a) Positions adjacent to all exits from machinery spaces.
(b) Navigating bridge.
(c) Control station in engine room.
(d) Fire control station.

2.8.6 The alarm system is to be designed with self-monitoring properties and system failures are to initiate an audible and visual alarm distinguishable from the fire alarm signal. This alarm may be incorporated in the machinery alarm system.

2.8.7 Power supplies for the alarm system are to be in accordance with Ch 2,17.1.

2.8.8 Fire detection control units (including addressable systems), indicating panels, detector heads, manual call points and short circuit isolation units are to be Type Approved in accordance with the LR *Type Approval System*. For addressable systems, *see also* 2.10.

2.8.9 Detector heads are to be located in the machinery spaces so that all potential fire outbreak points are guarded. A combination of detectors is to be provided in order that the system will react to all possible fire characteristics.

2.8.10 When fire detectors are provided with means to adjust their sensitivity, the arrangements are to be such that the set point can be fixed and readily identified.

2.8.11 When it is intended that a particular loop is to be temporarily switched off, this state is to be clearly indicated at the fire detection indicating panels.

2.8.12 When it is intended that a particular detector(s) is (are) to be temporarily switched off locally, this state is to be clearly indicated at the local position. Reactivation of the detector(s) is to be performed automatically after a preset time.

2.8.13 The fire detector heads are to be of a type which can be tested and reset without the renewal of any component. Facilities are to be provided on the fire control panel for functional testing and reset of the system.

2.8.14 It is to be demonstrated to the Surveyor's satisfaction that detector heads are so located that air currents will not render the system ineffective at sea and in port.

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2.9 Fixed water-based local application fire-fighting systems

2.9.1 Where fixed water-based local application fire-fighting systems are required to be installed by National Administration requirements, arrangements are to be in accordance with this sub-Section.

2.9.2 Systems are to be available for immediate use and arranged for manual activation from inside and outside the protected space. *See also* Ch 2,16.3.4.

2.9.3 Activation of a system is not to result in loss of electrical power or reduction of the manoeuvrability of the craft and is not to require confirmation of space evacuation or sealing, *see also* Ch 2,17.3.12.

2.9.4 System zones and protected areas are to be arranged to allow essential services to be provided by machinery and/or equipment located outside areas affected by direct spray or extended water in the event of a system activation, where the machinery and/or equipment is duplicated or otherwise replicated to provide redundancy.

2.9.5 A control panel is to be provided for managing actions such as opening of valves, starting of pumps and initiation of alarms and warnings and processing information from detectors. This panel is to be independent of the fire detection control unit required by 2.8.

2.9.6 Alarms are to be initiated upon activation of a system and are to indicate the specific zone released at the control panel. Alarms are to be provided in each protected space, at an attended machinery control station and in the wheelhouse. The audible alarm is to be distinguishable from other safety system alarms.

2.9.7 A failure in a manual system activation switch circuit is not to prevent system activation using other installed manual system activation switches or, where installed, automatic activation. The means of activation are to be provided with self-monitoring facilities which will activate an alarm at an attended control station in the event of failure detection.

2.9.8 Where, additionally, the system is required to be capable of automatic release, the arrangements are to be in accordance with 2.9.8 to 2.9.12.

2.9.9 A minimum of two fire detectors are to be provided for each protected area. One is to be a flame detector and the other is to be a smoke or heat detector, as considered appropriate to the nature of the risk and ambient conditions. The system is to be activated upon detection by two of the detectors. A fault in one detector is to initiate an alarm at an attended control stationand is not to inhibit activation of the system under the control of the other detector or manually.

2.9.10 The fire detectors are to be arranged (located, oriented, guarded, etc.) to ensure that a fire in one protected area will not result in the inadvertent automatic activation of a system for another protected area. Guards or barriers provided to comply with this requirement are not to reduce the ability to detect a fire in the protected area.

2.9.11 A fire detection alarm system panel in accordance with 2.8 may be used for receiving fire detection signals. Separate loops are not required provided that the address of the initiating device can be identified at the control panel. The received signals are then to be sent to the control panel required by 2.9.5 for processing and action.

2.9.12 The system's fire detection systems and control units are to meet the performance criteria stipulated by the National Administration and are to be Type Approved in accordance with *Test Specification Number 1* given in LR's Type Approval System for an environmental category appropriate for the locations in which they are intended to operate.

2.10 Programmable electronic systems – General requirements

2.10.1 The requirements of this sub-Section are to be complied with where control, alarm or safety systems incorporate programmable electronic equipment. Systems for essential services and safety critical applications, systems incorporating shared data communication links and systems which are integrated are to comply with the additional requirements of 2.11, 2.13 and 2.14, as applicable. For systems complying with ISO 17894, *Ships and marine technology – Computer applications – General principles for the development and use of programmable electronic systems in marine applications, see* 2.1.2.

2.10.2 Where programmable electronic systems share resources, any components that can affect the ability to effectively provide required control, alarm or safety functions are to fulfil the requirements of 2.10 to 2.14 related to providing those required functions.

2.10.3 Programmable electronic equipment is to revert to a defined safe state on initial start up or re-start in the event of failure.

2.10.4 In the event of failure of any programmable electronic equipment, the system and any other system to which it is connected, is to fail to a defined safe state or maintain safe operation, as applicable.

2.10.5 Programmable electronic equipment is to be certified by a recognised authority as suitable for the environmental conditions in which it is intended to operate, *see also* 2.13.3.

2.10.6 Emergency stops are to be hard-wired and independent of any programmable electronic equipment. Alternatively, the system providing emergency stop functions is to comply with the requirements of 2.13.2 and/or 2.13.9.

2.10.7 Programmable electronic equipment is to be provided with self-monitoring capabilities such that hardware and functional failures will initiate an audible and visual alarm in accordance with the requirements of 2.3 and, where applicable, 4.2. Hardware failures indications are to enable faults to be identifiable at least down to the level of the lowest replaceable unit and the self-monitoring capabilities are to ensure that diagnostic information is readily available.

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2.10.8 Means are to be provided to recover or replace data required for safe and effective system operation lost as a result of component failure. The submission required by 1.2.5 is to address reinstatement of system operation following data loss.

2.10.9 System configuration, programs and data are to be protected against loss or corruption in the event of failure of any power supply. For essential services and safety critical systems, *see* 2.13.6.

2.10.10 Where it is necessary to store data required for system operation in volatile memory, a back-up power supply is to be provided that prevents data loss in the event of loss of the normal power supply. The submission required by 1.2.5 is to include details of any routine maintenance necessary and the measures necessary to restore system operation in the event of data loss as a result of power supply failure.

2.10.11 Back-up power supplies required by 2.10.10 are to be rated to supply the connected load for a defined period of time that allows sufficient time to restore the supply in the event of loss of the normal power supply as a result of failure of a main source of electrical power. This period is not to be less than 30 minutes.

2.10.12 Where regular battery replacement is required to maintain the availability of volatile memory back-up power supply required by 2.10.10, these are to be included in the schedule of batteries required by Ch 2,1.2.10 and 12.7, irrespective of battery type and size. Applicable entries in this schedule are to note that these batteries are not for safety critical systems or essential or emergency services.

2.10.13 Access to system configuration, programs and data is to be restricted by physical and/or logical means providing effective security against unauthorised alteration.

2.10.14 Where date and time information is required by the equipment, this is to be provided by means of a battery backed clock with restricted access for alteration. Date and time information is to be fully represented and utilised.

2.10.15 Displays and controls are to be protected against liquid ingress due to spillage.

2.10.16 Display units are to comply with the requirements of an acceptable National or International Standard e.g., IEC 60950:2005, *Safety of information technology equipment,* in respect of emission of ionising radiation.

2.10.17 Where systems detect fault conditions, any affected mimic diagrams are to ensure that the status of unreliable and incorrect data is clearly identified.

2.10.18 Multi-function displays and controls are to be duplicated and interchangeable where used for the control or monitoring of more than one system, machinery item or item of equipment. At least one unit at the main control station is to be supplied from an independent uninterruptible power system (UPS).

2.10.19 The number of multi-function display and control units provided at the main control station and their power supply arrangements are to be sufficient to ensure continuing safe operation in the event of failure of any unit or any power supply.

2.10.20 Software lifecycle activities, e.g., design, develop-ment, supply and maintenance, are to be carried out in accordance with an acceptable quality management system. Software quality plans are to be submitted. These are to demonstrate that the provisions of ISO/IEC 90003:2004, *Software engineering – Guidelines for the application of ISO 9001:2000 to computer software*, or equivalent, are incorporated. The plans are to define responsibilities for the lifecycle activities, including verification, validation, module testing and integration with other components or systems.

2.11 Data communication links

2.11.1 Where control, alarm or safety systems use shared data communication links to transfer data, the requirements of 2.11.2 to 2.11.10 are to be complied with. The requirements apply to local area networks, fieldbuses and other types of data communication link which make use of a shared medium to transfer control, alarm or safety related data between distributed programmable electronic equipment or systems.

2.11.2 Data communication is to be automatically restored within 45 seconds in the event of a single component failure. Upon restoration, priority is to be given to updating safety critical data and control, alarm and safety related data for essential services. Components comprise all items required to facilitate data communication, including cables, switches, repeaters, software components and power supplies.

2.11.3 Loss of a data communication link is not to result in the loss of ability to operate any essential service by alternative means, *see also* 2.13.2.

2.11.4 The properties of the data communication link, (e.g., bandwidth, access control method, etc.), are to ensure that all connected systems will operate in a safe, stable and repeatable manner under all operating conditions. The latency of control, alarm and safety related data is not to exceed two seconds.

2.11.5 Protocols are to ensure the integrity of control, alarm and safety related data, and provide timely recovery of corrupted or invalid data.

2.11.6 Means are to be provided to monitor performance and identify hardware and functional failures. An audible and visual alarm is to operate in accordance with the requirements of 2.3 and, where applicable, 4.2 in the event of a failure of an active or standby component.

2.11.7 System self-monitoring capabilities are to be arranged to initiate transition to a defined safe state for the complete installation in the event of data communication failure, *see also* 2.5.5.

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2.11.8 Means are to be provided to prevent unintended connection or disconnection of any equipment where this may affect the performance of any other systems in operation.

2.11.9 Data cables are to comply with the applicable requirements of Ch 2,11. Other media will be subject to special consideration.

2.11.10 The installation is to provide adequate protection against mechanical damage and electromagnetic interference.

2.11.11 Components are to be located with appropriate segregation such that the risk of mechanical damage or electromagnetic interference resulting in the loss of both active and standby components is minimised. Duplicated data communication links are to be routed to give as much physical separation as is practical.

2.12 Additional requirements for wireless data communication links

2.12.1 The requirements of this sub-Section are in addition to 2.11 and apply to systems incorporating wireless data communication links.

2.12.2 Wireless data communication links are not to be used for safety critical systems or essential services that are required for the propulsion or safety of the craft, except as permitted by 2.12.3.

2.12.3 For services not required to operate continuously, wireless data communication links may be considered where an alternative means of operation that can be brought into action within an acceptable period of time is provided.

2.12.4 Wireless data communication is to employ recognised international wireless communication system protocols that incorporate the following:

(a) Message integrity: fault prevention, detection, diagnosis and correction, ensuring that the received message is not corrupted or altered when compared to the transmitted message.

(b) Configuration and device authentication: is to permit connection only of devices that are included in the system design.

(c) Message encryption: protection of the confidentiality and/or criticality of the data content.

(d) Security management: protection of network assets and prevention of unauthorised access to network assets.

2.12.5 The wireless system is to comply with the radio frequency and power level requirements of the International Telecommunications Union and any requirements of the National Administration with which the craft is registered.

2.12.6 Compliance with different port state and local regulations pertaining to the use of radio-frequency transmission that would prohibit the operation of a wireless data communication link, due to frequency and power level restrictions, is not addressed by these requirements and is the responsibility of the Owner and Operator.

2.13 Programmable electronic systems – Additional requirements for essential services and safety critical systems

2.13.1 The requirements of 2.13.2 to 2.13.10 are to be complied with where control, alarm or safety systems for essential services, as defined by Ch 2,1.6, or safety critical systems, incorporate programmable electronic equipment:

(a) Safety critical systems are those which provide functions intended to protect persons from physical hazards (e.g., fire, explosion, etc.), or to prevent mechanical damage which may result in the loss of an essential service (e.g., main engine low lubricating oil pressure shutdown).

(b) Applications that are not essential services may also be considered to be safety critical (e.g., domestic boiler low water level shutdown).

2.13.2 Alternative means of safe and effective operation are to be provided for essential services and, wherever practicable, these are to be by provision of a fully independent hard wired back-up system. Where these alternative means are not independent of any programmable electronic equipment, the software is to satisfy the requirements of LR's *Software Conformity Assessment System – Assessment Module GEN1 (1994)*.

2.13.3 Items of programmable electronic equipment used to implement control, alarm and safety functions are to satisfy the requirements of LR's *Type Approval System Test Specification Number 1* (2002).

2.13.4 The system is to be configured such that control, alarm and safety function groups are independent. A failure of the system is not to result in the loss of more than one of these function groups. Proposals for alternative arrangements providing an equivalent level of safety will be subject to special consideration.

2.13.5 For essential services, the system is to be arranged to operate automatically from an alternative power supply in the event of a failure of the normal supply.

2.13.6 Volatile memory is not to be used to store data required for:

- an essential service or safety critical functions; or
- ensuring safety or preventing damage, including during start-up or re-start.

Alternative proposals which demonstrates that an equivalent level of system integrity will be achieved may be submitted for consideration.

2.13.7 Failure of any power supply is to initiate an audible and visual alarm in accordance with the requirements of 2.3 and, where applicable, 4.2.

2.13.8 Where it is intended that the programmable electronic system implements emergency stop or safety critical functions, the software is to satisfy the requirements of LR's *Software Conformity Assessment System – Assessment Module GEN1 (1994)*. Alternative proposals providing an equivalent level of system integrity will be subject to special consideration, e.g., fully independent hard wired back-up system, redundancy with design diversity, etc.

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2.13.9 Control, alarm and safety related information is to be displayed in a clear, unambiguous and timely manner, and, where applicable, is to be given visual prominence over other information on the display.

2.13.10 Means of access to safety critical functions are to be dedicated to the intended function and readily distinguishable.

2.14 Programmable electronic systems – Additional requirements for integrated systems

2.14.1 The requirements of 2.14.2 to 2.14.7 apply to integrated systems providing control, alarm or safety functions in accordance with the Rules, including systems capable of independent operation interconnected to provide co-ordinated functions or common user interfaces. Examples include integrated machinery control, alarm and monitoring systems, power management systems and safety management systems providing a grouping of fire, passenger, crew or craft safety functions, *see* Ch 2,17 to 19.

2.14.2 System integration is to be managed by a single designated party, and is to be carried out in accordance with a defined procedure identifying the roles, responsibilities and requirements of all parties involved. This procedure is to be submitted for consideration where the integration involves control functions for essential services or safety functions including fire, passenger, crew, and craft safety.

2.14.3 The system requirements specification, *see* 1.2.5, is to identify the allocation of functions between modules of the integrated system, and any common data communication protocols or interface standards required to support these functions.

2.14.4 Reversionary modes of operation are to be provided to ensure safe and graceful degradation in the event of one or more failures. In general, the integrated system is to be arranged such that the failure of one part will not affect the functionality of other parts, except those that require data from the failed part.

2.14.5 Where the integration involves control functions for essential services or safety functions, including fire, passenger, crew and craft safety, a Failure Mode and Effects Analysis (FMEA) is to be carried out in accordance with IEC 60812, or an equivalent and acceptable National or International Standard and the report and worksheets submitted for consideration. The FMEA is to demonstrate that the integrated system will 'fail-safe', *see* 2.4.6 and 2.5.5, and that essential services in operation will not be lost or degraded beyond acceptable performance criteria where specified by these Rules.

2.14.6 The quantity and quality of information presented to the operator are to be managed to assist situational awareness in all operating conditions. Excessive or ambiguous information that may adversely affect the operator's ability to reason or act correctly is to be avoided, but information needed for corrective or emergency actions is not to be suppressed or obscured in satisfying this requirement.

2.14.7 Where information is required by the Rules or by National Administration requirements to be continuously displayed, the system configuration is to be such that the information may be viewed without manual intervention, e.g. the selection of a particular screen page or mode of operation. *See also* 2.10.23 and 2.10.24.

Section 3 Ergonomics of control stations

3.1 Objectives

3.1.1 In order to take account of operator tasks at control stations, enhance usability and reduce human error, the layout arrangements are to comply with the requirements set out in 3.2.

3.1.2 In order to establish a working environment that has minimum distractions, is sufficiently comfortable, helps maintain vigilance and maximises communication amongst operators at main control stations, the requirements of 3.3 are to be complied with.

3.1.3 The requirements of 3.4 to 3.6 apply to operator interfaces for essential engineering systems located either locally, remotely or within the main control room. The requirements are intended to enhance the usability of systems and equipment, reduce human error, enhance situational awareness and support safe and effective monitoring and control under normal and abnormal modes of operation.

3.2 Control station layout

3.2.1 Control stations are to provide sufficient space and access for the intended number of operators in the expected operating conditions.

3.2.2 Local control stations are to be positioned to minimise the risk of harm to the operator.

3.2.3 Controls, displays and indicators are to be both logically and physically grouped according to their function.

3.2.4 Where a function may be accessed from more than one interface, the arrangement of displays and controls is to be consistent.

3.2.5 Frequently used controls and displays are to be within easy reach and visible to the operator from the normal working position.

3.2.6 Controls and displays used infrequently and which may be used in an emergency are to be clearly identifiable, clearly visible, easily accessible and positioned to allow safe operability.

3.2.7 The relationship of a control with a display is to be immediately apparent.

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3.2.8 The relationship of controls and displays with the equipment under control is to be immediately apparent.

3.2.9 There is to be adequate spacing between controls and between controls and obstructions.

3.2.10 Controls and their associated displays are to be located such that the information on the displays can be easily read during the operation of the controls.

3.2.11 Indicators related to the controls are to be visible during their operation.

3.2.12 Instruments are to face the operator's intended working position.

3.3 Physical environment

3.3.1 Control stations are to be positioned, as far as practicable, away from, or insulated against, sources of structurally transmitted noise, such as ventilation fans, engine intake fans and other noise sources.

3.3.2 In general, noise levels are to comply with IMO Res. A.468(XII), Code on Noise Levels on Board Ships, and are to take into account IMO Res. A.343(IX), *Recommendation on Methods of Measuring Noise; Levels at Listening Posts*.

3.3.3 Where provided, the heating, ventilation and air-conditioning system is to be capable of maintaining the temperature between 18°C and 27°C.

3.3.4 The flow of air from heating or air-conditioning systems is not to be guided directly to the operator, or means are to be provided to adjust the direction of airflow from those systems.

3.3.5 Lighting is to be located to avoid glare from working and display surfaces, and is to be flicker-free. Surfaces are to have a non-reflective or matt finish.

3.3.6 Placement of controls, displays and indicators are to consider the position of light sources relative to the operator with respect to reflections and evenness of lighting.

3.3.7 Where a transparent cover is fitted over a control, display or indicator, it is to be designed to minimise reflections.

3.3.8 The level of lighting is to be sufficient to enable operation of user interfaces. Lighting levels, in accordance with Table 1.3.1, will be considered to satisfy this requirement.

3.3.9 Chairs provided for use at control stations are to be adjustable to allow for varying heights of operators.

3.3.10 Physical hazards, e.g., sharp edges, protuberances and trip hazards, are to be avoided.

3.3.11 Sufficient handrails or equivalent are to be fitted to enable operators to move and stand safely in rough seas.

Table 1.3.1 Specific lighting levels

Work area	Ideal Lux	Minimum Lux
General lighting	540	220
Control room consoles (front)	540	320
Control room consoles (rear)	325	110
Local operating panels	540	320
Remote operating panels	540	320

3.3.12 Work surfaces are to be capable of withstanding oils and solvents common to ships and are to be easy to clean.

3.4 Operator interface

3.4.1 The design of the operator interface is to permit the satisfactory monitoring, control and supervision of the machinery and equipment.

3.4.2 Information is to be presented to the operator consistently, both within and between different interfaces, *see* 3.6.2 to 3.6.4.

3.4.3 The response of the machinery and equipment to operator input is to be consistent between interfaces for the same function.

3.4.4 Visual, audible or mechanical feedback is to be provided to indicate that operator input has been acknowledged.

3.4.5 Functions requested by the operator are to be confirmed by the displays on completion.

3.4.6 Indications and documentation are to be in English or the language of the crew.

3.5 Controls

3.5.1 Operator inputs are to be checked for errors, for example, out of range data or incorrect actions, and alert the operator when they occur.

3.5.2 Means to rapidly and safely correct wrong inputs or commands is to be provided.

3.5.3 Assistance is to be provided to the operator to recover from operating errors, for example, through advisory screens where the automation system has this facility.

3.5.4 Operator confirmation is to be provided for any control action that could affect the safety of the ship, i.e., they should not rely on single keystrokes.

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3.5.5 The purpose of each control is to be clearly indicated. Where standard symbols have been internationally adopted, they should be used.

3.5.6 The settings of mechanical controls are to be immediately evident.

3.5.7 The means of operation of mechanical controls is to be consistent with expectations.

3.5.8 Controls or combined controls and indicators are to be distinguishable from indicators.

3.5.9 Where control is provided by touch screens, the size of the soft keys are to be of a sufficient size for operation in areas where vibration occurs or gloves are likely to be worn.

3.5.10 Where virtual keypads/keyboards or dialogue boxes are used on touch screens, they are not to obscure status or alarm areas of the display.

3.5.11 Keyboards are to be divided logically into functional areas. Alphanumeric, paging and specific keys are to be grouped separately.

3.6 Displays

3.6.1 The displays and indicators are to present the operator with clear, timely and relevant information.

3.6.2 Graphical symbols and colour coding are to be consistent. The graphical symbols of display functions are to be in accordance with a recognised International Standard, for example, ISO 14617, *Graphical symbols for diagrams.* Colour coding of functions and signals is to be in accordance with a recognised International Standard, for example, ISO 2412: 1982, *Shipbuilding – Colours of indicator lights.*

3.6.3 The symbols used in mimic diagrams for the services listed in Pt 16, Ch 2,1.5.1 are to be consistent across all displays.

3.6.4 The display of information is to be consistent with respect to screen layout and arrangement of information.

3.6.5 Flashing of information is to be reserved for unacknowledged alerts, or transient states, for example, valve moving.

3.6.6 The functions supported by a display are to be clearly indicated. For displays that can support multiple functions, it is to be possible to select the display associated with the primary function or an overview by a simple operator action.

3.6.7 The operating mode of the machinery and equipment is to be clearly indicated.

3.6.8 In general, indications provided by instrumentation which are displayed digitally are not to change more frequently than twice per second.

3.6.9 To indicate an increasing value in a single direction, on a fixed circular scale, the pointer is to move clockwise. If the pointer is fixed, the scale is to move anticlockwise to indicate an increase in value.

3.6.10 To indicate an increasing value on a horizontal linear scale, the pointer is to move from left to right. On a vertical linear scale, the pointer is to move upwards to indicate an increase in value.

3.6.11 The pointer is not to obscure the numbers on the scale.

3.6.12 Alphanumeric data, text, symbols and other graphical information is to be readable from relevant operator positions under lighting conditions as specified in 3.3.8. Character height in millimetres is to be not less than three and a half times the reading distance in metres and the character width is to be 0,7 times the character height.

3.6.13 A simple sans-serif character font is to be used in displays. In descriptive text, lower case letters are to be used, where appropriate, as opposed to capitals to improve readability.

3.6.14 Where information related to the safe operation of machinery and equipment is provided, it is to be continuously available to the operator.

3.6.15 Failures are to be indicated in a clear and unambiguous manner. Sufficient information is to be provided for the operator to identify the cause of the failure.

■ *Section 4* Unattended machinery space(s) – UMS notation

4.1 General

4.1.1 Where it is proposed to operate the following machinery in an unattended space, no matter what period is envisaged, the controls, alarms and safeguards required by the appropriate Chapters together with those given in 4.2 to 4.7 are to be provided:

- Air compressors.
- Controllable pitch propellers.
- Electric generating plant.
- Oil fuel transfer and storage systems.
- Propulsion machinery including essential auxiliaries.
- Steam raising plant (boilers and their ancillary equipment).
- Thermal fluid heaters.

4.2 Alarm system for machinery

4.2.1 An alarm system which will provide warning of faults in the machinery is to be installed. The system is to satisfy the requirements of 2.3.

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4.2.2 Audible and visual indication of machinery alarms is to be relayed to the engineers' accommodation so that engineering personnel are made aware that a fault has occurred.

4.2.3 The engineers' alarm required by 2.2.4 is to be activated automatically in the event that a machinery alarm or warning has not been acknowledged in the space within a predetermined time.

4.2.4 Audible and visual indication of machinery alarms is to be relayed to the navigating bridge control station in such a way that the navigating officer of the watch is made aware when:

(a) a machinery fault has occurred,
(b) the machinery fault is being attended to, and
(c) the machinery fault has been rectified.

4.2.5 Group alarms may be arranged on the bridge to indicate machinery faults, but alarms associated with faults requiring speed or power reduction or the automatic shutdown of propulsion machinery are to be identified by separate group alarms or by individual alarm parameters.

4.3 Bridge control for propulsion machinery

4.3.1 A bridge control system for the propulsion machinery is to be fitted. The system is to satisfy the requirements of 2.6.

4.4 Control stations for machinery

4.4.1 A control station(s) is to be provided in the space and on the bridge which satisfies the requirements of 2.2.

4.5 Fire detection alarm system

4.5.1 An automatic fire detection system is to be fitted in the space together with an audible and visual alarm system. The system is to satisfy the requirements of 2.8.

4.6 Bilge level detection

4.6.1 An alarm system is to be provided to warn when liquid in machinery space bilges has reached a predetermined level, and is to comply with 2.3. This level is to be sufficiently low to prevent liquid from overflowing from the bilges onto the tank top. The number and location of detectors are to be such that accumulation of liquids will be detected at all angles of heel and trim.

4.6.2 Local or remote controls of any valve within the space serving a sea inlet, a discharge below the waterline, a bilge injection or a direct bilge system, should be so sited as to be readily accessible and to allow adequate time for operation in case of influx of water to the space, having regard to the time which could be taken to reach and operate such controls.

4.6.3 Where the bilge pumps are arranged to start automatically, means are to be provided to indicate if the influx of liquids is greater than the pump capacity or, if the pump is operating more frequently than would be expected. Special attention should be given to oil pollution prevention requirements.

4.7 Supply of electric power, general

4.7.1 For craft operating with one generator set in service, arrangements are to be such that a standby generator will automatically start and connect to the switchboard in as short a time as practicable, but in any case within 45 seconds, on loss of the service generator. For craft operating with two or more generator sets in service, arrangements are to be such that on loss of one generator the remaining one(s) are to be adequate for continuity of essential services. For the detailed requirements of these arrangements, *see* Ch 2,2.2.

■ *Section 5*
Machinery operated from a centralised control station – CCS notation

5.1 General requirements

5.1.1 Where it is proposed to operate the machinery as listed in 4.1.1 with continuous supervision from a centralised control station, the control station is to be such that the machinery operation will be as effective as it would be under direct supervision.

5.1.2 The arrangements are to be such that corrective actions can be taken at the control station in the event of machinery faults, e.g., stopping of machinery, starting of standby machinery, adjustment of operating parameters, etc. These actions may be effected by either remote manual or automatic control.

5.1.3 The controls, alarms and safeguards required by the appropriate Chapters and by 4.6 together with a fire detection system satisfying the requirements of 2.8 are to be provided.

5.1.4 Additional requirements for controls, alarms and safeguards are given in 5.2.

5.2 Centralised control station for machinery

5.2.1 A centralised control station is to be provided at some suitable location, which satisfies the requirements of 5.2.2 to 5.2.7.

5.2.2 A system of alarm displays and controls is to be provided which readily ensures identification of faults in the machinery and satisfactory supervision of related equipment. The alarm and control systems are to satisfy the requirements of 2.3 and 2.5, as applicable.

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5.2.3 Indication of all essential parameters necessary for the safe and effective operation of the machinery is to be provided, e.g., temperatures, pressures, tank levels, speeds, powers, etc.

5.2.4 Indication of the operational status of running and standby machinery is to be provided.

5.2.5 At the centralised control station, means of communication with the bridge area, the accommodation for engineering personnel and, if necessary, the machinery space are to be provided.

5.2.6 In addition to the communication required by 5.2.5, a second means of communication is to be provided between the bridge and the centralised control station. One of these means is to be independent of the main electrical power supply.

5.2.7 Arrangements are to be provided in the centralised control station so that the normal supply of electrical power may be restored in the event of failure.

■ *Section 6* Requirements for craft which are not required to comply with the HSC Code

6.1 General

6.1.1 The relevant requirements of Sections 1 and 2 are to be complied with.

6.1.2 For vessels which are to be assigned or to be eligible for the **UMS** or **CCS** notations the requirements of Sections 4 and 5 are to be complied with.

6.1.3 For yachts less than 500 gt and small craft not requiring the **UMS** and **CCS** notation, the requirements of 6.2 and 6.3 apply.

6.1.4 Yachts that are 500 gt or more are to comply with the requirements of Sections 1 and 2.

6.2 Plans and information

6.2.1 Plans are required to be submitted in accordance with 1.2 only for the machinery items applicable to these craft.

6.3 Control and supervision of unattended machinery

6.3.1 Where machinery items applicable to these craft are fitted with automatic or remote controls so that under normal operating conditions they do not require any manual intervention by the operators they are to be provided with the alarms and safety arrangements specified in the appropriate Chapters of the Rules.

■ *Section 7* Trials

7.1 General

7.1.1 Before a new installation (or any alteration or addition to an existing installation) is put into service, trials are to be carried out. These trials are in addition to any acceptance tests which may have been carried out at the manufacturers' works and are to be based on the approved test schedules list as required by 1.2.3. In the case of new construction it will be expected that most of these trials will be carried out before the official sea trials of the craft. During sea trials, system dynamic tests are to be carried out to demonstrate overall satisfactory performance of the control engineering installation.

7.1.2 Means are to be provided to facilitate testing during normal machinery operation, e.g., by the provision of three-way test valves or equivalent.

7.1.3 Acceptance tests and trials for Programmable Electronic Systems are to include verification of software life-cycle activities appropriate to the stage in the system's lifecycle at the time of system examination. The documentation required by 1.2.5 is to be in accordance with the current configuration and the testing and trials are to address software modifications and configuration management procedures to the Surveyor's satisfaction.

7.1.4 Wireless data communication links are to be operational and tested during trials. Tests are to demonstrate that radio-frequency transmission does not interfere with the operation of equipment required by this Chapter or other Sections of the Rules and does not itself malfunction as a result of electromagnetic interference during expected operating conditions. Reversionary modes are to be activated to demonstrate continued safe and effective operation in the event of fault conditions.

7.2 Unattended machinery space operation – UMS notation

7.2.1 In addition to the tests required by 7.1, the suitability of the installation for operation in the unattended mode is to be demonstrated during sea trials observing the following:

(a) Occurring alarms and the frequency of operation both during steady steaming and under manoeuvring conditions using bridge control.

(b) Any intervention by personnel in the operation of the machinery.

7.3 Operation from a centralised control station – CCS notation

7.3.1 In addition to the tests required by 7.1, the suitability of the installation for operation from the centralised control station is to be demonstrated during sea trials.

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7.4 Record of trials

7.4.1 Two copies of the alarm and control equipment test schedules, as required by 1.2.3, signed by the Surveyor and Builder are to be provided on completion of the survey. One copy is to be placed on board the vessel and the other submitted to LR.

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Section

1 **General requirements**

2 **Main source of electrical power**

3 **Emergency source of electrical power**

4 **External source of electrical power**

5 **Supply and distribution**

6 **System design – Protection**

7 **Switchgear and control gear assemblies**

8 **Protection of personnel from hazards resulting from electric arcs within electrical equipment assemblies and enclosures**

9 **Rotating machines**

10 **Converter equipment**

11 **Electrical cables and busbar trunking systems (busways)**

12 **Batteries**

13 **Equipment – Heating, lighting and accessories**

14 **Electrical equipment for use in explosive atmospheres**

15 **Navigation and manoeuvring systems**

16 **Electric propulsion**

17 **Fire safety systems**

18 **Crew and passenger emergency safety systems**

19 **Craft safety systems**

20 **Cargo craft, patrol and pilot craft, workboats and other similar craft of less than 500 tons gross tonnage for operation in Service Groups 1 to 3, and yachts less than 500 gt**

21 **Testing and trials**

Section 1
General requirements

1.1 General

1.1.1 The requirements of Sections 1 to 19 and 21 are, in general, applicable to all the craft types indicated in Pt 1, Ch 2,2.1, with the exception of cargo craft, patrol and pilot craft, workboats and other similar craft of less than 500 tons gross tonnage for operation in Service Groups 1 to 3, and for yachts less than 500 gt, which are covered in Section 20.

1.1.2 Whilst this Chapter applies to the electrical engineering equipment and systems on special service craft intended to be classed, attention should also be given to any relevant Statutory Regulations of the National Authority of the country in which the craft is to be registered and the Code of Safety for High Speed Craft.

1.1.3 Electrical services required to maintain the craft in a normal seagoing, operational and habitable condition are to be capable of being maintained without recourse to the emergency source of electrical power.

1.1.4 Electrical services essential for safety are to be maintained under various emergency conditions.

1.1.5 The safety of passengers, crew and craft from electrical hazards is to be ensured.

1.1.6 Consideration will be given to special cases or to arrangements which are equivalent to the Rules.

1.2 Plans required for design review

1.2.1 The plans and particulars in 1.2.2 to 1.2.13 are to be submitted for design review.

1.2.2 Single line diagram of main and emergency power and lighting systems which is to include:
(a) ratings of machines, transformers, batteries and semi-conductor converters;
(b) all feeders connected to the main and emergency switchboards;
(c) section boards and distribution boards;
(d) insulation type, size and current loadings of cables;
(e) make, type and rating of circuit breakers and fuses;
(f) details of harmonic filters (where fitted).

1.2.3 A description of operation of the main and emergency electrical power systems.

1.2.4 An earthing philosophy document that defines the basic approach to be taken for earthing the electrical power systems and all electrical loads.

1.2.5 Simplified diagrams of generator circuits, inter-connector circuits and feeder circuits showing:
(a) protective devices, e.g., short circuit, overload, reverse power protection;
(b) instrumentation and synchronising devices;
(c) preference tripping;
(d) remote stops;
(e) earth fault indication/protection.

1.2.6 Calculations of short circuit currents at main and emergency switchboards and section boards including those fed from transformers, with details of circuit breaker and fuse operating times and discrimination curves showing compliance with 6.1 and 11.6.2.

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1.2.7 Where required by 8.1.1, the hazards resulting from electric arcs within electrical equipment and their consequences for personnel are to be identified, and at least the following supporting evidence is to be submitted:

(a) system design;
(b) operating philosophies, e.g., manual or automatic control, local or remote operation;
(c) general arrangement plans for switchboards, section boards and distribution boards, *see also* 1.3.5;
(d) general arrangement plans for the space in which the electrical equipment to be assessed are located, showing:
  (i) access to adjacent spaces;
  (ii) the location of the electrical equipment;
  (iii) ventilation arrangements for air-conditioning and/or the extraction of smoke, gas and vapours resulting from electric arcs; and
  (iv) positions within the space in which the electrical equipment is located where personnel will be performing tasks, e.g., switching, equipment maintenance, instrument observation or cleaning, or where personnel could be reasonably expected to enter;
(e) calculations in accordance with 8.3;
(f) system operating procedures; and
(g) details of defined additional safety measures to be taken during activities.

1.2.8 A test schedule which is to include the method of testing and the test facilities which are provided for the general emergency alarm system and the public address system.

1.2.9 For battery installations, arrangement plans and calculations to show compliance with Section 12.

1.2.10 A schedule of batteries fitted for use for emergency and essential services, giving details of:

- type and manufacturer's type designation;
- voltage and ampere-hour rating;
- location;
- equipment and/or system(s) served;
- maintenance/replacement cycle dates;
- date(s) of maintenance and/or replacement; and
- for replacement batteries in storage, the date of manufacture and shelf life, with accompanying battery replacement procedure documentation to show compliance with 12.7.

1.2.11 Details of electrically-operated fire, craft, crew and passenger emergency safety systems which are to include typical single line diagrams and arrangements, showing main vertical and, where applicable, horizontal fire zones and the location of equipment and cable routes, including identification of relevant high fire risk areas, to be employed for:

(a) emergency lighting;
(b) accommodation fire detection, alarm and extinction systems;
(c) fixed water-based local application fire-fighting systems;
(d) public address system;
(e) general emergency alarm;
(f) watertight doors, shell doors and other electrically operated closing appliances; and
(g) low location lighting.

NOTE
A general arrangement plan of the complete craft showing the main vertical fire zones and the location of equipment and cable routes, including identification of relevant high fire risk areas, for the above systems, is to be made available for the use of the Surveyor on board.

1.2.12 Evidence of the suitability of electrical and electronic equipment for use in protected areas and adjacent areas, as required by 17.3.11 and 17.3.12, including a schedule of electrical and electronic equipment located in protected areas and adjacent areas, and general arrangement plans showing the coverage of the protected areas and adjacent areas.

1.2.13 Schedule of normal and emergency operating loads on the system estimated for the different operating conditions expected. The following details are to be provided to meet this requirement:

(a) a description of the expected operating profiles (e.g. the number of generating sets connected when manoeuvring, at sea, etc.), including as required by Pt 5, Ch 2,1.1.1; and
(b) a schedule of the normal and emergency operating loads, which is to state the kilowatt rating of each load and a load factor between 0 and 1 that reflects:
  (i) the duty cycle of the load; and
  (ii) the proportion of its maximum rating at which the load is expected to operate.

1.3 Plans required for supporting evidence

1.3.1 The plans and particulars in 1.3.2 to 1.3.5 are to be submitted as supporting evidence.

1.3.2 In order to establish compliance with 1.11.2 and 5.1.3 to 5.1.5, a general arrangement plan of the craft showing the location of major items of electrical equipment, for example:

- main and emergency generators;
- switchboards;
- section boards and distribution boards supplying essential and emergency services;
- emergency batteries;
- motors for emergency services; and
- cable routes between these items of equipment.

1.3.3 Arrangement plans of main and emergency switchboards, and section boards, and documentation that demonstrates that creepage and clearance distances are in accordance with 7.5.

1.3.4 In order to establish compliance with the requirements of 1.7.3, when requested, evidence is to be submitted to demonstrate the suitability of electrical equipment for its intended purpose in the conditions in which it is expected to operate.

1.3.5 For non-metallic cable support systems or protective casings, test evidence, details of installation procedures and manufacturer's recommendations that show compliance with 11.13.

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1.4 Surveys

1.4.1 Electrical machinery and auxiliary services essential for the safety of the craft are to be installed in accordance with the relevant requirements of this Chapter, surveyed and have tests witnessed by the Surveyors.

1.4.2 The following equipment, where intended for use for essential and emergency services, is to be surveyed by the Surveyors during manufacture and testing:

- Converting equipment of 100 kW and over;
- Rotating machines of 100 kW and over;
- Switchboards and section boards; and
- UPS units of 50 kVA and over.

1.4.3 For electric propulsion systems, in addition to the equipment listed in 1.4.2, the following equipment is to be surveyed by the Surveyors during manufacture and testing:

- exciters;
- filters;
- reactors;
- dynamic braking assemblies;
- pre-magnetisation transformers; and
- slip ring assemblies.

1.4.4 All other electrical equipment, not specifically referenced in 1.4.2 and 1.4.3, intended for use for essential or emergency services is to be supplied with a manufacturer's works test certificate showing compliance with the constructional standard(s) as referenced by the relevant requirements of this Chapter.

1.5 Additions or alterations

1.5.1 No addition, temporary or permanent, is to be made to the approved load of an existing installation until it has been ascertained that the current carrying capacity and the condition of the existing equipment including cables and switchgear are adequate for the increased load.

1.5.2 Plans are to be submitted for consideration, and the alterations or additions are to be carried out under the survey, and to the satisfaction of the Surveyors.

1.5.3 When it is proposed to replace permanently installed secondary valve-regulated sealed batteries with vented batteries, details are to be submitted for consideration to ensure continued safety in the presence of the products of electrolysis and evaporation being allowed to escape freely from the cells to the atmosphere. These details are to demonstrate that there will be adequate ventilation in accordance with 12.5.9 and that the location and installation requirements of 12.3 and 12.4 are complied with.

1.5.4 Proposed modifications to the electrical protection systems are to be developed in accordance with 6.1.4 and plans submitted are also to address the updating of approved version of the details required by 1.2.5 and 1.2.6.

1.5.5 Where it is intended to replace an existing incandescent lamp type navigation light with a light emitting diode type navigation light, details are to be submitted for consideration that demonstrate compliance with 15.3. Light emitting diode type navigation light failure detection arrangements are to satisfy the requirements of 15.3.5 and 15.3.6.

1.6 Definitions

1.6.1 Essential services are those necessary for the propulsion and safety of the craft, such as the following:

- air compressors for starting and manoeuvring essential mains and auxiliary machinery;
- air pumps:
- automatic sprinkler systems;
- ballast pumps;
- bilge pumps;
- circulating and cooling water pumps;
- communication systems;
- electric starting systems for starting and manoeuvring essential main and auxiliary machinery;
- fire detection and alarm systems;
- fire pumps;
- fuel valve cooling pumps;
- hydraulic pumps for controllable pitch propellers and those serving essential services here listed that would otherwise be directly electrically-driven;
- hydraulic pumps serving essential services here listed which would otherwise be directly electrically driven;
- lubricating oil pumps;
- lighting systems for those parts of the craft normally accessible to and used by personnel and passengers;
- navigational aids where required by Statutory Regulations;
- navigation lights and special purpose lights where required by Statutory regulations;
- oil fuel pumps and oil fuel burning units;
- pumps for fire-extinguishing systems;
- scavenge blowers;
- steering gear;
- valves which are required to be remotely operated;
- ventilating fans for engine rooms;
- watertight doors, shell doors and other electrical operated closing appliances;
- windlasses;
- power sources and supply systems for supplying the above services.

1.6.2 Services such as the following are considered necessary for minimum comfortable conditions of habitability:

- cooking;
- heating;
- domestic refrigeration;
- mechanical ventilation;
- sanitary and fresh water.

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1.6.3 Services such as the following, which are additional to those in 1.6.1 and 1.6.2, are considered necessary to maintain the craft in a normal seagoing operational and habitable condition:

- cargo handling and cargo care equipment;
- hotel services, other than those required for habitable conditions;
- thruster systems for manoeuvring.

1.6.4 A 'high voltage' is a voltage exceeding 1000 V a.c. or 1500 V d.c. between conductors, *see also* 5.1.2.

1.6.5 A 'switchboard' is a switchgear and control gear assembly for the control of power generated by a source of electrical power and its distribution to electrical consumers.

1.6.6 A 'section board' is a switchgear and control gear assembly for controlling the supply of electrical power from a switchboard and distributing it to other section boards, distribution boards or final sub-circuits.

1.6.7 A 'distribution board' is an assembly of one or more protective devices arranged for the distribution of electrical power to final sub-circuits.

1.6.8 A 'final sub-circuit' is that portion of a wiring system extending beyond the final overcurrent device of a board.

1.6.9 'Special Category spaces' are those enclosed spaces above or below the bulkhead deck intended for the carriage of motor vehicles with fuel, for their own propulsion, in their tanks, into and from which such vehicles can be driven, and to which passengers have access.

1.6.10 'Machinery spaces of Category A' are those spaces and trunks to such spaces which contain:

(a) internal combustion machinery used for main propulsion; or

(b) internal combustion machinery used for purposes other than main propulsion where such machinery has in the aggregate a total power output of not less than 375 kW; or

(c) any oil-fired boiler or oil fuel unit.

1.6.11 'Dead craft condition' means that the entire machinery installation, including the power supply, is out of operation and that the auxiliary services for bringing the main propulsion systems into operation (e.g. compressed air, starting current from batteries, etc.) and for the restoration of the main power supply are not available. Means are to be available at all times to start the emergency generator, *see* Pt 10, Ch 1,7.6.

1.6.12 Protected space is a machinery space where a fixed water-based local application fire-fighting system is installed.

1.6.13 Protected areas are areas within a protected space which is required to be protected by a fixed water-based local application fire-fighting system.

1.6.14 Adjacent areas are areas, other than protected areas, exposed to direct spray or other areas where water may extend when a fixed water-based local application fire-fighting system is activated.

1.6.15 An 'electric arc' is an electrical discharge or a short-circuit through ionised air caused by isolation or insulation integrity failure.

1.6.16 'Incident energy' is the amount of energy impressed on a surface, a certain distance from the source, generated during an electric arc event.

1.7 Design and construction

1.7.1 Equipment for services essential for the safety of the craft are to be constructed in accordance with the relevant requirements of this Chapter.

1.7.2 The design and installation of other equipment is to be such that risk of fire due to its failure is minimised. It is to, as a minimum, comply with a National or International Standard revised where necessary for ambient conditions.

1.7.3 Electrical equipment is to be suitable for its intended purpose and accordingly, whenever practicable to be selected from the *List of Type Approved Products* published by Lloyd's Register (hereinafter referred to as 'LR'). A copy of the Procedure for LR Type Approval System will be supplied on application.

1.8 Quality of power supplies

1.8.1 All electrical equipment supplied from the main and emergency sources of electrical power and electrical equipment for essential and emergency services supplied from d.c. sources of electrical power is to be so designed and manufactured that it is capable of operating satisfactorily under normally occurring variations of voltage and frequency.

1.8.2 Unless specified otherwise, a.c. electrical equipment is to operate satisfactorily with the following simultaneous variations, from their nominal value, when measured at the consumer input terminals. Alarms are to be provided for High and Low Voltage and Low Frequency.

(a) Voltage:
- permanent variations +6 per cent, –10 per cent
- transient variations due to step changes in load ±20 per cent
- recovery time 1,5 seconds.

(b) Frequency:
- permanent variations ±5 per cent
- transient variations due to step changes in load ±10 per cent
- recovery time 5 seconds.

A maximum rate of change of frequency not exceeding ±1,5 Hz per second during cyclic frequency fluctuations.

1.8.3 Harmonics. Unless specified otherwise, the total harmonic distortion (THD) of the voltage waveform at any a.c. switchboard or section-board is not to exceed 8 per cent of the fundamental for all frequencies up to 50 times the supply frequency and no voltage at a frequency above 25 times supply frequency is to exceed 1,5 per cent of the fundamental of the supply voltage. THD is the ratio of the rms value of the harmonic content to the rms value of the fundamental,

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expressed in per cent and may be calculated using the expression:

$$THD = \frac{\sqrt{\sum_{h=2}^{\infty} V_h^2}}{V_1} \times 100$$

where

V_h = rms amplitude of a harmonic voltage of order h

V_1 = rms amplitude of the fundamental voltage.

1.8.4 Unless specified otherwise, d.c. electrical equipment is to operate satisfactorily with the following simultaneous variations, from their nominal value, when measured at the consumer input terminals:

(a) When supplied by d.c. generator(s) or a rectified a.c. supply:
Voltage tolerance (continuous) ±10 per cent
Voltage cyclic variation deviation 5 per cent
Voltage ripple 10 per cent
(a.c. rms over steady state d.c. voltage);

(b) When supplied by batteries:
(i) Equipment connected to the batteries during charging:
Voltage tolerance +30 per cent, –25 per cent;
(ii) Equipment not connected to batteries during charging:
Voltage tolerance +20 per cent, –25 per cent

Different voltage variations as determined by the charging/discharging characteristics, including ripple voltage from the charging device, may be considered. When battery chargers/battery combinations are used as d.c. power supply systems adequate measures are to be taken to keep the voltage within the specified limits during charging, boost charging and discharging of the battery.

1.9 Ambient reference and operating conditions

1.9.1 The rating for classification purposes of essential electrical equipment intended for installation in craft to be classed for unrestricted (geographical) service is to be based on an engine room ambient temperature of 45°C, and a sea-water temperature at the inlet of 32°C. The equipment manufacturer is not expected to provide simulated ambient reference conditions at a test bed.

1.9.2 In the case of craft to be classed for restricted service, the rating is to be suitable for the ambient conditions associated with the geographical limits of the restricted service which are part of the class notation.

1.9.3 Main and essential auxiliary machinery and equipment is to operate satisfactorily under the conditions shown in Pt 9, Ch 1,4.4. Electrical equipment satisfying alternative ambient operating condition requirements for installation on ships contained in an acceptable and relevant national or international standard may be considered to satisfy this requirement.

NOTE
Details of local environmental conditions are stated in Annex B of IEC 60092: *Electrical installations in ships – Part 101: Definitions and general requirements.*

1.9.4 Where electrical equipment is installed within environmentally controlled spaces, the ambient temperature for which the equipment is suitable for operation at its rated capacity may be reduced to a value not less than 35°C provided:

- the equipment is not for use for emergency services and is located outside of machinery space(s);
- temperature control is achieved by at least two cooling units so arranged that, in the event of loss of one cooling unit, for any reason, the remaining unit(s) will be capable of satisfactorily maintaining the design temperature;
- the equipment is able to be initially set to work safely within a 45°C ambient temperature until such a time that the lesser ambient temperature may be achieved; the cooling equipment is to be rated for an ambient temperature of not less than 45°C; and
- alarms are provided, at a continually attended control station, to indicate any malfunction of the cooling units.

See also Ch 1,1.3.3.

1.9.5 Where equipment is to comply with 1.9.4, it is to be ensured that electrical cables for their entire length are adequately rated for the maximum ambient temperature to which they are exposed along their length.

1.9.6 Equipment used for cooling and maintaining the lesser ambient temperature in accordance with 1.9.4 are considered essential services and are to satisfy the requirements of 5.2.

1.10 Inclination of craft

1.10.1 Emergency and essential electrical equipment is to operate satisfactorily under the conditions as shown in Table 1.4.1 in Pt 9, Ch 1.

1.11 Location and construction

1.11.1 All electrical equipment is to be constructed or selected, and installed such that:

(a) live parts cannot be inadvertently touched, unless they are supplied at the safety voltage specified in 1.12.2(h);
(b) it does not cause injury when handled or touched in the normal manner; and
(c) it is unaffected by any water, steam or oil and oil vapour to which it is likely to be exposed.

Electrical equipment having, as a minimum, the degrees of protection as specified in IEC 60092-201 for the relevant location will satisfy these requirements.

1.11.2 Switchboards, section boards and distribution boards supplying essential and emergency services, as well as cables from the respective generators to and between these boards, are to be arranged to avoid areas of high fire risk and elevated temperatures, for example, in close proximity to incinerators and boilers.

1.11.3 Electrical equipment, as far as is practicable, is to be located:

(a) such that it is accessible for the purpose of maintenance and survey;
(b) clear of flammable material;

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(c) in spaces adequately ventilated to remove the waste heat liberated by the equipment under full load conditions, at the ambient conditions specified in 1.9;
(d) where flammable gases cannot accumulate. If this is not practicable, electrical equipment is to be of the appropriate 'safe-type', *see* Section 14;
(e) where it is not exposed to the risk of mechanical injury or damage from water, steam or oil.

1.11.4 Equipment design and the choice of materials are to reduce the likelihood of fire, ensuring that:
(a) where the electrical energised part can cause ignition and fire, it is contained within the bounds of the enclosure of the electrotechnical product;
(b) the design, material(s) and construction of the enclosure minimises, as far as is practicable, any internal ignition causing ignition of adjacent materials; and
(c) where surfaces of the electrotechnical products can be exposed to external fire, they do not, as far as practicable, contribute to the fire growth.

NOTE
Compliance with IEC 60695: *Fire hazard testing*, or an alternative and acceptable Standard, will satisfy this requirement, *see also* 1.16.4.

1.11.5 Insulating materials and insulated windings are to be resistant to tracking, moisture, sea air, oil and oil vapour unless special precautions are taken to protect them.

1.11.6 The minimum creepage and clearance distances provided for electrical connections, terminals and similar bare live parts are to be in accordance with a relevant International or National Standard for the equipment or apparatus concerned. In cases where the rated voltage is outside that given in the Standard or where no Standard is available, the minimum creepage and clearance distances provided are to be in accordance with 7.5. Details of alternatives proposals including supporting design rationale and demonstration may be submitted for consideration.

1.11.7 Studs, screw-type or spring-type clamp terminations, satisfactory for the normal operating currents and voltages, are to be provided in electrical equipment for the connection of external cable, or bus-bar conductors, as appropriate, *see also* 11.15. There is to be adequate space and access for the terminations.

1.11.8 The design of equipment is to enable ease of access to all parts requiring inspection or replacement in service.

1.11.9 Equipment is not to remain alive through the control circuits and/or pilot lamps when switched off by the control switch. This does not apply to synchronising switches and/or plugs.

1.11.10 The operation of all electrical equipment and the lubrication arrangements are to be efficient under such conditions of vibration and shock as arise in normal practice.

1.11.11 All nuts, screws and clamping devices used in connection with current-carrying, supporting and working parts are to be provided with means to ensure that they cannot work loose by vibration and shock as arise in normal practice.

1.11.12 To allow ease of access, connectors are to be spaced far enough apart to permit connection and disconnection. At test points, adequate clearance is to be provided between connection points and controls to provide access for testing.

1.11.13 Conductors and equipment are to be placed at such a distance from the magnetic compasses, or are to be so disposed, that the interfering magnetic field is negligible when circuits are switched on and off.

1.11.14 Where electrical power is used for propulsion, the equipment is to be so arranged that it will operate satisfactorily in the event of partial flooding by bilge water above the tank top up to the bottom floor plate level, under the normal angles of inclination given in 1.10 for essential electrical equipment, *see* Pt 15, Ch 2.

1.12 Earthing of non-current carrying parts

1.12.1 Except where exempted by 1.12.2, all non-current carrying exposed metal parts of electrical equipment and cables are to be earthed.

1.12.2 The following parts may be exempted from the requirements of 1.12.1:
(a) lamp-caps, where suitably shrouded;
(b) shades, reflectors and guards supported on lampholders or light fittings constructed of, or shrouded in, non-conducting material;
(c) metal parts on, or screws in or through, non-conducting materials, which are separated by such material from current-carrying parts and from earthed non-current carrying parts in such a way that in normal use they cannot become live or come into contact with earthed parts;
(d) apparatus which is constructed in accordance with the principle of double insulation;
(e) bearing housings which are insulated in order to prevent circulation of current in the bearings;
(f) clips for fluorescent lamps;
(g) cable clips and short lengths of pipes for cable protection;
(h) apparatus supplied at a safety voltage not exceeding 50 V d.c. or 50 V a.c., between conductors, or between any conductor and earth in a circuit isolated from the supply. Autotransformers are not to be used for the purpose of achieving the alternating current voltage;
(j) apparatus or parts of apparatus which although not shrouded in insulating material is nevertheless otherwise so guarded that it cannot be touched and cannot come in contact with exposed metal.

1.12.3 Where extraneous-conductive parts (i.e. parts not forming part of the electrical installation and liable to introduce an electric potential) are not bonded by separate earthing conductors, details are to be submitted that demonstrate that a permanent, metal-to-metal connection of negligible impedance, which will not degrade due to corrosion or vibration, will be achieved.

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1.12.4 Armouring, braiding and other metal coverings of cables are to be effectively earthed. Where the armouring, braiding and other metal coverings are earthed at one end only, they are to be adequately protected and insulated at the unearthed end with the insulation being suitable for the maximum voltage that may be induced. *See* 14.1 for earthing of cables in hazardous zones or spaces.

1.12.5 The electrical continuity of all metal coverings of cables throughout the length of the cable, particularly at joints and tappings, is to be ensured.

1.12.6 Metal parts of portable appliances, other than current-carrying parts and parts exempted by 1.12.2 are to be earthed by means of an earth-continuity conductor in the flexible cable or cord through the associated plug and socket-outlet.

1.12.7 Earthing conductors are to be of copper or other corrosion-resistant material and be securely installed and protected where necessary against damage and also, where necessary, against electrolytic corrosion. Connections are to be so secured that they cannot work loose under vibration.

1.12.8 The nominal cross-section areas of copper earthing conductors are, in general to be equal to the cross-section of the current-carrying conductor up to 16 mm^2. Above this figure they are to be equal to at least half the cross-section of the current-carrying conductor with a minimum of 16 mm^2. Every other earthing conductor is to have a conductance not less than that specified for an equivalent copper earthing conductor.

1.12.9 The connection of the earthing conductor to the hull of the craft is to be made in an accessible position, and is to be secured by a screw or stud of a diameter appropriate for the size of earthing conductor, but not less than 6 mm which is to be used for this purpose only. Bright metallic surfaces at the contact areas are to be ensured immediately before the nut or screw is tightened and, where necessary, the joint is to be protected against electrolytic corrosion. The connection is to remain unpainted.

1.13 Electrical bonding for the control of static electricity

1.13.1 In non-metallic craft, all metallic parts of the craft are to be electrically bonded together, as far as possible, in consideration of galvanic corrosion between dissimilar metals, to ensure an earth return path and to connect the craft to the water when water-borne. This does not apply to isolated components which cannot become live, nor require control of static electricity.

1.13.2 Bonding straps for the control of static electricity are required for piping systems, including pressure refuelling points, which are not electrically continuous throughout their length and for flammable products, which are not permanently connected to the hull of the craft either directly or via their bolted or welded supports and where the resistance between them and the hull exceeds 1MΩ.

1.13.3 Where bonding straps are required for the control of static electricity, they are to be robust, that is, having a cross-sectional area of at least 10 mm^2, and are to comply with 1.12.7 and 1.12.9.

1.14 Labels, signs and notices

1.14.1 Labels, signs and notices required by this Chapter are to be positioned in clearly visible locations which will not be obscured.

1.14.2 Labels, signs and notices are to be easy to read under the expected operating conditions. Character height in accordance with Table 2.1.1 will be considered to satisfy this requirement.

Table 2.1.1 Character height and viewing distance

Work area	Minimum character height (mm)
Less than 500	2,3
500–1000	4,7
1000–2000	9,4
2000–4000	19
4000–8000	38

1.14.3 Controls, indicators and displays required by this Chapter are to be labelled to indicate their function. Labels are to be positioned in a manner that associates the label with the item being labelled.

1.14.4 Labels, signs and notices are to use short, clear messages. In general, warning signs and notices are to comprise:

- a word signalling the gravity of the risk (e.g., Danger, Warning or Caution);
- a statement of the nature and/or consequence of the hazard; and
- wherever practical, an instruction giving appropriate behaviour to avoid the hazard.

1.15 Alarms

1.15.1 Where alarms are required by this Chapter they are to be arranged in accordance with Ch 1,2.3. Sound signal equipment, fire and general alarm bells are not required to be supplemented by visual indications, except in areas having high levels of background noise, such as machinery spaces.

1.15.2 The alarms in this Chapter are additional to those required by Chapter 1. They may however form part of the alarm system that is required by Chapter 1.

1.15.3 Cables for emergency alarms and their power sources are to be in accordance with 1.16.

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1.15.4 Electrical equipment and cables for emergency alarms are to be so arranged that the loss of alarms in any one area due to localised fire, collision, flooding or similar damage is minimised, *see* 1.16.

1.16 Operation under fire conditions

1.16.1 As a minimum, the following emergency services and their emergency power supplies, are required to be capable of being operated under fire conditions:

- Emergency fire pump.
- Fire safety stops, *see also* 17.6.
- Control and power systems to power-operated watertight doors and status indication for all fire doors.
- Control and power systems to power-operated fire doors and their status indication.
- Emergency lighting.
- Fire and general alarms.
- Fire detection systems.
- Fire-extinguishing systems and fire-extinguishing media release alarms.
- Low location lighting, *see also* 18.4.3.
- Public address systems.

1.16.2 Where cables for services that are required to be capable of being operated under fire conditions, including their power supplies, pass through high fire risk areas, main vertical or horizontal fire zones or decks other than those which they serve, they are to be of a fire resistant type complying with 11.5.3, and:

(a) in the case of the emergency services: the fire resistant cable is to extend, at least, from the control/monitoring panel to the nearest local junction box serving the relevant deck/area; and

(b) in the case of power supplies: the fire resistant cable is to extend, at least, from the distribution point within the space containing the emergency source of electrical power to the nearest local distribution panel serving the relevant deck/area.

1.16.3 Electrical cables for the above services required to be capable of being operated under fire conditions, including their power supplies, are to be run as directly as is practicable, having regard to any special installation requirements, for example those concerning minimum bend radii.

1.16.4 In addition to 1.11.4, materials used for electrical equipment, cables and accessories within passenger accommodation areas are not to be capable of producing excessive quantities of smoke and toxic products, when tested in accordance with an acceptable and relevant Standard.

1.17 Lightning protection

1.17.1 In order to minimise the risks of damage to the craft and its electrical installation due to lightning, crafts having non-metallic masts or topmasts are to be fitted with lightning conductors in accordance with the applicable requirements of IEC 60092-401 *Electrical installations in ships. Part 401: Installation and test of completed installation* or an alternative and relevant National Standard.

1.17.2 In addition to the primary protection requirements in 1.17.1, precautions are to be taken to protect essential electronic equipment that may be susceptible to damage from voltage pulses attributable to the secondary effects of lightning. This may be achieved by suitable design and/or the use of additional protective devices, such as surge arrestors. Resultant induced voltages may be further reduced by the use of earthed metallic screened cables.

1.18 Programmable electronic systems

1.18.1 Where programmable electronic systems are implemented and used to control the electrical installation, or to provide safety functions in accordance with the requirements of this Chapter (e.g. electric propulsion, circuit-breaker settings, switchgear and control gear controllers, etc.), the arrangements are to satisfy the applicable requirements of Ch 1,2.10 to 2.13.

1.18.2 Where 1.18.1 applies, proposed modifications to software and acceptance testing and trials are to be in accordance with Ch 1,1.4 and Section 7 as applicable.

■ *Section 2*
Main source of electrical power

2.1 General

2.1.1 The main source of electrical power is to comply with the requirements of this Section without recourse to the emergency source of electrical power.

2.2 Number and rating of generators and converting equipment

2.2.1 Under seagoing conditions, the number and rating of service generating sets and converting sets, such as transformers and semi-conductor converters, when any one generating set or converting set is out of action, are:

(a) to be sufficient to ensure the operation of electrical services for essential equipment and habitable conditions;

(b) to have sufficient reserve capacity to permit the starting of the largest motor without causing any motor to stall or any device to fail due to excessive voltage drop on the system;

(c) to be capable of providing the electrical services necessary to start the main propulsion machinery from a 'dead craft condition'. The emergency source of electrical power may be used to assist if it can provide power at the same time to those services required to be supplied by Section 3, *see also* 2.3.2.

2.2.2 The arrangement of the craft's main source of power is to be such that the operation of electrical services for essential equipment and habitable conditions can be maintained regardless of the speed and direction of the propulsion machinery shafting.

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2.2.3 Where the electrical power requirement to maintain the craft in a normal operational and habitable condition is usually supplied by one generating set, arrangements are to be provided to prevent overloading of the running generator, *see* 6.9. On loss of power there is to be provision for automatic starting and connecting to the main switchboard of the standby set in as short a time as practicable, but in any case within 45 seconds, and automatic sequential restarting of essential services, *see* 1.6.1, in as short a time as practicable.

NOTE

Where the prime mover starting time will result in exceeding this starting and connection time, details are to be submitted for consideration.

2.3 Starting arrangements

2.3.1 The starting arrangements of the generating sets' prime movers are to comply with the requirements of Pt 10, Ch 1 and 2 as applicable.

2.3.2 Where the emergency source of electrical power is required to be used to restore propulsion from a 'dead craft condition', the emergency generator is to be capable of providing initial starting energy for the propulsion machinery within 30 minutes of the 'dead craft condition'. The emergency generator capacity is to be sufficient for restoring propulsion in addition to supplying those services in 3.2.7(a), 3.2.7(b), 3.2.7(c) for passenger craft and yachts greater than 500gt; or 3.3.7(a), 3.3.7(b), 3.3.7(c) and 3.3.7(d)(i) and (vi) for craft required to comply with HSC code; or 3.4.3(a) to (e) and (f) (i) as applicable. *See* Pt 10, Ch 1,7.1.1 and Ch 2,6.1.1 for starting arrangements.

2.4 Prime mover governors

2.4.1 The governing accuracy of the generating sets' prime movers is to meet the requirements of Pt 10, Ch 1 and Ch 2.

2.4.2 The maximum electrical step load switched on or off is not to cause the frequency variation of the electrical supply to exceed the parameters given in 1.8.2, *see also* Pt 10, Ch 1 and Ch 2.

2.5 Main propulsion driven generators not forming part of the main source of electrical power

2.5.1 Generators and generator systems, having the craft's propulsion machinery as their prime mover but not forming part of the craft's main source of electrical power may be used whilst the craft is at sea to supply electrical services required for normal operational and habitable conditions provided that the requirements of 2.5.2 to 2.5.4 are satisfied.

2.5.2 Within the declared operating range of the generators and/or generator system, the specified voltage and frequency variations of the Rules are to be met.

2.5.3 Where there is remote control of the propulsion machinery, arrangements are to ensure that essential machinery power supplies are maintained during manoeuvring conditions in order to prevent a blackout situation.

2.5.4 In addition to the requirements of 2.2.3, arrangements are to be fitted to automatically start one of the generators forming the main source of power should the frequency variations exceed those permitted by the Rules.

Section 3 Emergency source of electrical power

3.1 General

3.1.1 The requirements of this Section apply to passenger craft, to yachts that are 500 gt or more, to cargo craft, patrol and pilot craft, workboats and other similar craft of 500 tons gross tonnage and above, and to cargo craft, patrol and pilot craft, workboats and other similar craft of less than 500 tons gross tonnage for operation in Service Groups 4 and 5. For other craft, *see* Section 20.

3.1.2 Passenger craft and cargo craft constructed in compliance with the HSC Code are to comply with 3.3. Other specified craft are to comply with 3.2 or 3.4 as applicable.

3.1.3 The emergency source of power for other craft will be the subject of special consideration, with due regard to the size and the intended service of the craft.

3.1.4 Where the main source of electrical power is located in two or more compartments which are not contiguous, each of which has its own self-contained systems, including power distribution and control systems, completely independent of each other and such that a fire or other casualty in any one of the spaces will not affect the power distribution from the others, or to the services required by 3.2, 3.3 or 3.4, the requirements of this Section may be considered satisfied without an additional emergency source of electrical power, provided that:

(a) there is at least one generating set of sufficient capacity to meet the requirements of 3.2, 3.3 or 3.4 in each of at least two non-contiguous spaces;

(b) the generator sets referred to in 3.1.4(a) and their self-contained systems are installed such that a source of electrical power remains available at all times to supply emergency services after damage or flooding in any one compartment.

3.1.5 Non-passenger type craft of 300 tons gross tonnage and above are to comply with 3.7.

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3.2 Emergency source of electrical power in passenger craft and for yachts that are 500 gt or more

3.2.1 A self-contained emergency source of electrical power is to be provided.

3.2.2 The emergency source of electrical power, associated transforming equipment, if any, transitional source of emergency power, emergency switchboard and emergency lighting switchboard are to be located above the waterline in the final condition of damage, be operable in that condition, and be readily accessible from the open deck. They are not to be located forward of the collision bulkhead, if fitted. Consideration may also be given to alternative arrangements, such as 3.1.4, which provide an equivalent degree of safety from fire and flooding.

3.2.3 The location of:

- the emergency source of electrical power and associated transforming equipment, if any;
- the transitional source of emergency power;
- the emergency switchboard; and
- the emergency lighting switchboard;

in relation to:

- the main source of electrical power, associated transforming equipment, if any; and
- the main switchboard;

is to be such as to ensure that a fire or other casualty in spaces containing:

- the main source of electrical power, associated transforming equipment, if any, and the main switchboard; or
- in any machinery space of Category A;

will not interfere with the supply, control and distribution of emergency electrical power.

3.2.4 The space containing:

- the emergency source of electrical power, associated transforming equipment, if any;
- the transitional source of emergency electrical power; and
- the emergency switchboard;

is not to be contiguous to the boundaries of machinery spaces of Category A or those spaces containing:

- the main source of electrical power, associated transforming equipment, if any; or
- the main switchboard.

3.2.5 Where compliance with 3.2.3 or 3.2.4 is not practicable, details of the proposed arrangements are to be submitted.

3.2.6 Provided that suitable measures are taken for safeguarding independent emergency operation under all circumstances, the emergency generator may be used exceptionally, and for short periods, to supply non-emergency circuits. Failure of the emergency switchboard when being used in other than an emergency is not to put at risk the operation of the craft or yacht.

3.2.7 The electrical power available is to be sufficient to supply all those services that are essential for safety in an emergency, due regard being paid to such services as may have to be operated simultaneously. The emergency source of electrical power is to be capable, having regard to starting currents and the transitory nature of certain loads, of supplying simultaneously at least the following services for the periods specified hereinafter, if they depend upon an electrical source for their operation:

(a) for a period of 36 hours, emergency lighting:
  (i) at every lifeboat or liferaft preparation station, muster and embarkation station and oversides;
  (ii) in alleyways, stairways and exits, giving access to the muster and embarkation stations;
  (iii) in all service and accommodation alleyways, stairways and exits and personnel lift cars;
  (iv) in the machinery spaces, and main generating stations including their control positions;
  (v) in all control stations, machinery control rooms, and at each main and emergency switchboard;
  (vi) at the stowage positions for firemen's outfits and life saving appliances;
  (vii) at the steering gear; and
  (viii) at the fire pump, the sprinkler pump and the emergency bilge pump and at the starting position of their motors.

(b) for a period of 36 hours:
  (i) the navigation lights, and other lights as required by the International Regulations for Preventing Collisions at Sea in force; and
  (ii) the radiocommunications, as required by statutory regulations.

(c) for a period of 36 hours:
  (i) all internal communication equipment required in an emergency;
  (ii) the navigational equipment as required by statutory regulations; where such provision is unreasonable or impracticable this requirement may be waived for craft of less than 5000 tons gross;
  (iii) the fire detection, fire alarm and general alarm system, manual alarms, and the fire door holding and release system; and
  (iv) the intermittent operation of the daylight signalling lamps, the craft's whistle, the manually-operated call points and all internal signals that are required in an emergency;

  unless such services have an independent supply for the period of 36 hours from an accumulator battery, suitably located for use in an emergency;

(d) for a period of 36 hours:
  (i) emergency fire pump;
  (ii) the automatic sprinkler pump, if fitted;
  (iii) the emergency bilge pump and all the equipment essential for the operation of electrically powered remote controlled bilge valves; and
  (iv) essential electrically powered instruments and control for propulsion machinery, if alternate sources of power are not available for such devices.

(e) for a period of 10 min, power drives for directional control devices including those required to direct thrust forward and astern, unless there is a manual alternative complying with Pt 14, Ch 1,6.1.4;

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(f) for a period of half an hour;
  (i) any watertight doors required by Chapter 2 to be power operated together with their control, indication and alarm signals;
  (ii) the emergency arrangements to bring the lift cars to deck level for the escape of persons. The passenger lift cars may be brought to deck level sequentially in an emergency;
(g) where applicable, the services required by 2.3.2; and
(h) where applicable, the air compressors for breathing apparatus cylinders referred to in 17.10.1.

3.2.8 The emergency source of electrical power may be either a generator or an accumulator battery, which is to comply with the following:
(a) Where the emergency source of electrical power is a generator it is to be:
  (i) driven by a suitable prime mover with an independent supply of fuel having a flash point (closed cup test) of not less than 43°C;
  (ii) started automatically upon failure of the electrical supply from the main source of electrical power and is to be automatically connected to the emergency switchboard; those services referred to in 3.2.7 are then to be transferred automatically to the emergency generating set. The automatic starting system and the characteristics of the prime mover are to be such as to permit the emergency generator to carry its full rated load as quickly as is safe and practicable, subject to a maximum of 45 seconds; and
  (iii) provided with a transitional source of emergency electrical power according to 3.2.9.
(b) Where the emergency source of electrical power is an accumulator battery, it is to be capable of:
  (i) carrying the emergency electrical load without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage;
  (ii) automatically connecting to the emergency switchboard in the event of failure of the main source of electrical power; and
  (iii) immediately supplying at least those services specified in 3.2.9.

3.2.9 The transitional source of emergency electrical power required by 3.2.8 may consist of an accumulator battery suitably located for use in an emergency which is to operate without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage and be of sufficient capacity and so arranged as to supply automatically in the event of failure of either the main or emergency source of electrical power for half an hour at least the following services, if they depend upon an electrical source for their operation:
(a) (i) the lighting required by 3.2.7(a) and (b);
  (ii) the services required by 3.2.7(c)(i), (iii) and (iv) unless such services have an independent supply for the period specified from an accumulator battery suitably located for use in an emergency;
(b) with respect to watertight doors:
  (i) power to operate the watertight doors but not necessarily simultaneously, unless an independent temporary source of stored energy is provided. The power source should have sufficient capacity to operate each door at least three times i.e. closed-open-closed, against an adverse list of 15°;
  (ii) power to the control, indication and alarm circuits for the watertight doors.

3.2.10 The emergency switchboard is to be installed as near as is practicable to the emergency source of electrical power.

3.2.11 Where the emergency source of electrical power is a generator, the emergency switchboard is to be located in the same space unless the operation of the emergency switchboard would thereby be impaired.

3.2.12 No accumulator battery fitted in accordance with this Section, unless for engine starting, is to be installed in the same space as the emergency switchboard. An indicator is to be mounted in a suitable place on the main switchboard or in the machinery control room to indicate when the batteries constituting either the emergency source of electrical power or the transitional source of emergency electrical power are being discharged, and provision is to be made to charge them *in situ* from a reliable on board supply.

3.2.13 The emergency switchboard is to be supplied during normal operation from the main switchboard by an interconnector feeder which is to be adequately protected at the main switchboard against overload and short circuit and which is to be disconnected automatically at the emergency switchboard upon failure of the main source of electrical power. Where the system is arranged for feedback operation, the interconnector feeder is also to be protected at the emergency switchboard at least against short circuit.

3.2.14 In order to ensure the ready availability of the emergency source of electrical power to supply circuits required to provide emergency services, arrangements are to be made, where necessary, to automatically disconnect non-emergency circuits from the emergency switchboard in the event of overloading to ensure that electrical power is available to the emergency circuits.

3.2.15 Provision is to be made for the periodic testing of the complete emergency system and is to include the testing of automatic starting arrangements.

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3.2.16 In addition to the emergency lighting required by 3.2.7(a) passenger craft with roll on–roll off cargo spaces or special category spaces, are to be provided with the following:

(a) in all passenger public spaces and alleyways supplementary electric lighting that can operate for at least three hours when all other sources of electric power have failed and under any condition of heel. The illumination provided is to be such that the approach to the means of escape can be readily seen. The source of power for the supplementary lighting is to consist of accumulator batteries within the lighting units that are continuously charged where practicable, from the emergency switchboard. Consideration may be given to other means of lighting which is at least as effective. The supplementary lighting is to be such that any failure of the lamp will be immediately apparent. Any accumulator battery provided is to be replaced at intervals having regard to the specified service life in the ambient conditions that they are subject to in service.

(b) A portable rechargeable battery operated lamp is to be provided in every crew space alleyway, recreational space and every working space which is normally occupied unless supplementary emergency lighting, as required by (a) is provided.

3.2.17 A lesser period than the 36 hour period specified in 3.2.7, but not less than 18 hours, may be considered for yachts of 500 gt or more when in accordance with the relevant Statutory Regulations of the National Authority of the country in which the craft is to be registered.

3.3 Emergency source of electrical power in craft required to comply with the HSC Code

3.3.1 The arrangements for the emergency source of electrical power are to satisfy the requirements of this sub-Section and, additionally, 3.2.1, 3.2.6, 3.2.8, 3.2.11 and 3.2.13 to 3.2.15.

3.3.2 The emergency source of electrical power, associated transforming equipment, if any, transitional source of emergency power, emergency switchboard and emergency lighting switchboard are to be located above the waterline in the final condition of damage, be operable in that condition, and be readily accessible from the open deck. They are not to be located forward of the collision bulkhead, if fitted.

3.3.3 The location of:

- the emergency source of electrical power and associated transforming equipment, if any;
- the transitional source of emergency power;
- the emergency switchboard; and
- the emergency lighting switchboard;

in relation to:

- the main source of electrical power, associated transforming equipment, if any, and;
- the main switchboard;

is to be such as to ensure that a fire or other casualty in spaces containing:

- the main source of electrical power, associated transforming equipment, if any, and the main switchboard;
- or in any machinery space;

will not interfere with the supply, control and distribution of emergency electrical power.

3.3.4 The space containing:

- the emergency source of electrical power, associated transforming equipment, if any;
- the transitional source of emergency electrical power; and
- the emergency switchboard;

is not to be contiguous to the boundaries of machinery spaces and those spaces containing:

- the main source of electrical power, associated transforming equipment, if any; or
- the main switchboard.

3.3.5 Where compliance with 3.3.3 or 3.3.4 is not practicable, details of the proposed arrangements are to be submitted.

3.3.6 For passenger craft with the restrictive notation Passenger (A), the emergency source of power is to be capable of supplying simultaneously the services referred to in 3.3.7(a), 3.3.7(b) and 3.3.7(d)(ii) and (vi), for a period of 5 hours, the services referred to in 3.3.7(c) and (e) for the periods specified, and, additionally, the 'Not under command' lights for a period of 12 hours.

3.3.7 The electrical power available is to be sufficient to supply all those services that are essential for safety in an emergency, due regard being paid to such services as may have to be operated simultaneously. The emergency source of electrical power is to be capable, having regard to starting currents and the transitory nature of certain loads, of supplying simultaneously at least the following services for the periods specified hereinafter, if they depend upon an electrical source for their operation:

(a) for a period of 12 hours, emergency lighting:
  (i) at the stowage positions of life-saving appliances and, additionally, for passenger craft at the preparation, launching and deployed positions of survival craft and equipment for embarkation into those craft;
  (ii) at all escape routes, such as alleyways, stairways, exits from accommodation and service spaces, embarkation points, etc.;
  (iii) in the passenger compartments or public spaces, if any;
  (iv) in the machinery spaces, and main emergency generating spaces including their control positions;
  (v) in control stations;
  (vi) at the stowage positions for fireman's outfits; and
  (vii) at the steering gear;

(b) for a period of 12 hours:
  (i) the navigation lights, and other lights required by the *International Regulations for Preventing Collisions at Sea* in force;
  (ii) electrical internal communication equipment for announcements during evacuation;
  (iii) fire detection and general alarm system and manual fire-alarms; and
  (iv) remote control devices of fire-extinguishing systems if electrical;

(c) for a period of four hours of intermittent operation:
  (i) the daylight signalling lamps, if they have no independent supply from their own accumulator battery; and
  (ii) the craft's whistle or siren, if electrically driven;

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(d) for a period of 12 hours:
  (i) the navigational equipment as required by statutory Regulations; where such provision is unreasonable or impracticable, this requirement may be waived for craft of less than 5000 gross tonnage;
  (ii) essential electrically powered instruments and controls for propulsion machinery, if alternate sources of power are not available for such devices;
  (iii) emergency fire pump;
  (iv) the automatic sprinkler pump and drencher pump, if fitted;
  (v) the emergency bilge pump and all the equipment essential for the operation of electrically powered remote controlled bilge valves; and
  (vi) the craft radio facilities required to be available in an emergency;
(e) for a period of 10 minutes:
  (i) power drives for directional control devices including those required to direct thrust forward and astern, unless there is a manual alternative complying with Pt 14, Ch 1,6.1.4;
(f) for Passenger (B) craft only, for a period of half an hour:
  (i) power operated sliding watertight doors together with their indicators and warning signals.
(g) for any passenger high speed craft with lifts, for a period of half an hour:
  (i) the emergency arrangements to bring the lift cars to deck level for the escape of persons. The passenger lift cars may be brought to deck level sequentially in an emergency.

3.3.8 The emergency source of electrical power may be either a generator or an accumulator battery, which is to comply with the following:
(a) Where the emergency source of electrical power is a generator it is to be:
  (i) driven by a suitable prime mover with an independent supply of fuel, having a flashpoint (closed cup test) of not less than 43° C;
  (ii) started automatically upon failure of the main source of electrical power supply unless a transitional source of emergency electrical power complying with 3.3.9 is provided; where the emergency generator is automatically started, it is to be automatically connected to the emergency switchboard; those services referred to in 3.3.9 are to be connected automatically to the emergency generator; and
  (iii) provided with a transitional source of emergency electrical power as specified in 3.3.9, except on cargo craft where it may be omitted when an emergency generator is provided capable both of supplying the services mentioned in that paragraph and of being automatically started and supplying the required load as quickly as is safe and practicable subject to a maximum of 45 seconds.
(b) Where the emergency source of electrical power is an accumulator battery it is to be capable of:
  (i) carrying the emergency electrical load without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage;
  (ii) automatically connecting to the emergency switchboard in the event of failure of the main source of electrical power; and
  (iii) immediately supplying at least those services specified in 3.3.9.

3.3.9 The transitional source of emergency electrical power where required by 3.3.8 is to consist of an accumulator battery suitably located for use in an emergency which is to operate without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage and be of sufficient capacity and is to be so arranged as to supply automatically in the event of failure of either the main or the emergency source of electrical power for half an hour at least the following services if they depend upon an electrical source for their operation:
(a) the lighting required by 3.3.7(a) and (b). For this transitional phase, the required emergency electric lighting, in respect of the machinery space and accommodation and service spaces, may be provided by permanently fixed, individual, automatically charged, relay operated accumulator lamps; and
(b) the services required by 3.3.7(b) and (c);
(c) with respect to watertight doors:
  (i) power to operate the watertight doors but not necessarily simultaneously, unless an independent temporary source of stored energy is provided. The power source should have sufficient capacity to operate each door at least three times, i.e. closed-open-closed, against an adverse list of 15°; and
  (ii) power to the control, indication and alarm circuits for the watertight doors.

Alternatively, the above services may have independent supplies, for the period specified, from accumulator batteries suitably located for use in an emergency.

3.3.10 For passenger craft, propulsion and direction system instruments and controls power supplies are to be arranged to provide an uninterruptible supply of emergency power.

3.3.11 No accumulator battery fitted in accordance with this Section, unless for engine starting, is to be installed in the same space as the emergency switchboard. An indicator is to be mounted in a suitable place in the craft's operating compartment to indicate when the batteries constituting either the emergency source of electrical power or the transitional source of electrical power are being discharged, and provision is to be made to charge them *in situ* from a reliable on board supply.

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3.3.12 In addition to the emergency lighting required by 3.3.5(a) to (c), passenger craft with roll on-roll off spaces are to be provided with the following:

(a) in all passenger public spaces and alleyways supplementary electric lighting that can operate for at least three hours when all other sources of electric power have failed and under any condition of heel. The illumination provided is to be such that the approach to the means of escape can be readily seen. The source of power for the supplementary lighting is to consist of accumulator batteries within the lighting units that are continuously charged, where practicable, from the emergency switchboard. Consideration may be given to other means of lighting which is at least as effective. The supplementary lighting is to be such that any failure of the lamp will be immediately apparent. Any accumulator battery provided is to be replaced at intervals having regard to the specified service life in the ambient conditions that they are subject to in service; and

(b) a portable rechargeable battery operated lamp is to be provided in every crew space alleyway, recreational space and every working space which is normally occupied unless supplementary emergency lighting, as required by (a) is provided.

3.4 Emergency source of electrical power in cargo craft, patrol and pilot craft, workboats and other similar craft of 500 tons gross tonnage and above; and cargo craft, patrol and pilot craft, workboats and other similar craft of less than 500 tons gross tonnage for operation in Service Groups 4 to 6

3.4.1 The arrangements for the emergency source of electrical power are to satisfy the requirements of this sub-Section and, additionally, 3.2.1, 3.2.3, 3.2.6 and 3.2.10 to 3.2.15.

3.4.2 The emergency source of electrical power, associated transforming equipment, if any, transitional source of emergency power, emergency switchboard and emergency lighting switchboard are to be located such that the emergency generator and the main generators together meet the requirements of 3.1.4(a) and (b).

3.4.3 The electrical power available is to be sufficient to supply all those services that are essential for safety in an emergency, due regard being paid to such services as may have to be operated simultaneously. The emergency source of electrical power is to be capable, having regard to starting currents and the transitory nature of certain loads, of supplying simultaneously at least the following services for the periods specified hereinafter, if they depend upon an electrical source for their operation:

(a) for a period of three hours, emergency lighting at every survival craft preparation station, muster and embarkation station and over the sides;

(b) for a period of 12 hours, emergency lighting:
  (i) at the stowage positions of life-saving appliances:
  (ii) at all escape routes, such as alleyways, stairways, exits from accommodation and service spaces, embarkation points, etc.;
  (iii) in the public spaces, if any;
  (iv) in the machinery spaces, and main emergency generating spaces including their control positions;
  (v) in control stations;
  (vi) at the stowage positions for fireman's outfits;
  (vii) at the steering gear; and
  (viii) at the emergency fire pump, at the sprinkler pump, if any, and at the emergency bilge pump, if any, and at the starting positions of their motors;

(c) for a period of 12 hours:
  (i) the navigation lights, and other lights required by the *International Regulations for Preventing Collisions at Sea* in force; and
  (ii) the radio communications, as required by statutory regulations;

(d) for a period of 12 hours:
  (i) electrical internal communication equipment for announcements during evacuation;
  (ii) fire detection and general alarm system and manual fire alarms; and
  (iii) remote control devices of fire-extinguishing systems if electrical;

  unless such services have an independent supply for a period of 12 hours from an accumulator battery, suitably located for use in an emergency;

(e) for a period of four hours of intermittent operation:
  (i) the daylight signalling lamps, if they have no independent supply from their own accumulator battery; and
  (ii) the craft's whistle or siren, if electrically driven;

(f) for a period of 12 hours:
  (i) the navigational equipment as required by statutory regulations; where such provision is unreasonable or impracticable, this requirement may be waived for craft of less than 5000 tons gross tonnage;
  (ii) essential electrically powered instruments and controls for propulsion machinery, if alternate sources of power are not available for such devices;
  (iii) emergency fire pump;
  (iv) the automatic sprinkler pump and drencher pump, if fitted; and
  (v) the emergency bilge pump and all the equipment essential for the operation of electrically powered remote controlled bilge valves;

(g) for a period of 10 min:
  (i) power drives for directional control devices including those required to direct thrust forward and astern, unless there is a manual alternative complying with Pt 14, Ch 1,6.1.4.

(h) for a period of half an hour:
  (i) any watertight doors required by Chapter 2 to be power-operated together with their indicators and warning signals; and

(j) where applicable, the services required by 2.4.2.

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3.4.4 The emergency source of electrical power may be either a generator or an accumulator battery, which is to comply with the following:

(a) Where the emergency source of electrical power is a generator it is to be:
  (i) driven by a suitable prime mover with an independent supply of fuel, having a flash point (closed cup test) of not less than 43°C;
  (ii) started automatically upon failure of the main source of electrical power supply unless a transitional source of emergency electrical power in accordance with 3.4.5 is provided; where the emergency generator is automatically started, it is to be automatically connected to the emergency switchboard; those services referred to in 3.4.5 are to be connected automatically to the emergency generator; and
  (iii) provided with a transitional source of emergency electrical power as specified in 3.4.5 unless an emergency generator is provided capable both of supplying the services mentioned in that paragraph and of being automatically started and supplying the required load as quickly as is safe and practicable subject to a maximum of 45 seconds.

(b) Where the emergency source of electrical power is an accumulator battery it is to be capable of:
  (i) carrying the emergency electrical load without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage;
  (ii) automatically connecting to the emergency switchboard in the event of failure of the main source of electrical power; and
  (iii) immediately supplying at least those services specified in 3.4.5.

3.4.5 The transitional source of emergency electrical power where required by 3.4.4 is to consist of an accumulator battery suitably located for use in an emergency which is to operate without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage and be of sufficient capacity and is to be so arranged as to supply automatically in the event of failure of either the main or the emergency source of electrical power for half an hour at least the following services if they depend upon an electrical source for their operation:

(a) the lighting required by 3.4.3(a) to (c). For this transitional phase, the required emergency electric lighting, in respect of the machinery space and accommodation and service spaces may be provided by permanently fixed, individual, automatically charged, relay operated accumulator lamps, and

(b) all services required by 3.4.3(d)(i) to (iii) and (e) unless such services have an independent supply for the period specified from an accumulator battery suitably located for use in an emergency.

(c) with respect to watertight doors:
  (i) power to operate the watertight doors but not necessarily simultaneously, unless an independent temporary source of stored energy is provided. The power source should have sufficient capacity to operate each door at least three times i.e. closed-open-closed, against an adverse list of 15°;
  (ii) power to the control, indication and alarm circuits for the watertight doors for half an hour.

3.5 Starting arrangements

3.5.1 Where the emergency source of power is a generator, the starting arrangements are to comply with the requirements given in Part 10.

3.6 Prime mover governor

3.6.1 Where the emergency source of power is a generator, the governor is to comply with 2.4.

3.7 Radio installation

3.7.1 Every radio installation as required by statutory regulations is to be provided with reliable, permanently arranged electrical lighting, independent of the main and emergency sources of electrical power, for the adequate illumination of the radio controls for operating the radio installation.

3.7.2 A reserve source or sources of energy is to be provided on every craft, for the purpose of conducting distress and safety radio-communications, in the event of failure of the craft's main and emergency sources of electrical power. The reserve source or sources of energy is to be capable of simultaneously operating the VHF radio installation and, as appropriate for the sea or sea area for which the craft is equipped, either the MF radio installation, the MF/HF radio installation, or the INMARSAT 'ship to earth' station and any of the additional loads mentioned in 3.7.4, 3.7.5 and 3.7.7 for a period of at least one hour. The reserve source or sources of energy need not supply independent HF and MF radio installations at the same time.

3.7.3 The reserve source or sources of energy is to be independent of the propelling power of the craft and the craft's electrical system.

3.7.4 Where, in addition to the VHF radio installation, two or more of the other radio installations, referred to in 3.7.2, can be connected to the reserve source or sources of energy, the reserve source or sources are to be capable of simultaneously supplying, for the period specified by 3.7.2, the VHF radio installation and:

(a) all other radio installations which can be connected to the reserve source or sources of energy at the same time; or

(b) whichever of the other radio installations will consume the most power, if only one of the other radio installations can be connected to the reserve source or sources of energy at the same time as the VHF radio installation.

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3.7.5 The reserve source or sources of energy may be used to supply the electrical lighting required by 3.7.1.

3.7.6 Where a reserve source of energy consists of a rechargeable accumulator battery or batteries a means of automatically charging the batteries is to be provided which is to be capable of recharging them to minimum capacity requirements within 10 hours.

3.7.7 If an uninterrupted input of information from the craft's navigational or other equipment to a radio installation as referred to in 3.7.2 is needed to ensure its proper performance, means are to be provided to ensure the continuous supply of such information in the event of failure of the craft's main or emergency source of electrical power.

■ *Section 4* External source of electrical power

4.1 Temporary external supply (shore supply)

4.1.1 Where arrangements are made for the supply of electricity from a source on shore or elsewhere, a connection box is to be installed in a position suitable for the convenient reception of flexible cables from the external source and containing a circuit-breaker or isolating switch and fuses and terminals including one earthed, of ample size and suitable shape to facilitate a satisfactory connection of three-phase external supplies with earthed neutrals.

4.1.2 Suitable cables, permanently fixed, are to be provided, connecting the terminals in the connection box to a linked switch and/or a circuit-breaker at the main switchboard. An indicator is to be provided at the main switchboard in order to show when the cables are energised.

4.1.3 Means are to be provided for checking the phase sequence of the incoming supply.

4.1.4 At the connection box a notice is to be provided giving full information on the system of supply, the normal voltage and frequency of the installation's system and the procedure for carrying out the connection.

4.1.5 Alternative arrangements may be submitted for consideration.

4.2 Permanent external supply

4.2.1 Details are to be submitted.

■ *Section 5* Supply and distribution

5.1 Systems of supply and distribution

5.1.1 The following systems of generation and distribution are acceptable:

(a) d.c., two-wire;
(b) a.c., single-phase, two-wire;
(c) a.c., three-phase;
three-wire;
four-wire with neutral solidly earthed but without hull return.

5.1.2 System voltages for both alternating current and direct current in general are not to exceed:

(a) 15 000 V for propulsion purposes;
(b) 500 V for power, cooking and heating equipment permanently connected to fixed wiring;
(c) 250 V for lighting, heaters in cabins and public rooms, and other applications not mentioned above;
(d) Voltages exceeding these will be the subject of special consideration.

5.1.3 The arrangement of the main system of supply is to be such that a fire or other casualty in any space containing the main source of electrical power, associated converting equipment, if any, the main switchboard or the main lighting switchboard will not render inoperable any emergency service, other than those located within the space where the fire or casualty has occurred.

5.1.4 The main switchboard is to be so placed relative to the main source of power that, as far as is practicable, the integrity of the main system of supply will be affected only by a fire or other casualty in one space.

5.1.5 The arrangement of the emergency system of supply is to be such that a fire or other casualty in spaces containing the emergency source of electrical power, associated converting equipment, if any, the emergency switchboard and the emergency lighting switchboard, will not cause loss of services required to maintain the propulsion and safety of the craft.

5.1.6 Distribution systems required in an emergency are to be so arranged that a fire in any main vertical zone will not interfere with the emergency distribution in any other such zone.

5.1.7 Feeders from the main and the emergency sources of electrical power are to be separated both vertically and horizontally as widely as is practicable.

5.1.8 For Passenger (A) or Passenger (B) Craft or cargo craft of 500 tons gross tonnage and over, and in any case where the total installed electrical power of the main generating sets is in excess of 3 MW or is supplied at high voltage, arrangements are to be made so that it is possible to split the switchboard, by a multipole linked circuit-breaker, disconnector or switch-disconnector, into at least two independent sections, each supplied by at least one generator.

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5.1.9 Where 5.1.8 is applicable and the essential services which are duplicated are supplied from a section board, arrangements are to be made so that it is possible to split the section board into at least two independent sections each supplied by an independent section of the main switchboard either directly or through a transformer.

5.1.10 For Passenger (B) high speed craft, each part of the main busbars with its associated generators is to be arranged in separate compartments.

5.2 Essential services

5.2.1 Essential services that are required to be duplicated are to be served by individual circuits, separated in their switchboard or section board and throughout their length as widely as is practicable without the use of common feeders, protective devices, control circuits or control gear assemblies, so that any single fault will not cause the loss of both services.

5.2.2 Where 5.2.1 is applicable the main busbars of the switchboard, or section boards, are to be capable of being split, by removable links or other means, into at least two independent sections, each supplied by at least one generator, either directly or through a converter. The essential services are to be equally divided, as far as is practicable, between the independent sections.

5.2.3 Where 5.1.8 is applicable provision is to be made to transfer to a temporary circuit those essential services which are not required to be, and have not been, duplicated in the event of loss of their normal section of switchboard or section board.

5.2.4 Where the loss of the electrical supply to a particular essential service which is not duplicated would cause serious risk to the craft, it is to be fed by two independent supplies complying with 5.2.1. Such circuits are to be provided with short circuit protection and an overload and phase-failure alarm. Failure of either supply is not to cause risk to the craft during switching to the alternative supply.

5.3 Isolation and switching

5.3.1 The incoming and outgoing circuits from every switchboard or section board are to be provided with a means of isolation and switching to permit each circuit to be switched off:

(a) on load;
(b) for mechanical maintenance;
(c) in an emergency to prevent or remove danger.

Precautions are to be taken to minimise the risk of inadvertent or accidental switching.

5.3.2 Isolation and switching is to be by means of a circuit breaker or switch arranged to open and close simultaneously all insulated poles. Where a switch is used as the means of isolation and switching, it is to be capable of:

(a) switching off the circuit on load;
(b) withstanding, without damage, the overcurrents which may arise during overloads and short circuit.

In addition, these requirements do not preclude the provision of single pole control switches in final sub-circuits, for example light switches. For circuit-breakers, *see* 6.5 and 7.3.

5.3.3 Provision is to be made, in accordance with one of the following, to prevent any circuit being inadvertently energised:

(a) the circuit breaker or switch can be withdrawn, or locked in the open position;
(b) the operating handle of the circuit breaker or switch can be removed;
(c) the circuit fuses, where fitted, can be readily removed and retained by authorised personnel.

5.3.4 All lighting and power circuits installed in unattended spaces are to be controlled by multipole linked switches situated outside such spaces. Provision is to be made for the complete isolation of these circuits and locking the means of control in the off position.

5.3.5 Where arrangements are in place for automatic changeover between two or more supplies of electrical power in the event of failure of one supply, the arrangements are to be such that a fault in one feeder does not result in the loss of all supplies to the automatic changeover switch.

5.3.6 Where a section board, distribution board or item of equipment can be supplied by more than one circuit, a switching device is to be provided to permit each incoming circuit to be isolated and the supply transferred to the alternative circuit.

5.3.7 The switching device required by 5.3.6 is to be situated within or adjacent to the section board, distribution board or item of equipment. Where necessary, interlocking arrangements are to be provided to prevent circuits being inadvertently energised.

5.3.8 A notice is to be fixed to any section board, distribution board or item of equipment to which 5.3.5 applies warning personnel before gaining access to live parts of the need to open the appropriate circuit breakers or switches, unless an interlocking arrangement is provided so that all circuits concerned are isolated before access is gained.

5.4 Insulated distribution systems

5.4.1 A device(s) is to be installed for every insulated distribution system, whether primary or secondary, for power, heating and lighting circuits, to continuously monitor the insulation level to earth and to operate an alarm in the engine control room, or equivalent attended position, in the event of an abnormally low level of insulation resistance.

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5.4.2 Where any insulated lower voltage system is supplied through transformers from a high voltage system, adequate precautions are to be taken to prevent the low voltage system being charged by capacitive leakage from the high voltage system.

5.4.3 Where filters are fitted, for example to reduce EMC susceptibility, these are not to cause distribution systems to be unintentionally connected to earth.

5.5 Earthed distribution systems

5.5.1 No fuse, non-linked switch or non-linked circuit-breaker is to be inserted in an earthed conductor. Any switch or circuit-breaker fitted is to operate simultaneously in the earthed conductor and the insulated conductors. These requirements do not preclude the provision (for test purposes) of an isolating link to be used only when the other conductors are isolated.

5.5.2 For high speed craft, earthed electrical distribution systems are not to be used, with the exception of earthed intrinsically safe circuits, in areas where an explosive gas atmosphere may arise from the presence of fuel with a flash point below 43°C, *see* Pt 15, Ch 3,3.1.

5.5.3 For high voltage systems, where the earthed neutral system of generation and primary distribution is used, earthing is to be through an impedance in order to limit the total earth fault current to a magnitude which does not exceed that of the three phase short circuit current for which the generators are designed.

5.5.4 Generator neutrals may be connected in common, provided that the third harmonic content of the voltage waveform of each generator does not exceed five per cent.

5.5.5 Where a switchboard is split into sections operated independently or where there are separate switchboards, neutral earthing is to be provided for each section or for each switchboard. Means are to be provided to ensure that the earth connection is not removed when generators are isolated.

5.5.6 A means of isolation is to be fitted in the earthing connection of each generator so that generators can be completely isolated for maintenance.

5.5.7 All earthing impedances are to be connected to a common earth connection/bar. The connections to the common earth connection/bar are to be so arranged that any circulating currents in the earth connections do not interfere with radio, radar, communication and control equipment circuits.

5.6 Diversity factor

5.6.1 Circuits supplying two or more final sub-circuits are to be rated in accordance with the total connected load subject, where justified, to the application of a diversity factor. Where spare ways are provided on a section or distribution board, an allowance for future increase of load is to be added to the total connection load before application of any diversity factor.

5.6.2 A diversity factor may be applied to the calculation for size of cable and rating of switchgear and fusegear, taking into account the duty cycle of the connected loads and the frequency and duration of any motor starting loads.

5.6.3 For winches and crane motors the diversity factor is to be calculated and submitted when required.

5.7 Lighting circuits

5.7.1 Lighting circuits are to be supplied by final sub-circuits separate from those for heating and power. This does not preclude the supply from a lighting circuit supplying a single fixed appliance, such as a cabin fan, a dry shaver, a wardrobe or anti-condensation heater, taking a maximum current of 2 A. (This does not apply to cabin and wardrobe heaters).

5.7.2 Lighting for machinery spaces, control stations, normal working spaces, large galleys, corridors, stairways leading to boat decks and in public rooms is to be supplied from at least two final sub-circuits in such a way that failure of any one of the circuits does not leave the space in darkness. One of these circuits may be the emergency circuit, provided it is normally energised.

5.7.3 Lighting for enclosed hazardous spaces is to be supplied from at least two final sub-circuits to permit light from one circuit to be retained while maintenance is carried out on the other.

5.7.4 Emergency lighting is to be fitted in accordance with Section 3, *see also* Section 18.

5.8 Motor circuits

5.8.1 A separate final sub-circuit is to be provided for every motor for essential services, *see* 1.6.1.

5.9 Motor control

5.9.1 Every electric motor is to be provided with efficient means for starting and stopping so placed as to be easily operated by the person controlling the motor. Every motor above 0,5 kW is to be provided with control apparatus as given in 5.9.2 to 5.9.4.

5.9.2 Means to prevent undesired restarting after a stoppage due to low volts or complete loss of volts are to be provided. This does not apply to motors where a dangerous condition might result from the failure to restart automatically, e.g. steering gear motor.

5.9.3 Means for automatic disconnection of the supply in the event of excess current due to mechanical overloading of the motor are to be provided, *see also* 6.9.

5.9.4 Motor control gear is to be suitable for the starting current and for the full load rated current of the motor.

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Section 6
System design – Protection

6.1 General

6.1.1 Installations are to be protected against over-currents including short-circuits, and other electrical faults. The tripping/fault clearance times of the protective devices are to provide complete and co-ordinated protection to ensure:

(a) availability of essential and emergency services under fault conditions through discriminative action of the protective devices; as far as practicable the arrangements are also to secure the availability of other services;

(b) elimination of the fault to reduce damage to the system and hazard of fire.

6.1.2 Short-circuit and overload protection are to be provided in each non-earthed line of each system of supply and distribution, unless exempted under the provisions of any paragraph in this Section.

6.1.3 The protection of circuits is to be such that a fault in a circuit does not cause the interruption of supplies used to provide emergency or essential services other than those dependent on the circuit where the fault occurred. For circuits used to provide essential services which need not necessarily be in continuous operation to maintain propulsion and steering but which are necessary for maintaining the vessel's safety, arrangements that ensure that a fault in a circuit does not cause the sustained interruption of supply to healthy circuits may be accepted. Such arrangements are to ensure the supply to healthy circuits is automatically re-established in sufficient time after a fault in a circuit.

6.1.4 Protection systems are to be developed using a systematic design procedure incorporating verification and validation methods to ensure successful implementation of the requirements above. Details of the procedures used are to be submitted when requested. An approved copy of the details required by 1.2.5 and 1.2.6 is to be retained on board and made available to the Surveyor on request.

6.1.5 Short-circuit protection is to be provided for each source of power and at each point at which a distribution circuit branches into two or more subsidiary circuits.

6.1.6 Where protection for generator power circuits is provided at the associated switchboard, the cabling between generator and switchboard is to be of a type, and installed in a manner such as to minimise the risk of short-circuit.

6.1.7 Protection for battery circuits is to be provided at a position external and adjacent to the battery compartments. Where arrangements comply with 12.3.5, the protection may be installed at a suitable location in the battery compartment.

6.1.8 Protection may be omitted from the following:

(a) Engine starting battery circuits.

(b) Circuits for which it can be shown that the risk resulting from spurious operation of the protective device may be greater than that resulting from a fault.

6.1.9 Short-circuit protection may be omitted from cabling or wiring to items of equipment internally protected against short-circuit or where it can be shown that they are unlikely to fail to a short-circuit condition or it is impractical for operational reasons (e.g. within battery compartments), and where the cabling or wiring is installed in a manner such as to minimise the risk of short-circuit.

6.1.10 Overload protection may be omitted from the following:

(a) one line of circuits of the insulated type;

(b) circuits supplying equipment incapable of being overloaded, or overloading the associated supply cable, under normal conditions, and unlikely to fail to an overload condition.

6.2 Protection against short-circuit

6.2.1 Protection against short-circuit currents is to be provided by circuit-breakers or fuses.

6.2.2 The rated short-circuit making and breaking capacity of every protective device is to be adequate for the prospective fault level at its point of installation; the requirements for circuit breakers and fuses are detailed in 6.4 and 6.5 respectively.

6.2.3 The prospective fault current is to be calculated for the following set of conditions:

(a) all generators, motors and, where applicable, all transformers, connected as far as permitted by any interlocking arrangements;

(b) a fault of negligible impedance close up to the load side of the protective device.

6.2.4 In the absence of precise data, the prospective fault current may be taken to be:

(a) for alternating current systems at the main switchboard: 10 x f.l.c. (rated full load current) for each generator that may be connected, or, if the subtransient direct axis reactance, X"d,of each generator is known, $\frac{\text{f.l.c}}{X''_d \text{ (p.u.)}}$ for each generator and 3 x f.l.c. for motors simultaneously in service;
The value derived from the above is an approximation to the r.m.s. symmetrical fault current; the peak asymmetrical fault current may be estimated to be 2,5 times this figure (corresponding to a fault power factor of approximately 0,1).

(b) battery-fed direct current systems at the battery terminals:
  (i) 15 times ampere hour rating of the battery for vented lead-acid cells, or of alkaline type intended for discharge at low rates corresponding to a battery duration exceeding three hours, or
  (ii) 30 times ampere hour rating of the battery for sealed lead-acid cells having a capacity of 100 ampere hours or more, or of alkaline type intended for discharge at high rates corresponding to a battery duration not exceeding three hours and,
  (iii) 6 x f.l.c. for motors simultaneously in service, if applicable.

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6.3 Protection against overload

6.3.1 Fuses, circuit breakers and other protective devices provided for overload protection are to have fusing/tripping characteristics ensuring the protection of cabling and electrical machinery against overheating resulting from mechanical or electrical overload.

6.3.2 Fuses of a type intended for short-circuit protection only (e.g. fuse links complying with IEC 60269-1, of type "a") are not to be used for overload protection.

6.4 Protection against earth faults

6.4.1 Every distribution system that has an intentional connection to earth, by way of an impedance, is to be provided with a means to continuously monitor and indicate the current flowing in the earth connection.

6.4.2 If the current in the earth connection exceeds 5 A there is to be an alarm and the fault current is to be automatically interrupted or limited to a safe value.

6.4.3 The rated short circuit capacity of any device used for interrupting earth fault currents is to be not less than the prospective earth fault current at its point of installation.

6.4.4 Insulated neutral systems with harmonic distortion of the voltage waveform, which may result in earth fault currents exceeding the level given in 6.4.2 because of capacitive effects, are to be provided with arrangements to isolate the faulty circuit(s).

6.5 Circuit-breakers

6.5.1 Circuit-breakers for alternating current systems are to satisfy the following conditions:

(a) the r.m.s. symmetrical breaking current for which the device is rated is to be not less than the r.m.s. value of the a.c. component of the prospective fault current, at the instant of contact separation (i.e. first half cycle, or time of interruption where an intentional time delay is provided to ensure suitability);

(b) the peak asymmetrical making current for which the device is rated is not to be less than the peak value of the prospective fault current at the first half cycle, allowing for maximum asymmetry;

(c) the power factor at which the device short circuit ratings are assigned is to be no greater than that of the prospective fault current; alternatively for high voltage, the rated percentage d.c. component of the short-circuit breaking current of the device is to be not less than that of the prospective fault current.

6.5.2 Circuit-breakers for d.c. systems are to have a breaking current not less than the initial prospective fault current. The time constant of the fault current is not to be greater than that for which the circuit-breaker was tested.

6.5.3 The fault ratings considered in 6.5.1 and 6.5.2, are to be assigned on the basis that the device is suitable for further use after fault clearance.

6.5.4 Circuit- breaker selection is, and ratings are, to be in accordance with the relevant requirements of IEC 60092-202: *Electrical installations in ships – System design – Protection*. Alternative methods acceptable to LR of selecting suitable circuit-breakers may be considered.

6.6 Fuses

6.6.1 Fuses for a.c. systems are to have a breaking current rating not less than the initial r.m.s. value of the a.c. component of the prospective fault current.

6.6.2 Fuses for d.c. systems are to have a d.c. breaking current rating not less than the initial value of the prospective fault current.

6.7 Circuit-breakers requiring back-up by fuse or other device

6.7.1 The use of a circuit-breaker having a short-circuit current capacity less than the prospective short-circuit current at the point of installation is permitted, provided that it is preceded by a device having at least the necessary short-circuit capacity. The generator circuit breakers are not to be used for this purpose.

6.7.2 The same device may back-up more than one circuit-breaker provided that no essential or emergency service is supplied from there, or that any such service is duplicated by arrangements unaffected by tripping of the device.

6.7.3 The combination of back-up device and circuit-breaker is to have a short circuit performance at least equal to that of a single circuit-breaker satisfying the requirements of 6.5.

6.7.4 Evidence of testing of the combination is to be submitted for consideration; alternatively, consideration may be given to arrangements where it can be shown that:

(a) the takeover current, above which the back-up device would clear a fault, is not greater than the rated short-circuit breaking capacity of the circuit-breaker and;

(b) the characteristics of the back-up device, and the prospective fault level, are such that the peak fault current rating of the circuit-breaker cannot be exceeded and;

(c) the Joule integral of the let-through current of the back-up device does not exceed that corresponding to the rated breaking current and opening time of the circuit-breaker.

6.8 Protection of generators

6.8.1 The protective gear required by 6.8.2 and 6.8.3 is to be provided as a minimum.

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6.8.2 Generators not arranged to run in parallel are to be provided with a circuit-breaker arranged to open simultaneously, in the event of short-circuit, overload or under-voltage, all insulated poles. In the case of generators rated at less than 50 kW, a multiple linked switch with a fuse, complying with 5.3.2, in each insulated pole will be acceptable.

6.8.3 Generators arranged to operate in parallel are to be provided with a circuit-breaker arranged to open all insulated poles simultaneously in the event of a short-circuit, an overload or an under-voltage. This circuit-breaker is to be provided with reverse power protection with time delay, selected or set within the limits of two per cent to 15 per cent of full load to a value fixed in accordance with the characteristics of the prime mover. A fall of 50 per cent in the applied voltage is not to render the reverse power mechanism inoperative, although it may alter the amount of reverse power required to open the breakers.

6.8.4 The generator circuit-breaker short-circuit and overload tripping arrangements, or fuse characteristics, are to be such that the machine's thermal withstand capability is not exceeded.

6.8.5 Generators having a capacity of 1500 kVA or above are to be equipped with a protective device which, in the event of a short-circuit in the generator or in the cable between the generator and its circuit breaker, will instantaneously open the circuit breaker and de-excite the generator.

6.8.6 The voltage and time delay settings of the under-voltage release mechanism(s) required by 6.8.2 and 6.8.3 are to be chosen to ensure that the discriminative action required by 6.1.1(a) is maintained.

6.9 Load management

6.9.1 Arrangements are to be made to disconnect automatically, after an appropriate time delay, circuits of the categories noted below, when the generator(s) is/are overloaded; sufficient to ensure the connected generating set(s) is/are not overloaded:

(a) non-essential circuits;
(b) circuits feeding services for habitability, *see* 1.6.2;
(c) in cargo craft, circuits for cargo refrigeration.

NOTE
For emergency generators *see* 3.2.14, with 3.3.1 or 3.4.1 where applicable.

6.9.2 If required, this load switching may be carried out in one or more stages, in which case the non-essential circuits are to be included in the first group to be disconnected.

6.9.3 An alarm is to be provided to indicate when such switching has taken place.

6.9.4 Consideration is to be given to providing means to inhibit automatically the starting of large motors, or the connection of other large loads, until sufficient generating capacity is available to supply them.

6.9.5 When the electric generating plant is fitted with automatic or remote controls so that under normal operating conditions it does not require any manual intervention by the operators, it is to be provided with audible and visual alarms for:

(a) Busbar voltage; high or low.
(b) Busbar frequency; low.
(c) Operating of load switching.
(d) Generator cooling air temperature high; closed air circuit machines only.

6.10 Feeder circuits

6.10.1 Isolation and protection of each feeder circuit is to be ensured by a multiple circuit-breaker or linked switch with a fuse in each insulated conductor. Protection is to be in accordance with 6.2 and 6.3. The protective devices are to allow excess current to pass during the normal accelerating period of motors.

6.11 Motor circuits

6.11.1 Motors of rating exceeding 0,5 kW and all motors for essential services are to be protected individually against overload and short circuit. For motors which for essential services are duplicated, the overload protection may be replaced by an overload alarm; arrangements for steering unit motors are to comply with 15.1.

6.11.2 Protection for both the motor and its supply cable may be provided by the same device, provided that due account is taken of any differences between ratings of cable and motor.

6.11.3 Where operation of an item of equipment is dependent upon a number of motors, consideration may be given to the provision of a common means of short-circuit protection.

6.11.4 For motors for intermittent service, the characteristics of the arrangements for overload protection are to be chosen in relation to the load factor(s) of the motor(s).

6.11.5 Where fuses are used to protect polyphase motor circuits, means are to be provided to protect the motor from unacceptable overcurrent in the case of single phasing.

6.12 Protection of transformers

6.12.1 Short circuit protection for transformers is to be provided by circuit breakers or fuses in the primary circuit and in addition, overload protection is to be provided either in the primary or secondary circuit.

6.12.2 Arrangements are to be made to prevent the primary windings of transformers being inadvertently energised from their secondary side when disconnected from their source of supply.

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Section 7 Switchgear and control gear assemblies

7.1 General requirements

7.1.1 Switchgear and control gear assemblies and their components are to comply with one of the following standards amended where necessary for ambient temperature and other environmental conditions:

(a) IEC 61439: *Low voltage switchgear and control gear assemblies*;
(b) IEC 62271-200*: AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV*;
(c) IEC 60466: *AC insulated-enclosed switchgear for rated voltages above 1 kV and up to and including 38 kV*;
(d) IEC 60255: *Electrical relays*;
(e) acceptable and relevant National Standard.

In addition, the requirements of 7.2 to 7.18 are to be complied with.

7.2 Busbars

7.2.1 Busbars and their connections are to be of copper or aluminium, all connections being so made as to inhibit corrosion/oxidation between current-carrying mating faces, which may result in poor electrical contact giving rise to overheating. Busbars and their supports are to be designed to withstand the mechanical stresses which may arise during short-circuits. A test report or calculation to verify the short-circuit withstand strength of the busbar system is to be submitted for consideration when required.

7.2.2 The maximum permissible temperature rise for bare conductors is 45°C. A test report or calculation to verify the rated current assigned to the busbar system is to be submitted for consideration when required.

7.3 Circuit-breakers

7.3.1 Circuit-breakers are to comply with one of the following standards amended where necessary for ambient temperature:

(a) IEC 60947-2: *Low voltage switchgear and Control gear Pt 2: circuit breakers*;
(b) IEC 60056: *High voltage alternating-current circuit-breakers*;
(c) acceptable and relevant National Standard.

Type test reports to verify the characteristics of a circuit-breaker are to be submitted for consideration when required.

7.3.2 Circuit-breakers are to be capable of isolation.

7.3.3 Circuit-breakers are to be of the trip free type and, where applicable, be fitted with anti-pumping control.

7.3.4 High-voltage circuit-breakers are to be of the withdrawable type or with equivalent means or arrangements permitting safe maintenance whilst the busbars are live.

7.3.5 Where the means of setting adjustable protection characteristics are not durably marked and locked in position and cannot be visually inspected (e.g. electronic storage), the settings of characteristics are to be recorded and a copy of the records included in the details retained on board, *see* 6.1.4.

7.4 Contactors

7.4.1 High-voltage contactors are to comply with one of the following standards amended where necessary for ambient temperature.

(a) IEC 60470: *High-voltage alternating current contactors*.
(b) acceptable and relevant National Standard.

Type test reports to verify the characteristics of a contactor are to be submitted for consideration when required.

7.4.2 High-voltage contactors are to be of the withdrawable type or with equivalent means or arrangements permitting safe maintenance whilst the busbars are live.

7.5 Creepage and clearance distances

7.5.1 The shortest distances between conductive parts and between conductive parts and earth in air or along the surface of an insulating material, are to be suitable for the rated voltage having regard to the nature of the insulating material and the transient over voltages developed by switching and fault conditions. This requirement may be satisfied by subjecting each assembly type to an impulse voltage test in accordance with its constructional Standard or, alternatively, maintaining the minimum distances for bare conductive parts in switchgear and control gear assemblies given in Table 2.7.1.

Table 2.7.1 Minimum clearance distances

Nominal voltage (V)	Minimum clearance distance (mm)			
	Main switchboards		Other switchgear and control gear	
	Type-tested assemblies	Non-type-tested assemblies	Type-tested assemblies	Non-type-tested assemblies
≤ 250	8	15	6	15
>250 to ≤690	8	20	6	20
>690 to 1000	8	25	6	25
<1100	14	14	14	14
<3300	32	55	26	55
<6600	60	90	50	90
<11 000	100	120	80	120
≤15 000	100	160	100	160

NOTE
A minimum clearance distance of 25 mm is required for busbars and other bare conductors in main switchboards.

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7.5.2 Suitable shrouding or barriers are to be provided in way of connections to equipment, where necessary, to maintain the minimum distances in Table 2.7.1.

7.5.3 Switchgear and control gear assemblies for rated voltages up to and including 1 kV are to have creepage distances in accordance with IEC 60092-302, *Electrical installations in ships – Part 302: Low-voltage switchgear and control gear assemblies*, and Table 2.7.2.

Table 2.7.2 Minimum creepage distances

Nominal voltage (V)	Minimum creepage distance (mm)	
	Main switchboards	Other switchgear and control gear
≤250	20	20
>250 to ≤690	25	25
>690 to 1000	35	35
<3300	48	35
<6600	90	70
<11,000	150	120
≤15,000	150	120
NOTE A minimum creepage distance of 16 mm is permitted for type-tested assemblies for rated voltages up to and including 1 kV, *see* 7.5.4.		

7.5.4 For switchgear and control gear assemblies for rated voltages up to and including 1 kV, a minimum creepage distance of 16 mm is permitted for type-tested assemblies. The type tests are to include verification of the degree of protection, insulation material group and creepage and clearance distances in accordance with IEC 61439-1, *Low-voltage switchgear and control gear assemblies – Part 1: General Rules*.

7.5.5 Switchgear and control gear assemblies for rated voltages above 1 kV are to have creepage distances in accordance with IEC 60092-503, *Electrical installations in ships – Part 503: Special features – AC supply systems with voltages in the range of above 1 kV up to and including 15 kV*. In the absence of alternative proposals, including supporting design rationale, the distances stated in Table 2.7.2 are to be used, *see also* 1.3.3.

7.5.6 For switchgear and control gear assemblies for rated voltages of 1 kV and above, the type testing stated in Table 2.7.1 is to include verification of the degree of protection in accordance with a relevant International or National Standard.

7.6 Degree of protection

7.6.1 Low voltage assemblies where the rated voltage between conductors or to earth exceeds 55 V a.c. or 250 V d.c. are to be of the deadfront or enclosed type. High-voltage assemblies are to be of the enclosed type.

7.6.2 Where switchboards or section boards are required to comply with 5.2.2, barriers are to be installed to provide protection for the independent sections against contamination due to the products of arcing, which may result in a fault.

7.7 Distribution boards

7.7.1 Distribution boards are to be suitably enclosed unless they are installed in a cupboard or compartment to which only authorised persons have access in which case the cupboard may serve as an enclosure. *See* 7.16.4.

7.8 Earthing of high-voltage switchboards

7.8.1 High-voltage switchboards are to be provided with suitable means to earth isolated circuits so that they are discharged and so maintained that they are safe to touch.

7.8.2 Protective shutters associated with withdrawable parts are to be clearly marked, e.g. by colour coding, to indicate the incoming and outgoing circuits and bus tie connections.

7.9 Fuses

7.9.1 Fuses are to comply with one of the following standards amended where necessary for ambient temperature.

(a) IEC 60269: *Low-voltage fuses*;
(b) IEC 60282-1: *High voltage fuses Pt 1: Current-limiting fuses*;
(c) acceptable and relevant National Standard for enclosed current-limiting fuses.

Type test reports to verify the characteristics of a fuse are to be submitted for consideration when required.

7.10 Handrail or handles

7.10.1 All main and emergency switchboards are to be provided with an insulated handrail or insulated handles suitably fitted on the front of the switchboard. Where access to the rear is required, a horizontal insulated handrail is to be suitably fitted on the rear of the switchboard.

7.11 Instruments for alternating current generators

7.11.1 For alternating current generators not operated in parallel, each generator is provided with at least one voltmeter, one frequency meter, and one ammeter with an ammeter switch to enable the current in each phase to be read, or an ammeter in each phase. Generators above 50 kVA are also to be provided with a wattmeter.

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7.11.2 For alternating current generators operated in parallel, each generator is to be provided with a wattmeter, and one ammeter with an ammeter switch to enable the current in each phase to be read, or an ammeter in each phase.

7.11.3 For parallelling purposes, two voltmeters, two frequency meters and two synchronising devices, of which one at least is to be a synchroscope or a set of lamps are to be provided. One voltmeter and one frequency meter are to be connected to the busbars, the other voltmeter and frequency meter are to be switched to enable the voltage and frequency of any generator to be measured. Where the electrical power requirement to maintain the ship in a normal operational and habitable condition is usually supplied by two or more generators operating in parallel, the two synchronising devices are to be independent of each other, *see also* 2.2.1.

7.11.4 The indicators and displays required by 7.11.1 to 7.11.3 are to be located and arranged such that they may be viewed at a single operating position. Where manual paralleling is provided, it is to be possible to adjust voltage and frequency at this position.

7.11.5 Where the indications of voltage, frequency, current and power are displayed digitally, the indications are to be separately displayed.

7.12 Instrument scales

7.12.1 The upper limit of the scale of every voltmeter is to be approximately 120 per cent of the nominal voltage of the circuit, and the nominal voltage is to be clearly indicated.

7.12.2 The upper limit of the scale of every ammeter is to be approximately 130 per cent of the normal rating of the circuit in which it is installed. Normal full load is to be clearly indicated.

7.12.3 Kilowatt meters for use with alternating current generators which may be operated in parallel are to be capable of indicating 15 per cent reverse power.

7.12.4 Where the indications provided by the instrumentation required by 7.11 are displayed digitally, nominal voltage, over voltage, over current and reverse power indications are to be indicated by an appropriate means. The information provided is to be clearly visible and immediately available.

7.12.5 In general, indications provided by instrumentation which are displayed digitally are not to change more frequently than twice per second.

7.13 Labels

7.13.1 The identification of individual circuits and their devices is to be made on labels of durable material. The ratings of fuses and settings of protective devices are also to be indicated. Section and distribution boards are to be marked with the rated voltage.

7.14 Protection

7.14.1 For details of the electrical protection required of switchgear and control gear, *see* Section 6.

7.15 Wiring

7.15.1 Insulated wiring connecting components are to be stranded, flame retardant and manufactured in accordance with a relevant and acceptable National Standard.

7.16 Position of switchboards

7.16.1 An unobstructed space not less than 1 m wide is to be provided in front of switchboards and section boards. When switchboards and section boards contain withdrawable equipment the unobstructed space is to be not less than 0,4 m wide with this equipment in its fully withdrawn position.

7.16.2 Where necessary, the space at the rear of switchboards and section boards is to be ample to permit maintenance and in general not less than 0,6 m except that this may be reduced to 0,5 m in way of stiffeners or frames.

7.16.3 The spaces defined in 7.16.1 and 7.16.2 are to have non-slip surfaces. Where access to live parts within switchboards and section boards is normally possible the surface is, in addition, to be electrically insulated.

7.16.4 So far as practicable, pipes are not to be installed directly above or in front of or behind switchboards, section boards and distribution boards. If such placing is unavoidable, suitable protection is to be provided in these positions, *see* Pt 15, Ch 2,2.4.

7.16.5 For switchgear and control gear assemblies, for rated voltages above 1 kV, arrangements are to be made to protect personnel in the event of gases or vapours escaping under pressure as the result of arcing due to an internal fault. Where personnel may be in the vicinity of the equipment when it is energised, this may be achieved by an assembly that has been tested in accordance with Annex A of IEC 62271-200 and qualified for classification **IAC** (internal arc classification).

7.17 Switchboard auxiliary power supplies

7.17.1 Where the operation of a protective device relies upon a power supply, an alarm is to be provided to indicate failure of the power supply, unless its failure causes automatic tripping of the protected circuit.

7.18 Testing

7.18.1 Tests in accordance with 7.18.2 to 7.18.4 are to be satisfactorily carried out on all assemblies, complete or in sections, at the manufacturer's premises, and a test report issued by the manufacturer.

7.18.2 A high voltage test, *see* Section 21.

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7.18.3 Calibration of protective devices and indicating instruments is to be verified by means of current and/or voltage injection.

7.18.4 Demonstration of the satisfactory operation of protection circuits, control circuits and interlocks by means of simulated functional tests.

7.18.5 For switchgear and control gear assemblies, for rated voltages above 1 kV, type tests are to be carried out, in accordance with Annex A of IEC 62271-200 and **IAC** (internal arc classification) assigned, to verify that the assembly will withstand the effects of an internal arc occurring within the enclosure at a prospective fault level equal to, or in excess of, that of the installation.

7.19 Disconnectors and switch-disconnectors

7.19.1 Disconnectors, switch-disconnectors and their components are to comply with one of the following standards, amended where necessary for ambient temperature and other environmental conditions:

(a) IEC 60947-3: *Low voltage switchgear and control gear Part 3: switches, disconnectors, switch-disconnectors and fuse combination units*.

(b) IEC 60129: *Alternating current disconnectors (isolators) and earthing switches*.

(c) Acceptable and relevant National Standard.

Type test reports to verify the characteristics of a disconnector or switch-disconnector are to be submitted for consideration when required.

Section 8
Protection of personnel from hazards resulting from electric arcs within electrical equipment assemblies and enclosures

8.1 General

8.1.1 An assessment is to be carried out in accordance with 8.2.1 for all electrical equipment within which an arcing fault could occur, such as:

- harmonic filters;
- motor starter panels;
- semiconductor converters;
- switchboards, section boards and distribution boards; or
- transformers.

8.2 Hazard identification and assessment

8.2.1 An assessment is to be carried out to identify the hazards and their consequences for personnel resulting from electric arcs within the electrical equipment identified in 8.1.1. The purpose of the assessment is to demonstrate that the design incorporates adequate measures to reduce the risk of injury to personnel should an arcing fault occur within the electrical equipment, and that this will help to ensure both personnel and ship safety. Details of the following are to be submitted:

(a) each task to be performed, e.g. switching, equipment maintenance, instrument observation or cleaning;

(b) the hazards to personnel that could result from an electric arc occurring during each task, and the hazards to personnel that could result from the electric arc;

(c) the methods to be used to help to prevent electric arcs; and

(d) the methods to be used to protect personnel from hazards resulting from electric arcs within electrical equipment.

8.3 Calculations to be submitted

8.3.1 The following calculations are to be conducted and used in the hazard identification and assessment:

(a) Calculations of the maximum current that would flow through an electric arc between each conductor and its adjacent conductor, and between each conductor and the exposed conductive parts of the enclosure, in the case of an arcing fault;

(b) The maximum incident energy at the intended working distance in the case of an arcing fault; and

(c) The distance from each conductor at which the incident energy would be 5 Joules (1,2 calories) per centimetre squared in the case of an arcing fault when the enclosure door is open.

These calculations may be made in accordance with a relevant Standard acceptable to LR, for example, IEEE Standard 1584, *IEEE Guide for Performing Arc-Flash Hazard Calculations*.

8.4 Testing and trials

8.4.1 It is to be demonstrated that, where provided, arrangements to detect arcing faults function correctly.

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■ *Section 9*
Rotating machines

9.1 General requirements

9.1.1 Rotating machines are to comply with the relevant part of IEC 60092, or an acceptable and relevant National Standard, and the requirements of this Section.

9.1.2 For all the rotating machines a manufacturer's test certificate is to be provided, *see also* 1.4.

9.1.3 Shafts for rotating machines are to be forged or rolled and are to comply with the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

9.1.4 Where welding is applied to shafts of machines for securing arms or spiders, stress relieving is to be carried out after welding. The finalised assembly is to be visually examined by the Surveyors, crack detection carried out by an appropriate method and the finished welds found sound and free from cracks.

9.1.5 The rotating parts of machines are to be so balanced that when running at any speed in the normal working range the vibration does not exceed the levels of IEC 60034: *Rotating electrical machines*, Part 14.

9.1.6 The lubrication arrangement for bearings are to be effective under all operating conditions including the maximum craft inclinations defined by 1.10 and there are to be effective means provided to ensure that lubricant does not reach the machine windings or other conductors and insulators.

9.1.7 Means are to be taken to prevent the ill effects of the flow of currents circulating between the shaft and machine bearings or bearings of connected machinery.

9.1.8 Alternating current machines are to be constructed such that, under any operating conditions, they are capable of withstanding the effects of a sudden short-circuit at their terminals without damage.

9.2 Rating

9.2.1 Generators, including their excitation systems, and continuously rated motors are to be suitable for continuous duty at their full rated output at maximum cooling air or water temperature for an unlimited period, without the limits of temperature rise in 9.3 being exceeded. Generators are to be capable of an overload power of not less than 10 per cent at their rated power factor for a period of 15 minutes without injurious heating. Other machines are to be rated in accordance with the duty which they have to perform and, when tested under rated load conditions, the temperature rise is not to exceed the values in 9.3.

9.2.2 When a rotating machine is connected to a supply system with harmonic distortion the rating of the machine is to allow for the increased heating effect of the harmonic loading.

9.2.3 The design and construction of smoke extraction fan motors are to be suitable for the ambient temperature and operating time required. Type test reports to verify the performance of the electric motor are to be submitted for consideration.

9.3 Temperature rise

9.3.1 The limits of temperature rise specified in Table 2.9.1, are based on the cooling air temperature and cooling water temperature given in 1.9.

9.3.2 If it is known that the temperature of cooling medium exceeds the values given in 1.9 the permissible temperature rise is to be reduced by an amount equal to the excess temperature of the cooling medium.

9.3.3 If it is known that the temperature of cooling medium will be permanently less than the values given in 1.9 the permissible temperature rise may be increased by an amount equal to the difference between the declared temperature and that given in 1.9 up to a maximum of 15°C.

9.4 Generator control

9.4.1 Each alternating current generator, unless of the self-regulating type, is to be provided with automatic means of voltage regulation; voltage build-up is not to require an external source of power. Provision is to be made to safeguard the distributing system should there be a failure of the voltage regulating system resulting in a high voltage.

9.4.2 The voltage regulation of any alternating current generator with its regulating equipment is to be such that at all loads, from zero to full load at rated power factor, the rated voltage is maintained within ±2,5 per cent under steady conditions. There is to be provision at the voltage regulator to adjust the generator no load voltage.

9.4.3 Generators, and their excitation systems, when operating at rated speed and voltage on no-load are to be capable of absorbing the suddenly switched, balanced, current demand of the largest motor or load at a power factor not greater than 0,4 with a transient voltage dip which does not exceed 15 per cent of rated voltage. The voltage is to recover to rated voltage within a time not exceeding 1,5 seconds.

9.4.4 The transient voltage rise at the terminals of a generator is not to exceed 20 per cent of rated voltage when rated kVA at a power factor not greater than 0,8 is thrown off.

9.4.5 Generators and their voltage regulation systems are to be capable of maintaining, without damage, under steady state short circuit conditions a current of at least three times the full load rated current for a duration of at least two seconds or where precise data is available for the duration of any time delay which may be provided by a tripping device for discrimination purposes.

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Table 2.9.1 Limits of temperature rise of machines cooled by air

Limits of temperature rise of machines cooled by air, °C						
Part of machine	Method of temperature measurement	Insulation class				
		A	E	B	F	H
1. (a) a.c. windings of machines having output of 5000 kVA or more	ETD R	55 50	— —	75 70	95 90	115 110
(b) a.c. windings of machines having output of less than 5000 kVA	ETD R	55 50	— 65	80 70	100 95	115 110
2. Windings of armatures having commutators	R T	50 40	65 55	70 60	95 75	115 95
3. Field windings of a.c. and d.c. machines having d.c. excitation other than those in item 4	R T	50 40	65 55	70 60	95 75	115 95
4. (a) Field windings of synchronous machines with cylindrical rotors having d.c. excitation	R	—	—	80	100	125
(b) Stationery field windings of d.c. machines having more than one layer	R T	50 40	65 55	70 60	95 75	115 95
(c) Low resistance field windings of a.c. and d.c. machine and compensating windings of d.c. machines having more than one layer	R, T	50	65	70	90	115
(d) Single-layer windings of a.c. and d.c. machines with exposed bare or varnished metal surfaces and single-layer compensating windings of d.c. machines	R, T	55	70	80	100	125
5. Permanently short-circuited insulated windings	T	50	65	70	90	115
6. Permanently short-circuited uninsulated windings	T	The temperature rise of these parts shall in no case reach such a value that there is a risk to any insulation or other materials on adjacent parts or to the item itself				
7. Magnetic cores and other parts not in contact with windings	T					
8. Magnetic cores and other parts in contact with windings	T	50	65	70	90	110
9. Commutators and slip-rings open and enclosed	T	50	60	70	80	90

NOTES
1. Where water cooled heat exchangers are used in the machine cooling circuit the temperature rises are to be measured with respect to the temperature of the cooling water at the inlet to the heat exchanger and the temperature rises given in Table 2.9.1 shall be increased by 10°C provided the inlet water temperature does not exceed the values given in 1.9.
2. T = thermometer method
   R = resistance method
   ETD = embedded temperature detector
3. Temperature rise measurements are to use the resistance method whenever practicable.
4. The ETD method may only be used when the ETDs are located between coil sides in the slot.

9.4.6 Generators required to run in parallel are to be stable from no load (kW) up to the total combined full load (kW) of the group, and load sharing is to be such that the load on any generator does not normally differ from its proportionate share of the total load by more than 15 per cent of the rated output (kW) of the largest machine or 25 per cent of the rated output (kW) of the individual machine, whichever is less.

9.4.7 When generators are operated in parallel, the kVA loads of the individual generating sets are not to differ from the proportionate share of the total kVA load by more than 5 per cent of the rated kVA output of the largest machines.

9.5 Overloads

9.5.1 Machines are to withstand on test, without injury, the following momentary overloads:

(a) **Generators.** An excess current of 50 per cent for 15 seconds after attaining the temperature rise corresponding to rated load, the terminal voltage being maintained as near the rated value as possible. The forgoing does not apply to the overload torque capacity of the prime mover.

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(b) **Motors.** At rated speed or, in the case of a range of speeds, at the highest and lowest speeds, under gradual increase of torque, the appropriate excess torque given below. Synchronous motors and synchronous induction motors are required to withstand the excess torque without falling out of synchronism and without adjustment of the excitation circuit preset at the value corresponding to rated load:

d.c. motors	50 per cent for 15 seconds;
polyphase a.c. synchronous motors	50 per cent for 15 seconds;
polyphase a.c. synchronous induction motors	35 per cent for 15 seconds;
polyphase a.c. induction motors	60 per cent for 15 seconds.

9.6 Machine enclosure

9.6.1 Where water cooled heat exchangers are used in the machine cooling circuit there is to be provision for the detection of water leakage and the system is to be arranged so as to prevent the entry of water into the machine.

9.6.2 An alarm is to be provided to indicate high cooling water temperature.

9.7 Direct current machines

9.7.1 The final running position of brushgear is to be clearly and permanently marked.

9.7.2 Direct current machines are to work with fixed brush setting from no load to the momentary overload specified without injurious sparking.

9.8 Survey and testing

9.8.1 On machines for essential services tests are to be carried out and a certificate furnished by the manufacturer. The tests are to include temperature rise, momentary overload, high voltage, and commutation. The insulation resistance and the temperature at which it was measured are to be recorded.

9.8.2 In the case of duplicate machines, type tests of temperature rise, excess current and torque and commutation taken on a machine identical in rating and in all other essential details may be accepted in conjunction with abbreviated tests on each machine. Type tests for propulsion machines will be specially considered. For the abbreviated tests, each machine is to be run and is to be found electrically and mechanically sound and is to have a high voltage test and insulation resistance recorded.

9.8.3 A high voltage test, in accordance with Section 21, is to be applied to new machines, preferably at the conclusion of the temperature rise test. Where both ends of each phase are brought out to accessible separate terminals each phase is to be tested separately.

9.8.4 An impulse test is to be carried out on the coils of high voltage machines in order to demonstrate a satisfactory withstand level of the inter-turn insulation to voltage surges. The test is to be carried out on all coils after they have been inserted in the slots and after wedging and bracing. Each coil shall be subjected to at least five impulses of injected voltage, the peak value of the injected voltage being given by the formula:

$V_{peak} = 2{,}45V$

where

V = rated line voltage r.m.s.

Alternative proposals to demonstrate the withstand level of inter-turn insulation will be considered.

■ *Section 10* Converter equipment

10.1 Transformers

10.1.1 Paragraphs 10.1.2 to 10.1.11 apply to transformers rated for 5 kVA upwards.

10.1.2 Transformers are to comply with the requirements of IEC 60076: *Power transformers*, or an acceptable and relevant National Standard amended where necessary for ambient temperature, *see* 1.9.

10.1.3 Transformers may be of the dry type, encapsulated or liquid filled type.

10.1.4 The temperature rise of the winding of transformers above the ambient temperatures given in 1.9, when measured by resistance during continuous operation at the maximum rating, is not to exceed:

(a) For dry type transformers, air cooled:
- insulation of Class A – 50°C
- insulation of Class E – 60°C
- insulation of Class B – 70°C
- insulation of Class F – 90°C
- insulation of Class H – 110°C

(b) For liquid filled transformers:
- 50°C – where air provides cooling of the fluid
- 65°C – where water provides cooling of the fluid.

10.1.5 When a transformer is connected to a supply system with harmonic distortion, the rating of the transformer is to allow for the increased heating effect of the harmonic loading. Special attention is to be given to transformers connected for the purpose of reducing harmonic distortion.

10.1.6 The inherent regulation of transformers at their rated output is to be such that the total voltage drop to any point in the installation does not exceed that allowed by 1.8.

10.1.7 Transformers, except those for motor starting, are to be double wound.

10.1.8 Liquid fillings for transformers are to be non-toxic and of a type which does not readily support combustion. Liquid filled transformers are to have a pressure relief-device with an alarm and there is to be a suitable means provided to

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contain any liquid which may escape from the transformer due to the operation of the relief device or damage to the tank.

10.1.9 All transformers are to be capable of withstanding for two seconds, without damage, the thermal and mechanical effects of a short-circuit at the terminals of any winding.

10.1.10 When forced cooling is used, whether air or liquid, there is to be monitoring of the cooling medium and transformer winding temperatures with an alarm should these exceed preset limits. There are to be arrangements so that the load may be reduced to a level commensurate with the cooling available.

10.1.11 Where water cooled heat exchangers are used in transformer cooling circuits, there is to be provision for the detection of water leakage and the system is to be arranged so as to prevent the entry of water into the transformer.

10.1.12 The following tests are to be carried out on all transformers at the manufacturer's works, and a certificate of tests issued by the manufacturer, *see also* 1.4.2 and 1.4.3:

(a) measurement of winding resistances, voltage ratio, impedance voltage, short circuit impedance, insulation resistance, load loss, no load loss and current;
(b) dielectric tests;
(c) temperature rise test on one transformer of each size and type; and
(d) where evidence of compliance with 10.1.9 is not submitted for consideration, short-circuit withstand on one transformer of each size and type.

10.2 Semiconductor equipment

10.2.1 The requirements of 10.2.2 to 10.2.18 apply to semiconductor equipment rated for 5 kW upwards.

10.2.2 Semiconductor equipment is to comply with the requirements of IEC 60146: *Semiconductor converters*, or an acceptable and relevant National Standard amended where necessary for ambient temperature, *see* 1.9.

10.2.3 Semiconductor static power converter equipment is to be rated for the required duty having regard to peak loads, system transients and overvoltage.

10.2.4 Converter equipment may be air or liquid cooled and is to be so arranged that it cannot remain loaded unless effective cooling is maintained. Alternatively the load may be automatically reduced to a level commensurate with the cooling available.

10.2.5 Liquid cooled converter equipment is to be provided with leakage alarms and there is to be a suitable means provided to contain any liquid which may leak from the system in order to ensure that it does not cause an electrical failure of the equipment. Where the semiconductors and other current carrying parts are in direct contact with the cooling liquid, the liquid is to be monitored for satisfactory resistivity and an alarm initiated at the relevant control station should the resistivity be outside the agreed limits.

10.2.6 Where forced cooling is used there is to be temperature monitoring of the heated cooling medium with an alarm and shutdown when the temperature exceeds a preset value.

10.2.7 Cooling fluids are to be non-toxic and of low flammability.

10.2.8 Converter equipment is to be so arranged that the semiconductor devices, fuses, control and firing circuit boards may be readily removed from the equipment for repair or replacement.

10.2.9 Test and monitoring facilities are to be provided to permit identification of control circuit faults and faulty components.

10.2.10 Protection devices fitted for converter equipment protection are to ensure that, under fault conditions, the protective action of circuit breakers, fuses or control systems is such that there is no further damage to the converter or the installation.

10.2.11 Converter equipment, including any associated transformers, reactors, capacitors and filters, if provided, is to be so arranged that the harmonic distortion, and voltage spikes, introduced into the craft's electrical system are within the limits of 1.8.3 or restricted to a lower level necessary to ensure that it causes no malfunction of equipment connected to the electrical installation.

10.2.12 Overvoltage spikes or oscillations caused by commutation or other phenomena, are not to result in the supply voltage waveform deviating from a superimposed equivalent sine wave by more than 10 per cent of the maximum value of the equivalent sine wave.

10.2.13 When converter equipment is operated in parallel, load sharing is to be such that under normal operating conditions overloading of any unit does not occur and the combination of paralleled equipment is stable throughout the operating range.

10.2.14 When converter equipment has parallel circuits there is to be provision to ensure that the load is distributed uniformly between the parallel paths.

10.2.15 Transformers, reactors, capacitors and other circuit devices associated with converter equipment, or associated filters, are to be suitable for the distorted voltage and current waveforms to which they may be subjected and filter circuits are to be provided with facilities to ensure that their capacitors are discharged before the circuits are energised.

10.2.16 Any regenerated power developed during the operation of converter equipment is not to result in disturbances to the supply system voltage and frequency which exceeds the limits of 1.8.

10.2.17 Where control systems form an integral part of semiconductor equipment, they are to be designed and manufactured with regard to the environmental conditions to which they will be exposed in service and their performance is to be demonstrated during the test and trials programme.

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10.2.18 Tests at the manufacturer's works of converter equipment and any associated reactors or filters are to include the high voltage test of 21.1, a temperature rise test, on one of each size and type of converter equipment, and such other tests as may be necessary to demonstrate the suitability of the equipment for its intended duty. Details of tests are to be submitted for consideration when required, *see also* 1.4.2.

10.3 Uninterruptible power systems

10.3.1 Where uninterruptible power systems (UPS) are required to maintain essential services or provide emergency services, the requirements of this Sub-Section apply. This sub-Section is in addition to the requirements of 10.1 and 10.2 and Section 12, as applicable.

10.3.2 UPS units are to be constructed in accordance with IEC 62040: *Uninterruptible power systems (UPS)*, or an acceptable and relevant National or International Standard.

10.3.3 The operation of a UPS is not to depend upon external services.

10.3.4 The type of UPS unit employed, whether off-line, line-interactive or on-line, is to be appropriate to the power supply requirements of the connected load equipment.

10.3.5 An external bypass, that is hardwired and manually operated, is to be provided for UPS to allow isolation of UPS for safety during maintenance and maintain continuity of load power.

10.3.6 UPS units are to be monitored and an audible and visual alarm is to be initiated in the navigating bridge or the engine control room, or an equivalent attended location for:

- power supply failure (voltage and frequency) to the connected load;
- earth fault;
- operation of battery protective device;
- battery discharge; and
- bypass in operation for on-line UPS units.

10.3.7 UPS units required to provide emergency services are to be suitably located for use in an emergency.

10.3.8 UPS units utilising valve-regulated sealed batteries may be located in compartments with standard marine or industrial electrical equipment provided that the arrangements comply with 12.3.5. Ventilation arrangements in accordance with IEC 62040: *Uninterruptible power systems (UPS),* or an acceptable and relevant National or International Standard, may be considered to satisfy the requirements of 12.5.10.

10.3.9 Output power is to be maintained for the duration required for the connected equipment.

10.3.10 The UPS battery capacity is, at all times, to be capable of supplying the designated loads for the time specified. Where it is proposed that additional circuits are connected to the UPS unit, details verifying that the UPS unit has adequate capacity are to be submitted for consideration, *see* 1.5.

10.3.11 On restoration of the input power, the rating of the charge unit is to be sufficient to recharge the batteries while maintaining the output supply to the load equipment.

10.3.12 Tests at the manufacturer's works are to include such tests necessary to demonstrate the suitability of a UPS unit for its intended duty and location. This is expected to include as a minimum the following tests:

- a temperature rise test and battery capacity test on one of each size and type of UPS;
- the high voltage test of 20.1;
- a ventilation rate test; and
- functional testing, including operation of alarms.

Details of tests are to be submitted for consideration when required, *see also* 1.4.2.

10.3.13 Where the supply is to be maintained without a break following a power input failure, this is to be verified after installation by practical testing.

■ *Section 11*
Electrical cables and busbar trunking systems (busways)

11.1 General

11.1.1 The requirements of 11.1 to 11.16 apply to all electric cables for fixed wiring unless otherwise exempted. The requirements of 11.16 apply to busbar trunking systems (busways) where they are used in place of electric cables.

11.1.2 Electric cables for fixed wiring are to be designed, manufactured and tested in accordance with the relevant IEC Standard stated in Table 2.11.1 or an acceptable and relevant National Standard.

11.1.3 Electric cables for electric propulsion systems are to be Type Approved in accordance with LR's *Type Approval System Test Specification Number 3* or, alternatively, surveyed by the Surveyors during manufacture and testing to assess compliance with the applicable International or National Standards and application of an acceptable quality management system.

11.1.4 Provided that adequate flexibility of the finished cable is assured, conductors of nominal cross-section area 2,5 mm^2 and less need not be stranded.

11.1.5 Electric cables for non-fixed wiring applications are to comply with an acceptable and relevant Standard.

11.1.6 For the purpose of this Section, pipes, conduits, trunking or any other system for the additional mechanical protection of cables are hereafter referred to under the generic name 'protective casings'.

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Table 2.11.1 Electric cables

Application	IEC Standard	Title
General constructional and testing requirements	60092–350	Low-voltage shipboard power cables. General construction and test requirements
Fixed power and control circuits	60092–353	Single and multicore non-radial field power cables with extruded solid insulation for rated voltages 1kV and 3kV
Fixed power circuits	60092–354	Single and three-core power cables with extruded solid insulation for rated voltages 6kV, 10kV and 15kV
Instrumentation, control and communication circuits up to 60 V	60092–375	Shipboard telecommunication cables and radio frequency cables – General instrumentation, control and communication cables
Control circuits up to 250 V	60092–376	Shipboard multicore cables for control circuits
Mineral insulated	60702	Mineral insulated cables with a rated voltage not exceeding 750 V

11.2 Testing

11.2.1 Routine tests, consisting of at least:

(a) measurement of electrical resistance of conductors;
(b) high voltage test, *see also* Section 21;
(c) insulation resistance measurement;
(d) for high voltage cables, partial discharge tests are to be made in accordance with the requirements of the relevant publication or National Standard referred to in 11.1.2 at the manufacturer's works prior to despatch.

Evidence of successful completion of routine tests is to be provided by the manufacturer.

11.2.2 Particular, special and type tests are to be made, when required, in accordance with the requirements of the relevant publication or National Standard referred to in 11.1.2 and a test report issued by the manufacturer.

11.3 Voltage rating

11.3.1 The rated voltage of any electric cable is to be not lower than the nominal voltage of the circuit for which it is used. The maximum sustained voltage of the circuit is not to exceed the maximum voltage for which the cable has been designed.

11.3.2 Electric cables used in unearthed systems are to be suitably rated to withstand the additional stresses imposed on the insulation due to an earth fault.

11.4 Operating temperature

11.4.1 The maximum rated conductor temperature of the insulating material for normal operation is to be at least 10°C higher than the maximum ambient temperature liable to be produced in the space where the cable is installed.

11.4.2 The maximum rated conductor temperatures for normal and short-circuit operation, for the insulating materials included within the Standards referred to in 11.1.2 is not to exceed the values stated in Table 2.11.2.

Table 2.11.2 Maximum rated conductor temperature

Type of Insulating compound	Maximum rated conductor temperature °C	
	Normal operation	Short-circuit
Thermoplastics:		
• Based upon polyvinyl chloride or co-polymer of vinyl chloride and vinyl acetate	70	150
Elastomeric or thermosetting:		
• Ethylene-propylene rubber or similar (EPM or EPDM)	90	250
• High modulus or hard grade ethylene propylene rubber	90	250
• Cross-linked polyethylene	90	250
• Ethylene-propylene rubber or similar (EPM or EPDM) halogen-free	90	250
• High modulus or hard grade halogen-free ethylene propylene rubber	90	250
• Halogen-free cross-linked polyethylene	90	250
• Cross-linked polyolefin material for halogen-free cables	90	250
• Silicon rubber	95	350
• Halogen-free silicone rubber	95	350

11.4.3 Electric cables constructed of an insulating material not included in Table 2.11.2 are to be rated in accordance with the National Standard chosen in compliance with 11.1.2.

11.5 Construction

11.5.1 Electric cables are to be at least of a flame-retardant type. Compliance with IEC 60332-1-2: *Tests on electric and optical fibre cables under fire conditions – Part 1-2: Test for vertical flame propagation for a single insulated wire or cable – Procedure for 1kW pre-mixed flame*, will be acceptable.

11.5.2 Exemption from the requirements of 11.5.1 for applications such as radio frequency or digital communication systems, which require the use of particular types of cable, will be subject to special consideration.

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11.5.3 Where electric cables are required to be of a 'fire resistant type', they are in addition to be easily distinguishable and to comply with the performance requirements of the appropriate part of IEC 60331:*Tests for electric cables under fire conditions - Circuit integrity*, when tested with a minimum flame application time of 90 minutes, as follows:
IEC 60331-21*: Procedures and requirements – Cables of rated voltage up to and including 0.6/1.0kV;*
IEC 60331-23: *Procedures and requirements – Electric data cables;*
IEC 60331-25: *Procedures and requirements – Optical fibre cables*.

11.5.4 Where electric cables are installed in locations exposed to the weather, in damp and in wet situations, in machinery compartments, refrigerated spaces or exposed to harmful vapours including oil vapour they are to have the conductor insulating materials enclosed in an impervious sheath of material appropriate to the expected ambient conditions.

11.5.5 Where it is required that the construction of electrical cables includes metallic sheaths, armouring or braids are to be provided with an overall impervious sheath or other means to protect the metallic elements against corrosion, *see also* 11.8.7 and 11.8.8.

11.5.6 Where cables are installed in an area where contamination by oil is likely to occur, the oversheath is to be of an enhanced oil resistance grade.

11.5.7 Where single core electric cables are used in circuits rated in excess of 20 Amps and are armoured the armour is to be of a non-magnetic material.

11.5.8 Electric cables are to be constructed such that they are capable of withstanding the mechanical and thermal effects of the maximum short-circuit current which can flow in any part of the circuit in which they are installed, taking into consideration not only the time/current characteristics of the circuit protective device but also the peak value of the prospective short-circuit current. Where electric cables are to be used in circuits with a maximum short circuit current in excess of 70 kA, evidence is to be submitted for consideration when required demonstrating that the cable construction can withstand the effects of the short circuit current.

11.5.9 All high voltage electric cables are to be readily identified by suitable marking.

11.6 Conductor size

11.6.1 The maximum continuous load carried by a cable is not to exceed its continuous current rating. It is to be chosen such that the maximum rated conductor temperature for normal operation for the insulation is not exceeded. In assessing the current rating the correction factors in 11.7 may be applied as required.

11.6.2 The cross-sectional area of the conductors is to be sufficient to ensure that, under short-circuit conditions, the maximum rated conductor temperature for short-circuit operation is not exceeded, taking into consideration the time current characteristics of the circuit protective device and the peak value of the prospective short-circuit current.

11.6.3 The cable current ratings given in Tables 2.11.3 and 2.11.4 are based on the maximum rated conductor temperatures given in Table 2.11.2. When cable sizes are selected on the basis of precise evaluation of current rating based upon experimental and calculated data, details are to be submitted for consideration. Alternative short-circuit temperature limits, other than those given in Table 2.11.4, may be applied using the data provided in:

- IEC 60724: *Short-circuit temperature limits of electric cables with rated voltages of 1kV (Um=1,2kV) and 3kV (Um=3,6kV)*; or
- IEC 60986: *Short-circuit temperature limits of electric cables with rated voltages from 6kV (Um=7,2kV) and up to 30kV (Um=36kV)*.

Alternative short-circuit temperature limits provided in an acceptable and relevant National Standard may also be considered.

11.6.4 The cross-sectional area of the conductors is to be sufficient to ensure that at no point in the installation will the voltage variations stated in 1.8 be exceeded when the conductors are carrying the maximum current under their normal conditions of service.

11.6.5 The size of earth conductors is to comply with 1.12.8.

11.6.6 The cross-sectional area of conductors used in circuits supplying cyclic or non-continuous loads is to be sufficient to ensure that the cable's maximum rated conductor temperature for normal operation is not exceeded when the conductors are operating under their normal conditions of service, *see* 11.7.4.

11.7 Correction factors for cable current rating

11.7.1 The correction factors of 11.7.2 to 11.7.5 provide a guide for general applications in assessing a current rating. A more precise evaluation based upon experimental and calculated data may be submitted for consideration.

11.7.2 Bunching of cables. Where more than six electric cables, which may be expected to operate simultaneously at their full rated capacity, are laid close together in a cable bunch in such a way that there is an absence of free air circulation around them, a correction factor of 0,85 is to be applied. Signal cables may be exempted from this requirement.

11.7.3 Ambient temperature. The current ratings of Table 2.11.3 are based on an ambient temperature of 45°C. For other values of ambient temperature the correction factors shown in Table 2.11.5 are to be applied.

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Table 2.11.3 Electric cable current ratings, normal operation, based on ambient 45°C

Nominal cross-section (mm^2)	Continuous r.m.s current rating, in amperes								
	Thermoplastic (70°C)			Elastomeric (90°C)			Elastomeric or thermosetting, based on silicon rubber (95°C)		
	Single core	2 core	3 or 4 core	Single core	2 core	3 or 4 core	Single core	2 core	3 or 4 core
0,75	10	8	7	15	13	11	17	14	12
1	12	10	8	18	15	13	20	17	14
1,25	13	11	9	21	18	14	23	20	16
1,5	15	13	11	23	20	16	26	22	18
2	18	15	12	28	24	19	31	26	22
2,5	21	18	15	40	26	21	32	27	22
3,5	26	22	18	37	32	26	39	33	28
4	29	25	20	51	34	28	43	37	30
5,5	35	30	24	49	42	35	52	44	37
6	37	31	26	52	44	36	55	47	39
8	44	37	31	62	53	44	66	56	46
10	51	43	36	72	61	50	76	65	53
14	62	53	44	88	75	62	94	80	66
16	68	58	48	96	82	67	102	87	71
22	83	70	58	117	100	82	124	106	87
25	90	77	63	127	108	89	135	115	95
30	101	85	70	142	121	100	151	128	106
35	111	94	78	157	133	110	166	141	116
38	117	99	82	165	140	116	175	149	122
50	138	117	97	196	167	137	208	177	146
60	155	132	109	220	187	154	233	198	163
70	171	145	120	242	206	169	256	218	179
80	186	158	130	263	224	184	278	237	195
95	207	176	145	293	249	205	310	264	217
100	213	181	149	302	257	212	320	272	224
120	239	203	167	339	288	237	359	305	251
125	245	209	172	348	295	243	368	313	258
150	275	234	193	389	331	272	412	350	288
185	313	266	219	444	377	311	470	400	329
200	329	280	230	466	396	326	494	420	346
240	369	314	258	522	444	365	553	470	387
300	424	360	297	601	511	421	636	541	445

11.7.4 Short time duty. When the load is not continuous i.e. operates for periods of half an hour or one hour and the periods of no load are longer than three times the cable's time constant T in minutes, the cable's continuous rating may be increased by a duty factor, calculated in accordance with:

$$\text{Duty factor} = \sqrt{\frac{1,12}{1 - e^{\frac{-t_s}{T}}}}$$

When the load is not continuous, is repetitive and has periods of no-loads less than three times the cable's time constant, so that the cable has insufficient time to cool down between the applications of load, the cable's continuous rating may be increased by an intermittent factor, calculated in accordance with:

$$\text{Intermittent factor} = \sqrt{\frac{1 - e^{\frac{-t_p}{T}}}{1 - e^{\frac{-t_s}{T}}}}$$

where

T = $0,245d^{1,35}$ where d is the overall diameter of the cable, in mm

t_s = the service time of the load current, in minutes

t_p = the intermittent period in minutes, i.e. the total period of load and no-load before the cycle is repeated.

11.7.5 Diversity. Where cables are used to supply two or more final sub-circuits account may be taken of any diversity factors which may apply, *see* 5.6.

11.8 Installation of electric cables

11.8.1 Electric cable runs are to be as far as practicable fixed in straight lines and in accessible positions.

11.8.2 Bends in fixed electric cable runs are to be in accordance with the cable manufacturer's recommendations. The minimum internal radius of bend for the installation of fixed electric cables is to be chosen according to the construction and size of the cable and is not to be less than the values given in Table 2.11.6.

11.8.3 The installation of electric cables across expansion joints in any structure is to be avoided. Where this is not practicable, a loop of electric cable of length sufficient to accommodate the expansion of the joint is to be provided. The internal radius of the loop is to be at least 12 times the external diameter of the cable.

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Table 2.11.4 Electric cable current ratings, r.m.s. short-circuit current

Nominal cross-section (mm^2)	Fault current (kA) at 150°C			Fault current (kA) at 250°C			Fault current (kA) at 350°C		
	1 s duration	0,5 s duration	0,1 s duration	1 s duration	0,5 s duration	0,1 s duration	1 s duration	0,5 s duration	0,1 s duration
0,75	0,1	0,1	0,3	0,1	0,2	0,3	0,1	0,2	0,4
1	0,1	0,2	0,3	0,1	0,2	0,5	0,2	0,2	0,5
1,25	0,1	0,2	0,4	0,2	0,3	0,6	0,2	0,3	0,7
1,5	0,2	0,2	0,5	0,2	0,3	0,7	0,3	0,4	0,8
2	0,2	0,3	0,7	0,3	0,4	0,9	0,3	0,5	1,1
2,5	0,3	0,4	0,9	0,4	0,5	1,1	0,4	0,6	1,4
3,5	0,4	0,5	1,2	0,5	0,7	1,6	0,6	0,8	1,9
4	0,4	0,6	1,4	0,6	0,8	1,8	0,7	1,0	2,2
5,5	0,6	0,8	1,9	0,8	1,1	2,5	0,9	1,3	3,0
6	0,7	0,9	2,1	0,9	1,2	2,7	1,0	1,5	3,2
8	0,9	1,2	2,8	1,1	1,6	3,6	1,4	1,9	4,3
10	1,1	1,5	3,5	1,4	2,0	4,5	1,7	2,4	5,4
14	1,5	2,2	4,8	2,0	2,8	6,3	2,4	3,4	7,6
16	1,7	2,5	5,5	2,3	3,2	7,2	2,7	3,9	8,7
22	2,4	3,4	7,6	3,1	4,5	10,0	3,8	5,3	11,9
25	2,7	3,9	8,6	3,6	5,1	11,3	4,3	6,0	13,5
30	3,3	4,6	10,4	4,3	6,1	13,6	5,1	7,3	16,2
35	3,8	5,4	12,1	5,0	7,1	15,8	6,0	8,5	18,9
38	4,1	5,9	13,1	5,4	7,7	17,2	6,5	9,2	20,6
50	5,5	7,7	17,3	7,2	10,1	22,6	8,6	12,1	27,1
60	6,5	9,3	20,7	8,6	12,1	27,1	10,3	14,5	32,5
70	7,6	10,8	24,2	10,0	14,2	31,7	12,0	16,9	37,9
80	8,7	12,3	37,6	11,4	16,2	36,2	13,7	19,4	43,3
95	10,4	14,7	32,8	13,6	19,2	43,0	16,3	23,0	51,4
100	10,9	15,4	34,5	14,3	20,2	45,2	17,1	24,2	54,1
120	13,1	18,5	41,4	17,2	24,3	54,3	20,5	29,0	64,9
125	13,6	19,3	43,1	17,9	25,3	56,6	21,4	30,2	67,6
150	16,4	23,2	51,8	21,5	30,4	67,9	25,7	36,3	81,2
185	20,2	28,6	63,9	26,5	37,4	83,7	31,7	44,8	100,1
200	21,8	30,9	69,0	28,6	40,5	90,5	34,2	48,4	108,2
240	26,2	37,0	82,8	34,3	48,6	108,6	41,1	58,1	129,9
300	32,7	46,3	103,6	42,9	60,7	135,7	51,3	72,6	162,3

Table 2.11.5 Correction factors

Insulation material	Correction factor for ambient air temperature of °C										
	35	40	45	50	55	60	65	70	75	80	85
Thermoplastic (70°C)	1,18	1,10	1,00	0,89	0,77	0,63	—	—	—	—	—
Elastomeric or thermosetting (90°C)	1,10	1,05	1,00	0,94	0,88	0,82	0,74	0,67	0,58	0,47	—
Elastomeric or thermosetting, based on silicone rubber (90°C)	1,10	1,05	1,00	0,95	0,89	0,84	0,77	0,71	0,63	0,55	0,45

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Table 2.11.6 Minimum internal radii of bends in cables for fixed wiring

Cable construction		Overall diameter of cable	Minimum internal radius of bend (times overall diameter of cable)
Insulation	Outer covering		
Thermoplastic and elastomeric 600/1000 V and below	Metal sheathed Armoured and braided	Any	6*D*
	Other finishes	≤ 25 mm > 25 mm	4*D* 6*D*
Mineral	Hard metal sheathed	Any	6*D*
Thermoplastic and elastomeric above 600/1000 V – single core	Any	Any	12*D*
– multicore	Any	Any	9*D*

11.8.4 Electric cables for essential and emergency services are to be arranged, so far as is practicable, to avoid galleys, machinery spaces and other enclosed spaces and areas of high fire risk except as is necessary for the service being supplied. Such cables are also, so far as reasonably practicable, to be routed clear of bulkheads to preclude their being rendered unserviceable by heating of the bulkheads that may be caused by a fire in an adjacent space.

11.8.5 Electric cables having insulating materials with different maximum rated conductor temperatures are to be so installed that the maximum rated conductor temperature for normal operation of each cable is not exceeded.

11.8.6 Electric cables having a protective covering which may damage the covering of other cables are not to be bunched with those other cables.

11.8.7 Cables having an exposed metallic screen, braid or armour are to be installed in such a manner that galvanic corrosion by contact with other metals is prevented. Sufficient measures are also to be taken to prevent damage to exposed galvanised coatings during installation.

11.8.8 Protection is to be provided for cable oversheaths in areas where cables are likely to be exposed to damaging substances under normal circumstances or areas where the spillage or release of harmful substances is likely.

11.8.9 Electric cables are to be as far as practicable installed remote from sources of heat. Where installation of cables near sources of heat cannot be avoided and where there is consequently a risk of damage to the cables by heat, suitable shields, insulation or other precautions are to be installed between the cables and the heat source. The free air circulation around the cables is not to be impaired.

11.8.10 Where electric cables are installed in bunches, provision is to be made to limit the propagation of fire. This requirement is considered satisfied when cables of the bunch have been tested in accordance with the requirements of IEC 60332:*Tests on electric cables under fire conditions, Part 3-22, Test for vertical flame spread of vertically-mounted bunched wires or cables – Category A*, and are installed in the same configuration(s) as are used for the test(s). If the cables are not so installed, information is to be submitted to satisfactorily demonstrate that suitable measures have been taken to ensure that an equivalent limit of fire propagation will be achieved for the configurations to be used. Particular attention is to be given to cables in:

- atria or equivalent spaces; and
- vertical runs in trunks and other restricted spaces.

In addition, cables that comply with the requirements of IEC 60332-3-22 are also required to meet the requirements of IEC 60332-1-2.

11.8.11 Electric cables are not to be coated or painted with materials which may adversely affect their sheath or their fire performance.

11.8.12 Where electric cables are installed in refrigerated spaces they are not to be covered with thermal insulation but may be placed directly on the face of the refrigeration chamber, provided that precautions are taken to prevent the electric cables being used as casual means of suspension.

11.8.13 All metal coverings of electric cables are to be earthed in accordance with 1.12.

11.8.14 High voltage cables may be installed as follows:

(a) in the open, e.g. on carrier plating, when they are to be provided with a continuous metallic sheath or armour which is effectively bonded to earth to reduce danger to personnel. The metallic sheath or armour may be omitted provided that the cable sheathing material has a longitudinal electric resistance high enough to prevent sheath currents which may be hazardous to personnel;

(b) contained in earthed metallic protective casings when the cables may be as in (a) or the armour or metal sheath may be omitted. In the latter case care is to be taken to ensure that protective casings are electrically continuous and that short lengths of cable are not left unprotected.

11.8.15 High voltage electric cables are not to be run in the open through accommodation spaces.

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11.8.16 High voltage electric cables are to be segregated as far as is practicable from electric cables operating at lower voltages.

11.8.17 a.c. wiring is to be carried out using multicore cables wherever reasonably practicable. Where it is necessary to install single core electric cables for alternating current circuits in excess of 20 Amps the requirements of 11.14 are to be complied with, *see also* 11.5.7.

11.8.18 Electric cables are to be, so far as reasonably practicable, installed remote from sources of mechanical damage. Where necessary, the cables are to be protected in accordance with the requirements of 11.9.

11.8.19 Electric cables, with the exception of those for portable appliances and those installed in protective casings, are to be fixed securely in accordance with the requirements of 11.10.

11.8.20 Where electric cables penetrate bulkheads and decks, the requirements of 11.11 are to be complied with.

11.8.21 Where electric cables are installed in protective casings, the requirements of 11.12 are to be complied with.

11.9 Mechanical protection of cables

11.9.1 Where electric cables are exposed to risk of mechanical damage they are to be protected by suitable protective casings unless the protective covering (e.g. armour or sheath) is sufficient to withstand the possible cause of damage.

11.9.2 Electric cables installed in spaces where there is exceptional risk of mechanical damage such as holds, storage spaces, cargo spaces, etc., are to be suitably protected by metallic protective casings, even when armoured, unless the craft's structure affords adequate protection.

11.9.3 Metal protective casings are to be efficiently protected against corrosion, and effectively earthed in accordance with 1.12.

11.10 Cable support systems

11.10.1 Electric cables are to be effectively supported and secured, without being damaged, to the craft's structure, either indirectly by a cable support system, or directly by means of clips, saddles or straps to bulkheads, etc., *see* 11.8.4.

11.10.2 Cable support systems, which may be in the form of trays or plates, separate support brackets, hangers or ladder racks, together with their fixings and accessories, are to be robust and are to be of corrosion-resistant material or suitably corrosion inhibited before erection. The cable support system is to be effectively secured to the craft's structure, the spacing of the fixings taking account of the probability of vibration and any heavy external forces, e.g., where located in areas subject to impact by sea-water.

11.10.3 The distances between the points at which the cable is supported (e.g., distances between ladder rungs, support brackets, hangers, etc.) are to be chosen according to the construction of cable (i.e., size and rigidity) and the probability of vibration and are to be generally in accordance with those given in Table 2.11.7.

Table 2.11.7 Maximum spacing of supports or fixings for securing cables

External diameter of cable		Non-armoured cables	Armoured cables
Exceeding	Not exceeding		
mm	mm	mm	mm
—	8	200	250
8	13	250	300
13	20	300	350
20	30	350	400
30	—	400	450

11.10.4 Where the cables are laid on top of their support system, the spacings of fixings may be increased beyond those given in Table 2.11.7, but should take account of the probability of movement and vibration and in general is not to exceed 900 mm. This relaxation is not to be applied where cables can be subjected to heavy external forces, e.g. where they are run on, or above, open deck or in areas subject to impact by sea-water.

11.10.5 Single core electric cables are to be firmly fixed, using supports of strength adequate to withstand forces corresponding to the values of the peak prospective short-circuit current.

11.11 Penetration of bulkheads and decks by cables

11.11.1 Where electric cables pass through watertight, fire insulated or gas tight bulkheads, the arrangements are to be such as to ensure the integrity of the bulkhead or deck is not impaired. The arrangements chosen are to ensure that the cables are not adversely affected.

11.11.2 Where cables pass through non-watertight bulkheads or structural steel, the holes are to be bushed with suitable material. If the steel is at least 6 mm thick, adequately rounded edges may be accepted as the equivalent of bushing.

11.11.3 Electric cables passing through decks are to be protected by deck tubes or ducts.

11.11.4 Where cables pass through thermal insulation they are to do so at right angles, in tubes sealed at both ends.

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11.12 Installation of electric cables in protective casings

11.12.1 Protective casings are to be mechanically continuous across joints and effectively supported and secured to prevent damage to the electric cables.

11.12.2 Protective casings are to be suitably smooth on the interior and have their ends shaped or bushed in such a manner as not to damage the cables.

11.12.3 The internal radius of bends of protective casings are to be not less than that required for the largest cable installed therein, *see* 11.8.2.

11.12.4 The space factor (ratio of the sum of the cross sectional areas corresponding to the external diameters of the cables to the internal cross sectional area of the protective casings) is not to exceed 0,4.

11.12.5 Where necessary, ventilation openings are to be provided at the highest and lowest points of protective casings to permit air circulation and to prevent accumulation of water.

11.12.6 Expansion joints are to be provided in protective casings where necessary.

11.12.7 Protective casings containing high voltage electric cables are not to contain other electric cables and are to be clearly identified, defining their function and voltage.

11.13 Non-metallic cable support systems, protective casings and fixings

11.13.1 Where it is proposed to use non-metallic cable support systems, protective casings or fixings, the additional requirements of this sub-Section apply. For high voltage installations, metallic protective casings are required where 11.8.14(b) applies.

11.13.2 Non-metallic cable support systems and protective casings are to be installed in accordance with the manufacturer's recommendations. The support systems and protective casings are to have been tested in accordance with an acceptable test procedure for:

(a) ambient operating temperatures;
(b) safe working load;
(c) impact resistance;
(d) flame retardancy;
(e) smoke and toxicity; and
(f) use in explosive gas atmospheres or in the presence of combustible dusts, electrical conductivity;

with satisfactory results.

11.13.3 Non-metallic cable support systems, protective casings and fixings installed on the open deck are to be protected from degradation caused by exposure to solar radiation.

11.13.4 Where the cable support system, protective casing or fixings are manufactured from a material other than metal, suitable supplementary metallic fixings or straps spaced at regular distances are to be provided such that, in the event of a fire or failure, the cable support system, protective casing and the affixed cables are prevented from falling and causing an injury to personnel and/or an obstruction to any escape route. Alternatively, the cables may be routed away from such areas.

11.13.5 The load on non-metallic cable support systems or protective casings is not to exceed the tested safe working load.

11.13.6 When a cable support system or protective casing is secured by means of clips or straps manufactured from a material other than metal the fixings are to be supplemented by suitable metal clips or straps spaced at regular distances each not exceeding 2 m and, for non-metallic cable support systems or protective casing, that used during safe working load testing.

11.13.7 Non-metallic fixings are to be flame retardant in accordance with the requirements of IEC 60092-101, or an alternative, relevant National or International Standard.

11.14 Single core electric cables for alternating current

11.14.1 When installed in protective casings, electric cables belonging to the same circuit are to be installed in the same casing, unless the casing is of non-magnetic material.

11.14.2 Cable clips are to include electric cables of all phases of a circuit unless the clips are of non-magnetic material.

11.14.3 Single-core cables of the same circuit are to be in contact with one another, as far as possible. In any event the distance between adjacent electric cables is not to be greater than one cable diameter.

11.14.4 If single-core cables of current rating greater than 250 A are installed near a steel bulkhead, the clearance between the cables and the bulkhead is to be at least 50 mm unless the cables belonging to the same a.c. circuit are installed in trefoil formation.

11.14.5 Magnetic material is not to be used between single core cables of a group. Where cables pass through steel plates, all the conductors of the same circuit are to pass through a plate or gland, so made that there is no magnetic material between the cables, and the clearance between the cables and the magnetic material is not to be less than 75 mm, unless the cables belonging to the same a.c. circuit are installed in trefoil formation.

11.14.6 Electric cables are to be installed such that the induced voltages, and any circulating currents, in the sheath or armour are limited to safe values.

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11.15 Electric cable ends

11.15.1 Where screw-clamp or spring-clamp type terminations are used in electrical apparatus for external cable connections (*see* 1.11.7), cable conductors of the solid or stranded type may be inserted directly into the terminals. Where flexible conductors are used, a suitable termination is to be fitted to the cable conductor to prevent 'whiskering' of the strands.

11.15.2 If compression type conductor terminations are used on the cable ends, they are to be of a size to match the conductor and to be made with a compression type tool with the dies selected to suit the termination and conductor sizes and having a ratchet action to ensure completion of the compression action.

11.15.3 Soldered sockets may be used in conjunction with non-corrosive fluxes provided that the maximum conductor temperature at the joint, under short circuit conditions, does not exceed 160°C.

11.15.4 High voltage cables of the radial field type, i.e. having a conducting layer to control the electric field within the insulation, are to have terminations which provide electrical stress control.

11.15.5 Electric cables having hygroscopic insulation (e.g. mineral insulated) are to have their ends sealed against ingress of moisture.

11.15.6 Cable terminations are to be of such a design and dimensions that the maximum current likely to flow through them will not result in degradation of the contacts or damage to insulation as the result of overheating.

11.15.7 The fixing of conductors in terminals at joints and at tappings is to be capable of withstanding the thermal and mechanical effects of short circuit currents.

11.16 Joints and branch circuits in cable systems

11.16.1 If a joint is necessary it is to be carried out so that all conductors are adequately secured, insulated and protected from atmospheric action. The flame retardant properties of the cable are to be retained, the continuity of metallic sheath, braid or armour is to be maintained and the current carrying capacity of the cable is not to be impaired.

11.16.2 Tappings (branch circuits) are to be made in suitable boxes of such a design that the conductors remain suitably insulated, protected from atmospheric action and fitted with terminals or busbars of dimensions appropriate to the current rating.

11.16.3 Cables of a fire-resistant type, *see* 11.5.3, are to be installed so that they are continuous throughout their length, without any joints or tappings.

11.17 Busbar trunking systems (bustrunks)

11.17.1 Where busbar trunking systems are used in place of electric cables, they are to comply with the requirements of 11.17.2 to 11.17.6, in addition to the applicable requirements in Section 7.

11.17.2 The busbar trunking, or enclosure system, is to have a minimum ingress protection of IP54, according to IEC60529: *Degrees of protection provided by enclosures* (IP Code).

11.17.3 The internal and external arrangements of the busbar trunking, or enclosure system, are to ensure that the fire and/or watertight integrity of any structure through which it passes is not impaired.

11.17.4 Where the busbar trunking system is employed for circuits on and below the bulkhead deck, arrangements are to be made to ensure that circuits on other decks are not affected in the event of partial flooding under the normal angles of inclination given in 1.10 for essential electrical equipment.

11.17.5 Supports and accessories are to be robust and are to be of corrosion-resistant material or suitably corrosion inhibited before erection. The support system is to effectively secure the busbar trunking system to the craft's structure.

11.17.6 When accessories are fixed to the busbar system by means of clips or straps manufactured from a material other than metal, the fixings are to be supplemented by suitable metal clips or straps, such that, in the event of a fire or failure, the accessories are prevented from falling and causing injury to personnel and/or an obstruction to any escape route. Alternatively, the busbar system may be routed away from such areas.

■ *Section 12* Batteries

12.1 General

12.1.1 The requirements of this Section apply to permanently installed secondary batteries of the vented and valve-regulated sealed type.

12.1.2 A vented battery is one in which the cells have a cover provided with an opening through which the products of electrolysis and evaporation are allowed to escape freely from the cells to the atmosphere.

12.1.3 A valve-regulated sealed battery is one in which the cells are closed but have an arrangement (valve) which allows the escape of gas if the internal pressure exceeds a predetermined value. The electrolyte cannot normally be replaced.

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12.2 Construction

12.2.1 Batteries are to be constructed so as to prevent spilling of the electrolyte due to motion and to minimise the emission of electrolyte spray.

12.3 Location

12.3.1 Vented batteries connected to a charging device with a power output of more than 2 kW, calculated from the maximum obtainable charging current and the nominal voltage of the battery, are to be housed in an adequately ventilated compartment assigned to batteries only, or in an adequately ventilated suitable box on open deck.

12.3.2 Vented batteries connected to a charging device with a power output within the range 0,2 kW to 2 kW, calculated from the maximum obtainable charging current and the nominal voltage of the battery, are to be installed in accordance with 12.3.1, or may be installed within a well ventilated machinery or similar space.

12.3.3 Vented batteries connected to a charging device with a power output of less than 0,2 kW, calculated from the maximum obtainable charging current and the nominal voltage of the battery, may be installed in an open position or in a battery box in any suitable space.

12.3.4 Where more than one charging device is installed for any battery or group of batteries in one location, the total power output is to be used to determine the installation requirements of 12.3.1, 12.3.2 or 12.3.3.

12.3.5 Valve-regulated sealed batteries may be located in compartments with standard marine or industrial electrical equipment provided that the ventilation requirements of 12.5.10 and the charging requirements of 12.6.4 and 12.6.5 are complied with. Equipment that may produce arcs, sparks or high temperatures in normal operation is not to be in close proximity to battery vent plugs or pressure relief valve outlets.

12.3.6 Where lead-acid and nickel-cadmium batteries are installed in the same compartment precautions are to be taken, such as the provision of screens, to prevent possible contamination of electrolytes.

12.3.7 Where batteries may be exposed to the risk of mechanical damage or falling objects they are to be suitably protected.

12.3.8 Batteries installed in crew and passenger cabins, together with their associated corridors, are to be of the hermetically sealed type.

12.3.9 A permanent notice prohibiting smoking and the use of naked lights or equipment, capable of creating a source of ignition, is to be prominently displayed adjacent to the entrances of all compartments containing batteries.

12.3.10 Only electrical equipment necessary for operational reasons and for the provision of lighting is to be installed in compartments provided in compliance with 12.3.1, the compartment ventilation exhaust ducts and zones within a 1,5 m radius of the ventilation outlet(s). Such electrical equipment is to be certified for group IIC gases and temperature Class T1 in accordance with IEC 60079: *Electrical apparatus for explosive gas atmospheres*, or an acceptable and relevant National Standard.

12.3.11 A permanent notice is to be prominently displayed adjacent to battery installations advising personnel that replacement batteries are to be of an equivalent performance type. For valve-regulated sealed batteries, the notice is to advise of the requirement for replacement batteries to be suitable with respect to products of electrolysis and evaporation being allowed to escape from cells to the atmosphere, *see also* 1.5.3.

12.4 Installation

12.4.1 Batteries are to be arranged such that each cell or crate of cells is accessible from the top and at least one side and it is to be ensured that they are suitably secured to move with the craft's motion. For high speed craft, the securing arrangements for batteries are to, as far as practicable, prevent excessive movement during the accelerations due to grounding or collision.

12.4.2 The materials used in the construction of a battery rack or stand are to be resistant to the battery electrolyte or suitably protected by paint or a coating.

12.4.3 Measures are to be taken to minimise the effect of any electrolyte spillage and leakage, for example the use of rubber capping around the top of the cells and the provision of a tray of electrolyte-resistant material below the cells, unless the deck is suitably protected with paint or a coating.

12.4.4 The interiors of all compartments for batteries, including crates, trays, boxes, shelves and other structural parts therein, are to be of an electrolyte-resistant material or suitably protected, for example with paint or a coating.

12.4.5 High speed craft are to be provided with an alarm to indicate that immediate action is required in the event of thermal runaway of any nickel cadmium battery.

12.5 Ventilation

12.5.1 Battery compartments and boxes are to be ventilated to avoid accumulation of dangerous concentrations of flammable gas.

12.5.2 Where a battery compartment ventilator is required to be fitted with a closing device in accordance with Vol 3, Pt 3, Ch 4,11.4.1, a warning notice clearly stating the purpose of the closing device, for example, 'This closing device is to be kept open and only closed in the event of a fire or flooding – Explosive gas atmosphere', is to be provided at the closing device to mitigate the possibility of inadvertent closing of the ventilator. Furthermore, means to lock battery compartment ventilators in the open position are to be provided.

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12.5.3 Ducted natural ventilation may be employed for battery installations connected to a charging device with a power output of 2 kW or less, provided the exhaust duct can be run directly from the top of the compartment or box to the open air above, with no part of the duct more than 45° from the vertical. A suitable opening is also to be provided below the level of the top of the batteries, so as to ensure a free ventilation air flow. The ventilation duct is to have an area not less than 50 cm^2 for every 1 m^3 of battery compartment or box volume.

12.5.4 Where natural ventilation is impracticable or insufficient, mechanical ventilation is to be provided, with the air inlet located near the floor and the exhaust at the top of the compartment.

12.5.5 Mechanical exhaust ventilation complying with 12.5.9 is to be provided for battery installations connected to a charging device with a total maximum power output of more than 2 kW and also, to minimise the possibility of oxygen enrichment, compartments and spaces containing batteries with boost charging facilities are to be provided with mechanical exhaust ventilation irrespective of the charging device power output.

12.5.6 The ventilation system for battery compartments and boxes, other than boxes located on open deck or in spaces to which 12.3.2, 12.3.3 and 12.3.5 refer, is to be separate from other ventilation systems. The exhaust ducting is to be led to a location in the open air, where any gases can be safely diluted, away from possible sources of ignition and openings into spaces where gases may accumulate.

12.5.7 Fan motors associated with exhaust ducts from battery compartments are to be placed external to the ducts and the compartments.

12.5.8 Ventilating fans for battery compartments are to be so constructed and be of material such as to minimise risk of sparking in the event of the impeller touching the casing. Non-metallic-impellers are to be of an anti-static material.

12.5.9 Battery boxes are to be provided with sufficient ventilation openings located so as to avoid accumulation of flammable gas whilst preventing the entrance of rain or spray.

12.5.10 The ventilation arrangements for all installations of vented type batteries are to be such that the quantity of air expelled is at least equal to:

$$Q = 110 I n$$

where

n = number of cells in series

I = maximum current delivered by the charging equipment during gas formation, but not less than 25 per cent of the maximum obtainable charging current in amperes

Q = quantity of air expelled in litres/hr.

12.5.11 The ventilation rate for compartments containing valve-regulated sealed batteries may be reduced to 25 per cent of that given in 12.5.10.

12.6 Charging facilities

12.6.1 Charging facilities are to be provided for all secondary batteries such that they may be completely charged from the completely discharged state in a reasonable time having regard to the service requirements.

12.6.2 Suitable means, including an ammeter and a voltmeter, are to be provided for controlling and monitoring charging of batteries, and to protect them against discharge into the charging circuits.

12.6.3 For floating circuits or any other conditions where the load is connected to the battery whilst it is on charge, the maximum battery voltage is not to exceed the safe value for any connected apparatus.

12.6.4 Where valve-regulated sealed batteries are installed, the charging facilities are to incorporate independent means such as overvoltage protection to prevent gas evolution in excess of the manufacturer's design quantity.

12.6.5 Boost charge facilities, where provided, are to be arranged such that they are automatically disconnected should the battery compartment ventilation system fail.

12.7 Recording of batteries for emergency and essential services

12.7.1 A schedule of batteries fitted for use for essential and emergency services is to be compiled and maintained.

12.7.2 Procedures are to be put in place and documented to ensure that, where batteries are replaced, they are of an equivalent performance type, *see also* 1.5.3.

12.7.3 When additions or alterations are proposed to the existing batteries for essential and emergency services, the schedule and replacement procedure documentation are to be updated to reflect the proposed installation and submitted in accordance with 1.5.2.

12.7.4 The schedule and replacement procedure documentation are to be made available to the LR Surveyor on request.

12.8 Cables

12.8.1 Where it is impracticable to provide electrical protective devices for certain cables supplied from batteries, e.g. within battery compartments and in engine starting circuits, unprotected cable runs are to be kept as short as possible and special precautions should be taken to minimise risk of faults, e.g., use of single core cables with additional sleeve over the insulation of each core, with shrouded terminals.

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■ *Section 13*
Equipment – Heating, lighting and accessories

13.1 Heating and cooking equipment

13.1.1 The construction of heaters is to give a degree of protection according to IEC 60529: *Degrees of protection provided by enclosures (IP Code)*, or an acceptable and relevant National Standard, suitable for the intended location.

13.1.2 Heating elements are to be suitably guarded.

13.1.3 Heating and cooking equipment is to be installed such that adjacent bulkheads and decks are not subjected to excessive heating.

13.2 Lighting – General

13.2.1 Lampholders are to be constructed of flame retarding non-hygroscopic materials.

13.2.2 Lighting fittings are to be so arranged as to prevent temperature rises which overheat or damage surrounding materials. They must not impair the integrity of fire divisions.

13.3 Incandescent lighting

13.3.1 Tungsten filament lamps and lampholders are to be in accordance with Table 2.13.1.

Table 2.13.1 Lamps and lampholders

Designation	Maximum lamp rating		Maximum lampholder current, A
	Voltage, V	Power, W	
Screw cap lamps			
E40	250	3000	16
E27	250	200	4
E14	250	15	2
E10	24	—	2
Bayonet cap lamps			
B22	250	200	4
B15d	250	15	2
B15s	55	15	2
Tubular fluorescent lamps			
G13	250	80	—
G5	250	13	—

13.3.2 Lampholders of type E40 are to be provided with a means of locking the lamp in the lampholder.

13.4 Fluorescent lighting

13.4.1 Fluorescent lamps and lampholders are to be in accordance with Table 2.13.1.

13.4.2 Fittings, reactors, capacitors and other auxiliaries are not to be mounted on surfaces which are subject to high temperatures. If mounted separately they are additionally to be enclosed in an earthed conductive casing.

13.4.3 Where capacitors of 0,5 microfarads and above are installed, means are to be provided to promptly discharge the capacitors on disconnection of the supply.

13.5 Discharge lighting

13.5.1 Discharge lamps operating in excess of 250 V are only acceptable as fixed fittings. Warning notices calling attention to the voltage are to be permanently displayed at points of access to the lamps and where otherwise necessary.

13.6 Socket outlets and plugs

13.6.1 The temperature rise on the live parts of socket outlet and plugs is not to exceed 30°C. Socket outlets and plugs are to be so constructed that they cannot be readily short-circuited whether the plug is in or out, and so that a pin of the plug cannot be made to earth either pole of the socket outlet.

13.6.2 All socket outlets of current rating in excess of 16 A are to be provided with a switch, and be interlocked such that the plug cannot be inserted or withdrawn when the switch is in the 'on' position.

13.6.3 Where it is necessary to earth the non-current carrying parts of portable or transportable equipment, an effective means of earthing is to be provided at the socket outlet.

13.6.4 On weather decks, galleys, laundries, machinery spaces and all wet situations socket outlets and plugs are to be effectively shielded against rain and spray and are to be provided with means of maintaining this quality after removal of the plug.

13.7 Enclosures

13.7.1 Enclosures for the containing and mounting of electrical accessories are to be of metal, effectively protected against corrosion, or of flame-retardant insulating materials.

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Section 14
Electrical equipment for use in explosive atmospheres

14.1 General

14.1.1 Electrical equipment is not to be installed in areas where an explosive atmosphere may be present, except where necessary for operational and/or safety purposes, when the equipment is to be of a certified safe type as listed below and details of the equipment and installation are to be submitted for consideration. The construction and type testing is to be in accordance with IEC 60079: *Electrical Equipment for Explosive Gas Atmospheres* or an acceptable and relevant National Standard.

Intrinsically safe	–	Ex 'i'
Increased safety	–	Ex 'e'
Flameproof	–	Ex 'd'
Pressurised enclosure	–	Ex 'p'
Powder filled	–	Ex 'q'
Encapsulated	–	Ex 'm'

14.1.2 The installation of electrical equipment in spaces and locations in which flammable mixtures are liable to collect, e.g., areas containing flammable gas or vapour and/or combustible dust, are, to comply with the relevant requirements of Pt 6, Ch 2,13 of the *Rules and Regulations for the Classification of Ships*.

14.1.3 Where cables are installed in hazardous areas, precautions are to be taken against risks being introduced in the event of an electrical fault.

14.1.4 For craft with spaces for carrying vehicles with fuel in their tanks for their own propulsion, the following requirements are also applicable:

(a) electrical equipment fitted within a height of 45 cm above the vehicle deck, or any platform on which vehicles are carried, or within the exhaust ventilation trunking for the space, is to be of a safe type;

(b) electrical equipment situated elsewhere within the space is to have an enclosure of ingress protection rating of at least IP55, if not of a safe type. (*See* IEC 60529: *Classification of Degrees of Protection Provided by Enclosures*). Smoke and gas detector heads are exempt from this requirement.

Section 15
Navigation and manoeuvring systems

15.1 Steering systems

15.1.1 The requirements of 15.1.2 to 15.1.7 are to be read in conjunction with those in Pt 14, Ch 1.

15.1.2 Two exclusive circuits, fed from the main source of electrical power and each having adequate capacity to supply all the motors which may be connected to it simultaneously are to be provided for each electric or electrohydraulic steering unit arrangement consisting of one or more electric motors. One of these circuits may pass through the emergency switchboard. For high speed craft, one of these circuits is to be fed either from the emergency source of electric power or from an independent power source located in such a position as to be unaffected by fire or flooding affecting the main source of power. *See also* Pt 14, Ch 1,6.

15.1.3 The main and auxiliary steering unit motors are to be capable of being started from a position on the navigating bridge and also arranged to restart automatically when power is restored after a power failure.

15.1.4 The motor of an associated auxiliary electric or electrohydraulic power unit may be connected to one of the circuits supplying the main steering unit.

15.1.5 Only short circuit protection is to be provided for each main and auxiliary steering unit motor circuit.

15.1.6 In craft of less than 1600 gross tonnage, if an auxiliary steering unit is not electrically powered or is powered by an electric motor primarily intended for other services, the main steering unit may be fed by one circuit from the main switchboard. Consideration would be given to other protective arrangements other than described in 15.1.5 for such a motor primarily intended for other services.

15.1.7 Each main and auxiliary steering unit electric control system which is to be operated from the navigating bridge is to be served with electric power by a separate circuit supplied from the associated steering gear power circuit, from a point within the steering unit compartment, or directly from the same section of switchboard busbars, main or emergency, to which the associated steering unit power circuit is connected. Each separate circuit is to be provided with short circuit protection only.

15.2 Thruster systems for manoeuvring

15.2.1 Where a tunnel or athwartship thruster is fitted solely for the purpose of manoeuvring, and is electrically driven, its starting and operation is not to cause the loss of any essential services.

15.2.2 In order to ensure that the thruster system is not tripped inadvertently whilst manoeuvring the craft, overload protection in the form of an alarm is to be provided for the electric motor and any associated supply converters, in lieu of tripping.

15.2.3 The thruster electric motor is not to be disconnected as part of a load management switching operation.

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15.3 Navigation lights

15.3.1 Navigation lights are to be connected separately to a distribution board reserved for this purpose only and accessible to the officer of the watch. This distribution board is to be connected directly or through transformers to the emergency source of electrical power in compliance with, for passenger craft, 3.2.7(b)(i) and (ii) and 3.2.9(a) or, for cargo craft, 3.3.8(b)(i) and (ii) and 3.3.8(a). An alarm is to be activated in the event of failure of a power supply from the distribution board.

15.3.2 Each navigation light is to be controlled and protected in each insulated pole by a switch and fuse or circuit-breaker mounted on the distribution board.

15.3.3 Provision is to be made on the navigating bridge for the navigation lights to be transferred to an alternative circuit fed from the main source of electrical power.

15.3.4 Each navigation light is to be provided with an automatic indicator giving audible and/or visual indication of failure of the light. If an audible device alone is fitted, it is to be connected to an independent source of supply, e.g., a battery, with means provided to test this supply. If a visual signal is used connected in series with the navigation light, means are to be provided to prevent extinction of the navigation light due to failure of the signal. The requirements of this paragraph do not apply to pilot boats, fishing boats and similar small vessels.

15.3.5 For navigation lights using light emitting diodes (consisting of multiple light sources) means to ensure that the overall luminous intensity of the navigation light is sufficient are to be provided in addition to the alarm to indicate the complete loss of the navigation light illumination required by 15.3.4. For replacement navigation lights, *see* 1.5.5.

15.3.6 To satisfy 15.3.5, an audible and visual alarm is to be activated to notify the Officer of the Watch that the luminous intensity of the light reduces below the level required by the IMO Convention on the International Regulations for Preventing Collisions at Sea. Alternative measures to ensure continuing acceptable performance of navigation lights using light emitting diodes may be considered that are in accordance with:

- IMO Res. MSC.253(83), *Performance Standards for Navigation Lights, Navigation Light Controllers and associated Equipment*, and
- EN 14744, *Inland navigation vessels and sea-going vessels – Navigation light*, or a relevant National or International Standard.

Where alternative measures are proposed that require periodic verification by personnel of the luminous intensity of navigation lights using light emitting diodes, details of the inspection implementation in the ships safety management system and acceptance by the National Administration requirements are to be submitted for consideration.

15.3.7 Navigation light power supply units installed to convert, control and/or monitor the distribution board power supply required by 15.3.1 above for connection to the light source(s) (e.g. for LED type navigation lights) are, in the event of a short-circuit on the unit output, are to disconnect or limit the supply to prevent further damage and activate an alarm in the event of a short-circuit on the unit output side.

15.3.8 Navigation light power supply units are to be self-checking, detecting failures of the unit itself and activating an alarm. These are to include:

- detection of system lock-ups (program hangs);
- means to detect whether navigation light switching command input circuits or links; and
- means to detect failure of the navigation light monitoring arrangements required to provide the alarms required by 15.3.4 and 15.3.5, as applicable.

15.3.9 The navigation light power supply failure alarms required by 15.3.1 are not to be displayed as a group alarm. Other navigation light alarms may be grouped for each navigation light where means are provided for personnel to determine the cause of the alarm. Activation of more than one of the navigation light alarms as a result of a single failure is to be prevented.

15.3.10 Any statutory requirements of the country of registration are to be complied with and may be accepted as an alternative to the above.

15.4 Navigational aids

15.4.1 Navigational aids as required by statutory regulations are to be fed from the emergency source of electrical power. *See also* 3.2.7(d)(i) and 3.3.7(d)(i).

15.5 Stabilisation

15.5.1 Where the stabilisation of a craft is essentially dependent upon a single device which in turn is dependent upon a continuous supply of electrical power, the supply arrangements are to comply with 5.2.3.

15.5.2 Where such systems are not dependent upon the continuous availability of electrical power, but one or more alternative systems not dependent upon the electrical supply are installed, a single circuit may be provided, with the protection and alarms required by 5.2.3.

■ *Section 16* Electric propulsion

16.1 General

16.1.1 Where electric propulsion is proposed, details are to be submitted and the arrangements will be subject to special consideration.

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Section 17
Fire safety systems

17.1 Fire detection and alarm systems

17.1.1 Fire detection and alarm systems are to be in accordance with Chapter 9 of the Fire Safety Systems Code (FSS Code) and 17.1.2 to 17.1.19.

17.1.2 Fire detection and alarm systems are to be provided with at least two power supplies. One supply is to be connected to the main source of electrical power and another supply is to be connected to the emergency source of electrical power required by 3.2, 3.3 or 3.4, or an accumulator battery capable of supplying power for the same period of time as the emergency source of electrical power. All power supply feeders for fire detection and alarm systems are to be in accordance with 11.6.4.

17.1.3 Automatic changeover facilities in accordance with 5.3.5 are to be located in, or adjacent to, the main fire control panel. Power supply changeover is to be achieved without adverse effect. Failure of any power supply is to operate an audible and visual alarm. *See also* 1.15 and 1.16.

17.1.4 Where an accumulator battery provides a power supply, on restoration of the main source of electrical power, the rating of the charge unit is to be sufficient to recharge the battery while maintaining the output supply to the fire detection and alarm system.

17.1.5 Power supplies from the main and emergency switchboards are to be supplied by separate feeders that are reserved solely for this purpose. Where the emergency feeder for the electrical equipment used in the operation of the fixed fire detection and fire alarm system is supplied from the emergency switchboard, it is to be run from this switchboard to the automatic changeover switch without passing through any other switchboard.

17.1.6 For machinery spaces the requirements of Ch 1,2.8 are applicable.

17.1.7 Fire detection systems within the accommodation spaces and cabin balconies are, in addition to the requirements of Chapter 1, as applicable, to comply with 17.1.8 to 17.1.19.

17.1.8 The fire control panel is to be located on the navigating bridge or in a central fire control station and may form part of that panel specified in Ch 1,2.8.2. In passenger craft carrying more than 36 passengers, the fire control panel is to be located in the continuously manned central control station.

17.1.9 Detectors and manually operated call points are to be grouped into sections. The activation of any detector or manually operated call point is to initiate a visual and audible fire signal at the control panel and indicating units. If the signals have not received attention within two minutes an audible alarm is to be automatically sounded throughout the crew accommodation and service spaces, control stations and machinery spaces of Category A. For craft required to comply with the HSC Code, there is to be no time delay for the audible alarms in crew accommodation areas, following initiation of an audible and visual alarm at the control panel and indicating units, when all the control stations are unattended. This alarm sounder system need not be an integral part of the detection system.

17.1.10 In yachts, the fixed fire detection and fire alarm system is to be capable of remotely and individually identifying each detector and manually operated call point. On other craft, indicating units are to denote, as a minimum, the section in which a detector or manually operated call point has operated. At least one unit is to be so located that it is easily accessible to responsible members of the crew. One indicating unit is to be located on the navigating bridge if the control panel is located in the central control station.

17.1.11 Clear information is to be displayed on or adjacent to each indicating unit about the spaces covered and the location of the section and, for yachts, each detector and manually operated call point.

17.1.12 Where the fire detection system does not include means of remotely identifying each detector and manually operated call point individually no section covering more than one deck within accommodation, service spaces and control stations is normally to be permitted except a section which covers an enclosed stairway. The number of enclosed spaces in each section are to be limited to the minimum considered necessary in order to avoid delay in identifying the source of fire. In no case are more than fifty spaces permitted in any section.

17.1.13 In passenger craft other than yachts, where the fire detection system does not include means of remotely identifying each detector individually a section of detectors is neither to serve spaces on both sides of the craft nor on more than one deck except when permitted by 17.1.18.

17.1.14 A section of fire detectors and manually operated call points which covers a control station, a service space or an accommodation space is not to include a machinery space of Category A.

17.1.15 The fire detection system is not to be used for any other purpose, except that closing of fire doors and similar functions may be permitted at the control panel. For craft required to comply with the HSC Code, the control panel may be used to activate a paging system, fan stops, closure of fire doors, closure of fire and smoke dampers, and/or a sprinkler system.

17.1.16 A loop circuit of an addressable fire detection system, capable of remotely identifying from either end of the loop, individually each detector and manually operated call point served by the circuit, may serve spaces on both sides of the craft and on several decks, but is not to be situated in more than one main vertical or horizontal fire zone, nor is a loop circuit which covers an accommodation space, service space and/or control station to include a machinery space of Category A.

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17.1.17 A loop circuit of an addressable fire detection system may comprise one or more sections of detectors and manually operated call points. Where the loop comprises more than one section, the sections are to be separated by devices which will ensure that if a short-circuit occurs anywhere in the loop, only the affected section of detectors and manually operated call points will be isolated from the control panel. No section of detectors and manually operated call points is in general to include more than 50 detectors.

17.1.18 A section of fire detectors and manually operated call points is not to be situated in more than one main vertical or horizontal fire zone. Additionally, for craft required to comply with the HSC Code, a section of detectors and manually operated call points section of detectors of an addressable fire detection system is neither to serve spaces on both sides of the craft nor on more than one deck, except that:

(a) a section of detectors and manually operated call points may serve spaces on more than one deck if those spaces are located in either the fore or aft end of the craft, or they constitute common spaces occupying several decks, i.e. public spaces, enclosed stairways, etc.

(b) in craft of less than 20 m in breadth, a section of detectors and manually operated call points may serve spaces on both sides of the craft.

17.1.19 The wiring for each section of detectors and manually operated call points in an addressable fire detector system is to be separated as widely as practicable from that of all other sections on the same loop. When this is not practical, such as in large public spaces, the part of the loop which by necessity passes through the space for a second time is to be installed at the maximum possible distance from other parts of the loop.

17.2 Automatic sprinkler system

17.2.1 Any electrically driven power pump, provided solely for the purpose of continuing automatically the discharge of water from the sprinklers, is to be brought into action automatically by the pressure drop in the system before the standing fresh water charge in the pressure tank is completely exhausted.

17.2.2 For passenger craft, electrically driven sea-water pumps for automatic sprinkler systems are to be served by not less than two circuits reserved solely for this purpose, one fed from the main source of electrical power and one from the emergency source of electrical power. Such feeders are to be connected to an automatic change-over switch situated near the sprinkler pump and the switch is to be normally closed to the feeder from the main source of electrical power. No other switches are permitted in the feeders. The switches on the main and emergency switchboards are to be clearly labelled and normally kept closed.

17.2.3 The automatic alarm and detection system is to be fed by exclusive feeders from two sources of electrical power, one of which is to be an emergency source, with automatic change-over facilities located in, or adjacent to, the main alarm and detection panel.

17.2.4 Feeders for the sea-water pump and the automatic alarm and detection system are to be arranged so as to avoid galleys, machinery spaces and other enclosed spaces of high fire risk, except in so far as it is necessary to reach the appropriate switch boards. The cables are to be of a fire resistant type where they pass through such high risk areas.

17.3 Fixed water-based local application fire-fighting systems

17.3.1 Where fixed water-based local application fire-fighting system pressure sources are reliant on external power they need only be supplied by the main source of electrical power.

17.3.2 The fire detection, control and alarm systems are to be provided with an emergency source of electrical power required by 3.2, 3.3 or 3.4 and are also to be connected to the main source of electrical power. Separate feeders, reserved solely for this purpose, with automatic changeover facilities located in, or adjacent to, the main control panel are to be provided.

17.3.3 Failure of any power supply is to operate an audible and visual alarm. *See also* 1.15 and 1.16.

17.3.4 Means to activate a system are to be located at easily accessible positions inside and outside the protected space. Arrangements inside the space are to be situated such that they will not be cut off by a fire in the protected areas and are suitable for activation in the event of escape. Where it is proposed to install local activation means outside of the protected space, details are to be submitted for consideration.

17.3.5 For the electrical safety of electrical and electronic equipment in areas protected by fixed water-based local application, fire-fighting systems and adjacent areas where water may extend, the requirements of 17.3.6 to 17.3.10 apply.

17.3.6 As far as is practicable, electrical and electronic equipment is not to be located within protected areas or adjacent areas. The system pump, its electrical motor and the sea valve if any, may be in a protected space provided that they are outside areas where water or spray may extend.

17.3.7 High voltage equipment and their enclosures are not to be installed in protected areas or adjacent areas. For high voltage generators enclosures which cannot be fully located outside of adjacent areas due to close proximity, a technical justification, including proposed degree of protection ratings that are normally not to be lower that IP54, may be submitted for consideration that demonstrates the overall safety of the installation in the event of system operation.

17.3.8 In addition to the degree of protection requirements of 1.11.1, electrical and electronic equipment enclosures located within protected areas and within adjacent areas are to provide adequate protection in the event of system operation.

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17.3.9 To demonstrate compliance with 17.3.8, evidence of the suitability of electrical and electronic equipment for use in protected areas and adjacent areas is to be submitted in accordance with 1.2.12. The evidence is to demonstrate that additional precautions have been taken, where necessary, in respect of:

(a) satisfying 17.3.6 and 17.3.7;
(b) personnel protection against electric shock;
(c) cooling airflow, where necessary, for equipment required to operate during system operation; and
(d) maintenance requirements for equipment before return to operation following system activation.

Any test evidence submitted is to consider the overall installation, including equipment types, system configuration and nozzles and the potential effects of airflows in the protected space.

17.3.10 The evidence required by 17.3.9 is to demonstrate the safe and effective operation of the overall arrangements in the event of system operation. This evidence is to demonstrate that exposure to system spray and/or water:

- cannot result in loss of essential services (e.g. unintended activation of automatic machinery shut-down);
- cannot result in loss of availability of emergency services;
- will not affect the continued safe and effective operation of electrical and electronic equipment required to operate during the required period of system operation;
- does not present additional electrical or fire hazards; and
- would require only identified readily replaceable components to be repaired or replaced.

The installation of electrical and electronic equipment required to provide essential or emergency services in enclosures with a degree of protection less than IP44 within areas exposed to direct spray is to be acceptable to LR, and evidence of suitability is to be submitted accordingly.

17.3.11 Fixed water-based local application fire-fighting system electrically-driven pumps may be shared with:

- equivalent automatic sprinkler systems;
- equivalent main machinery space fire-fighting systems; or
- local fire-fighting systems for deep-fat cooking equipment;

provided that the shared use is accepted by the National Administration as complying with applicable statutory regulations and the arrangements comply with the requirements of 17.3.12 to 17.3.14.

17.3.12 Shared electrically-driven sea-water pumps are to be served by not less than two circuits reserved solely for this purpose, one fed from the main source of electrical power and one from the emergency source of electrical power. Such feeders are to be connected to an automatic changeover switch situated near the pumps and the switch is to be normally closed to the feeder from the main source of electrical power. No other switches are permitted in the feeders. The switches on the main and emergency switchboards are to be clearly labelled and normally kept closed.

17.3.13 Failure of a component in the power and control system is not to result in a reduction of the total available pump capacity below that required by any of the areas which the system is required to protect. For equivalent automatic sprinkler systems, a failure is not to prevent automatic release or reduce sprinkler pump capacity by more than 50 per cent.

17.3.14 Where fire-fighting systems share fire-fighting pumps, failure of one system is not to prevent activation of the pumps by any other system.

17.4 Fire pumps

17.4.1 When the emergency fire pump is electrically driven, the power is to be supplied by a source other than that supplying the main fire pumps. This source is to be located outside the machinery spaces containing the main fire pumps and their source of power and drive units.

17.4.2 The cables to the emergency fire pump are not to pass through the machinery spaces containing the main fire pumps and their source of power and drive units. The cables are to be of a fire resistant type where they pass through other high fire risk areas.

17.5 Refrigerated liquid carbon dioxide systems

17.5.1 Where there are electrically driven refrigeration units for carbon dioxide fire-extinguishing systems, one unit is to be supplied by the main source of electrical power and the other unit from the emergency source of electrical power.

17.5.2 Each electrically driven carbon dioxide refrigerating unit is to be arranged for automatic operation in the event of loss of the alternative unit.

17.6 Fire safety stops

17.6.1 In order to limit the fire growth potential in every space of the craft, means for controlling the air supply to the spaces and flammable liquids within the spaces are to be provided.

17.6.2 To control air supply, a means of stopping all forced and induced draught fans, and all ventilation fans serving accommodation spaces, service spaces, control stations and machinery spaces from an easily accessible position outside of the space being served is to be provided. The position is not to be readily cut off in the event of a fire in the spaces served by the fans.

17.6.3 In passenger craft carrying more than 36 passengers, a second means of stopping ventilation fans serving accommodation spaces, service spaces and control stations is to be provided at a position as far apart from the position required by 17.6.2 as is practicable. At both positions, the controls are to be grouped so that all fans can be stopped from either of the two positions.

17.6.4 A second means of stopping ventilation fans serving machinery spaces is to be provided at a position as far apart from the position required by 17.6.2 as is practicable. At both positions the controls are to be grouped so that all fans are operable from either of the two positions. The means for stopping machinery space ventilation fans are to be entirely

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separate from the means for stopping fans serving all other spaces.

17.6.5 In passenger craft, the means of stopping machinery ventilation fans required by 17.6.2 is to be located at the central control station which is to have safe access from the open deck. The central control station is to be provided with ventilation fan OFF status indications, together with a means for restarting the ventilation fans.

17.6.6 In passenger craft carrying 36 passengers or more with main laundries, electrically operated fire dampers fitted at the lower end of the laundry exhaust ducts required to comply with relevant statutory regulations are to be fitted with additional remote-control arrangements for shutting off the exhaust fans and supply fans and operating the fire dampers from within the space.

17.6.7 To control flammable liquids, a means of stopping all fuel oil, lubricating oil, hydraulic oil, cargo oil and thermal oil pumps and oil purifiers from outside the spaces being served is to be provided. The position is not to be cut off in the event of a fire.

17.6.8 Means of cutting off all electrical power to the galley except lighting circuits, in the event of a fire, are to be provided outside the galley exits, at positions which will not readily be rendered inaccessible by such a fire.

17.6.9 Following activation of any fire safety stops, a manual reset is to be provided in order to restart the associated equipment.

17.6.10 Fire safety stop systems are to be designed on the fail-safe principle or alternatively the power supplies to, and the circuits of, the fire safety stop systems are to be continuously monitored and an alarm initiated in the event of a fault. Cables are to be of a fire-resistant type, *see* 11.5.3. *See also* 5.2.1.

17.6.11 High speed craft bridge areas are to be provided with suitable emergency means to:

(a) close ventilation openings and stop ventilating machinery supplying spaces covered by fixed fire-extinguishing systems;

(b) shut off fuel supplies to machinery in main and auxiliary machinery spaces; and

(c) stop main engine(s) and auxiliary machinery.

NOTE

These emergency means are to be sited in conjunction with required fixed fire extinguishing system activation means.

17.6.12 Additionally, Passenger (B) high speed craft are to be provided with the means required by 17.6.11 at one or more alternative stations separate from the bridge area. *See also* Ch 1,2.6.7.

17.7 Fire doors

17.7.1 The electrical power required for the control, indication and alarm circuits of fire doors is to be provided by an emergency source of electrical power as required by 3.2. In passenger craft carrying more than 36 passengers an alternative supply fed from the main source of electrical power, with automatic change-over facilities, is to be provided at the central control station. Failure of any power supply is to operate an audible and visual alarm, *see also* 1.15 and 1.16.

17.7.2 The control and indication systems for the fire doors are to be designed on the fail-safe principle with the release system having a manual reset.

17.8 Fire dampers

17.8.1 The electrical power required for the control and indication circuits of fire dampers is to be supplied from the emergency source of electrical power.

17.8.2 The control and indication systems for the fire dampers are to be designed on the fail-safe principle with the release system having a manual reset.

17.8.3 In passenger craft carrying 36 passenger or more with main laundries, where electrically operated fire dampers are required to comply with relevant statutory regulations to be fitted at the lower end of exhaust ducts from any main laundries, they are to be capable of automatic and remote operation.

17.8.4 For craft required to comply with the HSC Code with galley range exhaust ducts, electrically operated fire dampers fitted in the lower or upper end of the duct are to be remotely operated and, additionally, the fire damper at the lower end of the duct is to be automatically operated.

17.9 Fire-extinguishing media release alarms

17.9.1 Where it is required that alarms be provided to warn of the release of a fire extinguishing medium, and these are electrically operated, they are to be provided with an emergency source of electrical power, as required by 3.2, 3.3 or 3.4 and also connected to the main source of electrical power, with automatic changeover facilities located in, or adjacent to, the fire-extinguishing media release panel, *see also* 1.15. Failure of any power supply is to operate an audible and visual alarm, *see also* 1.15 and 1.16.

17.10 Electrically powered air compressors for breathing air cylinders

17.10.1 In yachts that are 500 gt or more carrying more than 36 passengers where electrically powered air compressors are installed as part of the means required by the National Administration, for recharging breathing apparatus air cylinders for fire-fighter's outfits, the compressors are to be supplied by the main and emergency sources of electrical power. Details of the emergency supply electrical load, supply changeover arrangements and operation under fire conditions are to be submitted for consideration. The arrangements are to be to the satisfaction of the National Administration with which the craft is registered.

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Section 18
Crew and passenger emergency safety systems

18.1 Emergency lighting

18.1.1 For the purpose of this Section emergency lighting, transitional emergency lighting and supplementary emergency lighting are hereafter referred to under the generic name 'emergency lighting'.

18.1.2 Emergency lighting provided in compliance with Section 3 is to be arranged so that a fire or other casualty in the spaces containing the emergency source of electrical power, associated transforming equipment and the emergency lighting switchboard does not render the main lighting system inoperative.

18.1.3 The level of illumination provided by the emergency lighting is to be adequate to permit safe evacuation in an emergency, having regard to the possible presence of smoke, *see* 18.4.

18.1.4 The exit(s) from every main compartment occupied by passengers or crew is to be continuously illuminated by an emergency lighting fitting.

18.1.5 Switches are not to be installed in the final subcircuits to emergency light fittings unless the light fittings are serving normally unmanned spaces, e.g., storage-rooms, cold rooms, etc., or they are normally required to be extinguished for operational reasons, e.g., for night visibility from the navigating bridge. Where switches are fitted they are to be accessible only to craft crew with provision made to ensure that the emergency lighting is energised when such spaces are manned and/or during emergency conditions.

18.1.6 Where emergency lighting fittings are connected to dimmers, provision is to be made, upon the loss of the main lighting, to automatically restore them to their normal level of illumination.

18.1.7 Fittings are to be specially marked to indicate that they form part of the emergency lighting system.

18.2 General emergency alarm system

18.2.1 An electrically operated bell or klaxon or other equivalent warning system installed in addition to the craft's whistle or siren, for sounding the general emergency alarm signal, is to comply with the *International Life-saving Appliances (LSA) Code* and with the requirements of this Section, *see also* 1.15 and 1.16.

18.2.2 The general emergency alarm system is to be provided with an emergency source of electrical power as required by 3.2, 3.3, 3.4 or 20.10 and also connected to the main source of electrical power with automatic changeover facilities located in, or adjacent to, the main alarm signal distribution panel. Failure of any power supply is to operate an audible and visual alarm, *see also* 1.15.

18.2.3 The general emergency alarm distribution system is to be so arranged that a fire or casualty in any one main vertical zone, as defined by SOLAS Reg. II-2/A, Reg. 3.9, other than the zone in which the public address control station is located, will not interfere with the distribution in any other such zone.

18.2.4 There are to be segregated cable routes to public rooms, alleyways, stairways, control stations and on passenger craft on open decks, so arranged that any single electrical fault, localised fire or casualty will not cause the loss of the facility to sound the general emergency alarm in any public rooms, alleyways, stairways, control stations and on passenger craft on open decks, albeit at a reduced capacity.

18.2.5 Where the special alarm fitted to summon the crew, operated from the navigation bridge, or fire control station, forms part of the craft's general alarm system, it is to be capable of being sounded independently of the alarm to the passenger spaces.

18.2.6 The sound pressure levels are to be measured during a practical test and documented, *see* 21.2.

18.3 Public address system

18.3.1 Public address systems are to comply with the *International Life-saving Appliances (LSA) Code* and the requirements of this Section.

18.3.2 The public address system is to be provided with an emergency source of electrical power as required by 3.2, 3.3, 3.4 or 20.10 and also connected to the main source of electrical power with automatic changeover facilities located adjacent to the public address system. Failure of any power supply is to operate an audible and visual alarm, *see also* 1.15 and 1.16.

18.3.3 The public address system is to have multiple amplifiers having their power supplies so arranged that a single fault will not cause the loss of the facility to broadcast emergency announcements in public rooms, alleyways, stairways and control stations, albeit at a reduced capacity.

18.3.4 The public address distribution system is to be so arranged that a fire or casualty in any one main vertical zone, as defined by SOLAS Reg. II-2/A, Reg.3.9, other than the zone in which the public address control station is located, will not interfere with the distribution in any other such zone.

18.3.5 There are to be segregated cable routes to public rooms, alleyways, stairways, and control stations so arranged that any single electrical fault, fire or casualty will not cause the loss of the facility to broadcast emergency announcements in any public rooms, alleyways, stairways, and control stations, albeit at a reduced capacity.

18.3.6 Amplifiers are to be continuously rated for the maximum power that they are required to deliver into the system for audio and, where alarms are to be sounded through the public address system, for tone signals.

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18.3.7 Loudspeakers are to be continuously rated for their proportionate share of amplifier output and protected against short-circuits.

18.3.8 Amplifiers and loudspeakers are to be selected and arranged to prevent feedback and other interference. There are also to be means to automatically override any volume controls, so as to ensure the specified sound pressure levels are met.

18.3.9 Where the public address system is used for sounding the general emergency alarm and the fire-alarm, the following requirements are to be met in addition to those of 18.2:

(a) The emergency system is given automatic priority over any other system input.

(b) More than one device is provided for generating the sound signals for the emergency alarms.

18.3.10 Where more than one alarm is to be sounded through the public address system, they are to have recognisably different characteristics and additionally be arranged, so that any single electrical failure which prevents the sounding of any one alarm will not affect the sounding of the remaining alarms.

18.3.11 The sound pressure levels are to be measured during a practical test using speech and, where applicable, tone signals, and documented, *see* 21.2.

18.4 Escape route or low location lighting (LLL)

18.4.1 Where required escape route or low location lighting (LLL) is satisfied by electric illumination, the LLL system is to comply with the requirements of this sub-Section.

18.4.2 The LLL system is to be provided with an emergency source of electrical power and also be connected to the main source of electrical power, with automatic changeover facilities located adjacent to the control panel, *see also* 1.16.

18.4.3 The power supply arrangements to the LLL are to be arranged so that a single fault or a fire in any one fire zone or deck does not result in loss of the lighting in any other zone or deck. This requirement may be satisfied by the power supply circuit configuration, use of fire-resistant cables complying with 11.5.3, and/or the provision of suitably located power supply units having integral batteries adequately rated to supply the connected LLL for a minimum period of 60 minutes, *see* 12.3.7.

18.4.4 The performance and installation of lights and lighting assemblies are to comply with ISO standard 15370: *Ships and marine technology – Low location lighting on passenger ships*.

Section 19
Craft safety systems

19.1 Watertight doors

19.1.1 The electrical power required for power-operated sliding watertight doors is to be separate from any other power circuit and supplied from the emergency switchboard either directly or by a dedicated distribution board situated above the waterline in the final condition of damage or above the bulkhead deck as applicable. The associated control, indication and alarm circuits are to be supplied from the emergency switchboard either directly or by a dedicated distribution board situated above the waterline in the final condition of damage or above the bulkhead deck as applicable and for passenger craft be capable of being automatically supplied by the transitional source of emergency electrical power required by 3.2.9 or, where applicable, 3.3.9 in the event of failure of either the main or emergency source of electrical power.

19.1.2 A single failure in the power operating or control system of power-operated sliding watertight doors is not to result in a closed door opening or prevent the hand operation of any door.

19.1.3 Availability of the power supply is to be continuously monitored at a point in the electrical circuit adjacent to the door operating equipment. Loss of any such power supply is to activate an audible and visual alarm at the central operating console at the navigating bridge.

19.1.4 Electrical power, control, indication and alarm circuits are to be protected against fault in such a way that a failure in one door circuit will not cause a failure in any other door circuit. Short circuits or other faults in the alarm or indicator circuits of a door are not to result in a loss of power operation of the door. Arrangements are to be such that leakage of water into the electrical equipment located below the bulkhead deck will not cause the door to open.

19.1.5 The enclosures of electrical components necessarily situated below the waterline in the final condition of damage or below the bulkhead deck as applicable are to provide suitable protection against the ingress of water with ratings as defined in IEC 60529 or an acceptable and relevant national standard, as follows:

(a) Electrical motors, associated circuits and control components, protected to IPX7 Standard.

(b) Door position indicators and associated circuit components protected to IPX8 Standard, where the water pressure testing of the enclosures is to be based on the pressure that may occur at the location of the component during flooding for a period of 36 hours.

(c) Door movement warning signals, protected to IPX6 Standard.

19.1.6 Watertight door electrical controls including their electric cables are to be kept as close as is practicable to the bulkhead in which the doors are fitted and so arranged that the likelihood of them being involved in any damage which the craft may sustain is minimised.

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19.1.7 An audible alarm, distinct from any other alarm in the area, is to sound whenever the door is closed remotely by power and sound for at least five seconds but no more than ten seconds before the door begins to move and is to continue sounding until the door is completely closed. The audible alarm is to be supplemented by an intermittent visual signal at the door in passenger areas and areas where the noise level exceeds 85 dB(A).

19.1.8 A central operating console is to be fitted on the navigating bridge and is to be provided with a 'master-mode' switch having:

(a) a 'local control' mode for normal use which is to allow any door to be locally opened and locally closed after use without automatic closure, and;

(b) a 'doors closed' mode for emergency use which is to allow any door that is opened to be automatically closed whilst still permitting any doors to be locally opened but with automatic reclosure upon release of the local control mechanism.

19.1.9 The 'master mode' switch is to be arranged to be normally in the 'local control' mode position; be clearly marked as to its emergency function and be Type Approved in accordance with LR's Procedure for Type Approved Products.

19.1.10 The central operating console at the navigating bridge is to be provided with a diagram showing the location of each door, with visual indicators to show whether each door is open or closed. A red light is to indicate a door is fully open and a green light, a door fully closed. When the door is closed remotely a red light is to indicate the intermediate position by flashing. The indicating circuit is to be independent of the control circuit for each door.

19.1.11 The arrangements are to be such that it is not possible to remotely open any door from the central operating console.

19.2 Shell doors, loading doors and other closing appliances

19.2.1 Where it is required that indicators be provided for shell doors, loading doors and other closing appliances, which are intended to ensure the watertight integrity of the craft's structure in which they are located, the indicator system is to be designed on the fail-safe principle. The system is to indicate if any of the doors or closing appliances are open or are not fully closed or secured.

19.2.2 Where such doors and appliances are to be operated at sea, the requirements of 19.1 are to be complied with as far as is practicable.

19.2.3 The electrical power supply for the indicator system is to be independent of any electrical power supply for operating and securing the doors.

■ *Section 20*
Cargo craft, patrol and pilot craft, workboats and other similar craft of less than 500 tons gross tonnage for operation in Service Groups 1 to 3, and yachts less than 500 gt

20.1 General requirements

20.1.1 The requirements of this Section are applicable to electrical installations where the voltage of supply does not exceed 440 V a.c. or d.c.

20.1.2 The electrical installations for propulsion and auxiliary service where the voltage of supply exceeds 440 volts are to be constructed and installed in accordance with Sections 1 to 18.

20.1.3 Cargo craft of 300 tons gross tonnage and above are also to comply with 3.7.

20.1.4 Alternative arrangements, including those in accordance with IEC 60092-507:2008-01, *Electrical installations in ships – Small vessels*, or a relevant International or National Standard acceptable to LR may be considered.

20.2 Plans

20.2.1 At least three copies of the plans and particulars in 20.2.2 to 20.2.6 are to be submitted for consideration. Single copies only are required of plans in 20.2.7.

20.2.2 Single line diagram of main power and lighting systems which is to include:

(a) rating of machines; transformers; batteries and semi-conductor converters;

(b) all feeders connected to the main switchboard;

(c) section boards and distribution boards;

(d) insulation type, size and current loadings of cables;

(e) make, type and rating of circuit breakers and fuses.

20.2.3 Simplified diagrams of generator circuits and feeder circuits showing:

(a) protective devices;

(b) instrumentation and control devices;

(c) preference tripping;

(d) earth fault indication/protection.

20.2.4 Calculations of short circuit currents at main switchboard and distribution boards, details of circuit breaker and fuse operating times and discrimination curves.

20.2.5 For battery installation, arrangement plans and calculations are to show compliance with 20.12.

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20.2.6 Details of electrically operated personnel safety systems which are to include single line diagrams and a general arrangement plan of the vessel showing location and cable routes of:
(a) fire detection, alarm and extinction systems;
(b) internal communication and alarm systems.

20.2.7 Schedule of normal operating loads on the system.

20.3 Survey

20.3.1 The installation is to be inspected and tested by the Surveyors, in accordance with the requirements of Section 21, as appropriate, and is to be to their satisfaction.

20.4 Addition or alterations

20.4.1 No addition, temporary or permanent is to be made to an approved installation until it has been ascertained that the current carrying capacity and the condition of the existing equipment, including cables and switchgear, are adequate for the increased load.

20.4.2 Plans are to be submitted for consideration, and the alterations or additions are to be carried out under the survey and to the satisfaction of the Surveyors.

20.5 Location and construction of equipment

20.5.1 Electrical equipment is to be accessibly placed, clear of flammable material in well ventilated, adequately lighted spaces, in which flammable gases cannot accumulate and where it is not exposed to risk of mechanical damage or damage from water, steam or oil. Where necessarily exposed to such risks, the equipment is to be suitably constructed or enclosed. Equipment is to be accessible for maintenance.

20.5.2 Insulating materials and insulated windings are to be flame retardant, and resistant to tracking, moisture, sea air and oil vapour unless special precautions are taken to protect them.

20.5.3 Securing arrangements used in connection with current carrying parts are to be effectively locked.

20.5.4 The operation of all electrical equipment is to be satisfactory under such conditions of vibrations, movements and shock as may arise in normal practice.

20.5.5 The design and installation of electrical equipment is to be such that the risk of fire due to its failure is minimised. It is, as a minimum, to comply with a National or International Standard revised where necessary for ambient conditions. Equipment is to be tested at the manufacturer's works and a certificate of tests issued by the manufacturer.

20.6 Systems of distribution

20.6.1 The following systems of generation and distribution are acceptable:
(a) two wire insulated;
(b) two wire with one pole earthed;
(c) three phase three wire insulated neutral;
(d) three phase, four wire with neutral earthed but without hull return.

20.6.2 A device(s) is to be installed for every insulated distribution system, whether primary or secondary, for power, heating and lighting circuits to continuously monitor the insulation level to earth.

20.7 Earthing

20.7.1 Except where exempted by 20.7.2 all non-current carrying exposed metal parts of electrical equipment and cables are to be earthed.

20.7.2 The following parts may be exempted from the requirements of 20.7.1:
(a) lamp-caps, where suitably shrouded;
(b) shades, reflectors and guards supported in lampholders or light fittings constructed of, or shrouded in, non-conducting material;
(c) metal parts on, or screws in or through, non-conducting materials, which are separated by such material from current-carrying parts and from earthed non-current carrying parts in such a way that in normal use they cannot become live or come into contact with earthed parts;
(d) apparatus which is constructed in accordance with the principle of double insulation;
(e) bearing housings which are insulated in order to prevent circulation of current in the bearings;
(f) clips for fluorescent lamps;
(g) cable clips and short lengths of pipes for cable protection;
(h) apparatus supplied at a voltage not exceeding 55V direct current or 55V root mean square, between conductors, or between any conductor and earth in a circuit isolated from the supply. Autotransformers are not to be used for the purpose of achieving the alternating current voltage;
(j) apparatus or parts of apparatus which although not shrouded in insulating material is nevertheless otherwise so guarded that it cannot be touched and cannot come in contact with exposed metal.

20.7.3 With wood and other non-metallic hull constructions earthing connections are to be made to the generator frame, engine bedplate and earthing plate. Earthing connections are not to be made to hull sheathing, skin fittings or plumbing.

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20.8 Protection

20.8.1 Installations are to be protected against over-currents including short circuits. The tripping/fault clearance times of protective devices are to provide complete and co-ordinated protection to ensure:

(a) availability of services not affected by the faulty circuit;

(b) elimination of the fault to reduce damage to the system and hazard of fire.

20.8.2 Short circuit protection and a means of complete isolation is to be provided for each source of power.

20.8.3 Protection for battery circuits is to be provided at a position external and adjacent to the battery compartments; batteries used solely for engine starting may be provided with only a means of isolation.

20.8.4 Short circuit and overload protection together with a means of isolation is to be provided in each non-earthed outgoing circuit of the main switchboard and each distribution board.

20.8.5 Each final sub-circuit is to be provided with short circuit protection and a means of isolation in each non-earthed line.

20.8.6 Lighting circuits are to be supplied by circuits separate from those for power.

20.8.7 Control circuits for engine monitoring and other services are to be provided with short circuit protection.

20.8.8 Protective devices are not to be fitted in any earthed line of a distribution system.

20.8.9 Circuit breakers and fuses are to have a certified fault rating adequate for the installation and are to comply with a National or International Standard.

20.8.10 In the absence of precise data the calculation methods given in 6.2.4 are to be used for evaluation of short circuit currents.

20.8.11 Generators for a.c. systems are to be provided, as a minimum, with the protective gear required by 6.8.2 and 6.8.3 and additionally provided with the instrumentation required by 7.11.

20.9 Quality of power supplies

20.9.1 Unless specified otherwise electrical equipment, other than that supplied by battery systems, is to operate satisfactorily with the following simultaneous variations, from their nominal value, when measured at the consumer input terminals:

(a) Voltage:
- Permanent variations +6 per cent, –10 per cent
- Transient recovery +20 per cent, –15 per cent
- Recovery time 1,5 seconds.

(b) Frequency:
- Permanent variations ±5 per cent
- Transient variations ±10 per cent
- Recovery time five seconds.

20.9.2 Generator voltage regulators and engine governors are to be such as to ensure that the above supply variations are not exceeded.

20.10 Sources of electrical power

20.10.1 Under sea-going conditions where electrical power is required for services for the propulsion, navigation and safety of the craft and crew, it is to be provided by either a generator(s) having a rating sufficient to ensure the operation of these services or by an engine-driven charging system in conjunction with a battery(ies).

20.10.2 Under emergency conditions where electrical power is required for lighting to enable persons to evacuate the craft, for navigational lights, fire detection and alarm systems and internal communication and alarm systems, it is to be provided by alternative source(s) of electrical power located separately from the source(s) of power in 20.10.1 and suitably located for use in an emergency. This source(s) of electrical power is to be adequate to permit evacuation and to supply the navigation lights, fire detection and alarm systems and internal communication and alarm systems, for a period of 5 hours duration.

20.10.3 Where electrical power is required for services for the propulsion, navigation and safety of the yacht or craft and for the safety of the crew it is to be provided by:

(a) for **non-passenger type yachts of scantling length between 24 m and 50 m**, at least two generators having ratings sufficient to ensure the operation of these services when any one generator is out of action; or

(b) for **non-passenger type service craft for Service Groups 1 to 3**, a generator(s) having a rating sufficient to ensure the operation of these services without being overloaded.

20.10.4 Additionally, for **non-passenger type yachts of scantling length between 24 m and 50 m**:

(a) generators fitted to satisfy the requirements of 20.10.3(a) may be driven by the main engine provided the requirements of 20.9.1 are satisfied for all main engine speed and load conditions and that there is at least one of the remaining generators driven by a prime mover independent of the main engine; and

(b) any batteries provided for the duty, referred to in 20.10.2, are to be rated for at least 5 hours duration.

20.10.5 Additionally, for **non-passenger type service craft for Service Groups 1 to 3**, in a single generator installation, or where in a multiple generator installation with one generator out of action the remaining generator(s) is not capable of supplying the circuits serving any safety, essential lighting and communication equipment, an alternative source of electrical power of 5 hours duration is to be provided for these services.

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20.11 Cables

20.11.1 Cables and cable installations are to be in accordance with the requirements of Section 11.

20.12 Batteries

20.12.1 Batteries and battery installations are to be in accordance with the requirements of Section 12.

20.13 Lightning conductors

20.13.1 Lightning conductors complying with IEC 60092-401 are to be fitted to each mast of all wood, composite and steel craft having wooden masts or topmasts. They need not be fitted to steel craft having steel masts.

20.14 Fire detection and alarm systems

20.14.1 Where a fire detection and alarm system is fitted, it is to be in accordance with the requirements of 17.1.

20.15 Internal communication and alarm systems

20.15.1 Where internal communication and alarm systems are provided for use in an emergency, they are to comply with the requirements of 18.2 and 18.3 as appropriate.

■ *Section 21* Testing and trials

21.1 Testing

21.1.1 Tests in accordance with 21.1.2 to 21.1.4 are to be satisfactorily carried out on all electrical equipment, complete or in sections, at the manufacturer's premises and a test report issued by the manufacturer.

21.1.2 A high voltage at any frequency between 25 and 100 Hz is to be applied between:
(a) all current carrying parts connected together and earth;
(b) all current carrying parts of opposite polarity or phase.
For rotating machines the value of test voltage is to be 1000 V plus 2 x rated voltage with a minimum of 2000 V, and for other electrical equipment, it is to be in accordance with Table 2.21.1. Items of equipment included in the assembly for which a test voltage lower than the above is specified may be disconnected during the test and tested separately at the appropriate lower test voltage. The test is to be commenced at a voltage of about one-third the test voltage and is to be increased to full value as rapidly as is consistent with its value being indicated by the measuring instrument. The full test voltage is then to be maintained for one minute, and then reduced to one-third full value before switching off. The assembly is considered to have passed the test if no disruptive discharge occurs.

Table 2.21.1 Test voltage

Rated voltage, U_n U_n V	Test voltage a.c. (r.m.s.), V
$U_n \leq 60$	500
$60 < U_n \leq 1000$	$2 \times U_n + 1000$
$1000 < U_n \leq 2500$	6500
$2500 < U_n \leq 3500$	10000
$3500 < U_n \leq 7200$	20000
$7200 < U_n \leq 12000$	28000
$12000 < U_n \leq 15000$	38000

21.1.3 When it is desired to make additional high voltage tests on equipment which has already passed its tests, the voltage of such additional tests is to be 80 per cent of the test voltage the equipment has already passed.

21.1.4 Immediately after the high voltage test, the insulation resistance is to be measured using a direct current insulation tester, between:
(a) all current carrying parts connected together and earth;
(b) all current carrying parts of different polarity or phase.
The minimum values of test voltage and insulation resistance are given in Table 2.21.2.

Table 2.21.2 Test voltage and minimum insulation

Rated voltage U_n V	Minimum voltage of the tests, V	Minimum insulation resistance, MΩ
$U_n \leq 250$	$2 \times U_n$	1
$250 < U_n \leq 1000$	500	1
$1000 < U_n \leq 7200$	1000	$\frac{U_n}{1000} + 1$
$7200 < U_n \leq 15000$	5000	$\frac{U_n}{1000} + 1$

21.1.5 Tests in accordance with the standard with which the equipment complies may be accepted as an alternative to the above.

21.2 Trials

21.2.1 Before a new installation, or any alteration or addition to an existing installation, is put into service the applicable trials in 21.2.2 to 21.2.7 are to be carried out. These trials are in addition to any acceptance tests which may have been carried out at the manufacturer's works.

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21.2.2 The insulation resistance is to be measured of all circuits and electrical equipment, using a direct current insulation tester, between:

(a) all current carrying parts connected together and earth; and, so far as is reasonably practicable,

(b) all current carrying parts of different polarity or phase;

The minimum values of test voltage and insulation resistance are given in Table 2.21.2. The installation may be subdivided and appliances may be disconnected if initial tests produce results less than these figures.

21.2.3 Tests are to be made to verify the effectiveness of:

(a) earth continuity conductor;

(b) the earthing of non-current carrying exposed metal parts of electrical equipment and cables not exempted by 1.12.2 or 20.7.2;

(c) bonding for the control of static electricity.

21.2.4 It is to be demonstrated that the Rules have been complied with in respect of:

(a) satisfactory performance of each generator throughout a run at full rated load;

(b) temperature of joint, connections, circuit-breakers and fuses;

(c) the operation of engine governors, synchronising devices, overspeed trips, reverse-current, reverse-power and over-current trips and other safety devices;

(d) voltage regulation of every generator when full rated load is suddenly thrown off and when starting the largest motor connected to the system;

(e) voltage drop at the worst case condition;

(f) harmonic distortion of the voltage waveform, where declared;

(g) satisfactory parallel operation, and kW and KVA load sharing of all generators capable of being operated in parallel at all loads up to normal working load;

(h) alarm sound pressure levels; and

(j) all essential and other important equipment are to be operated under service conditions, though not necessarily at full load or simultaneously, for a sufficient length of time to demonstrate that they are satisfactory.

21.2.5 Measurements are to be taken as part of the trials specified in 21.2.4(c), (d), (e) and (f) to verify that the installation will provide a quality of power supply in accordance with the values listed in 1.8.

21.2.6 It is to be demonstrated by practical tests that the Rules have been complied with in respect of fire, crew and passenger emergency and craft safety systems.

21.2.7 On completion of the general emergency alarm system and public address system tests, the Surveyor is to be provided with two copies of the test schedule, detailing the measured sound pressure levels. Such schedules are to be signed by the Surveyor and the Builder.

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Rules and Regulations for the Classification of Special Service Craft

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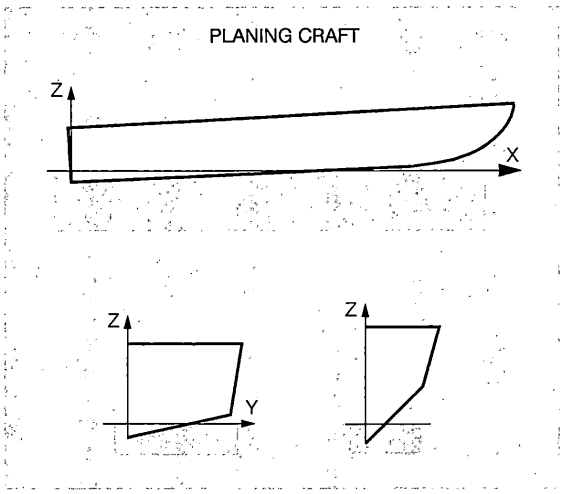
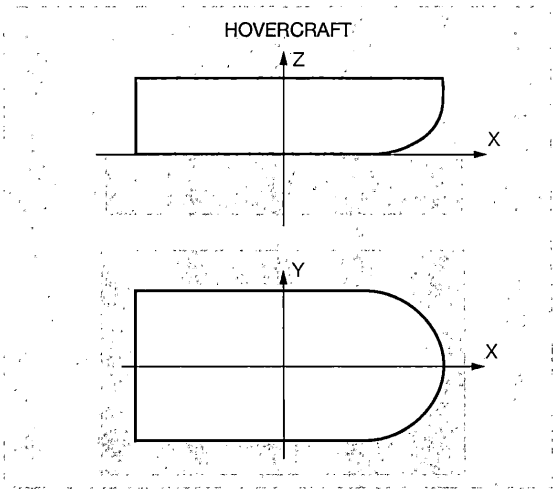
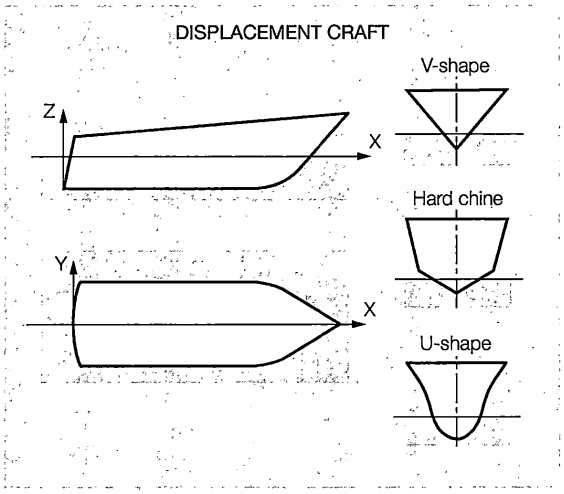
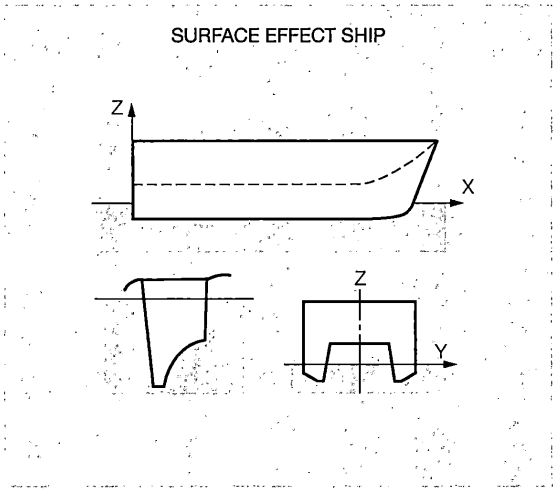
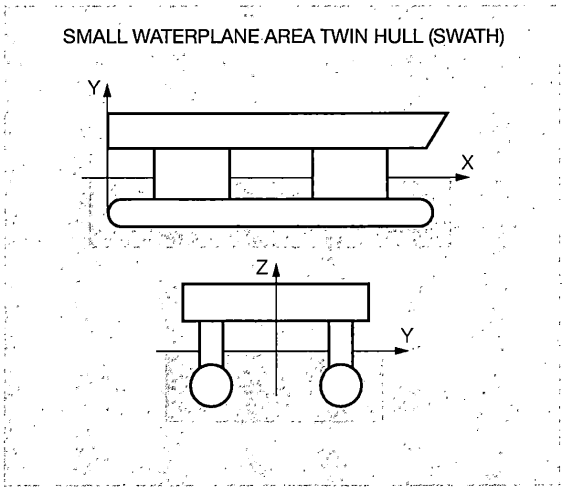
DIFFERENT TYPES OF HULL FORMS COVERED BY THE SPECIAL SERVICE CRAFT RULES

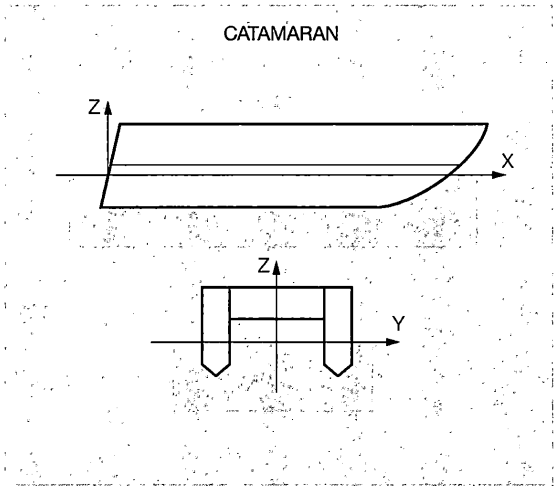












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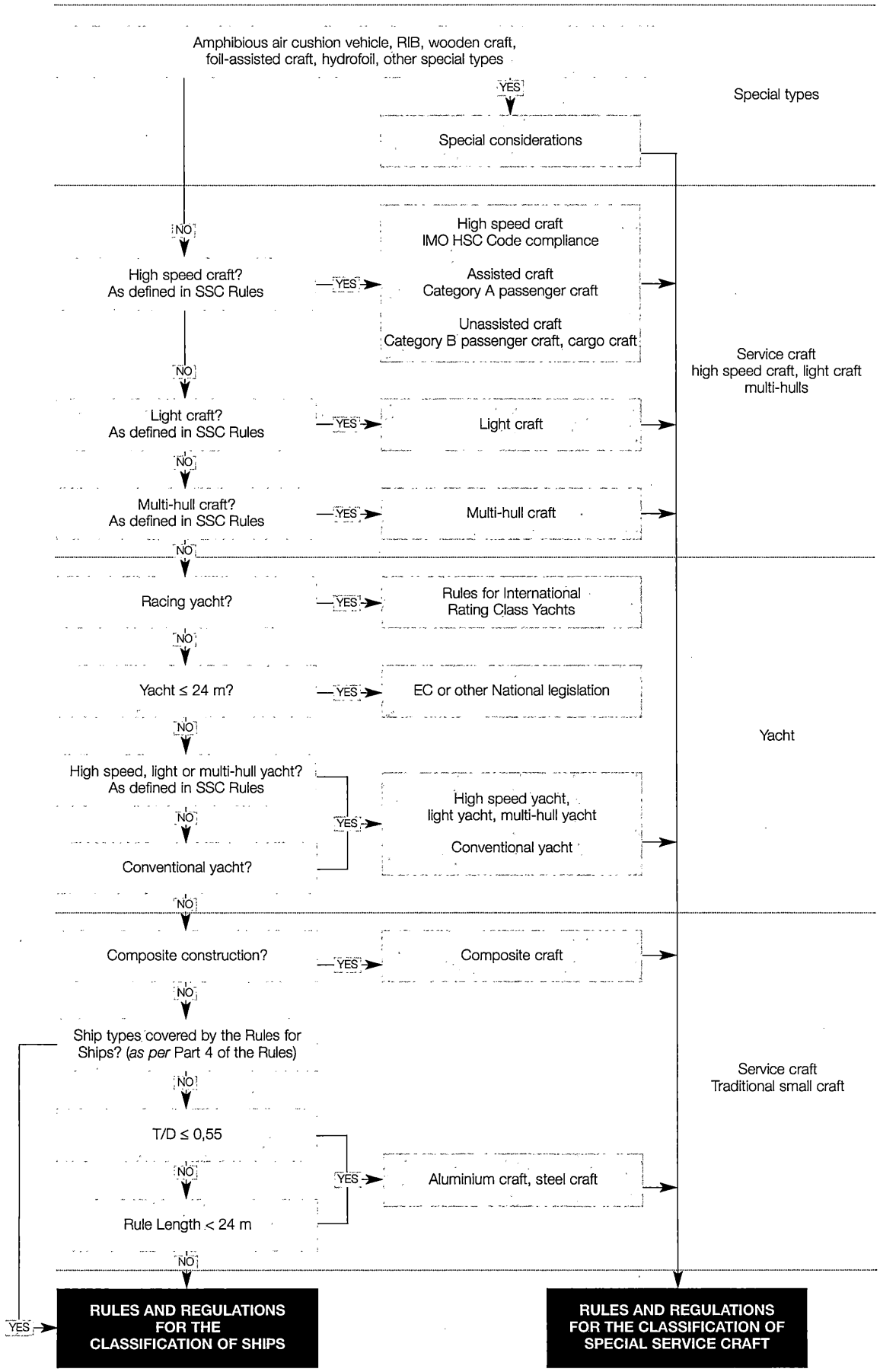
DIFFERENT TYPES OF CRAFT COVERED BY THE SPECIAL SERVICE CRAFT RULES



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Section

1 **General requirements**

2 **Definitions**

Section 1 General requirements

1.1 Application

1.1.1 The requirements of this Part apply to yachts with an overall length, L_{OA} (as defined in Pt 3, Ch 1,6.2.4) of 24 m or greater, 3000 gross registered tonnage or less, and intended for the carriage of 12 passengers or less, and service craft (*see also* 1.1.2(c)) built in accordance with these Rules.

1.1.2 Consideration will be given to the acceptance of fire safety measures:

(a) which, for Service Craft, have been prescribed and approved by the Government of the Flag State. In this instance, the requirements of Chapter 2 and Chapter 4 of these Rules are not applicable;

(b) which, for yachts, have been prescribed and approved by the Government of the Flag State, provided these are shown to be equivalent to those required by the MCA LY2 Code as amended. In this instance, the requirements of Chapter 3 and Chapter 4 of these Rules are not applicable;

(c) where the arrangements are considered equivalent to those required by these Rules as a result of risk assessment studies; or

(d) where the arrangements are considered acceptable compared to those required by these Rules, due cognisance having been taken of any restricted service limits.

1.1.3 Special consideration, consistent with the fire hazard involved, will be given to construction or arrangements not covered by this Chapter.

1.1.4 High speed cargo craft of 500 gross tons and over on international voyages and high speed passenger craft on international voyages are to be provided with the fire safety measures required by the *International Convention for the Safety of Life at Sea, 1974* as amended (SOLAS 74), Chapter X – Safety Measures for High Speed Craft (*International Code of Safety for High Speed Craft*).

1.1.5 High speed cargo craft of 500 gross tons and over employed on national voyages and high speed passenger craft employed on national voyages are to comply with the fire safety measures of the Government of the Flag State.

1.1.6 High speed cargo craft of less than 500 gross tons employed on national or international voyages are to comply with the fire safety measures of the Government of the Flag State.

1.1.7 It is the responsibility of the Government of the Flag State to give effect to the fire safety measures of 1.1.4, 1.1.5 and 1.1.6. However, Lloyd's Register (hereinafter referred to as LR) will undertake to do this in cases where:

(a) Contracting Governments have authorised LR to apply the requirements of SOLAS 74 and issue the appropriate certification on their behalf; or

(b) the Government of the Flag State is not a signatory to SOLAS 74; or

(c) the craft is to be classed for restricted or special service in national waters and the Government of the Flag State has no National requirements.

1.1.8 When implementing the provisions of 1.1.7, LR will apply the fire safety measures required by SOLAS 74 Chapter X – Safety Measures for High Speed Craft (*International Code of Safety for High Speed Craft*). However, due consideration will be given to arrangements deemed to provide an equivalent level of fire safety, taking due cognisance of the circumstances of the restricted or special service.

1.2 Submission of plans and information

1.2.1 The plans and information detailed in 1.2.2 to 1.2.4, where applicable, are to be submitted at least in triplicate for approval, together with all additional information such as gross tonnage and number of passengers/guests.

1.2.2 For fire protection, the following plans and information are to be submitted:

(a) Structural fire protection plan showing extent of materials used in construction, steel, aluminium, or alternative forms of construction, together with details of the thermal characteristics of the alternative forms of construction that include the temperature at which the material starts to lose its strength, and proposals for protection, etc.

(b) A general arrangement plan showing the main fire zones, escape stairways and the fire compartmentation bulkheads and decks within the main fire zones, including engine rooms, galleys, bonded stores, paint stores, navigating bridge, radio room, fire-fighting control room, emergency generator rooms and battery locker, helicopter arrangements, including re-fuelling and petrol stowage arrangements.

(c) A plan showing the details of construction of the fire protection bulkheads and decks and particulars of any surface laminates employed.

(d) Copies of Certificates of Approval by National Authorities and Fire Test Reports in respect of all 'A' and 'B' Class fire divisions, non-combustible materials and materials having low flame-spread characteristics, etc., which are to be used but have not been approved by LR. Copies of Certificates issued by other recognised approval bodies may be submitted for consideration.

(e) A ventilation plan showing ducts and any dampers in them, closing appliances and the position of the controls for stopping the system.

(f) A plan showing the fire detection and alarm system.

(g) A plan showing the remote control system for fire doors, if applicable.

(h) A fire control plan meeting the requirements of Ch 4,5.

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1.2.3 For fire-extinguishing the following plans are to be submitted:

(a) A general arrangement plan showing the disposition of all the fire-fighting equipment including the fire main, the fixed fire-extinguishing systems; the disposition of the portable and non-portable extinguishers and the types used; and the position and details of the firemen's outfits.

(b) A plan showing the layout and construction of the fire main, including the main and emergency fire pumps, isolating valves, pipe sizes and materials, and the cross connections to any other system.

(c) A plan showing details of each fixed fire-fighting system, including calculations for the quantities of the media used and the proposed rates of application.

1.2.4 Fire-control plans as required by Ch 4,5 are to be submitted.

1.2.5 For yachts, where fire plans and the information listed above have been appraised, approved and verified on board by the Flag Administration in compliance with the MCA LY2 Code as amended, Lloyd's Register will only acknowledge the aforementioned and therefore no further appraisal, approval or survey should be provided.

■ *Section 2* Definitions

2.1 Materials

2.1.1 **Non-combustible material** means a material which neither burns nor gives off flammable vapours in sufficient quantity for self-ignition when heated to approximately 750°C, according to an established test procedure, *see* IMO *International Code for Application of Fire Test Procedures* (FTP Code), Annex 1, Part 1. Any other material is a **combustible material**.

2.1.2 **Steel or other equivalent material.** Where the words 'steel or other equivalent material' occur, 'equivalent material' means any non-combustible material which, by itself, or due to insulation provided, has structural and integrity properties equivalent to steel at the end of the applicable fire exposure to the standard fire test (e.g. aluminium with appropriate insulation).

2.1.3 **Alternative forms of construction** means any combustible material may be accepted if it can be demonstrated that the material, which by itself or due to insulation provided has structural and fire integrity properties equivalent to 'A' or 'B' class divisions, or steel, as applicable, at the end of the applicable fire exposure to the standard fire test.

2.2 Fire test

2.2.1 A **standard fire test** is one in which the specimens of the relevant bulkheads and decks are exposed in a test furnace to temperatures corresponding approximately to the standard time-temperature curve. The test methods are to be in accordance with the IMO FTP Code, Annex 1, Part 3.

2.3 Flame spread

2.3.1 **Low flame spread** means that the surface thus described will adequately restrict the spread of flame, having regard to the risk of fire in the spaces concerned, this being determined by an acceptable test procedure, *see* IMO FTP Code, Annex 1, Part 5.

2.3.2 **Not readily ignitable** means that the surface thus described will not continue to burn for more than 20 seconds after the removal of a suitable impinging test flame.

2.4 Ship divisions and spaces

2.4.1 **'A' Class divisions** are those divisions formed by bulkheads and decks, and:

(a) Are to be constructed of steel or other equivalent material.

(b) Are to be suitably stiffened.

(c) Are to be so constructed as to be capable of preventing the passage of smoke and flame up to the end of the one-hour standard fire test, *see* 2.2.1.

(d) Are to be insulated with approved non-combustible materials such that the average temperature of the unexposed side will not rise more than 140°C above the original temperature, nor will the temperature, at any one point, including any joint, rise more than 180°C above the original temperature, within the time listed below:

Class 'A-60' 60 minutes.
Class 'A-30' 30 minutes.
Class 'A-15' 15 minutes.
Class 'A-0' 0 minutes.

(e) May be required to demonstrate that they meet the above requirements for integrity and temperature rise, through a test.

2.4.2 **'B' Class divisions** are those divisions formed by bulkheads, decks, ceilings or linings and:

(a) Are to be so constructed as to be capable of preventing the passage of flame to the end of the first half hour of the standard fire test, *see* IMO FTP Code, Annex 1, Part 3.

(b) Are to be insulated such that the average temperature of the unexposed side will not rise more than 140°C above the original temperature, nor will the temperature at any one point, including any joint, rise more than 225°C above the original temperature, within the time listed below:

Class 'B-15' 15 minutes.
Class 'B-0' 0 minutes.

(c) Are to be constructed of approved non-combustible materials and all materials entering into the construction and erection of 'B' Class divisions are to be non-combustible, except where permitted by other requirements of this Chapter.

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(d) May be required to ensure that they meet the above requirements for integrity and temperature rise through a test of a prototype division.

2.4.3 **'C' Class divisions** are divisions to be constructed of approved non-combustible materials. They need to meet neither requirements relative to the passage of smoke and flame nor limitations relative to the temperature rise. Combustible veneers are permitted provided they meet other requirements of this Chapter.

2.4.4 **Continuous 'B' Class ceilings or linings** are those 'B' Class ceilings or linings which terminate only at an 'A' or 'B' Class division.

2.4.5 **Accommodation spaces** are those spaces used for public spaces, corridors, lavatories, cabins, offices, hospitals, cinemas, games and hobbies rooms, pantries containing no cooking appliances and similar spaces.

2.4.6 **Service spaces** are those used for galleys, pantries containing cooking appliances, stores, mail and specie rooms, store rooms, lockers, workshops other than those forming part of the machinery spaces and similar spaces and trunks to such spaces.

2.4.7 **Cargo spaces** are all spaces used for cargo (including cargo oil tanks) and trunks to such spaces.

2.4.8 **Machinery spaces of Category A** are those spaces and trunks to such spaces which contain:

(a) internal combustion machinery used for main propulsion; or

(b) internal combustion machinery used for purposes other than main propulsion where such machinery has in the aggregate a total power output of not less than 375 kW; or

(c) any oil-fired boiler or oil fuel unit.

2.4.9 **Machinery spaces** are all machinery spaces of Category 'A' and all other spaces containing propelling machinery, boilers, oil fuel units, steam and internal combustion engines, generators and major electrical machinery, oil filling stations, refrigerating, stabilising, ventilation and air conditioning machinery, and similar spaces; and trunks to such spaces.

2.4.10 **Control stations** are those spaces in which the craft's radio or main navigating equipment or the emergency source of power is located or where the fire recording or fire-control equipment is centralised.

2.4.11 **Cargo area** is that part of the craft that contains cargo tanks, slop tanks and cargo pump rooms including pump rooms, cofferdams, ballast and void spaces adjacent to cargo tanks and also deck areas throughout the entire length and breadth of the part of the craft over the above-mentioned spaces.

2.4.12 **Main vertical zones** are those sections into which the hull, superstructure and deck houses are divided by 'A' Class divisions, the mean length and width of which on any one deck does not, in general, exceed 48 m.

2.5 Equipment

2.5.1 **Oil fuel unit** is the equipment used for the preparation of oil fuel for delivery to an oil-fired boiler, or equipment used for the preparation for delivery of heated oil to an internal combustion engine, and includes any oil pressure pumps, filters and heaters dealing with oil at a pressure of more than 1,8 bar (1,8 kgf/cm^2) gauge.

2.6 Craft types

2.6.1 For the purpose of this Part the definitions of craft types given in 2.6.2 and 2.6.3 apply.

2.6.2 A **passenger craft** is a craft which carries more than twelve passengers.

2.6.3 A **yacht** is a recreational craft used for sport or pleasure and may be propelled mechanically, by sail or by a combination of both.

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Section

1 **General requirements**

2 **Fire safety measures for service craft**

Section 1
General requirements

1.1 Application

1.1.1 The requirements of this Chapter apply to service craft built in accordance with these Rules.

1.1.2 Where service craft incorporate fire hazards not covered in this Part, appropriate fire protection, detection and extinction arrangements are to be provided. Details are to be submitted for approval.

Section 2
Fire safety measures for service craft

2.1 General

2.1.1 Table 2.2.1 is a guide to the major requirements of this Section. The Table is intended as a quick reference to the requirements and is not to be used in isolation when designing the fire safety arrangements.

Table 2.2.1 General fire protection, detection and extinction requirements

Form of construction, *see* 2.2	Steel or equivalent, or alternative forms of construction may be accepted, subject to requirements in high fire risk areas
Passive fire protection, *see* 2.3 to 2.6	Category 'A' machinery spaces: • For craft >150 gross tons: A-30/A-0 • For craft <150 gross tons: A-0 Galleys: • For craft >50 gross tons: B-15
Means of escape, *see* 2.7: • Machinery spaces • Accommodation, etc.	} 2
Fixed fire detection system, *see* 2.13	• Fitted in all machinery spaces • Fitted in stairways, service spaces, machinery spaces, control stations and accommodation spaces of craft >50 gross tons with sleeping accommodation
Fire pumps, *see* 2.14	• 1 fixed power pump + 1 portable pump • For craft <150 gross tons: 1 portable pump
Fire-extinguishing arrangements in machinery spaces, *see* 2.15	• A fixed fire-extinguishing system • A minimum of 2, but need not exceed 5 portable foam extinguishers or equivalent
Portable fire-extinguishers in accommodation, *see* 2.18	Sufficient to ensure that at least one will be readily available in every compartment

2.2 Forms of construction – Structure

2.2.1 The hull, superstructure, structural bulkheads, decks and deckhouses may be constructed of steel, other equivalent material, *see* Ch 1,2.1.2, or be of alternative forms of construction, *see* Ch 1,2.1.3.

2.2.2 The structure in way of Category 'A' machinery spaces, galleys containing appliances of significant fire risk, *see* 2.4.2, and other high risk areas is to be protected such that the material by itself or due to insulation provided can maintain its required strength at the end of 30 minutes exposure to the standard fire test.

2.2.3 Details of the method of construction, supported by calculations and/or fire test data, demonstrating compliance with 2.2.2, are to be submitted.

2.2.4 For aluminium alloy structures, the insulation is to be such that the temperature of the structural core does not rise more than 200°C above the ambient temperature at any time during the specified fire exposure.

2.2.5 For composite structures, the insulation is to be such that the temperature of the laminate does not rise more than the minimum temperature of deflection under load of the resin at any time during the specified fire exposure. The temperature of deflection under load is to be determined as in Ch 14,3.7 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

2.2.6 For structures in contact with sea-water, the required insulation should extend to at least 300 mm below the lightest waterline, *see also* 2.6.1.

2.3 Forms of construction – Fire divisions

2.3.1 Fire divisions required by 2.4 are to be constructed in accordance with the remaining paragraphs of this sub-Section.

2.3.2 Fire divisions using steel equivalent or alternative forms of construction may be accepted if it can be demonstrated that the material by itself, or due to insulation provided, has the fire resistance properties equivalent to 'A' or 'B' class divisions.

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2.3.3 Insulation required by 2.3.2 is to be such that the temperature of the structural core does not rise above the point at which the structure would begin to lose its strength at any time during the applicable exposure to the standard fire test. For 'A' class divisions, the applicable exposure is 60 minutes, and for 'B' Class divisions, the applicable exposure is 30 minutes.

2.3.4 For aluminium alloy structures the insulation is to be such that the temperature of the structural core does not rise more than 200°C above the ambient temperature at any time during the applicable fire exposure.

2.3.5 For composite structures, the insulation is to be such that the temperature of the laminate does not rise more than the minimum temperature of deflection under load of the resin at any time during the applicable fire exposure. The temperature of deflection under load is to be determined as in Ch 14,3.7 of the Rules for Materials.

2.4 Structural fire protection

2.4.1 Category 'A' machinery spaces are to be enclosed by A-30 Class divisions where adjacent to accommodation spaces, or control positions and A-0 Class divisions elsewhere. For craft below 150 gross tons, Category 'A' machinery spaces are to be enclosed by A-0 Class divisions, regardless of adjacent space use.

2.4.2 For craft greater than 50 gross tons, galleys are to be enclosed by B-15 Class divisions unless the cooking appliances contained therein have an insignificant fire risk.

(a) For the purposes of this Chapter, coffee automats, toasters, dishwashers, microwave ovens, water boilers and similar appliances each with a maximum power of 5 kW may be regarded as having an insignificant fire risk. Electrically-heated cooking plates and hot plates for keeping food warm, each of them having a maximum power of 2 kW and a surface temperature not above 150°C may also be regarded as having insignificant fire risk. If spaces containing this equipment are lockable, then means of cutting-off the power to the space are to comply with Pt 16, Ch 2,17.6.7.

(b) Other equipment such as fat fryers, open flame cookers, etc., are to be regarded as having a significant fire risk.

2.4.3 Openings in 'A' Class divisions are to be provided with permanently attached means of closing that are to be at least as effective for resisting fires as the divisions in which they are fitted.

2.4.4 Interior stairways serving machinery spaces, accommodation spaces, service spaces or control stations are to be of steel or other equivalent material.

2.4.5 Doors are to be self-closing in way of Category 'A' machinery spaces.

2.4.6 Where 'A' Class divisions are penetrated for the passage of electric cables, pipes, trunks, ducts, etc., or for girders, beams or other structural members, arrangements are to be made to ensure that the fire resistance is not impaired.

2.4.7 Where the structure or 'A' Class divisions are required to be insulated, it is to be ensured that the heat from a fire is not transmitted through the intersections and terminal points of the divisions or penetrations to uninsulated boundaries. Where the insulation installed does not achieve this, arrangements are to be made to prevent this heat transmission by insulating the horizontal and vertical boundaries or penetrations for a distance of 450 mm.

2.5 Materials

2.5.1 Paints, varnishes and other finishes used on exposed interior surfaces are not to be capable of producing excessive quantities of smoke, toxic gases or vapours and are to be of the low flame spread type. Reference is also to be made to the IMO FTP Code, Annex 1, Parts 2 and 5.

2.5.2 Except in refrigerated compartments of service space, all insulation (e.g. fire and comfort) is to be of non-combustible materials.

2.5.3 Pipes penetrating 'A' Class divisions are to be of approved materials having regard to the temperature such divisions are required to withstand.

2.5.4 Pipes conveying oil or combustible liquids through accommodation and service spaces are to be of approved materials having regard to the fire risk.

2.5.5 Materials readily rendered ineffective by heat are not to be used for overboard scuppers, sanitary discharges, and other outlets which are close to the waterline and where the failure of the material in the event of fire would give rise to danger of flooding.

2.5.6 Primary deck coverings within accommodation spaces, service spaces and control stations are to be of a type that will not readily ignite, or give rise to toxic or explosive hazards at elevated temperatures. Reference is also to be made to the IMO FTP Code, Annex 1, Parts 2 and 6.

2.5.7 Vapour barriers and adhesives used in conjunction with insulation, as well as insulation of pipe fittings for cold service systems need not be non-combustible, but they are to be kept to the minimum quantity practicable and their exposed surfaces are to have low flame spread characteristics.

2.5.8 All waste receptacles are to be constructed of non-combustible materials with no openings in the sides or bottom.

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2.6 Surface of insulation

2.6.1 In spaces where penetration of oil products is possible, the surface of insulation is to be impervious to oil or oil vapours. Insulation boundaries are to be arranged to avoid immersion in oil spillages.

2.7 Means of escape

2.7.1 Stairways, ladders and corridors serving crew spaces and other spaces to which the crew normally have access are to be arranged so as to provide ready means of escape to a deck from which disembarkation may be effected.

2.7.2 Where reasonable and practicable, and having regard to the number of crew and size of space, at least two means of escape, as widely separated as possible, are to be provided from each section of accommodation spaces, service spaces and control stations:

(a) The normal means of access to the accommodation and service spaces below the open deck is to be arranged so that it is possible to reach the open deck without passing through intervening spaces containing a possible source of fire.

(b) The second means of escape may be through portholes, or hatches of adequate size, leading to the open deck.

(c) No dead-end corridors having a length of more than 7 m will be accepted. A 'dead-end corridor' is a corridor or part of a corridor from which there is only one escape route.

2.7.3 At least two means of escape are to be provided from machinery spaces, except where the small size of the machinery space makes it impractical. Escape is to be by steel ladders that are as widely separated as possible.

2.8 Ventilation systems

2.8.1 Ventilation fans are to be capable of being stopped, and main inlets and outlets of ventilation systems closed, from outside the spaces being served, *see also* Pt 16, Ch 2,17.6.

2.8.2 Ventilation ducts for Category 'A' machinery spaces and exhaust ducts for galleys of significant fire risk are not to pass through accommodation spaces, service spaces or control stations unless the ducts are constructed of steel and arranged to preserve the integrity of the division.

2.8.3 Ventilation ducts for accommodation spaces, service spaces or control stations are not to pass through Category 'A' machinery spaces unless the ducts are constructed of steel and arranged to preserve the integrity of the division.

2.8.4 Store-rooms containing highly flammable products are to be provided with ventilation arrangements that are separate from other ventilation systems. Ventilation is to be arranged to prevent the build-up of flammable vapours at high and low levels. The inlets and outlets of ventilators are to be positioned so that they do not draw from or vent into an area which would cause undue hazard, and are to be fitted with spark arrestors.

2.8.5 Ventilation systems serving Category 'A' machinery spaces are to be independent of systems serving other spaces.

2.8.6 All enclosed spaces containing free-standing fuel tanks are to be ventilated independently of systems serving other spaces.

2.8.7 Ventilation is to be provided to prevent the accumulation of dangerous concentrations of flammable gas that may be emitted from batteries. The requirements of Pt 16, Ch 2,12.5 are to be complied with.

2.8.8 Ventilation openings may be fitted in and under the lower parts of cabin and public space doors in corridor bulkheads. Ventilation grills are to be of non-combustible material. The total net area of any such openings is not to exceed 0,05 m^2. Bridging ducts are not allowed in fire divisions.

2.8.9 For additional requirements for the ventilation of domestic gaseous fuel, *see* 2.11.

2.9 Fuel arrangements

2.9.1 In service craft in which oil fuel is used, the arrangements for the storage, distribution and utilisation of the oil fuel are to be such as to ensure the safety of the service craft and persons on board. For details, *see* Pt 15, Ch 3.

2.9.2 Oil fuel tanks situated within the boundaries of Category 'A' machinery spaces are not to contain oil fuel having a flashpoint of less than 60°C.

2.9.3 Oil fuel, lubricating oil and other flammable oils are not to be carried in fore peak tanks.

2.10 Special arrangements in machinery spaces and, where necessary, other spaces

2.10.1 Openings are to be provided with closing appliances constructed so as to maintain the fire integrity of the machinery space boundaries.

2.10.2 The type of equipment installed and the layout of the craft are to take account of the risk and spread of fire. Special attention is to be paid to the surroundings of open flame devices, hot areas and main and auxiliary machinery, oil and fuel overflows, and uncovered oil and fuel pipes.

2.10.3 Fuel filling, storage, venting and supply systems are to be installed so as to minimise the risk of fire and explosion.

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2.10.4 Machinery components and accessories that require frequent maintenance and inspection are to be readily accessible.

2.10.5 Windows are not to be fitted in machinery space boundaries. This does not preclude the use of glass in control rooms within the machinery spaces.

2.10.6 In Category 'A' machinery spaces means of control are to be provided for:

(a) closure of openings which normally allow exhaust ventilation, and closure of ventilator dampers;
(b) permitting the release of smoke;
(c) stopping ventilating fans; and
(d) stopping forced and induced draught fans, oil fuel transfer pumps, oil fuel unit pumps and other similar fuel pumps.

2.10.7 The controls required in 2.10.6 are to be located outside the space concerned, in a position where they will not be cut off in the event of fire in the space they serve. Such controls and the controls for any required fire-extinguishing system are to be situated at one control position or grouped in as few positions as possible. Such positions are to have a safe access from the open deck. *See also* Pt 15, Ch 3,4.5.1 and 4.9.2.

2.11 Arrangements for gaseous fuel for domestic purposes

2.11.1 Where gaseous fuel is used for domestic purposes, the arrangements for the storage, distribution and utilisation of the fuel are to be such that, having regard to the hazards of fire and explosion which the use of such fuel may entail, the safety of the service craft and the persons onboard is preserved. The installation is to be in accordance with recognised National or International Standards.

2.11.2 Storage lockers for gas cylinders are to be provided with:

(a) effective ventilation;
(b) an outward-opening door accessible directly to the open deck; and
(c) gas-tight boundaries, including doors and other means of closing any openings therein, which form boundaries between such lockers and adjoining spaces.

2.11.3 Arrangements for storage on open deck will be specially considered.

2.12 Space heaters

2.12.1 Space heaters, if used, are to be fixed in position and so constructed as to reduce fire risks to a minimum. The design and location of these units are to be such that clothing, curtains or other similar materials cannot be scorched or set on fire by heat from the unit.

2.13 Fixed fire detection and fire-alarm systems

2.13.1 A fixed fire detection and fire-alarm system is to be installed in all Category 'A' machinery spaces and is to comply with the requirements of Pt 16, Ch 1,2.8.

2.13.2 In craft over 50 gross tons, where sleeping accommodation is provided on board, a fixed fire detection and fire-alarm system is to be installed in all stairways, service spaces, machinery spaces, control stations and accommodation spaces (except toilets, bathrooms, void spaces, etc.). The fixed fire detection and fire-alarm system is to be installed in accordance with Ch 4,2.

2.14 Fire pumps and fire main system

2.14.1 **Application**:

(a) Every service craft is to be provided with a fire pump(s), fire mains, hydrants and hoses as required by this Chapter.
(b) For very small service craft, where it is not considered possible to fit a fire pump, the arrangements will be specially considered.

2.14.2 **Capacity of fire pumps.** The capacity of the fixed main fire pump(s) is not to be less than:

$$Q = (0{,}15\,(L_R\,(B + D))^{1/2} + 2{,}25)^2$$

but need not exceed 25 m^3/hour

where

B = greatest moulded breadth of craft, in metres
D = moulded depth to bulkhead deck, in metres
L_R = Rule length of craft, as defined in Pt 3, Ch 1,6.2.1, in metres
Q = total capacity in m^3/hours.

2.14.3 **Fire pumps**:

(a) In service craft of 150 tons gross or more, a minimum of one fixed power pump and one portable pump, complying with 2.14.4, are to be provided.
(b) For service craft of less than 150 tons gross, one portable pump or alternative as required by 2.14.4, is to be provided.
(c) Sanitary, ballast, bilge or general service pumps may be accepted as fire pumps, provided that they are not normally used for pumping oil, and that, if they are subject to occasional duty for the transfer or pumping of fuel oil, suitable changeover arrangements are fitted.
(d) In service craft classed for navigation in ice, the fire pump sea inlet valves are to be provided with ice clearing arrangements, *see* Pt 1, Ch 2,3.8.1.
(e) Relief valves are to be provided in conjunction with any fire pumps if the pump is capable of developing a pressure exceeding the design pressure of the water service pipes, hydrants and hoses. These valves are to be so placed and adjusted as to prevent excessive pressure in any part of the fire main system.
(f) Where centrifugal pumps are provided in order to comply with this Section, a non-return valve is to be fitted in the pipe connecting each pump to the fire main.

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2.14.4 **Portable fire pumps**:

(a) Except for electric pumps, which will be specially considered, portable fire pumps are to comply with the following:
  (i) The pump is to be self priming.
  (ii) The suction head in operation is not to exceed 4,5 m.
  (iii) The portable fire pump is to be fitted with a length of discharge hose and nozzle capable of maintaining a pressure sufficient to produce a jet throw of at least 12 m, or that required to enable a jet of water to be directed on any part of the engine room or the exterior boundary of the engine room and casing, whichever is the greater. The jet throw required need not exceed the length of the craft.
  (iv) The pump set is to have its own fuel tank of sufficient capacity to operate the pump for three hours.
  (v) Details of the fuel type and storage location are to be submitted. If the fuel type has a flashpoint below 60°C, further consideration will be given to the fire safety aspects.
  (vi) The pump set is to be stored in a secure, safe and enclosed space, accessible from open deck and clear of the Category 'A' machinery space.
  (vii) The pump set is to be easily moved and operated by two persons and be readily available for immediate use.
  (viii) Arrangements are to be provided to secure the pump at its anticipated operating position(s).
  (ix) The overboard suction hose is to be non-collapsible and of sufficient length to cater for the craft's motion under all operational conditions. A suitable strainer is to be fitted at the inlet end of the hose.
  (x) Any diesel-driven power source for the pump is to be capable of being readily started in its cold condition down to a temperature of 0°C by hand (manual) cranking.

(b) If it is not possible to comply with the requirements of 2.14.4(a), an additional fixed fire pump will be required, which is to comply with the following:
  (i) The pump, its source of power and sea connection are to be located in accessible positions outside the Category 'A' machinery space, or in a different space to the main fire pump, if the main fire pump is located outside the Category 'A' machinery space. In the case of craft defined in 2.14.3(b), the pump may be situated in the Category 'A' machinery space, if so desired.
  (ii) The sea valve is to be capable of being operated from a position near the pump.
  (iii) The space where the fire pump prime mover is located is to be illuminated from the emergency source of electrical power, except for craft defined in 2.14.3(b), and is to be well ventilated.
  (iv) If the pump is required to supply water for a fixed fire-extinguishing system in the space where the main fire pumps are situated, it is to be capable of simultaneously supplying water to this system and the fire main at the required rates.
  (v) The pump may also be used for other suitable purposes, subject to approval in each case.
  (vi) The pressure and quantity of water delivered by the pump is to be sufficient to produce a jet of water at any nozzle of not less than 12 m.
  (vii) In the case of craft defined in 2.14.3(b), a fire main, hydrants and hoses are to be installed in accordance with 2.14.5 to 2.14.10.

(c) Means to illuminate the stowage area of the portable pump and its necessary areas of operation are to be provided from the emergency source of electrical power.

(d) If preferred, a pump complying with 2.14.4(b) may be fitted instead of a portable pump complying with 2.14.4(a).

2.14.5 **Fire main**:

(a) The diameter of the fire main is to be based on the required capacity of the fixed main fire pump(s). The diameter of the water service pipes are to be sufficient to ensure an adequate supply of water for the operation of at least one fire-hose.

(b) The wash deck line may be used as a fire main provided that the requirements of this Section are satisfied.

(c) All exposed water pipes for fire-extinguishing are to be provided with drain valves for use in frosty weather. The valves are to be located where they will not be damaged by cargo.

2.14.6 **Pressure in the fire main**. When the fixed main fire pump, or the fire pump described in 2.14.4(b), is delivering the quantity of water required by 2.14.2 through the fire main, fire hoses and nozzles, the pressure maintained at any hydrant is to be sufficient to produce a jet throw at any nozzle of not less than 12 m.

2.14.7 **Number and position of hydrants**. The number and position of the hydrants are to be such that at least one jet of water is to reach any part normally accessible to the crew while the service craft is being navigated and any part of any cargo space when empty. Furthermore, such hydrants are to be positioned near the accesses to the protected spaces. At least one hydrant is to be provided in each machinery space.

2.14.8 **Pipes and hydrants**:

(a) Materials readily rendered ineffective by heat are not to be used for fire mains. Where steel pipes are used, they are to be galvanised internally and externally. Cast iron pipes are not acceptable. The pipes and hydrants are to be so placed that the fire-hoses may be easily coupled to them. The arrangements of pipes and hydrants is to be such as to avoid the possibility of freezing. In service craft where deck cargo may be carried, the positions of the hydrants are to be such that they are always readily accessible and the pipes are to be arranged, as far as practicable, to avoid risk of damage by such cargo. Unless one hose and nozzle is provided for each hydrant in the service craft, there is to be complete interchange-ability of hose couplings and nozzles.

(b) A valve is to be fitted at each fire hydrant so that any fire-hose may be removed while the fire pumps are at work.

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(c) Where an additional fixed fire pump is fitted in accordance with 2.14.4(b) or 2.14.4(d):
  (i) An isolating valve is to be fitted in the fire main so that all the hydrants in the service craft, except those in the Category 'A' machinery space containing the main fire pump, can be supplied with water by the additional fixed fire pump. The isolating valve is to be located in an easily accessible and tenable position outside the Category 'A' machinery space; and
  (ii) The fire main is not to re-enter the machinery space downstream of the isolating valve.

2.14.9 **Fire-hoses:**

(a) Fire-hoses are to be of approved non-perishable material. The hoses are to be sufficient in length to project a jet of water to any of the spaces in which they may be required to be used. Their length, in general, is not to exceed 18 m. Each hose is to be provided with a nozzle and the necessary couplings. Fire-hoses, together with any necessary fittings and tools, are to be kept ready for use in conspicuous positions near the water service hydrants or connections.
(b) The number of fire-hoses to be provided, each complete with couplings and nozzles, is to be one for each 15 m length of the service craft, or part thereof, but need not exceed the number of hydrants provided. This number does not include any hoses required in any engine room. If necessary, the number of hoses is to be increased so as to ensure that hoses in sufficient numbers are available and accessible at all times.

2.14.10 **Nozzles:**

(a) For the purpose of this Chapter, standard nozzle sizes are to be 12 mm, 16 mm or 19 mm, or as near thereto as possible, so as to make full use of the maximum discharge capacity of the fire pump(s).
(b) For accommodation and service spaces, the nozzle size need not exceed 12 mm.
(c) The size of nozzles intended for use in conjunction with a portable fire pump need not exceed 12 mm.
(d) All nozzles are to be of an approved dual purpose type (i.e. spray/jet type) incorporating a shut-off.

2.15 Fire-extinguishing arrangements in Category 'A' machinery spaces

2.15.1 Except where provided for in 2.15.2, Category 'A' machinery spaces are to be provided with:

(a) one of the fixed fire-extinguishing systems given in Ch 4,3; and
(b) at least two portable foam extinguishers or equivalent, *see* Ch 4,6.3.2. Where internal combustion machinery is installed, an additional portable extinguisher is to be provided for every 375 kW of power output, but the total number of such additional extinguishers need not exceed five.

2.15.2 Where the size of the machinery space precludes access under normal operating conditions, provision is to be made such that a manually-released extinguishing medium, of a type allowed in Chapter 4, can be remotely discharged into the space. Such arrangements may utilise a portable extinguisher of adequate size. Details of the arrangements with supporting calculations are to be submitted for approval.

2.16 Fire-extinguishing appliances in other machinery spaces

2.16.1 Where a fire hazard exists in any machinery space for which no specific provisions for fire-extinguishing appliances are prescribed in 2.15 and 2.17, there is to be provided in, or adjacent to, that space a satisfactory number of approved portable fire-extinguishers or other approved means of fire-extinction.

2.17 Machinery spaces in craft which are constructed mainly or wholly of alternative forms of construction

2.17.1 Machinery spaces in craft which are constructed mainly or wholly with alternative forms of construction that contain internal combustion machinery, are to comply with the fire-extinguishing requirements for Category 'A' machinery spaces, *see* 2.15.1.

2.18 Fixed fire-extinguishing systems not required by this Chapter

2.18.1 Where a fixed fire-extinguishing system not required by this Chapter is installed, the arrangement is to comply with the relevant requirements of this Chapter.

2.19 Portable fire-extinguishers

2.19.1 All portable fire-extinguishers are to comply with the requirements of Ch 4,6.

2.19.2 The portable fire-extinguishers are to be stowed in readily accessible positions.

2.19.3 One of the portable fire-extinguishers intended for use in any space is to be stowed near the entrance to that space.

2.19.4 At least one portable fire-extinguisher is to be located so that it can easily be reached from the main steering position of the craft.

2.19.5 Accommodation spaces, service spaces and control stations are to be provided with a sufficient number of portable fire-extinguishers to ensure that at least one extinguisher will be readily available for use in every compartment.

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2.19.6 Where cooking facilities are provided a portable fire-extinguisher of a type appropriate to the energy source used is to be located in a position readily accessible for use in the event of a fire.

2.20 Fire blanket

2.20.1 A fire blanket is to be installed in all galleys.

2.21 Protection of paint lockers and flammable liquid lockers

2.21.1 Paint lockers and flammable liquid lockers with a deck area 4 m^2 or over are to be provided with a fixed fire-extinguishing system enabling the crew to extinguish a fire without entering the space. One of the following systems is to be provided:

- A carbon dioxide system designed for 40 per cent of the gross volume of the space.
- A dry powder system designed to discharge 0,5 kg powder per cubic metre of gross volume of the space.
- A water spray system designed to give a coverage of 5 litres per square metre of deck area per minute. Water spray systems may be connected to the fire main.

2.21.2 Consideration will be given to the acceptance of other arrangements which provide equivalent protection.

2.21.3 Lockers having a deck area of less than 4 m^2 may be protected by carbon dioxide or dry powder portable extinguishers located near the entrance to the locker.

2.22 Arrangements where deep-fat cooking equipment is installed

2.22.1 Where deep-fat cooking equipment is installed in high speed craft, all installations are to be fitted with:

(a) an automatic or manual fixed extinguishing system type approved in accordance with ISO 15371, *Ships and marine technology – Fire extinguishing systems for protection of galley deep-fat cooking equipment – Fire tests*, or an acceptable alternative National or International Standard, for protection of the deep-fat cooking equipment;

(b) a primary and back up thermostat with an alarm to alert the operator in the event of failure of either thermostat;

(c) means to automatically shut off the deep-fat cooking equipment electrical power upon activation of the fire-extinguishing system;

(d) an alarm for indicating operation of the fire-extinguishing system in the galley where the equipment is installed; and

(e) controls for manual operation of the fire-extinguishing system which are clearly labelled for ready use by the crew.

Control and electrical engineering arrangements are to be in accordance with the requirements of Pt 16, Ch 1 and Ch 2, as applicable.

2.23 Helicopter decks

2.23.1 The requirements of IMO Resolution A.855(20) are to be complied with having due regard to the hazards involved.

2.23.2 If a helicopter hangar is not provided and if two fireman's outfits are supplied as per 2.24.1, then the fireman's outfits required by IMO Resolution A.855(20) need not be provided.

2.24 Fireman's outfit

2.24.1 All service craft of 350 gross tons or more and having enclosed spaces which are normally accessible, are to carry at least two fireman's outfits complying with the requirements of Ch 4,4.

2.25 Fire-control plans

2.25.1 Fire-control plans are to meet the requirements of Ch 4,5.

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Section

1 **General requirements**

2 **Fire safety measures for yachts of overall length greater than 24 m but less than 500 gt**

3 **Fire safety measures for yachts 500 gt or more**

Section 1
General requirements

1.1 Application

1.1.1 The requirements of this Chapter apply to yachts with an overall length, L_{OA} (as defined in Pt 3, Ch 1,6.2.4) of 24 m or greater built in accordance with the Rules.

1.1.2 Where yachts incorporate fire hazards not covered in this Part, appropriate fire protection, detection and extinction arrangements are to be provided. Details are to be submitted for approval.

1.1.3 For yachts with an overall length of 24 m or more, and less than 500 gt, the fire safety measures are to comply with Section 2.

1.1.4 For yachts 500 gt or more, the fire safety measures are to comply with Section 3.

Section 2
Fire safety measures for yachts of overall length greater than 24 m but less than 500 gt

2.1 General

2.1.1 Table 3.2.1 is a guide to the major requirements of this Section. The Table is intended as a quick reference to the requirements and is not to be used in isolation when designing the fire safety arrangements.

Table 3.2.1 General fire protection, detection and extinction requirements

Form of construction, *see* 2.2	Steel or equivalent, or alternative forms of construction may be accepted subject to requirements
Passive fire protection, *see* 2.3 to 2.6	• Category 'A' machinery spaces 'A-30'/'A-0' • Galleys: 'B-15' where significant fire risk • Bulkheads in escape route corridors greater than 7 m in length: 'B-0' • Stairway enclosures: 'B-0'
Means of escape, *see* 2.7 • Category 'A' machinery spaces • Accommodation, etc.	} 2
Fixed fire detection system, *see* 2.13	• Fitted in machinery spaces • Fitted in service spaces, control stations and accommodation spaces
Fire pumps, *see* 2.14	1 fixed power pump + 1 portable pump
Fire extinguishing arrangements in Category 'A' machinery spaces, *see* 2.15	• A fixed fire-extinguishing system • A minimum of 2 and maximum of 5 portable foam extinguishers or equivalent
Portable fire-extinguishers in accommodation, *see* 2.18	At least 3
Automatic sprinkler system or equivalent, *see* 2.16	Fitted in yachts >350 gross tons

2.2 Forms of construction – Structure

2.2.1 The hull, superstructure, structural bulkheads, decks and deckhouses may be constructed of steel, other equivalent material, *see* Ch 1,2.1.2, or be of alternative forms of construction, *see* Ch 1,2.1.3.

2.2.2 The structure in way of Category 'A' machinery spaces, galleys containing appliances of significant fire risk, *see* 2.4.2, and other high risk areas is to be protected such that the material by itself or due to insulation provided can maintain its required strength at the end of 30 minutes exposure to the standard fire test.

2.2.3 Details of the method of construction, supported by calculations and/or fire test data, demonstrating compliance with 2.2.2 are to be submitted.

2.2.4 For aluminium alloy structures, the insulation is to be such that the temperature of the structural core does not rise more than 200°C above the ambient temperature at any time during the specified fire exposure.

2.2.5 For composite structures, the insulation is to be such that the temperature of the laminate does not rise more than the minimum temperature of deflection under load of the resin at any time during the specified fire exposure. The temperature of deflection under load is to be determined as in Ch 14,3.7 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

2.2.6 For structures in contact with sea-water, the required insulation should extend to at least 300 mm below the lightest waterline, *see also* 2.6.1.

2.3 Forms of construction – Fire divisions

2.3.1 Fire divisions required by 2.4 are to be constructed in accordance with the remaining paragraphs of this sub-Section.

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2.3.2 Fire divisions using steel equivalent, or alternative forms of construction may be accepted if it can be demonstrated that the material by itself, or due to insulation provided, has the fire resistance properties equivalent to 'A' or 'B' Class divisions.

2.3.3 Insulation required by 2.3.2 is to be such that the temperature of the structural core does not rise above the point at which the structure would begin to lose its strength at any time during the applicable exposure to the standard fire test. For 'A' Class divisions, the applicable exposure is 60 minutes, and for 'B' Class divisions, the applicable exposure is 30 minutes.

2.3.4 For aluminium alloy structures, the insulation is to be such that the temperature of the structural core does not rise more than 200°C above the ambient temperature at any time during the applicable fire exposure.

2.3.5 For composite structures, the insulation is to be such that the temperature of the laminate does not rise more than the minimum temperature of deflection under load of the resin at any time during the applicable fire exposure. The temperature of deflection under load is to be determined as in Ch 14,3.7 of the Rules for Materials.

2.4 Structural fire protection

2.4.1 Category 'A' machinery spaces, spaces containing vehicles or craft with fuel in their tanks, or lockers storing such fuels, are to be enclosed by 'A-30' Class divisions where adjacent to accommodation or service spaces, control positions or each other, and 'A-0' Class divisions elsewhere.

2.4.2 Galleys are to be enclosed by 'B-15' Class divisions, unless the cooking appliances contained therein have an insignificant fire risk:

(a) For the purposes of this Chapter, coffee automats, toasters, dishwashers, microwave ovens, water boilers and similar appliances each with a maximum power of 5 kW may be regarded as having an insignificant fire risk. Electrically-heated cooking plates and hot plates for keeping food warm, each of them having a maximum power of 2 kW and a surface temperature not above 150°C may also be regarded as having insignificant fire risk. If spaces containing this equipment are lockable, then means of cutting-off the power to the space are to comply with Pt 16, Ch 2,17.6.7.

(b) Other equipment such as fat fryers, open flame cookers, etc., would be regarded as having a significant fire risk.

2.4.3 Where forming escape routes, corridor bulkheads and ceilings may be constructed of combustible materials provided they have a non-combustible core such that the 'B-0' Class standard fire test criteria are met.

2.4.4 Stairways connecting spaces below the main deck to the deck above are to be protected at one level by at least 'B-0' Class divisions and self-closing doors.

2.4.5 Lift and dumbwaiter trunks are to be enclosed by at least 'B-0' Class divisions and self-closing doors.

2.4.6 Openings in 'A' and 'B' Class divisions are to be provided with permanently attached means of closing that are to be at least as effective for resisting fires as the divisions in which they are fitted.

2.4.7 Interior stairways serving machinery spaces, accommodation spaces, service spaces or control stations are to be of steel, or other equivalent material.

2.4.8 Where 'A' Class divisions are penetrated for the passage of electric cables, pipes, trunks, ducts, etc., or for girders, beams or other structural members, arrangements are to be made to ensure that the fire resistance is not impaired.

2.4.9 Where 'B' Class divisions are penetrated for the passage of electric cables, pipes, trunks, ducts, etc., or for the fitting of ventilation terminals, lighting fixtures and similar devices, arrangements are to be made to ensure that the fire resistance is not impaired.

2.4.10 Where the structure or 'A' Class divisions are required to be insulated, it is to be ensured that the heat from a fire is not transmitted through the intersections and terminal points of the divisions or penetrations to uninsulated boundaries. Where the insulation installed does not achieve this, arrangements are to be made to prevent this heat transmission by insulating the horizontal and vertical boundaries or penetrations for a distance of 450 mm.

2.5 Materials

2.5.1 Except in refrigerated compartments of service spaces, all insulation other than fire insulation is to be of not-readily ignitable type. Fire insulation is to be of the non-combustible type.

2.5.2 Pipes penetrating 'A' or 'B' Class divisions are to be of approved materials having regard to the temperature such divisions are required to withstand.

2.5.3 Pipes conveying oil or combustible liquids through accommodation and service spaces are to be of approved materials having regard to the fire risk.

2.5.4 Materials readily rendered ineffective by heat are not to be used for overboard scuppers, sanitary discharges and other outlets which are close to the waterline and where the failure of the material in the event of fire would give rise to danger of flooding.

2.5.5 Primary deck coverings within accommodation spaces, service spaces and control stations are to be of a type that will not readily ignite, or give rise to toxic or explosive hazards at elevated temperatures. Reference is also to be made to the IMO FTP Code, Annex 1, Parts 2 and 6.

2.5.6 Vapour barriers and adhesives used in conjunction with insulation, as well as insulation of pipe fittings for cold service systems need not be non-combustible, but they are to be kept to the minimum quantity practicable and their exposed surfaces are to have low flame spread characteristics.

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2.5.7 All waste receptacles are to be constructed of non-combustible materials with no openings in the sides or bottom.

2.6 Surface of insulation

2.6.1 In spaces where penetration of oil products is possible, the surface of the insulation is to be impervious to oil or oil vapours. Insulation boundaries are to be arranged to avoid immersion in oil spillages.

2.7 Means of escape

2.7.1 Stairways, ladders and corridors serving all spaces normally accessible are to be arranged so as to provide ready means of escape to a deck from which embarkation into survival craft may be effected.

2.7.2 Where reasonable and practicable, and having regard to the number of personnel involved and size of space, at least two means of escape, as widely separated as possible, are to be provided from each section of accommodation and service spaces and control stations:

(a) The normal means of access to the accommodation and service spaces below the open deck are to be arranged so that it is possible to reach the open deck without passing through intervening spaces containing a possible source of fire.

(b) Where accommodation arrangements are such that access to compartments is through another compartment, as is often the case with an Owner's suite, a second means of escape is to be provided. The second escape route is to be as remote as possible from the main escape route.

(c) This second means of escape may be through portholes, or hatches of adequate size, leading to the open deck.

(d) No dead-end corridors having a length of more than 7 m will be accepted. A 'dead-end corridor' is a corridor or part of a corridor from which there is only one escape route.

2.7.3 At least one of the means of escape from each space referred to in 2.7.2 is to be enclosed by 'B-0' Class divisions, unless it gives access directly to the open decks from the space.

2.7.4 At least two means of escape are to be provided from machinery spaces, except where the small size of the machinery space makes it impracticable. Escape is to be by steel ladders that are as widely separated as possible.

2.7.5 Lifts are not considered as forming a means of escape.

2.8 Ventilation systems

2.8.1 Ventilation fans are to be capable of being stopped, and main inlets and outlets of ventilation systems closed, from outside the spaces being served, *see* Pt 16, Ch 2,17.6.

2.8.2 Ventilation ducts for Category 'A' machinery spaces, exhaust ducts for galleys of significant fire risk, spaces containing vehicles or craft with fuel in their tanks, or lockers storing such fuels, are not to pass through accommodation spaces, service spaces or control stations unless the ducts are constructed of steel and arranged to preserve the integrity of the division.

2.8.3 Ventilation ducts for accommodation spaces, service spaces or control stations are not to pass through Category 'A' machinery spaces, spaces containing vehicles or craft with fuel in their tanks, or lockers storing such fuels, unless the ducts are constructed of steel and arranged to preserve the integrity of the division.

2.8.4 Store-rooms containing highly flammable products are to be provided with ventilation arrangements that are separate from other ventilation systems. Ventilation is to be arranged to prevent the build up of flammable vapours at high and low levels. The inlets and outlets of ventilators are to be positioned so that they do not draw from or vent into an area which would cause undue hazard, and are to be fitted with spark arresters.

2.8.5 Ventilation systems serving Category 'A' machinery spaces are to be independent of systems serving other spaces.

2.8.6 All enclosed spaces containing free-standing fuel tanks are to be ventilated independently of systems serving other spaces.

2.8.7 Ventilation is to be provided to prevent the accumulation of dangerous concentrations of flammable gas which may be emitted from batteries. The requirements of Pt 16, Ch 2,12.5 are to be complied with.

2.8.8 Ventilation openings may be fitted in and under the lower parts of cabin and public space doors in corridor bulkheads. The total net area of any such openings is not to exceed 0,05 m^2. Bridging ducts are not allowed in fire divisions.

2.8.9 For spaces containing vehicles or craft with fuel in their tanks or lockers storing such fuels, *see* 2.20.1(d). For additional requirements for the ventilation of domestic gaseous fuel, *see* 2.11.

2.9 Fuel arrangements

2.9.1 In yachts in which oil fuel is used, the arrangements for the storage, distribution and utilisation of the oil fuel are to be such as to ensure the safety of the yacht and persons on board. For details, *see* Pt 15, Ch 3.

2.9.2 Oil fuel tanks situated within the boundaries of Category 'A' machinery spaces are not to contain oil fuel having a flashpoint of less than 60°C.

2.9.3 Oil fuel, lubricating oil and other flammable oils are not to be carried in fore peak tanks.

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2.10 Special arrangements in Category 'A' machinery spaces and, where necessary, other machinery spaces

2.10.1 Openings are to be provided with closing appliances constructed so as to maintain the fire integrity of the machinery space boundaries.

2.10.2 The type of equipment installed and the layout of the yacht are to take account of the risk and spread of fire. Special attention is to be paid to the surroundings of open flame devices, hot areas and main and auxiliary machinery, oil and fuel overflows, and uncovered oil and fuel pipes.

2.10.3 Fuel filling, storage, venting and supply systems are to be installed so as to minimise the risk of fire and explosion.

2.10.4 Machinery components and accessories that require frequent maintenance and inspection are to be readily accessible.

2.10.5 Windows are not to be fitted in machinery space boundaries. This does not preclude the use of glass in control rooms within the machinery spaces.

2.10.6 Means of control are to be provided for:

(a) closure of openings which normally allow exhaust ventilation, and closure of ventilator dampers;
(b) permitting the release of smoke;
(c) stopping ventilating fans; and
(d) stopping forced and induced draught fans, oil fuel transfer pumps, oil fuel unit pumps and other similar fuel pumps.

2.10.7 The controls required in 2.10.6 are to be located outside the space concerned, where they will not be cut off in the event of fire in the space they serve. Such controls and the controls for any required fire-extinguishing system are to be situated at one control position or grouped in as few positions as possible. Such positions are to have a safe access from the open deck. *See also* Pt 15, Ch 3,4.5.1 and 4.9.2.

2.11 Arrangements for gaseous fuel for domestic purposes

2.11.1 Where gaseous fuel is used for domestic purposes, the arrangements for the storage, distribution and utilisation of the fuel are to be such that, having regard to the hazards of fire and explosion which the use of such fuel may entail, the safety of the yacht and the persons onboard is preserved. The installation is to be in accordance with recognised National or International Standards.

2.11.2 Storage lockers for gas cylinders are to be provided with:

(a) effective ventilation;
(b) an outward-opening door accessible directly to the open deck; and
(c) gas-tight boundaries, including doors and other means of closing any openings therein, which form boundaries between such lockers and adjoining spaces.

2.11.3 Arrangements for storage on open deck will be specially considered.

2.12 Space heaters

2.12.1 Space heaters, if used, are to be fixed in position and so constructed as to reduce fire risks to a minimum. The design and location of these units are to be such that clothing, curtains or other similar materials cannot be scorched or set on fire by heat from the unit.

2.13 Fixed fire detection and fire-alarm systems

2.13.1 A fixed fire detection and fire-alarm system are to be installed in all Category 'A' machinery spaces and are to comply with the requirements of Pt 16, Ch 1,2.8.

2.13.2 A fixed fire detection and fire-alarm system are to be fitted in all stairways (including lift and dumbwaiter trunks), service spaces, control stations and accommodation spaces (except toilets, bathrooms, void spaces, etc.). The fixed fire detection and fire-alarm system are to be installed in accordance with Ch 4,2.

2.13.3 All yachts at all times when at sea, or in port (except when out of service), are to be so equipped as to ensure that any initial fire-alarm is immediately received by a responsible member of the crew.

2.13.4 A special alarm, operated from the navigating bridge or fire-control station, is to be fitted to summon the crew.

2.14 Fire pumps and fire main system

2.14.1 **Application.** Every yacht is to be provided with a fire pump(s), fire mains, hydrants and hoses as required by this Section.

2.14.2 **Capacity of fire pumps.** The capacity of the fixed main fire pump(s) is not to be less than:

$$Q = (0{,}15\,(L_R\,(B + D))^{1/2} + 2{,}25)^2$$

but need not exceed 25 m^3/hour.

where

B = greatest moulded breadth of yacht, in metres
D = moulded depth to bulkhead deck, in metres
L_R = Rule length of yacht, as defined in Pt 3, Ch 1,6.2.1, in metres
Q = total capacity in m^3/hour.

2.14.3 **Fire pumps:**

(a) A minimum of one fixed power pump and one portable pump or alternative, complying with 2.14.4, are to be provided.
(b) Sanitary, ballast, bilge or general service pumps may be accepted as fire pumps, provided that they are not normally used for pumping oil, and that, if they are subject to occasional duty for the transfer or pumping of fuel oil, suitable changeover arrangements are fitted.

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(c) In yachts classed for navigation in ice, the fire pump sea inlet valves are to be provided with ice clearing arrangements, *see* Pt 1, Ch 2,3.8.1.

(d) Relief valves are to be provided in conjunction with any fire pump if the pump is capable of developing a pressure exceeding the design pressure of the water service pipes, hydrants and hoses. These valves are to be so placed and adjusted as to prevent excessive pressure in any part of the fire main system.

(e) Where centrifugal pumps are provided in order to comply with this Section, a non-return valve is to be fitted in the pipe connecting each pump to the fire main.

2.14.4 **Portable fire pumps**:

(a) Except for electric pumps, which will be specially considered, portable fire pumps are to comply with the following:

(i) The pump is to be self priming.

(ii) The suction head in operation is not to exceed 4,5 m.

(iii) The portable fire pump is to be fitted with a length of discharge hose and nozzle capable of maintaining a pressure sufficient to produce a jet throw of at least 12 m or that required to enable a jet of water to be directed on any part of the engine room or the exterior boundary of the engine room and casing, whichever is the greater.

(iv) The pump set is to have its own fuel tank of sufficient capacity to operate the pump for three hours.

(v) Details of the fuel type and storage location are to be submitted. If the fuel type has a flashpoint below 60°C, further consideration will be given to the fire safety aspects.

(vi) The pump set is to be stored in a secure, safe and enclosed space, accessible from open deck and clear of the Category 'A' machinery space.

(vii) The pump set is to be easily moved and operated by two persons and be readily available for immediate use.

(viii) Arrangements are to be provided to secure the pump at its anticipated operating position(s).

(ix) The overboard suction hose is to be non-collapsible and of sufficient length to cater for the yacht's motion under all operational conditions. A suitable strainer is to be fitted at the inlet end of the hose.

(x) Any diesel driven power source for the pump is to be capable of being readily started in its cold condition down to a temperature of 0°C by hand (manual) cranking.

(b) If it is not possible to comply with the requirements of 2.14.4(a), an additional fixed fire pump will be required, which is to comply with the following:

(i) The pump, its source of power and sea connection are to be located in accessible positions outside the Category 'A' machinery space, or in a different space to the main fire pump, if the main fire pump is located outside the Category 'A' machinery space.

(ii) The sea valve is to be capable of being operated from a position near the pump.

(iii) The room where the fire pump prime mover is located is to be illuminated from the emergency source of electrical power and is to be well ventilated.

(iv) If the pump is required to supply water for a fixed fire-extinguishing system in the space where the main fire pumps are situated, it is to be capable of simultaneously supplying water to this system and the fire main at the required rates.

(v) The pump may also be used for other suitable purposes, subject to approval in each case.

(vi) The pressure and quantity of water delivered by the pump are to be sufficient to produce a jet of water at any nozzle of not less than 12 m.

(c) Means to illuminate the stowage area of the portable pump and its necessary areas of operation are to be provided from the emergency source of electrical power.

(d) If preferred, a pump complying with 2.14.4(b) may be fitted instead of a portable pump complying with 2.14.4(a), *see also* 2.14.8(c).

2.14.5 **Fire main**:

(a) The diameter of the fire main is to be based on the required capacity of the fixed main fire pump(s). The diameter of the water service pipes is to be sufficient to ensure an adequate supply of water for the operation of at least one fire-hose.

(b) The wash deck line may be used as a fire main provided that the requirements of this Section are satisfied.

(c) All exposed water pipes for fire-extinguishing are to be provided with drain valves for use in frosty weather. The valves are to be located where they will not be damaged.

2.14.6 **Pressure in the fire main**. When the fixed main fire pump, or the fire pump described in 2.14.4(b), is delivering the quantity of water required by 2.14.2 through the fire main, fire-hoses and nozzles, the pressure maintained at any hydrant is to be sufficient to produce a jet throw at any nozzle of not less than 12 m.

2.14.7 **Number and position of hydrants**. The number and position of the hydrants are to be such that at least one jet of water is to reach any part normally accessible to any person while the yacht is being navigated. Furthermore, such hydrants are to be positioned near the accesses to the protected spaces. At least one hydrant is to be provided in each Category 'A' machinery space.

2.14.8 **Pipes and hydrants**:

(a) Materials readily rendered ineffective by heat are not to be used for fire mains. For the use of aluminium alloy *see* Pt 15, Ch 1,10.1.4. Where steel pipes are used, they are to be galvanised internally and externally. Cast iron pipes are not acceptable. The pipes and hydrants are to be so placed that the fire-hoses may be easily coupled to them. The arrangement of pipes and hydrants is to be such as to avoid the possibility of freezing. Unless one hose and nozzle is provided for each hydrant in the yacht, there is to be complete interchangeability of hose couplings and nozzles.

(b) A valve is to be fitted at each fire hydrant so that any fire-hose may be removed while the fire pump is at work.

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(c) Where an additional fixed fire pump is fitted in accordance with 2.14.4(b) or 2.14.4(d):
  (i) An isolating valve is to be fitted in the fire main so that all the hydrants in the yacht, except those in the Category 'A' machinery space containing the main fire pump, can be supplied with water by the additional fixed fire pump. The isolating valve is to be located in an easily accessible and tenable position outside the Category 'A' machinery space; and
  (ii) the fire main is not to re-enter the machinery space downstream of the isolating valve.

2.14.9 **Fire-hoses**:

(a) Fire-hoses are to be of approved non-perishable material. The hoses are to be sufficient in length to project a jet of water to any of the spaces in which they may be required to be used. Their length, in general, is not to exceed 18 m. Each hose is to be provided with a nozzle and the necessary couplings. Fire-hoses, together with any necessary fittings and tools, are to be kept ready for use in conspicuous positions near the water service hydrants or connections.
(b) A minimum of three fire-hoses are to be provided, each complete with couplings and nozzles. These numbers do not include any hoses required in any engine room. If necessary, the number of hoses is to be increased so as to ensure that hoses in sufficient number are available and accessible at all times.

2.14.10 **Nozzles**:

(a) For the purpose of this Chapter, standard nozzle sizes are to be 12 mm, 16 mm or 19 mm, or as near thereto as possible, so as to make full use of the maximum discharge capacity of the fire pump or pumps.
(b) For accommodation and service spaces, the nozzle size need not exceed 12 mm.
(c) The size of nozzles intended for use in conjunction with a portable fire pump need not exceed 12 mm.
(d) All nozzles are to be of an approved dual purpose type (i.e. spray/jet type) incorporating a shut-off.

2.15 Fire-extinguishing arrangements in machinery spaces

2.15.1 **Category 'A' machinery spaces** are to be provided with:

(a) One of the fixed fire-extinguishing systems given in Ch 4,3; and
(b) at least two portable foam extinguishers or equivalent, *see* Ch 4,6.3.2. Where internal combustion machinery is installed, an additional portable extinguisher is to be provided for every 375 kW of power output, but the total number of such additional extinguishers need not exceed five.

2.15.2 **Fire-extinguishing appliances in other machinery spaces.** Where a fire hazard exists in any machinery space for which no specific provisions for fire-extinguishing appliances are prescribed in 2.15.1 or 2.15.3 there is to be provided in or adjacent to that space, a satisfactory number of approved portable fire-extinguishers or other approved means of fire-extinction.

2.15.3 **Machinery spaces, other than Category 'A', in yachts which are constructed mainly or wholly with alternative forms of construction.** In yachts that are constructed mainly or wholly with alternative forms of construction, machinery spaces, other than Category 'A', containing internal combustion machinery, are to comply with the fire-extinguishing requirements for Category 'A' machinery spaces, *see* 2.15.1.

2.16 Automatic sprinkler, fire detection and fire-alarm system

2.16.1 A fixed automatic sprinkler must be fitted in yachts over 350 gross tons, fire detection and fire-alarm system, or equivalent system (e.g. watermist), are to be fitted in all stairways, service spaces, control stations and accommodation spaces, except in general, in spaces which afford no fire risk such as void spaces.

2.16.2 The arrangements are to be in accordance with Ch 4,1, particular attention should be given to Ch 4,1.2.16 and 1.2.17.

2.17 Fixed fire-extinguishing systems not required by this Section

2.17.1 Where a fixed fire-extinguishing system not required by this Chapter is installed, the arrangement is to comply with the relevant requirements of this Chapter.

2.18 Portable fire-extinguishers

2.18.1 All portable fire-extinguishers are to comply with the requirements of Ch 4,6.

2.18.2 The portable fire-extinguishers are to be stowed in readily accessible positions.

2.18.3 One of the portable fire-extinguishers intended for use in any space is to be stowed near the entrance to that space.

2.18.4 At least one portable fire-extinguisher is to be located so that it can easily be reached from the main steering position of the yacht.

2.18.5 Accommodation spaces, service spaces and control stations are to be provided with a sufficient number of portable fire-extinguishers to ensure that at least one extinguisher will be readily available for use in every compartment. In any case, their number is to be not less than three.

2.18.6 Where cooking facilities are provided, a portable fire-extinguisher of a type appropriate to the energy source used is to be located in a position readily accessible for use in the event of a fire.

2.19 Fire blanket

2.19.1 A fire blanket is to be installed in all galleys.

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2.20 Protection of spaces containing vehicles or craft with fuel in their tanks or lockers storing such fuels

2.20.1 Spaces containing vehicles or craft with fuel in their tanks, or lockers storing such fuels, are to be provided with the following:

(a) A fixed fire detection and fire-alarm system complying with the requirements of Pt 16, Ch 1,2.8.

(b) A manually-operated water spray deluge system having a water application rate of 5 litres per square metre of deck area per minute. Where the deck height does not exceed 2,5 m, an application rate of 3,5 litres per square metre of deck area per minute will be accepted. Adequate drainage of the protected spaces is to be provided generally in accordance with the requirements for vehicle or cargo spaces, *see* Pt 3, Ch 4,9.4.4. The drainage piping and connection for the space are to be non-combustible. Other fixed fire-extinguishing systems may be permitted, provided they are not less effective in controlling the type of fire likely to occur.

(c) At least two portable foam extinguishers or equivalent.

(d) An independent mechanical ventilation system, which is entirely separate from other ventilation systems, providing at least six air changes per hour. The ducted air is not to pass through other spaces, except as allowed under 2.8.2, or vent into areas where it could be drawn into accommodation areas or cause undue hazard.

(e) Electrical equipment of a safe type is to be provided, *see* Pt 16, Ch 2,14.

(f) Prominently displayed 'No Smoking' signs.

(g) 'A-30' Class divisions where adjacent to Category 'A' machinery spaces, accommodation or service spaces, or control positions and 'A-0' Class divisions elsewhere.

2.20.2 Such spaces are not to give access to any space other than the fuel store or lockers for use within the space. Lockers storing fuel are to be accessed from an exterior location, unless the locker is within the space containing the vehicles or craft. Exceptionally, where the engine room escape cannot be routed elsewhere, it may exit into the space providing that:

(a) the connecting door is self-closing;

(b) no door hold back devices are fitted;

(c) an audible and visual alarm is fitted on the bridge to signify when the door is open; and

(d) a notice is posted at the door stating that the door is to remain closed and that the area beside the door is an escape route and is to be kept clear.

2.20.3 The requirements of 2.9 are to be complied with, as appropriate.

2.21 Protection of paint lockers and flammable liquid lockers

2.21.1 Paint lockers and flammable liquid lockers with a deck area of 4 m^2 or more are to be provided with a fixed fire-extinguishing system enabling the crew to extinguish a fire without entering the space. One of the following systems is to be provided:

- A carbon dioxide system designed for 40 per cent of the gross volume of the space.
- A dry powder system designed to discharge 0,5 kg powder per cubic metre of gross volume of the space.
- A water spray system designed to give a coverage of 5 litres per square metre of deck area per minute. Water spray systems may be connected to the fire main.

2.21.2 Consideration will be given to the acceptance of other arrangements which provide equivalent protection.

2.21.3 Lockers having a deck area of less than 4 m^2 may be protected by carbon dioxide or dry powder portable extinguishers located near the entrance to the locker.

2.22 Helicopter decks

2.22.1 The requirements of IMO Resolution A.855(20) are to be complied with having due regard to the hazards involved.

2.22.2 If a helicopter hangar is not provided and if two fireman's outfits are supplied as in 2.23.1, then the fireman's outfits required by IMO Resolution A.855(20) need not be provided.

2.23 Fireman's outfit

2.23.1 All yachts of 350 gross tons or more are to carry at least two fireman's outfits complying with the requirements of Ch 4,4.

2.24 Fire-control plans

2.24.1 Fire control plans are to meet the requirements of Ch 4,5.

■ *Section 3*
Fire safety measures for yachts 500 gt or more

3.1 General

3.1.1 Table 3.3.1 is a guide to the major requirements of this Section. The Table is intended as a quick reference to the requirements and is not to be used in isolation when designing the fire safety arrangements.

3.2 Forms of construction – Structure

3.2.1 The hull, superstructure, structural bulkheads, decks and deckhouses may be constructed of steel, other equivalent material, *see* Ch 1,2.1.2 or be of alternative forms of construction, *see* Ch 1,2.1.3.

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Table 3.3.1 General fire protection, detection and extinction requirements

Form of construction, *see* 3.2	Steel or equivalent, or alternative forms of construction may be accepted subject to extensive insulation requirements
Passive fire protection, *see* 3.3 to 3.12	*See* Table 3.3.2 and Table 3.3.3
Means of escape, *see* 3.15: • Category 'A' machinery spaces • Accommodation, etc.	2
Fixed fire detection system, *see* 3.24	• Fitted in machinery spaces • Fitted in service spaces, control stations and accommodation spaces
Fire pumps, *see* 3.25.1 to 3.25.10	• In general, 2 independent power pumps • For yachts of ≥4000 gross tons: 3 independent power pumps • A fire in any one compartment is not to put all the fire pumps out of action
International shore connection, *see* 3.25.11	At least 1
Fire extinguishing arrangements in Category 'A' machinery spaces, *see* 3.26. *See also* 3.27 for oil fuel units	• A fixed fire extinguishing system • Portable air-foam equipment • 45 litre foam extinguisher • Portable foam extinguishers within 10 m walking distance
Portable fire-extinguishers in accommodation, *see* 3.32	Sufficient to ensure that at least one will be readily available in every compartment, but a minimum of five
Automatic sprinkler system or equivalent, *see* 3.29	Fitted in all yachts
Fireman's outfits, *see* 3.38	At least 2

3.2.2 The structure in way of Category 'A' machinery spaces, galleys containing appliances of significant fire risk and other high risk areas is to be protected such that the material by itself or due to insulation provided can maintain its required strength at the end of 60 minutes exposure to the standard fire test.

3.2.3 Details of the method of construction, supported by calculations and/or fire test data, demonstrating compliance with 3.2.2 are to be submitted.

3.2.4 For aluminium alloy structures, the insulation is to be such that the temperature of the structural core does not rise more than 200°C above the ambient temperature at any time during the specified fire exposure.

3.2.5 For composite structures, the insulation is to be such that the temperature of the laminate does not rise more than the minimum temperature of deflection under load of the resin at any time during the specified fire exposure. The temperature of deflection under load is to be determined as in Ch 14,3.7 of the Rules for Materials.

3.2.6 For structures in contact with sea-water, the required insulation should extend to at least 300 mm below the lightest waterline, *see also* 2.6.1.

3.3 Forms of construction – Fire divisions

3.3.1 Fire divisions required by 3.4 are to be constructed in accordance with the remaining paragraphs of 3.3.

3.3.2 Fire divisions using steel equivalent, or alternative forms of construction, may be accepted if it can be demonstrated that the material by itself due to insulation provided, has the fire resistance properties equivalent to 'A' or 'B' Class divisions.

3.3.3 Insulation required by 3.3.2 is to be such that the temperature of the structural core does not rise above the point at which the structure would begin to lose its strength at any time during the applicable exposure to the standard fire test. For 'A' Class divisions, the applicable exposure is 60 minutes, and for 'B' Class divisions, the applicable exposure is 30 minutes.

3.3.4 For aluminium alloy structures, the insulation is to be such that the temperature of the structural core does not rise more than 200°C above the ambient temperature at any time during the applicable fire exposure.

3.3.5 For composite structures, the insulation is to be such that the temperature of the laminate does not rise more than the minimum temperature of deflection under load of the resin at any time during the applicable fire exposure. The temperature of deflection under load is to be determined as in Ch 14,3.7 of the Rules for Materials.

3.4 Structural fire protection – Main vertical zones and horizontal zones

3.4.1 The hull, superstructure and deckhouses in way of accommodation and service spaces are to be subdivided into main vertical zones by 'A' Class divisions, *see* Ch 1,2.4.12. These divisions are to have insulation values in accordance with Tables 3.3.2 and 3.3.3.

3.4.2 As far as practicable, the bulkheads forming the boundaries of the main vertical zones above the bulkhead deck are to be in line with watertight subdivision bulkheads situated immediately below the bulkhead deck.

3.4.3 The bulkheads mentioned in 3.4.2 are to extend from deck to deck and to the shell or other boundaries.

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Table 3.3.2 Fire integrity of bulkheads separating adjacent spaces

Spaces		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Control stations	(1)	'A-0' *See* Note 3	'A-0'	'A-60'	'A-0'	'A-15'	'A-60'	'A-15'	'A-60'	*See* Note 7
Corridors	(2)	—	C *See* Note 4	'B-0' *See* Note 4	'A-0' *See* Note 1 'B-0' *See* Note 4	'B-0' *See* Note 4	'A-60'	'A-0'	'A-15' 'A-0' *See* Note 6	*See* Note 7
Accommodation spaces	(3)	—	—	C *See* Note 4	'A-0' *See* Note 1 'B-0' *See* Note 4	'B-0' *See* Note 4	'A-60'	'A-0'	'A-15' 'A-0' *See* Note 6	*See* Note 7
Stairways	(4)	—	—	—	'A-0' *See* Note 1 'B-0' *See* Note 4	'A-0' *See* Note 1 'B-0' *See* Note 4	'A-60'	'A-0'	'A-15' 'A-0' *See* Note 6	*See* Note 7
Service spaces (low risk)	(5)	—	—	—	—	C *See* Note 4	'A-60'	'A-0'	'A-0'	*See* Note 7
Machinery spaces of Category 'A' and spaces containing vehicles or craft with fuel in their tanks or lockers storing such fuels	(6)	—	—	—	—	—	'A-60' *See* Note 2	'A-0'	'A-60'	*See* Note 7
Other machinery spaces	(7)	—	—	—	—	—	—	'A-0' *See* Note 2	'A-0'	*See* Note 7
Service spaces (high risk)	(8)	—	—	—	—	—	—	—	'A-0' *See* Note 2	*See* Note 7
Open decks	(9)	—	—	—	—	—	—	—	—	—

NOTES
1. For clarification as to which applies, *see* 3.7.
2. Where spaces are of the same numerical category and Note 2 appears, a bulkhead or deck of the ratings shown in the Table is only required when the adjacent spaces are for a different purpose, e.g. in category (8), a galley next to a galley does not require a bulkhead, but a galley next to a paint room requires an 'A-0' Class bulkhead.
3. Bulkheads separating the wheelhouse and chartroom from each other may be 'B-0' rating.
4. For the application of 3.4.1 all 'B-0' and 'C' Class bulkheads where appearing in this Table are to be taken as 'A-0' Class.
5. Fire insulation need not be fitted if the machinery space of category (7) has little or no fire risk.
6. Where the spaces are protected by the sprinkler system on both sides of the division, the division may be 'A-0' Class. Where the sprinkler system only protects a space on one side of the division the rating is to be the higher of the two values given.
7. The division is to be of steel, other equivalent material, or alternative forms of construction, but is not required to be of 'A' Class standard. However, where decks, except open decks, are penetrated for the passage of electric cables, pipes and vent ducts, such penetrations are to be made tight to prevent the passage of flame and smoke.
8. For requirements for main vertical zones, *see* 3.4.1.

3.5 Structural fire protection of bulkheads within a main vertical zone

3.5.1 All such divisions may be faced with combustible materials.

3.5.2 When continuous 'B' Class ceilings and/or linings are fitted on both sides of the bulkhead, the portion of the bulkhead behind the continuous ceiling or lining is to be of material which in thickness and composition is acceptable in the construction of 'B' Class divisions but which may meet 'B' Class standards only insofar as is reasonable and practicable.

3.5.3 All bulkheads required to be 'B' Class divisions, except corridor bulkheads prescribed in 3.5.2, are to extend from deck to deck and to the shell or other boundaries unless continuous 'B' Class ceilings or linings fitted on both sides of the bulkhead are at least of the same fire resistance as the bulkhead, in which case the bulkhead may terminate at the continuous ceiling or lining.

3.6 Structural fire protection – Fire integrity of bulkheads and decks

3.6.1 In addition to complying with the specific provisions for fire integrity of bulkheads and decks mentioned elsewhere in this Section the minimum fire integrity of bulkheads and decks are to be as prescribed in Tables 3.3.2 and Table 3.3.3.

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Table 3.3.3 Fire integrity of decks separating adjacent spaces

		Space above								
Space below		*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*
Control stations	*(1)*	'A-0'	'A-0'	'A-0'	'A-0'	'A-0'	'A-60'	'A-0'	'A-0'	*See* Note 3
Corridors	*(2)*	'A-0'	*See* Note 3	*See* Note 3	'A-0'	*See* Note 3	'A-60'	'A-0'	'A-0'	*See* Note 3
Accommodation spaces	*(3)*	'A-60'	'A-0'	*See* Note 3	'A-0'	*See* Note 3	'A-60'	'A-0'	'A-0'	*See* Note 3
Stairways	*(4)*	'A-0'	'A-0'	'A-0'	*See* Note 3	'A-0'	'A-60'	'A-0'	'A-0'	*See* Note 3
Service spaces (low risk)	*(5)*	'A-15'	'A-0'	'A-0'	'A-0'	*See* Note 3	'A-60'	'A-0'	'A-0'	*See* Note 3
Machinery spaces of Category 'A' and spaces containing vehicles or craft with fuel in their tanks or lockers storing such fuels	*(6)*	'A-60'	'A-60'	'A-60'	'A-60'	'A-60'	'A-60'	'A-60' *See* Note 1	'A-60'	*See* Note 3
Other machinery spaces	*(7)*	'A-15'	'A-0'	'A-0'	'A-0'	'A-0'	'A-0'	*See* Note 3	'A-0'	*See* Note 3
Service spaces (high risk)	*(8)*	'A-60' 'A-0' *See* Note 2	'A-30' 'A-0' *See* Note 2	'A-30' 'A-0' *See* Note 2	'A-30'	'A-0'	'A-60'	'A-0'	'A-0'	*See* Note 3
Open decks	*(9)*	*See* Note 3	*See* Note 3	*See* Note 3	*See* Note 3	*See* Note 3	*See* Note 3	*See* Note 3	*See* Note 3	—

NOTE
1. Fire insulation need not be fitted if the machinery space of category (7) has little or no fire risk.
2. Where the spaces are protected by the sprinkler system on both sides of the division, the division may be 'A-0' Class. Where the sprinkler system only protects a space on one side of the division the rating is to be the higher of the two values given.
3. The division is to be of steel, other equivalent material, or alternative forms of construction, but is not required to be of 'A' Class standard. However, where decks, except open decks, are penetrated for the passage of electric cables, pipes and vent ducts, such penetrations are to be made tight to prevent the passage of flame and smoke.

3.6.2 For determining the appropriate fire integrity standards to be applied to divisions between adjacent spaces, such spaces are classified in Table 3.3.2 and Table 3.3.3 according to their fire-risk as shown in space categories ***(1)*** to ***(9)***. The title of each category is intended to be typical (general) rather than restrictive. The number in parentheses preceding each space category refers to the applicable column or row in the Tables.

(1) Control stations:
- Spaces containing emergency sources of power and lighting.
- Wheelhouse and chartroom.
- Spaces containing the ship's radio equipment.
- Fire-extinguishing rooms, fire-control stations and fire recording stations.
- Control room for propulsion machinery when located outside the machinery space.
- Spaces containing centralised fire-alarm equipment.

(2) Corridors:
- Guest and crew corridors and lobbies.

(3) Accommodation spaces:
- Spaces as defined in Ch 1,2.4.5 excluding corridors.

(4) Stairways:
- Interior stairways, lifts and escalators (other than those wholly contained within the machinery spaces) and enclosures thereto.
- In this connection, a stairway which is enclosed only at one level is to be regarded as part of the space from which it is not separated by a fire door.

(5) Service spaces (low risk):
- Lockers and store-rooms having areas of less than 4 m^2, drying rooms and laundries.

(6) Category 'A' machinery spaces, spaces containing vehicles or craft with fuel in their tanks, or lockers storing such fuels:
- Spaces as defined in Ch 1,2.4.8.

(7) Other machinery spaces:
- Spaces as defined in Ch 1,2.4.9 excluding Category 'A' machinery spaces.

(8) Service spaces (high risk):
- Galleys, pantries containing cooking appliances, paint and lamp rooms, lockers and store-rooms having areas of 4 m^2 or more, spaces for the storage of flammable liquids, bonded stores and workshops other than those forming part of the machinery spaces.

(9) Open decks:
- Open deck spaces and enclosed promenades having no fire-risk. Air spaces (the space outside superstructures and deckhouses).

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3.6.3 Continuous 'B' Class ceilings or linings, in association with the relevant decks or bulkheads, may be accepted as contributing, wholly or in part, to the required insulation and integrity of a division.

3.7 Structural fire protection – Protection of stairways and lifts in accommodation and service spaces

3.7.1 All stairways are to be of steel construction except where the use of other equivalent material is specially approved, and are to be within enclosures formed of 'A' Class divisions, with positive means of closure at all openings, except that:

(a) A stairway connecting only two decks need not be enclosed, provided that the integrity of the deck is maintained by proper bulkheads or doors at one level to at least 'B-0' Class. When a stairway is closed at one level, the stairway enclosure is to be protected in accordance with Tables 3.3.2 and 3.3.3; and

(b) Stairways may be fitted in the open in a public space, provided that they lie wholly within such public space.

3.7.2 Stairway enclosures are to have a direct access to the corridors and to be of sufficient area to prevent congestion, having in view the number of persons likely to use them in an emergency. Within the perimeter of such stairway enclosures, only toilets and lockers of non-combustible material providing storage for safety equipment are permitted. Only public spaces, corridors, other escape stairways required by 3.15.1(e), pantries containing cooking appliances with an insignificant fire risk, *see* 2.4.2, and external areas are to have direct access to these stairway enclosures. Small corridors or lobbies may be used to separate an enclosed stairway from other spaces.

3.7.3 Lift trunks are to be so fitted as to prevent the passage of smoke and flame from one 'tween deck to another and are to be provided with means of closing so as to permit the control of draught and smoke.

3.8 Structural fire protection – Openings in 'A' Class divisions

3.8.1 The construction of all doors and door frames in 'A' Class divisions, and the means of securing them when closed, is to provide resistance to fire as well as to the passage of smoke and flame, as far as practicable, equivalent to that of the bulkheads in which the doors are situated. Such doors and door frames are to be constructed of steel or other equivalent material. Steel watertight doors need not be insulated.

3.8.2 It is to be possible for each door to be opened and closed from each side of the bulkhead by one person only.

3.8.3 Fire doors in main vertical zone bulkheads and stairway enclosures are to satisfy the following requirements:

(a) The doors shall be self-closing and be capable of closing with an angle of inclination of up to 3,5° opposing closure. The approximate time of closure for hinged fire-doors is to be no more than 40 s and not less than 10 s from the beginning of their movement with the ship in the upright position. The approximate uniform rate of closure for sliding fire doors is to be no more than 0,2 m/s and no less than 0,1 m/s with the ship in the upright position.

(b) Remote-controlled sliding or power-operated doors are to be equipped with an alarm that will sound not less than 5 s but no more than 10 s before the door begins to move and will continue to sound until the door is completely closed. Doors designed to re-open upon contacting an object in its path are to re-open sufficiently to allow a clear passage of at least 0,75 m but not more than 1 m.

(c) All doors are to be capable of remote and automatic release from the continuously manned central control station, either simultaneously or in groups and also individually from a position at both sides of the door. Indication is to be provided at the fire control panel in the continuously manned central control station whether each of the remotely-controlled doors are closed. The release mechanism is to be so designed that the door will automatically close in the event of disruption of the control system or central power supply. Release switches shall have an on-off function to prevent automatic resetting of the system. Hold-back devices not subject to central control station release are not permitted.

(d) Local power accumulators for power-operated doors are to be located in the immediate vicinity of the doors. They are to have the capacity to enable the doors to be fully opened and closed at least 10 times using local controls.

(e) Double-leaf doors dependent on a latch to maintain their fire integrity are to be arranged so that the latch is automatically activated by the action of the closing doors.

(f) Doors which are power-operated and automatically closed, giving direct access to special category spaces need not be equipped with the alarms and remote release mechanisms required by (b) and (c).

(g) The components of the local control system are to be accessible for maintenance and adjusting.

3.8.4 Where 'A' Class divisions are penetrated for the passage of electric cables, pipes, trunks, ducts, etc., or for girders, beams or other structural members, arrangements are to be made to ensure that the fire resistance is not impaired.

3.9 Structural fire protection – Openings in steel outer boundaries

3.9.1 The requirements for steel or other equivalent material on the outer boundaries of a yacht do not apply to glass partitions, windows and sidescuttles. The requirements of 3.11.2 for such boundaries to have 'A' class integrity are to be adhered to.

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3.10 Structural fire protection – Openings in 'B' Class divisions

3.10.1 Doors and door frames in 'B' Class divisions and means of securing them are to provide a method of closure which has resistance to fire as far as practicable equivalent to the divisions they serve, except that ventilation openings may be permitted in the lower portion of such doors. Where such openings are in or under a door the total net area of any such opening or openings is not to exceed 0,05 m^2. When such an opening is cut in a door it is to be fitted with a grill made of non-combustible material. Bridging ducts are not allowed in fire divisions.

3.10.2 Cabin doors in 'B' class divisions are to be self-closing. Hold-backs are not permitted.

3.10.3 Where 'B' Class divisions are penetrated for the passage of electric cables, pipes, trunks, ducts, etc., or for the fitting of ventilation terminals, lighting fixtures and similar devices, arrangements are to be made to ensure that the fire resistance is not impaired.

3.11 Structural fire protection – Windows and side scuttles

3.11.1 Notwithstanding the requirements of Table 3.3.2 and Table 3.3.3, all windows and side scuttles in bulkheads separating accommodation and service spaces and control stations from weather are to be constructed with frames of steel or other suitable material. The glass is to be retained by a metal glazing bead or angle. Alternative forms of construction and retention will be considered.

3.11.2 Glass is not to be installed as an interior main vertical zone or stairway enclosure bulkhead.

3.11.3 For yachts having a freeboard length of 85 m and over, windows and side scuttles situated in the yacht's side shell below the life raft and escape slide embarkation areas and below lifeboat embarkation areas are to have fire integrity of at least equal to 'A-0' Class.

3.12 Structural fire protection – Details of construction

3.12.1 In accommodation and services spaces, control stations, corridors and stairways, air spaces enclosed behind ceilings, panelling or linings are to be suitably divided by close-fitting draught stops not more than 7 m apart. In the vertical direction, such spaces, including those behind linings of stairways, trunks, etc., are to be closed at each deck.

3.12.2 The draught stops are to be non-combustible and are to form a continuation above the ceiling of the bulkhead below or the other side of the panelling or lining to the bulkhead, as far as possible.

3.12.3 Where the structure or 'A' Class divisions are required to be insulated, it is to be ensured that the heat from a fire is not transmitted through the intersections and terminal points of the divisions or penetrations to uninsulated boundaries. Where the insulation installed does not achieve this, arrangements are to be made to prevent this heat transmission by insulating the horizontal and vertical boundaries or penetrations for a distance of 450 mm.

3.13 Structural fire protection – Materials

3.13.1 Except in cargo spaces, mail rooms, baggage rooms, or refrigerated compartments, of service spaces, all insulation (e.g. fire and comfort) is to be of non-combustible materials. Partial bulkheads or decks used to subdivide a space for utility or artistic treatment are to have a non-combustible core.

3.13.2 The use of combustible materials is to be kept to a minimum.

3.13.3 Pipes penetrating 'A' or 'B' Class divisions are to be of approved materials having regard to the temperature such divisions are required to withstand.

3.13.4 Pipes conveying oil or combustible liquids through accommodation and service spaces are to be of approved materials having regard to the fire risk.

3.13.5 Materials readily rendered ineffective by heat are not to be used for overboard scuppers, sanitary discharges and other outlets which are close to the waterline and where the failure of the material in the event of fire would give rise to danger of flooding.

3.13.6 Primary deck coverings within accommodation spaces, service spaces and control stations are to be of a type which will not readily ignite, or give rise to toxic or explosive hazards at elevated temperatures. Reference is also to be made to the IMO FTP Code, Annex 1, Parts 2 and 6.

3.13.7 Vapour barriers and adhesives used in conjunction with insulation, as well as insulation of pipe fittings for cold service systems need not be non-combustible, but they shall be kept to the minimum quantity practicable and their exposed surfaces shall have low flame spread characteristics.

3.13.8 All waste receptacles are to be constructed of non-combustible materials with no openings in the sides or bottom.

3.13.9 Furniture in the stairway enclosures is to be limited to seating. If required, it is to be fixed, limited to four seats on each deck in each stairway enclosure and is not to obstruct the escape route. Additional seating may be permitted in the main reception area within a stairway enclosure provided it is fixed and does not obstruct the escape route. Furniture is not permitted in corridors forming escape routes in cabin areas. Lockers for the storage of safety equipment may be permitted.

3.14 Structural fire protection – Surface of insulation

3.14.1 In spaces where penetration of oil products is possible, the surface of insulation is to be impervious to oil or oil vapours. Insulation boundaries are to be arranged to avoid immersion in oil spillages so far as is practicable.

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3.15 Structural fire protection – Means of escape

3.15.1 Stairways and ladders are to be arranged to provide ready means of escape to the survival craft embarkation deck from all guest and crew spaces and from spaces in which the crew is normally employed, other than machinery spaces. In particular, the following provisions are to be complied with:

(a) Below the bulkhead deck, two means of escape, at least one of which is to be independent of watertight doors, are to be provided for each watertight compartment or similarly restricted space or group of spaces. One of these means of escape may be dispensed with, due regard being paid to the nature and the location of spaces concerned, and to the number of persons who normally might be accommodated or employed there.

(b) Above the bulkhead deck, there are to be at least two practical means of escape from each main vertical zone or similarly restricted space or group of spaces, at least one of which is to give access to a stairway forming a vertical escape.

(c) If a radio-telegraph station has no direct access to the open deck, two means of escape from or access to such station are to be provided, one of which may be a port-hole or window of sufficient size or other satisfactory means to provide an emergency escape.

(d) A corridor, lobby, or part of a corridor from which there is only one route of escape is not to exceed 7 m. Where accommodation arrangements are such that access to compartments is through another compartment, as is often the case with an Owner's suite, a second means of escape is to be provided. The second escape route is to be as remote as possible from the main escape route. The second means of escape may be through portholes or hatches of adequate size, leading to the open deck.

(e) At least one of the means of escape required by (a) or (b) is to be by means of a readily accessible enclosed stairway, which will provide continuous fire shelter from the level of its origin to the appropriate survival craft embarkation decks, or the uppermost weather deck if the embarkation deck does not extend to the main vertical zone being considered. In the latter case, direct access to the embarkation deck by external open stairways and passageways is to be provided and is to have emergency lighting and slip-free surfaces underfoot. Boundaries facing external open stairways and passageways forming part of an escape route and boundaries in such a position that their failure during a fire would impede escape to the embarkation deck, are to have fire integrity and insulation values in accordance with Tables 3.3.2 and 3.3.3. The widths, number and continuity of escape routes are to be as follows:

  (i) Stairways are to be not less than 900 mm clear width between handrails. Stairways are to be fitted with handrails on each side. The minimum clear width of stairways is to be increased by 10 mm for every person provided for in excess of 90 persons. The maximum clear width between handrails where stairways are wider than 900 mm is to be 1800 mm. The total number of persons to be evacuated by such stairways is to be two-thirds of the crew and total number of passengers in the areas served by such stairways.

  (ii) Stairways with a clear width in excess of 900 mm are to be aligned in a fore-and-aft direction.

  (iii) Doorways, corridors and intermediate landings included in the means of escape are to have widths sized in the same manner as the stairways.

  (iv) Stairways are not to exceed 3,5 m vertical rise without the provision of a landing and are not to have angle of inclination greater than 45° to the horizontal.

  (v) Landings at each deck level are to be not less than 2 m^2 in area and are to be increased by 1 m^2 for every 10 persons provided for in excess of 20 persons but need not exceed 16 m^2, except for those landings serving public spaces having direct access onto the stairway enclosure.

(f) Protection of access from the stairway enclosures to the survival craft embarkation areas are to comply with the requirements of Tables 3.3.2 and 3.3.3.

(g) Where public spaces span three or more open decks, contain combustibles such as furniture and give access to other enclosed spaces, each level within the space is to have two means of escape, one of which is to give direct access to an enclosed vertical means of escape meeting the requirements of (e).

(h) Where a dispensation has been granted under the provisions of (a), a safe means of escape is to be provided. Stairways are to be provided with handrails on both sides and are to have a clear width between handrails of not less than 800 mm.

3.15.2 Two means of escape are to be provided from each machinery space. In particular, the following provisions are to be complied with:

(a) Where the space is below the bulkhead deck the two means of escape are to consist of either:

  (i) Two sets of steel ladders and walkways as widely separated as possible, leading to doors in the upper part of the space similarly separated and from which access is provided to the appropriate survival craft embarkation decks. One of these ladders is to provide continuous fire shelter from the lower part of the space to a safe position outside the space. This shelter is to be of steel or equivalent material, insulated where necessary, and provided with a self closing door of steel or equivalent material at the lower end. If access is provided at other levels each level is to be provided with a door of steel or equivalent material; or

  (ii) one steel ladder leading to a door in the upper part of the space from which access is provided to the embarkation deck and additionally, in the lower part of the space and in a position well separated from the ladder referred to, a steel or equivalent material door capable of being operated from each side and which provides access to a safe escape route from the lower part of the space to the embarkation deck.

(b) Where the space is above the bulkhead deck, the two means of escape are to be as widely separated as possible and the doors leading from such means of escape are to be in positions from which access is provided to the appropriate survival craft embarkation decks. Where such means of escape require the use of ladders these are to be of steel.

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3.15.3 One of the means of escape from any such space required by 3.15.2 may be dispensed with, so long as either a door or a steel ladder and walkways provides a safe escape route to the embarkation deck, due regard being paid to the nature and location of the space and whether persons are normally employed in that space.

3.15.4 Two means of escape are to be provided from a machinery control room located inside a machinery space, at least one of which is to provide continuous fire shelter to a safe position outside the machinery space.

3.15.5 Adequate deck area is to be provided at muster stations and embarkation areas having due regard to the expected number of persons.

3.16 Ventilation systems

3.16.1 Ventilation ducts are to be of non-combustible material. Short lengths of ducts not exceeding 2 m in length and with a cross-section not exceeding 0,02 m^2 need not be non-combustible, subject to these ducts being:

(a) of a material that has low flame spread characteristics;
(b) used at the end of the ventilation device; and
(c) situated not less than 600 mm, measured along the duct, from an opening in an 'A' or 'B' Class division including continuous 'B' Class ceilings.

3.16.2 Where the ventilation ducts with a free cross-sectional area exceeding 0,02 m^2 pass through Class 'A' bulkheads or decks, the openings are to be lined with a steel sheet sleeve unless the ducts passing through the bulkheads or decks are of steel in the vicinity of passage through the deck or bulkhead and the ducts and sleeves are to comply in this part with the following:

(a) Steel ducts, or sleeves lining such ducts, are to have a thickness of at least 3 mm and a length of at least 900 mm. When passing through bulkheads, this length is to be divided preferably into 450 mm on each side of the bulkhead. These ducts, or sleeves lining such ducts, are to be provided with fire insulation. The insulation is to have at least the same fire integrity as the bulkhead or deck through which the duct passes.
(b) Steel ducts with a free cross-sectional area exceeding 0,075 m^2 are to be fitted with fire dampers in addition to the requirements of (a). The fire damper is to operate automatically but is also to be capable of being closed manually from both sides of the bulkhead or deck. The damper is to be provided with an indicator which shows whether the damper is open or closed. Fire dampers are not required, however, where ducts pass through spaces surrounded by 'A' Class divisions, without serving those spaces, provided those ducts have the same fire integrity as the divisions which they pierce.
(c) Compliance with 3.8.4.

3.16.3 Ventilation ducts with a free cross-sectional area exceeding 0,02 m^2 passing through 'B' Class bulkheads are to be lined with steel sheet, or other equivalent material, sleeves of 900 mm in length divided preferably into 450 mm on each side of the bulkheads unless the duct is of steel for this length, *see also* 3.10.3.

3.16.4 Ducts provided for the ventilation of Category 'A' machinery spaces, galleys, spaces containing vehicles or craft with fuel in their tanks or lockers storing such fuels, are not to pass through accommodation spaces, service spaces or control stations unless the ducts are:

(a) either:
  (i) constructed of steel having a thickness of at least 3 mm and 5 mm for ducts the widths or diameters of up to and including 300 mm and 760 mm and over respectively and, in the case of such ducts, the widths or diameters of between 300 mm and 760 mm having a thickness to be obtained by interpolation;
  (ii) suitably supported and stiffened;
  (iii) fitted with automatic fire dampers close to the boundaries penetrated; and
  (iv) insulated to 'A-60' Class standard from the machinery spaces, galleys, spaces containing vehicles or craft with fuel in their tanks or lockers storing such fuels, to a point at least 5 m beyond each fire damper;
(b) or:
  (i) constructed of steel in accordance with (a)(i) and (ii); and
  (ii) insulated to 'A-60' Class standard throughout the accommodation spaces, service spaces or control stations;

except that penetrations of main zone divisions are also to comply with 3.16.8.

3.16.5 Ducts provided for ventilation to accommodation spaces, service spaces or control stations are not to pass through such spaces, unless, where they pass through Category 'A' machinery space, galleys, spaces containing vehicles or craft with fuel in their tanks or lockers storing such fuels, the ducts:

(a) either:
  (i) are constructed of steel in accordance with 3.16.4(a)(i) and (ii);
  (ii) are fitted with automatic fire dampers close to the boundaries penetrated; and
  (iii) have the integrity of boundaries of the machinery space, galley, spaces containing vehicles or craft with fuel in their tanks, or lockers storing such fuels, maintained at the penetrations;
(b) or:
  (i) are constructed of steel in accordance with 3.16.4(a)(i) and (ii); and
  (ii) are insulated to 'A-60' Class standard within the machinery space, galley or spaces containing vehicles or craft with fuel in their tanks or lockers storing such fuels;

except that penetration of main zone divisions is also to comply with 3.16.8.

3.16.6 Such measures as are practicable are to be taken in respect of control stations outside machinery spaces in order to ensure that ventilation, visibility and freedom from smoke are maintained, so that in the event of fire the machinery and equipment contained therein may be supervised and continue to function effectively. Alternative and separate means of air supply are to be provided; air inlets of the two sources of supply are to be so disposed that the risk of both inlets drawing in smoke simultaneously is minimised. Such requirements need not apply to control stations situated on,

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and opening on to, an open deck, or where local closing arrangements would be equally effective.

3.16.7 Where they pass through accommodation spaces or spaces containing combustible materials, the exhaust ducts from galley ranges are to comply with 3.16.4. Such exhaust ducts are to be fitted with:

(a) a grease trap readily removable for cleaning;
(b) a fire damper located in the lower end of the duct;
(c) arrangements, operable from within the galley, for shutting off the exhaust fans; and
(d) fixed means for extinguishing a fire within the duct.

3.16.8 Where it is necessary that a ventilation duct passes through a main vertical zone division, a fail-safe automatic closing fire damper is to be fitted adjacent to the division. The damper is also to be capable of being manually closed from each side of the division. The operating position is to be readily accessible and be marked in red light-reflecting colour. The duct between the division and the damper is to be of steel or other equivalent material and, if necessary, insulated to comply with 3.8.4. The damper is to be fitted on at least one side of the division with a visible indicator showing whether the damper is in the open position.

3.16.9 Where public spaces span three or more open decks and contain combustibles such as furniture and other enclosed spaces, the space is to be equipped with a smoke extraction system. The smoke extraction system is to be activated by the smoke detection system required by Ch 4,2 and is to be capable of manual control. The fans are to be capable of exhausting the entire volume within the space in not more than 10 min.

3.16.10 The main inlets and outlets of all ventilation systems are to be capable of being closed from outside the spaces being ventilated.

3.16.11 Power ventilation of accommodation spaces, service spaces, control stations and machinery spaces is to be capable of being stopped from an easily accessible position outside the space being served. This position should not be readily cut off in the event of a fire in the spaces served. The means provided for stopping the power ventilation of the machinery spaces is to be entirely separate from the means provided for stopping ventilation of other spaces, *see also* Pt 16, Ch 2,17.6.

3.16.12 Reference is also made to 2.8.4 to 2.8.7, 2.8.9 and 3.10.1.

3.16.13 Ducts provided for exhaust ventilation from laundries are to be fitted with suitably located cleaning and inspection openings.

3.16.14 Fire dampers required by 3.16.2, 3.16.4, 3.16.5 and 3.16.8, including relevant means of operation are to be fire tested. Reference is also to be made to IMO FTP Code, Annex 1, Part 3.

3.17 Oil fuel arrangements

3.17.1 In a yacht in which oil fuel is used, the arrangements for the storage, distribution and utilisation of the oil fuel are to be such as to ensure the safety of the yacht and persons on board. For details, *see* Pt 15, Ch 3.

3.17.2 As far as practicable, oil fuel tanks are to be part of the yacht's structure and are to be located outside Category 'A' machinery spaces.

3.17.3 Where oil fuel tanks, other than double bottom tanks, are necessarily located adjacent to or within Category 'A' machinery spaces, at least one of their vertical sides is to be contiguous to the machinery space boundaries, and is preferably to have a common boundary with the double bottom tanks, and the area of the tank boundary common with the machinery spaces is to be kept to a minimum. Where the vertical boundary of a tank directly exposed to a machinery space meets the yacht's side plating at an acute angle, a small horizontal surface at the base of the tank, necessary to accommodate practical constructional considerations may be permitted. If the arrangement of the machinery is such that a tank with a large horizontal surface at the base is necessary then a cofferdam with suitable ventilation arrangements, to protect the base of the tank from the effect of a machinery space fire, will be specially considered. *See also* Pt 15, Ch 3. Oil fuel tanks situated within the boundaries of Category 'A' machinery spaces are not to contain oil fuel having a flashpoint of less than 60°C. The use of free-standing oil fuel tanks is prohibited.

3.18 Lubricating oil arrangements

3.18.1 The arrangements for the storage, distribution and utilisation of oil used in pressure lubrication systems are to be such as to ensure the safety of the yacht and persons on board, *see also* Pt 15, Ch 3.

3.19 Arrangements for other flammable oils

3.19.1 The arrangements for the storage, distribution and utilisation of other flammable oils employed under pressure in power transmission systems, control and activating systems and heating systems are to be such as to ensure the safety of the ship and persons on board, *see also* Pt 15, Ch 3.

3.20 Prohibition of carriage of flammable oils in forepeak tanks

3.20.1 Oil fuel, lubricating oil and other flammable oils are not to be carried in forepeak tanks.

3.21 Special arrangements in Category 'A' machinery spaces

3.21.1 Openings are to be provided with closing appliances constructed so as to maintain the fire integrity of the machinery space boundaries.

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3.21.2 Doors other than power operated watertight doors, are to be so arranged that positive closure is assured in case of fire in the space, by power-operated closing arrangements or by the provision of self-closing doors capable of closing against an inclination of 3,5° opposing closure and having a fail-safe hook-back facility, provided with a remotely operated release device.

3.21.3 Windows are not to be fitted in machinery space boundaries. This does not preclude the use of glass in control rooms within the machinery spaces.

3.21.4 Means of control are to be provided for:
(a) closure of openings which normally allow exhaust ventilation, and closure of ventilator dampers;
(b) permitting the release of smoke;
(c) closing power-operated doors or actuating release mechanism on doors other than power-operated watertight doors;
(d) stopping ventilating fans; and
(e) stopping forced and induced draught fans, oil fuel transfer pumps, oil fuel unit pumps and other similar fuel pumps.

3.21.5 The controls required in 3.21.4 are to be located outside the space concerned, where they will not be cut off in the event of fire in the space they serve. Such controls and the controls for any required fire-extinguishing system are to be situated at one control position or grouped in as few positions as possible. Such positions are to have a safe access from the open deck, *see also* Pt 15, Ch 3,4.5.1 and 4.9.2.

3.21.6 When access to any Category 'A' machinery space is provided at a low level from an adjacent space there is to be provided near the watertight door, a light steel fire-screen door operable from each side.

3.22 Arrangements for gaseous fuel for domestic purposes

3.22.1 Where gaseous fuel is used for domestic purposes, the arrangements for the storage, distribution and utilisation of the fuel is to be such that, having regard to the hazards of fire and explosion which the use of such fuel may entail, the safety of the yacht and the persons on board is preserved. The installation is to be in accordance with recognised National or International Standards.

3.22.2 Storage lockers for gas cylinders are to be provided with:
(a) effective ventilation;
(b) an outward-opening door accessible directly to the open deck; and
(c) gas-tight boundaries, including doors and other means of closing any openings therein, which form boundaries between such lockers and adjoining enclosed spaces.

3.23 Space heaters

3.23.1 Space heaters, if used, are to be fixed in position and so constructed as to reduce fire risks to a minimum. The design and location of these units are to be such that clothing, curtains or other similar materials cannot be scorched or set on fire by heat from the unit.

3.24 Fixed fire detection and fire-alarm systems

3.24.1 A fixed fire detection and fire-alarm system is to be installed in any machinery space and is to comply with the requirements of Pt 16, Ch 1,2.8.

3.24.2 A fixed fire detection and fire-alarm system is to be fitted in all stairways (including lift and dumbwaiter trunks), service spaces, control stations and accommodation spaces (except toilets, bathrooms, void spaces, etc.). The fixed fire detection and fire-alarm system is to be installed in accordance with Ch 4,2.

3.24.3 All yachts at all times when at sea, or in port (except when out of service), are to be so equipped as to ensure that any initial fire-alarm is immediately received by a responsible member of the crew.

3.24.4 A special alarm, operated from the navigating bridge or fire-control station, is to be fitted to summon the crew.

3.24.5 For yachts having a freeboard length of 85 m or more, a public address system is to be available throughout the accommodation spaces, service, and control stations and open decks. The arrangements are to comply with Pt 16, Ch 2,18.3.

3.25 Fire pumps and fire main system

3.25.1 **Application.** Every yacht is to be provided with fire pumps in accordance with this Section. Fire mains, hydrants and hoses are also to be provided as required by this Section.

3.25.2 **Capacity of fire pumps:**
(a) The fire pumps required are to be capable of delivering for fire-fighting purposes a quantity of water, at the pressure specified in 3.25.5 of not less than two-thirds of the quantity required to be dealt with by the bilge pumps when employed for bilge pumping. For number and capacity of bilge pumps, *see* Pt 15, Ch 2.
(b) As an alternative to (a) the capacity of fire pumps may be determined by hydrostatic calculations based on the requirement of 3.25.5(a).
(c) Where more pumps than the minimum number of required pumps are installed the capacity of such additional pumps will be specially considered.

3.25.3 **Fire pumps:**
(a) In yachts of 4000 tons gross or more, at least three independently driven fire pumps are to be provided and, in yachts of less than 4000 tons gross, at least two such fire pumps.
(b) Sanitary, ballast, bilge or general service pumps may be accepted as fire pumps, provided that they are not normally used for pumping oil, and that, if they are subject to occasional duty for the transfer or pumping of fuel oil, suitable changeover arrangements are fitted.

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(c) In yachts classed for navigation in ice, the fire pump sea inlet valves are to be provided with clearing arrangements, *see* Pt 1, Ch 2,3.8.1.

(d) The arrangements of sea connections, fire pumps and their sources of power are to be such as to ensure that in the event of a fire in any one compartment, all the fire pumps will not be put out of action.

(e) The arrangements for the ready availability of water supply are to be as follows:

(i) In yachts of 1000 gross tons or more, or any yacht of an alternative form of construction, the arrangements are to be such that at least one effective jet of water is immediately available from any hydrant in an interior location and so as to ensure the continuation of the output of water by the automatic starting of a required fire pump.

(ii) Yachts not provided with arrangements complying with (i), but to which a UMS notation is to be assigned, are to have remote starting of a required fire pump from the navigating bridge and fire-control station, if any.

(f) Relief valves are to be provided in conjunction with any fire pump if the pump is capable of developing a pressure exceeding the design pressure of the water service pipes, hydrants and hoses. These valves are to be so placed and adjusted as to prevent excessive pressure in any part of the fire main system.

(g) Where centrifugal pumps are provided in order to comply with this sub-Section, a non-return valve is to be fitted in the pipe connecting the pump to the fire main.

3.25.4 **Fire main**:

(a) The diameter of the fire main is to be based on the required capacity of two fire pumps, and the diameter of the water service pipes are to be sufficient to ensure an adequate supply of water for the simultaneous operation of at least two fire-hoses. In general, the diameter of the fire main is to be not less than:

$$d = (L_{pp}/1,2) + 25 \text{ mm}$$

but need not exceed 180 mm in yachts, and is in no case to be less than 50 mm

where

d = internal diameter of the fire main, in mm

L_{pp} = length of yacht measured between perpendiculars, in metres, as defined in Pt 3, Ch 1,6.2.2.

(b) The wash deck line may be used as a fire main provided that the requirements of this sub-Section are satisfied.

(c) All exposed water pipes for fire-extinguishing are to be provided with drain valves for use in frosty weather. The valves are to be located where they will not be damaged.

3.25.5 **Pressure in the fire main**:

(a) The fire pumps, associated piping and fire main are to be so designed that the following minimum pressures will be maintained at all hydrants under conditions where two fire pumps required by 3.25.3 are simultaneously delivering water to the fire main of the size required by 3.25.4 through adjacent nozzles of sizes required by 3.25.9:

4000 tons gross and over 4 bar (0,4 N/mm^2)

Less than 4000 tons gross 3 bar (0,3 N/mm^2)

(b) The maximum pressure at any hydrant shall not exceed that at which the effective control of a fire-hose can be demonstrated.

3.25.6 **Number and position of hydrants**:

(a) The number and position of the hydrants are to be such that at least two jets of water not emanating from the same hydrant, one of which is to be from a single length of hose, may reach any part of the yacht normally accessible to the guests and crew while the yacht is being navigated. In yachts of 1000 tons gross or more, at least two hydrants are to be provided in the machinery spaces; in smaller yachts one hydrant will be accepted.

(b) In the accommodation, service and machinery spaces, the number and position of hydrants are to be such that the requirements of (a) may be complied with when all watertight doors and all doors in main vertical zone bulkheads are closed.

(c) Where access is provided to a machinery space of Category 'A' at a low level, two hydrants are to be provided external to, but near the entrance, to that machinery space.

3.25.7 **Pipes and hydrants**:

(a) Materials readily rendered ineffective by heat are not to be used for fire mains. Where steel pipes are used, they are to be galvanised internally and externally. Cast iron pipes are not acceptable. The pipes and hydrants are to be so placed that the fire-hoses may be easily coupled to them. The arrangement of pipes and hydrants is to be such as to avoid the possibility of freezing. Unless one hose and nozzle is provided for each hydrant in the yacht, there is to be complete interchangeability of hose couplings and nozzles.

(b) A valve is to be fitted at each fire hydrant so that any fire-hose may be removed while the fire pump is at work.

(c) Isolating valve(s) to isolate the section of the fire main within the Category 'A' machinery space containing the main fire pump(s) from the rest of the fire main are to be fitted in an easily accessible and tenable position outside the Category 'A' machinery space. The fire main is to be so arranged that when the isolating valve(s) is shut, all the hydrants on the yacht, except those in the Category 'A' machinery space referred to above, can be supplied with water by a fire pump not located in this Category 'A' machinery space through pipes which do not enter this space.

3.25.8 **Fire-hoses**:

(a) Fire-hoses are to be of approved non-perishable material. The hoses are to be sufficient in length to project a jet of water to any of the spaces in which they may be required to be used. Their length, in general, is not to exceed 18 m. Each hose is to be provided with a nozzle and the necessary couplings. Fire-hoses, together with any necessary fittings and tools, are to be kept ready for use in conspicuous positions near the water service hydrants or connections.

(b) There is to be at least one fire-hose for each of the hydrants required by 3.25.6.

3.25.9 **Nozzles**:

(a) For the purpose of this Chapter, standard nozzle sizes are to be 12 mm, 16 mm or 19 mm, or as near thereto as possible, so as to make full use of the maximum discharge capacity of the fire pumps.

(b) For accommodation and service spaces, the nozzle size need not exceed 12 mm.

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(c) For machinery spaces and exterior locations, the nozzle size is to be such as to obtain the maximum discharge possible from two jets at the pressure indicated in 3.25.5 from the smallest pump, however a nozzle size greater than 19 mm need not be used.
(d) All nozzles are to be of an approved dual purpose type (i.e. spray/jet type) incorporating a shut-off.

3.25.10 **Location and arrangement of water pumps, etc., for other fire-extinguishing systems.** Pumps required for the provision of water for other fire-extinguishing systems required by this Chapter are to have their sources of power and their controls installed outside the space or spaces protected by such systems and are to be so arranged that a fire in the space or spaces protected will not put any such system out of action.

3.25.11 **International shore connection.** At least one international shore connection is to be provided.

3.26 Fire-extinguishing arrangements in spaces containing internal combustion machinery

3.26.1 Category 'A' machinery spaces containing internal combustion machinery are to be provided with:
(a) one of the fire-extinguishing systems described in Ch 4,3;
(b) at least one set of portable air-foam equipment complying with 3.29;
(c) in each such space approved foam type fire-extinguishers, each of at least 45 litres capacity or equivalent, sufficient in number to enable foam or its equivalent to be directed on to any part of the fuel and lubricating oil pressure systems, gearing and other fire hazards; and
(d) a sufficient number of portable foam extinguishers or equivalent are to be located so that no point in the space is more than 10 m walking distance from an extinguisher and that there are at least two such extinguishers in each such space.

3.26.2 Machinery spaces in yachts which are constructed mainly or wholly with alternative forms of construction, containing internal combustion machinery, are to comply with the requirements of 3.26.1.

3.27 Fire-extinguishing arrangements in spaces containing oil fuel units

3.27.1 Category 'A' machinery spaces containing oil fuel units are to be provided with one of the fixed fire-extinguishing systems described in Ch 4,3.

3.27.2 There are to be at least two portable foam extinguishers or equivalent in each space in which a part of the oil fuel unit is situated.

3.28 Limitations on the use of oil as a fuel

3.28.1 For the limitations of the use of oil as a fuel, *see* Pt 15, Ch 3.

3.29 Automatic sprinkler, fire detection and fire-alarm system

3.29.1 A fixed automatic sprinkler, fire detection and fire-alarm system, or equivalent system (e.g. watermist), is to be fitted in all stairways, service spaces, control stations and accommodation spaces except spaces which afford no fire risk such as void spaces.

3.29.2 The arrangements are to be in accordance with Ch 4,1.

3.30 Fixed fire-extinguishing systems not required by this Section

3.30.1 Where a fixed fire-extinguishing system not required by this Section is installed, the arrangement is to comply with the relevant requirements of this Chapter.

3.31 Portable foam applicator

3.31.1 A portable foam applicator unit is to consist of an air foam nozzle of an inductor type capable of being connected to the fire main by a fire-hose, together with a portable tank containing at least 20 litres of foam-making liquid and one spare tank. The nozzle is to be capable of producing effective foam, suitable for extinguishing an oil fire, at the rate of at least 1,5 m^3/min.

3.32 Portable fire-extinguishers

3.32.1 All fire-extinguishers are to comply with the requirements of Ch 4,6.

3.32.2 The extinguishers are to be stowed in readily accessible positions.

3.32.3 One of the portable fire-extinguishers, or the portable fire-extinguisher, dedicated for use in any space is to be stowed near the entrance to that space.

3.32.4 At least one portable fire-extinguisher is to be located so that it can easily be reached from the main steering position of the yacht.

3.32.5 Accommodation spaces, service spaces and control stations are to be provided with a sufficient number of portable fire-extinguishers to ensure that at least one extinguisher will be readily available for use in every compartment. In any case, their number is to be not less than five.

3.32.6 Where cooking facilities are provided, a portable fire-extinguisher of a type appropriate to the energy source used is to be located in a position readily accessible for use in the event of a fire.

3.33 Fire blanket

3.33.1 A fire blanket is to be installed in all galleys.

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3.34 Protection of spaces containing vehicles or craft with fuel in their tanks, or lockers storing such fuels

3.34.1 Spaces containing vehicles or craft with fuel in their tanks, or lockers storing such fuels, are to be provided with the following:

(a) A fixed fire detection and fire-alarm system complying with the requirements of Pt 16, Ch 1,2.8.

(b) A manually-operated water spray deluge system having a water application rate of 5 litres per square metre of deck area per minute. Where the deck height does not exceed 2,5 m, an application rate of 3,5 litres per square metre of deck area per minute will be accepted. Adequate drainage of the protected spaces is to be provided generally in accordance with the requirements for vehicle or cargo space, *see* Pt 3, Ch 4,9.4.4. The drainage piping and connections for the space are to be non-combustible. Other fixed fire-extinguishing systems may be permitted, provided they are not less effective in controlling the type of fire likely to occur.

(c) At least two portable foam extinguishers, or equivalent;

(d) An independent mechanical ventilation system , which is entirely separate from other ventilation systems, providing at least six air changes per hour. The ducted air is not to pass through other spaces, except as allowed under 3.16.4, or vent into areas where it could be drawn into accommodation areas or cause undue hazard.

(e) Electrical equipment of a safe type is to be provided, *see* Pt 16, Ch 2,14.

(f) Prominently displayed 'No Smoking' signs; and

(g) Structural fire protection as required by Table 3.3.2 and Table 3.3.3.

3.34.2 Such spaces are not to give access to any space other than the fuel store or lockers for use within the space. Lockers storing fuel are to be accessed from an exterior location, unless the locker is within the space containing the vehicles or craft. Exceptionally, where the engine room escape cannot be routed elsewhere, it may exit into the space providing that:

(a) the connecting door is self-closing;

(b) no door hold-back devices are fitted;

(c) an audible and visual alarm is fitted on the bridge to signify when the door is open; and

(d) a notice is posted at the door stating that the door is to remain closed and that the area beside the door is an escape route and is to be kept clear.

3.34.3 The requirements of 3.17 are to be complied with, as appropriate.

3.35 Protection of paint lockers and flammable liquid lockers

3.35.1 Paint lockers and flammable liquid lockers of deck area 4 m^2 or more are to be provided with a fixed fire-extinguishing system enabling the crew to extinguish a fire without entering the space. One of the following systems is to be provided:

- A carbon dioxide system designed for 40 per cent of the gross volume of the space.
- A dry powder system designed to discharge 0,5 kg powder per cubic metre of gross volume of the space.
- A water spray system designed to give a coverage of 5 litres per square metre of deck area per minute. Water spray systems may be connected to the fire main.

3.35.2 Consideration will be given to the acceptance of other arrangements which provide equivalent protection.

3.35.3 Lockers having a deck area less than 4 m^2 may be protected by carbon dioxide or dry powder portable extinguishers located near the entrance to the locker.

3.36 Arrangements where deep fat cooking equipment is installed

3.36.1 Where deep-fat cooking equipment is installed, all installations are to be fitted with:

(a) an automatic or manual fixed extinguishing system type approved in accordance with ISO 15371, *Ships and marine technology – Fire extinguishing systems for protection of galley deep-fat cooking equipment – Fire tests*, or an acceptable alternative National or International Standard, for protection of the deep-fat cooking equipment;

(b) a primary and back up thermostat with an alarm to alert the operator in the event of failure of either thermostat;

(c) arrangements for automatically shutting off the deep-fat cooking equipment electrical power upon activation of the fire-extinguishing system;

(d) an alarm for indicating operation of the fire-extinguishing system in the galley where the equipment is installed; and

(e) controls for manual operation of the fire-extinguishing system which are clearly labelled for ready use by the crew.

Control and electrical engineering arrangements are to be in accordance with the requirements of Pt 16, Ch 1 and Ch 2, as applicable.

3.36.2 For fryers of up to 15 litres cooking oil capacity, the provision of a suitably sized extinguisher of a suitable type located for specific use on the cooking equipment together with manual isolation of the electrical power supply may be considered an acceptable alternative to 3.36.1 provided the arrangements are to the satisfaction of the National Administration.

3.37 Helicopter decks

3.37.1 The requirements of IMO Resolution A.855(20) are to be complied with having due regard to the hazards involved.

3.37.2 If a helicopter hangar is not provided and if two fireman's outfits are supplied as per 3.38.1, then the fireman's outfits required by IMO Resolution A.855(20) need not be provided.

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3.38 Fireman's outfit

3.38.1 Each yacht is to carry at least two fireman's outfits complying with Ch 4,4. Additional fireman's outfits are to be provided as applicable to ensure that at least two fireman's outfits are stored in each main vertical zone.

3.38.2 The fireman's outfits are to be so stored as to be easily accessible and ready for use. Where more than two fireman's outfits are required, they are to be located in widely separated positions. At least two fireman's outfits are to be available at any one position.

3.38.3 Additional sets of personal equipment and breathing apparatus, may be required, having due regard to the size of the yacht.

3.39 Fire-control plans

3.39.1 Fire-control plans are to meet the requirements of Ch 4,5.

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Section

1 **Automatic sprinkler, fire detection and fire-alarm systems**

2 **Fixed fire detection and fire-alarm systems**

3 **Fixed fire-extinguishing systems in machinery spaces**

4 **Fireman's outfits**

5 **Fire-control plans**

6 **Fire-extinguishers (portable and non-portable)**

Section 1
Automatic sprinkler, fire detection and fire-alarm systems

1.1 General

1.1.1 Any required automatic water sprinkler and fire-alarm and fire detection system is to be designed for immediate use at any time. Where such a system is fitted, it is to be of the wet pipe type. Any part of the system which may be subjected to freezing temperatures in service are to be suitably protected against freezing. It is to be kept charged at the necessary pressure and have provision for a continuous supply of water.

1.1.2 As an alternative to the system specified in 1.1.1, any one of the following systems may be considered:

(a) **Dry pipe system**. A sprinkler system employing automatic sprinklers attached to a piping system containing air or nitrogen under pressure, the release of which (as from the opening of a sprinkler) permits the water pressure to open a valve known as a dry pipe valve. The water then flows into the piping system and out of the opened sprinklers.

(b) **Pre-action system**. A sprinkler system employing automatic sprinklers attached to a piping system containing air that may or may not be under pressure, with a supplemental detection system installed in the same area as the sprinklers. Actuation of the detection system opens a valve that permits water to flow into the sprinkler piping system and to be discharged from any sprinklers that may be open.

(c) **Deluge system**. A sprinkler system employing open sprinklers attached to a piping system connected to a water supply through a valve that is opened by the operation of a detection system installed in the same areas as the sprinklers. When this valve opens water flows into the piping system and discharges from all sprinklers attached thereto.

1.2 Wet pipe type

1.2.1 Any required automatic sprinkler, fire detection and fire-alarm system is to comply with the requirements of Pt 16, Ch 2,17.2.

1.2.2 Sprinklers are to be grouped into separate sections, each of which is to contain not more than 200 sprinklers. Any section of sprinklers is not to serve more than two decks nor be situated in more than one main vertical zone, except where it is satisfactorily shown that the protection of the yacht against fire will not thereby be reduced.

1.2.3 Each section of sprinklers is to be capable of being isolated by one stop valve only. The stop valve in each section is to be readily accessible and its location is to be clearly and permanently indicated. Means are to be provided to prevent the operation of the stop valves by any unauthorised person.

1.2.4 A gauge indicating the pressure in the system is to be provided at each section stop valve and at a central station.

1.2.5 The sprinklers are to be resistant to corrosion by marine atmosphere. In accommodation and service spaces the sprinklers are to come into operation within the temperature ranges from 68°C to 79°C, except that in locations such as drying rooms, where high ambient temperatures might be expected, the operating temperature may be increased by not more than 30°C above the maximum deck head temperature.

1.2.6 A list or plan is to be displayed at each indicating unit showing the spaces covered and the location of the zone in respect of each section. Suitable instructions for testing and maintenance are to be available.

1.2.7 Sprinklers are to be placed in an overhead position and spaced in a suitable pattern to maintain an average application rate of not less than 5 litres per square metre per minute over the nominal area covered by the sprinklers. The use of sprinklers providing other amounts of water suitably distributed, will be considered provided they are shown to be not less effective.

1.2.8 A pressure tank having a volume equal to at least twice that of the charge of water specified in 1.2.9 is to be provided.

1.2.9 The tank is to contain a standing charge of fresh water, equivalent to the amount of water which would be discharged in one minute by the pump referred to in 1.2.12, and the arrangements are to provide for maintaining such air pressure in the tank to ensure that where the standing charge of fresh water in the tank has been used the pressure will be not less than the working pressure of the sprinkler, plus the pressure exerted by a head of water measured from the bottom of the tank to the highest sprinkler in the system. Suitable means of replenishing the air under pressure and of replenishing the fresh water charge in the tank are to be provided. A glass gauge suitably protected is to be provided to indicate the correct level of the water in the tank.

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1.2.10 Means are to be provided to prevent the passage of sea water into the tank.

1.2.11 An independent power pump is to be provided solely for the purpose of automatically continuing the discharge of water from the sprinklers. The pump is to be brought into action automatically by the pressure drop in the system before the standing fresh water charge in the pressure tank is completely exhausted.

1.2.12 The pump and the piping system are to be capable of maintaining the necessary pressure at the level of the highest sprinkler to ensure a continuous output of water sufficient for the simultaneous coverage of a minimum area of the maximum width of the craft squared or 280 m^2 whichever is the less, at the application rate specified in 1.2.7.

1.2.13 The pump is to have fitted on the delivery side a test valve with a short open-ended discharge pipe. The effective area through the valve and pipe is to be adequate to permit the release of the required pump output while maintaining the pressure in the system specified in 1.2.9.

1.2.14 The sea inlet to the pump is to be, wherever possible, in the space containing the pump and is to be so arranged that when the vessel is afloat it will not be necessary to shut off the supply of sea water to the pump for any purpose other than the inspection or repair of the pump.

1.2.15 The sprinkler pump and tank are to be situated in a position reasonably remote from any machinery space of Category 'A' and not in any space required to be protected by the sprinkler system.

1.2.16 Where the arrangement precludes locating the pump and tank in accordance with 1.2.15, for yachts of not greater than 50 m Rule length, the sprinkler pump and tank required by Ch 3,2.16 may be situated within Category 'A' machinery spaces, but not within the spaces that are protected by the system.

1.2.17 For yachts of not greater than 50 m Rule length and all service craft, the sources of electrical power supply for the sea-water pump may be fed from the main source of electrical power.

1.2.18 There are to be not less than two sources of power supply for the sea water pump and automatic alarm and detection system. Where one of the sources of power for the pump is an internal combustion engine it is to be so situated that a fire in any protected space will not affect the air supply to the machinery, in addition to complying with 1.2.15. When the sources of power for the pump are electrical, *see* Pt 16, Ch 2,2 and Pt 16, Ch 2,3.

1.2.19 The sprinkler system is to have a connection from the vessel's fire main by way of a lockable screw-down non-return valve at the connection which will prevent a backflow from the sprinkler system to the fire main.

1.2.20 A test valve is to be provided for testing the automatic alarm for each section of sprinklers by a discharge of water equivalent to the operation of one sprinkler. The test valve for each section is to be situated near the stop valve for that section.

1.2.21 Means are to be provided for testing the automatic operation of the pump, on reduction of pressure in the system.

1.2.22 Each section of sprinklers is to include means for giving a visual and audible alarm signal automatically at one or more indicating units whenever any sprinkler comes into operation. Such alarm systems are to be arranged to indicate if any fault occurs in the system. Such units are to indicate in which section, served by the system, fire has occurred and are to be centralised on the navigation bridge. In addition, visible and audible alarms from the unit are to be located in a position other than on the navigation bridge, so as to ensure that the indication of fire is immediately received by the crew. Switches are to be provided at one of these indicating positions, which will enable the alarm and the indicators for each section of sprinklers to be tested.

1.2.23 Spare sprinkler heads are to be provided as specified in Table 4.1.1. The spare sprinkler heads are to be stowed in boxes or holders provided for that purpose, together with a tool suitable for removing and installing sprinkler heads. The boxes or holders are to be situated near the control valve for the section, and are to be clearly and permanently marked to indicate their contents.

Table 4.1.1 Spares requirements

Number of sprinkler heads provided	Number of spare sprinkler heads required
300	One spare sprinkler head is to be provided for each 50 sprinkler heads fitted, with a minimum of one spare being provided for each type fitted
301 to 1000	12
>1000	24

1.3 Arrangements which will be accepted as an alternative to 1.2

1.3.1 The alternative system is to be tested, type approved and installed in accordance with IMO Resolution A.800(19). The following exceptions to Section 3 of the Annex may be applied:

(a) Where the arrangement precludes locating the pump and tank in accordance with 1.2.15, for yachts not greater than 50 m Rule length, the sprinkler pump and tank required by Ch 3,2.16 may be situated within Category 'A' machinery spaces, but not within the spaces that are protected.

(b) Pumps and alternative supply components are to be sized so as to be capable of maintaining the required flow to the hydraulically most demanding area of not less than the maximum width of the craft squared or 280 m^2 whichever is the less.

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1.3.2 Spare nozzles are to be provided as specified in Table 4.1.2. The spare nozzles are to be stowed in boxes or holders provided for that purpose, together with a tool suitable for removing and installing nozzles. The boxes or holders are to be situated near the control valve for the section, and are to be clearly and permanently marked to indicate their contents.

Table 4.1.2 Spares requirements

Number of nozzles provided	Number of spare nozzles required
300	One spare nozzle is to be provided for each 50 nozzles fitted, with a minimum of one spare being provided for each type fitted
301 to 1000	12
>1000	24

■ *Section 2* Fixed fire detection and fire-alarm systems

2.1 General requirements

2.1.1 Any required fixed fire detection and fire-alarm system with manually operated call points is to be capable of immediate operation at all times.

2.1.2 Fire detection systems are to comply with the requirements of Pt 16, Ch 2,17.1 in addition to the requirements of this Section.

2.1.3 Detectors are to be operated by heat, smoke or other products of combustion, flame, or any combination of these factors. Detectors operated by other factors indicative of incipient fires may be considered provided that they are no less sensitive than such detectors. Flame detectors are only to be used in addition to smoke or heat detectors.

2.1.4 Suitable instructions for testing and maintenance are to be provided.

2.1.5 For each type of detector installed, one spare detector head is to be provided for every 10 heads or part thereof. They are to be stowed in a suitable container at the control station.

2.1.6 The function of the detection system is to be periodically tested by means of equipment producing hot air at the appropriate temperature, or smoke or aerosol particles having the appropriate range of density or particle size, or other phenomena associated with incipient fires to which the detector is designed to respond. All detectors are to be of a type such that they can be tested for correct operation and restored to normal surveillance without the renewal of any component.

2.2 Installation requirements

2.2.1 Manually operated call points are to be installed throughout the accommodation spaces, service spaces and control stations. One manually operated call point is to be located at each exit. Manually operated call points are to be readily accessible in the corridors of each deck such that no part of the corridor is more than 20 m from a manually operated call point.

2.2.2 Smoke detectors are to be installed in all stairways, corridors and escape routes within accommodation spaces.

2.2.3 Where a fixed fire detection and fire-alarm system is required for the protection of spaces other than those specified in 2.2.2, at least one detector complying with 2.1.3, is to be installed in each such space.

2.2.4 Detectors are to be located for optimum performance. Positions near beams and ventilation ducts or other positions where patterns of air flow could adversely affect performance and positions where impact or physical damage is likely are to be avoided. In general, detectors which are located overhead are to be a minimum distance of 0,5 m away from bulkheads.

2.2.5 The maximum spacing of detectors is to be in accordance with Table 4.2.1. Other spacings based upon test data which demonstrate the characteristics of the detectors may be required or permitted.

Table 4.2.1 Maximum spacing of detectors

Maximum		Maximum	
Maximum floor		Distance apart between centres, in metres	Distance away from bulkheads, in metres
Type of detector	Area per detector, m^2		
Heat	37	9	4,5
Smoke	74	11	5,5

2.2.6 Electrical wiring which forms part of the system is to be so arranged as to avoid galleys, machinery spaces of Category 'A', and other enclosed spaces of high fire-risk except where it is necessary to provide for fire detection or fire-alarm in such spaces or to connect to the appropriate power supply. *See also* Pt 16, Ch 2.

2.3 Design requirements

2.3.1 Smoke detectors required by 2.2.2 are to be certified to operate before the smoke density exceeds 12,5 per cent obscuration per metre, but not until the smoke density exceeds two per cent obscuration per metre. Smoke detectors to be installed in other spaces are to operate within satisfactory sensitivity limits having regard to the avoidance of detector insensitivity or oversensitivity.

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2.3.2 Heat detectors are to be certified to operate before the temperature exceeds 78°C but not until the temperature exceeds 54°C, when the temperature is raised to those limits at a rate less than 1°C per minute. At higher rates of temperature rise, the heat detector is to operate within satisfactory temperature limits having regard to the avoidance of detector insensitivity or oversensitivity.

2.3.3 The permissible temperature of operation of heat detectors may be increased to 30°C above the maximum deckhead temperature in drying rooms and similar spaces of a normal high ambient temperature.

2.4 Requirements for machinery spaces

2.4.1 The arrangements of the fixed fire detection and fire-alarm system in machinery spaces are to comply with the requirements of Pt 16, Ch 1,2.8.

■ *Section 3* Fixed fire-extinguishing systems in machinery spaces

3.1 Gas fire-extinguishing systems

3.1.1 The use of a fire-extinguishing medium which, either by itself or under expected conditions of use, gives off toxic gases in such quantities as to endanger persons is not permitted.

3.1.2 New installations that use fire-extinguishing media, which have ozone-depleting properties under the Montreal Protocol, are not permitted.

3.1.3 The necessary pipes for conveying a fire-extinguishing medium into protected spaces are to be provided with control valves which are to be so placed that they will be easily accessible and not readily cut off from use by an outbreak of fire. The control valves are to be so marked as to indicate clearly the spaces to which the pipes are led. Suitable provision is to be made to prevent inadvertent admission of the medium to any space. Where pipes pass through accommodation spaces they are to be seamless and the number of pipe joints is to be kept to a minimum and made by welding.

3.1.4 The piping for the distribution of fire-extinguishing medium is to be of adequate size and so arranged, and discharge nozzles so positioned that a uniform distribution of medium is obtained. All pipes are to be arranged to be self draining and where led into refrigerated spaces, the arrangement will be specially considered. A means whereby the individual pipes to all protected spaces can be tested using compressed air is to be provided. Distribution pipes are to extend at least 50 mm beyond the last nozzle.

3.1.5 Steel pipes fitted in spaces where corrosion is likely to occur are to be galvanised, at least internally.

3.1.6 Distribution pipes for carbon dioxide are not to be smaller than 20 mm bore.

3.1.7 Means are to be provided to close all openings which may admit air into, or allow gas to escape from, a protected space.

3.1.8 The volume of starting air receivers, converted to free air volume, is to be added to the gross volume of the machinery space when calculating the necessary quantity of extinguishing medium. Alternatively a discharge pipe from the safety valves may be fitted and led directly to the open air.

3.1.9 Means are to be provided for automatically giving audible and visual warning of the release of fire-extinguishing medium into any space in which personnel normally work or to which they have access. The alarm is to operate for a suitable period before the medium is released.

3.1.10 Where pneumatically operated alarms are fitted which require periodic testing, carbon dioxide is not to be used as an operating medium. Air operated alarms may be used provided that the air supply is clean and dry.

3.1.11 Where electrically operated alarms are used, the arrangements are to be such that the electric operating mechanism is located outside hazardous spaces.

3.1.12 The means of control of any fixed gas fire-extinguishing system is to be readily accessible and simple to operate and shall be grouped together in as few locations as possible at positions not likely to be cut off by a fire in a protected space. At each location there is to be clear instructions relating to the operation of the system having regard to the safety of personnel. Two separate controls are to be provided for releasing carbon dioxide into a protected space and each is to ensure the activation of the alarm. One control is to be used to discharge the gas from its storage cylinder(s). A second control is to be used for opening the valve of the piping which conveys the gas into the protected space. The two controls are to be located inside a release box clearly identified for the particular space. If the box containing the controls is to be locked, a key to the box is to be in a break-glass type enclosure conspicuously located adjacent to the box. There is to be a dedicated release box for each protected space, in which personnel normally work or to which they have access, *see also* 3.1.9. The space served is to be identified at the release box.

3.1.13 Automatic release of fire-extinguishing medium is not permitted.

3.1.14 Where the quantity of extinguishing medium is required to protect more than one space, the quantity of medium available need not be more than the largest quantity required for any one space so protected.

3.1.15 Means are to be provided for the crew to safely check the quantity of medium in the containers.

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3.1.16 Containers for the storage of fire-extinguishing media and associated pressure components are to be designed and tested to Codes of Practice recognised by Lloyd's Register (hereinafter referred to as 'LR') having regard to their locations and the maximum ambient temperatures expected in service.

3.1.17 The fire-extinguishing medium is to be stored outside a protected space, in a room which is situated in a safe and readily accessible position and effectively ventilated. Any entrance to such a storage room is to preferably be from the open deck and in any case be independent of the protected space. Access doors are to open outwards, and bulkheads and decks including doors and other means of closing any opening therein, which form the boundaries between such rooms and adjoining enclosed spaces are to be gastight. Such storage rooms are to be treated as control stations.

3.1.18 In systems where containers discharge into a common manifold, non-return valves are to be provided at the connections of the container discharge pipes to the manifold to allow any container to be disconnected without preventing the use of other containers in the system and to prevent the discharge of extinguishing medium into the container storage room in the event of the system being operated. Manifolds are to be tested by hydraulic pressure to 1,5 times the design pressure. The design pressure is the maximum gauge pressure to which the system may be subjected and is not to be less than the gauge pressure corresponding to the maximum ambient temperature expected in service. The design pressure need not be greater than the maximum setting of the manifold pressure relief valve. After the hydraulic test, manifolds are to be carefully cleaned and dried before the non-return valves are finally fitted.

3.1.19 For craft on unrestricted service, spare parts for the system are to be stored on board. As a minimum these are to consist of:

- 1 actuator;
- 1 flexible hose (cylinder to manifold); and
- the cylinder bursting discs and sealing washers for all cylinders.

3.2 Carbon dioxide systems

3.2.1 Carbon dioxide systems are to comply with 3.1 in addition to the remaining requirements of this sub-Section.

3.2.2 For the purpose of this paragraph the volume of free carbon dioxide is to be calculated at 0,56 m^3/kg.

3.2.3 For machinery spaces:

(a) The quantity of carbon dioxide carried is to be sufficient to give a minimum volume of free gas equal to the larger of:
   - 40 per cent of the gross volume of the largest machinery space so protected, the volume to exclude that part of the casing above the level at which the horizontal area of the casing is 40 per cent or less of the horizontal area of the space concerned taken midway between the tank top and the lowest part of the casing; or
   - 35 per cent of the gross volume of the largest machinery space protected, including the casing.

(b) The above mentioned percentages may be reduced to 35 per cent and 30 per cent respectively for craft less than 2000 gross tons.

(c) The fixed piping system is to be such that 85 per cent of the gas can be discharged into the space within two minutes.

(d) The distribution arrangements are to be such that approximately 15 per cent of the required quantity of carbon dioxide is led to the bilge areas.

3.2.4 Two separate controls are to be provided for releasing carbon dioxide into a protected space and each is to ensure the activation of the alarm. One control is to be used to discharge the gas from its storage cylinder(s). A second control is to be used for opening the valve of the piping which conveys the gas into the protected space. The two controls are to be located inside a release box clearly identified for the particular space. If the box containing the controls is to be locked, a key to the box is to be in a break-glass type enclosure conspicuously located adjacent to the box. There is to be a dedicated release box for each protected space in which personnel normally work or to which they have access, *see also* 3.1.8. The space served is to be identified at the release box.

3.3 High-expansion foam systems

3.3.1 Any required fixed high-expansion foam system in machinery spaces is to be capable of rapidly discharging through fixed discharge outlets a quantity of foam sufficient to fill the greatest space to be protected at a rate of at least 1 m in depth per minute. The quantity of foam-forming liquid available is to be sufficient to produce a volume of foam equal to five times the volume of the largest space to be protected.

3.3.2 The expansion ratio of the foam is not to exceed 1000 to 1.

3.3.3 Alternative arrangements and discharge rates will be permitted provided that equivalent protection is achieved.

3.3.4 Supply ducts for delivering foam, air intakes to the foam generator and the number of foam producing units are to be such as will provide effective foam production and distribution.

3.3.5 The arrangement of the foam generator delivery ducting is to be such that a fire in the protected space will not affect the foam-generating equipment.

3.3.6 The foam generator, its sources of power supply, foam-forming liquid and means of controlling the system are to be readily accessible and simple to operate and are to be grouped in as few locations as possible at positions not likely to be cut off by fire in the protected space. Such spaces are to be treated as control stations.

3.3.7 Foam concentrates are to be of an approved type.

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3.4 Pressure water-spraying systems

3.4.1 Any required fixed pressure water-spraying fire-extinguishing system in machinery spaces is to be provided with spraying nozzles of an approved type.

3.4.2 The number and arrangement of the nozzles is to be such as to ensure an effective average distribution of water of at least five litres per square metre per minute in the spaces to be protected. Where increased application rates are considered necessary, these will be specially considered. Nozzles are to be fitted above bilges, tank tops and other areas over which oil fuel is liable to spread and also above other specific fire hazards in the machinery spaces.

3.4.3 The system may be divided into sections, the distribution valves of which are to be operated from easily accessible positions outside the spaces to be protected and which will not be readily cut off by fire in the protected space.

3.4.4 The system is to be kept charged at the necessary pressure, and the pump supplying the water for the system is to be put automatically into action by a pressure drop in the system.

3.4.5 The pump is to be capable of simultaneously supplying, at the necessary pressure, all sections of the system in any one compartment to be protected. The pump and its controls are to be installed outside the space or spaces to be protected. It is not to be possible for a fire in the space or spaces protected by the water-spraying system to put the system out of action.

3.4.6 The pump may be driven by independent internal combustion type machinery but if it is dependent upon power being supplied from the emergency generator, that generator is to be arranged to start automatically in case of main power failure so that power for the pump required by 3.4.5 is immediately available. When the pump is driven by independent internal combustion machinery it is to be so situated that a fire in the protected space will not affect the air supply to the machinery.

3.4.7 Precautions are to be taken to prevent the nozzles from becoming clogged by impurities in the water or corrosion of the piping, nozzles, valves and pump.

3.5 Arrangements which will be accepted as an alternative to 3.4

3.5.1 The system is to be tested, type approved and installed in accordance with MSC/Circ. 668 as amended by IMO MSC/Circ. 728.

3.6 Other systems

3.6.1 Other fixed fire-extinguishing systems will be specially considered.

3.6.2 The use of steam as a fire-extinguishing medium in fixed fire-extinguishing systems is not permitted.

■ *Section 4* Fireman's outfits

4.1 Components

4.1.1 A fireman's outfit is to consist of:

(a) Personal equipment comprising:
  (i) Protective clothing of material to protect the skin from the heat radiating from the fire and from burns and scalding by steam. The outer surface is to be water-resistant.
  (ii) Boots and gloves of rubber or other electrically non-conducting material.
  (iii) A rigid helmet providing effective protection against impact.
  (iv) An electric safety lamp (hand lantern) of an approved type with a minimum burning period of three hours.
  (v) An axe with an insulated handle.

(b) A self contained breathing apparatus of an approved type. The volume of air contained in the cylinders of which is to be at least 1200 litres or other self contained breathing apparatus which is to be capable of functioning for a period of at least 30 minutes. Spare bottles are to be provided which are to be maintained fully charged except where facilities for re-charging the bottles are available on board. At least two spare charges for each breathing apparatus are to be provided, and all air cylinders for breathing apparatus are to be interchangeable.

4.1.2 For each breathing apparatus a fireproof life-line of sufficient length and strength is to be provided capable of being attached by means of a snaphook to the harness of the apparatus or to a separate belt in order to prevent the breathing apparatus becoming detached when the life-line is operated.

■ *Section 5* Fire-control plans

5.1 Description of plans

5.1.1 General arrangement plans are to be permanently exhibited for the guidance of the ship's officers, using graphical symbols in accordance with IMO Resolution A.654(16), which show clearly for each deck the control stations, the various fire sections enclosed by steel or 'A' and 'B' Class divisions, together with particulars of:

- the fire detection and fire-alarm system;
- any sprinkler installation;
- the fire-extinguishing appliances;
- the means of access to different compartments, decks, etc.;
- the position of the fireman's outfits;
- the ventilating system, including particulars of the fan control positions, the position of dampers and identification numbers of the ventilating fans serving each section; and

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- the location and arrangement of the emergency stop(s) for pumps, and for remote closing the valves on the pipes from tanks, for oil fuel, lubricating oil and other flammable oils.

5.1.2 Alternatively, the details required by 5.1.1 may be set out in a booklet, a copy of which is to be supplied to each officer, and one copy is at all times to be available on board in an accessible position.

5.1.3 The plans and booklets are to be kept up to date, any alterations being recorded thereon as soon as practicable. Description in such plans and booklets is to be in the official language of the flag state. If the language is neither English nor French, a translation into one of those languages is to be included. In addition, instructions concerning the maintenance and operation of all the equipment and installations on board for the fighting and containment of fire are to be kept under one cover, readily available in an accessible position.

5.1.4 A duplicate set of fire-control plans or a booklet containing such plans is to be permanently stored in a prominently marked weathertight enclosure outside the deckhouse for the assistance of shoreside fire-fighting personnel.

■ *Section 6* Fire-extinguishers (portable and non-portable)

6.1 Approved types

6.1.1 All fire-extinguishers are to be of approved types and designs.

6.2 Extinguishing medium

6.2.1 The extinguishing media employed are to be suitable for extinguishing fires in the compartments in which they are intended to be used.

6.2.2 The extinguishers required for use in the machinery spaces using oil as fuel are to be of a type suitable for extinguishing oil fires.

6.2.3 Fire-extinguishers containing an extinguishing medium which, either by itself or under expected conditions of use, gives off toxic gases in such quantities as to endanger persons, are not permitted.

6.3 Capacity

6.3.1 The capacity of required portable fluid extinguishers is to be not more than 13,5 litres but not less than nine litres. Other extinguishers are to be at least as portable as the 13,5 litre fluid extinguishers and are to have a fire-extinguishing capability at least equivalent to a 9,0 litre fluid extinguisher.

6.3.2 The following capacities may be taken as equivalents:

- 9 litre fluid extinguisher;
- 4,5 kg dry powder;
- 5 kg carbon dioxide.

6.4 Spare charges

6.4.1 A spare charge is to be provided for each required portable fire-extinguisher which can be readily re-charged on board. If this cannot be done, duplicate extinguishers are to be provided.

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Guidance Notes for the Classification of Special Service Craft

Calculation Procedures for Composite Construction

July 2012

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3 Design of Sandwich Panel Laminates

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Introduction

Section

Application of procedures

Alternative procedures

Symbols and definitions

■ Application of procedures

To clarify the procedures contained in the *Rules and Regulations for the Classification of Special Service Craft* (hereinafter referred to as the Rules for Special Service Craft) a series of typical calculation procedures are contained in these 'Guidance Notes'. The procedures describe the fundamental principles contained in Part 8 of the Rules for Special Service Craft and the associated computer software.

The procedures contained in these Guidance Notes are for:
(a) Design of single skin hull laminates.
(b) Design of sandwich panel laminates.
(c) Design of typical stiffening members.

■ Alternative procedures

The procedures describe the Rule method of calculating the various stresses in laminates. Where alternative theoretical methods are to be adopted they are to be in addition to the Rule calculation procedures and the designer is to submit full details of their assumptions and calculation procedures such that the submitted calculations may be validated.

■ Symbols and definitions

All symbols and definitions are as indicated in Pt 8, Ch 3 of the Rules for Special Service Craft.

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Design Procedures

Chapter 1

Sections 1 to 4

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1 **General**

2 **Structural analysis**

3 **Fibre composites**

4 **Fibre reinforced composite construction**

5 **Direct calculation**

■ *Section 1* General

1.1 This Section outlines the Rule approach to the design of structural members to be built in FRP and provides example calculations.

1.2 The procedures contained in these Guidance Notes are for:

(a) Design of single skin hull laminates.
(b) Design of sandwich panel laminates.
(c) Design of typical stiffening members.

■ *Section 2* Structural analysis

2.1 The Rules for Special Service Craft provide scantling requirements for a basic structural configuration for both mono and multi-hull craft with multi-deck or single deck hulls which include a double bottom, or a single bottom arrangement. The structural configuration may also include a single or multiple arrangement of cargo hatch openings. The Rules for Special Service Craft provide for both longitudinal and transverse framing systems. Alternative types of framing systems will be specially considered on the basis of the Rules for Special Service Craft.

2.2 Every effort has been taken to make the Rules for Special Service Craft scantling formulae as transparent as possible, and to achieve this objective the following approach has been adopted:

- lay down requirements,
- specify modelling considerations,
- indicate limit states,
- state constraints in an explicit manner.

2.3 This approach will enable the designers and Builders to decide for themselves the suitability of the Rules for Special Service Craft for their project. Further and perhaps more importantly changes may be easily made to the requirements based upon experience gained, discussions with interested parties and as development progresses. This is similar to the current Rule development process which is continually updating and 'tailoring' Rule requirements.

■ *Section 3* Fibre composites

3.1 Part 8 of the Rules for Special Service Crafts apply to craft constructed of fibre reinforced plastics using hand lay-up, mechanical deposition, contact moulding techniques or vacuum assisted techniques. Construction may be either single-skin or sandwich construction, or a combination of both. Where moulding techniques and methods of construction differing from those assumed to be used within the Rules for Special Service Craft are proposed, details are required to be submitted for consideration.

3.2 For the purposes of the Rules for Special Service Craft a 'plastic' is regarded as an organic substance which may be thermosetting or thermoplastic and which, in its finished state, may contain reinforcements or additives. The quantities of such additives are strictly limited by the Rules for Special Service Craft.

3.3 The resins used in production are to be of a type which have been approved by Lloyd's Register (hereinafter referred to as LR) for marine construction purposes. Samples of the resin batches being used in the construction may require to be taken for limited quality control examinations.

3.4 All fibre reinforcements are to be of a type approved by LR. The other materials used in the construction of the craft are also to be manufactured and tested in accordance with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials), of the Rules for Special Service Craft, with particular reference to Chapter 14 for plastics materials.

■ *Section 4* Fibre reinforced composite construction

4.1 The properties of composite sections and laminates are to be determined from the results of test data. The mechanical properties to be used for scantling calculation purposes are to be 90 per cent of the mean first ply/resin cracking failure values determined from accepted mechanical tests. All test pieces are to be representative of the product to be manufactured. This is particularly important since the material of construction is 'manufactured' on site, at the same time as the product.

4.2 The mechanical properties of the materials are also to be estimated from the appropriate procedures and formulae contained within the Rules for Special Service Craft. The acceptable design values for glass reinforced polyester resin laminates are not to be greater than those contained with the Rules for Special Service Craft unless agreed otherwise by LR. Additional information on the application of the various formulae is given in these Guidance Notes.

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4.3 The various formulae referred to above require that sufficient input data be available which relates to each of the proposed materials. Where it is proposed to use design values greater than the nominal value indicated in the Rules for Special Service Craft the designers and/or Builders should agree the values for use in the scantling analysis with LR at the design stage and prior to the submission of plans and data for appraisal.

4.4 Strength calculations for all advanced fibre composites are to be based on the Rules values and the results of testing of truly representative sections of the proposed design. The sections are to be manufactured under typical production conditions using the same materials, fibre contents, methods of lay-up and time delays. Mechanical testing is, in general, to be based upon the requirements specified in Chapter 14 of the Rules for Materials.

4.5 A through ply analysis is required to be conducted for both plate and stiffener elements and the resultant stresses compared with the allowable stress limits for the particular element. Example procedures are described in these Guidance Notes.

■ *Section 5*
Direct calculations

5.1 Direct calculations may be specifically required by the Rules for Special Service Craft. They may be required for craft having novel design features, or may be submitted in support of alternative arrangements and scantlings. LR may, when requested, undertake calculations on behalf of designers or Builders and make recommendations with regard to the suitability of any required model tests. Where model testing is undertaken to complement direct calculations details would normally be required to be submitted indicating the schedule of tests, details of test equipment, input data, analysis and calibration procedures together with tabulated and plotted output.

5.2 All direct calculations are to be submitted for examination. Where calculation procedures other than those available within the Rules for Special Service Craft are employed, supporting documentation is to be submitted for appraisal and this is to include details of the following:

- calculation methods,
- assumptions and references,
- loading data,
- structural modelling,
- design criteria.

5.3 LR will consider the use of Builder's and/or designer's programs for direct calculations in the following cases:

- where it can be established that the program has previously been satisfactorily used to perform a direct calculation similar to that now submitted,
- where sufficient information and evidence of satisfactory performance is submitted to substantiate the validity of the computation performed by the program.

5.4 Where items are of a novel or unconventional design or manufacture, it is the responsibility of the Builder and/or designer to demonstrate their suitability and equivalence to the Rule requirements. Alternative arrangements, which are in accordance with the requirements of a National Authority, may be accepted as equivalent to the requirements of the Rules for Special Service Craft.

5.5 These Guidance Notes are published to enable designers/Builders to carry out the Rule calculations without using the Rules for Special Service Craft software.

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Design of Single Skin Hull Laminates

Section

1 **Calculation procedure**

2 **Concluding remarks**

Section 1 Calculation procedure

1.1 The stress in individual plies of a laminate is calculated in accordance with Pt 8, Ch 3,1.12 of the Rules for Special Service Craft, based on bending moment (*see* 1.9) and the laminate stiffness of a 1 cm wide elemental strip of material.

1.2 Considering the model shown in Figs. 2.1.1 and 2.1.2 of a typical single skin hull laminate. Assume a pressure of 33 kN/m^2 and that there is no significant panel curvature.

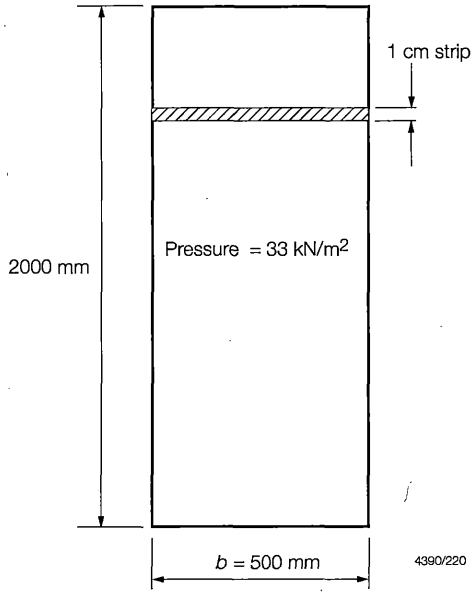

Fig. 2.1.1 Single skin example model

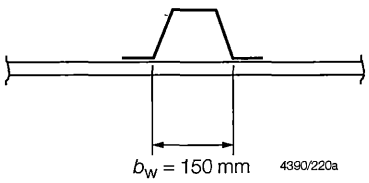

Fig. 2.1.2 'Top-hat' stiffener used in model

1.3 In this example the maximum bending moment is determined from Pt 8, Ch 3,1.9 of the Rules for Special Service Craft and occurs under the web at the base of the stiffener. It should be noted that no reduction in the bending moment, M_b, due to aspect ratio effect is given since the panel aspect ratio, i.e. panel length/panel breadth is greater than 2. *See* Pt 8, Ch 3,1.10.1 of the Rules for Special Service Craft.

$$\gamma = \frac{b_w}{b} = \frac{150}{500} = 0,3$$

$$k = \frac{\gamma^3 + 1}{\gamma + 1} = 0,79$$

$$M_b = \frac{k\,p\,b^2}{12} \times 10^{-5} \text{ Nm}$$

$$= \frac{0,79}{12} \times 33 \times 500^2 \times 10^{-5}$$

$$= 5,43 \text{ Nm.}$$

1.4 The laminate section modulus calculation is shown in Table 2.1.1 at the end of this Section. From Fig. 2.1.3 it will be noted that there will be positions where tension and compression considerations will apply. Such calculations are ideally suited to computer based investigation.

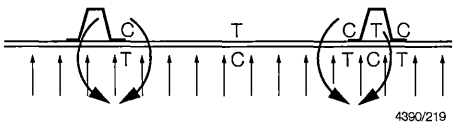

Fig. 2.1.3
Regions of tension (T) and compression (C) in example model

1.5 In order to apply a more detailed investigation it is necessary to establish the position of the neutral axis. However, in relatively balanced laminates this may be assumed to be at mid-depth. The procedure is simply to carry out the calculations assuming compressive properties on one face and tensile properties on the other face. Subsequently, the properties should be reversed and the layer stress calculations repeated. The calculated values should then be compared with the appropriate ultimate properties, i.e., dependent upon whether tension or compression considerations apply.

1.6 In the example the moments were evaluated about the base, which was taken to be the outer (wet) surface. The stiffness, EI, per 1 cm width, about the neutral axis, is determined using the parallel axis theorem:
In general:

$$I_{na} = I_{xx} - Ay^2$$

$$EI_{sect} = \Sigma EI_{base} - (\Sigma Et) \times 10 \times y^2$$

where

y = distance of neutral axis above the base (mm).

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Table 2.1.1 Tabulation of single skin laminate calculations

	Ply No.	Description	G_c	Weight (g/m^2)	t (mm)	Lever @ base, x (mm)	E (N/mm^2)	$E.t$	$E.t.x$	I @ base	EI @ base
Dry, *see* Note	1	CSM	0,33	600	1,250	10,149	7200	9000	91341	1289,2	9281917
	2	CSM	0,33	600	1,250	8,899	7200	9000	80091	991,5	7139017
	3	CSM	0,33	600	1,250	7,649	7200	9000	68841	733,0	5277367
	4	CSM	0,33	600	1,250	6,399	7200	9000	57591	513,5	3696967
	5	WR	0,5	600	0,734	5,407	14000	10276	55562	214,9	3008869
	6	CSM	0,33	600	1,250	4,415	6950	8688	38355	245,3	1704699
	7	CSM	0,33	600	1,250	3,165	6950	8688	27496	126,8	881558
	8	WR	0,5	600	0,734	2,173	14500	10643	23127	35,0	507333
	9	CSM	0,33	600	1,250	1,181	6950	8688	10260	19,1	132482
Wet (*see* Note)	10	CSM	0,286	225	0,556	0,278	6290	3497	972	0,6	3604
TOTALS					10,774			86479	453637		31633812

NOTE
'Dry' indicates the inner surface of the hull and 'wet' the outside of the shell laminate.

Position of neutral axis above base = $\frac{453637}{86479}$ = 5,246 mm

Tensile modulus of section = $\frac{86479}{10,774}$ = 8027 N/mm^2

Stiffness EI about neutral axis = 783,8 N cm^4/mm^2 (based on 1 cm wide strip)

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1.7 A factor of 10 (width in mm) is introduced to correct the value of area used in the parallel axis theorem, since a 1 cm wide strip of material is considered in the calculations.
From the tabulation:

EI_{sect} = 31633812 – (86479 x 10 x 5,246^2)
= 7837614 Nmm^4/mm^2
= 783,8 Ncm^4/mm^2.

1.8 From Pt 8, Ch 3,1.12 of the Rules for Special Service Craft the individual layer stresses (tensile consideration) are determined from:

$$\sigma_{ti} = \frac{E_{ti}\, y_i\, M}{\Sigma\,(E_i\, I_i)} \times 10^{-1} \quad N/mm^2$$

1.9 More generally, the calculation of the stresses in individual layers becomes:

$$\sigma_{ti} = \frac{5,43}{783,8} \times E_i\, y_i \times 10^{-1} \quad N/mm^2$$

$$= 693 \times 10^{-6} \times E_i\, y_i \quad N/mm^2$$

where

E_i = E_{ti} or E_{ci} for the ply relative to its position above or below the neutral axis

y_i = distance from the neutral axis to the outer extremity of an individual ply, *i*, in mm.

1.10 Consider the following typical arrangement and the associated stresses for a single shell panel outside of the slamming zone:

Consider the outer (wet) surface:
Consider the 225g/m^2 chopped strand mat reinforcement in tension:

σ_{ti} = 693 x 10^{-6} x $E_i\, y_i$
= 693 x 10^{-6} x 6290 x 5,246
= 22,9 N/mm^2.

From Pt 8, Ch 3, Table 3.1.1 of the Rules for Special Service Craft.

$\sigma_{ult\ tension}$ = 82,2 N/mm^2 for CSM at G_c =0,286
Hence, stress fraction = 22,9/82,2 = 0,278.

1.11 From Table 7.3.1 in Pt 8, Ch 7 of the Rules for Special Service Craft, the limiting tensile stress fraction is 0,33 for the side shell outside of the slamming zone. Hence, the calculated stress fraction is lower than the limiting stress factor and is therefore acceptable.

1.12 Similarly, consider the 600g/m^2 woven roving reinforcement in tension:

σ_{ti} = 693 x 10^{-6} x $E_i\, y_i$
= 693 x 10^{-6} x 14500 x (5,246–0,556–1,25)
= 34,6 N/mm^2

$\sigma_{ult\ tension}$ = 190 N/mm^2 for woven roving at G_c = 0,5
Stress fraction = 34,6/190 = 0,182
Hence acceptable.

1.13 Consider the inner (dry) surface:
The 600 g/m^2 chopped strand mat reinforcements at the inner surface in compression:

σ_{ci} = 693 x 10^{-6} x $E_i\, y_i$
= 693 x 10^{-6} x 7200 x (10,774–5,246)
= 27,6 N/mm^2

$\sigma_{ult\ comp}$ = 122 N/mm^2 for CSM at G_c = 0,33
Stress fraction = 27,6/122 = 0,226
Hence acceptable.

■ *Section 2* Concluding remarks

2.1 From the example, the highest stress factor occurs in the outer 225 g/m^2 chopped strand mat reinforcement (in tension) but this is significantly lower than the limiting stress fraction required by the Rules. The bending moment at the centre of the panel is smaller than that at the boundary and consequently, the stress factor will be correspondingly reduced. The design may be optimised by sequentially removing plies, changing reinforcement weights and/or by providing receiving strips under the base of the 'top-hat' stiffeners.

2.2 For the design of side shell laminates there are no shear and deflection criteria to be fulfilled. In this example a significant reserve exists between the actual and the ultimate stresses.

2.3 It is of paramount importance that the strain compatibility of the component materials is carefully considered.

2.4 Consider typical values of apparent strain, ε_a, at failure for the following materials in laminate form:

	Tension	Compression
'E' glass	1,3%	1,05%
Carbon fibre	0,9%	0,55%
Aramid fibre	1,3%	0,60%

2.5 The actual strain permissible is controlled by the material with the lowest apparent strain. The level of strain depends upon whether the reinforcements are in tension or compression and depends on their relative positions within the laminate. Consequently if, for example, a carbon fibre reinforcement is used in the outer plies of laminate then the strain must be constrained to a maximum of 0,33 x 0,9 per cent, i.e., 0,297 per cent. Therefore, the corresponding allowable stress in the other reinforcements must be related to the strain in the reinforcement relative to its position away from the neutral axis and that of the carbon fibre reinforcement, e.g.:

$$\varepsilon_{limitCSM} = \frac{\varepsilon_{allowable\ carbon} \times y_{CSM}}{y_{carbon}}$$

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2.6 Where aramid reinforcements are being used, special consideration must be given to the compressive properties. For comparison purposes aramid reinforcements, at a fibre content of 0,45 (by weight), typically have the following properties:

	Tension	Compression
Ultimate strength (N/mm^2)	300	100
Elastic modulus (N/mm^2)	21000	17000

2.7 The radical reduction in ultimate compressive strength may prove to be unacceptable on the inside at the panel boundaries or on the outside at the panel centre. Designs which feature aramid fibres in the outer plies, in an attempt to make use of the superior impact properties, must be checked at the panel centre for compression in the individual layers. This also applies to hybrid reinforcements containing aramid fibres. These reinforcements have one off properties of higher than one of the constituent fibres however, in service the individual allowable strains for each fibre reinforcement should not be exceeded.

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Design of Sandwich Panel Laminates

Chapter 3

Section 1

Section

1 **Calculation procedure**

2 **Deflection of sandwich panel**

3 **Bending moment applied**

4 **Stresses in facings**

Section 1
Calculation procedure

1.1 Consider the model of a side shell sandwich panel having dimensions 700 mm x 2000 mm shown in Fig. 3.1.1. Assume a design pressure of 50 kN/m^2 and a panel of negligible curvature.

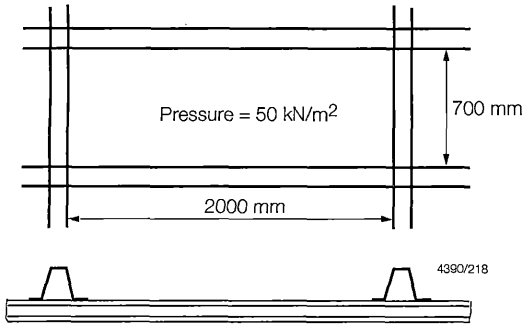

Fig. 3.1.1 Sandwich panel laminate example model

1.2 The panel is to be designed in accordance with the requirements of Pt 8, Ch 3 of the Rules for Special Service Craft. Firstly it is necessary to estimate the core thickness using Pt 8, Ch 3,1.13.2 of the Rules for Special Service Craft assuming a nominal value of tensile modulus of 11000 N/mm^2 for sandwich panel facings:

$$t_s = \phi\, k_s\, b \sqrt[3]{\frac{p}{E_{tpS}}} \text{ mm}$$

$$= 0{,}144 \times 700 \times \sqrt[3]{\frac{50}{11000}}$$

$$= 16{,}7 \text{ mm}$$

Hence, select 20 mm core as a typically available size.

1.3 From Pt 8, Ch 3,1.13.9 of the Rules for Special Service Craft the maximum core shear at the mid-point along the edge of the sandwich panel is given by:

$$\tau_c = \frac{p\, b\, k_S}{2t_c} \times 10^{-3} \text{ N/mm}^2$$

$$= \frac{50 \times 700 \times 1}{2 \times 20} \times 10^{-3}$$

$$= 0{,}875 \text{ N/mm}^2$$

1.4 The panel aspect ratio correction factor is given in Pt 8, Ch 3,1.13.9 of the Rules for Special Service Craft. $A_R = 2000/700 = 2{,}86$, hence $k_S = 1$.
No correction factor applied since $A_R > 2$.

1.5 To achieve an allowable shear stress fraction of 0,30, *see* Pt 8, Ch 7,3.5 of the Rules for Special Service Craft, this design would require the selection of 200 kg/m^3 foam core. Clearly being unacceptable the conclusion is to adopt a 50 mm thick core to reduce the core shear stress. The stress varies inversely with core thickness:

$$\tau_{50} = \tau_{20} \times \frac{20}{50} = 0{,}35 \text{ N/mm}^2.$$

1.6 To achieve the required allowable shear stress fraction the foam core must have a core shear strength of 0,35/0,30 = 1,17 N/mm^2. This may be achieved using a 100 kg/m^3 foam core using 90 per cent of the manufacturer's quoted value.

1.7 However, there are numerous solutions to achieve an acceptable arrangement. The options include:
(a) Repositioning the stiffeners to reduce panel sizes.
(b) Inclusion of shear ties in accordance with Pt 8, Ch 3,1.13.10 of the Rules for Special Service Craft.
(c) Accept the higher density core solution.

1.8 From Pt 8, Ch 3,1.13.3 of the Rules for Special Service Craft the skin thicknesses may be re-calculated allowing for the change in core thickness:

$$t_S = \phi_2 \frac{p\, b^3}{E_{tps}\, t_c^2} \times 10^{-3} \text{ mm}$$

$$t_{inner} = 0{,}446 \times \frac{50}{11000} \times \frac{700^3}{50^2} \times 10^{-3} = 0{,}28 \text{ mm}$$

$$t_{outer} = 0{,}594 \times \frac{50}{11000} \times \frac{700^3}{50^2} \times 10^{-3} = 0{,}37 \text{ mm}$$

Clearly, the increase in core thickness gives a substantial increase in panel stiffness. Consequently the skin thicknesses default to the minimum requirement quoted in Pt 8, Ch 3,3.5.5 of the Rules for Special Service Craft. The minimum side shell sandwich skin thicknesses are:

Outer 4 mm
Inner 3 mm.

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1.9 The minimum skin thicknesses relate to an assumed fibre content, f_c, of 0,5. Where the fibre content by weight is less than 0,5 the required minimum thickness are to be determined from Pt 8, Ch 3,2.4.2 of the Rules for Special Service Craft.

1.10 In order to comply with the Rules for Special Service Craft, chopped strand mat reinforcements are required against the core. The initial proposal to meet the requirement, features such CSM reinforcements together with a CSM against the gel coat surface.

1.11 The proposed sandwich skin laminate schedule for the outer skin is:

1 x 450 g/m^2 CSM @ G_c = 0,286	= 1,112 mm
3 x 600 g/m^2 WR @ G_c = 0,5	= 2,202 mm
1 x 300 g/m^2 CSM @ G_c = 0,33	= 0,625 mm
Total outer skin thickness	= 3,94 mm
Total reinforcement weight	= 2550 g/m^2

1.12 By transforming the relationship given in Pt 8, Ch 3,1.6.1 of the Rules for Special Service Craft the equivalent fibre content by weight, f_c, is 0,42.
The adjusted minimum skin thickness for the outer skin is:

$$t_{outer} = t_{0,5}\,(1,65 - 1,3f_c)$$
$$= 4 \times (1,65 - 1,3 \times 0,42)$$
$$t_{outer} = 4,42 \text{ mm.}$$

1.13 The proposed outer skin is deficient by 4,42 – 3,94 = 0,48 mm. Hence one additional woven roving reinforcement may be added to achieve the minimum requirement. The actual thickness of outer skin is 4,67 mm.

1.14 The proposed sandwich skin laminate schedule for the inner skin is:

1 x 300 g/m^2 CSM @ G_c = 0,33	= 0,625 mm
4 x 600 g/m^2 WR @ G_c = 0,5	= 2,936 mm
Total inner skin thickness	= 3,56 mm
Total reinforcement weight	= 2700 g/m^2

The equivalent overall fibre content of the inner skin is 0,473.
The adjusted minimum skin thickness for the inner skin is:

$$t_{inner} = t_{0,5}\,(1,65 - 1,3f_c)$$
$$= 3 \times (1,65 - 1,3 \times 0,473)$$
$$t_{inner} = 3,1 \text{ mm.}$$

1.15 The proposed arrangement which meets both core shear and minimum sandwich skin requirements is given in Table 3.1.1.

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Table 3.1.1 Tabulation of sandwich panel calculations

	Ref No.	Description	G_c	Weight (g/m^2)	t (mm)	Lever @ base, x (mm)	E (N/mm^2)	$E.t$	$E.t.x$	I @ base	EI @ base
Inner skin	1	WR	0,5	600	0,734	57,87	14000	10276	594641	24579	344105690
	2	WR	0,5	600	0,734	57,13	14000	10276	587099	23959	335431718
	3	WR	0,5	600	0,734	56,40	14000	10276	579556	23348	326868472
	4	WR	0,5	600	0,734	55,67	14000	10276	572014	22744	318415951
	5	CSM	0,33	300	0,625	54,99	7200	4500	247435	18896	136054699
Core	6	100 kg/m^3	–	–	50,000	29,67	83,7	4185	124182	544410	45567128
	7	CSM	0,33	300	0,625	4,36	6950	4344	18941	119	827333
	8	WR	0,5	600	0,734	3,68	14500	10643	39177	100	1446879
	9	WR	0,5	600	0,734	2,95	14500	10643	31365	64	929103
	10	WR	0,5	600	0,734	2,21	14500	10643	23553	36	526005
Outer skin	11	WR	0,5	600	0,734	1,48	14500	10643	15741	16	237588
	12	CSM	0,286	450	1,112	0,56	6290	6994	3889	5	28830
TOTALS					58,23			103699	2837592		1510439396

Inner skin in compression/outer skin in tension.

Position of neutral axis above base = $\frac{2837592}{103699}$ = 27,36 mm

Tensile modulus of elasticity of section = $\frac{103699 - 4185}{58,234 - 50} = \frac{99514}{8,234}$ = 12086 N/mm^2

Stiffness EI about neutral axis = 73397 N cm^4/mm^2 per 1 cm wide strip

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Section 2
Deflection of sandwich panel

2.1 Consider the revised model shown in Fig. 3.2.1:

E_{ms} = 12086 N/mm^2 from Table 3.1.1

b = breadth in direction of bending = 700 mm

G = shear modulus for 100 kg/m^3 core
= 36 N/mm^2 being 90 per cent of the manufacturer's quoted value

t_s = mean skin thickness
(3,56 + 4,67)/2 = 4,11 mm

$(1 - v_f^2)$ = unity (approximately)

Calculation of deflection in accordance with Pt 8, Ch 3,1.13.15 of the Rules for Special Service Craft

$$\delta = \frac{p\,b^2}{8t_c}\left(\frac{b^2}{24E_{ms}\,t_s\,t_c} + \frac{1}{G}\right) \times 10^{-3} \text{ mm}$$

$$= \frac{50 \times 700^2}{8 \times 50}\left(\frac{700^2}{24 \times 12086 \times 4{,}11 \times 50} + \frac{1}{36}\right) \times 10^{-3} \text{ mm}$$

$$= 61{,}25 \times (0{,}00822 + 0{,}0278)$$

$$= 2{,}2 \text{ mm total deflection.}$$

2.2 The total deflection comprises 23 per cent due to bending and 77 per cent due to shear.

The deflection criterion is given in Table 7.2.1 in Pt 8, Ch 7 of the Rules for Special Service Craft.

$$\delta_{RULE} < \frac{b}{100} \quad \text{where} \quad \frac{b}{100} = 7 \text{ mm}$$

Hence the 2,2 mm total deflection is acceptable.

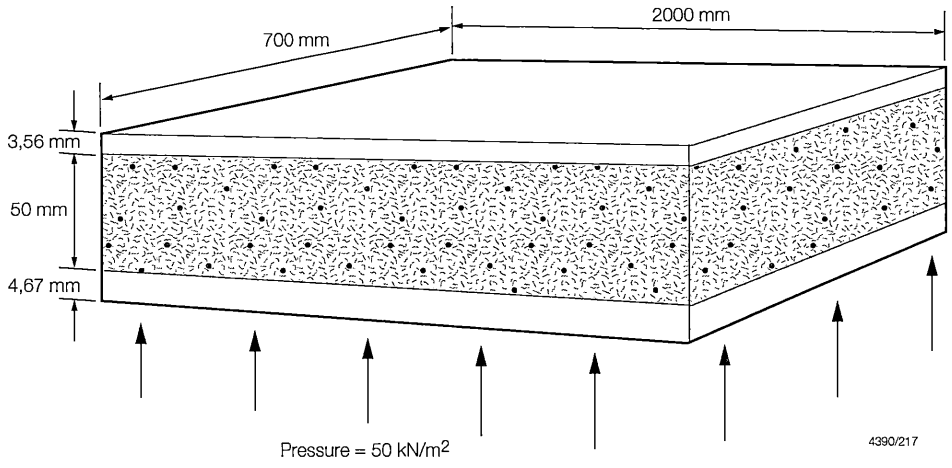

Fig. 3.2.1 Sandwich panel example model

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Section 3
Bending moment applied

3.1 The bending moment to be applied at 1 cm width of the sandwich panel is given by Pt 8, Ch 3,1.9 of the Rules for Special Service Craft. In this example it is evident that the maximum bending moment and hence maximum stress occurs under the base of the stiffener. Due to the high aspect ratio no correction factor needs to be applied to modify the applied bending moment.

$$\gamma = \frac{b_w}{b} = \frac{150}{700} = 0{,}2143$$

$$k = \frac{\gamma^3 + 1}{\gamma + 1} = 0{,}8316$$

$$M_b = \frac{k\,p\,b^2}{12} \times 10^{-5} \text{ Nm}$$

$$= \frac{0{,}8316}{12} \times 50 \times 700^2 \times 10^{-5}$$

$$= 17 \text{ Nm.}$$

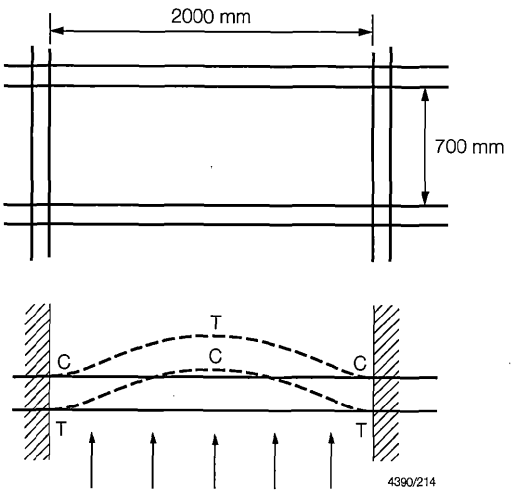

Fig. 3.4.1
Regions of tension (T) and compression (C) in example model

Section 4
Stresses in facings

4.1 Consider the revised model, see Fig 3.4.2, with 50 mm thick and 100 kg/m^3 density core having the proposed side shell sandwich skins which comply with the Rules for Special Service Craft minimum requirements. As indicated in Fig. 3.4.1 there will be positions where tension and compression considerations will apply. The relevant elastic modulus has been applied to the element dependent upon its relative position in the sandwich. The proposed schedule together with the tabular calculations are given in Table 3.1.1. Such calculations are ideally suited to computer based investigation.

4.2 The stiffness, *EI*, per 1 cm width is determined using the parallel axis theorem:
In general,

$$I_{na} = I_{xx} - Ay^2$$
$$EI_{sect} = \Sigma EI_{base} - (\Sigma Et) \times 10 \times y^2$$

where
y = distance of neutral axis above base (mm).

4.3 It should be noted that the factor 10 (width in mm) is introduced to correct the value of area used in the parallel axis theorem, since a 1 cm wide strip of material is considered in the calculations.

From the tabulated calculations the overall stiffness of the section is calculated:

EI_{sect} = 1510439396 – (103699 x 10 x 27,36^2)
= 1510439396 – 776259189 Nmm^4/mm^2
= 734200000 Nmm^4/mm^2
= 73,4 x 10^3 Ncm^4/mm^2.

4.4 From Pt 8, Ch 3,1.13.7 of the Rules for Special Service Craft the individual layer stresses are determined from:

$$\sigma_{ti} = \frac{E_{ti}\,y_i\,M}{\Sigma\,(E_i\,I_i)} \times 10^{-1} \text{ N/mm}^2$$

The calculation of the tensile stress in the individual layers becomes:

$$\sigma_{ti} = \frac{17{,}0}{73{,}4 \times 10^3} \times E_{ti}\,y_i \times 10^{-1} \text{ N/mm}^2$$

$$\sigma_{ti} = 23{,}2 \times 10^{-6} \times E_i\,y_i \text{ N/mm}^2$$

where
E_i = modulus of elasticity of layer (N/mm^2)
y_i = distance of layer from the neutral axis (mm).

4.5 Consider the model as shown in Fig. 3.4.1.

4.5.1 Consider wet surface in tension at the panel boundary:

(a) Consider the CSM reinforcement in the outer ply (450 g/m^2 and G_c = 0,286)

σ_{CSMult} = 82,2 N/mm^2
E_t = 6290 N/mm^2
y_i = 27,36 mm
σ_{CSM} = 23,2 x 10^{-6} $E_t\,y_i$ N/mm^2
= 23,2 x 10^{-6} x 6290 x 27,36 N/mm^2
= 3,99 N/mm^2

Stress factor = 3,99/82,2 = 0,05 < 0,33 hence accept.

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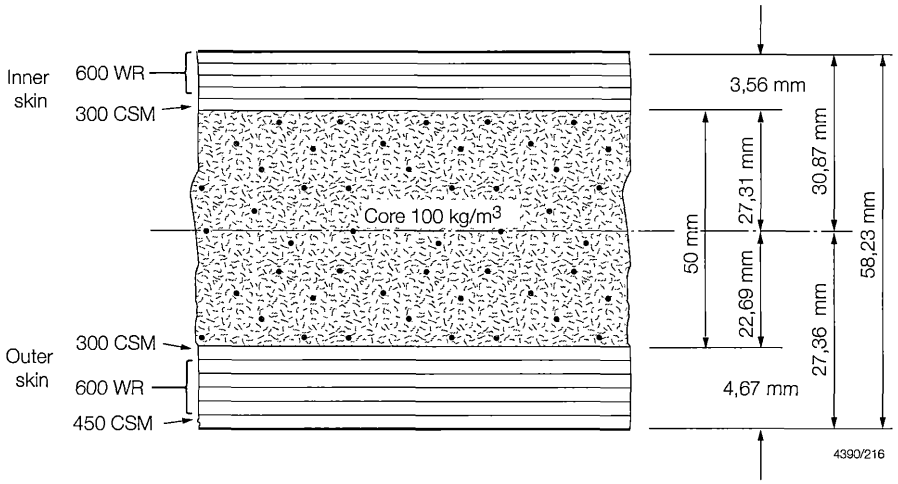

Fig. 3.4.2 Sandwich skin laminate details

(b) Consider the WR reinforcement in the in outer plies (600 g/m^2 and G_c = 0,5)

σ_{WRult} = 190 N/mm^2
E_t = 14500 N/mm^2
y_i = 27,36 – 1,112 = 26,25 mm
σ_{WR} = 23,2 x 10^{-6} E_t y_i N/mm^2
= 23,2 x 10^{-6} x 14500 x 26,25 N/mm^2
= 8,83 N/mm^2

Stress factor = 8,83/190 = 0,046 < 0,33 hence accept.

4.5.2 Consider inner surface in compression at the panel boundary:

(a) Consider top WR reinforcement in compression (600 g/m^2 and G_c = 0,5)

σ_{WRult} = 147 N/mm^2
E_c = 14000 N/mm^2
y_i = 58,23 – 27,36 = 30,87 mm
σ_{WR} = 23,2 x 10^{-6} E_c y_i N/mm^2
= 23,2 x 10^{-6} x 14000 x 30,87 N/mm^2
= 10,03 N/mm^2

Stress factor = 10,03/147 = 0,068 < 0,33 hence accept.

(b) Consider CSM reinforcement in compression (300 g/m^2 and G_c = 0,33)

σ_{CSMult} = 122 N/mm^2
E_c = 7200 N/mm^2
y_i = 30,87 – (4 x 0,734) = 27,93 mm
σ_{CSM} = 23,2 x 10^{-6} E_c y_i N/mm^2
= 23,2 x 10^{-6} x 7200 x 27,93 N/mm^2
= 4,67 N/mm^2

Stress fraction = 4,67/122 = 0,038 < 0,33 hence accept.

4.6 Stress fractions in this example are considerably lower than those required by the Rules for Special Service Craft and it is evident that the design is controlled by and core shear considerations and minimum skin thickness requirements.

4.7 As indicated in Chapter 2, Sections 2.4 to 2.7 of these Guidance Notes for Single Skin Laminates, consideration must be given to the strain compatibility of the reinforcements incorporated in the sandwich skins.

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Design of Stiffening Members

Section

1 **Calculation procedure**

2 **Bending moment at fixed end of stiffener**

3 **Web thickness to meet shear requirement**

4 **Calculation of deflection**

Section 1 Calculation procedure

1.1 Assume a design pressure of 70 kN/m^2 applied to a fully fixed bottom longitudinal located outside of the slamming zone as shown in Fig. 4.1.1.

1.2 The bending moment is determined from Pt 8, Ch 3,1.14.1 of the Rules for Special Service Craft. For a fully fixed stiffener the maximum bending moment coefficient from Table 3.1.5(a) in Pt 8, Ch 3 of the Rules for Special Service Craft is 1/12.

1.3 Hence, maximum bending moment, M_s, is given by:

$$M_s = \frac{s\, l_e^2\, p}{12} \text{ Nm}$$

$$M_s = \frac{500 \times l^2 \times 70}{12} \text{ Nm}$$

$$M_s = 2917 \text{ Nm}$$

Assumed shell laminate:

5 x 800/300 combination mats

G_c = 0,5 (WR in combination mat)
t_{WR} = 0,979 mm
E_t = 14500 N/mm^2

G_c = 0,33 (CSM in combination mat)
t_{CSM} = 0,625 mm
E_t = 6950 N/mm^2

1 x 450 CSM adjacent to gel coat

G_c = 0,286
t_{CSM} = 1,112 mm
E_t = 6290 N/mm^2

Total thickness, t_p = 9,132 mm

The effective width of attached plating $2b_1$ from Pt 8, Ch 3,1.7.1 of the Rules for Special Service Craft for single skin construction is:

$b_1 = 0{,}5b_w + 10t_{ap}$
$= 0{,}5 \times 120 + 10 \times 9{,}132$
$= 151$ mm

Hence, apply 302 mm attached plating.

Consider typical layup over 'top hat' stiffener:

450 g/m^2 CSM @ G_c = 0,33 – first ply over former
800 g/m^2 WR @ G_c = 0,5
800 g/m^2 WR @ G_c = 0,5
600 g/m^2 UDT @ G_c = 0,54
600 g/m^2 UDT @ G_c = 0,54
800 g/m^2 WR @ G_c = 0,5
800 g/m^2 WR @ G_c = 0,5 – top ply

1.4 Consider the idealised section shown in Fig. 4.1.2.

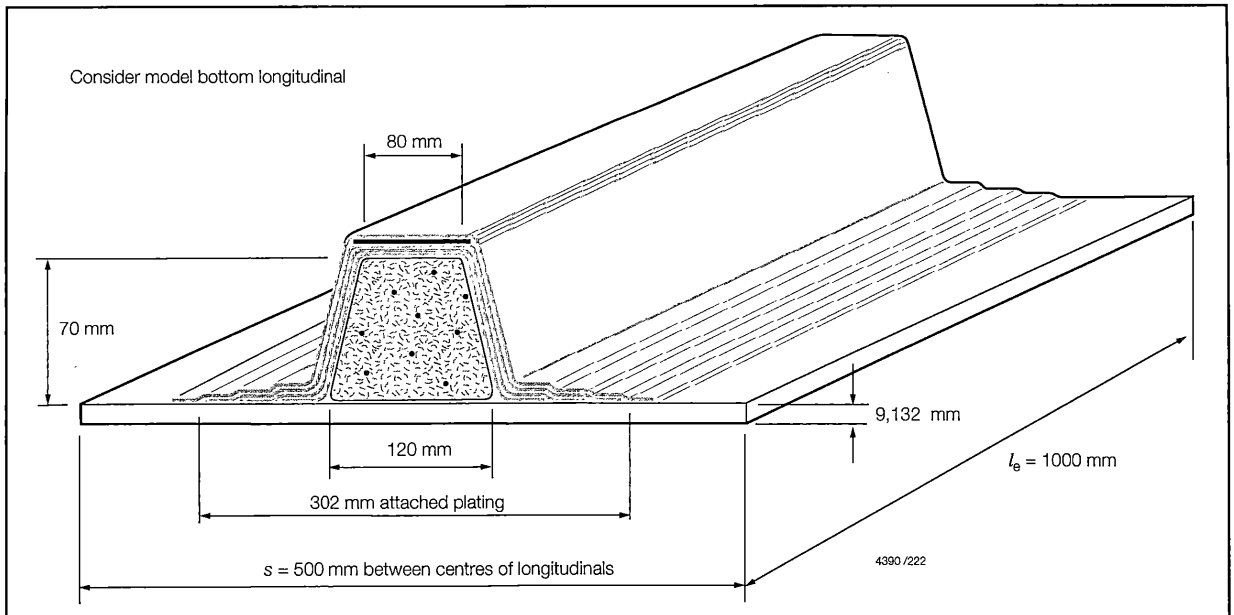

Fig. 4.1.1 'Top-hat' stiffener example model

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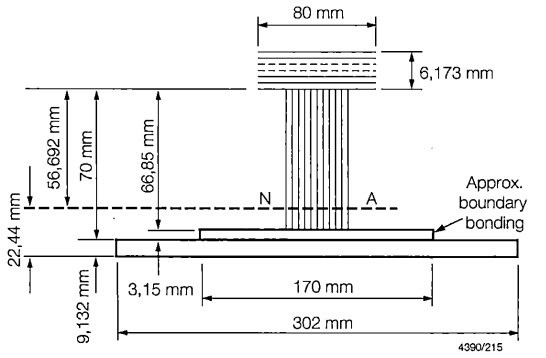

Fig. 4.1.2 Idealised section

1.5 The stiffener bonding is to be in accordance with Pt 8, Ch 3,1.18.6 of the Rules for Special Service Craft and a typical arrangement is shown in Fig. 4.1.3. To simplify the calculation of the stiffness of the overall section the tapered bonding is assumed to be an effective constant thickness. The effective thickness of the bonding is calculated as:

$$t_{bb} = \frac{(4{,}853 \times 25) + (4 + 3 + 2 + 1) \times 0{,}079 \times 15}{25 + (4 \times 15)}$$

$$t_{bb} = \frac{268{,}2}{85} = 3{,}15 \text{ mm}$$

The boundary bonding may be approximated to a thickness of 3,15 mm over an (85 x 2) mm width to account for both flanges. The majority of the flange comprises of woven rovings and it may be assumed that the tensile modulus is 145000 N/mm^2. The discrepancy is negligible since the element is very close to the neutral axis.

The effective depth and width of the web used in the idealised section are:

d_{web} = 70 – effective thickness on bonding
= 70 – 3,15
= 66,85 mm

t_{web} = 2 x (0,937 + 4 x 0,979)
= 2 x 4,853
= 9,706 mm

Now the web consists of two types of reinforcements, namely one ply of CSM and four plies of woven rovings. The majority of the web will be in compression and the overall modulus of elasticity may be calculated in accordance with Pt 8, Ch 3,1.13.5 of the Rules for Special Service Craft.

$$E_{web} = \frac{\Sigma (E_{ci}\, t_i)}{\Sigma\, t_i}$$

$$E_{web} = \frac{(0{,}937 \times 7200) + (0{,}979 \times 4 \times 14000)}{0{,}937 + (0{,}979 \times 4)}$$

E_{web} = 12687 N/mm^2

The web may now be treated as a single laminate item having an overall compressive modulus, given above.

1.6 The laminate section modulus calculation is shown in Table 4.1.1. The tabulation consists of each element having the compressive moduli in the section above the neutral axis and tensile moduli below. The actual breadth of each element must be entered to calculate the overall section properties. The tabulation corresponds to the idealised section in Fig. 4.1.2.

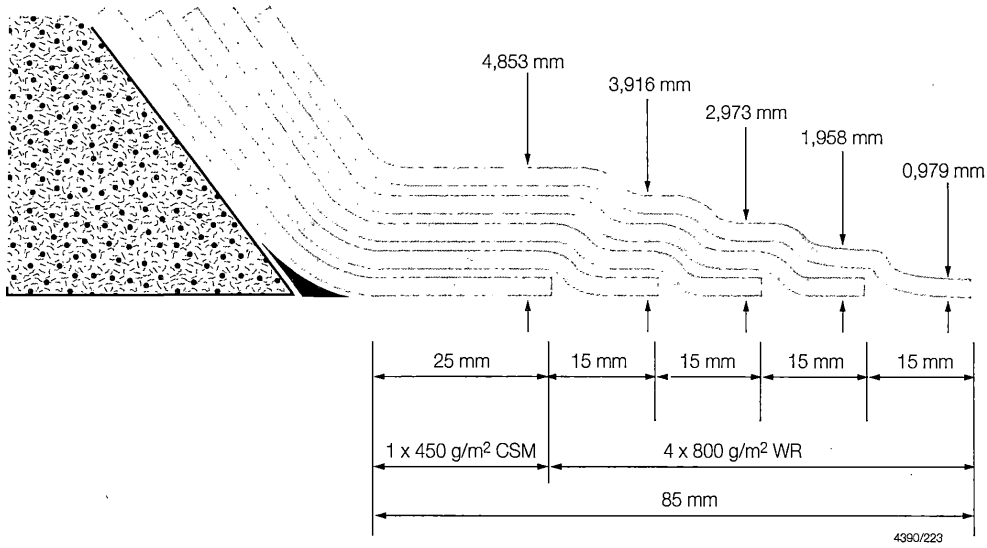

Fig. 4.1.3 Typical stiffener bonding arrangement

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Table 4.1.1 Initial tabulation of 'top-hat' stiffener calculations

	Ply No.	Description	G_c	Weight (g/m^2)	t (mm)	Breadth, b (mm)	Lever @ base, x (mm)	E (N/mm^2)	$t.b$	$E.t.b$	$E.t.b.x$	I @ base	EI @ base
Dry, *see* Note	1	WR	0,5	800	0,979	80	84,816	14000	78,32	1096480	92998499	563414,4	7887801805
	2	WR	0,5	800	0,979	80	83,837	14000	78,32	1096480	91925046	550483,0	7706761655
	3	UDT	0,54	600	0,660	80	83,017	20748	52,80	1095494	90944659	363890,1	7549992490
	4	UDT	0,54	600	0,660	80	82,357	20748	52,80	1095494	90221632	358127,2	7430422738
	5	WR	0,5	800	0,979	80	81,538	14000	78,32	1096480	89404238	520706,1	7289885632
	6	WR	0,5	800	0,979	80	80,559	14000	78,32	1096480	88330784	508277,4	7115883045
	7	CSM	0,33	450	0,937	80	79,601	7200	74,96	539712	42961345	474970,0	3419784035
	8	Web	0,5	–	66,85	9,706	45,707	12687	648,85	8231910	376255932	1597160,7	20263177372
	9	bonding	0,5	–	3,15	170	10,707	14500	535,50	7764750	83137178	61832,4	896570245
	10	WR	0,5	800	0,979	302	8,643	14500	295,66	4287041	37050752	22107,1	320553529
	11	CSM	0,33	300	0,625	302	7,840	6950	188,75	1311813	10285266	11609,3	80684330
	12	WR	0,5	800	0,979	302	7,039	14500	295,66	4287041	30174338	14670,7	212724485
	13	CSM	0,33	300	0,625	302	6,236	6950	188,75	1311813	8181119	7347,4	51064249
	14	WR	0,5	800	0,979	302	5,435	14500	295,66	4287041	23297924	8755,5	126954976
	15	CSM	0,33	300	0,625	302	4,632	6950	188,75	1311813	6076971	4056,7	28194272
	16	WR	0,5	800	0,979	302	3,831	14500	295,66	4287041	16421511	4361,7	63245002
	17	CSM	0,33	300	0,625	302	3,028	6950	188,75	1311813	3972824	1737,3	12074400
	18	WR	0,5	800	0,979	302	2,227	14500	295,66	4287041	9545097	1489,3	21594564
	19	CSM	0,33	300	0,625	302	1,424	6950	188,75	1311813	1868677	389,2	2704632
Wet, *see* Note	20	CSM	0,286	450	1,112	302	0,556	6290	335,82	2112333	1174457	138,4	870664
TOTALS					85,305				4436,05	53219882	1194228249		70480944121

NOTE
The crown of the stiffener is considered to be in compression in this example. 'Dry' indicates the face of the stiffener within the hull and 'wet' the outside of the shell laminate, *see* Fig. 4.1.4.

Position of neutral axis above base = $\frac{1194228249}{53219882}$ = 22,44 mm above base

Tensile modulus of elasticity of section = $\frac{53219882}{4436,05}$ = 11997 N/mm^2

Stiffness EI of section about NA = 4368304 N cm^4/mm^2

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1.7 The tabulation considers the entire section and calculates all moments about the base, which is taken to be the outer (wet) surface. The stiffness, EI, of the entire section, about the neutral axis, is determined using the parallel axis theorem:

In general,

$$I_{na} = I_{xx} - Ay^2$$
$$EI_{sect} = \Sigma EI_{base} - (\Sigma Etb) \times y^2$$

where

y = distance of neutral axis above the base (mm)

From the tabulation:

$$EI_{sect} = 70480944121 - 53219882 \times (22,44)^2$$
$$= 4368304336 \text{ Nmm}^4/\text{mm}^2$$
$$EI_{sect} = 4,368 \times 10^6 \text{ Ncm}^4/\text{mm}^2$$

From Pt 8, Ch 3,1.15 of the Rules for Special Service Craft the individual layer stresses are determined from:

$$\sigma_{ti} = \frac{E_{ti}\, y_i\, M}{\Sigma (E_i\, I_i)} \times 10^{-1} \text{ N/mm}^2$$

The calculation of the stresses in individual layers becomes:

$$\sigma_{ti} = \frac{2917}{4,368 \times 10^6} \times E_i\, y_i \times 10^{-1} \text{ N/mm}^2$$

$$\sigma_{ti} = 66,8 \times 10^{-6} \times E_i\, y_i \text{ N/mm}^2$$

where

E_i = modulus of elasticity of layer (N/mm^2)

y_i = distance of layer from the neutral axis (mm)

The 'top-hat' stiffener is subjected to a load model shown in Fig. 4.1.4. The diagram indicates the areas of tension and compression that exist on either side of the stiffener.

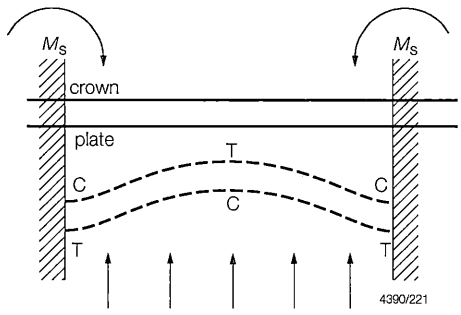

Fig. 4.1.4
Regions of tension (T) and compression (C) in example model

Section 2
Bending moment at fixed end of stiffener

2.1 The generalised stress equation is:

$$\sigma_i = 66,8 \times 10^{-6} \times E_i\, y_i \text{ N/mm}^2$$

The ultimate material properties may be found from Tables 3.1.1 and 3.1.2 in Pt 8, Ch 3 of the Rules for Special Service Craft and the limiting stress fractions from Table 7.3.1 in Pt 8, Ch 3 of the Rules for Special Service Craft.

2.1.1 Consider the crown of the stiffener:

(a) Consider the WR (G_c = 0,5) in compression:

E_c = 14000 N/mm^2
y_i = 85,305 – 22,44
= 62,865 mm
$\sigma_{WR\ comp}$ = 66,8 x 10^{-6} x 14000 x 62,865
= 58,8 N/mm^2
$\sigma_{WR\ ucs}$ = 147 N/mm^2

Stress fraction = 58,8/147 = 0,40 hence reject.

(b) Consider the UDT (G_c = 0,54) in compression:

E_c = 20748 N/mm^2
y_i = 85,305 – 22,44 – (2 x 0,979)
= 60,907 mm
$\sigma_{UDT\ comp}$ = 66,8 x 10^{-6} x 20748 x 60,907
= 84,4 N/mm^2
$\sigma_{UDT\ ucs}$ = 279 N/mm^2

Stress fraction = 84,4/279 = 0,303 hence acceptable.

(c) Consider the CSM (G_c = 0,33) over the stiffener former in compression:

E_c = 7200 N/mm^2
y_i = (85,305 – 22,44) – (4 x 0,979) – (2 x 0,66)
= 57,629 mm
$\sigma_{CSM\ comp}$ = 66,8 x 10^{-6} x 7200 x 57,629
= 27,7 N/mm^2
$\sigma_{CSM\ ucs}$ = 122 N/mm^2

Stress fraction = 27,7/122 = 0,227 hence acceptable.

2.1.2 Consider the loaded face of the shell:

(a) Consider the wet surface CSM (G_c = 0,286) in tension:

E_t = 6290 N/mm^2
y_i = 22,44 mm
$\sigma_{CSM\ tension}$ = 66,8 x 10^{-6} x 6290 x 22,44
= 9,4 N/mm^2
$\sigma_{CSM\ uts}$ = 91 N/mm^2

Stress fraction = 9,4/91 = 0,10 hence acceptable.

Due to such a low stress fraction the adjacent CSM (G_c = 0,33) will also be acceptable.

(b) Consider the WR (G_c = 0,5) in tension:

E_t = 14500 N/mm^2
y_i = 22,44 – 1,112 – 0,625
= 20,703 mm
$\sigma_{WR\ tension}$ = 66,8 x 10^{-6} x 14500 x 20,703
= 20,05 N/mm^2
$\sigma_{WR\ uts}$ = 190 N/mm^2

Stress fraction = 20,05/190 = 0,105 hence acceptable.

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2.2 However, the conclusion is that the compressive stress fraction in the WR in the crown of the stiffener is unacceptable. A number of options exist, which include:

(a) The use of higher strength materials such as carbon fibre or aramid reinforcements.
(b) Add UDT reinforcements in the crown of the stiffener.
(c) Laminate local collars at the end of the stiffeners to increase the section stiffness. This is usually labour intensive and not weight efficient.

2.3 Logically, for this example, the easiest solution is to add UDT reinforcements in the crown of the stiffener. Two additional UDT reinforcements have been included in the revised arrangement. The effect on the section stiffness of the revised schedule is shown in Table 4.2.1.

2.4 Recalculation of stress in the WR reinforcement in the stiffener crown using the revised section stiffness of 5200996 Ncm/mm^2:

$$\sigma_{ti} = \frac{2917}{5200996} \times E_i y_i \times 10^{-1} \text{ N/mm}^2$$

$$\sigma_{ti} = 56{,}09 \times 10^{-6} \times E_i y_i \text{ N/mm}^2$$

Consider the WR (G_c = 0,5) in the crown of the stiffener in compression:

E_c = 14000 N/mm^2
y_i = 86,625 – 24,926
= 61,7 mm
$\sigma_{WR\ comp}$ = 56,09 x 10^{-6} x 14000 x 61,7
= 48,4 N/mm^2
$\sigma_{WR\ ucs}$ = 147 N/mm^2

Stress fraction = 48,4/147 = 0,329 hence acceptable.

2.5 Re-consider the outermost UDT (G_c = 0,54) in compression:

E_c = 20748 N/mm^2
y_i = 86,625 – 24,926 – 0,979
= 60,720 mm
$\sigma_{UDT\ comp}$ = 56,07 x 10^{-6} x 20748 x 60,720
= 70,66 N/mm^2
$\sigma_{UDT\ ucs}$ = 279 N/mm^2

Stress fraction = 70,66/279 = 0,25 hence acceptable.

2.6 The example demonstrates that the additional two UDT's in the crown increases the section stiffness by 19 per cent and is accompanied by a movement in the neutral axis from 22,44 – 24,926 mm above the base. The stress fraction in the woven roving in the crown is reduced from 0,4 to 0,329 and meets the Rule requirement of 0,33.

Considerable care must be exercised when additional material radically affects the position of the neutral axis. For this reason the stress in the outermost UDT's has also been re-calculated and found to be satisfactory.

2.7 Where aramid reinforcements are being used then special consideration must be given to the compressive properties. For comparison purposes aramid reinforcements, at a fibre content of 0,45, typically have the following properties:

	Tension	Compression
Ultimate strength (N/mm^2)	300	100
Elastic modulus (N/mm^2)	21000	17000

2.8 The radical reduction in ultimate compressive strength may prove to be unsuitable in the crown of the stiffener at the end or in the panel at mid span. Designs which feature aramid fibres in the outer plies of the panel, in an attempt to make use of the superior impact properties, must be checked at mid span for compression in the individual layers. This also applies to hybrid reinforcements containing aramid fibres. These reinforcements have one off properties of higher than one of the constituent fibres however, in service the individual allowable strains for each fibre reinforcement should not be exceeded.

2.9 In accordance with Pt 8,Ch 3,1.5.1 of the Rules for Special Service Craft, it is of paramount importance that the strain compatibility of the component materials is carefully considered.

2.10 Consider typical values of apparent strain, ε_a, at failure for the following materials in laminate form:

	Tension	Compression
'E' glass	1,3%	1,05%
Carbon fibre	0,9%	0,55%
Aramid fibre	1,3%	0,60%

2.11 The actual strain permissible is controlled by the material with the lowest apparent strain. The level of strain depends upon whether the reinforcements are in tension or compression and depends on their relative positions within the laminate. Consequently if, for example, a carbon fibre reinforcement is used in the crown of the stiffener then the compression strain must be constrained to a maximum of 0,33 x 0,55 per cent, i.e., 0,297 per cent. Therefore, the corresponding allowable stress in the other reinforcements must be related to the strain in the reinforcement relative to its position away from the neutral axis and that of the carbon fibre reinforcement, e.g.:

$$\varepsilon_{limitWR} = \frac{\varepsilon_{allowable\ carbon} \times y_{WR}}{y_{carbon}}$$

2.12 Other materials incoporated into stiffening members requiring strain compability consideration are plywoods, timbers, etc., which have very differing strains at failure dependent upon the direction of the grain.

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Table 4.2.1 Revised tabulation of 'top-hat' stiffener calculations including additional uni-directional reinforcements

	Ply No.	Description	G_c	Weight (g/m^2)	t (mm)	Breadth, b (mm)	Lever @ base, x (mm)	E (N/mm^2)	$t.b$	$E.t.b$	$E.t.b.x$	I @ base	EI @ base
Dry, *see* Note	1	WR	0,5	800	0,979	80	86,136	14000	78,32	1096480	94445853	581087,7	8135228350
	2	UDT	0,54	600	0,660	80	85,316	20748	52,80	1095494	93463200	384323,6	7973946157
	3	WR	0,5	600	0,979	80	84,497	14000	78,32	1096480	92648722	559184,3	7828580341
	4	UDT	0,54	600	0,660	80	83,677	20748	52,80	1095494	91667685	369699,1	7670516637
	5	UDT	0,54	600	0,660	80	83,017	20748	52,80	1095494	90944659	363890,1	7549992490
	6	WR	0,5	800	0,979	80	82,198	14000	78,32	1096480	90127915	529169,8	7408376853
	7	UDT	0,54	600	0,660	80	81,378	20748	52,80	1095494	89149143	349663,5	7254818749
	8	WR	0,5	800	0,979	80	80,559	14000	78,32	1096480	88330784	508277,4	7115883045
	9	CSM	0,33	450	0,937	80	79,601	7200	74,96	539712	42961345	474970,0	3419784035
	10	web	0,5	–	66,850	9,706	45,707	12687	648,85	8231910	376255932	1597160,7	20263177372
	11	bonding	0,5	–	3,150	170,000	10,707	14500	535,50	7764750	83137178	61832,4	896570245
	12	WR	0,5	800	0,979	302	8,643	14500	295,66	4287041	37050752	22107,1	320553529
	13	CSM	0,33	300	0,625	302	7,840	6950	188,75	1311813	10285266	11609,3	80684330
	14	WR	0,5	800	0,979	302	7,039	14500	295,66	4287041	30174338	14670,7	212724485
	15	CSM	0,33	300	0,625	302	6,236	6950	188,75	1311813	8181119	7347,4	51064249
	16	WR	0,5	800	0,979	302	5,435	14500	295,66	4287041	23297924	8755,5	126954976
	17	CSM	0,33	300	0,625	302	4,632	6950	188,75	1311813	6076971	4056,7	28194272
	18	WR	0,5	800	0,979	302	3,831	14500	295,66	4287041	16421511	4361,7	63245002
	19	CSM	0,33	300	0,625	302	3,028	6950	188,75	1311813	3972824	1737,3	12074400
	20	WR	0,5	800	0,979	302	2,227	14500	295,66	4287041	9545097	1489,3	21594564
	21	CSM	0,33	300	0,625	302	1,424	6950	188,75	1311813	1868677	389,2	2704632
Wet, *see* Note	22	CSM	0,286	450	1,112	302	0,556	6290	335,82	2112333	1174457	138,4	870664
TOTALS					86,625				4541,65	55410871	1381181352		86437539378

NOTE: 'Dry' indicates the face of the stiffener within the hull and 'wet' the outside of the shell laminate, *see* Fig. 4.1.4. Consider the crown of the stiffener in compression.

Position of neutral axis above base = $\frac{1381181352}{55410871}$ = 24,926 mm above base

Tensile modulus of elasticity of section = $\frac{55410871}{4541,65}$ = 12201 N/mm^2

Stiffness EI of section about NA = 5200996 N cm^4/mm^2

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Section 3
Web thickness to meet shear requirement

3.1 Ultimate shear stress from Table 3.1.2 in Pt 8, Ch 3 of the Rules for Special Service Craft. From the web thickness (4,853 mm) given in 1.5 and the web laminate schedule given in Fig. 4.1.3 (*i.e.* total weight of 3650 g/m^2) the effective glass content may be calculated, by transforming the relationship given in Pt 8, Ch 4,1.6.1 of the Rules for Special Service Craft. The effective glass content of the web is therefore 0,47.

$\tau_S = 80\,G_c + 38 = 76$ N/mm^2

From Pt 8, Ch 7, Table 7.3.1 of the Rules for Special Service Craft.
Limiting shear stress fraction = 0,33
Limiting shear stress = 0,33 x 76 = 25,08 N/mm^2.

3.2 The shear stress requirement is given in Pt 8, Ch 3,1.14.3 of the Rules for Special Service Craft. By setting the shear stress to the limiting shear stress the equation may be rearranged:

$t_w = F_S/(2 \times d_w \times \tau_S)$ mm

The actual shear load is given in Pt 8, Ch 3,1.14.2 of the Rules for Special Service Craft.

$F_s = \phi_S\, p\, s\, l_e$ N

The shear stress coefficient is obtained from Table 3.1.5 in Pt 8, Ch 3 of the Rules for Special Service Craft.

$F_s = 0,5 \times 70 \times 500 \times 1 = 17500$ N

Consequently, the minimum web thickness to meet the Rule requirement is:

$t_w = 17500/(2 \times 70 \times 25,08) = 4,98$ mm

The actual web thickness is 4,853 mm. The deficiency is only 0,127 mm and is considered acceptable.

3.3 Finally, check the minimum Rule requirement for web thickness. From Pt 8, Ch 3,1.16.2 of the Rules for Special Service Craft.

$$t_w = \frac{0,025 d_w + 1,1}{1,3 f_w + 0,61}$$

For a web depth of 70 mm and fibre content of 0,47 the minimum web thickness is 2,33 mm. Hence the minimum requirement is fulfilled.

Section 4
Calculation of deflection

4.1 The deflection is calculated from Pt 8, Ch 3,1.14.5 of the Rules for Special Service Craft. From the tabulation the overall section stiffness is $(EI)_s = 5200996$ Ncm^4/mm^2

$$\delta_s = \frac{\phi_S\, p\, s\, l^4}{(EI)_s} \times 10^5 \text{ mm}$$

$$\delta_s = \frac{1}{348} \quad \frac{70 \times 500 \times 1^4}{5200996} \times 10^5 \text{ mm}$$

$\delta_s = 1,93$ mm.

4.2 The limiting span/deflection ratio is given in Table 7.2.1 in Pt 8, Ch 7 of the Rules for Special Service Craft and typically for a bottom longitudinal (not in the slamming zone) the ratio required is 150.

Span/deflection ratio = length/mid-point deflection
= 1000/1,7
= 588 hence acceptable.

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Section

1 **Introduction**

2 **Fatigue – General considerations**

Section 1 Introduction

1.1 Purpose of the Guidance Notes

1.1.1 With the advent of novel and high speed craft types the need for good structural detail has never been more important. Most structural failures that occur in the service life of a craft result from fatigue. A considerable amount of published data exists for more conventional steel vessels, however, little or no such data exists for the novel or high speed craft constructed from aluminium alloy or composite materials. Lloyd's Register (hereinafter referred to as LR) has amassed considerable knowledge in respect of structural detail which has demonstrated satisfactory service experience in resisting structural failure from fatigue. The details contained within these Guidance Notes are therefore provided to assist Builders and designers in identifying a minimum level of design detail which has provided acceptable levels of resistance to structural failure arising from fatigue.

1.1.2 It is not intended that the details contained within these Guidance Notes are the only solution to a particular structural design. Alternative structural details that have demonstrated satisfactory service experience will be acceptable.

1.2 General

1.2.1 Quality of detail design is fundamental if the craft's envisaged design life is to be attained. Experience over the past two decades, when structural concepts were revolutionised and aspects such as speed greatly increased, clearly indicated that areas of detail design became more prone to fatigue cracking with the traditional structural arrangements for details being used at that time.

1.2.2 Service experience has shown that provided the general concepts of a structural design are adequate then success or failure in structural terms will depend on the quality of detail design.

1.2.3 In general, the problems associated with aspects of detail design are those relating to fatigue ageing and failure.

1.2.4 Fatigue is failure under repeated loads. There are three phases in a fatigue fracture: crack initiation, crack propagation, and fracture. These phases are not completely separable. The process may be described as the formation of a crack, because of repeated local plasticity, its progression until a critical size is reached, where upon the structure fails. Fatigue accounts for a large percentage of all service failures.

1.2.5 A structural element can be subjected to various kinds of loading conditions, including fluctuating stress/strain, fluctuating temperature (thermal stress/strain), or any of these in a corrosive environment or at elevated temperatures. Most service failures occur as a result of tensile stresses.

1.2.6 Fatigue cracks generally initiate at high stress locations such as structural discontinuities, weld toes, matting in connections, etc. As these cracks propagate the ultimate load carrying capability of the structure is reduced until sufficient fatigue damage is accumulated for the structure to fail at normal working loads. Since fatigue cracks can be possible points of initiation for catastrophic failures or costly craft repairs, it is essential that fatigue is given more detailed consideration in the design of the structure.

1.2.7 Fatigue ageing of structural components is an accumulative process which is largely due to the environment and the loads experienced. An important realisation is that it is inevitable and where stress concentrations are present in association with significant magnitudes of stress variation then fatigue cracking will, in general, occur. Factors which influence performance, in that they affect the magnitude of stress ranges and provide stress concentrations, are as follows:

(a) The loading experienced.
(b) The quality of detail design.
(c) The selecting of the type and grade of material.
(d) The standard of workmanship in the craft construction.
(e) Corrosion rates and magnitudes (metallic structures).
(f) Erosion rates and magnitudes (composite structures).

1.2.8 Since the fatigue properties of higher tensile strength metallic materials are, in general, similar to those of the basic grade materials, the higher allowable stress magnitudes could entail a shorter fatigue life in standard details. Assuming that the fatigue life is a function of the stress range to the third power, it is clear that detail design requires special consideration to reduce the effects of stress concentrations. If higher tensile strength materials are incorporated and hence higher stress levels are accepted, then structural details, which would have been acceptable in mild steel structure manufactured from the basic grade material, might not be adequate.

1.2.9 The occurrence of cracking in craft is of prime concern from both a safety and maintenance point of view. Experience has shown that fatigue cracks in craft structures are normally of a self limiting nature. However, the existence of fatigue cracking may, if not repaired, render the structure susceptible to subsequent brittle or fast fracture. Thus both types of cracks are significant from a maintenance point of view. Fatigue cracks, if not repaired, may also initiate catastrophic failure as a consequence of the more extensive use of structural optimisation leading to a decrease in the level of structural redundancy.

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Section 2
Fatigue – General considerations

2.1 Basis of the Guidance Notes

2.1.1 In assessing fatigue performance, the effect of cyclic loading should be taken into consideration. The types of cyclic loading experienced in service, will, in general, depend upon the size, type and speed of the craft. Cyclic wave induced loads created by the passage of waves along the craft sides and the associated local structural response create the highest risk for fatigue damage and cracking for large craft whereas, the major consideration for small high speed craft will relate to impact considerations, hard spots and discontinuities in the structure, etc.

2.1.2 Loading associated with bottom structures, in terms of hull girder response and local pressure variation, are heavily influenced by the length of waves and their direction in relation to the craft length and draught. Similarly, the deck structure is exposed to hull girder loads in response to relatively longer waves and cargo local loads arising from craft responses. Alternatively, these can be associated with structural discontinuities and slamming in shorter waves.

2.1.3 Deck and bottom longitudinal structure require attention to detail design and structural continuity to reduce the effects of stress concentration. Depending on the type of craft, the side shell structure may be exposed to dynamic loading from the internal pressure head from storage of consumables or cargo, in association with wave induced pressure variations, resulting in high cycle local bending stresses applied to the longitudinals and connection details at the transverse bulkhead stiffeners. This may transfer moments resulting in further increased stresses in the side longitudinals.

2.1.4 Every stress concentration and welded joint is a potential source of fatigue cracking and the design, taking note of symmetry, should reflect this. To ensure the structural integrity of the stiffening members particular attention should be given to the detail design. This document provides initial design guidance on fatigue and includes recommendations for the improvement of welded joint fatigue strength, or the bonded joint fatigue strength in the case of composite structures.

2.1.5 The fatigue strength of a structural detail is dependent on the following factors:

(a) The direction of the fluctuating stress relative to the detail.
(b) The location of initiating crack in the detail.
(c) The geometrical arrangements and relative proportion of the detail.

It may also depend on:

(d) The material (unless welded).
(e) The method of fabrication.
(f) The degree of inspection.

2.2 Fatigue mechanism

2.2.1 Fatigue damage starts prior to the initiation of a crack. With repeated loading, localised regions of slip (plastic deformation) develop. These deformations are accentuated by repeated loading, until a discernable crack finally appears.

2.2.2 The initial cracks form along slipped planes. The crack is crystallographically oriented along the slip plane for a short distance. This is sometimes referred to as Stage I crack growth. Eventually the crack propagation direction becomes macroscopically normal to the maximum tensile stress. This is referred to as Stage II crack propagation, and it comprises most of the crack propagation life.

2.2.3 The relative cycles for crack initiation and propagation depend on the applied stress. As the stress increases, the crack initiation phase decreases. At very low stresses (high cycle fatigue), therefore, most of the fatigue life is utilised to initiate a crack. At very high stresses (low cycle fatigue), cracks form very early. The separation of high and low cycle fatigue is not clear-cut. Generally, the low cycle region is that which results from stresses that are often high enough to develop significant plastic strains. It is usually assumed that the separation zone for low and high cycles is of the order of $10^4 - 10^5$ cycles to failure.

2.2.4 There are visual differences between high cycle (low stress) and low cycle (high stress) fatigue. In the latter, deformation resembles that seen with unidirectional loading. Strain hardening can occur and the slip bands are coarse. In high cycle fatigue, the slip bands are usually very fine.

2.3 Allowable stresses

2.3.1 For a particular craft component the allowable stresses should be in accordance with the requirements of LR's *Rules and Regulations for the Classification of Special Service Craft* (hereinafter referred to as the Rules for Special Service Craft).

2.4 Design loads

2.4.1 Applied design loads must take into consideration the appropriate environmental and dynamic conditions. Such loads are indicated in Part 5 of the Rules for Special Service Craft.

2.4.2 Realistic assessment of the fatigue loading is crucial to the estimation of fatigue life. Little or no published data for loading exists for the types of craft covered by the Rules for Special Service Craft. LR is conducting research in this field, the results of which will form the basis of Rules for Special Service Craft requirements in the future.

2.5 Stress concentrations

2.5.1 The design, fabrication and construction of all structural details should be based on procedures and processes to minimise stress concentrations.

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2.5.2 Fatigue strength is seriously reduced by the introduction of a stress raiser such as a notch, of the method of termination of stiffeners and brackets, etc., or a hole. Since actual hull structure elements invariably contain stress raisers like fillet welds, end brackets, cut-outs, etc., it is not surprising to find that fatigue cracks in structural parts usually start at such geometrical irregularities. One of the most effective ways of minimising fatigue failure is by the reduction of avoidable stress raisers through careful design and the prevention of accidental stress raisers by careful processing and fabrication. While this section is concerned with stress concentrations resulting from geometrical discontinuities, stress concentration can also arise from surface roughness and metallurgical stress raisers such as porosity, inclusions, local overheating in grinding and decarburisation, etc., as appropriate to the construction material.

2.5.3 The effect of stress raisers on fatigue under uniaxial loading is that;

(a) there is an increase or concentration of stress at the root of the notch,
(b) a stress gradient is set up from the root of the notch,
(c) a triaxial state of stress is produced.

2.5.4 The ratio of the maximum stress to the nominal stress is the Stress Concentration Factor.

2.5.5 Values of the stress concentration factor will vary depending upon:

(a) the severity of the notch,
(b) the type of notch,
(c) the material,
(d) the type of loading, and
(e) the stress level.

2.6 Stiffness

2.6.1 Abrupt changes in stiffness of the structure should be avoided as they can induce local stress concentrations and reductions of fatigue life.

2.7 Vibration

2.7.1 If possible, precautions should be taken in the design against the possibility of excessive structural vibration being induced, for example, by machinery. This would entail investigation of the natural frequencies of the panel members and of the sources of excitation.

2.8 Potential modes of failure

2.8.1 The potential modes of fatigue failure are dependent upon the direction of the applied stress relative to the position of the weld and the position of stress concentrations due to structural discontinuities.

2.8.2 For longitudinal butt welds in plates, dressed flush, and lying parallel to the direction of applied stress, the initiation of potential fatigue failures is expected to be found at weld defect locations. In the 'as-welded' condition, fatigue cracks may be initiated at the weld start-stop positions or, weld surface ripples.

2.8.3 For transverse butt welds in plates, essentially perpendicular to the direction of applied stress, the fatigue strength depends largely upon the shape of the weld profile. Fatigue cracks normally initiate at the weld toe.

2.8.4 Cruciform fillet weld joints associated with the four way connection of plate or stiffeners, may be separated into two distinct types depending on whether or not the fillet weld transmits direct load i.e. non-load carrying or load carrying cruciform joints. In the case of the non-load carrying cruciform joint, the fatigue crack will initiate at the weld toe and propagate through the thickness of the load bearing plate in a plane perpendicular to the direction of the applied stress.

2.8.5 In load carrying cruciform joints, in addition to the weld toe, acute stress concentration occurs at the root of the fillet weld and generally fatigue cracks are initiated at the root of the weld and propagate through the weld throat. The fatigue life of such connections can be improved either by increasing the throat size of the fillet weld or by requiring improved weld penetration. In high stress regions however, such measures may not be adequate and there is then a need to specify a full penetration weld in order to achieve the necessary fatigue life for the joint.

2.8.6 Tee joints, since they represent a semi-cruciform joint in a three way connection of plates or stiffeners, would be expected to demonstrate similar fatigue characteristics to the load bearing cruciform joint. However, if bending stresses are induced in the base plate material of the tee, which are of a similar or greater magnitude than the direct stress in the tee, then a fatigue crack may initiate in the base plate at the toe of the fillet weld and propagate through the base plate.

2.8.7 Where tee or cruciform connections employ full penetration welds, and the plate material is subject to significant strains in a direction perpendicular to the rolled surfaces, it is recommended that consideration be given to the use of special plate material with specific through thickness properties, as detailed in Ch 3,8 of the *Rules for Manufacture, Testing and Certification of Materials* (hereinafter referred as the Rules for Materials).

2.8.8 For welded stiffeners and girders, fatigue cracks can be expected to be initiated at weld toes and may be associated with local stress concentrations at the weld ends of connecting end brackets or stiffeners.

2.8.9 The most common sites for potential fatigue cracks therefore are:

(a) Toes and roots of fusion welds.
(b) Machined corners.
(c) Drilled holes, cut-outs or other openings.

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2.8.10 The main conditions affecting fatigue performance are:

(a) High ratios of dynamic to static loads.
(b) Loading frequency.
(c) Material selection.
(d) Welding.
(e) Complexity of joint detail.
(f) Environment.

2.8.11 For craft operating for long periods in low air temperatures, or high temperatures for composites, the material of exposed structures will need to be specially considered.

2.9 Welds

2.9.1 Some commonly used weld details have low fatigue strength. This applies not only to joints between members, but also to any attachment to a loaded member, whether or not the resulting connections are considered to be structural.

2.9.2 The heat-affected zone (HAZ) is of great importance to the fatigue strength of welds because this is usually the region where a fatigue crack will develop. Moreover, when the reinforcement of a butt weld is not removed, or when fillet welds are used, a resulting sudden change of section occurs, and stress concentrations occur at the weld toe.

2.9.3 For the specification of welding and structural details, *see* Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft for steel and aluminium alloy craft respectively.

2.10 S-N curves

2.10.1 A material's fatigue characteristics are fatigue strength and fatigue limit.

2.10.2 The fatigue strength is the stress value beyond which the material will fail at a specified number of stress cycles.

2.10.3 The fatigue limit is the fatigue strength corresponding to an infinite number of stress cycles.

2.10.4 The S-N curve represents the dependence of the life of the 'specimen' in a number of cycles, N, to the maximum applied stress, S. N is usually taken (unless specified otherwise) as the number of stress cycles to cause a complete fracture in the 'specimen'.

2.10.5 Usually no distinction is made between the number of cycles to initiate a crack and the number of cycles to propagate the crack completely through the specimen, although it can be appreciated that the number of cycles for crack propagation will vary with the dimensions of the specimen. Fatigue tests for high cycle fatigue are usually carried out for $10^5 - 10^7$ cycles and sometimes to 5×10^8 cycles for non-ferrous metals. For a few important engineering materials such as steel and titanium, the S-N curve becomes horizontal at a certain limiting stress. Below this limiting stress, which is called the fatigue limit, or endurance limit, the material can presumably endure an infinite number of cycles without failure.

2.11 Complexity of joint detail

2.11.1 Complex joints frequently lead to high stress concentrations due to local variations on stiffness and load path. Whilst these may have little effect on the ultimate static capacity of the joint they can have a severe effect on fatigue resistance.

2.11.2 If fatigue control is the dominant criteria, the member cross-sectional shape should be selected to ensure smoothness and simplicity of joint design, so that stresses can be calculated and adequate standards of fabrication and inspection assured.

2.11.3 The best fatigue behaviour will be obtained by ensuring that the structure is detailed and constructed so that stress concentrations are kept to a minimum and that, where possible, the elements may deform without introducing secondary deformations and stresses due to local restraints.

2.11.4 Stresses may be reduced by increasing the thickness of the parent metal and this would theoretically increase fatigue life due to a reduction of the nominal stresses. However, it should be borne in mind that fatigue strength decreases, in general, with increasing thickness.

2.12 Surface properties

2.12.1 Since fatigue failure is dependent on the condition of the surface, anything that changes the fatigue strength of the surface material will greatly alter the fatigue properties.

2.12.2 As an example most mechanically finished metallic parts have a shallow surface layer in residual compression. Aside from the effect on surface roughness, the final surface finishing process will be beneficial to fatigue when it increases the depth and intensity of the compressively stressed layer and detrimental when it decreases or removes this desirable layer. Thus sandblasting, glass bead peening, burnishing, and other similar operations generally improve fatigue properties.

2.13 Residual stress

2.13.1 Residual stresses arise when plastic deformation is not uniform throughout the entire cross section of the detail being deformed. They therefore comprise a system of internal stresses in the material balanced within the material itself and can exist in the absence of any external loading. Thus if there is an area of tensile residual stress in any cross section at one part of a material there must be a residual compressive stress at some other point. There would in addition be a variation of stress through the thickness of the material, particularly for thicker sections.

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2.13.2 In a welded joint residual stresses are induced as a consequence of local heating and cooling cycles associated with the welding procedure and in particular the shrinkage of the weld metal. The actual situation in a welded joint is complicated by practical factors such as the type and size of joint, the welding process used and the weld procedure. In a butt weld for example, high residual tensile stress will exist in the direction of the weld and at right angles to it. In the case of multi-pass or high energy welding these residual stresses may reach the level of the yield strength of the material. As such tensile residual stresses can occur in locations where fatigue cracks are likely to initiate, it will be appreciated that they can lead to a proportional reduction in the fatigue strength of a joint when it is subjected to additional dynamic tensile loads.

2.14 Compressive residual stress

2.14.1 The formation of a favourable compressive residual-stress pattern at the surface is probably the most effective method of increasing fatigue performance. As indicated in 2.13, residual stresses are locked-in stresses which are present in a part which is not subjected to an external force. Only macro-stresses, which act over regions which are large compared with the grain size, are considered here.

2.14.2 In general, for a situation where part of the cross section is deformed plastically while the rest undergoes elastic deformation, the region which was plastically deformed in tension will have a compressive residual stress after unloading, while the region which was deformed plastically in compression will have a tensile residual stress when the external force is removed. The maximum value of residual stress which can be produced is equal to the elastic limit of the metal.

2.14.3 The high compressive residual stresses at the surface must be balanced by tensile residual stresses over the interior of the cross section.

2.14.4 The improvement in fatigue performance, which results from the introduction of surface compressive residual stress, will be greater when the loading is one in which a stress gradient exists than the case when no stress gradient is present.

2.14.5 It is important to recognise that improvements in fatigue properties do not automatically result from the use of shot peening or surface rolling. It is possible to damage the surface by excessive peening or rolling.

2.14.6 In order for the desirable effect of surface cold working to be maintained, the cold-working process must be accomplished in the final heat-treated condition and subsequent thermal treatment eliminated when feasible and closely controlled when essential. Exposure of cold-worked surfaces to elevated temperature initially results in stress relief of the plastically deformed zone and ultimately in recovery or perhaps re-crystallisation of the work-hardened area, with complete loss of the desirable residual stress gradient.

2.15 Grinding

2.15.1 There are some processes that are capable of developing high localised surface temperatures which are often difficult to detect and occasionally are responsible for a failure in service. Grinding can be one of these processes.

2.15.2 The rapid quenching of the material immediately below the grinding wheel by the large mass of cold metal can produce cracks or 'check'. High strength steels (for which grinding is most often used) are particularly sensitive to grinding techniques.

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Guidance for Designers for Steel/Aluminium Construction

Section

1 **Introduction**

2 **Fatigue strength improvement methods**

■ *Section 1* Introduction

1.1 Definition

1.1.1 **Critical areas** can be defined as locations that, by reason of stress concentration, alignment/discontinuity and corrosion will have a higher probability of failure during the life of the craft than the surrounding structures. **Critical locations** are defined as the specific locations within the critical area that can be prone to fatigue damage for which design improvements are provided.

1.2 General

1.2.1 In order to assist the designer to minimise fatigue failures, LR has developed an extensive database on structural detail design aspects.

1.2.2 Utilising the results from detailed finite element analyses for an extensive range of structural details it has been possible to examine a variety of configurations for each detail thereby enabling a grading to be made of their relative fatigue performance.

1.2.3 The outcome from some of this work has been condensed into these Guidance Notes. It is intended as a conservative approach to improving the fatigue life performance of structural details.

1.2.4 The designer may therefore, using these Guidance Notes, readily upgrade the detail design arrangements to provide a higher fatigue performance configuration.

1.2.5 It is intended that the detail design database given in Chapter 4 will be extended to incorporate further detail arrangements, to reflect in-service experience of their fatigue performance, design and construction practice, as well as any significant data made available from research studies.

1.2.6 In addition, guidance is provided to the designer and Builder on other methods to improve the fatigue life performance of the structural detail such as detail geometry, construction tolerances, welding sequence, weld defect, weld dressing, etc.

1.3 Application

1.3.1 The detail design improvements provided in these Guidance Notes are applicable to all grades of steel, commonly used aluminium alloys and composite structures. This is because the fatigue life improvement will be achieved through the suggested change of **geometry** which will reduce the stress concentrations and the **improved construction** requirements which will improve the performance throughout the design lifetime of the structural detail under the expected stress variations.

1.3.2 In areas where **mild steel** and basic grade aluminium may be used a number of the suggested detail improvements may not be necessary due to the lower stress ranges that the details are designed to experience. However, in areas where **higher tensile steel** (HTS) or higher strength grade aluminium are used, the operating stresses will generally be higher. Therefore the detail improvements suggested may become necessary in order to meet the fatigue strength of the structure.

1.3.3 **Alternative structural arrangements** will, in general, be acceptable provided it can be demonstrated, that a satisfactory fatigue life performance will be maintained throughout the design life span. In addition the structural arrangements and scantlings are to satisfy the Rules for Special Service Craft.

1.3.4 Where suggested values are indicated regarding geometries or scantlings, these are given as guidance.

■ *Section 2* Fatigue strength improvement methods

2.1 General

2.1.1 In general, the presence of a weld or a bonded joint in a structural component represents a possible weakness with regard to both brittle fracture and fatigue life. The low fatigue life of welded details can be considered as a limiting factor for the design of more efficient structures, in particular, since the fatigue strength of steel and aluminium materials does not increase with the yield strength.

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2.1.2 Upgrading of the fatigue life of a structural detail can be achieved in a number of ways as follows:

Design Stage
- By adopting good detail design configuration, i.e., by the provision of soft connections, the geometrical stress concentration factor due to the geometrical discontinuity may be reduced to a satisfactory level.
- By increasing the local scantlings, in particular those of the plate in which the potential crack sites are located, to reduce the local hot spot stresses.
- By modifying the structural load path and/or reducing the structural load level by the provision of additional load carrying members.

Fabrication Stage
- By improving the fatigue life of the detail by using an improvement method.

2.1.3 It is LR's intention to promote the Design Stage method for fatigue strength improvement of a craft's structural details. Fabrication stage improvement methods should only be considered as remedial measures, and subjected to strict quality control procedures. Where a fabrication stage improvement method is planned at the design stage, it is to be specially considered by LR to ensure that a satisfactory level of fatigue strength improvement is achieved.

2.2 Significant variables affecting fatigue strength improvement methods

2.2.1 The significant variables affecting the fatigue strength of a craft's structural details are reviewed:
- The geometrical notch at the weld toe region is normally the most fatigue critical area. Welded joints inherently contain a number of defects, most of which are so sharp that they start growing as fatigue cracks when the structure is subjected to dynamic loads, thus eliminating the crack initiation stage of the fatigue life.
- The fatigue crack is most likely to initiate and propagate in the Heat Affected Zone (HAZ) region, since local metallurgical changes may affect the local fatigue properties of the material, and defects are usually concentrated in this area.
- Residual stresses are set up in and near the weld due to the contraction of the weld metal during the cooling phase. These local residual stresses due to welding may reach yield stress magnitude, and affect the fatigue properties in a similar manner to externally imposed loads. Tensile residual stresses tend to reduce the fatigue strength, while compressive residual stresses may improve the fatigue strength. Attention to residual stresses is not only limited to the welding process, residual stresses may arise due to the restraints applied to the prefabricated units, the forcing of the prefabricated units during assembly, or uneven thermal expansion creating long range residual stresses acting over large areas. These long range residual stresses tend not to be relaxed by the occurrence of peak loads resulting in the so called shakedown process, or local treatment of the structural detail. However, they are generally of small magnitude compared to welding residual stresses.

2.3 Design stage fatigue strength improvement methods

2.3.1 It is clear that the most efficient method to improve the fatigue strength of welded structural details is at the design stage. To this effect, there are four factors which need to be specially considered to improve the fatigue strength of ship structural details as follows:
- Nominal stress level.
- Geometrical stress concentration due to the structural detail geometry.
- Weld geometry and construction tolerances.
- Residual stresses and construction procedure.

Each item outlined above is presented in the following Sections.

2.3.2 **Nominal stress level.** The most efficient way to improve fatigue strength is to increase the local scantling to reduce the nominal stress level, and hence the hot spot stress for a given structural detail. In general, structural details on higher tensile steel and aluminium require improvement in detail design over the mild steel and the base grade aluminium equivalent structural detail by virtue of the higher stress level and the constant fatigue strength for material of various yield strength. The advantages and disadvantages of this fatigue strength improvement method are summarised in Table 2.3.1.

Table 2.3.1 Nominal stress level

Advantages	Disadvantages
• Reduce stress level • Increase static strength • Potential decrease in number of structural components and/or complexity required over that for a structural detail in higher tensile strength material	• Increase structure weight

2.3.3 **Geometrical stress concentration.** The adoption of a good detail design configuration by the provision of soft connections reduces the geometrical stress concentration factor due to the geometrical discontinuity to a satisfactory level. Typical detail design improvements for the critical areas are provided in Chapters 4 and 5 of these Guidance Notes for steel/aluminium alloy and composite construction respectively. These detail design improvements have been developed from the consolidation of service experience and finite element analysis. The advantages and disadvantages of the subject fatigue improvement method are summarised in Table 2.3.2.

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Table 2.3.2 Geometrical stress concentration

Advantages	Disadvantages
• Reduce hot spot stress level by reducing the local geometrical stress concentration • Most effective fatigue strength improvement technique • May provide additional structural redundancy	• May increase structural weight if additional pieces are required • Requires good workmanship where soft toe/heel are required

2.3.4 **Weld geometry and construction tolerances.** At the design stage, special attention may be given to achieving a favourable geometry and smooth transition at the weld toe, and minimising secondary stress concentration which may arise from the fit up and misalignment. Since the weld notch stress concentration is a direct function of the weld flank angle and the weld toe radius, critical structural details may be specified with an enhanced weld procedure and construction tolerances.

In view of the size and hull form of special service craft, additional considerations must, in general, be given to the accessibility for welding. This should include the selection of the depth, geometry and orientation of the stiffening members to provide the necessary access to carry out the required welding sequences, with the type and size of welding equipment available to the Builder.

The advantages and disadvantages of the subject fatigue improvement method are summarised in Table 2.3.3.

Table 2.3.3 Weld geometry and construction tolerances

Advantages	Disadvantages
• The improvement may be introduced at the design stage • The improvement is performed in the welding process itself • Subject to well defined inspection plan and hence higher reliability	• Improvement can be subject to large scatter if not controlled under QA survey conditions i.e., Fatigue Control Plan

2.3.5 **Residual stresses, and construction procedures.** The minimising of residual stresses through the adoption of appropriate welding procedures and sequences, the use of adequate unit size, and appropriate sequence of erection of the prefabrication unit do not constitute in themselves a fatigue strength improvement procedure. Nevertheless careful planning should be considered at the design stage to ensure that detrimental effects will not be introduced during the construction process.

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Construction Tolerances and Defect Correction Procedures for Steel/Aluminium Construction

Section

1 **Introduction**

2 **Construction tolerances**

3 **Defect correction procedures**

■ *Section 1* Introduction

1.1 General

1.1.1 The fatigue life of structural details can be adversely affected by a variety of imperfections. The most common type of imperfections are:

(a) Misalignment of structural members, poor fit-up.
(b) Welding defects.
(c) Material defects.
(d) Poor manufacture and fabrication procedures resulting in stress concentrations.
(e) Unfairness of plating.

1.1.2 The actual influence on fatigue life will depend on the number, location and size of such imperfections.

1.1.3 Where design calculations highlight regions of stress concentration then experience clearly indicates that such regions will have a higher probability of failure during the life of the craft than surrounding structures. Hence in such locations there is a need to introduce standards that will reduce or eliminate the number or type of imperfections present.

1.1.4 Basic requirements concerning welding and structural details are given in Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft for steel and aluminium alloy craft respectively. The individual standards employed by Builders are normally based on individual national standards, e.g. British Standards, and these supplement the Rule requirements.

1.1.5 Construction and erection criteria in accordance with such standards must inevitably be taken into account in the fatigue life calculation for any structural detail. Whilst it may be anticipated that such criteria may, in general, in association with an acceptable detail arrangement, provide for adequate fatigue life, there may well be instances where there is a specific need to introduce construction tolerances that are more rigorous.

1.1.6 The LR Surveyors will be required to confirm that the work is carried out in accordance with the approved construction tolerances. Where the approved tolerances are exceeded then corrective action to the satisfaction of the Surveyor will be required. Details of the construction tolerances and defect correction procedures to be applied are indicated in Pt 3, Ch 1 of the Rules for Special Service Craft.

■ *Section 2* Construction tolerances

2.1 General

2.1.1 Construction tolerances are to comply with Pt 3, Ch 1 of the Rules for Special Service Craft. The additional guidance given in this Chapter should also be complied with where practicable.

2.2 Defects in steel/aluminium products

2.2.1 Where defects are found in materials after delivery to the Builder, any rectification should be agreed with the LR Surveyor and should generally be in accordance with Ch 3,1.10 or Ch 8,1.10 of the Rules for Materials and aluminium respectively.

2.2.2 If lamination is found during plate preparation the extent of the lamination should be ascertained by ultrasonic examination. Renewal of the affected material is normally recommended.

2.3 Construction standards

2.3.1 Construction standards (including preparation of material, joint alignment, type of welded joint, fit-up prior to welding, steps to be taken for rectification of defects, etc.) are to be agreed between LR and the Builder. Such standards will be recorded and kept on file by LR. In a number of countries national standards exist in respect of the acceptable ship-building standards.

2.3.2 In shipyards certified under the LR Quality Assurance Scheme, the standards will have received general approval as part of the certification procedures and their application to particular craft will be included in the quality plan submitted to LR for approval.

2.3.3 In considering critical locations and their construction standards it also has to be borne in mind that craft construction is a traditional process with alignment standards based on heel lines. In addition, therefore, to establishing the more critical joints in terms of fatigue life, consideration of the thicknesses to be employed in these joints should be a fundamental factor. If the heel line principle is maintained at the toes of, for example, primary member end brackets, where increased thicknesses are employed, the arrangements will in reality, be out of line, even though perfect alignment is attained to the standard, *see* Fig. 3.2.1(a). It is therefore recommended, particularly for aluminium, that a median line principle is employed at this local area so that an improved alignment can be more easily attained. From LR's point of view the various thicknesses of plating at structural joints, particularly the higher stress joints, is an important consideration. In this respect the gradient of load through the through-thickness loaded plate should be controlled to a maximum of one in three, *see* Fig. 3.2.1(b).

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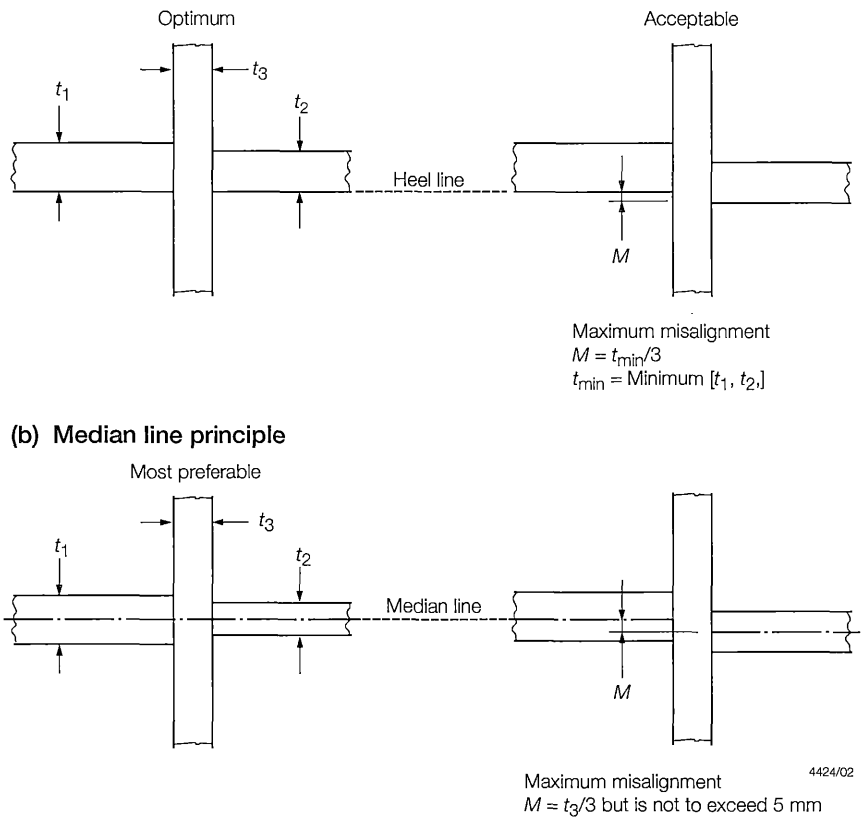

Fig. 3.2.1 Recommended alignment of primary members

2.3.4 In addition to cruciform joint misalignment, the alignment of secondary stiffening and associated brackets is also important. Recommendations are made in Fig. 3.2.1 and Fig. 3.2.2. Where centreline alignment is recommended the tolerance guideline in Fig. 3.2.2 should be followed.

2.3.5 Whenever possible the plate thicknesses, t_1 and t_2, (*see* Fig. 3.2.1) should be kept as close as possible in order to minimise the potential difficulties associated with a median line alignment.

2.4 Prefabrication

2.4.1 Throughout the preparation of material and assembly of prefabrication units, the workmanship is to be inspected in order to ensure that correct procedures are being followed. By attention in the early stages of construction, undesirable procedures and faulty workmanship can be avoided, or their consequences minimised. When the existence of such defects is noticed prompt and suitable measures are to be taken for rectification.

2.4.2 Examination of structure will normally be carried out during the prefabrication of units, and liaison between the LR Surveyor and the Builder's drawing offices and quality control departments will ensure that attention is also given to details which may not have been included on approved plans (air and drainage holes, etc.) during early material preparation stages.

2.4.3 It should be borne in mind that visual examination of welds and plating of a finished structure does not necessarily ensure a complete and satisfactory survey. Procedures are to be such as to ensure that adequate inspection is made of joint preparation before welding. Attention is drawn to the guidance on welding and structural details in Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft for steel and aluminium alloy craft respectively. Regular examination by the LR Surveyor, in conjunction with the Builder, of non-destructive examination and other Quality records provides a check on the quality of welding operations and any decline in standards should be investigated, including additional tests as considered desirable.

2.4.4 It is essential that a good standard of cleaning be achieved for these inspections. Special attention, as indicated in Pt 7, Ch 2,3.11.5 of the Rules for Special Service Craft, are to be applied for aluminium. For steel structures welding slag should be removed and rusting of weld deposits should be removed by wire brushing.

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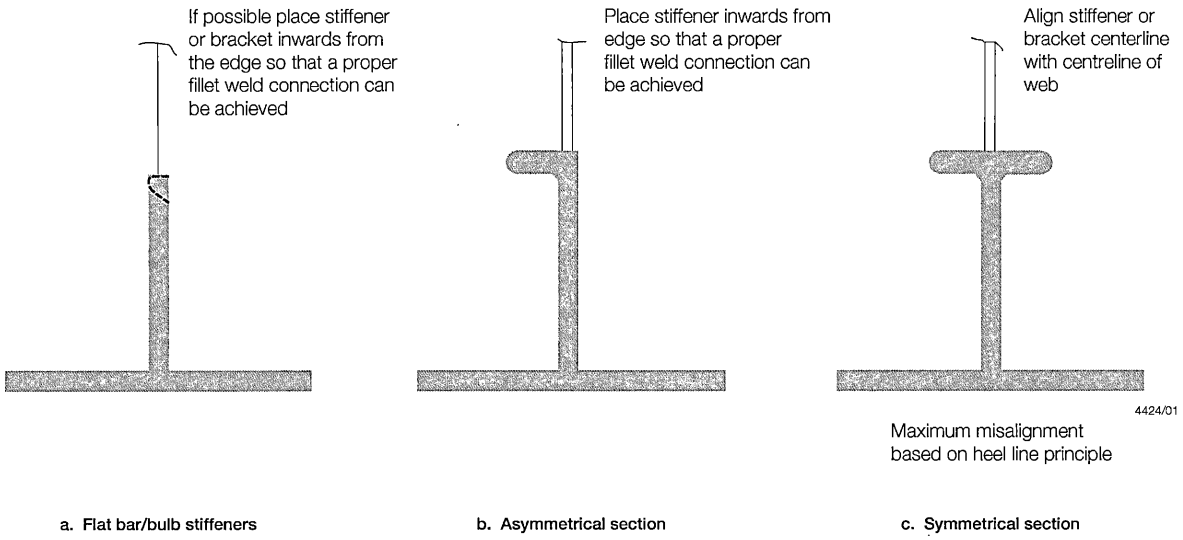

Fig. 3.2.2 Recommended alignment of secondary stiffening members

2.5 Assembly of units

2.5.1 The Builder and the LR Surveyors must ensure by regular and systematic examination that the control exercised up to the stage of block assembly is maintained by the efficient erection of blocks at the berth. It is particularly necessary at this point to ensure that fit-up, alignment, adjustment and welding of blocks is in accordance with the approved plans and building standards. Attention is to be given to the sequence of erection and of welding. Particular attention should be given to length allowance for unwelded stiffening member alignment.

2.5.2 With the assembly of large blocks careful attention should be paid to the areas in way of lifting lugs. It is not unusual to find small cracks in the vicinity of the weld area after removal of lugs. Where lugs are removed the dressing of the plate must be thorough and examination by means of crack detection of the finished surface is good practice. Repair of any cracks found must be carried out by skilled welders under strict control.

2.5.3 Any unusual incidents during construction, such as fracturing of plates, should be noted and brought to the attention of the LR Surveyor. It will be necessary to have full information on the circumstances affecting such cases, such as position and extent of the fracture relative to adjacent structure and welds, atmospheric temperature, details of joints, precise stage and sequence of welding, type of electrode filler wire used, whether or not pre-heating was used, grades of steel or aluminium alloy involved and any other factors considered to have had a possible influence. Test details of affected plates and proposals for remedial measures should also be made available. Where doubt exists in establishing the source of such incidents, the assistance of LR's staff at Headquarters, should be sought.

Section 3
Defect correction procedures

3.1 Inspection and testing

3.1.1 The fabrication specification should state the extent of visual inspection and non-destructive examination along with details of the techniques and the appropriate acceptance criteria.

3.1.2 All non-destructive examination should be in accordance with written procedures. (*See also* Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft for steel and aluminium craft respectively).

3.1.3 Quality control levels for weld flaws found by radiographs, ultrasonic testing, magnetic particle and dye penetrant inspection, as appropriate, are to be approved by LR and shall be imposed during fabrication as a means of quality control.

3.1.4 Welded joints critical to the integrity of the structure should be subjected to radiographic examination and/or, where applicable, surface examination during construction. This non-destructive examination should be carried out prior to delivery, after the completion of welding and prior to any coating which would adversely effect the type of non-destructive examination being undertaken. Any repairs resulting from the testing are be re-examined.

3.1.5 Any necessary repairs and corrective actions are to be carried out to the satisfaction of the LR Surveyor and in accordance with an agreed procedure.

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Detail Design Improvement for Steel/Aluminium Construction

Section

1 **Identification of critical areas**

2 **Structural details**

■ *Section 1* Identification of critical areas

1.1 General

1.1.1 LR has applied direct calculation procedures in the structural appraisal and approval of new buildings and in various investigations on special service craft of both steel and aluminium alloy construction. Through these procedures and the wealth of information collected on the LR fleet database, a number of locations have been identified where good design, workmanship and alignment during construction are particularly important. These are usually locations where high stress variations can be experienced during the lifetime of the craft. These are referred to to as **critical locations** and are highlighted in this Chapter.

1.1.2 This Chapter identifies the **critical areas** within various structural elements of the hull structure and transverse bulkheads.

1.1.3 In Section 2 the structural **detail design improvements** that can be applied to increase the fatigue life of the structural components are provided. These detail improvements are intended to give the designer guidance for meeting the design criteria for structural detail components.

1.1.4 The application of 2 and 3-dimensional finite element analyses techniques to the hull structure enables the global and local capabilities of the hull structure to withstand static and dynamic loadings to be assessed. Such analyses will enable those high stress locations and joints within the craft to be readily identified. Such locations will then, by their very nature, be at risk to fatigue damage unless appropriate measures are taken at the design stage and subsequently during construction.

1.1.5 Extensive 'in service' experience of the performance of existing craft structures, already provide an awareness of those critical locations which merit particular attention either due to stress or alignment difficulties.

1.2 Critical areas

1.2.1 Stress concentrations occur in both the primary and secondary structures of all craft and are identified during the design process by such means as finite element calculations. The designer will modify the detail to alleviate the stress concentration either by redesign or increase in scantlings. However, even after modification that area will still, in general, be exposed throughout the life of the craft to stresses higher than in surrounding areas.

1.2.2 At the design appraisal stage, a plan of the structure should, where appropriate, be prepared indicating by the Builder or designer these regions, and consideration can then be given, by the production team, into the appropriate methods of construction and the tolerances to be applied in order to remain within the assigned design parameters.

1.3 Misalignment during construction

1.3.1 The very nature of steel/aluminium construction requires the assembly of a multitude of structural components into blocks within an assembly shop and then the erection of these blocks within a building dock or on a building berth. The welded interface between structural components in sub-assembly areas can be reasonably controlled; however, the welded connections between large prefabricated blocks in the building dock or on the building berth cannot be so easily controlled due to the sheer size of the blocks being handled.

1.3.2 The most critical type of joint is the welded cruciform joint where it is subjected to high magnitudes of tensile stress normal to the table member of the joint.
The double bottom construction lends itself to the block construction. The interfaces between these blocks and those formed by the primary transverse structure may lie in areas of high stress. Critical cruciform joints are also found within the prefabricated blocks and also require close attention to alignment, but this is more easily achieved.

1.3.3 It can readily be seen that the combination of stress concentration and misalignment is to be avoided if the fatigue strength is to be satisfactory during the service life of the craft.

1.4 Fatigue considerations

1.4.1 The bottom shell area of high speed craft is subjected to the highest cyclic loading throughout the life of such craft.

1.4.2 The fatigue fractures in bottom longitudinal end-connections of higher tensile steel and aluminium alloy has been well documented, and constructional details in way of these connections, designed to increase fatigue life, are now incorporated by many Builders as standard. It is, therefore, important that due consideration be given to this detail at the design stage to reduce the risk of fatigue cracking during service.

1.4.3 Detailed recommendations are given herein for the critical areas, *see* Section 2.

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Section 2
Structural details

2.1 Detail design improvement

2.1.1 For the purposes of these Guidance Notes, structural locations have been divided into three separate groups, with a series of examples of critical structural areas together with alternative associated detail design improvements.

2.1.2 A summary of the data presented is given in Table 4.2.1 whilst the full details are given in Figs. 1 to 29 as contained in this Section.

2.1.3 Generally, where alternative structural detail design improvements are provided, the details shown will provide improved fatigue strength.

2.1.4 Where asymmetrical sections are shown, the same requirements apply to bulb plate stiffeners and flat bars.

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Detail Design Improvement for Steel/Aluminium Construction

Table 4.2.1

Group	Application	Area	Item	Fig. No
	High speed craft			
1		Hull structure	Chine to frame connection	1
		Hull structure	Chine and chine bar details (1)	2
		Hull structure	Chine and chine bar details (2)	3
		Hull internal structure	Frame to beam connection (radiused)	4
		Hull internal structure	Frame to beam connection (continuous bracket)	5
		Hull internal structure	Lug connections between secondary stiffeners and primary stiffener webs (1)	6
		Hull internal structure	Lug connections between secondary stiffeners and primary stiffener webs (2)	7
		Watertight/oiltight bulkheads	Shell longitudinals collared, brackets aligned	8
		Watertight/oiltight bulkheads	Shell longitudinal (fitted brackets)	9
		Watertight/oiltight bulkheads with boundary bar	Shell longitudinal (fitted brackets)	10
		Watertight/oiltight bulkheads	Collar inserts in way of secondary stiffening members	11
		Watertight/oiltight bulkheads	Collar inserts in way of primary stiffening members	12
		Cross-deck structure, multi-hulls	Inner side web frame to deck transverse connection	13
		Cross-deck structure	Deck transverse to watertight bulkhead connection	14
		Multi-hull structure	Cross-deck beam to bulkhead connection	15
	Low speed craft			
2		Hull internal structure	Floor to frame connection (bracketed)	16
		Hull internal structure	Frame to beam connection	17
		Watertight/oiltight bulkheads with boundary bar	Shell longitudinals (lapped brackets)	18
		Watertight/oiltight bulkheads	Shell longitudinals (lapped brackets)	19
		Watertight/oiltight bulkheads	Shell longitudinals collared, brackets lapped	20
		Cross-deck structure, multi-hulls	Connection between cross-deck beams and side hulls	21
	General detail			
3		Cross-deck structure, multi-hulls	Connection between cross-deck beams and side hulls	22
		Hull centreline structure	Bar and plate keels	23
		Hull centreline structure	Bar keels	24
		Hull centreline structure	Fabricated plate keel/skeg	25
		Hull centreline structure	Round bar and flat bar stems	26
		Hull centreline structure	Fabricated and plate stems	27
		Hull internal structure	Floors to frame connection (radiused)	28
		Hull internal structure	Web frame to tank boundary connection	29

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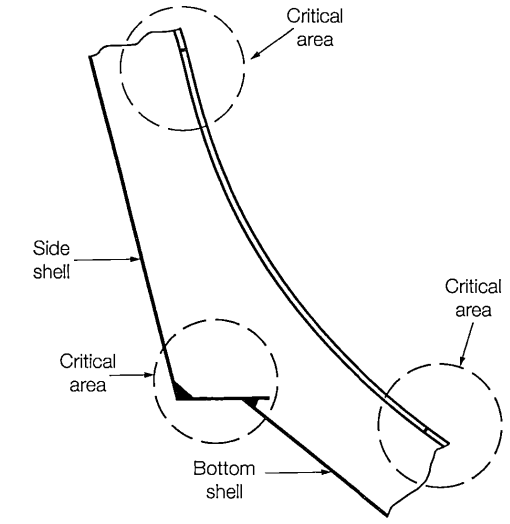
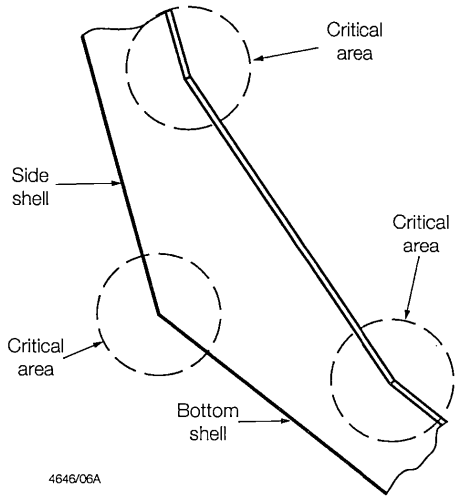
Detail Design Improvement for Steel/Aluminium Construction

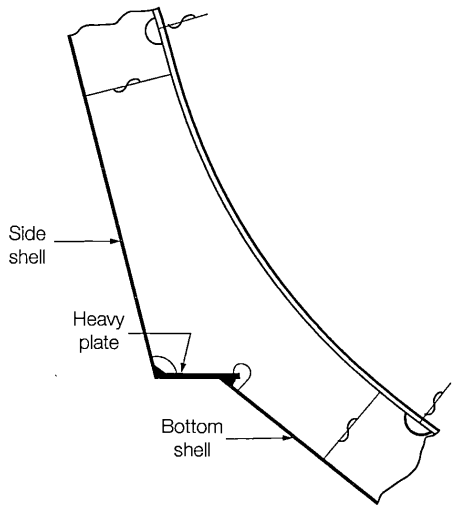
AREA: Hull structure

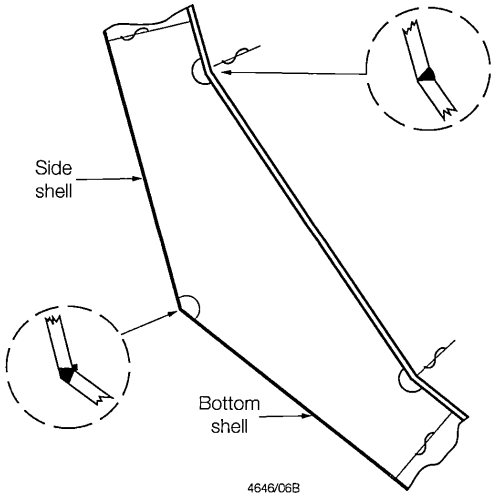
ITEM: Chine to frame connection

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT









NOTES

Failure Mechanism	Fatigue fractures from areas of tri-axial stress.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. All welding between chine bars and shell plating is to be full penetration type. Butts in web plating and face flats are to be staggered.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
1	STEEL/ALUMINIUM CONSTRUCTION	1

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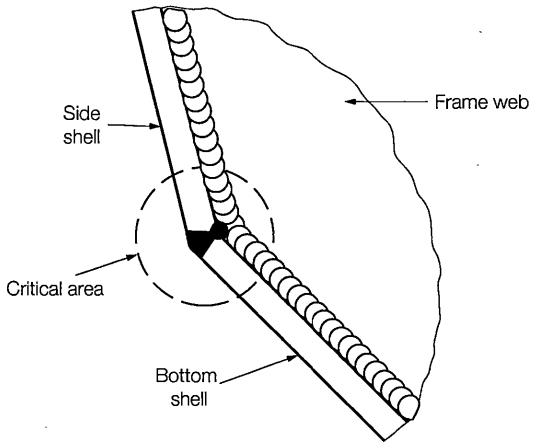
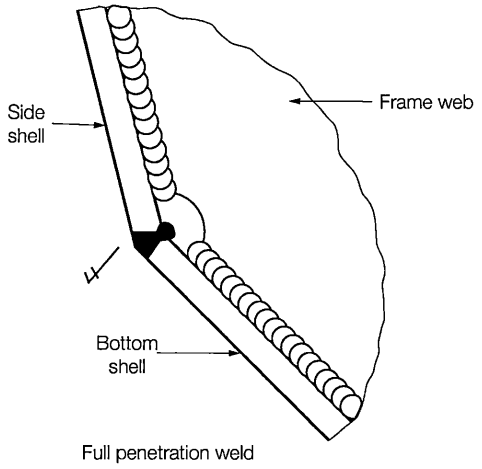
Detail Design Improvement for Steel/Aluminium Construction

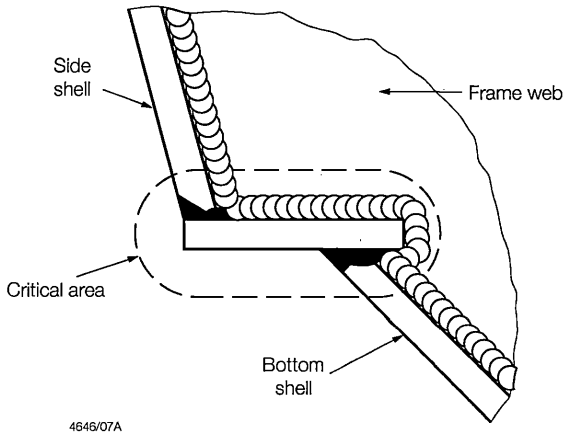
AREA: Hull structure

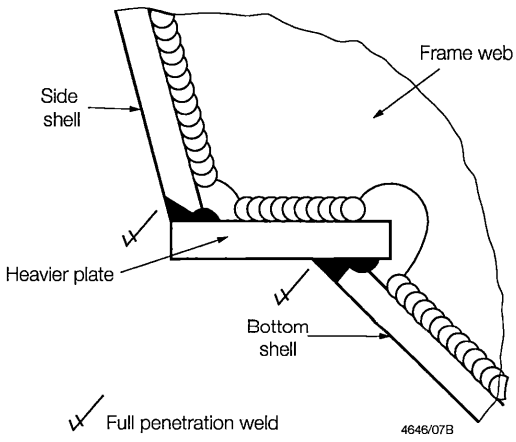
ITEM: Chine and chine bar details (1)

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT









NOTES

Failure Mechanism	Fatigue fractures from areas of tri-axial stress.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. All welding in way of shell plating and between chine bar and shell plating is to be full penetration type. Welds are to be returned around scallops.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
1	STEEL/ALUMINIUM CONSTRUCTION	2

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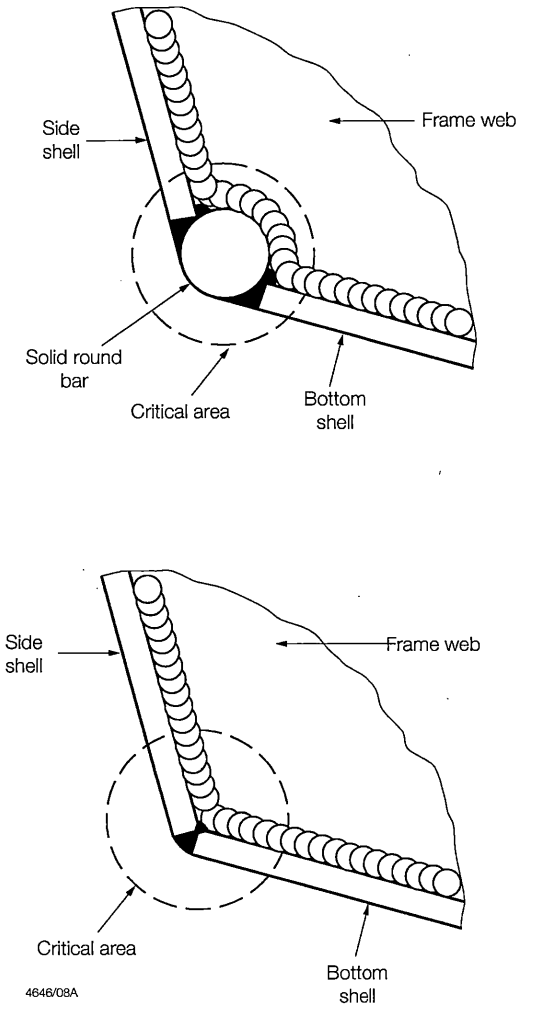
Detail Design Improvement for Steel/Aluminium Construction

AREA: Hull structure

ITEM: Chine and chine bar details (2)

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT



NOTES

Failure Mechanism	Fatigue fractures from areas of tri-axial stress.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. All welding in way of shell plating and between chine bar and shell plating is to be full penetration type. Welds to be returned around scallops.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
1	STEEL/ALUMINIUM CONSTRUCTION	3

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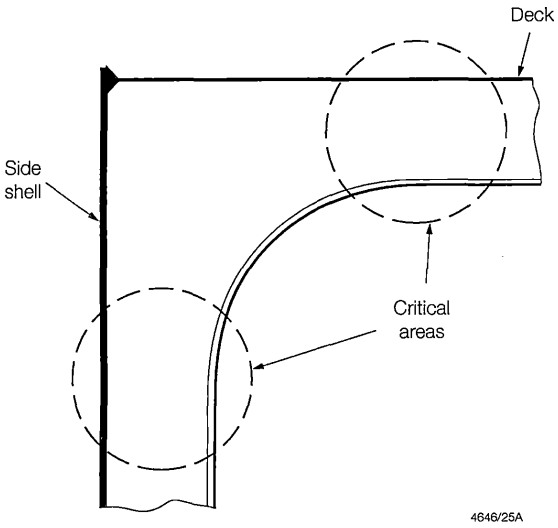
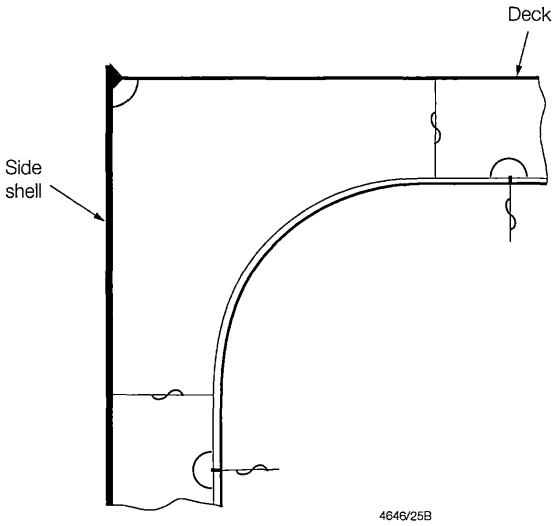
Detail Design Improvement for Steel/Aluminium Construction

AREA: Hull internal structure

ITEM: Frame to beam connection (radiused)

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT
	

NOTES

Failure Mechanism	Fatigue fractures in way of welds.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. Webs to be accurately aligned. Butts in webs are to be staggered from the butts in face flats. All welds to be returned around scallops.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
1	STEEL/ALUMINIUM CONSTRUCTION	4

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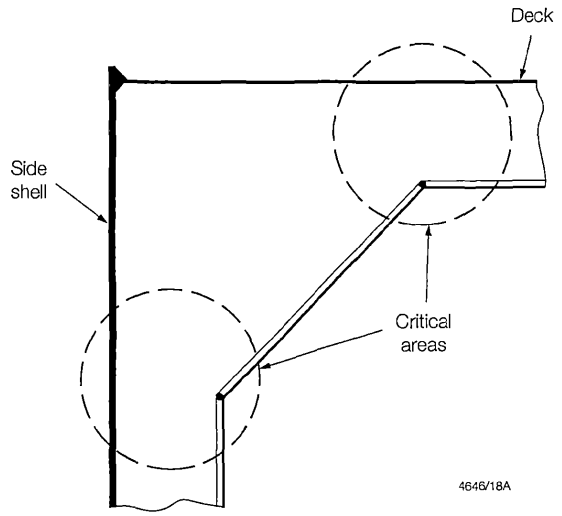
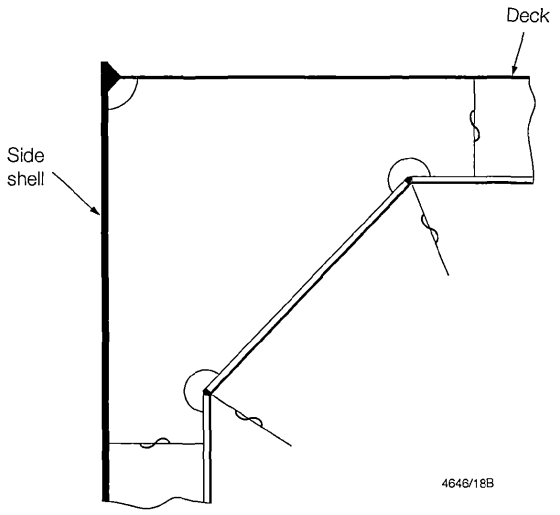
Detail Design Improvement for Steel/Aluminium Construction

AREA: Hull internal structure

ITEM: Frame to beam connection (continuous bracket)

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT
	

NOTES

Failure Mechanism	Fatigue fractures in way of welds.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. Webs to be carefully aligned. Butts in webs are to be staggered from the butts in face flats. All welds to be returned around scallops.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
1	STEEL/ALUMINIUM CONSTRUCTION	5

003328

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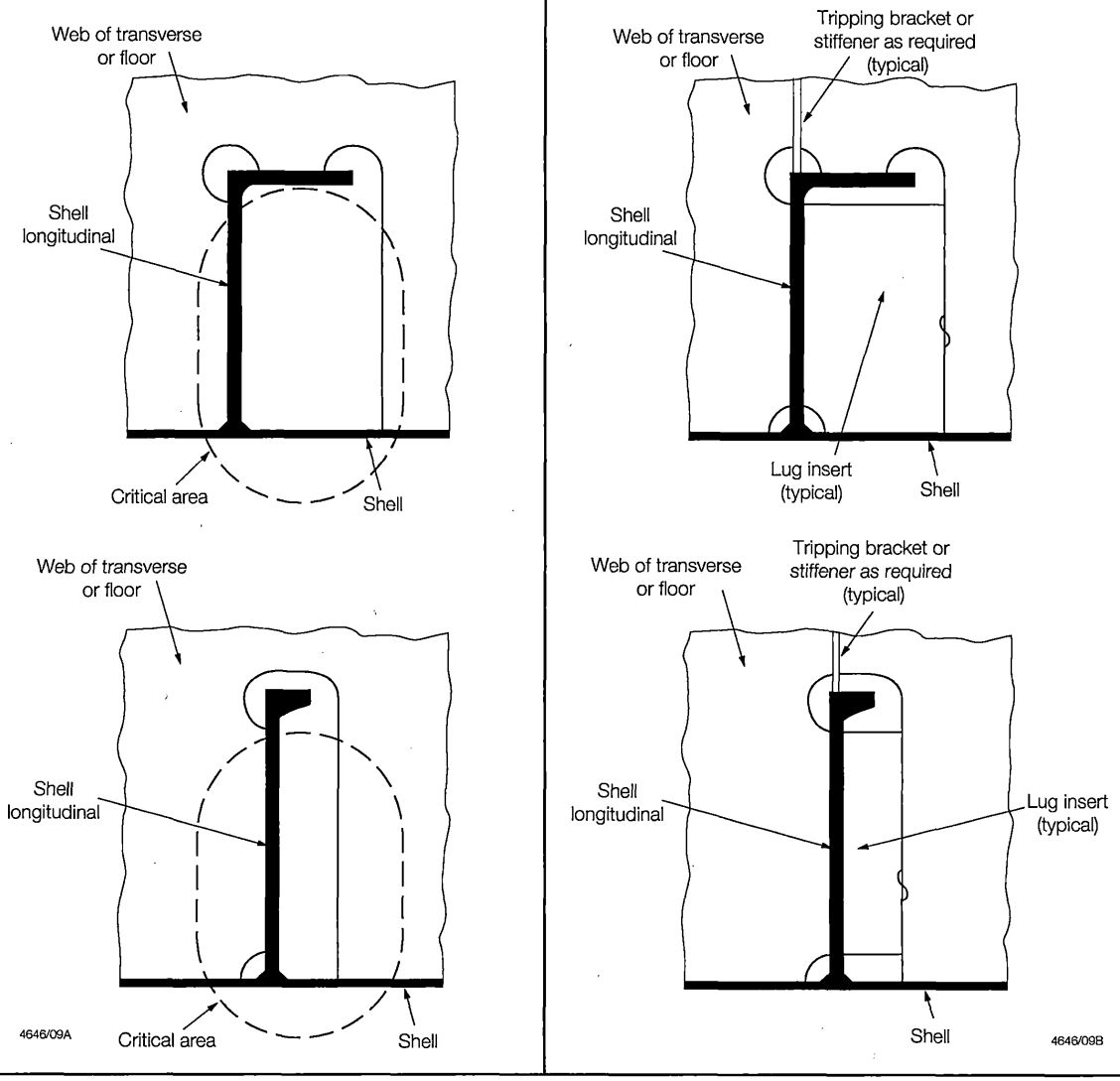
Detail Design Improvement for Steel/Aluminium Construction

AREA: Hull internal structure

ITEM: Lug connections between secondary stiffeners and primary stiffener webs (1)

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT



NOTES

Failure Mechanism	Fatigue cracking of shell plate in way of hardspot, buckling and shear failure of the web of the primary member.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. All welding in way of lugs is to be double continuous. Welds to be returned around scallops. Lug inserts to align with primary stiffener web plating or floor.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
1	STEEL/ALUMINIUM CONSTRUCTION	6

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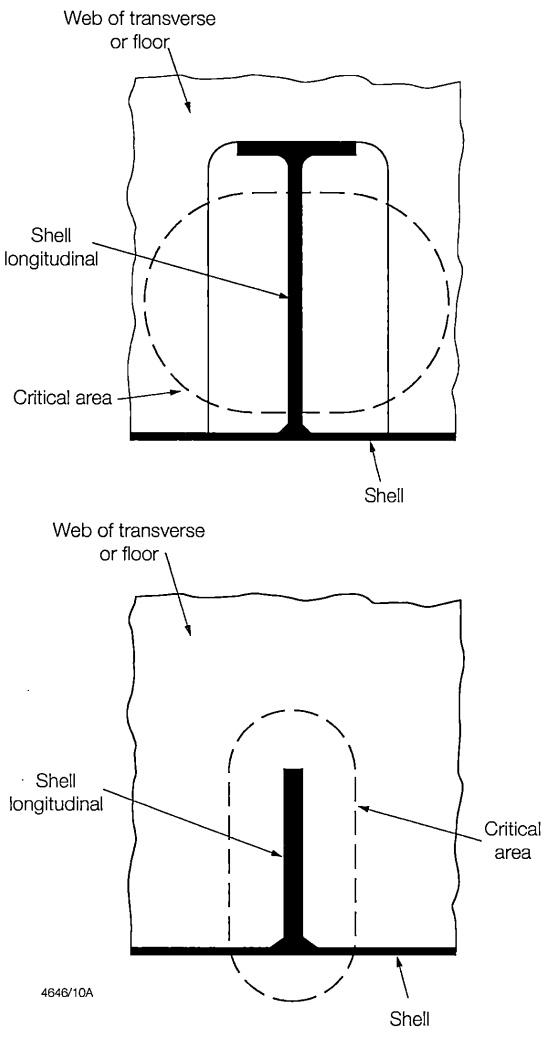
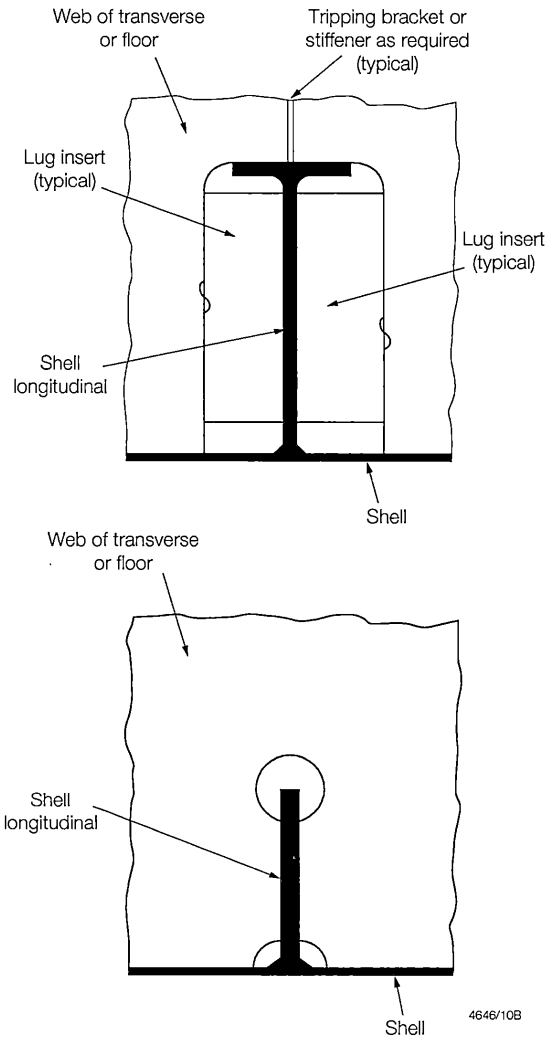
Detail Design Improvement for Steel/Aluminium Construction

AREA: Hull internal structure

ITEM: Lug connections between secondary stiffeners and primary stiffener webs (2)

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT





NOTES

Failure Mechanism	Fatigue cracking of shell plate in way of hardspot, buckling and shear failure of the web of the primary member.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. All welding in way of lugs is to be double continuous. Welds to be returned around scallops. Lug inserts to align with primary stiffener web plating or floor.

GROUP 1	GUIDANCE NOTES FOR DESIGN DETAILS STEEL/ALUMINIUM CONSTRUCTION	FIGURE 7

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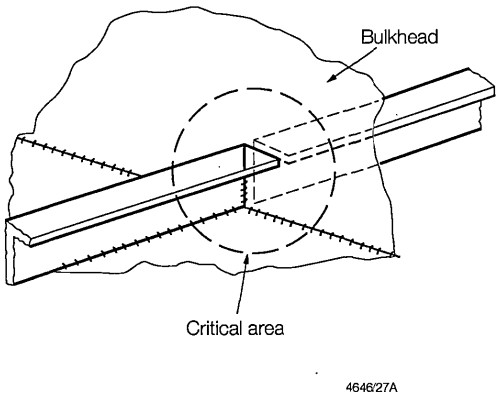
Detail Design Improvement for Steel/Aluminium Construction

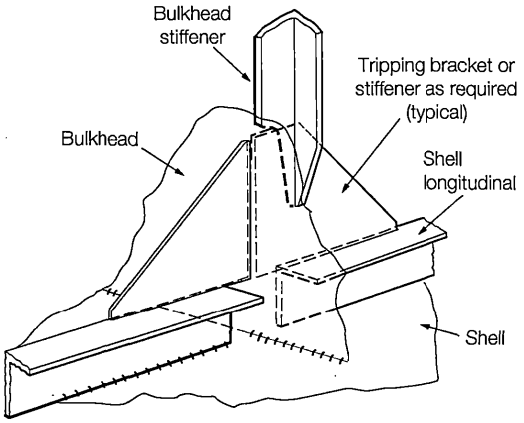
AREA: Watertight/oiltight bulkheads

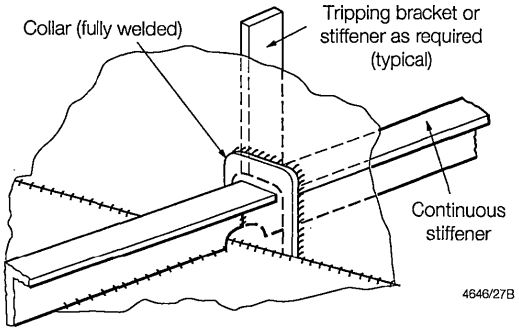
ITEM: Shell longitudinals collared, brackets aligned

Lloyd's Register

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT







NOTES

Failure Mechanism	Fractures in bulkhead plating arising from stress concentrations in way of longitudinal stiffener end connections.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. All welding in way of collar and stiffener end connections is to be double continuous type. Welds to be returned around scallops.

GROUP 1	GUIDANCE NOTES FOR DESIGN DETAILS STEEL/ALUMINIUM CONSTRUCTION	FIGURE 8

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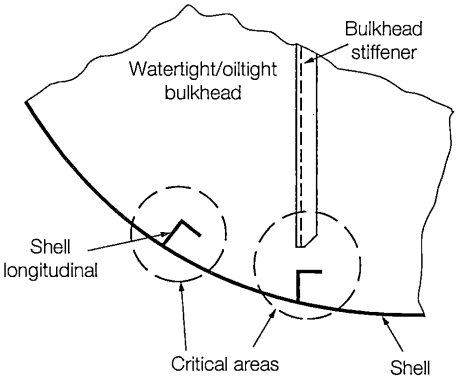
Detail Design Improvement for Steel/Aluminium Construction

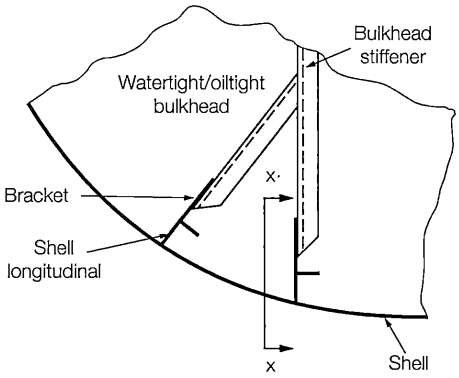
AREA: Watertight/oiltight bulkheads

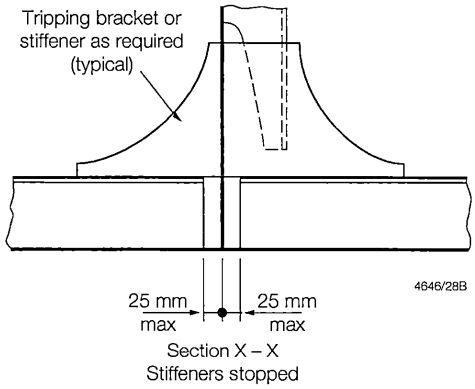
ITEM: Shell longitudinals (fitted brackets)

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT



4646/28A





4646/28B

NOTES

Failure Mechanism	Fractures in bulkhead plating arising from stress concentrations in way of longitudinal stiffener end connections.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. Webs of brackets are to be accurately aligned through the bulkhead plating and with the webs of the longitudinal stiffeners. All welding in way of brackets and stiffener end connections is to be double continuous type.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
1	STEEL/ALUMINIUM CONSTRUCTION	9

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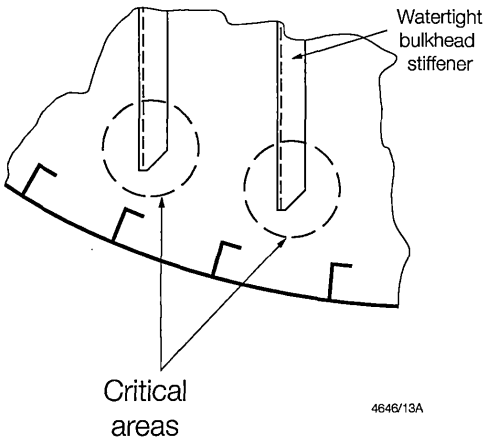
Detail Design Improvement for Steel/Aluminium Construction

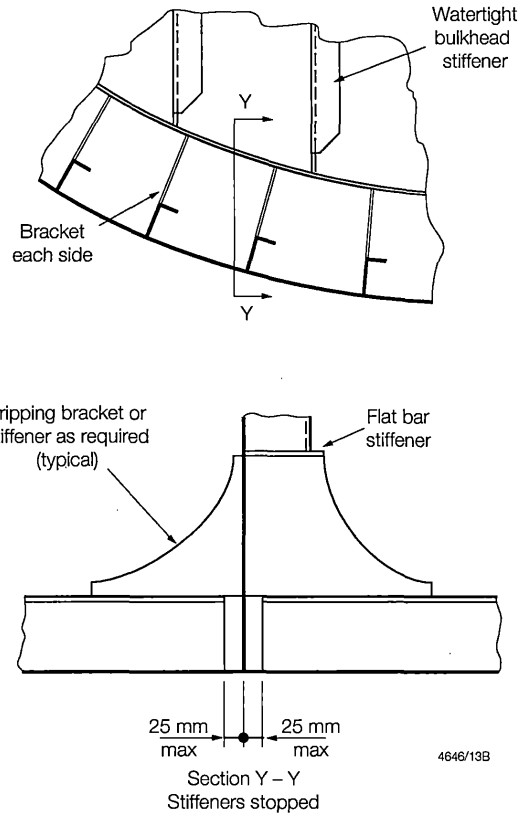
AREA: Watertight/oiltight bulkheads with boundary bar

ITEM: Shell longitudinals (fitted brackets)

Lloyd's Register

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT





NOTES

Failure Mechanism	Fractures in bulkhead plating arising from stress concentrations in way of longitudinal stiffener end connections.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. Webs of brackets are to be accurately aligned through the bulkhead plating and with the webs of the longitudinal stiffeners. All welding in way of brackets and stiffener end connections is to be double continuous type.

GROUP 1	GUIDANCE NOTES FOR DESIGN DETAILS STEEL/ALUMINIUM CONSTRUCTION	FIGURE 10

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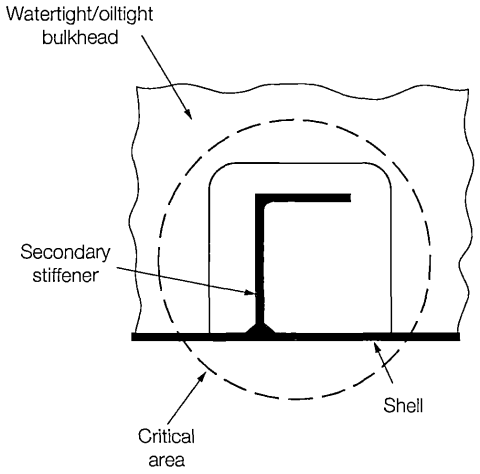
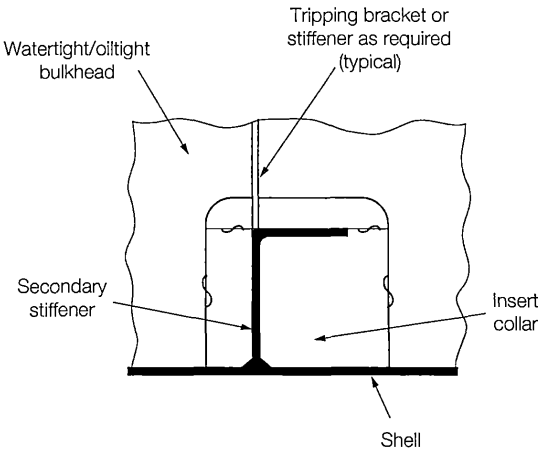
Detail Design Improvement for Steel/Aluminium Construction

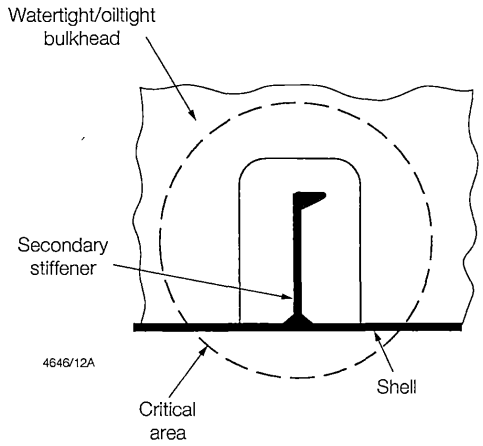
AREA: Watertight/oiltight bulkheads

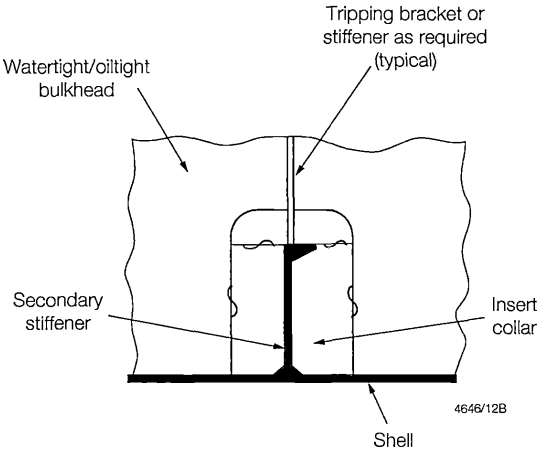
ITEM: Collar inserts in way of secondary stiffening members

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT









NOTES

Failure Mechanism	Fatigue fractures and leakage.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. Inserts to align with watertight/oiltight bulkhead plating. All welding in way of collar inserts and stiffener end connections is to be double continuous type.

GROUP 1	GUIDANCE NOTES FOR DESIGN DETAILS STEEL/ALUMINIUM CONSTRUCTION	FIGURE 11

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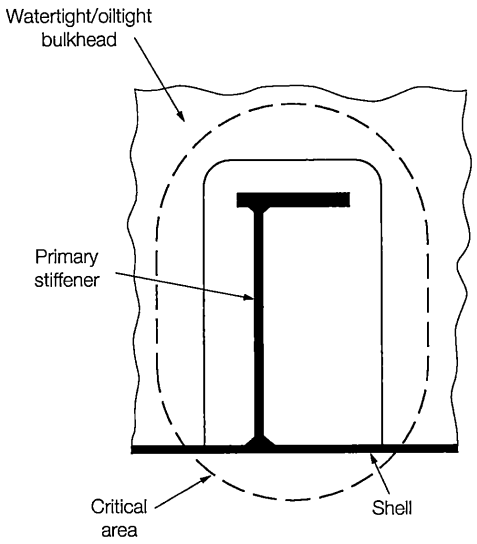
Detail Design Improvement for Steel/Aluminium Construction

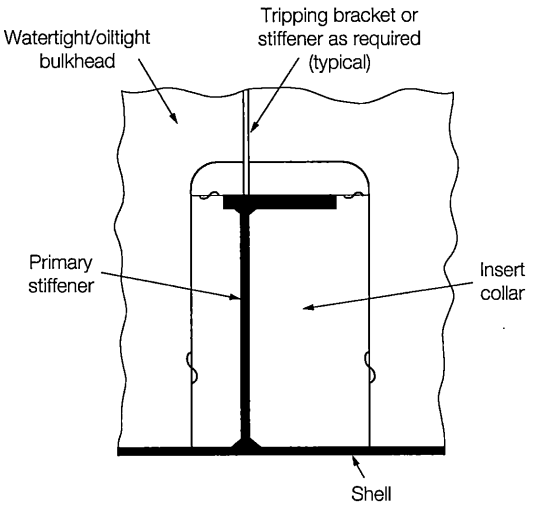
AREA: Watertight/oiltight bulkheads

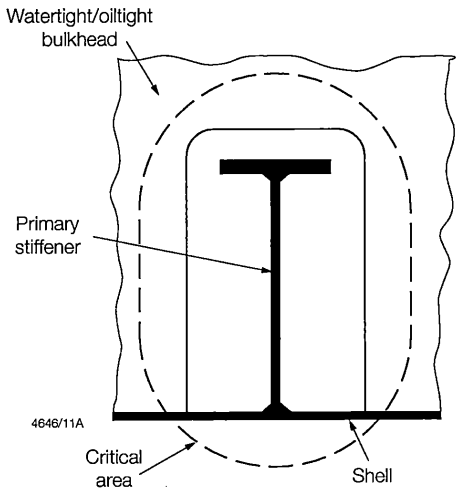
ITEM: Collar inserts in way of primary stiffening members

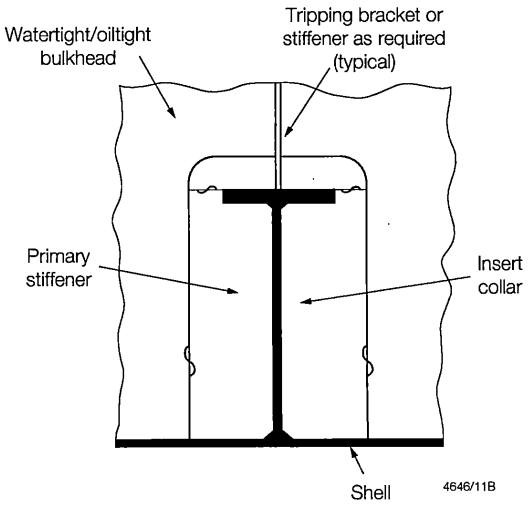
Lloyd's Register

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT









NOTES

Failure Mechanism	Fatigue fractures and leakage.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. Inserts to align with watertight/oiltight bulkhead plating. All welding in way of collar inserts and stiffener end connections is to be double continuous type.

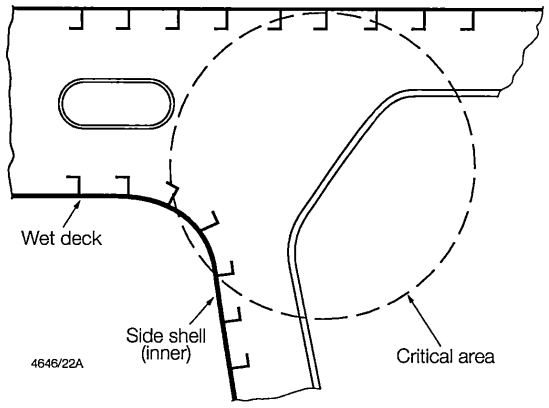
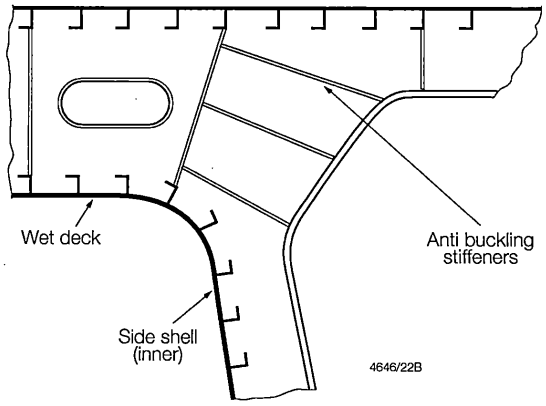
GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
1	STEEL/ALUMINIUM CONSTRUCTION	12

Document Released Under the Access to Information Act / Document divulgué en vertu de la Loi sur l'accès à l'information.

Detail Design Improvement for Steel/Aluminium Construction

AREA: Cross-deck structure, multi-hulls

ITEM: Inner side web frame to deck transverse connection

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT
	

NOTES

Failure Mechanism	Buckling of deep webs.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
1	STEEL/ALUMINIUM CONSTRUCTION	13

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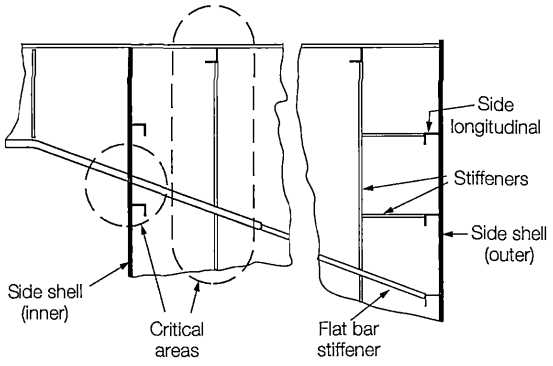
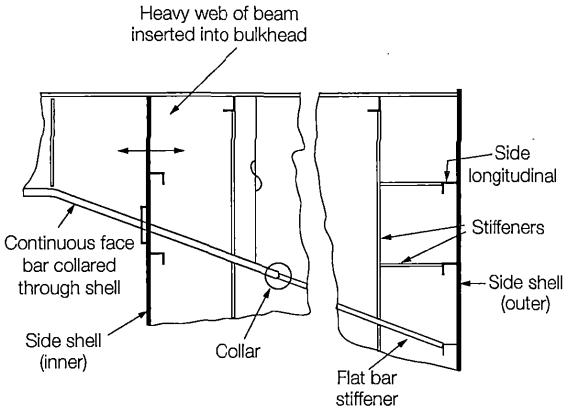
Detail Design Improvement for Steel/Aluminium Construction

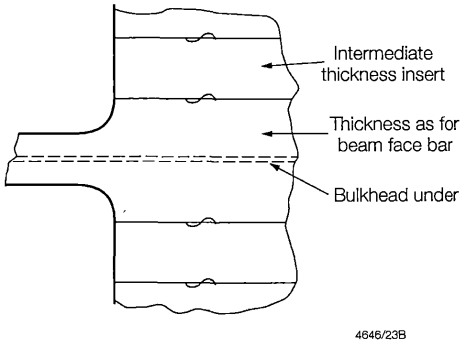
AREA: Cross-deck structure

ITEM: Deck transverse to watertight bulkhead connection

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT







Plan view

NOTES

Failure Mechanism	Failure fractures in areas of high stress, cracking due to both stress concentrations and tri-axial stress.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. All welds in way of shell penetration are to be full penetration type.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
1	STEEL/ALUMINIUM CONSTRUCTION	14

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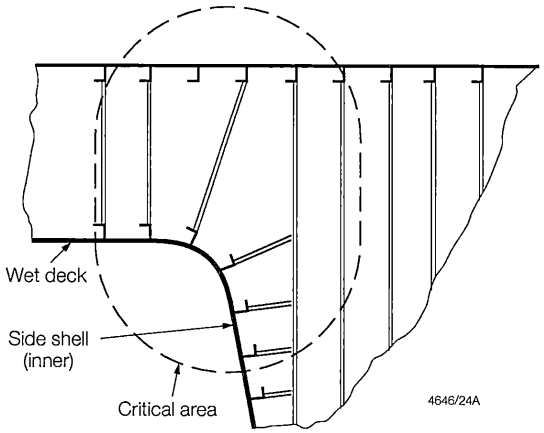
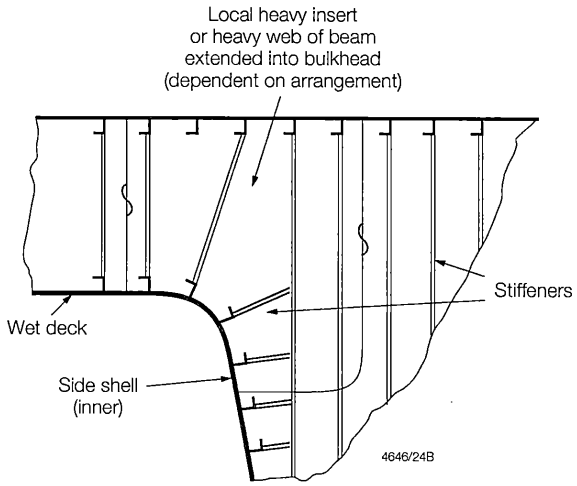
Detail Design Improvement for Steel/Aluminium Construction

AREA: Multi-hull structure

ITEM: Cross-deck beam to bulkhead connection

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT





NOTES

Failure Mechanism	Buckling of deep webs and bulkhead in way of connection.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. Webs of deep transverses are to be accurately aligned with the bulkhead plating. All welding in way of end connection is to be double continuous type.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
1	STEEL/ALUMINIUM CONSTRUCTION	15

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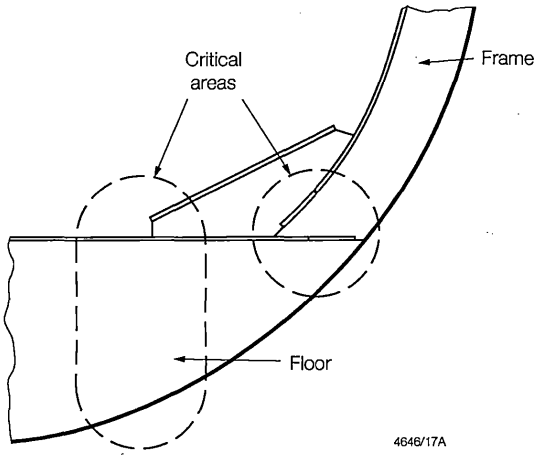
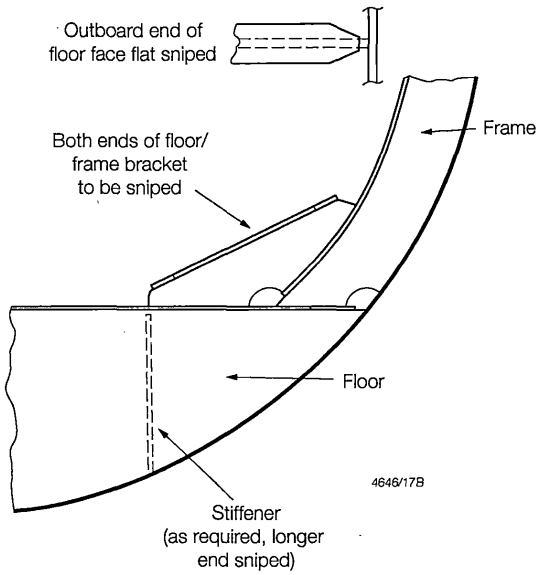
Detail Design Improvement for Steel/Aluminium Construction

AREA: Hull internal structure

ITEM: Floor to frame connection (bracketed)

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT





NOTES

Failure Mechanism	Buckling of floor under bracket toe. Fracturing of frame and floor structure in way of end connections.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. All welding in way of brackets and end connections is to be double continuous type. All welds to be returned around scallops. Webs of frames to be accurately aligned with floor plating.

GROUP 2	GUIDANCE NOTES FOR DESIGN DETAILS STEEL/ALUMINIUM CONSTRUCTION	FIGURE 16

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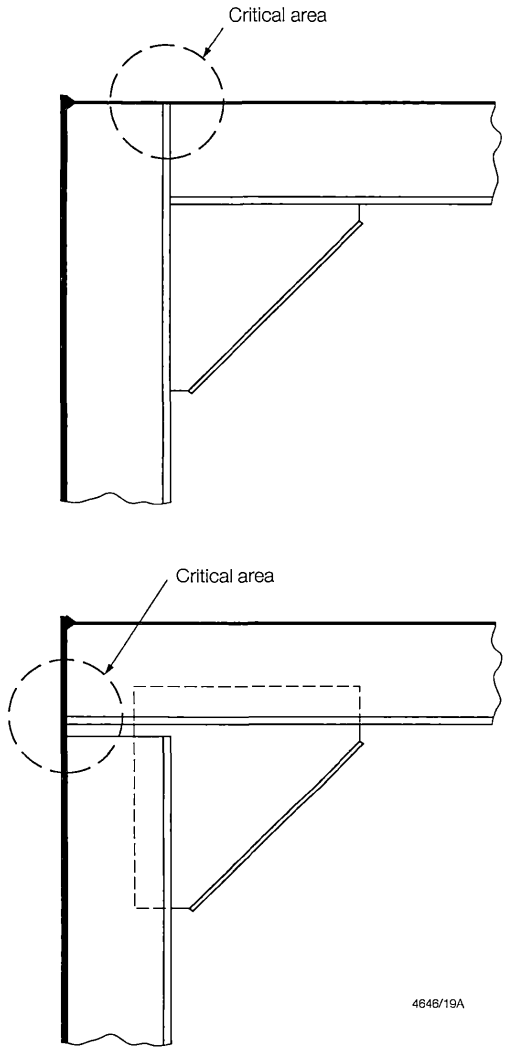
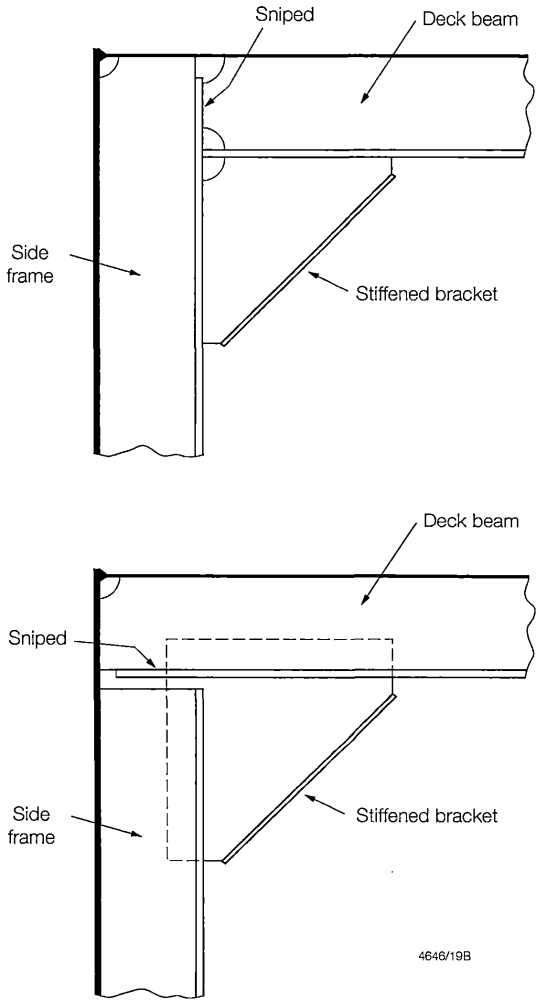
Detail Design Improvement for Steel/Aluminium Construction

AREA: Hull internal structure

ITEM: Frame to beam connection

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT





NOTES

Failure Mechanism	Fractures in the shell and deck plating due to stress concentration arising from hard spots.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. Webs of deck beam to be accurately aligned with webs of frames. All welding in way of end connections and brackets is to be double continuous type. All welds to be returned around scallops.

GROUP 2	GUIDANCE NOTES FOR DESIGN DETAILS STEEL/ALUMINIUM CONSTRUCTION	FIGURE 17

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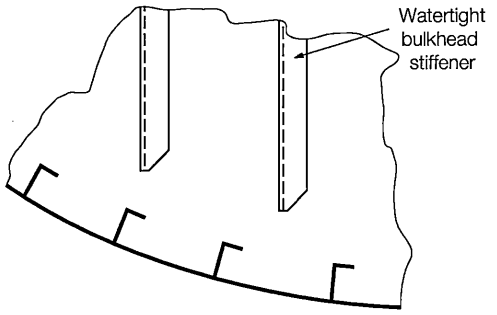
Detail Design Improvement for Steel/Aluminium Construction

AREA: Watertight/oiltight bulkheads with boundary bar

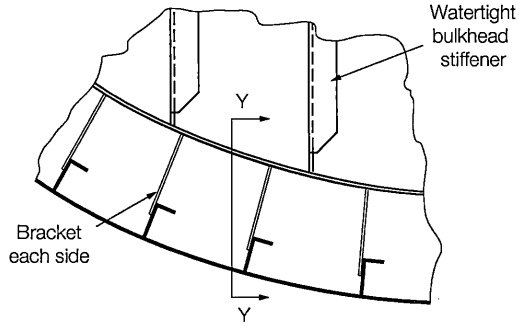
ITEM: Shell longitudinals (lapped brackets)

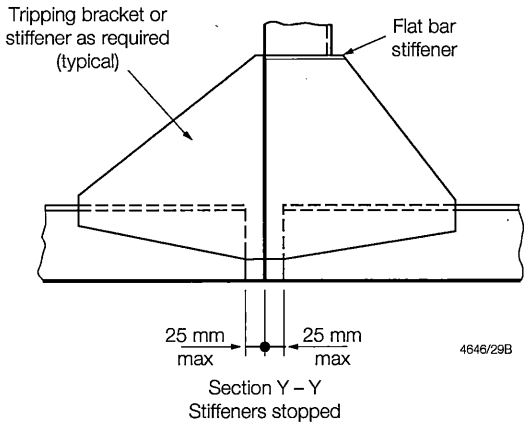
Lloyd's Register

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT



4646/29A





4646/29B

NOTES

Failure Mechanism	Fractures in bulkhead plating arising from stress concentrations in way of longitudinal stiffener end connections.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. Webs of brackets are to be accurately aligned through the bulkhead platings. All welding in way of brackets and stiffener end connections is to be double continuous type.

GROUP 2	GUIDANCE NOTES FOR DESIGN DETAILS STEEL/ALUMINIUM CONSTRUCTION	FIGURE 18

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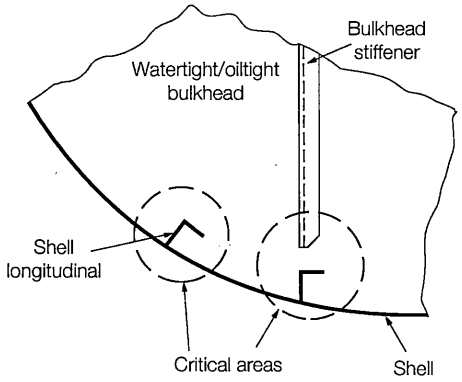
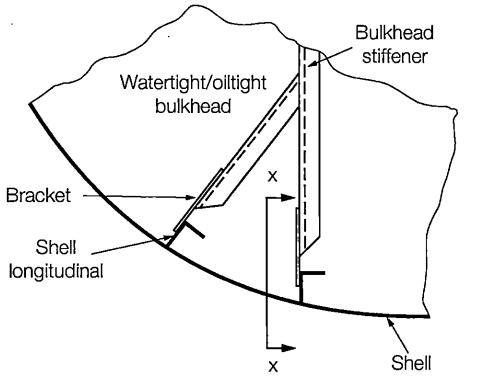
Detail Design Improvement for Steel/Aluminium Construction

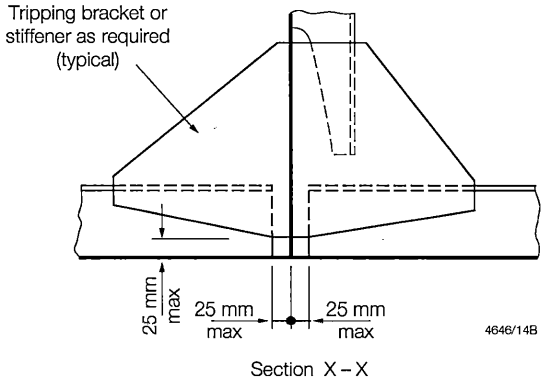
AREA: Watertight/oiltight bulkheads

ITEM: Shell longitudinals (lapped brackets)

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT







Section X – X

NOTES

Failure Mechanism	Fractures in bulkhead plating arising from stress concentrations in way of longitudinal stiffener end connections.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. Webs of brackets are to be accurately aligned through the bulkhead platings. All welding in way of brackets and end connections of stiffeners is to be double continuous type.

GROUP 2	GUIDANCE NOTES FOR DESIGN DETAILS STEEL/ALUMINIUM CONSTRUCTION	FIGURE 19

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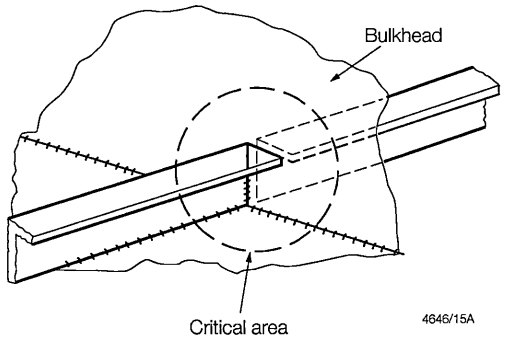
Detail Design Improvement for Steel/Aluminium Construction

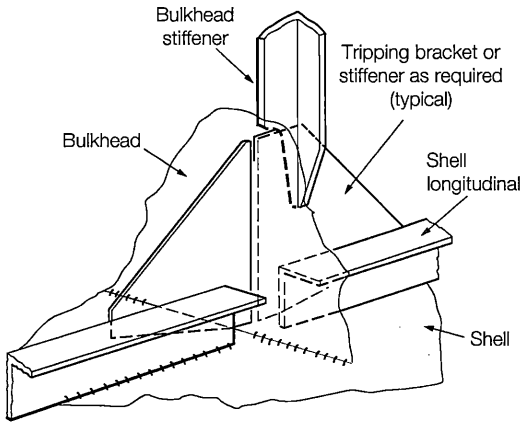
AREA: Watertight/oiltight bulkheads

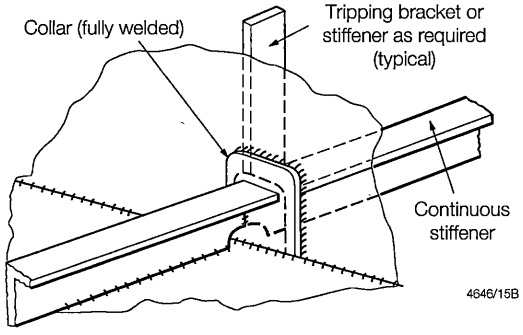
ITEM: Shell longitudinals collared, brackets lapped

Lloyd's Register

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT







NOTES

Failure Mechanism	Fractures in bulkhead plating arising from stress concentrations in way of longitudinal stiffener end connections.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. All welding in way of collar and stiffener end connections is to be double continuous type. Welds are to be returned around scallops.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
2	STEEL/ALUMINIUM CONSTRUCTION	20

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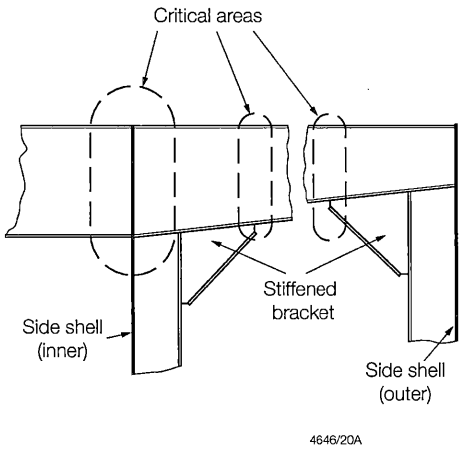
Detail Design Improvement for Steel/Aluminium Construction

AREA: Cross-deck structure, multi-hulls

ITEM: Connection between cross-deck beams and side hulls

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT



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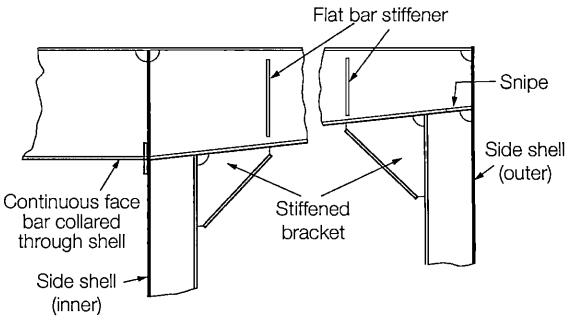

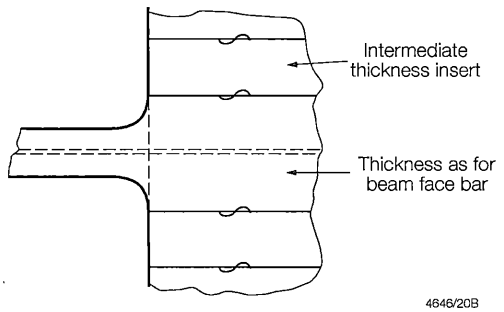

4646/20B

Plan view

NOTES

Failure Mechanism	Buckling of webs of cross-deck beams, and fracturing of deck plating in way of end connection due to hard spot.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. Webs of frames to be accurately aligned with webs of cross-deck beams. All welds in way of end connection of frames are to be double continuous type. Webs of transverse beams are to be accurately aligned.

GROUP 2	GUIDANCE NOTES FOR DESIGN DETAILS STEEL/ALUMINIUM CONSTRUCTION	FIGURE 21

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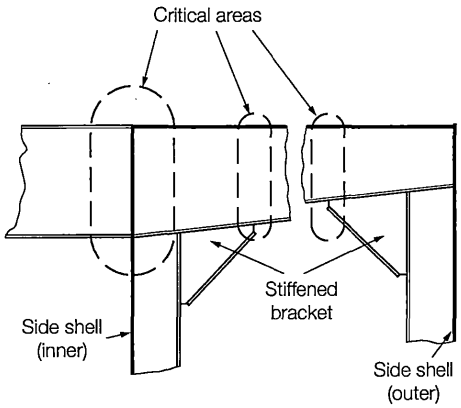
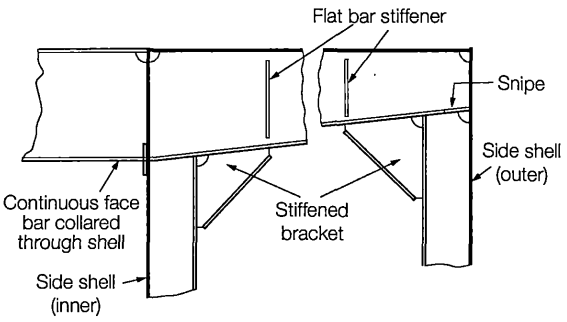
Detail Design Improvement for Steel/Aluminium Construction

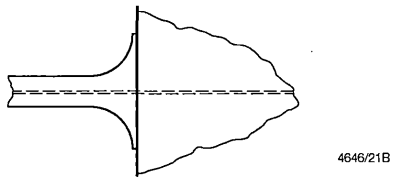
AREA: Cross-deck structure, multi-hulls

ITEM: Connection between cross-deck beams and side hulls

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT







Plan view

NOTES

Failure Mechanism	Buckling of webs of cross-deck beams, and fracturing of deck plating in way of end connection due to hard spot.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. Webs of frames to be accurately aligned with webs of cross-deck beams. All welds in way of end connections to be double continuous type. Webs of transverse beams are to be accurately aligned.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
3	STEEL/ALUMINIUM CONSTRUCTION	22

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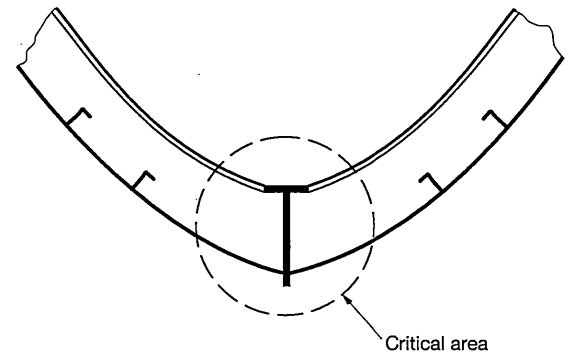
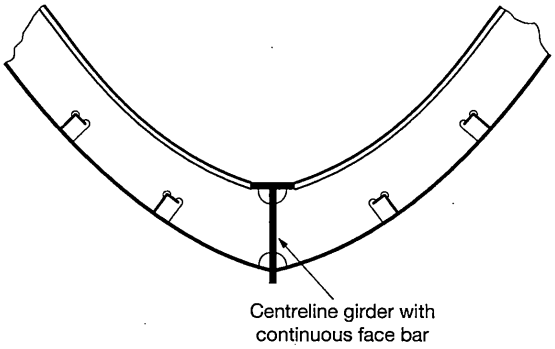
Detail Design Improvement for Steel/Aluminium Construction

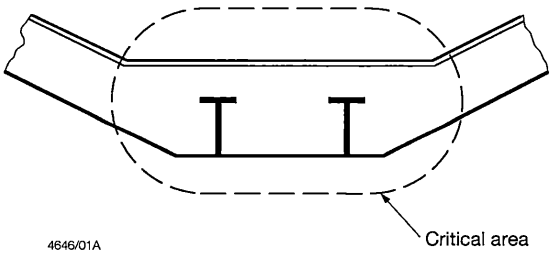
AREA: Hull centreline structure

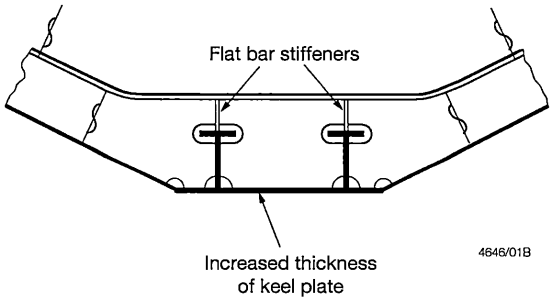
ITEM: Bar and plate keels

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT









NOTES

Failure Mechanism	Fracturing of centre girder(s), buckling of keel plate and floors.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. Butts in webs are to be staggered from butts in face flats.

GROUP 3	GUIDANCE NOTES FOR DESIGN DETAILS STEEL/ALUMINIUM CONSTRUCTION	FIGURE 23

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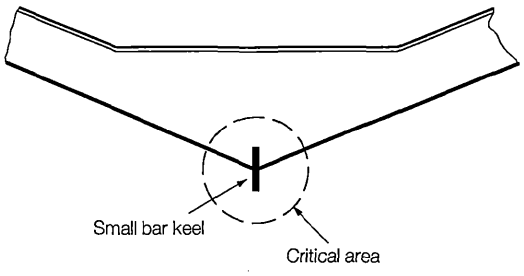
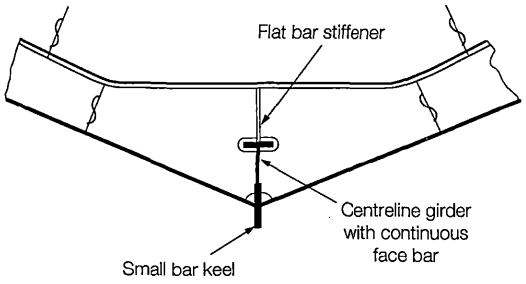
Detail Design Improvement for Steel/Aluminium Construction

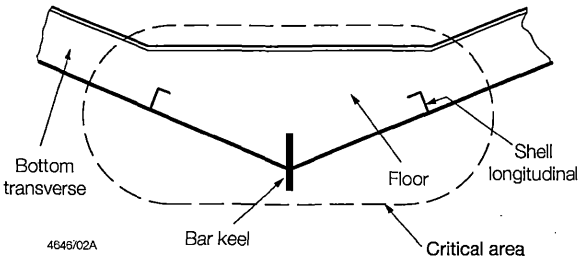
AREA: Hull centreline structure

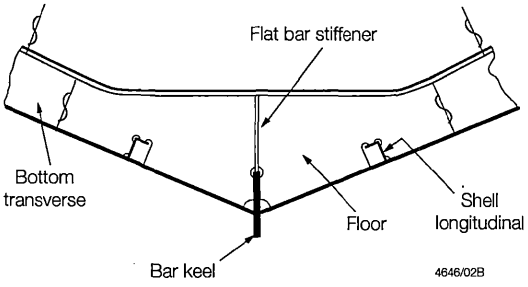
ITEM: Bar keels

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT









NOTES

Failure Mechanism	Buckling of bar keel, shell plate and floors.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. Butts in webs are to be staggered from butts in face flats.

GROUP 3	GUIDANCE NOTES FOR DESIGN DETAILS STEEL/ALUMINIUM CONSTRUCTION	FIGURE 24

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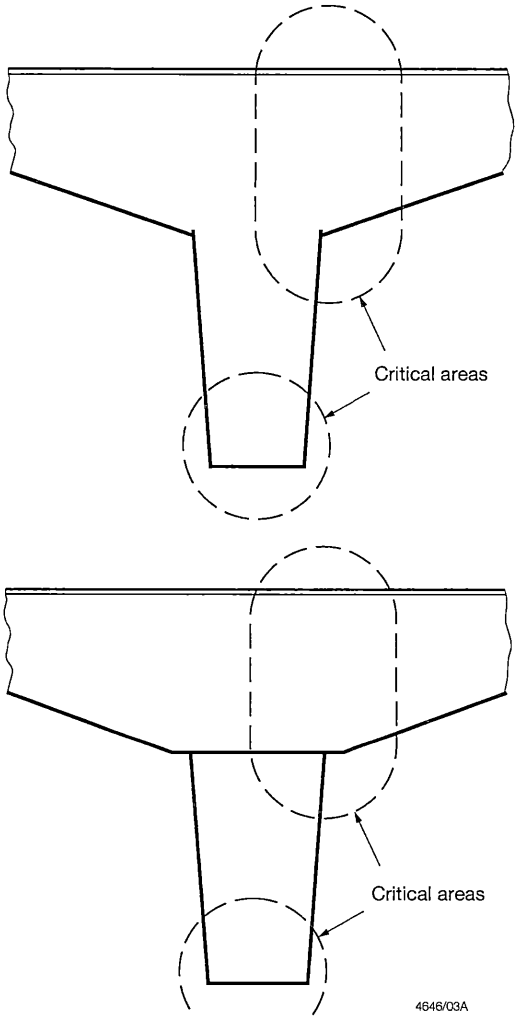
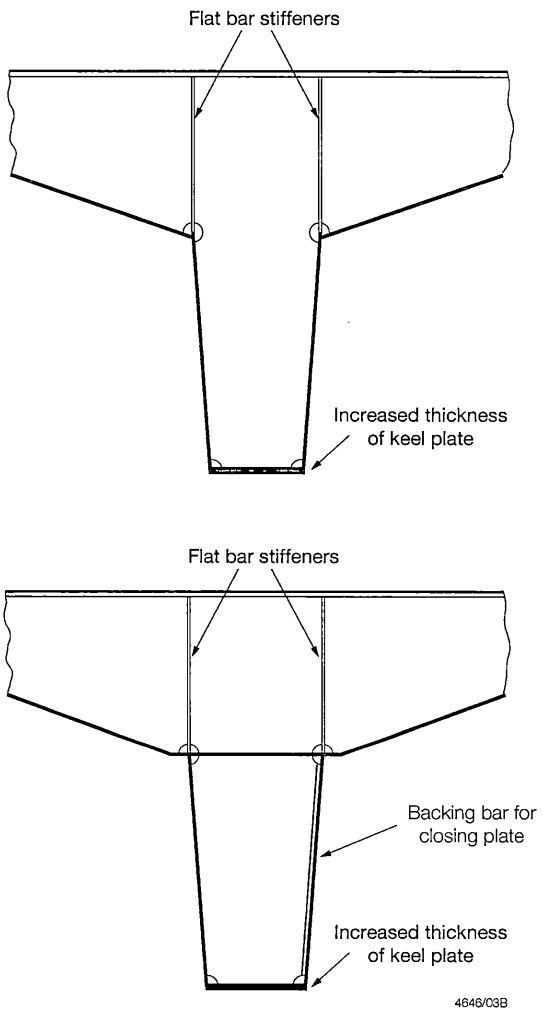
Detail Design Improvement for Steel/Aluminium Construction

AREA: Hull centreline structure

ITEM: Fabricated plate keel/skeg

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT





NOTES

Failure Mechanism	Buckling of keel plate, shell and floor. Fractures from stress concentrations.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
3	STEEL/ALUMINIUM CONSTRUCTION	25

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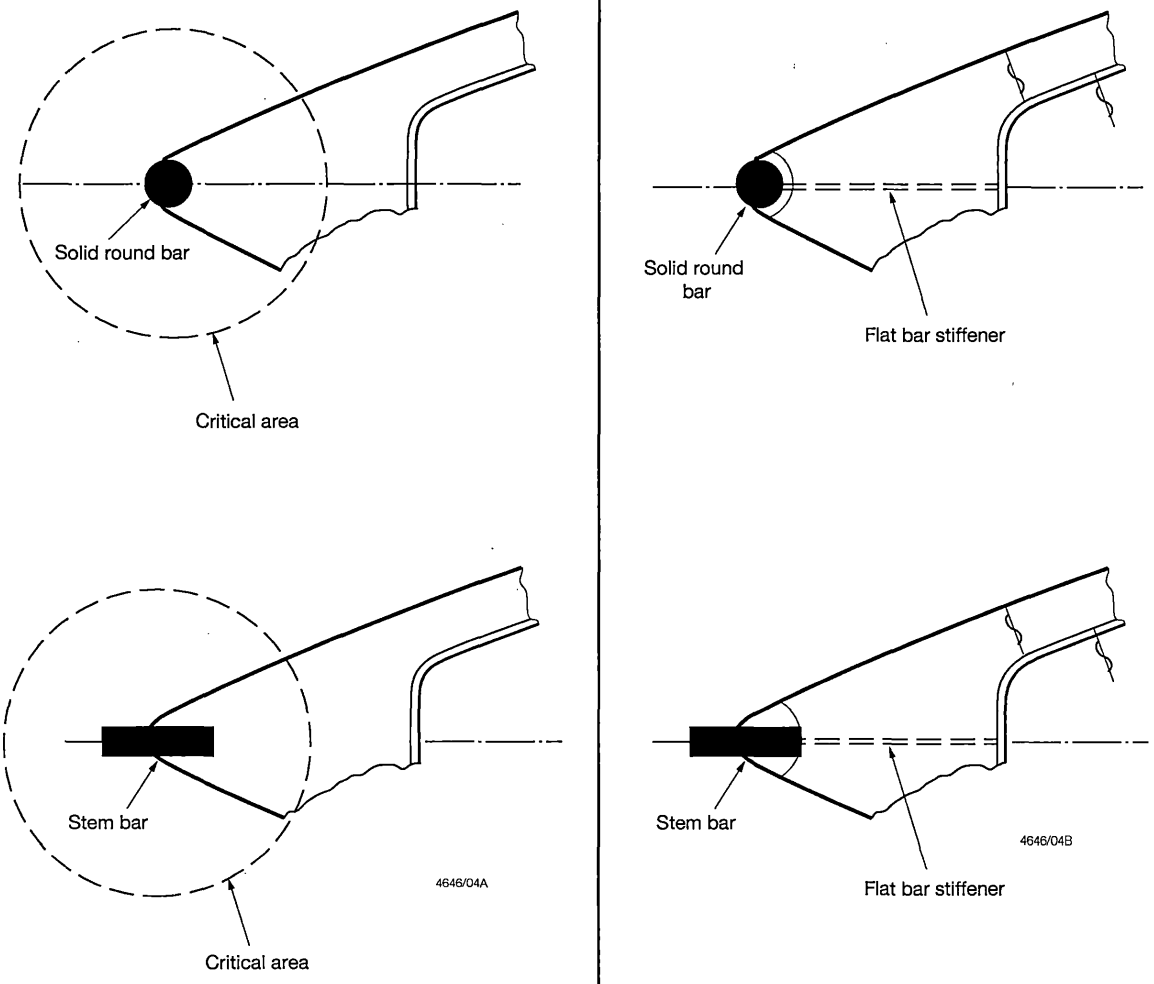
Detail Design Improvement for Steel/Aluminium Construction

AREA: Hull centreline structure

ITEM: Round bar and flat bar stems

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT



NOTES

Failure Mechanism	Buckling of stem plating due to collision and impact with floating debris.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. All welding between stem bar and shell plating to be full penetration type. Butts in webs are to be staggered from butts in face flats.

GROUP 3	GUIDANCE NOTES FOR DESIGN DETAILS STEEL/ALUMINIUM CONSTRUCTION	FIGURE 26

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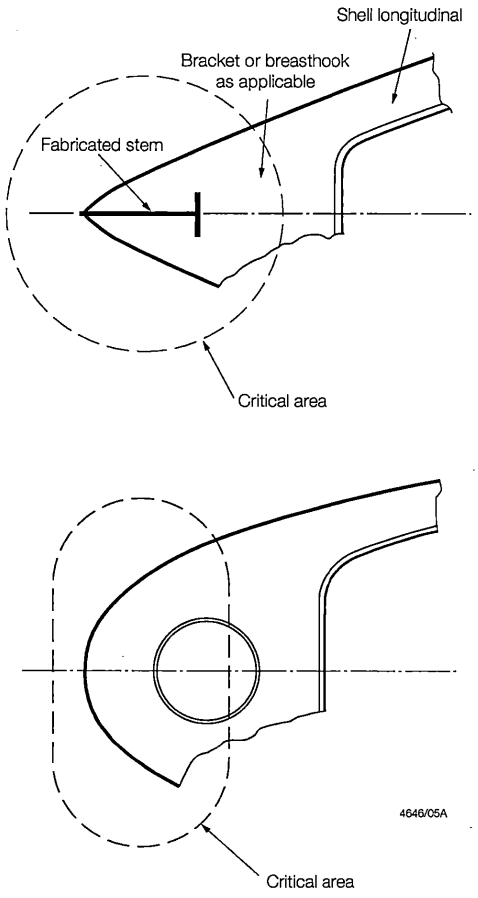
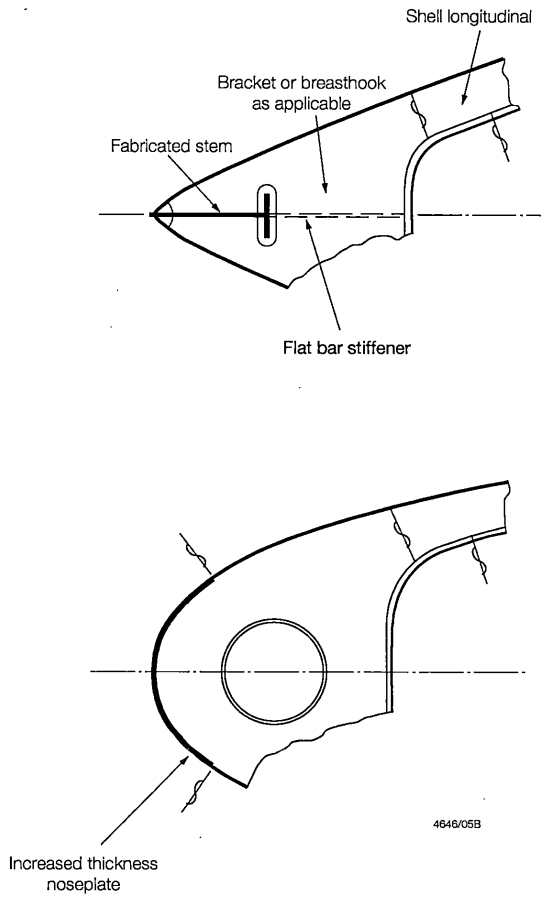
Detail Design Improvement for Steel/Aluminium Construction

AREA: Hull centreline structure

ITEM: Fabricated and plate stems

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT





NOTES

Failure Mechanism	Buckling of stem plating due to collision and impact with floating debris.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. All welding between stem and shell plating to be full penetration type. Butts in webs are to be staggered from the butts in face flats.

GROUP 3	GUIDANCE NOTES FOR DESIGN DETAILS STEEL/ALUMINIUM CONSTRUCTION	FIGURE 27

Document Released Under the Access to Information Act / Document divulgué en vertu de la Loi sur l'accès à l'information.

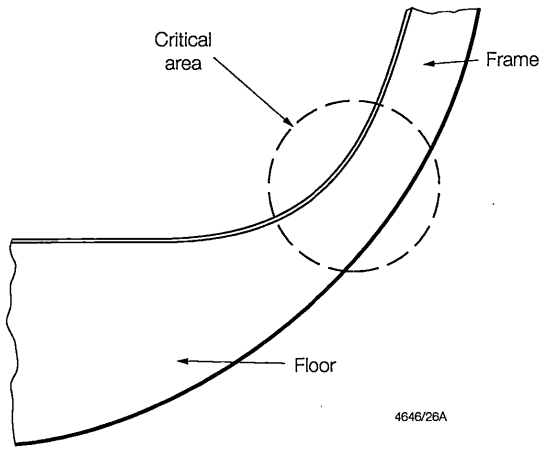
Detail Design Improvement for Steel/Aluminium Construction

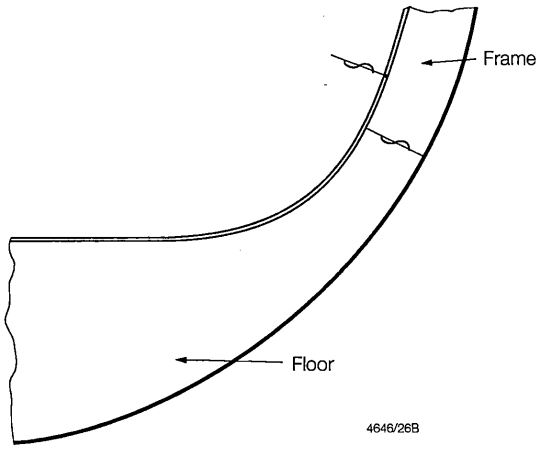
AREA: Internal hull structure

ITEM: Floor to frame connection (radiused)

Lloyd's Register

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT





NOTES

Failure Mechanism	Fatigue fractures in way of welds.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. Webs and face flats are to be accurately aligned with butts between face flats staggered from the butts in the frame webs.

GROUP 3	GUIDANCE NOTES FOR DESIGN DETAILS STEEL/ALUMINIUM CONSTRUCTION	FIGURE 28

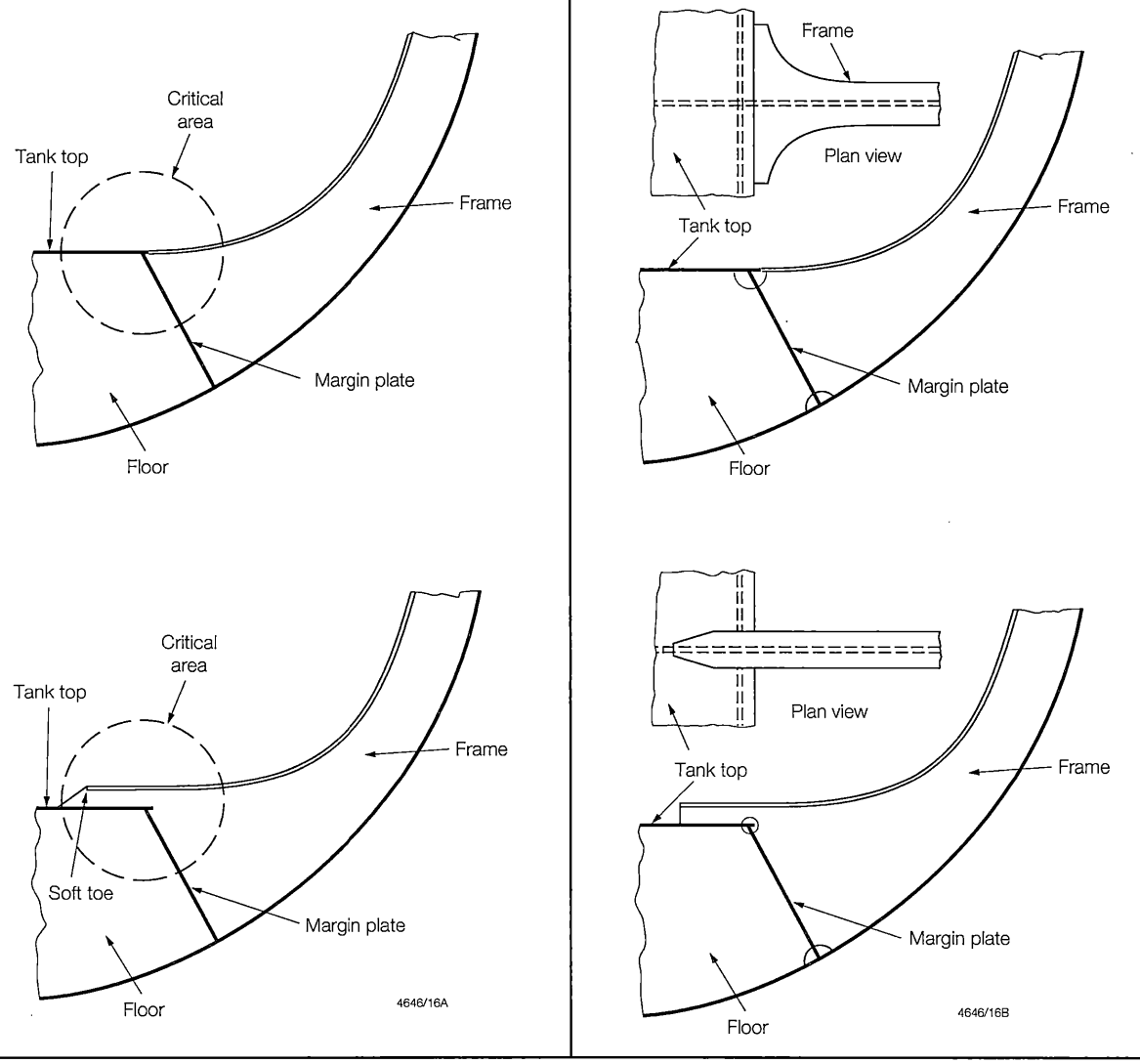
Document Released Under the Access to Information Act / Document divulgué en vertu de la Loi sur l'accès à l'information.

Detail Design Improvement for Steel/Aluminium Construction

AREA: Hull internal structure

ITEM: Web frame to tank boundary connection

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT



NOTES

Failure Mechanism	Fractures arising from stress concentrations.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. Webs of frames to be accurately aligned with floor plating. All welds in way of end connection of frames are to be double continuous type.

GROUP 3	GUIDANCE NOTES FOR DESIGN DETAILS STEEL/ALUMINIUM CONSTRUCTION	FIGURE 29

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Detail Design Improvement for Composite Construction

Section

1 **Identification of critical areas**

2 **Structural details**

■ *Section 1* Identification of critical areas

1.1 General

1.1.1 LR has applied direct calculation procedures in the structural appraisal and approval of new buildings and in various investigations on special service craft of composite construction. Through these procedures and the wealth of information collected on the LR fleet database, a number of locations have been identified where good design, workmanship and alignment during construction are particularly important. These are usually locations where high stress variations can be experienced during the lifetime of the craft. These are referred to to as **critical locations** and are highlighted in this Chapter.

1.1.2 This Chapter identifies the **critical areas** within various structural elements of the hull structure and transverse bulkheads.

1.1.3 In Section 2 the structural **detail design improvements** that can be applied to increase the fatigue life of the structural components are provided. These detail improvements are intended to give the designer guidance for meeting the design criteria for structural detail components.

1.1.4 The application of 2 and 3-dimensional finite element analyses techniques to the hull structure enables the global and local capabilities of the hull structure to withstand static and dynamic loadings to be assessed. Such analyses will enable those high stress locations and joints within the craft to be readily identified. Such locations will then, by their very nature, be at risk to fatigue damage unless appropriate measures are taken at the design stage and subsequently during construction.

1.1.5 Extensive 'in-service' experience of the performance of existing craft structures, already provide an awareness of those critical locations which merit particular attention either due to stress or alignment difficulties.

1.2 Critical areas

1.2.1 Stress concentrations occur in both the primary and secondary structures of all craft and are identified during the design process by such means as finite element calculations. The designer will modify the detail to alleviate the stress concentration either by redesign or increase in scantlings. However, even after modification that area will still, in general, be exposed throughout the life of the craft to stresses higher than in surrounding areas.

1.2.2 At the design appraisal stage, a plan of the structure should, where appropriate, be prepared by the Builder or designer indicating these regions, and consideration can then be given, by the production team, into the appropriate methods of construction and the tolerances to be applied in order to remain within the assigned design parameters.

1.3 Misalignment during construction

1.3.1 The very nature of composite construction involves the manufacture of the material at the same time as the product and therefore, the alignment of the moulds and formers is one of the major considerations. The bonded interface between structural components in sub-assembly areas, prefabrication stages must also be carefully controlled to ensure accurate alignment and to achieve a satisfactory bond.

1.3.2 The most critical type of joint is the bonded 'tee joint' where it is subjected to high magnitudes of tensile and shear stresses. Particular attention must also be given to the transition between different types of stiffener members i.e., top-hat to plate laminates.

1.3.3 It can readily be seen that the combination of stress concentration and misalignment is to be avoided if the fatigue strength is to be satisfactory during the service life of the craft.

1.4 Fatigue considerations

1.4.1 The bottom shell area of high speed craft is subjected to the highest cyclic loading throughout the life of such craft.

1.4.2 The fatigue cracks in bottom shell laminates in way of internal hard spots, and in way of longitudinal end-connections, has been well documented. Constructional details in way of these areas, designed to increase fatigue life, are now incorporated by many Builders as standard. It is, therefore, important that due consideration be given to these details at the design stage to reduce the risk of fatigue cracking during service.

1.4.3 Detailed recommendations are detailed herein for the critical areas, *see* Section 2.

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Section 2
Structural details

2.1 Detail design improvement

2.1.1 For the purposes of these Guidance Notes, structural locations have been divided into five separate groups, with a series of examples of critical structural areas together with alternative associated detail design improvements.

2.1.2 A summary of the data presented is given in Table 5.2.1 whilst the full details are given in Figs. 1 to 30 as contained in this Section.

2.1.3 Generally, where alternative structural detail design improvements are provided, the details shown will provide improved fatigue strength.

2.1.4 Where 'top-hat' sections are shown, the same requirements apply to plate and other stiffening members sections.

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Table 5.2.1

Group	Application	Area	Item	Fig. No
	High speed craft			
1	Sandwich	Chine in way of side shell and bottom shell connection	Chine reinforcement	1
		Stem	Stem reinforcement	2
		Hull bottom structure	Bulkhead to hull connection	3
		Hull bottom structure	Bulkhead to hull connection	4
2	Single skin	Hull structure	Spray rails	5
		Hull structure	Spray rails	6
		Chine in way of side shell and bottom shell connection	Chine reinforcement	7
		Hull internal structure	Bulkhead to hull connection	8
		Hull internal structure	Bulkhead to hull connection	9
	Low speed craft			
3	Sandwich	Hull internal structure	Bulkhead to hull connection	10
		Hull internal structure	Bulkhead to hull connection	11
4	Single skin	Hull bottom structure	Bulkhead to hull connection	12
		Hull bottom structure	Bulkhead to hull connection	13
5	General detail	Hull centreline structure	Keel/stem reinforcement and keel stiffening	14
		Hull centreline structure	Keel/stem reinforcement and keel stiffening	15
		Hull structure	Deck to hull connection	16
		Hull structure	Transom boundary	17
		Hull structure	Deck to hull connection	18
		Hull bottom structure	Limber holes	19
		Hull bottom structure	Machinery seating, tapping plates	20
		Hull internal structure	Deep girders and floors	21
		Hull internal structure	'Top-hat' stiffeners penetrating tank boundaries	22
		Hull internal structure	Lower deck/tank top to bottom shell connection	23
		Hull internal structure	Integral tanks access manholes	24
		Skeg (open type)	Skeg stiffening and reinforcement	25
		Skeg (closed type)	Skeg diaphragm plates and sealing laminate	26
		Deck structure	Well deck, lower/sole deck to hull connection	27
		Deck structure	Well deck, lower/sole deck to hull connection	28
		Deck	Bulkhead to deck connection	29
		Deck	Deckhouse to deck connection	30

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Detail Design Improvement for Composite Construction

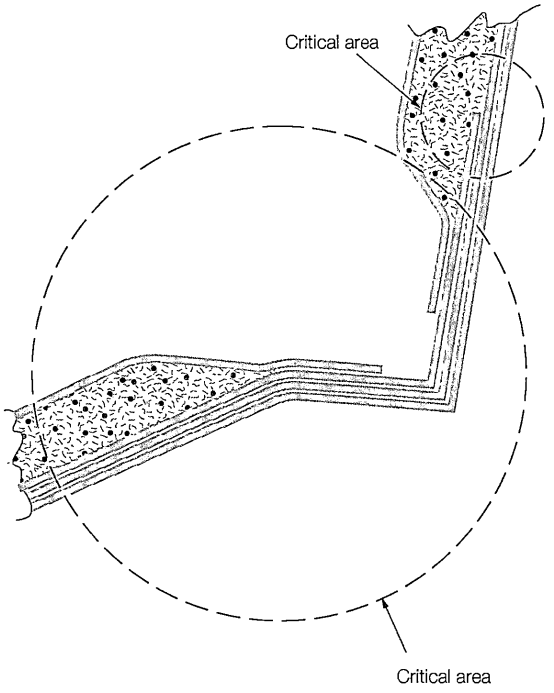
AREA: Chine in way of side shell and bottom shell connection

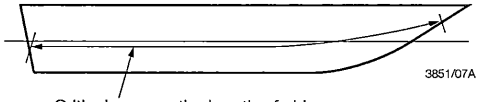
ITEM: Chine reinforcement

Lloyd's Register

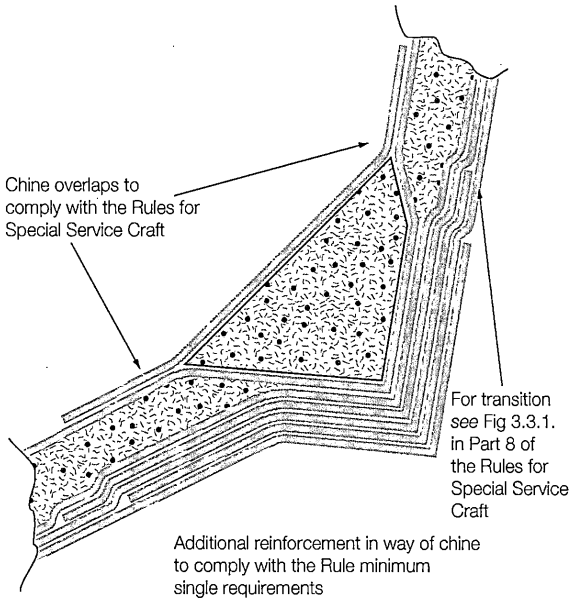
CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

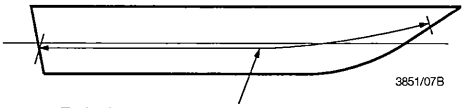
Sandwich construction





Critical area, entire length of chine





Entire length of chine reinforced to comply with the Rules for Special Service Craft

NOTES

Failure Mechanism	Excess loads due to grounding, docking, slinging, hydrodynamic and other types of impact.
Building Tolerance	All FRP materials to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
1	COMPOSITE CONSTRUCTION	1

Document Released Under the Access to Information Act / Document divulgué en vertu de la Loi sur l'accès à l'information.

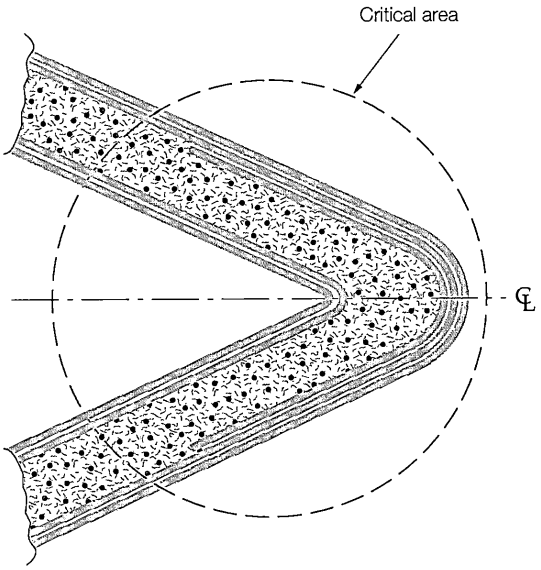
Detail Design Improvement for Composite Construction

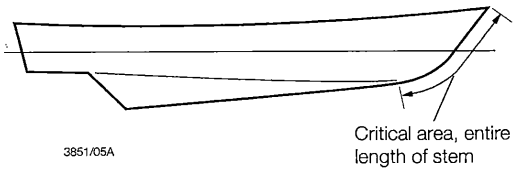
AREA: Stem

ITEM: Stem reinforcement

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

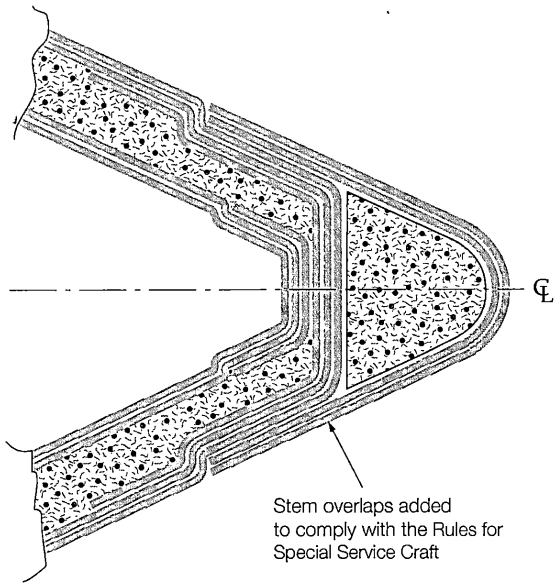
Sandwich construction

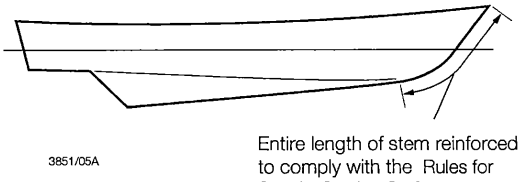




3851/05A

Critical area, entire length of stem





3851/05A

Entire length of stem reinforced to comply with the Rules for Special Service Craft

NOTES

Failure Mechanism	Excess loads due to collision and impact with floating debris.
Building Tolerance	All FRP materials to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
1	COMPOSITE CONSTRUCTION	2

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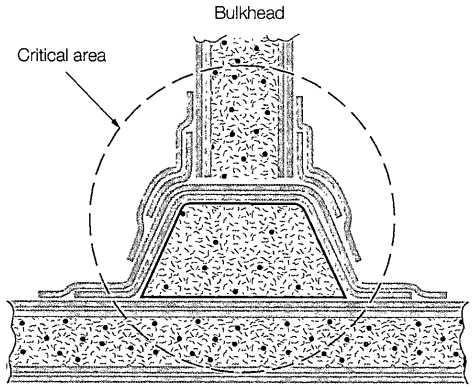
Detail Design Improvement for Composite Construction

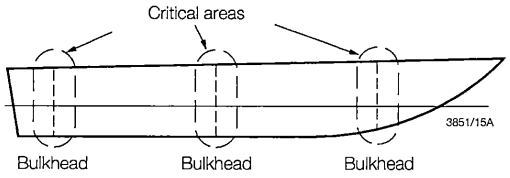
AREA: Hull bottom structure

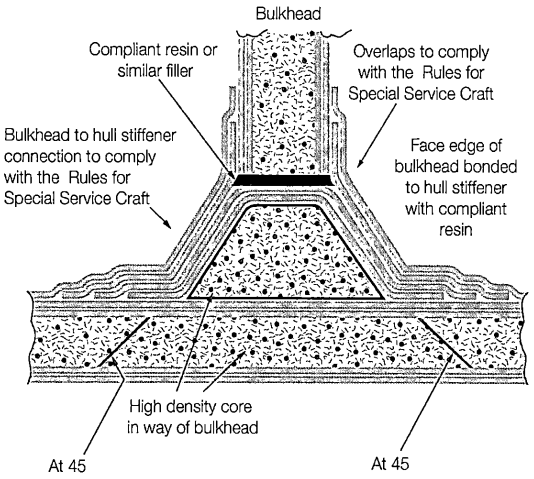
ITEM: Bulkhead to hull connection

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

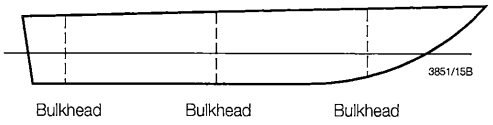
Sandwich construction, high speed







All bulkhead hull connections to comply with the Rules for Special Service Craft



NOTES

Failure Mechanism	Crushing of the sandwich core under the bulkhead, and delamination of the sandwich bulkhead due to excess loads arising from berthing, slinging, impact and racking.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
1	COMPOSITE CONSTRUCTION	3

Document Released Under the Access to Information Act / Document divulgué en vertu de la Loi sur l'accès à l'information.

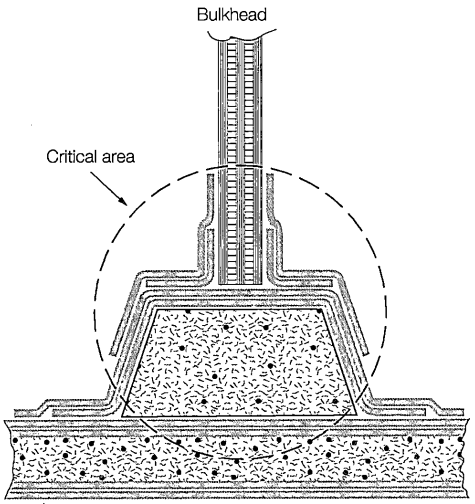
Detail Design Improvement for Composite Construction

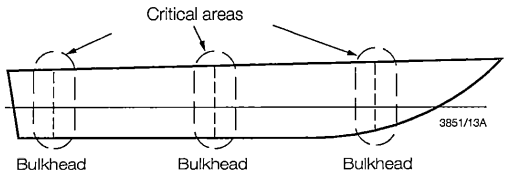
AREA: Hull bottom structure

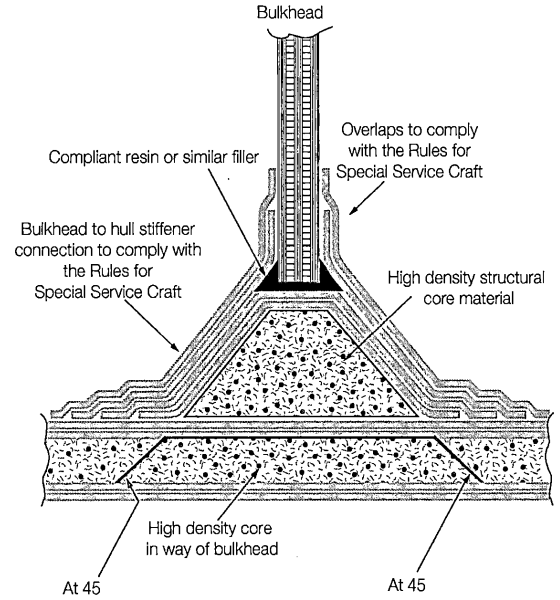
ITEM: Bulkhead to hull connection

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

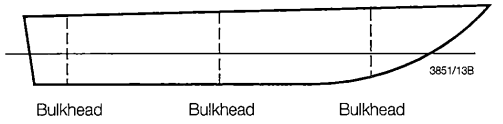
Sandwich construction, high speed







All bulkhead hull connections to comply with the Rules for Special Service Craft



NOTES

Failure Mechanism	Crushing of the sandwich core under the bulkhead due to excess loads arising from berthing, slinging, impact and racking.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
1	COMPOSITE CONSTRUCTION	4

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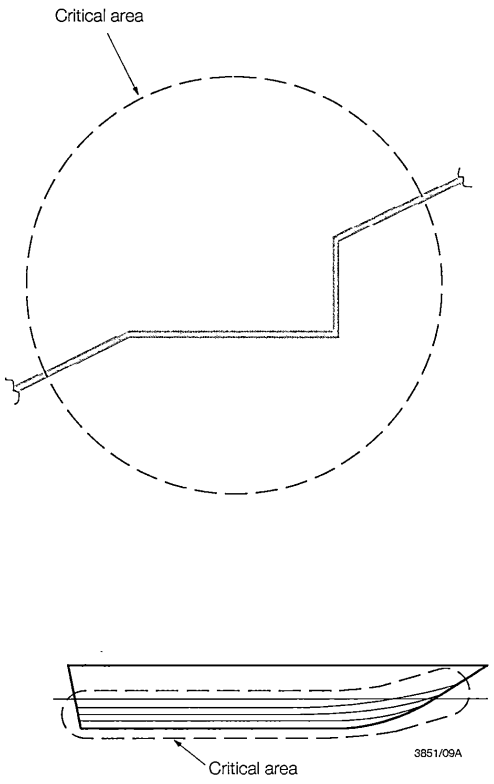
Detail Design Improvement for Composite Construction

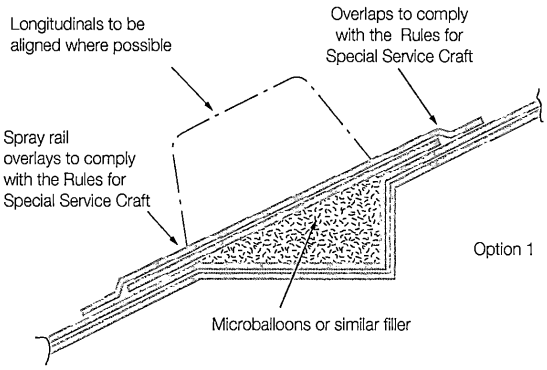
AREA: Hull structure

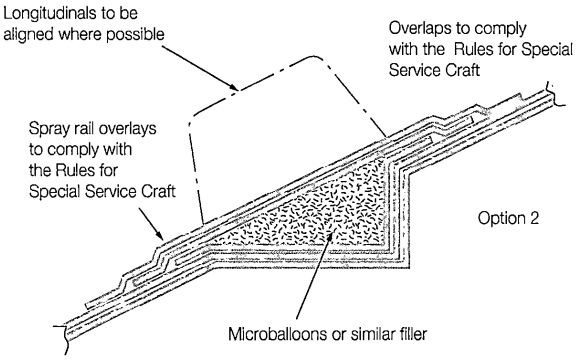
ITEM: Spray rails

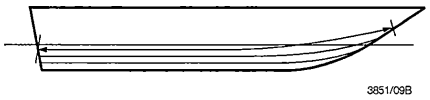
CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

Single skin construction









Entire length of spray rails overlaid to comply with the Rules for Special Service Craft

NOTES

Failure Mechanism	Excess loads due to grounding and impact.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
2	COMPOSITE CONSTRUCTION	5

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Detail Design Improvement for Composite Construction

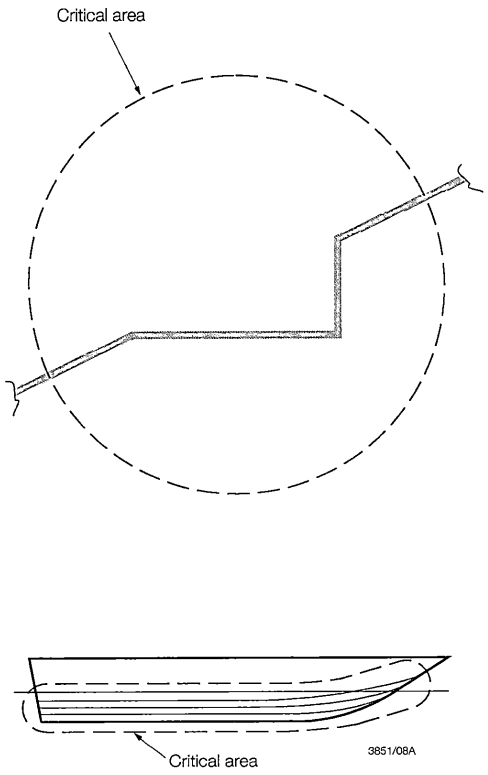
AREA: Hull structure

ITEM: Spray rails

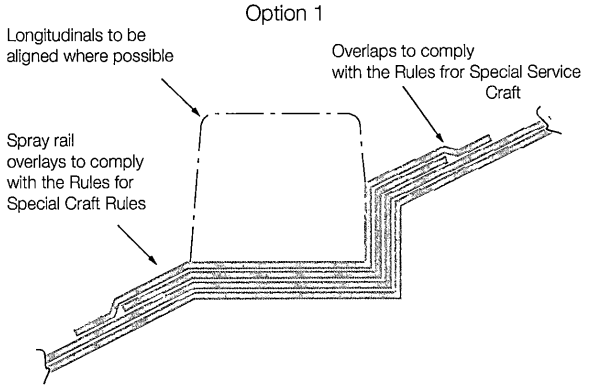
Lloyd's Register

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

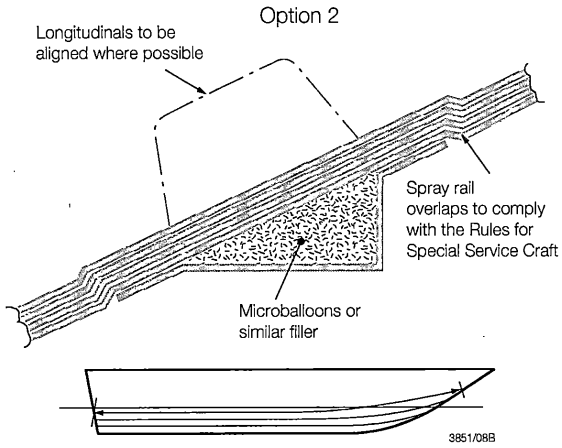
Single skin construction



Option 1



Option 2



Entire length of spray rails overlaid to comply with the Rules for Special Service Craft

NOTES

Failure Mechanism	Excess loads due to grounding and impact.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with the Part 8 of the Rules for Special Service Craft.

GROUP 2	GUIDANCE NOTES FOR DESIGN DETAILS COMPOSITE CONSTRUCTION	FIGURE 6

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Detail Design Improvement for Composite Construction

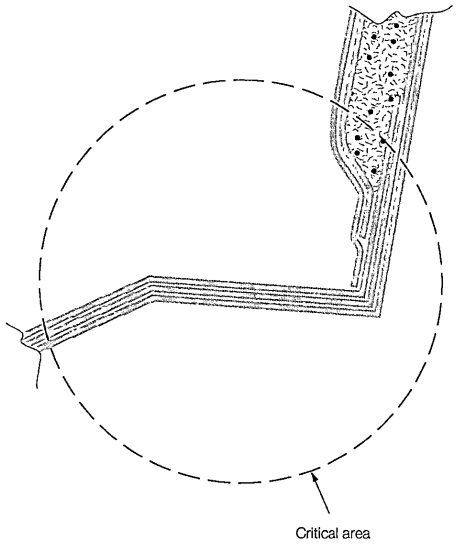
AREA: Chine in way of side shell and bottom shell connection

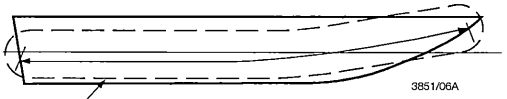
ITEM: Chine reinforcement

Lloyd's Register

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

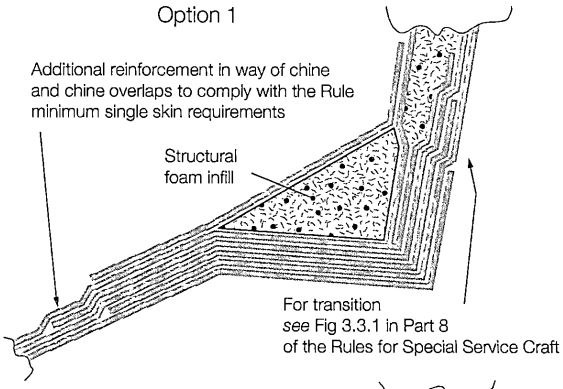
Sandwich side and single skin bottom





Critical area, entire length of chine

Option 1



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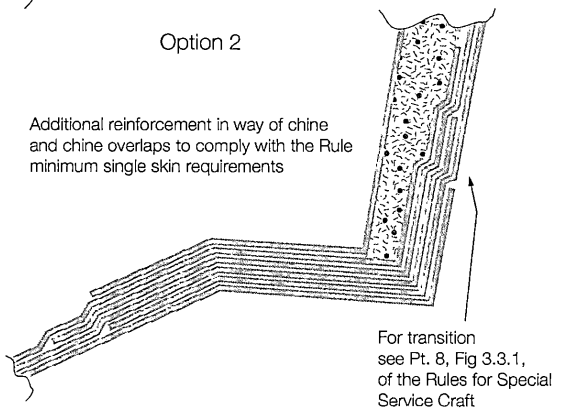

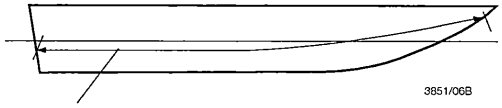

Entire length of chine reinforced
to comply with the Rules for Special Service Craft

NOTES

Failure Mechanism	Excess loads due to grounding, docking, slinging and hydrodynamic impact.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft
Laminating Requirements	To be in accordance with the Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
2	COMPOSITE CONSTRUCTION	7

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Detail Design Improvement for Composite Construction

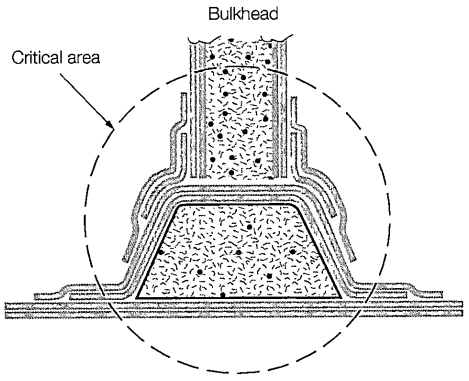
AREA: Hull internal structure

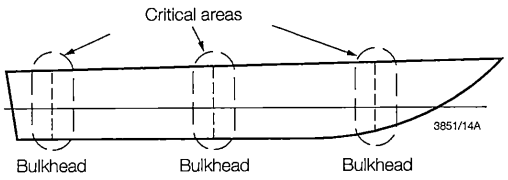
ITEM: Bulkhead to hull connection

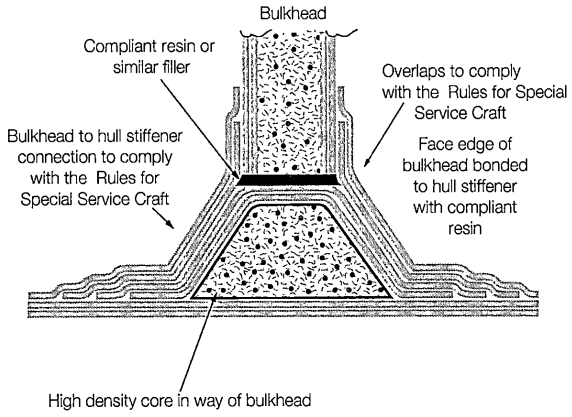
Lloyd's Register

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

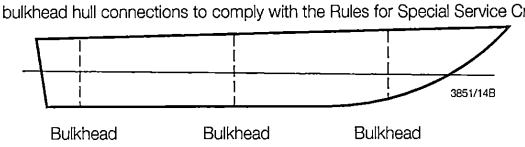
Single skin construction, high speed







All bulkhead hull connections to comply with the Rules for Special Service Craft



NOTES

Failure Mechanism	Excess loads due to berthing, slinging, impact and racking.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with the Part 8 of the Rules for Special Service Craft.

GROUP 2	GUIDANCE NOTES FOR DESIGN DETAILS COMPOSITE CONSTRUCTION	FIGURE 8

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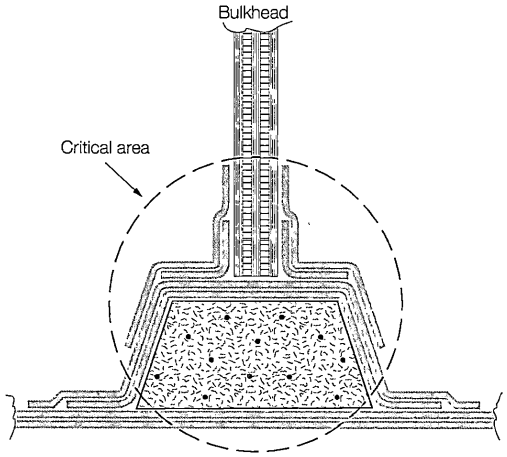
Detail Design Improvement for Composite Construction

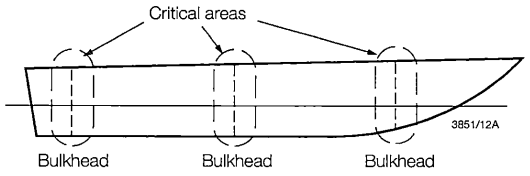
AREA: Hull internal structure

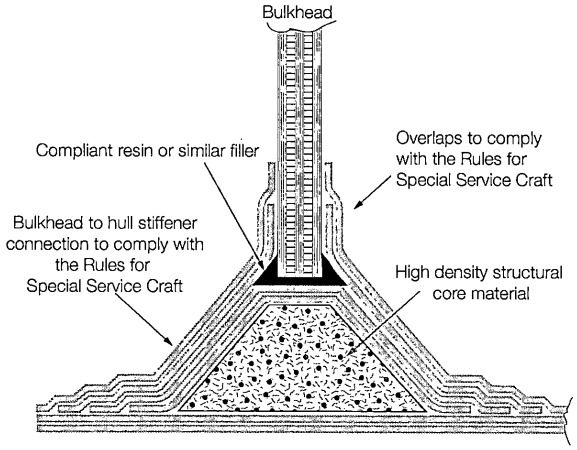
ITEM: Bulkhead to hull connection

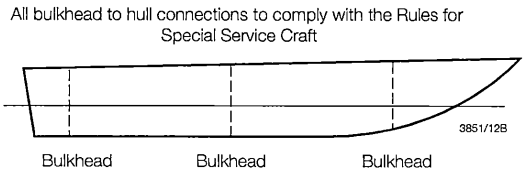
CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

Single skin construction, high speed









NOTES

Failure Mechanism	Excess loads due to berthing, slinging, impact and racking.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP 2	GUIDANCE NOTES FOR DESIGN DETAILS COMPOSITE CONSTRUCTION	FIGURE 9

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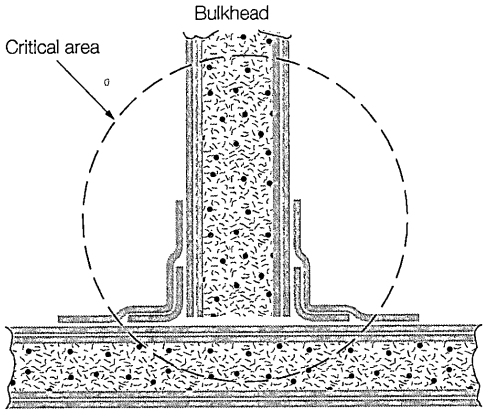
Detail Design Improvement for Composite Construction

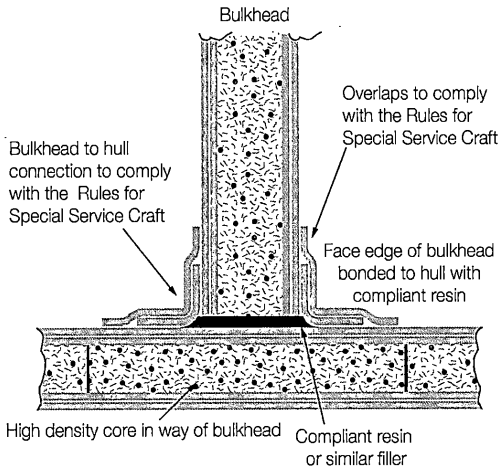
AREA: Hull internal structure

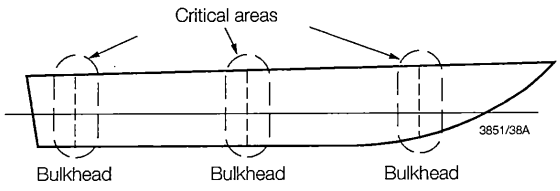
ITEM: Bulkhead to hull connection

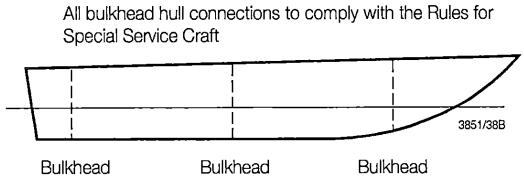
CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

Sandwich construction, low speed









NOTES

Failure Mechanism	Crushing of the sandwich core under the bulkhead, and delamination of the sandwich bulkhead due to excess loads arising from berthing, slinging, impact and racking.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
3	COMPOSITE CONSTRUCTION	10

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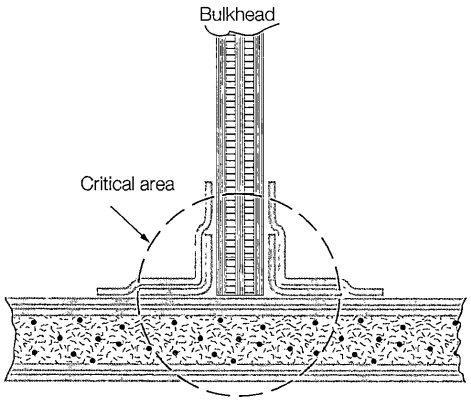
Detail Design Improvement for Composite Construction

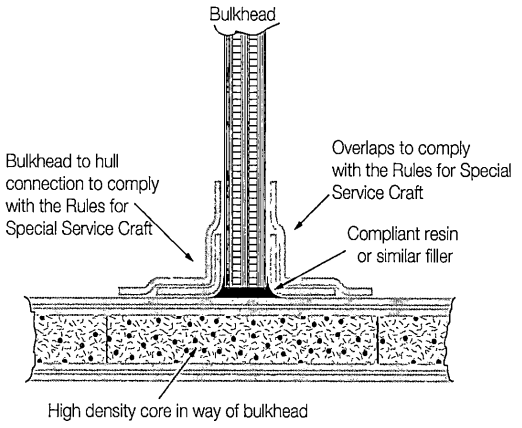
AREA: Hull internal structure

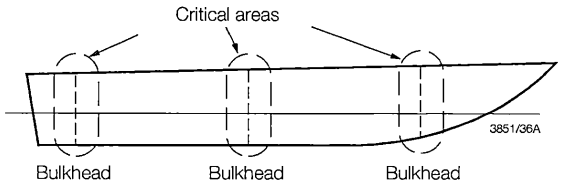
ITEM: Bulkhead to hull connection

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

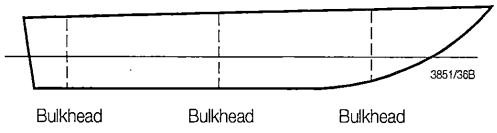
Sandwich construction, low speed







All bulkhead hull connections to comply with the Rules for Special Service Craft



NOTES

Failure Mechanism	Crushing of the sandwich core under the bulkhead due to excess loads arising from berthing, slinging, impact and racking.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP 3	GUIDANCE NOTES FOR DESIGN DETAILS COMPOSITE CONSTRUCTION	FIGURE 11

Document Released Under the Access to Information Act / Document divulgué en vertu de la Loi sur l'accès à l'information.

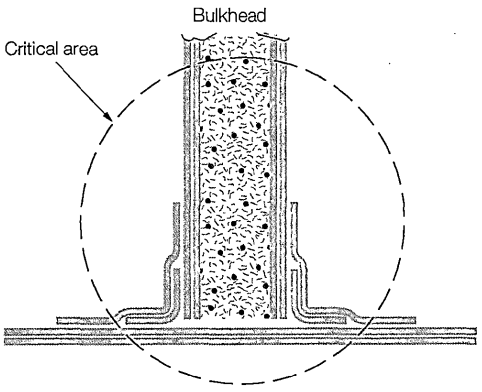
Detail Design Improvement for Composite Construction

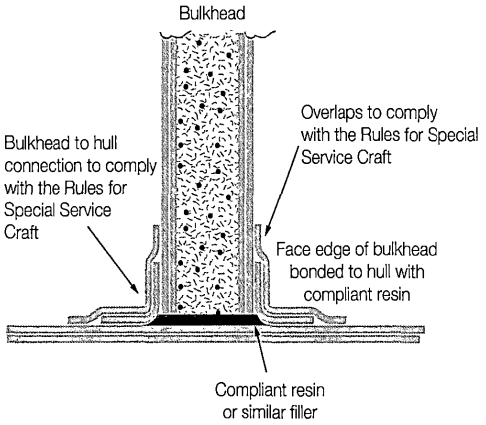
AREA: Hull bottom structure

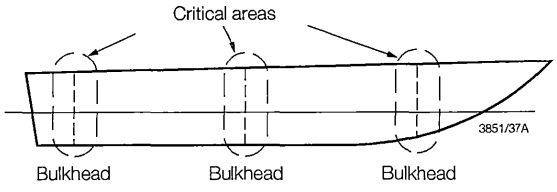
ITEM: Bulkhead to hull connection

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

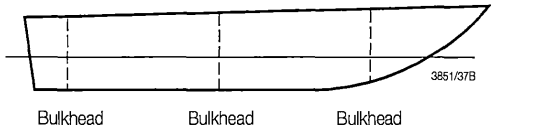
Single skin construction, low speed







All bulkhead hull connections to comply with the Rules for Special Service Craft



NOTES

Failure Mechanism	Excess loads due to berthing, slinging, impact and racking.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP 4	GUIDANCE NOTES FOR DESIGN DETAILS COMPOSITE CONSTRUCTION	FIGURE 12

Document Released Under the Access to Information Act / Document divulgué en vertu de la Loi sur l'accès à l'information.

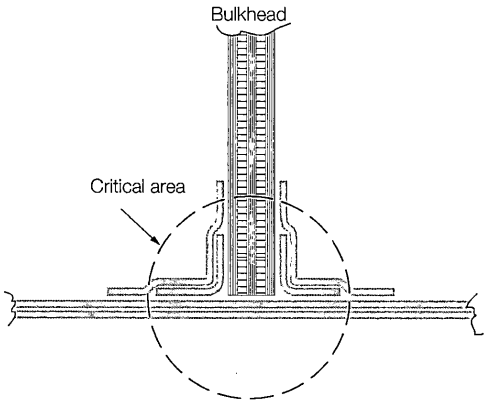
Detail Design Improvement for Composite Construction

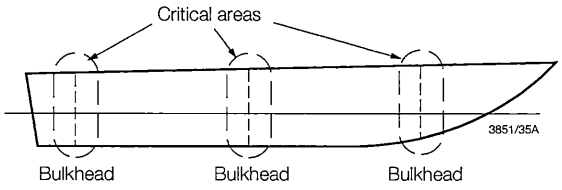
AREA: Hull bottom structure

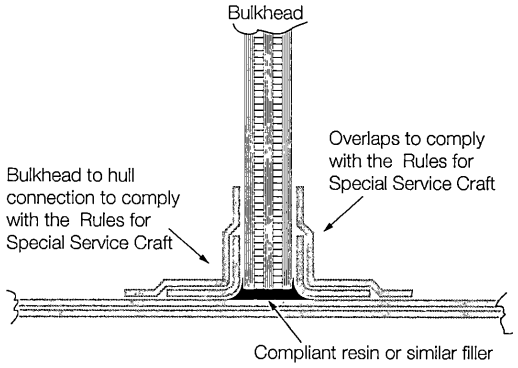
ITEM: Bulkhead to hull connection

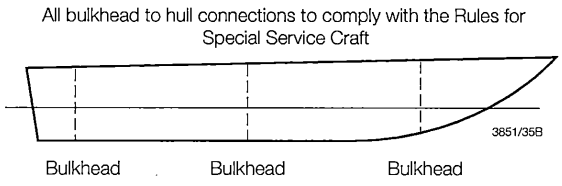
CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

Single skin construction, low speed









NOTES

Failure Mechanism	Excess loads due to berthing, slinging, impact and racking.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP 4	GUIDANCE NOTES FOR DESIGN DETAILS COMPOSITE CONSTRUCTION	FIGURE 13

Document Released Under the Access to Information Act / Document divulgué en vertu de la Loi sur l'accès à l'information.

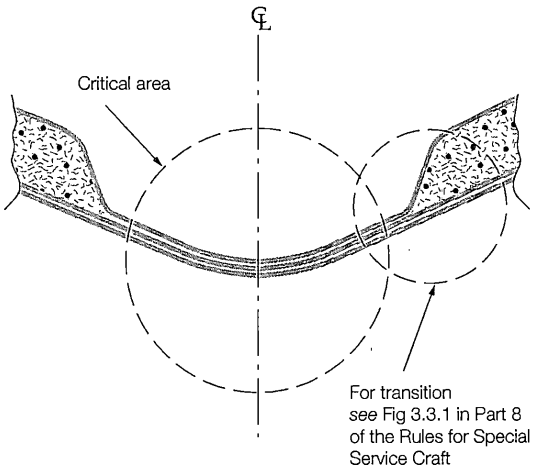
Detail Design Improvement for Composite Construction

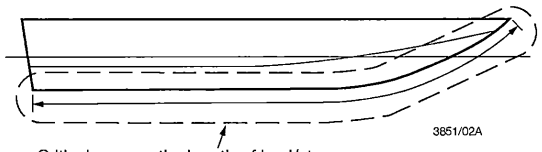
AREA: Hull centreline structure

ITEM: Keel/stem reinforcement and keel stiffening

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

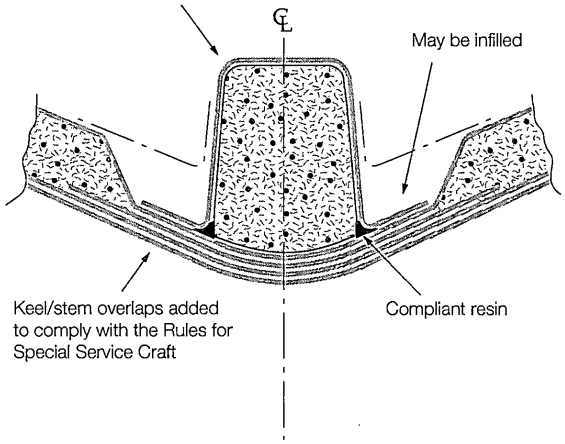
Sandwich construction

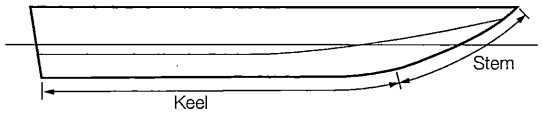




Critical area, entire length of keel/stem

Centre line stiffener/girder added in way of keel
to accomodate docking, grounding and slinging loads





Entire length of keel/stem reinforced
to comply with the Rules for Special Service Craft

NOTES

Failure Mechanism	Excess loads due to grounding, docking and slinging.
Building Tolerance	All FRP materials to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with the Part 8 of the Rules for Special Service Craft.

GROUP 5	GUIDANCE NOTES FOR DESIGN DETAILS COMPOSITE CONSTRUCTION	FIGURE 14

Document Released Under the Access to Information Act / Document divulgué en vertu de la Loi sur l'accès à l'information.

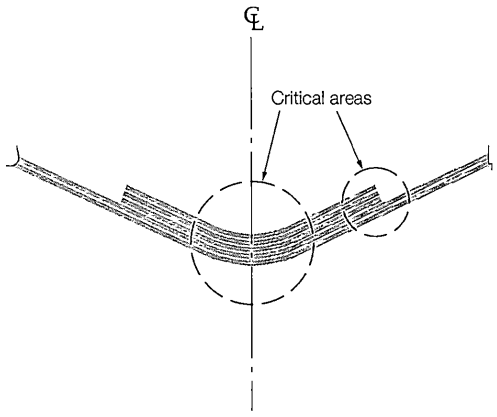
Detail Design Improvement for Composite Construction

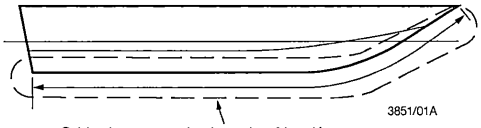
AREA: Hull centreline structure

ITEM: Keel/stem reinforcement and keel stiffening

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

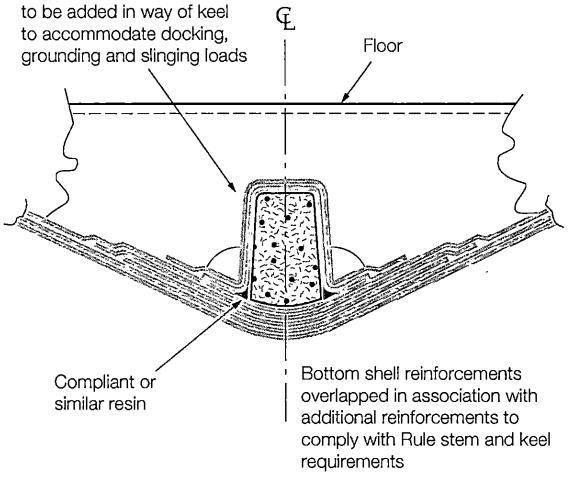
Single skin construction

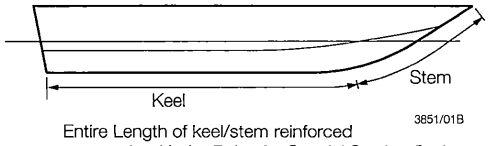




Critical area, entire length of keel/stem

Where a skeg is not fitted a centre line stiffener/girder is to be added in way of keel to accommodate docking, grounding and slinging loads





Entire Length of keel/stem reinforced to comply with the Rules for Special Service Craft

NOTES

Failure Mechanism	Excess loads due to grounding, docking and slinging.
Building Tolerance	All FRP materials to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP 5	GUIDANCE NOTES FOR DESIGN DETAILS COMPOSITE CONSTRUCTION	FIGURE 15

Document Released Under the Access to Information Act / Document divulgué en vertu de la Loi sur l'accès à l'information.

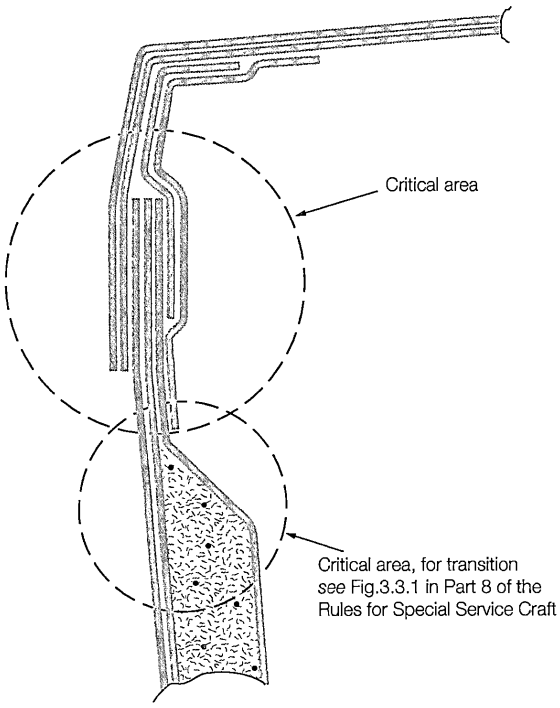
Detail Design Improvement for Composite Construction

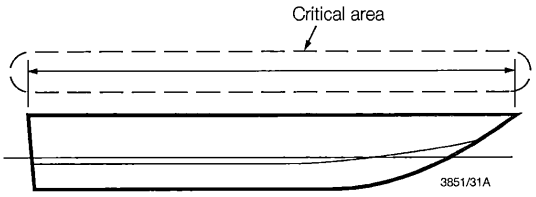
AREA: Hull structure

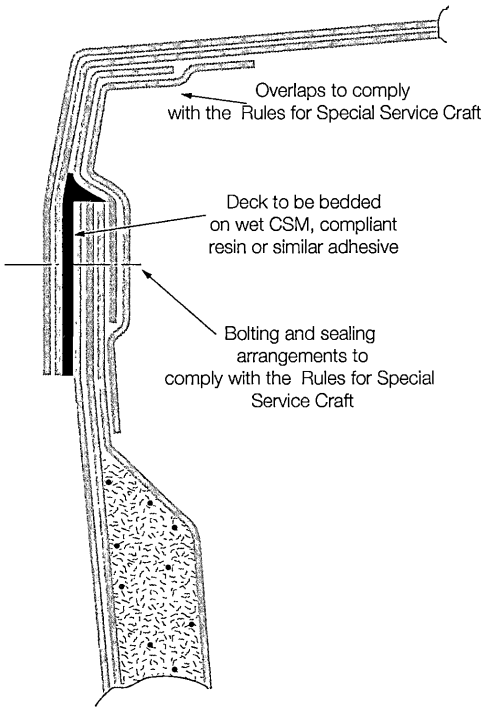
ITEM: Deck to hull connection

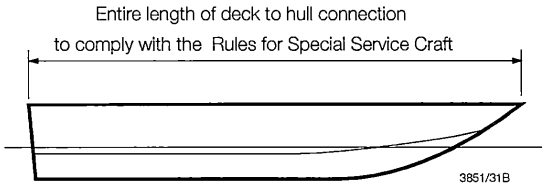
CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

Sandwich construction









NOTES

Failure Mechanism	Excess loads due to berthing, slinging, impact from green seas and other loadings arising from heavy weather.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
5	COMPOSITE CONSTRUCTION	16

Document Released Under the Access to Information Act / Document divulgué en vertu de la Loi sur l'accès à l'information.

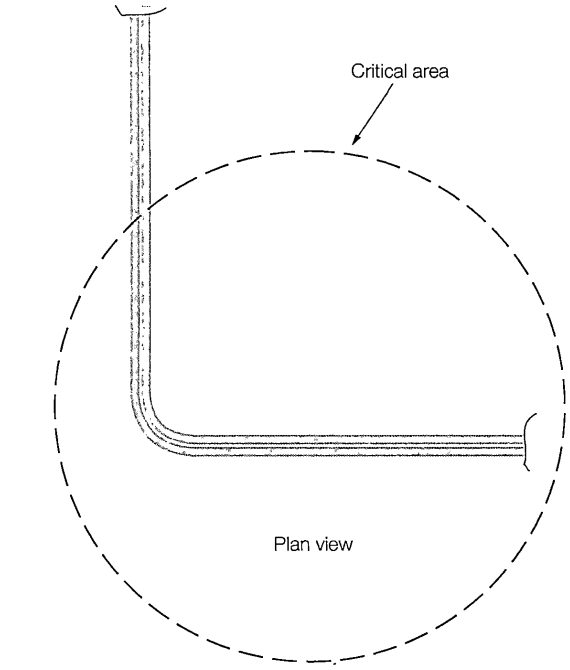
Detail Design Improvement for Composite Construction

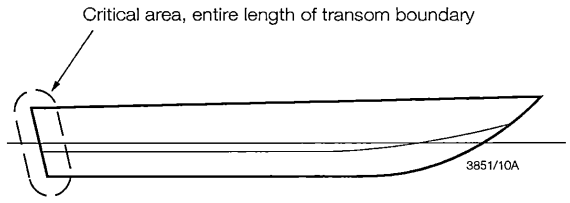
AREA: Hull structure

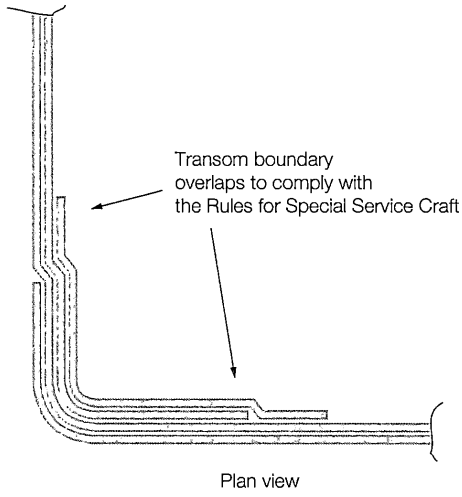
ITEM: Transom boundary

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

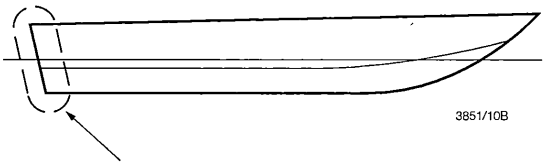
Single skin construction







Additional reinforcement in way of transom boundary to comply with the Rules for Special Service Craft



Entire length of transom boundary reinforced to comply with the Rules for Special Service Craft

NOTES

Failure Mechanism	Excess loads due to docking and impact due to berthing.
Building Tolerance	All FRP materials to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP 5	GUIDANCE NOTES FOR DESIGN DETAILS COMPOSITE CONSTRUCTION	FIGURE 17

Document Released Under the Access to Information Act / Document divulgué en vertu de la Loi sur l'accès à l'information.

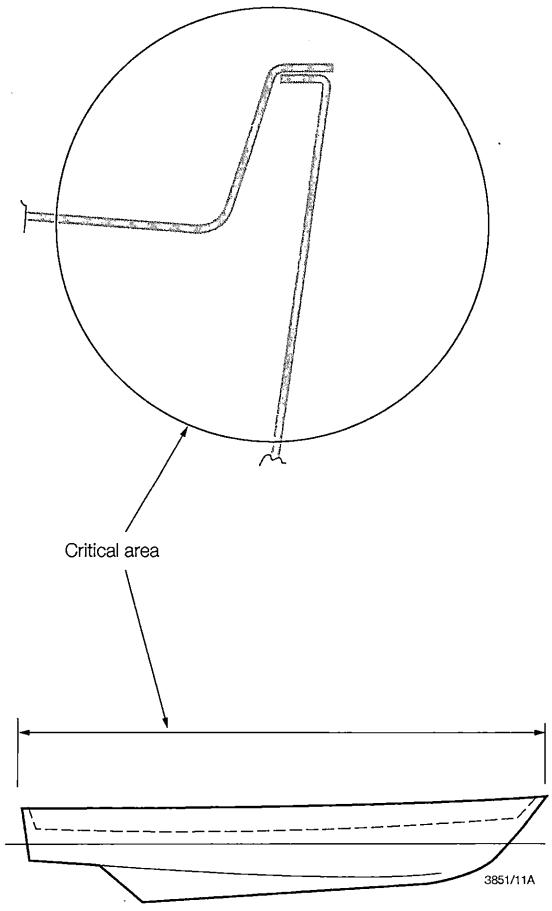
Detail Design Improvement for Composite Construction

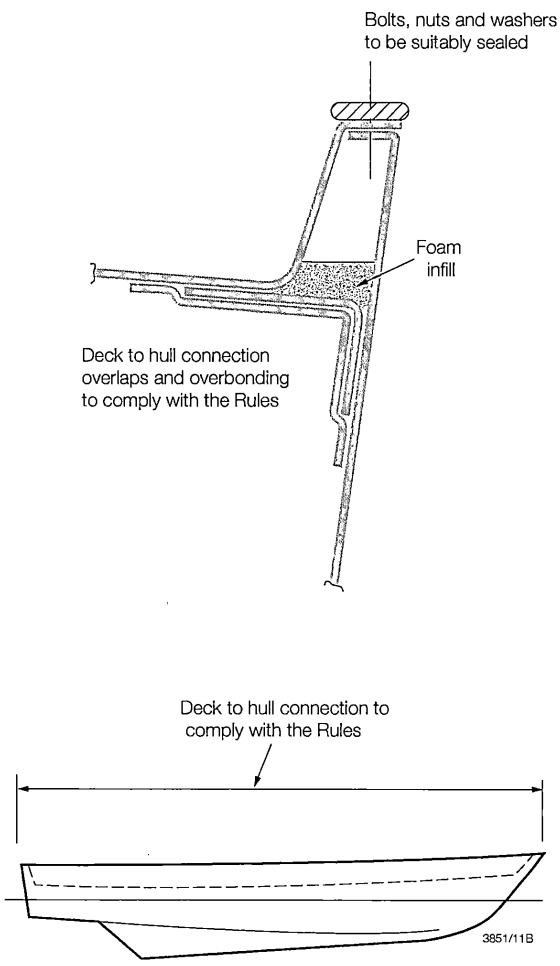
AREA: Hull structure

ITEM: Deck to hull connection

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

Single skin construction





NOTES

Failure Mechanism	Excess loads due to berthing, slinging, impact from green seas and other loadings arising from heavy weather.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP 5	GUIDANCE NOTES FOR DESIGN DETAILS COMPOSITE CONSTRUCTION	FIGURE 18

Document Released Under the Access to Information Act / Document divulgué en vertu de la Loi sur l'accès à l'information.

Detail Design Improvement for Composite Construction

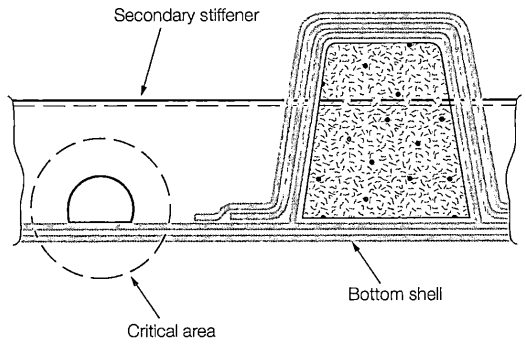
AREA: Hull bottom structure

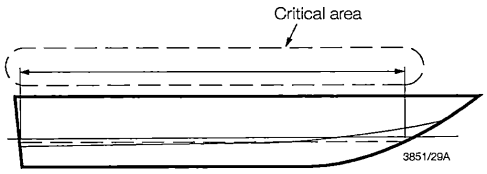
ITEM: Limber holes

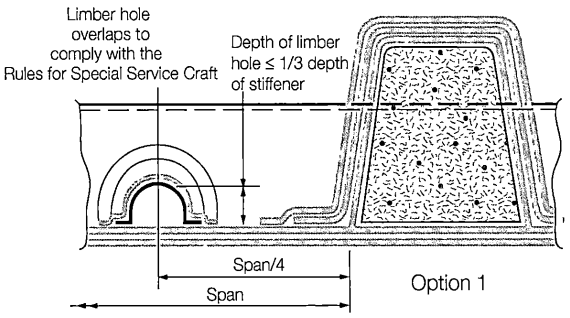
Lloyd's Register

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

Single skin construction

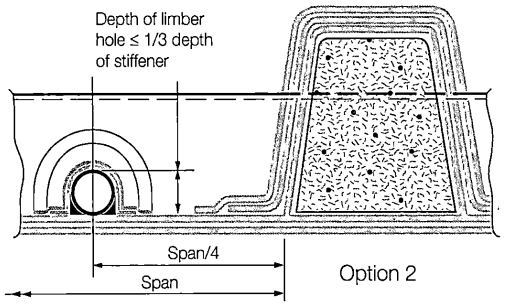


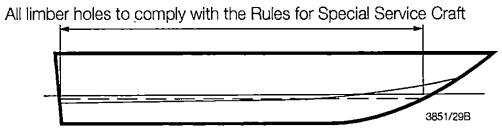




FRP preform bonded to shell and stiffener with compliant resin adhesive

NOTE: PVC preforms to be overlaminated to shell before installation of stiffener





NOTES

Failure Mechanism	Excess loads due to hydrodynamic impact, grounding, docking and slinging leading to stiffener web failure.
Building Tolerance	All FRP materials to be in accordance with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP 5	GUIDANCE NOTES FOR DESIGN DETAILS COMPOSITE CONSTRUCTION	FIGURE 19

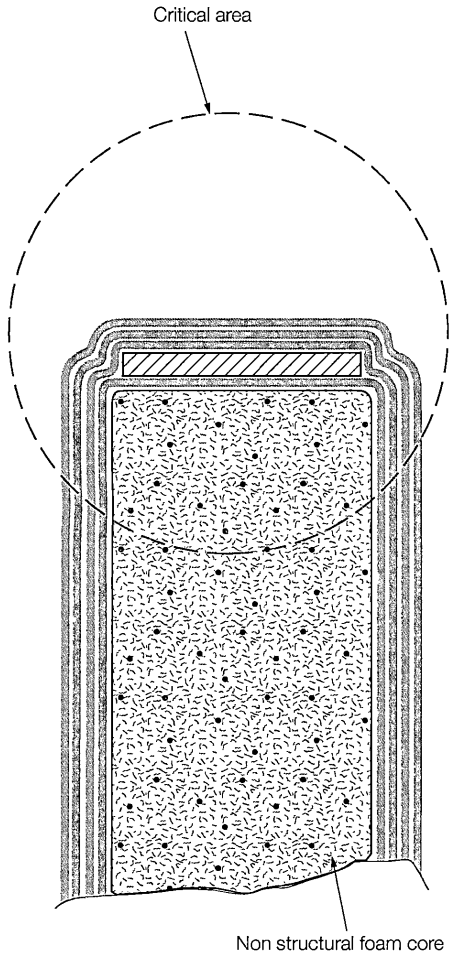
Document Released Under the Access to Information Act / Document divulgué en vertu de la Loi sur l'accès à l'information.

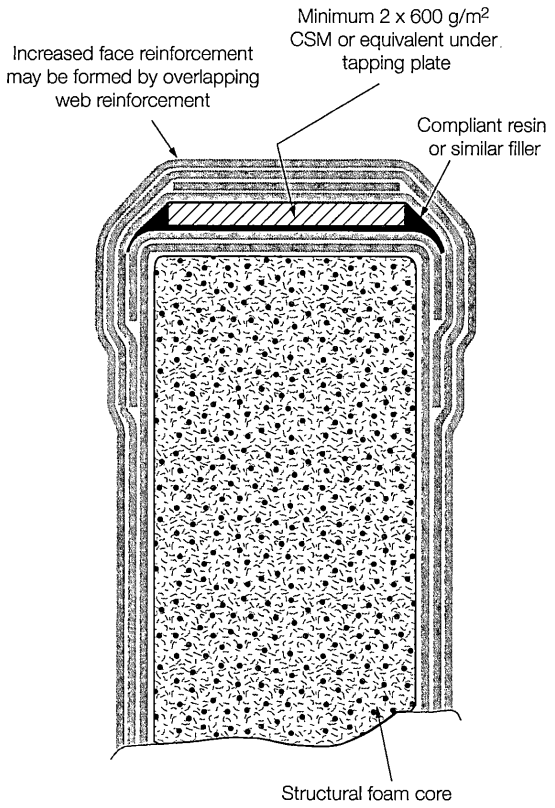
Detail Design Improvement for Composite Construction

AREA: Hull bottom structure

ITEM: Machinery seating, tapping plates

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT





Tapping plate is to be suitably abraded, all sharp edges removed and all corners radiused prior to encapsulating

NOTES

Failure Mechanism	Engine loadings arising from thrust, torque and mass.
Building Tolerance	All FRP materials to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
5	COMPOSITE CONSTRUCTION	20

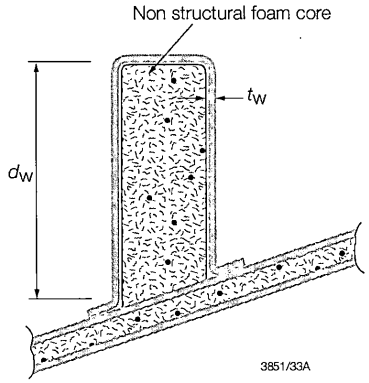
Document Released Under the Access to Information Act / Document divulgué en vertu de la Loi sur l'accès à l'information.

Detail Design Improvement for Composite Construction

AREA: Hull internal structure

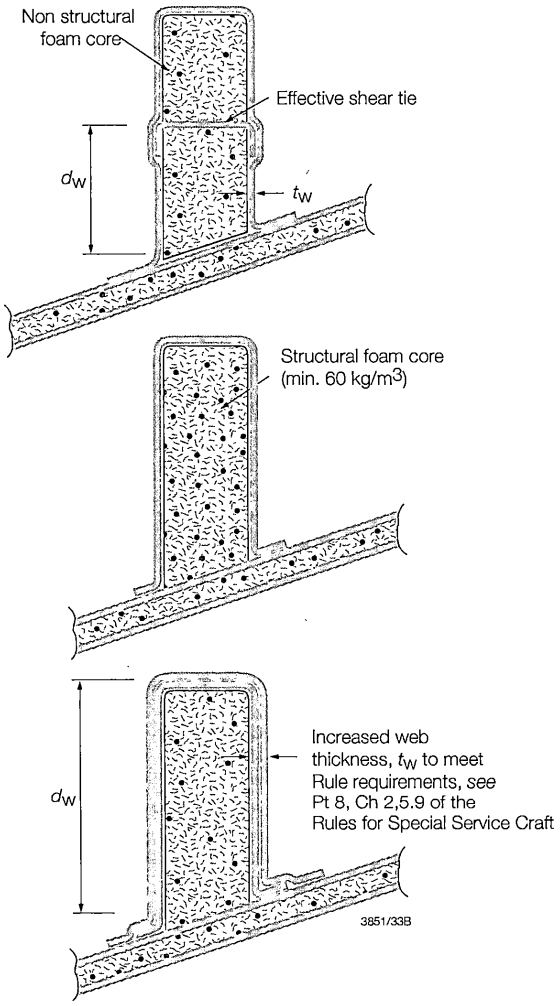
ITEM: Deep girders and floors

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT
Sandwich construction/single skin construction	



t_W is to satisfy the Rule requirement for d_W, *see* Pt 8, Ch 2,5.9 of the Rules for Special Service Craft

d_W = unsupported web depth
t_W = web thickness



NOTES

Failure Mechanism	Web buckling under design load, docking and berthing loads.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
5	COMPOSITE CONSTRUCTION	21

Document Released Under the Access to Information Act / Document divulgué en vertu de la Loi sur l'accès à l'information.

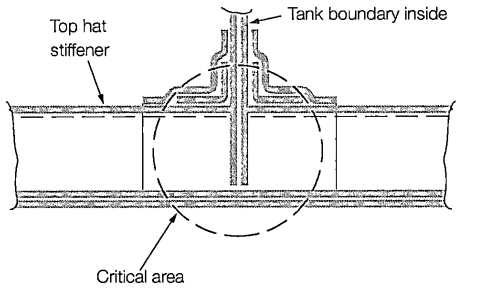
Detail Design Improvement for Composite Construction

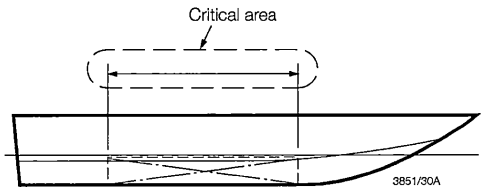
AREA: Hull internal structure

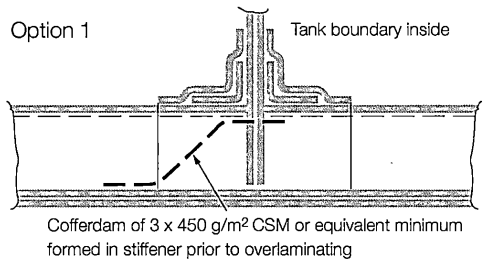
ITEM: 'Top-hat' stiffeners penetrating tank boundaries

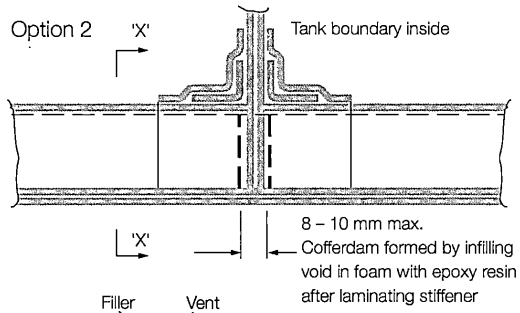
Lloyd's Register

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT









NOTES

Failure Mechanism	Ingress and permeation of fluid along stiffener.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft. Fit-up is to be very good.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
5	COMPOSITE CONSTRUCTION	22

Document Released Under the Access to Information Act / Document divulgué en vertu de la Loi sur l'accès à l'information.

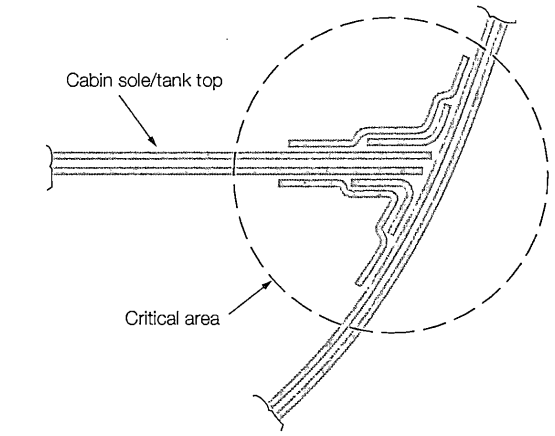
Detail Design Improvement for Composite Construction

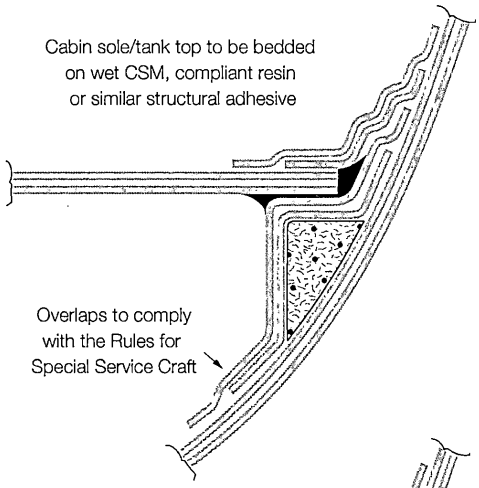
AREA: Hull internal structure

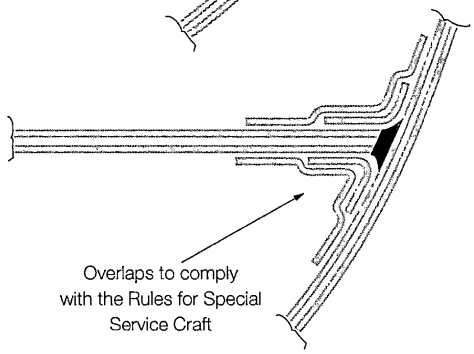
ITEM: Lower deck/tank top to bottom shell connection

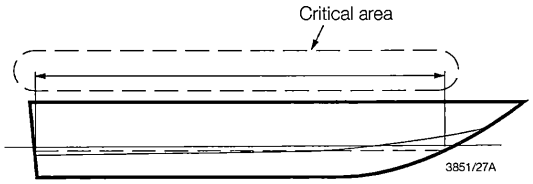
CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

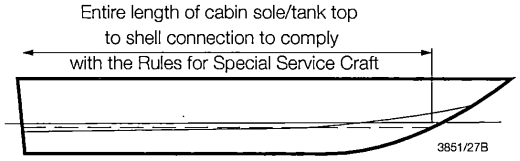
Single skin construction











NOTES

Failure Mechanism	Excess loads due to impact also hydrostatic pressure where the internal structure forms the boundary of an integral tank.
Building Tolerance	All FRP materials to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
5	COMPOSITE CONSTRUCTION	23

Document Released Under the Access to Information Act / Document divulgué en vertu de la Loi sur l'accès à l'information.

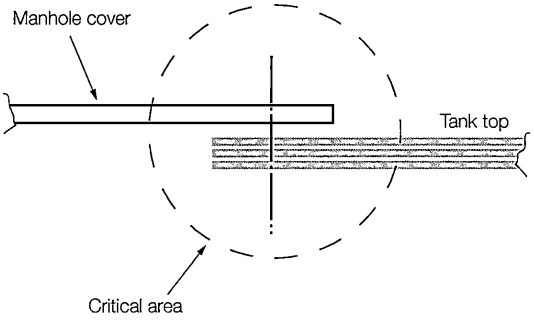
Detail Design Improvement for Composite Construction

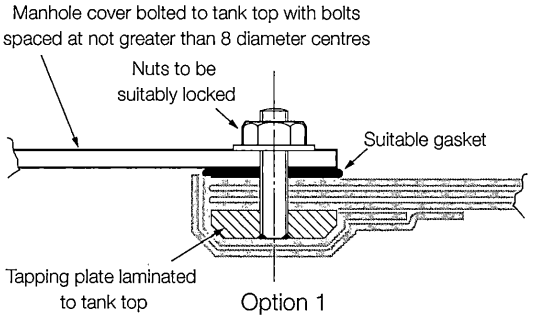
AREA: Hull internal structure

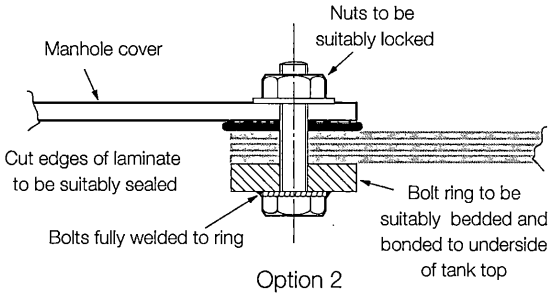
ITEM: Integral tanks access manholes

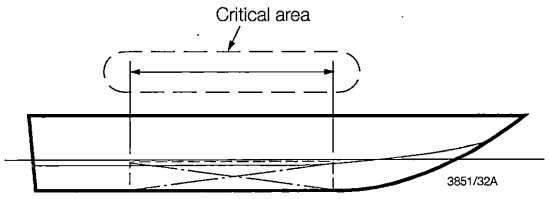
Lloyd's Register

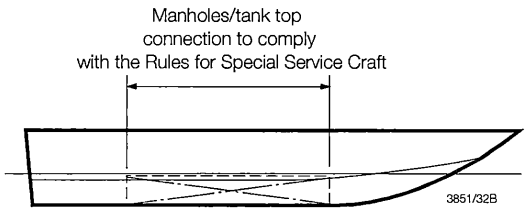
CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT











NOTES

Failure Mechanism	Leakage under hydrostatic pressure.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP 5	GUIDANCE NOTES FOR DESIGN DETAILS COMPOSITE CONSTRUCTION	FIGURE 24

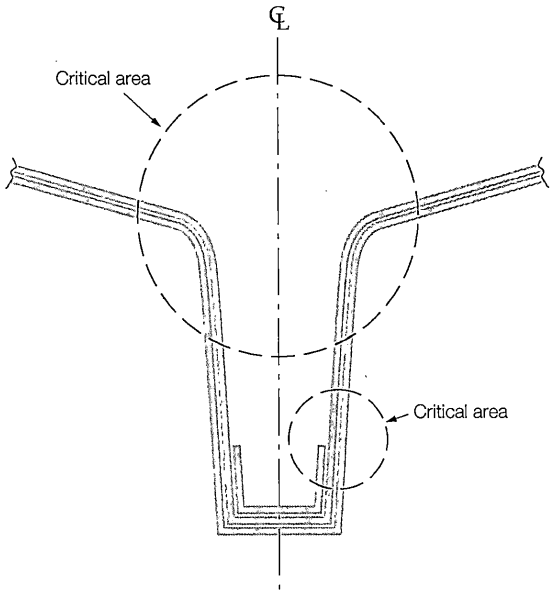
Document Released Under the Access to Information Act / Document divulgué en vertu de la Loi sur l'accès à l'information.

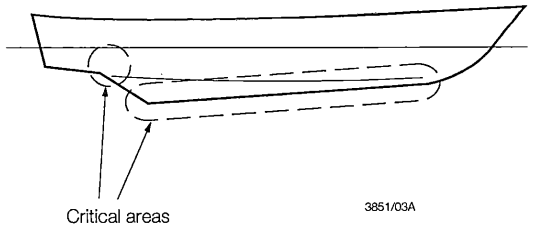
Detail Design Improvement for Composite Construction

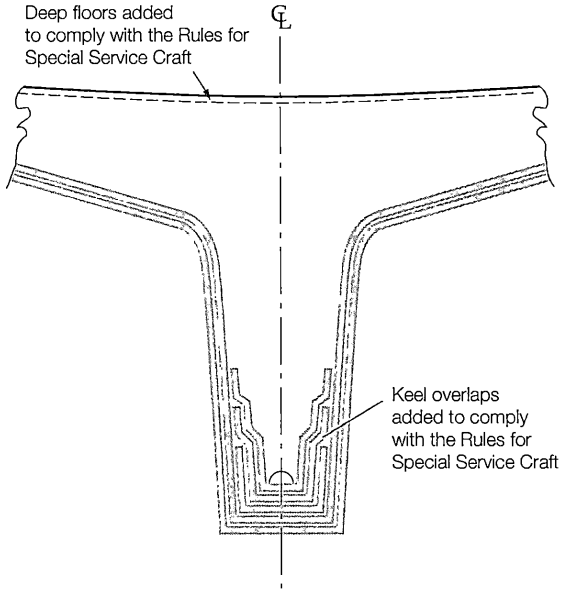
AREA: Skeg (open type)

ITEM: Skeg stiffening and reinforcement

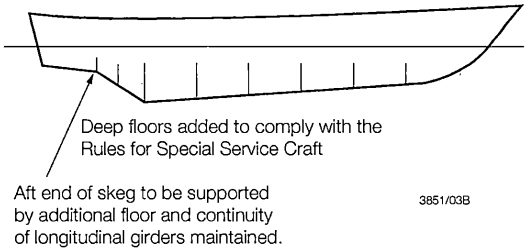
CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT







Note : Where the hull is moulded in two halves, the bottom shell laminate is to be reinstated across ℄ prior to additional reinforcements to comply with the Rule keel requirements.



NOTES

Failure Mechanism	Excess loads due to grounding, docking, slinging and hydrostatic pressure.
Building Tolerance	All FRP materials to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP 5	GUIDANCE NOTES FOR DESIGN DETAILS COMPOSITE CONSTRUCTION	FIGURE 25

Document Released Under the Access to Information Act / Document divulgué en vertu de la Loi sur l'accès à l'information.

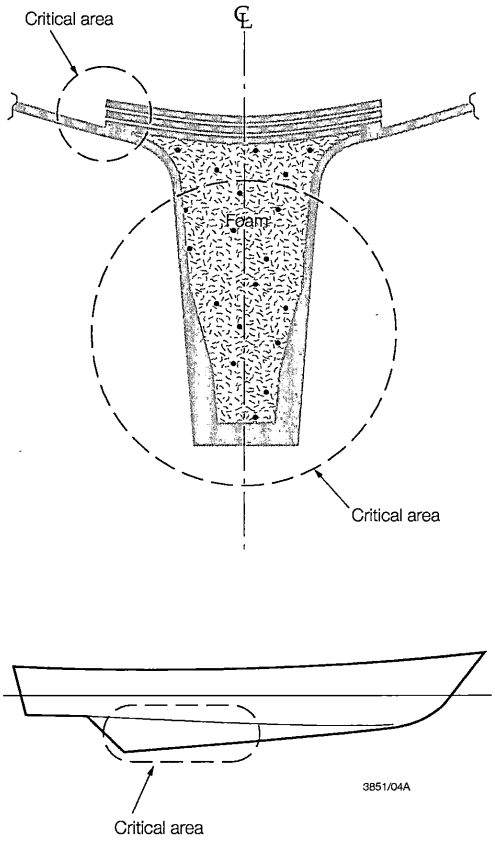
Detail Design Improvement for Composite Construction

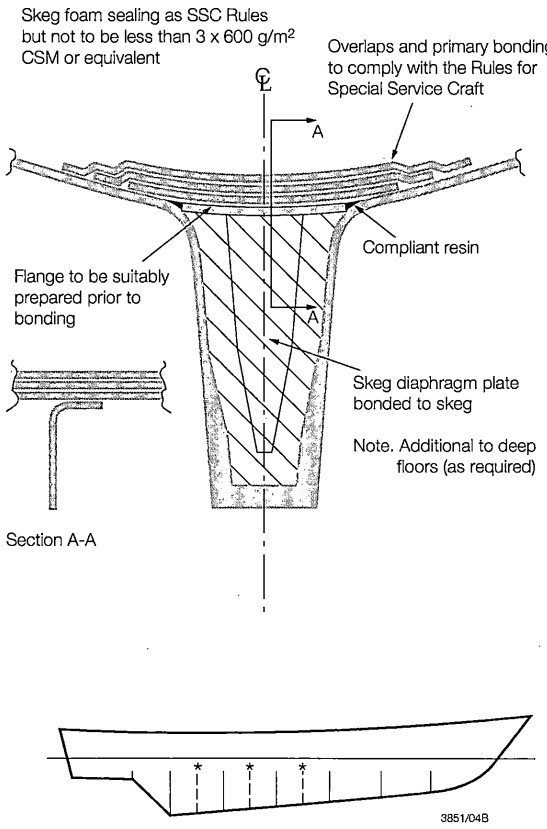
AREA: Skeg (closed type)

ITEM: Skeg diaphragm plates and sealing laminate

Lloyd's Register

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT





NOTES

Failure Mechanism	Excess loads due to grounding, docking, slinging and hydrostatic pressure both externally and internally in the case of integral tanks.
Building Tolerance	To align with bottom framing. All FRP materials to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP 5	GUIDANCE NOTES FOR DESIGN DETAILS COMPOSITE CONSTRUCTION	FIGURE 26

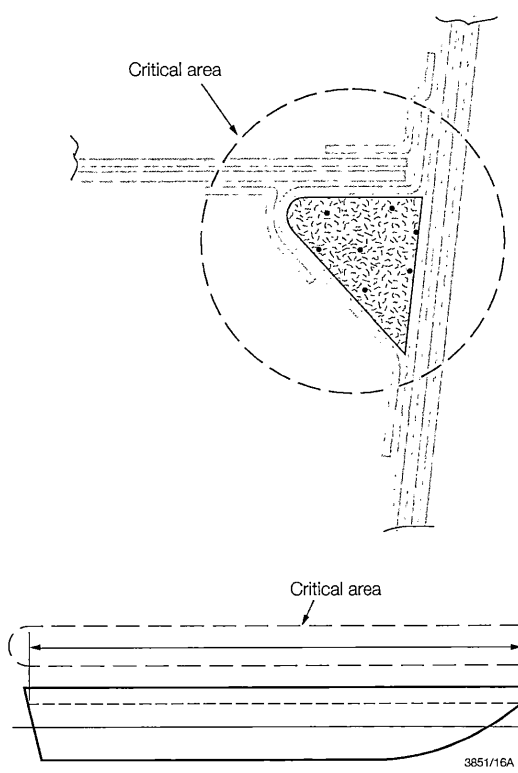
Document Released Under the Access to Information Act / Document divulgué en vertu de la Loi sur l'accès à l'information.

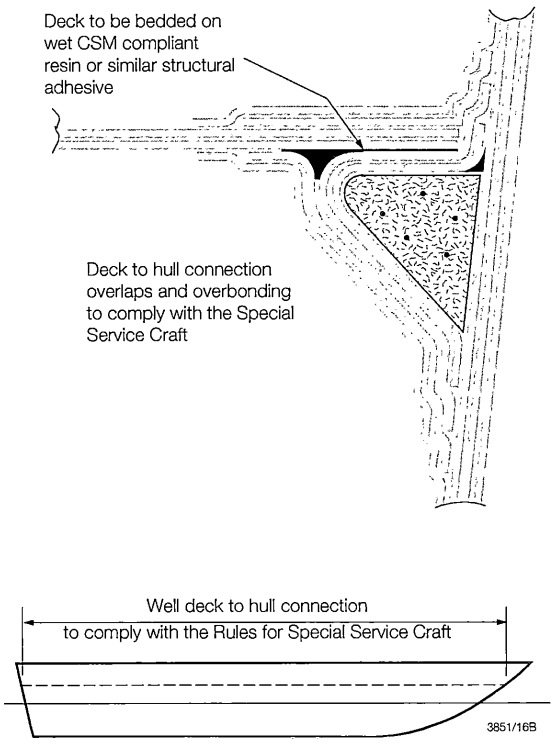
Detail Design Improvement for Composite Construction

AREA: Deck structure

ITEM: Well deck, lower/sole deck to hull connection

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT





NOTES

Failure Mechanism	Excess loads due to berthing and slinging.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
5	COMPOSITE CONSTRUCTION	27

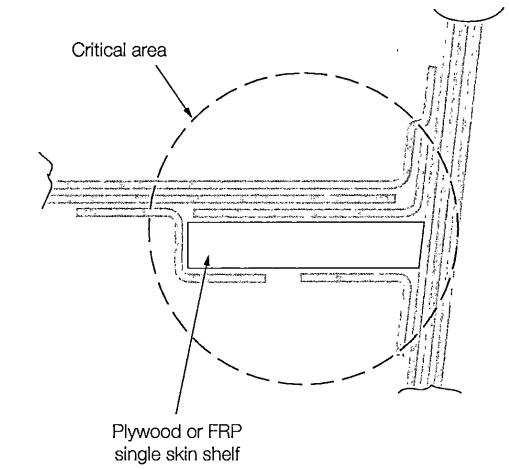
Document Released Under the Access to Information Act / Document divulgué en vertu de la Loi sur l'accès à l'information.

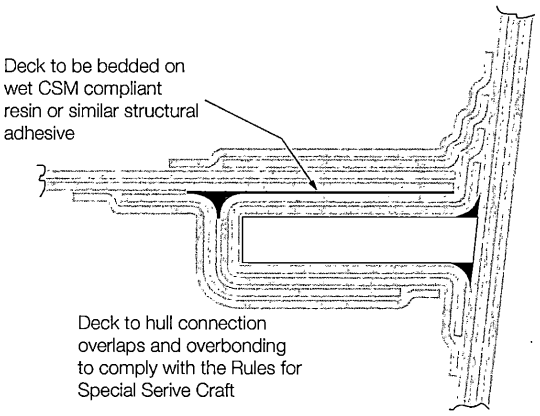
Detail Design Improvement for Composite Construction

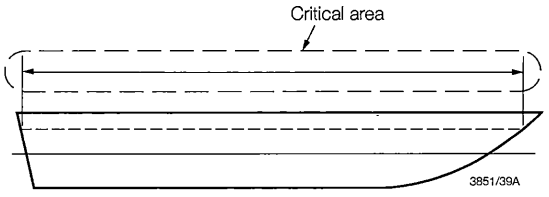
AREA: Deck structure

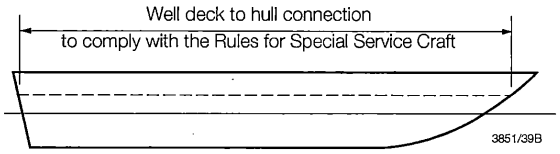
ITEM: Well deck, lower/sole deck to hull connection

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT









NOTES

Failure Mechanism	Excess loads due to berthing and slinging.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
5	COMPOSITE CONSTRUCTION	28

Document Released Under the Access to Information Act / Document divulgué en vertu de la Loi sur l'accès à l'information.

Detail Design Improvement for Composite Construction

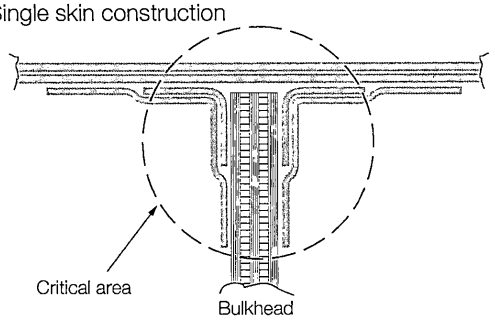
AREA: Deck

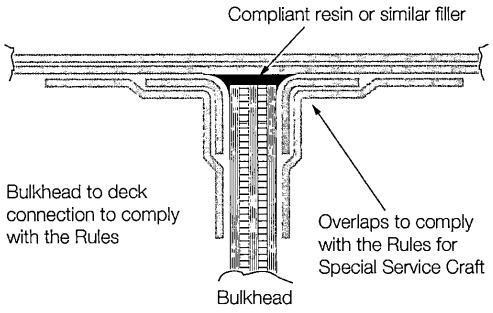
ITEM: Bulkhead to deck connection

Lloyd's Register

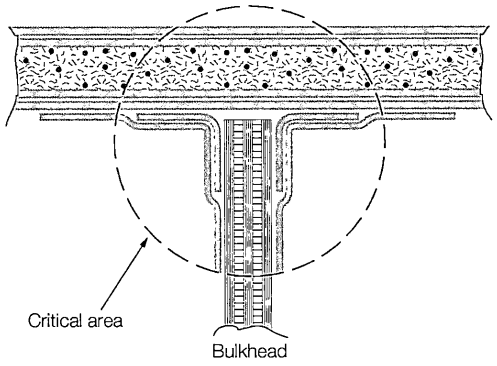
CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

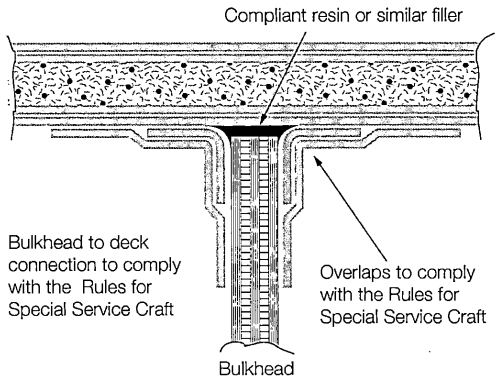
Single skin construction

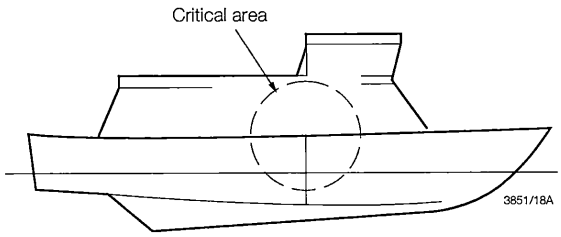


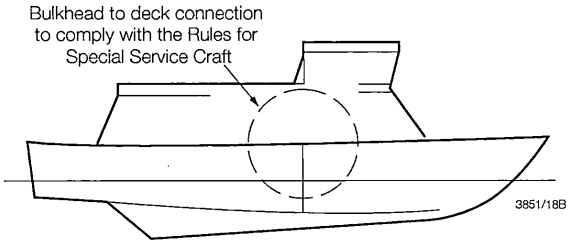


Sandwich construction









NOTES

Failure Mechanism	Excess loads due to berthing, slinging and impact.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft. Alignment and fit to be good, all gaps to be filled.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

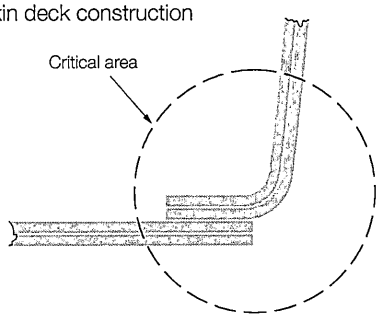
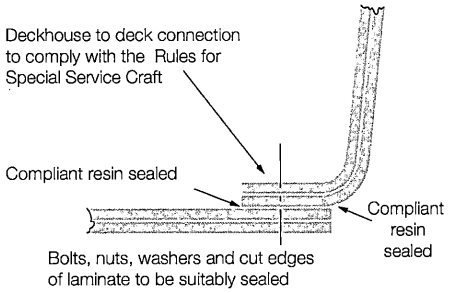
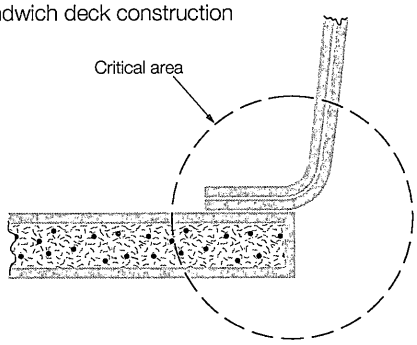
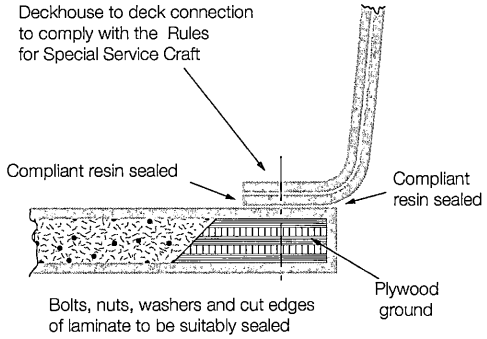
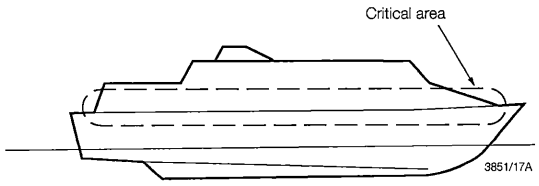
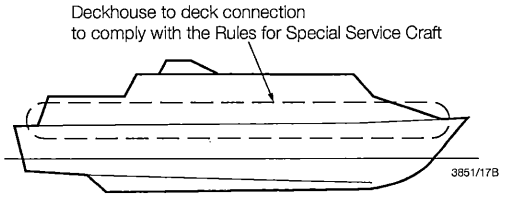
GROUP 5	GUIDANCE NOTES FOR DESIGN DETAILS COMPOSITE CONSTRUCTION	FIGURE 29

Document Released Under the Access to Information Act / Document divulgué en vertu de la Loi sur l'accès à l'information.

Detail Design Improvement for Composite Construction

AREA: Deck

ITEM: Deckhouse to deck connection

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT
Single skin deck construction 	
Sandwich deck construction 	
	

NOTES

Failure Mechanism	Excess loads due to berthing, slinging, impact from green seas and other loads arising from heavy weather.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP 5	GUIDANCE NOTES FOR DESIGN DETAILS COMPOSITE CONSTRUCTION	FIGURE 30

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